Nov. 29, 1949 H. W. G. SALINGER 2,489,328

ELECTRON BEAM CONTROLLING SYSTEM

Filed Oct. 7, 1946 3 Sheets-Sheet 1

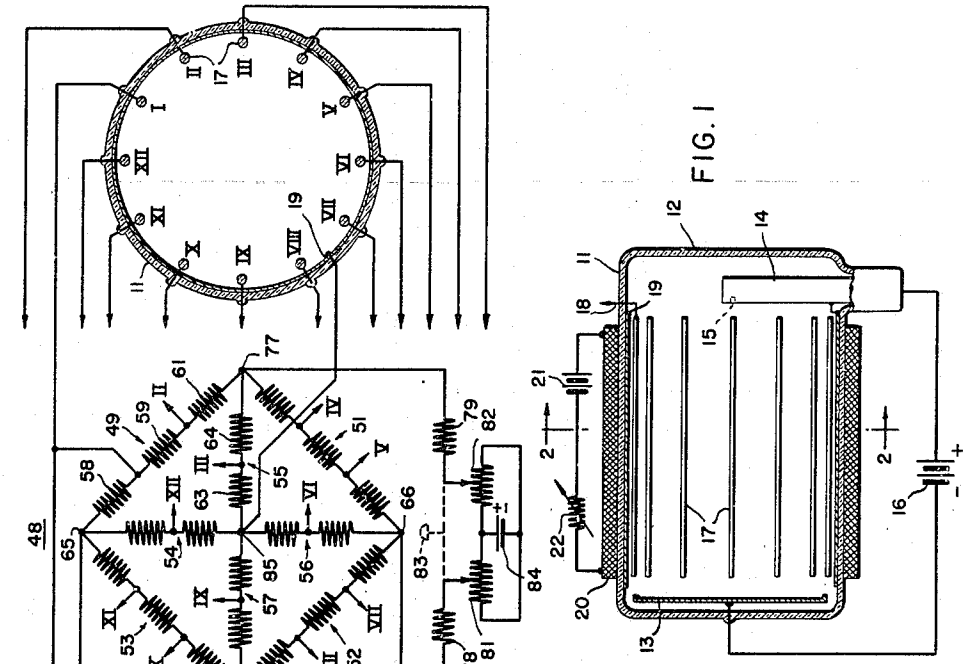

FIG. 1

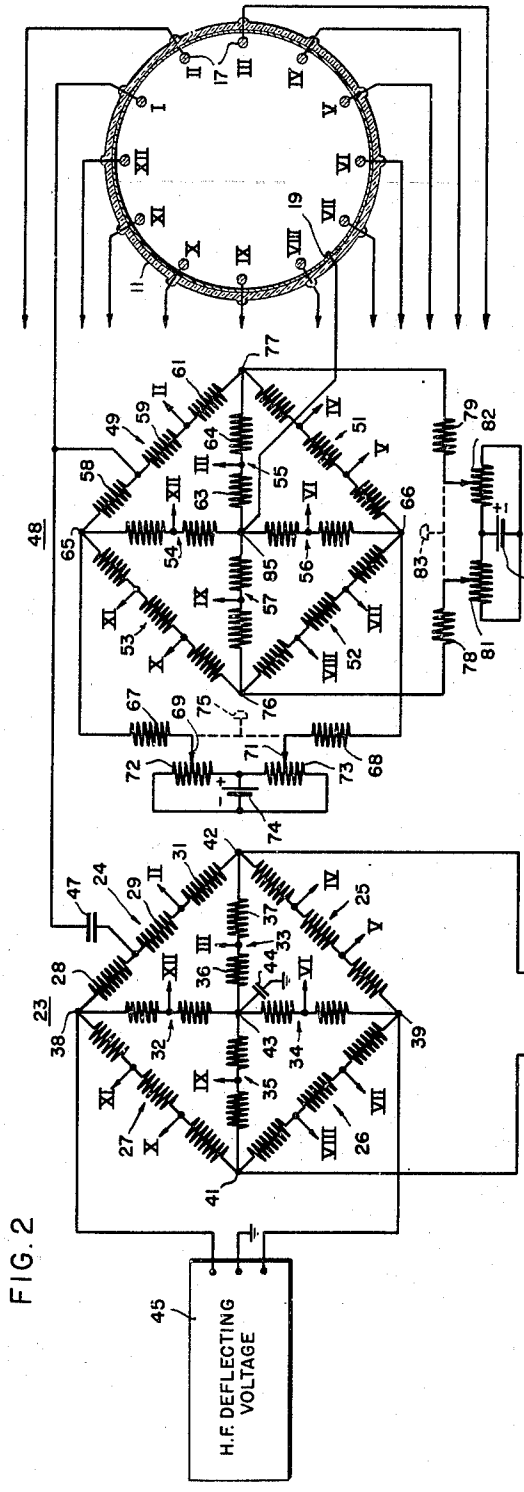

FIG. 2

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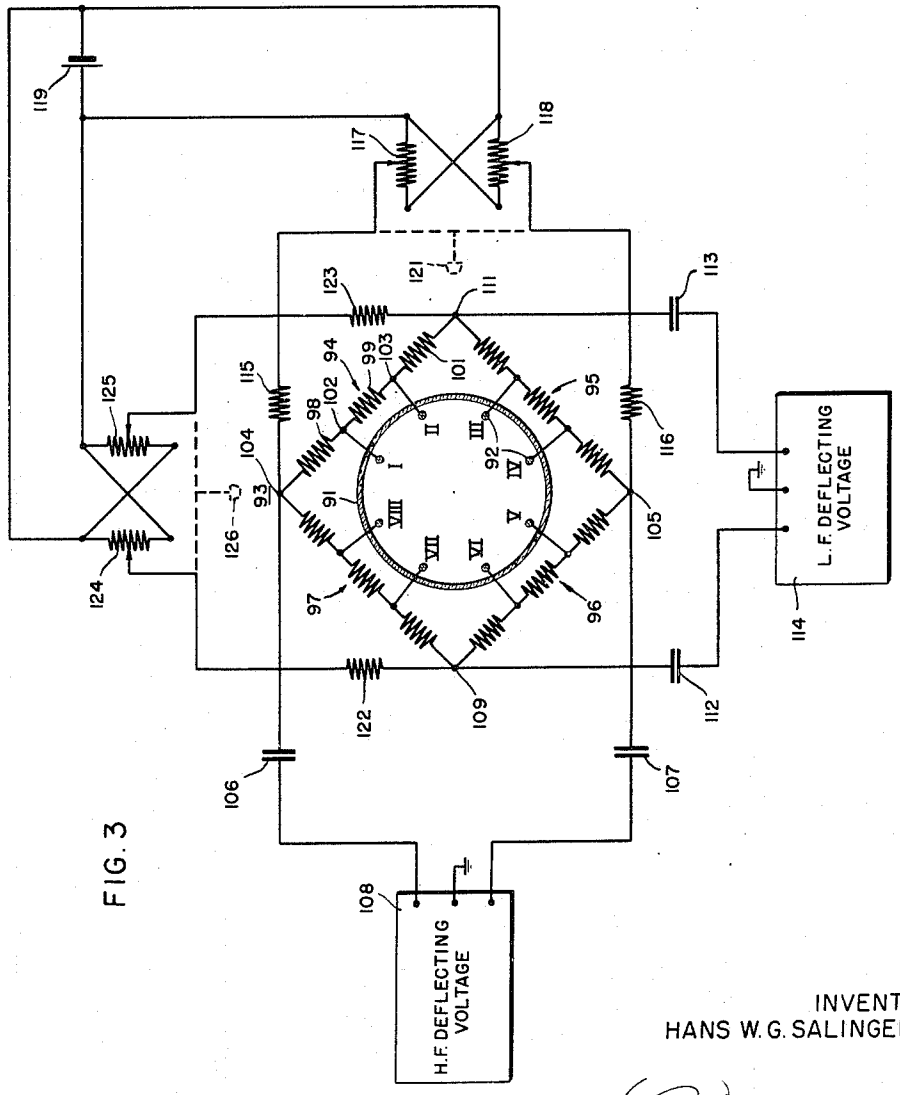

