

Sept. 12, 1967

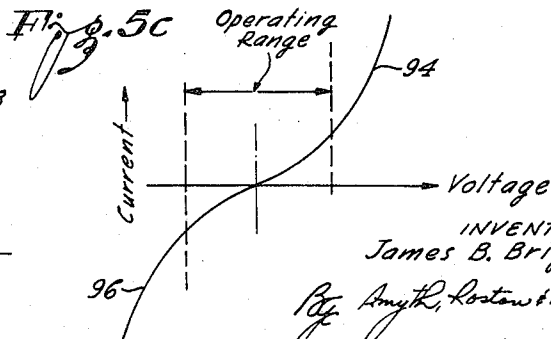
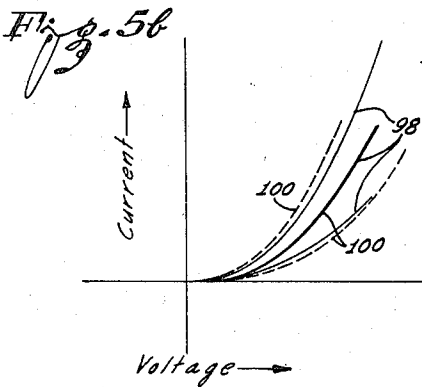
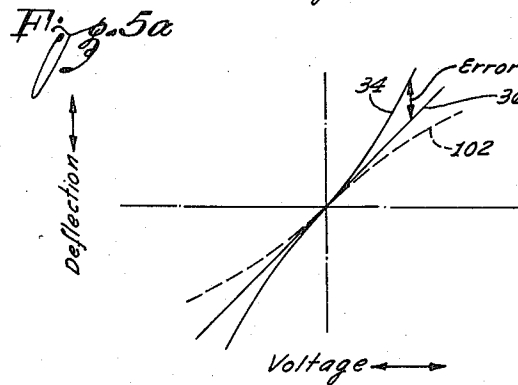
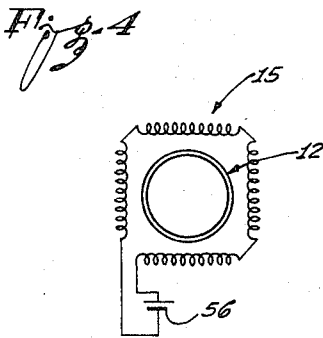
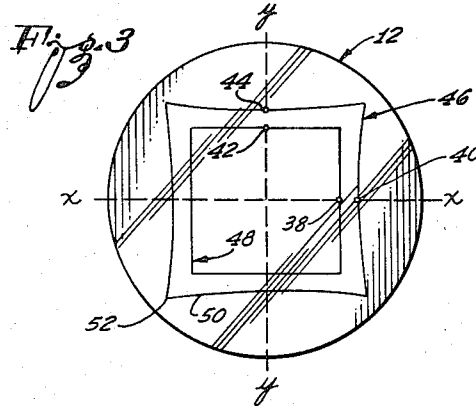
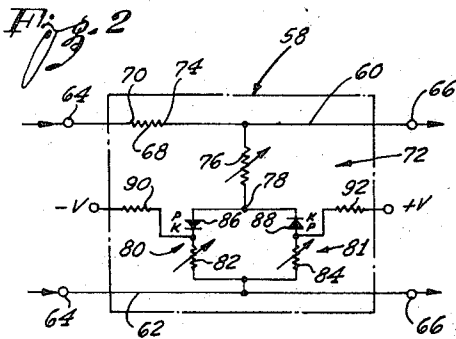
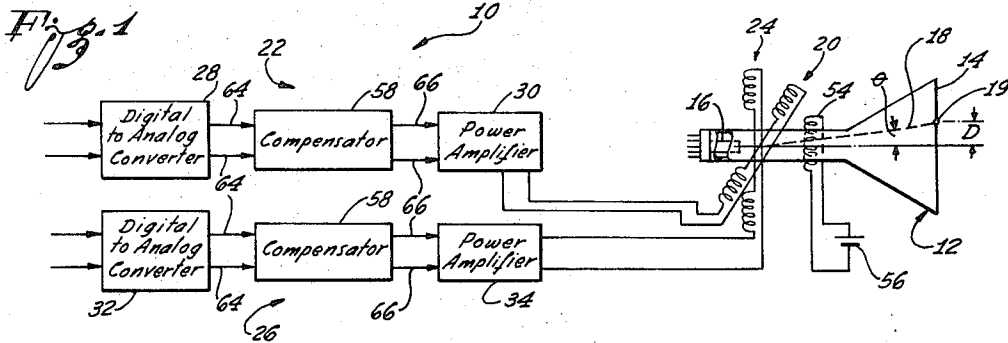
J. B. BRIGGS