FIG. 3

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FIG. 4

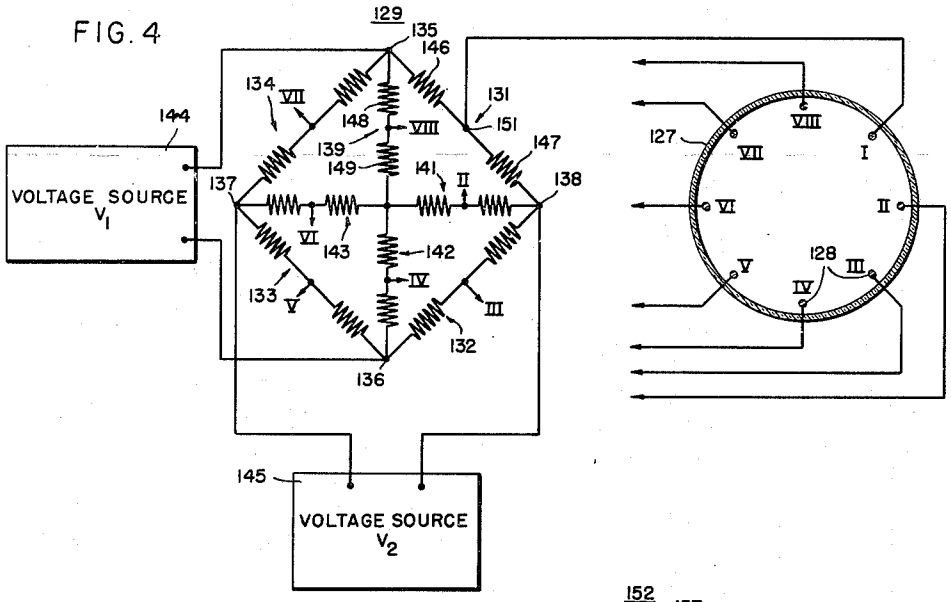
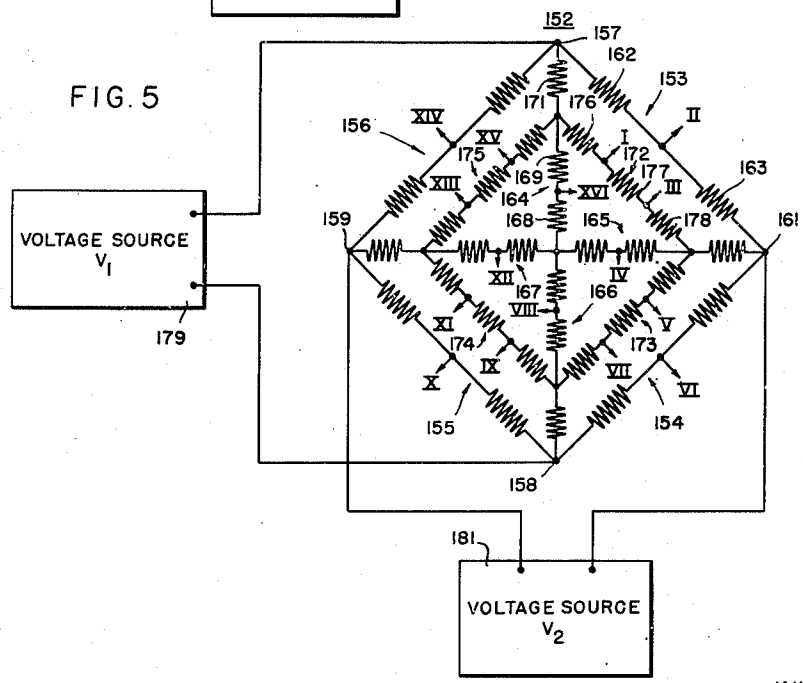


FIG. 5



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UNITED STATES PATENT OFFICE

2,489,328

ELECTRON BEAM CONTROLLING SYSTEM

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Application October 7, 1946, Serial No. 701,722

20 Claims. (Cl. 315—24)

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This invention relates to systems for controlling a beam of electrons and particularly has reference to voltage distribution networks for impressing the deflecting and centering voltages upon the field producing electrodes of a cathode ray tube.

According to conventional practice, the electron beams of cathode ray tubes have been deflected over their associated target electrodes either by electromagnetic or by electrostatic deflecting systems. In the case of tubes wherein electrostatic deflecting systems have been used, a plurality of pairs of field producing electrodes have been employed for producing the necessary deflecting fields. It is usual to provide two such pairs of electrodes. In such apparatus the electrodes of each pair are placed opposite to one another and the two pairs of electrodes are mounted at 90 degrees relative to one another. As is well known, the deflection of an electron beam may be effected in two coordinate directions by the impression upon the two pairs of electrodes of suitable scanning voltages. Such a deflecting system is particularly well adapted for use in cathode ray tubes wherein an electron beam of relatively small cross-sectional area is used. Typical examples of such tubes are found in oscilloscopes, television image reproducing tubes and the like.

In certain tubes, such as a television image dissector, the electron beam which is to be deflected is of considerably larger cross-sectional area. Heretofore, it has been generally customary to deflect such an electron beam by means of electromagnetically produced deflecting fields for the reason that electrostatic deflection of these electron beams has not been particularly easy to accomplish. In the first place, where electrostatic beam deflection is employed, it is customary to effect the two coordinate deflections of the beam in two different planes. Consequently, the two pairs of electrodes are mounted in two different planes spaced from one another along the path of the electron beam. Such a displacement of the deflecting electrodes has been necessary in order to avoid a distortion of the electrostatic field which generally results by mounting both pairs of deflecting electrodes in the same plane. As a result of such a distorted field, the beam deflection ceases to be a linear function of the deflection voltage impressed upon the electrodes.

There previously has been proposed a deflecting system particularly adapted for use in an image dissector whereby to produce a composite

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electrostatic field in one plane which is capable of effecting the deflection of the electron beam in a linear manner with respect to the deflecting voltage. Such a deflecting system forms the subject matter of Patent No. 2,297,949 granted to P. T. Farnsworth on October 6, 1942, for a Deflecting system. This patent comprises a cathode ray tube such as an image dissector which is provided with a plurality of pairs of deflecting elements all mounted in the same plane and surrounding a portion of the path of the electron beam. In one form of the patented structure, a number of elongated rods are used as the deflecting elements. Each of these rods extends generally longitudinally of the electron beam path. The high frequency and low frequency deflecting voltages are impressed upon these electrodes by means of a voltage distribution network. Each one of the deflecting electrodes has impressed thereon a predetermined proportion of each of the deflecting voltages depending upon its particular location relative to the two coordinate scanning directions. By this means, it has been determined that the desired electrostatic deflecting field may be produced without appreciable distortion whereby to effect the deflection of an electron beam, particularly one having a cross-sectional area of considerable magnitude, over a target electrode in two coordinate directions.

In accordance with the subject matter of the Farnsworth patent, the voltage distribution system comprises a network of impedances arranged in such a manner that the two deflecting voltages are separated or decoupled in accordance with the respective frequencies thereof. Inasmuch as the vertical deflecting voltage has a frequency of the order of 60 cycles per second and the horizontal deflecting voltage has a frequency of the order of 15,000 cycles per second, according to present television standards, the frequency separation or decoupling of the two deflecting voltages is accomplished quite readily at the fundamental frequencies.

However, since both of these deflecting voltages have complex wave forms, generally that of a saw-tooth, there also is present, in addition to the fundamental frequencies, a number of harmonic frequencies. In order to maintain the desired linearity, it is essential that a considerable number of these harmonic frequencies be present and effective in producing the beam deflection. In practice it has been determined that, in order to achieve this result, it is necessary to maintain the effectiveness of all of the harmonic frequencies up to and including at least the fif-

nth harmonic. As a consequence it is neces-
y to maintain the separation or decoupling
the two deflecting voltages through an appre-
ble band of frequencies. In the case of the
tical deflecting voltage, the frequency band
tends from about 60 to about 900 cycles per
ond. In the case of the horizontal deflecting
ltage, the frequency band extends from about
,000 to about 200,000 cycles per second. Thus,
reason of the frequency band widths required
be maintained, a deflecting voltage distribu-
n system operated on the principle of fre-
ency discrimination has not been entirely suc-
ssful, especially when operation is attempted
the relatively high horizontal deflecting fre-
encies required for 525 line scansion, accord-
g to present television standards.

It is well known that, when deflecting an elec-
on beam over a target electrode, the beam first
ust be oriented relative to the target. In prac-
e, this is known as centering the electron beam.
the case of an image dissector, particularly, it
nerally is preferable to direct the electron beam
that, in the absence of any deflecting fields, the
nter of the beam falls in line with the scanning
erture. Then, when the beam is deflected over
e aperture, the deflecting movement thereof
ll be symmetrical in all directions with a con-
quent minimizing of distortion effects. Inas-
uch as the centering of an electron beam, once
fected, is not ordinarily subject to change, a
ld of substantially constant intensity is em-
oyed for this purpose Customarily, this field
produced by the impression of a direct current
ltage upon the field producing deflecting elec-
odes. Then for deflecting purposes, a saw-tooth
ltage is superimposed upon the direct current
ltage to achieve the desired results. Where an
ectrostatic dissector, such as that disclosed in
e Farnsworth patent referred to, is used, the
nstant unidirectional voltages for centering the
ectron beam must be impressed upon the various
flecting elements in suitable respective propor-
ons to create a constant uniform field.

It is an object of the present invention, there-
re, to provide a novel distribution system for
multaneously impressing both high frequency
d low frequency deflecting voltages upon a plu-
lity of electrostatic electron beam deflecting
ectrodes whereby to secure a beam deflection
hich is a linear function of the deflection volt-
ges and at the same time whereby the two de-
ecting voltages are effectively decoupled at sub-
antially all frequencies thereof.

Another object of the invention is to provide a
istribution network for impressing both high
nd low frequency scanning voltages upon a
lurality of electrostatic electron beam deflect-
ng elements which operates entirely independ-
ntly of frequency differences of the two deflect-
ng voltages.

A further object of the invention is to provide
distribution network for impressing upon a
lurality of electrostatic electron beam deflecting
lements substantially constant unidirectional
oltages for orienting an electron beam relative
o a target electrode.

Still another object of the invention is to pro-
ide a novel distribution network for impressing
pon a plurality of electrostatic electron beam
eflecting elements electron beam centering volt-
ges in suitable proportions to produce a sub-
antially constant beam deflecting field, together
ith facilities for varying in the proper propor-

tions the individual voltages impressed upon the respective deflecting elements whereby to alter the orientation of the electron beam relative to the target electrode.

A still further object of the invention is to provide a system including a distribution network for impressing upon a plurality of electrostatic electron beam deflecting elements, both high frequency and low frequency voltages for deflecting an electron beam over a target electrode, together with unidirectional voltages for orienting the beam relative to the target electrode.

In accordance with this invention there is provided a tube which has facilities for developing an electron beam and directing it toward a target electrode. The tube is also provided with a plurality of field producing electrodes which are uniformly spaced in a circle around the path of the beam. In general, $4k$ electrodes are required, k being equal to any whole number. These electrodes, when energized by suitable voltages in accordance with the invention, are employed to move an electron beam relative to the target electrode. In order to effect the beam movement according to a predetermined scanning pattern deflecting voltages are impressed upon the electrodes in respective proportions to produce in the path of the beam a homogeneous field which varies periodically in magnitude as a function of time. In order to suitably orient the electron beam relative to the target electrode, unidirectional voltages are impressed upon the electrodes to produce a homogeneous field of relative constant magnitude. These voltages are impressed upon the electrodes by suitable connections to one or more voltage distributing networks.

Such a network consists of a balanced bridge arrangement of a plurality of impedance devices. The impedance devices are connected so as to provide the network with a mirror electrical symmetry about four axes of the network, each being located at angles of 45 degrees relative to one another. The connections of the impedance devices is such that the network is provided with two pairs of conjugate corner points. Voltages V1 and V2 are connected to the respective pairs of corner points. The network further is provided with intermediate tap points on the various branches thereof. As many tap points are provided as there are field producing electrodes in the tube and the tap points are connected respectively to these electrodes. In order to produce a homogeneous field in the path of the electron beam the impedance devices of the network are proportioned so as to impress upon any given one of the electrodes located at an angle A relative to an axis of symmetry of the electrodes, a voltage proportional to $V1 \sin A + V2 \cos A$.

In one form of the invention one such network is employed to impress the high frequency and the low frequency deflecting voltages upon the tube electrodes. Another network of a similar character is provided to impress the orienting or centering voltages upon the electrodes. In conjunction with the centering network there are provided facilities for varying the magnitudes of the energizing voltages impressed upon the corner points of the network.

In another form of the invention there is provided a single network of this character for distributing both the deflecting and the centering voltages to the tube electrodes.

For a better understanding of the invention, together with other and further objects thereof,

reference is made to the following description, taken in connection with the accompanying drawings and its scope will be pointed out in the appended claims.

In the accompanying drawings:

Fig. 1 is a longitudinal sectional view of a television image dissector tube having a plurality of electrodes whereby to effect electrostatic deflection of an electron beam over a target electrode;

Fig. 2 is a schematic circuit diagram of apparatus embodying the invention whereby suitable deflecting and centering voltages are impressed upon the tube deflecting electrodes;

Fig. 3 is a schematic circuit diagram of apparatus embodying another form of the invention wherein one voltage distributing network is used for both the deflecting and the centering voltages;

Fig. 4 is another schematic diagram of apparatus embodying the invention in still another form wherein one network is used for both deflecting and centering voltages; and

Fig. 5 is a schematic circuit diagram of apparatus embodying the invention wherein a more complicated form of network is used for impressing both the deflecting and the centering voltages upon a tube having a relatively greater number of field producing electrodes.

Having reference now to Fig. 1 of the drawing, there is shown a television image dissector tube 11. One end wall of the tube is provided with an optically plane window 12 and there is mounted adjacent the other end wall of the tube, a photoelectric cathode 13. The photosensitive surface of the cathode faces the window 12 so that an optical image may be projected through the window onto the cathode. The tube also is provided with a target electrode 14 located at one end of the tube adjacent the window 12. The target electrode is provided with a relatively small aperture 15 substantially of the size of an elemental area of the picture which it is desired to analyze. Preferably the aperture 15 is located on the central axis of the tube. In any case, it faces the cathode 13 so that electrons from the cathode may enter the target electrode through the scanning aperture 15. In accordance with generally preferred practice, the target electrode serves as a housing for a multi-stage static electron multiplier whereby a preliminary video amplification may be effected. The target electrode is maintained at a suitable positive potential relative to the cathode by means such as a battery 16.

The tube 11 also is provided with a plurality, twelve in the case illustrated herein, of elongated deflecting electrodes such as 17. These electrodes may be in the form of relatively stiff wires or small rods and are spaced uniformly about the longitudinal axis of the tube adjacent the inner periphery of the tube envelope. Preferably, they extend from the region of the cathode 13 to a plane adjacent to the scanning aperture 15 of the target electrode. Each of the deflecting electrodes is connected through the tube envelope by means such as a conductor 18. In this manner electrical connections may be made to each of the deflecting electrodes. An electrically conducting wall coating 19 also is provided on the inside wall of the tube envelope. This wall coating may be connected, as shown, to the target electrode 14. The tube additionally is provided with a focusing device such as an electromagnetic coil 20 mounted around the exterior portion of the tube envelope in such a manner that it substantially completely envelopes the space between the cathode 13 and the target electrode 14. The focusing coil may be energized from a suitable source of unidirectional voltage such as a battery 21 which may be connected to the coil through an adjustable resistor 22. By this means the magnitude of the current flowing in the focusing coil may be adjusted suitably to produce the desired focusing of the electron beam within the tube.

The electrical connections to the voltage distributing networks according to one form of the present invention are indicated in Fig. 2 to which reference now will be made. In this figure there is shown a transverse section of the image dissector tube 11. The deflecting electrodes are twelve in number and are identified by Roman numerals from I to XII in the well known manner of a clock dial. The connection of only the electrode I is shown complete to the voltage distributing networks, all other connections are similar and have merely been indicated so as not to unnecessarily complicate the drawing.

The deflecting electrodes such as 17 are coupled to a deflecting voltage distributing network 23. In general this network resembles that of a Wheatstone bridge. It comprises a balanced bridge arrangement of a plurality of impedance devices. The arrangement of these impedance devices in the network and the respective values thereof is such that the network has a mirror electrical symmetry about four axes located at angles of 45 degrees relative to one another. The network consists of four exterior branches 24, 25, 26 and 27 connected in series as shown to form a continuous loop. Each of these branches such as the branch 24 is composed of three resistors such as 28, 29, and 31 connected in series and having a combined impedance equal to that of the impedance of each of the other exterior branches, and corresponding resistors in the respective branches are of identical impedance values. In addition, the network includes four interior branches 32, 33, 34 and 35. Each of the interior branches is composed of two resistors such as 36 and 37 connected in series and having a combined impedance equal to that of the impedance of each of the other interior branches and corresponding resistors in the respective branches are of identical impedance values. The branches 32 and 34 are connected in series with one another and the terminals of this series arrangement are connected to one pair of conjugate corner points 38 and 39 of the network. Similarly the interior branches 33 and 35 are connected in series and to the other pair of conjugate corner points 41 and 42 of the network. The junction point 43 between the interior branches 32—34 and 33—35 constitutes the central point 43 of the network. In a preferred form of the invention the central point 43 is grounded for alternating currents through a condenser 44.