3,341,735

DISPLAY SYSTEM UTILIZING CATHODE RAY TUBE DEFLECTION

ERROR COMPENSATING MEANS

Filed Jan. 31, 1964



INVENTOR:
James B. Briggs
By Amyth, Roston & Parity
Attorneys

1

2

3,341,735

DISPLAY SYSTEM UTILIZING CATHODE RAY TUBE DEFLECTION ERROR COMPENSATING MEANS

James B. Briggs, La Crescenta, Calif., assignor to Sargent Industries, Inc., a corporation of Delaware
Filed Jan. 31, 1964, Ser. No. 341,666
14 Claims. (Cl. 315—27)

The present invention relates to display means, and more particularly to means for providing a precise display in a cathode ray display system.

In a cathode ray display system, an electron beam is directed against a fluorescent screen on the face of the cathode ray picture tube. As the electron beam strikes the fluorescent screen, it will cause a point of visible light to be produced at the point of incidence. The intensity of the light at the point will be a function of the intensity of the electron beam. In order to form a visible display, the electron beam is deflected across the face and the intensity of the beam is modulated. The character of the display and the accuracy with which the various portions of the display are positioned is dependent upon the electron beam being properly aimed at the particular point on the screen to be illuminated. In display systems requiring a very accurate display, it is customary to use a cathode ray tube having a flat face and a pair of magnetic deflection coils. The two coils are disposed at right angles to each other whereby deflection currents in the two coils will be effective to create a pair of orthogonal magnetic fields. One of these fields will deflect the electron beam along an "X" axis while the other field will deflect the beam along the "Y" axis. By careful design and construction, it is possible to provide a deflection coil that will produce a flux field having a density that is a linear function of the current in the coil. However, as a result of the inherent geometry of the tube and the coil, the deflection current in the coil will be proportional to the sine of the angle through which the beam is deflected. The amount of displacement of the bright spot from the center of the display will, in turn, be a function of the tangent of the angle of deflection. As will become apparent subsequently, this relationship will cause the bright spot to be displaced as a resultant of several components. The first and major component is linear with respect to the current. The remaining or error components vary exponentially with respect to the current. As a consequence, as the current and the amount of deflection progressively increase, the magnitude of the error component increases as higher order function and very rapidly becomes a significant factor. This error is inherent in the geometry of the tubes and coils and will limit the accuracy with which the display can be produced.

Another form of distortion that limits the accuracy of the display is so-called "pin cushion" distortion. This form of distortion results from the fact that where two orthogonal coils are provided, the amount of deflection produced by each coil is not totally independent of the other coil. In other words, the amount of deflection along the "X" axis will increase as the amount of deflection along the "Y" axis increases, and vice versa. As a result, if signals are supplied to the display system for drawing a square, the first form of distortion will cause the square to be larger than intended. With the amount of error increasing as a higher order function of the size of the square, the square will be increasingly oversize. At the same time, the pin cushion distortion will cause the sides of the square to be curved and concave instead of straight.

Although numerous efforts have been made to permit reproducing a precisely accurate display, no satisfactory solution has been provided. Heretofore, it has been necessary to endeavor to reduce the distortion to an accept-

able level by employing a cathode ray tube of great length. This will be effective to reduce the angle of deflection and the magnitudes of the deflection currents required to produce the deflection. Since the distortions are a function of these two factors, the distortions will be reduced but not eliminated. With good design, the errors can be reduced to a level approaching 1% error.

It is now proposed to provide a display system that overcomes the foregoing difficulties. More particularly, it is proposed to provide a display system that will eliminate distortions in the deflections of the electron beam and will insure the bright spot always being deflected as a truly linear function of the deflection current. This is to be accomplished by providing means for isolating the vertical and horizontal deflection means and the deflections they produce from each other and providing compensating means in the deflection circuits that will compensate for the errors which are inherent in the cathode ray tube.