A source 45 of high-frequency deflecting voltage which has a saw-tooth wave form is connected to the conjugate network points 38 and 39. Likewise a low frequency source 46 of deflecting voltage is connected to the conjugate network points 41 and 42. Both of these deflecting voltages are supplied to the network in a push-pull relationship and are balanced relative to ground. The junction points between certain of the resistors comprising the network 23 are coupled respectively to the deflecting electrodes such as 17 of the image dissector tube 11. One such con-

nection is shown completely from the junction point of resistors 28 and 29. This intermediate junction or tap point is coupled by a condenser 47 to the deflecting electrode I. Similar connections are made from the other junction points of the network resistors to the tube deflecting electrodes as indicated by the Roman numerals.

The impedance relationship between each of the exterior branches of the network 23 and each of the interior branches is somewhat arbitrary depending upon the effective network impedance desired. For simplicity of disclosure, assume that the combined impedance of each of the interior branches such as 33 is w_1 and that the combined impedance of each of the exterior branches such as 24 is w_2. In its simplest form, the network 23 is of such a character that the ratio w_1/w_2 is equal to unity. In any case the resistors 28 and 31 and all others corresponding thereto each has a value which is equal to $0.367w_2$. The resistor 29 and all others like it has a value which is approximately equal to $0.266w_2$. In each of the interior branches of the network, the value of each of the resistors such as 36 is approximately equal to $0.734w_1$ and the value of each of the resistors such as 37 is approximately equal to $0.266w_1$. In the interest of making the disclosure of a particular embodiment of the invention as complete as possible, one successfully operated device according to the invention employed resistors such as 28 and 31 having values of 5500 ohms, resistors such as 29 and 37 having values of 4000 ohms, and resistors such as 36 having values of 11,000 ohms.

For the purpose of centering or otherwise orienting the electron beam, the deflecting electrodes of the tube 11 are coupled to a centering voltage distributing network 48. In form this network may be substantially similar to the network 23. In such a case it comprises four exterior branches 49, 51, 52 and 53. It also includes four interior branches 54, 55, 56 and 57. Each of the exterior branches such as the branch 49 includes a series connection of resistors such as 58, 59 and 61. Each of the interior branches such as the branch 55 includes a series connection of two resistors such as 63 and 64. As in the case of the network 23, the impedance values of all of the exterior branches and all of the interior branches are respectively equal. Also the ratio of the impedance value of each of the interior branches such as the branch 55 to that of each of the exterior branches such as the branch 49 is arbitrary but for convenience is taken as unity. In one practical embodiment of the invention the resistors 58 and 61 were of 180,000 ohms value. The resistors 59 and 64 had values of 133,000 ohms and the resistor 63 had value of 360,000 ohms.

One pair of conjugate corner points 65 and 66 of the centering network 48 is connected through respective resistors 67 and 68 to the movable contacts 69 and 71, respectively of two potentiometers 72 and 73. The potentiometers are connected in series as shown with both terminals thereof connected to the negative terminal of a source of unidirectional voltage such as a battery 74. The junction point between the potentiometers 72 and 73 are connected to the positive terminal of the battery 74. For ease of manipulation and adjustment of the voltage impressed upon the conjugate points 65 and 66, the movable contacts 69 and 71 of the potentiometers may be mechanically connected as indicated by the broken line for simultaneous movement thereof by a single control knob 75.

The other pair of conjugate corner points 76 and 77 of the network 48 are similarly connected through resistors 78 and 79, respectively to potentiometers 81 and 82. Also in this case, a single control knob 83 is provided to adjust the two potentiometers 81 and 82 simultaneously. These potentiometers are connected in a manner similar to the previously described potentiometers 72 and 73 and are further connected to a source of unidirectional voltage such as 84. If desired, the batteries 74 and 84 may be a single source of voltage. With resistance values of the network taken as indicated hereinbefore, satisfactory operation of the apparatus has been obtained with these batteries having values of approximately 600 volts.

The junction or tap points between certain of the resistors forming the network 48 are conductively coupled to the deflecting electrodes such as 17 of the tube 11. For example, the junction point between resistors 58 and 59 is directly connected to the tube electrode I. Other points of the network are similarly connected to the other tube electrodes as indicated. The central point 85 of the network 48 preferably is connected to the wall coating 19 of the tube as shown.

In order better to consider the problem of producing a homogeneous deflecting field, by means of a plurality of electrodes such as 17, assume that the total number of such electrodes is represented by n and that any particular one of these electrodes is represented by m. If then V represents the peak voltage impressed on the electrode XII, it is required to supply to electrode m a high frequency saw-tooth deflecting voltage of amplitude

$$V \sin \frac{2\pi m}{n}$$

and at the same time a low frequency saw-tooth deflecting voltage of amplitude

$$V \cos \frac{2\pi m}{n}$$

This general relationship may be applied to the particular embodiment of the invention disclosed herein. Consider for example the high frequency deflecting voltage required for electrode I. In this case m is equal to 1 and n is equal to 12. The high frequency deflecting voltage which is required to be impressed upon the electrode I is equal to 0.866 of the high frequency voltage impressed upon the electrode XII. It may be seen that a voltage of the same amplitude and polarity must be impressed upon the electrode XI. Also the voltage impressed upon the electrode XII is equal and opposite in polarity to the voltage impressed upon electrode VI. Similarly electrodes V and VII have impressed thereon voltages which are equal in magnitude and opposite in polarity to the voltages impressed upon electrodes I and XI. In like manner the voltages which are required to be impressed on electrodes II and X and also upon electrodes IV and VIII may be determined from the general expression and are equal to 0.5 of the voltage impressed upon electrode XII. Obviously with respect to the high frequency deflecting field, the voltage impressed upon electrodes III and IX is zero. This also is in conformity with the general expression.

In like manner it may be determined that, with respect to the low frequency scanning field, the voltage which is impressed upon the electrodes II and IV should be 0.866 of the voltage which is impressed upon the electrode III which latter voltage is equal and opposite in polarity to the voltage impressed upon electrode IX. A voltage

which is equal in magnitude but opposite in polarity should be impressed upon electrodes VIII and X. A voltage of the same polarity but of a magnitude equal to 0.5 of the voltage impressed upon electrode III is required for impression upon electrodes I and V. A voltage of the same magnitude but of opposite polarity should be impressed upon electrodes VII and XI. In this case the low frequency deflecting voltage impressed upon electrodes VI and XII is zero.

The values of the resistors comprising the network 23 have been chosen in their relationship to one another in such a manner that the voltage distribution required, as outlined in the preceding paragraphs, may be secured. Another consideration in the determination of the values of the network resistors is that it is necessary to minimize the effect of the capacity of the deflecting electrodes. In a particular practical embodiment of the present invention it was determined that the capacity of one of the conductors is approximately 4.5 micromicrofarads. Such a capacity, at a frequency equal to the fifteenth harmonic of the high frequency deflecting voltage, is equivalent to a reactance of 150,000 ohms. Hence, it was necessary to so construct the network 23 that it would have a relatively low resistance. Accordingly, each of the exterior branches such as 24 and each of the interior branches such as 32 was made to have an impedance of approximately 15,000 ohms.

Similar considerations should be given to the construction of the centering network 48. Having a centering network such as that specified previously, the potentiometers 72 and 73 may be adjusted to move the electron beam in one coordinate direction. The manner in which this is effected by the network 48 in conjunction with the potentiometers 72 and 73 may be more clearly understood if it is assumed that initially the adjustable contacts 69 and 71 of these potentiometers are each engaged with the center points on the respective potentiometers. Inasmuch as each of the potentiometers is connected in parallel across the battery 74, it is seen that the network points 65 and 66 are at the same potential and, therefore, there is no vertical centering voltage impressed upon the electrodes such as 17. If now the control knob 75 is manipulated to move both of the movable contacts 69 and 71 in an upward direction as viewed in the drawing, the contact 69 is moved toward a negative point on the potentiometer 72, and at the same time the contact 71 is moved to a positive point on its associated potentiometer 73. The result of such an adjustment is to make the voltage impressed upon the point 65 negative, and at the same time to make the voltage impressed upon the point 66 positive by a like amount. The polarity and magnitude of the voltages which are impressed upon the tube electrodes by means of the connections thereof to the network 48 are effective to shift the electric centering field to one side or the other of the central axis of the tube depending upon the sense of the adjustment of the knob 75. In this case the electron beam will be moved horizontally.

A similar shifting of the electric field in the tube in the other coordinate direction is effected by suitable manipulation of the control knob 83 whereby the beam may be moved vertically.

It should be noted that in the case of both of the networks 23 and 48, the voltages by which it is desired to move the electron beam horizontally are impressed upon the electrodes in a vertical sense. Also, the vertical deflecting voltages are impressed upon the electrode in a horizontal sense. The reason for this is the well-known fact that in a tube of the character described, a 90 degree rotation of the beam is effected between the cathode and the target electrode.

It should be evident from a consideration of the foregoing description of a specific embodiment of the invention that the principles underlying the invention are not necessarily limited to use with the tube having just twelve deflecting electrodes. It is contemplated to obviously fall within the purview of the invention to have more or fewer deflecting electrodes. Also it is to be understood that the form of the network is not necessarily restricted to that shown in Fig. 2 so long as the balanced bridge requirement is fulfilled. It is considered that it is by reason of the balanced nature of the bridge that the necessary decoupling of the two deflecting voltages is secured. Likewise it should be obvious to one skilled in the art that other types of impedances could be used to form the deflecting network. For example, in certain applications it may be considered that the power consumption by a network such as that illustratively disclosed herein is too great. In such a case the network resistors may be replaced with condensers which would consume substantially no power and yet would give the proper deflecting voltage distribution for both the high frequency and the low frequency deflecting fields. However, the capacitive reactances would have to be much smaller than any parallel resistances that might be present such as in the case where a centering network such as 48 is employed in conjunction with this form of scanning voltage distributing network. Leakage current would also be a factor in the design of such a network.

In order for a device of the character described to operate satisfactorily it is necessary as previously noted to maintain at a minimum the values of any impedance elements connected to the tube electrodes. Consequently, the effective resistance of the deflecting network 23 is made relatively small. In one preferred form of apparatus embodying the invention, it is desirable to derive the unidirectional voltage supplies for the centering network 48 from the voltage divider network which furnishes accelerating voltages to the electron multiplier housed in the target anode 14 of Fig. 1. Ordinarily such a voltage supply is incapable of furnishing current in any substantial magnitude. Therefore, in order to minimize the current drain on such a power supply, it is necessary to so construct the centering network 48 that its effective impedance is relatively high. Such a network may then be connected effectively in parallel with the relatively low impedance deflecting network 23. Such an arrangement further decreases the effective impedance connected to the tube electrodes so as to insure satisfactory operation of the tube and at the same time does not require voltage supplies such as those represented by the batteries 74 and 84 which have to furnish any appreciable current.

Nevertheless, an arrangement such as that illustrated in Fig. 2 requires a large number of circuit components to provide two voltage distribution networks, one for deflecting and one for centering the electron beam. Furthermore an arrangement of this type requires decoupling of the two networks for direct current. A plurality of condensers such as 47 are required for this purpose. These condensers must be of appreciable size so that they may be employed in

onjunction with the low frequency deflecting oltage which, in a television tube, is of the order f 60 cycles per second. The presence of these ondensers has a distorting influence on the delecting voltages. Even though these voltages nay be supplied to the network 23 with good inearity characteristics the voltages which are mpressed upon the tube electrodes from the net- vork branches tend to be distorted somewhat rom linearity by reason of the fact that coupling :ondensers such as 47 are employed.

As will be disclosed presently, certain ones of :ome other forms of the invention may be em-)loyed to overcome the disadvantage of using cou-)ling condensers between the voltage distribut- ng network and the tube electrodes. The ad- vantage of obviating the use of the coupling con- lensers, however, is offset somewhat by the re- quirement that other sources of unidirectional voltages must be furnished which are capable)f producing a greater flow of current than the power system used primarily to furnish accelerat- ng voltages to an electron multiplier.

Reference now will be made to Fig. 3 which diagrammatically illustrates another form of the invention. In this case the invention is shown in conjunction with a tube which is provided with eight field producing electrodes. The tube 91 is shown in transverse section. It is provided with eight elongated electrodes such as 92 uniformly spaced in a circle around the interior periphery of the tube envelope. In this case the electrodes are situated in such a manner that the vertical and horizontal axes of the tube lie mid-way between two adjacent electrodes. The electron beam controlling fields which are to be produced by these electrodes are for effecting movement of the beam in the two coordinate directions corresponding to these axes.

The voltage distributing network which is used in conjunction with a tube having electrodes arranged in this manner is, as in all forms of the present invention, a balanced bridge arrangement of a plurality of impedance devices. The arrangement of the impedance devices is such that the network has a mirror electrical symmetry about four axes each located at angles of 45 degrees relative to one another. In this case, there is provided a network 93 which comprises four branches 94, 95, 96 and 97. These branches are arranged in a series connection forming a closed loop and corresponds in this respect to the exterior branches of the networks 23 and 48 of Fig. 2. Each of the branches is substantially identical to the others in total impedance and each branch comprises the series connection of three resistors. For example, the branch 94 includes resistors 98, 99 and 101. The terminals of each of the branches are connected to terminals of two of the other branches as shown. The intermediate junction or tap points between the three resistors of each branch are connected respectively to two of the tube electrodes. For example, the tap point 102 and the tap point 103 of branch 94 are connected respectively to the tube electrodes I and II.

The corner points of the network are connected in conjugate pairs to the voltage supplies for producing the desired fields within the tube. For effecting horizontal deflection of the electron beam the corner points 104 and 105 are coupled respectively by condensers 106 and 107 to the output terminals of a source 108 of high frequency deflecting voltage. As in the previous instance this source is capable of supplying to these two corner points a push-pull saw-tooth voltage of considerable magnitude which is balanced relative to ground. Likewise the corner points 109 and 111 are coupled respectively by condensers 112 and 113 to a source 114 of low frequency deflecting voltage which also is a balanced push-pull saw-tooth voltage.

In addition, the corner points 104 and 105 are coupled respectively through isolating resistors 115 and 116 and further through respective potentiometers 117 and 118 to a source of unidirectional voltage which is represented in the drawing as a battery 119. The potentiometers 117 and 118 are arranged for simultaneous adjustment by means of a single control knob 121. The corner points 109 and 111 similarly are coupled respectively through isolating resistors 122 and 123 and respective potentiometers 124 and 125 to the battery 119. The potentiometers 124 and 125 also are arranged for simultaneous adjustment by a knob 126.

The network 93 is so constructed that the proper voltage distribution is effected to the various tube electrodes dependent upon their angular relationship relative to an axis of symmetry of the electrodes. This is accomplished by selecting the proper impedance values for the resistors comprising each of the network branches. The impedance values of these resistors are so proportioned to impress upon any given one of the electrodes located at an angle A relative to an axis of symmetry a voltage which is proportional to $V1 \sin A + V2 \cos A$ where V1 and V2 are the respective voltages impressed upon the two pairs of corner points of the network.

In this particular form of the network all resistors such as 98 and 101 which connect to corner points of the network are of equal values. In general, let w_3 represent the impedance value of such resistors. The resistors such as 99 connected at the centers of each of the branches also are equal to one another in impedance which may be represented by w_4. In order to develop the desired voltages for impression upon the tube electrodes, the ratio w_4/w_3 must be equal to $\sqrt{2}$. The actual values of these network resistors will depend upon the total impedance which is desired for the network.

The operation of the apparatus illustrated in Fig. 3 is substantially the same as that previously described in connection with Fig. 2. The high frequency deflecting voltage derived from the source 108 is effective to produce a component of the field within the tube whereby the electron beam is deflected over a target electrode at a relatively rapid rate in a horizontal direction, for example. The low frequency deflecting voltage derived from the source 114 is effective to produce a component of the field within the tube whereby the electron beam is deflected vertically relative to a target electrode at a relatively slow rate. The unidirectional voltages derived from the battery 119 are impressed upon the network 93 by the two pairs of potentiometers 117—118 and 124—125. A relatively constant component of the field within the tube is produced by such means to suitably orient the electron beam with respect to the target electrode. Adjustment of the beam orientation is accomplished horizontally by manipulation of the knob 121 and vertically by the knob 126.

Referring now to Fig. 4, there is shown another embodiment of the invention for use with a tube 127, also having eight elongated electrodes 128

uniformly spaced in a circle around the interior periphery of the tube envelope. In this case, however, two pairs of opposite electrodes are located so that they lie respectively on the vertical and horizontal axes of the tube. The deflection of the electron beam is to be effected relative to these axes.

The tube electrodes are coupled to a voltage distributing network 129 by means of which suitable voltages are impressed upon the electrodes to produce the field necessary to effect the desired control of the electron beam. As in all forms of the invention, the network consists of a balanced bridge arrangement of a plurality of impedance devices. The connections of these impedance devices and the respective values thereof is such that the network has a mirror electrical symmetry about four axes each located at angles of 45 degrees relative to one another. The network 129 consists of four exterior branches 131, 132, 133, and 134 connected in series to form a closed loop having two pairs of corner points 135—136 and 137—138. The network also includes four interior branches 139, 141, 142 and 143. The interior branches are connected in pairs in series between respective pairs of corner points. For example, the interior branches 139 and 142 are connected in series between the corner points 135 and 136. Similarly, the interior branches 141 and 143 are connected in series between the corner points 137 and 138. The mid-points of each of the two series connections of the interior branches are connected together and, as described in connection with Fig. 2, preferably may be grounded.