In one operative embodiment, the compensator includes a non-linear load that is effective to produce a compensating signal that is combined with the deflection signal. The compensating signal is a higher order function of the deflection signal whereby it will increase substantially identically to the error signal.

These and other features and advantages of the present invention will become readily apparent from the following detailed description of one embodiment thereof, particularly when taken in connection with the accompanying drawings wherein like reference numerals refer to like parts and wherein:

FIGURE 1 is a block diagram of a precision display system embodying one form of the present invention;

FIGURE 2 is a wiring diagram of compensating means employed in the display system of FIGURE 1;

FIGURE 3 is an end view of a cathode ray oscilloscope employed in the display system of FIGURE 1;

FIGURE 4 is a transverse cross-sectional view of the cathode ray tube of FIGURE 3; and

FIGURES 5a, 5b and 5c are graphs of the operating characteristics of various portions of the system.

Referring to the drawings in more detail and particularly to FIGURE 1, the present invention is particularly adapted to be embodied in a precision display system 10 for producing visual displays. The present display system 10 includes a cathode ray picture tube 12 having a face 14 on one end and an electron gun 16 on the other end. The face 14 is normally flat or planar and includes a layer of fluorescent material on the inside thereof. The electron gun 16 is effective to direct a beam 18 of electrons against the fluorescent layer and cause it to fluoresce with visible light to form a bright spot 19 at the point of incidence.

To position the bright spot at the desired location on the face 14 for producing an illuminous display, suitable deflection means are provided. The deflection means are of the orthogonal variety for deflecting the electron beam horizontally or in an "X" direction and vertically or in a "Y" direction. The deflection means include a horizontal or "X" yoke 20 located adjacent the neck of the tube 12 for deflecting the beam 18 in a horizontal or "X" direction and horizontal or "X" deflection channel 22 for energizing the yoke 20. It also includes a vertical or "Y" yoke 24 disposed adjacent the neck at right angles to the horizontal yoke 20 so as to deflect the beam 18 in the vertical direction and a vertical channel 26 for energizing the yoke 24. The two channels 22 and 26 can be made to energize the two yokes 20 and 24 with currents so as to deflect the beam 18 vertically and horizontally.

The first or horizontal deflection channel 22 includes an input for being interconnected with a source of horizontal deflection signals. Although these signals may be of any suitable variety, in the present instance the signals

are of a digital type. Accordingly, the input includes a digital-to-analog converter 28. The horizontal deflection signals will consist of a series of pulses that are coded to represent the amount of horizontal deflection. As is well known, the digital signal can be made as accurate as desired. The digital signals are supplied to the converter 28 where they are connected into an essentially continuous analog deflection signal. The analog deflection signal will have a voltage which is proportional to the magnitude of the digital signal. By careful design, the converter 28 can be made very linear so as to convert the digital signal to an analog signal with a very high degree of linearity.

An amplifier 30 may be provided in the horizontal channel 22 so as to receive the analog signals and amplify the voltage signal into a form more suitable for controlling the deflection of the electron beam 18 in the tube 12. Since the horizontal deflection is produced by a yoke 20 having one or more coils, substantial amounts of power may be required to deflect the beam 18. Accordingly, the amplifier 30 is of a power type capable of producing a substantial current that is proportional to the voltage present at the input to the amplifier 30. By careful design and the use of large amounts of negative feedback amplifiers of this type may be made very linear.

The output of the horizontal amplifier 30 is interconnected with the horizontal deflection yoke 20 in the tube 12 so as to supply the amplified deflection current signal thereto. Although any suitable deflection means may be employed, as previously stated the present deflection means is in the form of a pair of orthogonal coils or deflection yokes.

The first or horizontal yoke 20 is positioned adjacent the neck of the tube 12 and normal to the axis thereof. The coils are wound so that the current from the power amplifier 30 will flow through the coil and produce a flux field that will be effective to deflect the electrons in the electron beam 18 horizontally across the face 14 of the tube 12. The beam 18 is deflected through an angle θ as seen in FIGURE 1. When the beam strikes the fluorescent layer on the face 14 of the tube 12, a bright spot will be produced. This bright spot will be moved to the right or left of the center of the tube 12 by a displacement distance D. The displacement D of the bright spot will be a function of the tangent of the angle θ through which the beam 18 is deflected.