The sources of the voltages which it is desired to distribute to the tube electrodes by means of the network 129 are illustrated in this figure diagrammatically. A source 144 of a voltage V1 is coupled to the corner points 135—136. Another source 145 of a voltage V2 is similarly coupled to the corner points 137—138. It will be understood that the voltage sources 144—145 may furnish either the deflecting voltages or the centering voltages, or both.

In this form of the invention, the network 129 has two resistors in each of the exterior and interior branches thereof. For example, the exterior branch 131 consists of the series connection of two resistors 146 and 147. A typical interior branch of the network such as the branch 139 consists of the series connection of two resistors 148 and 149. Selected intermediate tap points on the network branches are connected respectively to the various tube electrodes as indicated by the Roman numerals. For example, the tap or junction point 151 between the resistors 146 and 147 of the exterior network branch 131 is connected to the tube electrode I.

The impedance values of the network components are selected to distribute the voltages properly to the tube electrodes. In each of the exterior branches of the network the two resistors such as 146 and 147 of the branch 131 are of the same impedance. As in previous cases, the total impedance of each of the exterior branches may be represented by w_5. Also, the total impedance of each of the interior branches such as the branch 139 may be represented by w_6. In this form of the invention, as in that disclosed in Fig. 2, the relationship between w_5 and w_6 is arbitrary. The two resistors comprising each of the interior branches such as the resistors 148 and 149 of the branch 139 are related to one another in impedance in such a manner that the value of the resistor 148 and all others like it in the other interior branches is substantially equal to $0.293w_6$ and the value of the resistor 149 and all others like it in the other interior branches is substantially equal to $0.707w_6$.

The operation of the form of the invention illustrated in Fig. 4 is similar to that previously described in connection with other forms of the invention and consequently need not be described in any further detail.

Referring now to Fig. 5, there is shown a network capable of effecting the desired voltage distribution to sixteen field producing electrodes of a cathode ray tube. The electrodes (not shown) are uniformly spaced in a circle around the interior periphery of the tube envelope and are arranged as in Figs. 2 and 4, so that two pairs of opposite electrodes lie on two coordinate axes of the tube.

For such a tube there is provided a voltage distributing network 152. It has a form similar to that of all other networks embodying the invention and consists of a balanced bridge arrangement of a plurality of impedance devices so connected as to produce a network having a mirror electrical symmetry about four axes located at angles of 45 degrees relative to one another. In this case the network comprises four exterior branches 153, 154, 155 and 156 connected together in series so as to form a closed loop having two pairs of corner points 157—158 and 159—161. Each of the exterior branches, such as the branch 153, consists of a series connection of two resistors 162 and 163. The network also includes four interior branches 164, 165, 166 and 167, each of which is made up of the series connection of three resistors. The branch 164, for example, includes resistors 168, 169 and 171. The interior branches 164 and 166 are connected together in series between the corner points 157—158. The interior branches 165 and 167 are connected in series between the corner points 159—161. In this form of the invention the network also includes four auxiliary branches 172, 173, 174 and 175. The auxiliary branches are connected in series to form a closed loop much in the same manner as the exterior branches are connected. Each of the auxiliary branches consists of the series connection of three resistors. The auxiliary branch 172, for example, comprises resistors 176, 177, 178. The terminals of each of the auxiliary branches are connected to intermediate junction points of the interior branches. For example, the terminal of the auxiliary branch 172 extending from the resistor 176 is connected to the junction point between the interior branch resistors 169 and 171. Corresponding terminals of all other auxiliary exterior branches are similarly connected to the interior branches.

A source 179 of a voltage V1 is coupled to the corner points 157—158. Also, a source 181 of a voltage V2 is connected to the corner points 159—161. The network 152 is designed to furnish field producing voltages to sixteen electrodes of a tube wherein the electrodes VIII and XIV lie on the vertical axis and the electrodes IV and XII lie on the horizontal axis. All of the tube electrodes are connected to selected intermediate or tap points on the network as indicated by the Roman numerals.

The impedance relationship between the various components of the network are chosen to

impress voltages upon the respective tube electrodes whereby to produce the desired field for controlling the electron beam. The resistors employed in each of the exterior branches all are of equal impedance values. For example, in the exterior branch 153, the total impedance thereof may be represented by w_7. In this case the values of each of the resistors such as 162 and 163 will be represented as $0.5w_7$. The total impedance of each of the auxiliary branches such as 172 may be represented as w_8. The resistors 176 and 178 and all others like them in the other auxiliary branches are equal to $0.293w_8$. The value of the resistor 177 and all others like it of the other auxiliary branches is equal to $0.414w_8$. The combined impedance of the resistors 168 and 169 of the interior branch 164 and all others like them of the other interior branches may be represented as w_9. The impedance of the resistor 166 and all others like it is substantially equal to $0.765w_9$. The impedance of the resistor 171 and all others like it of the other interior branches is substantially equal to $0.0817w_7w_8/w_7+w_8$. The relationship between the impedance values w_7, w_8 and w_9 are arbitrary and may be chosen to produce a network having any desired effective impedance.

The operation of the form of the invention illustrated in Fig. 5 is substantially the same as the operation of all other forms of the invention and, therefore, will not be described.

The general character of the impedance networks in accordance with the present invention may be determined from a consideration of the typical examples which have been disclosed herein by way of illustration. As previously stated, the invention is not limited to any particular specific form of network so long as it is of such a character to satisfy certain underlying essentials. One of these essential requirements of a network within the scope of the invention is that it be a balanced bridge arrangement of a plurality of impedance devices. The character of the impedance devices is immaterial so long as, in a given network, they are all of the same kind. The arrangement of the impedance devices must be such that the network is provided with a plurality of pairs of conjugate corner points; one pair for each of the voltages which it is desired to distribute. The character of these voltages is immaterial to the successful practicing of the invention. They may be unidirectional voltages having fixed or variable magnitudes. Also, they may be voltages of a periodic character such as an alternating voltage which is cyclically variable as a function of time. Another requirement of a network falling within the scope of the invention is that it have a mirror electrical symmetry about all of a plurality of equiangular axes, as for example, four axes located at angles of 45 degrees relative to one another.

Such a network may be used to distribute voltages to a plurality of electrodes uniformly spaced around a circle, as illustrated herein. It does not matter whether pairs of opposite electrodes lie on axes of symmetry of the electrodes or whether these axes are located at an equal distance between adjacent electrodes. In either case the impedance devices of the network may be suitably proportioned to impress upon the electrodes respective voltages which are proportional to the angular relationships of the electrodes with respect to an axis of symmetry thereof.

It should be obvious from the foregoing description that practically any even number of voltages may be distributed to a plurality of electrodes by means of a network embodying the present invention. Also, it is considered to be apparent that, while for illustrative purposes a television tube operating according to the conventional rectilinear scanning pattern has been described, a network of the character disclosed also is susceptible of use with other cathode ray tubes which may be operated according to substantially any other desired scanning pattern.

While there has been described what, at present, is considered the preferred embodiment of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is aimed, therefore, in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A system for controlling the direction of an electron beam comprising, $4k$ electrodes uniformly spaced in a circle around the path of said beam k being equal to any whole number, a voltage distributing network consisting of a balanced bridge arrangement of a plurality of branches having impedance, said branches being connected so as to give said network a mirror electrical symmetry about four axes located at angles of 45 degrees relative to one another, said network having two pairs of corner points, two sources of voltages V1 and V2 connected to the respective pairs of network corner points, $4k$ tap points provided on said network branches, said tap points being connected respectively to said electrodes, and the impedances of said network branches being so proportioned to impress upon any given one of said electrodes located at an angle A relative to an axis of symmetry of said electrodes, a voltage proportional to $V1 \sin A+V2 \cos A$.

2. A system for deflecting an electron beam comprising, $4k$ elongated electrodes uniformly spaced in a circle around the path of said beam, k being equal to any whole number, a deflecting voltage distributing network consisting of a balanced bridge arrangement of a plurality of impedance devices, said impedance devices being connected so as to give said network a mirror electrical symmetry about each of four axes located at angles of 45 degrees relative to one another, said network having two pairs of corner points, two sources of deflecting voltages V1 and V2 connected to the respective pairs of network corner points, $4k$ tap points provided in said network between certain ones of said impedance devices, said tap points being connected respectively to said electrodes, and the impedance devices of said network being so proportioned to impress upon any given one of said electrodes located at an angle A relative to an axis of symmetry of said electrodes, a voltage proportional to

$$V1 \sin A+V2 \cos A.$$

3. A system for deflecting an electron beam comprising, a plurality of elongated electrodes located in spaced positions around the path of said beam, a deflecting voltage distributing network consisting of a balanced bridge arrangement of a plurality of exterior branches connected together to form a closed loop and a plurality of interior branches connected between respective pairs of conjugate points of said exterior branches, a source of high frequency deflecting

voltage coupled to one pair of said conjugate network points, a source of low frequency deflecting voltage coupled to the other pair of said conjugate network points, and couplings between points on said network branches and respective ones of said electrodes, whereby to deflect said beam by all of said electrodes in one direction in response to said high frequency deflecting voltage and to deflect said beam by all of said electrodes in another direction in response to said low frequency deflecting voltage.

4. A system for deflecting an electron beam comprising, a plurality of elongated electrodes located in spaced positions around the path of said beam a deflecting voltage distributing network consisting of a balanced bridge arrangement of a plurality of exterior branches connected together to form a closed loop and an equal number of interior branches connected in pairs between respective pairs of conjugate points of said exterior branches, a source of high frequency deflecting voltage coupled to one pair of said conjugate network points, a source of low frequency deflecting voltage coupled to another pair of said conjugate network points, and couplings between selected points on said network branches and respective ones of said electrodes, whereby to deflect said beam by all of said electrodes in one direction in response to said high frequency deflecting voltage and to deflect said beam by all of said electrodes in another direction in response to said low frequency deflecting voltage.

5. A system for deflecting an electron beam comprising, a plurality of elongated electrodes located in uniformly spaced positions around the path of said beam, a deflecting voltage distributing network consisting of a balanced bridge arrangement of an even number of substantially equal impedance exterior branches connected in series to form a closed loop and an even number of substantially equal impedance interior branches connected in pairs in series between respective pairs of conjugate points of said exterior branches, a source of high frequency deflecting voltage coupled to one pair of said conjugate network points, a source of low frequency deflecting voltage coupled to another pair of said conjugate network points, and couplings between selected points on said network branches and respective ones of said electrodes, whereby to deflect said beam by all of said electrodes in one direction in response to said high frequency deflecting voltage and to deflect said beam by all of said electrodes in another direction in response to said low frequency deflecting voltage.

6. A system for deflecting an electron beam comprising, a plurality of elongated electrodes located in uniformly spaced positions around the path of said beam, a deflecting voltage distributing network consisting of a balanced bridge arrangement of four substantially equal impedance exterior branches connected in series to form a closed loop and four substantially equal impedance interior branches connected in pairs in series between respective pairs of conjugate points of said exterior branches, said interior branches being connected together at their mid points, a source of high frequency deflecting voltage coupled to one pair of said conjugate network points, a source of low frequency deflecting voltage coupled to the other pair of said conjugate network points, and couplings between selected points on said network branches and respective ones of said electrodes, whereby to deflect said beam by all of said electrodes in one direction in response to said high frequency deflecting voltage and to deflect said beam by all of said electrodes in another direction in response to said low frequency deflecting voltage.

7. A system for deflecting an electron beam comprising, a plurality of elongated electrodes located in uniformly spaced positions around the path of said beam, a deflecting voltage distributing network consisting of a balanced bridge arrangement of four substantially equal impedance exterior branches connected in series to form a closed loop and four substantially equal impedance interior branches connected in pairs in series between respective pairs of conjugate points of said exterior branches, said interior branches being grounded at their mid points for alternating voltages, a source of high frequency deflecting voltage coupled to one pair of said conjugate network points, a source of low frequency deflecting voltage coupled to the other pair of said conjugate network points, and couplings between selected intermediate points on said network branches and respective ones of said electrodes, whereby to deflect said beam by all of said electrodes in one direction in response to said high frequency deflecting voltage and to deflect said beam by all of said electrodes in another direction in response to said low frequency deflecting voltage.

8. A system for controlling an electron beam relative to a target electrode comprising, a plurality of electrodes located around the path of said beam, a distributing network for beam-deflecting voltages, a distributing network for voltages by which to orient said beam relative to said target electrode, each of said networks consisting of a balanced bridge arrangement of a plurality of exterior branches connected to form a closed loop and a plurality of interior branches connected between respective pairs of conjugate points of said exterior branches, a source of high frequency deflecting voltage coupled to one pair of conjugate points of said deflecting voltage-distributing network, a source of low frequency deflecting voltage connected to the other pair of conjugate points of said deflecting voltage-distributing network, couplings between points on said deflecting voltage-distributing network branches and respective ones of said electrodes, whereby to deflect said beam by all of said electrodes in one direction in response to said high frequency deflecting voltage and to deflect said beam by all of said electrodes in another direction in response to said low frequency deflecting voltage, a source of unidirectional voltage coupled to each pair of conjugate points of said orienting voltage-distributing network, couplings between points on said orienting voltage-distributing network branches and respective ones of said electrodes, and means for varying at least one of the unidirectional voltages impressed upon the respective pairs of conjugate points of said orienting voltage-distributing network, whereby to control the orientation of said beam relative to said target electrode.

9. A system for controlling an electron beam relative to a target electrode comprising, a plurality of electrodes located around the path of said beam, a distributing network for beam-deflecting voltages, a distributing network for voltages by which to orient said beam relative to said target electrode, each of said networks consisting of a balanced bridge arrangement of a plurality of exterior branches connected together to form a closed loop and an equal number of

nterior branches connected in pairs between respective pairs of conjugate points of said exterior branches, a source of high frequency deflecting voltage coupled to one pair of conjugate points of said deflecting voltage-distributing network, a source of low frequency deflecting voltage connected to the other pair of conjugate points of said deflecting voltage-distributing network, couplings between suitable points on said deflecting voltage-distributing network branches and respective ones of said electrodes, whereby to deflect said beam by all of said electrodes in one direction in response to said high frequency deflecting voltage and to deflect said beam by all of said electrodes in another direction in response to said low frequency deflecting voltage, a source of unidirectional voltage coupled to each pair of conjugate points of said orienting voltage-distributing network, couplings between points on said orienting voltage-distributing network branches and respective ones of said electrodes, and means for varying the unidirectional voltages impressed upon the respective pairs of conjugate points of said orienting voltage-distributing network, whereby to control the orientation of said beam relative to said target electrode.

10. A system for controlling an electron beam relative to a target electrode comprising, a plurality of electrodes located in spaced positions around the path of said beam, a distributing network for beam-deflecting voltages, a distributing network for voltages by which to orient said beam relative to said target electrode, each of said networks consisting of a balanced bridge arrangement of an even number of substantially equal impedance exterior branches connected in series to form a closed loop and an even number of substantially equal impedance interior branches connected in pairs in series between respective pairs of conjugate points of said exterior branches, a source of high frequency deflecting voltage coupled to one pair of conjugate points of said deflecting voltage-distributing network, a source of low frequency deflecting voltage connected to the other pair of conjugate points of said deflecting voltage-distributing network, couplings between selected points on said deflecting voltage-distributing network branches and respective ones of said electrodes, whereby to deflect said beam by all of said electrodes in one direction in response to said high frequency deflecting voltage and to deflect said beam by all of said electrodes in another direction in response to said low frequency deflecting voltage, a source of unidirectional voltage coupled to each pair of conjugate points of said orienting voltage-distributing network, couplings between selected points on said orienting voltage-distributing network branches and respective ones of said electrodes, and means for varying the unidirectional voltages impressed upon the respective pairs of conjugate points of said orienting voltage-distributing network, whereby to selectively control the orientation of said beam in two coordinate directions relative to said target electrode.

11. A system for controlling an electron beam relative to a target electrode comprising, a plurality of elongated electrodes located in spaced positions around the path of said beam, a distributing network for beam-deflecting voltages, a distributing network for voltages by which to orient said beam relative to said target electrode, each of said networks consisting of a balanced bridge arrangement of four substantially equal impedance exterior branches connected in series to form a closed loop and four substantially equal impedance interior branches connected in pairs in series between respective pairs of conjugate points of said exterior branches, a source of high frequency deflecting voltage coupled to one pair of conjugate points of said deflecting voltage-distributing network, a source of low frequency deflecting voltage connected to the other pair of conjugate points of said deflecting voltage-distributing network, couplings between selected points on said deflecting voltage-distributing network branches and respective ones of said electrodes, whereby to deflect said beam by all of said electrodes in one direction in response to said high frequency deflecting voltage and to deflect said beam by all of said electrodes in another direction in response to said low frequency deflecting voltage, a source of unidirectional voltage coupled to each pair of conjugate points of said orienting voltage-distributing network, couplings between selected points on said orienting voltage-distributing network branches and respective ones of said electrodes, and means for varying the unidirectional voltages impressed upon the respective pairs of conjugate points of said orienting voltage-distributing network, whereby to selectively control the orientation of said beam in two coordinate directions relative to said target electrode.