The second or vertical channel 26 may be substantially identical to the horizontal channel 22. It includes an input for being interconnected with a source of vertical deflection signals. Normally, these signals will be in the same form as the horizontal signals. Accordingly, the input includes a digital-to-analog converter 32 that is effective to convert the digital signals into an analog signal having a voltage that is a function of the magnitude of the digital signal.

The vertical channel 26 also includes a power amplifier 34 that is effective to amplify the signal into an analog signal having a current that is proportional to the magnitude of the analog signal. The output of the amplifier 34 is connected to the coils in the vertical yoke 24 so as to feed the current therethrough. The coils in the vertical yoke 24 are disposed adjacent the neck of the tube 12 substantially normal to the axis of the tube 12 and also to the first or horizontal yoke 20. As a consequence, the current from the power amplifier 34 will flow through the vertical yoke 24 and produce a deflection θ of the beam 18 in the vertical direction. This, in turn, will cause the bright spot to move vertically of the face of the tube a distance D.

It may thus be seen that during normal operation a horizontal digital deflection signal will be fed to the digital-to-analog converter 28. This converter 28 will convert the signal to an analog horizontal deflection signal and supply it to the power amplifier 30. The power amplifier 30 will amplify the signal and produce a current which will energize the horizontal yoke 20 so as to deflect the electron

beam 18 through the angle θ in the horizontal direction, and move the bright spot 19 right or left through distance D in accordance with the deflection signal. At the same time, a vertical digital signal may be supplied to the converter 32 in the vertical channel 26. This converter 32 will convert the digital signal to an analog signal and supply it to the power amplifier 34. The power amplifier 34 will then provide a current which energizes the vertical yoke 24 and deflects the beam 18 vertically through angle θ and moves the bright spot 19 a distance D.

If the vertical signal remains constant while the horizontal signal is varied, the bright spot 19 will be moved horizontally across the face 14 and if the vertical signal is then varied while the horizontal signal remains constant the bright spot 19 will make a vertical trace on the face 14 of the tube 12. As a consequence, by first varying one signal and then the other, it will be possible to draw a square on the face 14 of the tube 12 similar to that shown in FIGURE 3.

By carefully winding the coils in the vertical and horizontal deflection yokes 20 and 24, it is possible to provide yokes that will produce very linear flux fields. As a consequence, the deflection forces which are exerted on the electron beam 18 will be very linear with respect to the deflection currents in the coil. As a result, the angle of deflection θ of the beam 18 will be a function of the arc sine of the deflection current or

$$I = a \sin \theta \quad (1)$$

where a is a constant.

The amount of displacement D of the bright spot 19 on the face 14 of the tube 12 is a function of the tangent of this angle θ and can be expressed as follows:

$$D = b \tan \theta = b \frac{\sin \theta}{\cos \theta} = b \frac{\sin \theta}{\sqrt{1 - \sin^2 \theta}} \quad (2)$$

where b is another constant.

By substituting Equation 1 into Equation 2

$$D = \frac{b}{a} \frac{I}{\sqrt{1 - \frac{I^2}{a^2}}} \quad (3)$$

By well known methods, Equation 3 can be expanded into the following series for expressing the displacement of the bright spot 19 in terms of the amount of deflection current:

$$D = cI + dI^3 + eI^5 \dots \quad (4)$$

where c , d and e are constants.

It may thus be seen that the bright spot 19 will be deflected linearly as a function of the current I. However, it will also be deflected non-linearly by the higher order components and as the amount of deflection increases, the amount of error will increase. Normally, the coefficients for the higher order factors will be very small and as a practical matter the coefficients for the fifth order factor and all of the factors of higher order will be so small as to make these factors insignificant. However, the coefficient d for the third order factor is of a material magnitude. As a consequence, the only material non-linear factor in the Equation 4 is the second term or $+dI^3$.