12. A system for controlling an electron beam relative to a target electrode comprising, a plurality of elongated electrodes located in uniformly spaced positions around the path of said beam, a distributing network for beam-deflecting voltages, a distributing network for voltages by which to orient said beam relative to said target electrode, each of said networks consisting of a balanced bridge arrangement of four substantially equal impedance exterior branches connected in series to form a closed loop and four substantially equal impedance interior branches connected in pairs in series between respective pairs of conjugate points of said exterior branches, a source of high frequency deflecting voltage coupled to one pair of conjugate points of said deflecting voltage-distributing network, a source of low frequency deflecting voltage connected to the other pair of conjugate points of said deflecting voltage-distributing network, reactive couplings between selected intermediate points on said deflecting voltage-distributing network branches and respective ones of said electrodes, whereby to deflect said beam by all of said electrodes in one direction in response to said high frequency deflecting voltage and to deflect said beam by all of said electrodes in another direction in response to said low frequency deflecting voltage, a source of unidirectional voltage coupled to each pair of conjugate points of said orienting voltage-distributing network, conductive couplings between selected intermediate points on said orienting voltage-distributing network branches and respective ones of said electrodes, and means for individually varying the unidirectional voltages impressed upon the respective pairs of conjugate points of said orienting voltage-distributing network, whereby to selectively control the orientation of said beam in two coordinate directions relative to said target electrode.

13. A system for controlling the movement of an electron beam comprising, a plurality of electrodes uniformly spaced around the path of said beam, a voltage-distributing network comprising a plurality of impedance devices connected to provide a balanced bridge, said network having

two pairs of conjugate corner points and a plurality of tap points at selected intermediate positions on said impedance devices, a source of high frequency deflecting voltage coupled to a first pair of said corner points, a source of low frequency deflecting voltage connected to a second pair of said corner points, a source of unidirectional horizontal centering voltage coupled to said first pair of corner points, a source of unidirectional vertical centering voltage coupled to said second pair of corner points, and couplings between said network tap points and respective ones of said electrodes, said network tap points being selected so as to impress the beam-controlling voltages upon said respective electrodes in suitable proportions to effect the production by all of said electrodes of a homogeneous field in the path of said beam.

14. A system for controlling the movement of an electron beam comprising, a plurality of electrodes uniformly spaced around the path of said beam, a voltage distributing network comprising a plurality of impedance devices connected to provide a balanced bridge, said network having two pairs of conjugate corner points and a plurality of tap points at selected intermediate positions on said impedance devices, a first source of each of two independent voltages coupled to a first pair of said corner points, a second source of each of two independent voltages connected to a second pair of said corner points, and couplings between said network tap points and respective ones of said electrodes, said network tap points being selected so as to impress the beam-controlling voltages upon said respective electrodes in suitable proportions to effect the production by all of said electrodes of a homogeneous field in the path of said beam.

15. A system for controlling the movement of an electron beam relative to two coordinate axes comprising, a plurality of electrodes uniformly spaced around the path of said beam, said electrodes being located relative to said coordinate axes so that the axes pass mid-way between predetermined adjacent electrodes, a voltage distributing network comprising a plurality of impedance devices connected to provide a balanced bridge, said impedance devices being connected in series to form a closed loop having two pairs of conjugate corner points and a plurality of intermediate tap points, means for impressing a first voltage upon one pair of said conjugate corner points, means for impressing a second voltage upon the other pair of said conjugate corner points, and couplings between said network tap points and respective ones of said electrodes, whereby to control the movement of said beam by all of said electrodes in one direction relative to said coordinate axes in response to said first voltage and to control the movement of said beam by all of said electrodes in another direction relative to said axes in response to said second voltage, said network tap points being selected so as to impress the beam-controlling voltages upon said respective electrodes in suitable proportions to effect the production by all of said electrodes of a homogeneous field in the path of said beam.

16. A system for controlling the movement of an electron beam relative to two coordinate axes comprising, eight elongated electrodes uniformly spaced around the path of said beam, said electrodes being located relative to said coordinate axes so that the axes pass mid-way between predetermined adjacent electrodes, a voltage distributing network comprising a balanced bridge arrangement of four substantially equal impedance branches connected in series to form a closed loop having two pairs of conjugate corner points, each of said branches being provided with two intermediate tap points, means for impressing a first voltage upon one pair of said conjugate corner points, means for impressing a second voltage upon the other pair of said conjugate corner points and couplings between said network tap points and respective ones of said electrodes, whereby to control the movement of said beam by all of said electrodes in one direction relative to said coordinate axes in response to said first voltage and to control the movement of said beam by all of said electrodes in another direction relative to said axes in response to said second voltage.

17. A system for controlling the movement of an electron beam relative to two coordinate axes comprising, a plurality of electrodes uniformly spaced around the path of said beam, two pairs of opposite electrodes lying respectively on said two axes, a voltage distributing network comprising a balanced bridge arrangement of a plurality of substantially equal impedance exterior branches connected in series to form a closed loop and a plurality of substantially equal impedance interior branches connected in pairs in series between respective pairs of conjugate points of said exterior branches, each of said network branches being provided with at least one intermediate tap point, means for impressing a first voltage upon one pair of said conjugate network points, means for impressing a second voltage upon the other pair of said conjugate network points, and couplings between said network tap points and respective ones of said electrodes, whereby to control the movement of said beam by all of said electrodes in one direction relative to said coordinate axes in response to said first voltage and to control the movement of said beam by all of said electrodes in another direction relative to said coordinate axes in response to said second voltage.

18. A system for controlling the movement of an electron beam relative to two coordinate axes comprising, twelve elongated electrodes uniformly spaced around the path of said beam, two pairs of opposite electrodes lying respectively on said two axes, a voltage distributing network comprising a balanced bridge arrangement of four substantially equal impedance exterior branches connected in series to form a closed loop and four substantially equal impedance exterior branches connected in pairs in series between respective pairs on conjugate points of said exterior branches, each of said exterior branches being provided with two intermediate tap points and each of said interior branches being provided with one intermediate tap point, a source of a first voltage coupled to one pair of said conjugate network points, a source of a second voltage coupled to the other pair of said conjugate network points, and couplings between said network tap points and respective ones of said electrodes, whereby to control the movement of said beam by all of said electrodes in one direction relative to said coordinate axes in response to said first voltage and to control the movement of said beam by all of said electrodes in another direction relative to said axes in response to said second voltage.

19. A system for controlling the movement of an electron beam relative to two coordinate axes

comprising, a plurality of electrodes uniformly spaced around the path of said beam, a voltage distributing network comprising a balanced bridge arrangement of a plurality of substantially equal impedance exterior branches having intermediate tap points and connected in series to form a closed loop having two pairs of corner points, a plurality of substantially equal impedance interior branches having intermediate tap points and connected in pairs in series between respective pairs of corner points of said exterior branches and a plurality of substantially equal impedance auxiliary branches having intermediate tap points and connected in series to form a closed loop having two pairs of conjugate points connected respectively to corresponding tap points on said interior branches, means for impressing a first voltage upon one pair of said corner network points, means for impressing a second voltage upon the other pair of said corner network points, and couplings between said network tap points and respective ones of said electrodes, whereby to control the movement of said beam by all of said electrodes in one direction relative to said coordinate axes in response to said first voltage and to control the movement of said beam by all of said electrodes in another direction relative to said coordinate axes in response to said second voltage.

20. A system for controlling the movement of an electron beam relative to two coordinate axes comprising, sixteen elongated electrodes uniformly spaced around the path of said beam, two pairs of opposite electrodes lying respectively on said two axes, a voltage distributing network comprising a balanced bridge arrangement of

four substantially equal impedance exterior branches having intermediate tap points and connected in series to form a closed loop having two pairs of corner points, four substantially equal impedance interior branches having intermediate tap points and connected in pairs in series between respective pairs of corner points of said exterior branches and four substantially equal impedance auxiliary branches having intermediate tap points and connected in series to form a closed loop having two pairs of conjugate points connected respectively to corresponding tap points on said interior branches, a source of a first voltage coupled to one pair of said corner network points, a source of a second voltage coupled to the other pair of said corner network points, and couplings between said network tap points and respective ones of said electrodes, whereby to control the movement of said beam by all of said electrodes in one direction relative to said coordinate axes in response to said first voltage and to control the movement of said beam by all of said electrodes in another direction relative to said coordinate axes in response to said second voltage.

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