Referring to FIGURE 5a, the amount of deflection of the electron beam 18 will follow the solid line 34. This line 34 will include a linear or straight line function 36 plus the higher order function. To obtain an accurate display, the deflection D should be a linear or straight line function similar to the line 36. However, because of the non-linear factor dI^3 , the line 34 will deviate from the straight line as a 3rd order function. As will be seen from FIGURE 5a, the error will be a 3rd order function that increases very rapidly as the deflection increases. This error is inherent in the geometry of the tube 12 and deflection yokes 20 and 24 and has heretofore limited the accuracy of the display. In order to reduce this error

to a minimum, it has been customary to employ a long tube so that deflection angles are small.

The effects of this distortion will become apparent by reconsidering the effects of supplying signals to the yokes 20 and 24 for drawing the above described square. If the beam 18 is deflected horizontally so as to strike the "X" axis at point 38, the electron beam 18 will be deflected in excess of that desired whereby it will strike the face at point 40. If the beam 18 is deflected vertically to strike the point 42, it will actually strike the point 44. As a consequence, the square that is actually drawn will be larger than the intended square 48. The amount of error will be equal to $+dI^3$ and will therefore increase as a third order of the current. As a result, when the square 48 begins to assume a substantial size, the amount of error will become very large. If the tube 12 has a long length, the angle of deflection and the amount of current flowing in the coils may be reduced. Although this will not eliminate the error, by careful design heretofore it has been possible to reduce the error to a limit on the order of about 1%.

In addition to the foregoing distortion, so-called "pin cushion" distortion will also be present. This form of distortion results from the fact that where two orthogonal coils are provided the effects produced by the two coils are not totally independent of each other. That is, although the vertical deflection signal remains constant, as the horizontal deflection increases, the vertical deflection increases. The converse of this is also true. This relationship may be expressed by:

$$D_x = fI_x \sqrt{b^2 + x^2 + y^2} \quad (5)$$

$$D_y = fI_y \sqrt{b^2 + x^2 + y^2} \quad (6)$$

Since the horizontal deflection of the beam 18 will increase as the amount of vertical deflection increases, a vertical line is drawn, the upper and lower ends will be deflected farther than the middle. As a consequence, the various sides of the square 46 will not be truly straight. As can be seen in FIGURE 3, each side 50 will be slightly concave whereby the corners 52 of the square 46 will be pointed and meet at less than right angles.

To eliminate the pin cushion distortion, an isolating yoke 54 may be provided. The yoke 54 is normally disposed around the neck of the tube 12 between the face 14 and the vertical and horizontal deflection yokes 20 and 24 so as to be in the region of the drift space. This yoke 54 includes a plurality of coils which are disposed at right angles to each other so as to encircle the neck. The coils are interconnected with a bias voltage such as the battery 56 so as to maintain a steady current flow through the coils. When the coils are energized, they will maintain a magnetic flux field in the region of the drift space so as to react with the electron beam 18.

By a proper adjustment of the position of the coils and the current flowing therethrough, the inter-reaction of the vertical and horizontal deflection systems may be eliminated. This, in turn, will cause the deflection in the vertical or horizontal direction to be totally independent of the amount of deflection at right angles thereto. By eliminating the "pin-cushion" distortion and making the deflections independent of each other, a straight line will appear as a straight line. Accordingly, the various sides of the above described square will be straight lines. However, the non-linear or third order distortion will still be present. As a consequence, although the square will appear as a square, it will be over size.

To eliminate the non-linear or third order distortion, a compensator 58 may be provided in each of the deflection channels 22 and 26. The compensators 58 may be disposed in any portion of the channels 22 and 26. However, since inductive deflection yokes 20 and 24 are employed, the currents from the power amplifiers 30 and 34 will be of a substantial nature. It is, therefore, desirable for the compensators 58 to be disposed anterior to the power amplifiers 30 and 34. This will not only reduce

the power requirements from the amplifiers 30 and 34 and increase the efficiency, but will also reduce the power ratings of the components in the compensators 58. Accordingly, one of the compensators 58 is disposed in the horizontal channel 22 to couple the converter 28 to the power amplifier 30 while the other compensator 58 is disposed in the vertical channel 26 to couple the converter 32 to the power amplifier 34.

Each of the compensators 58 includes a pair of electrically parallel lines 60 and 62. The input ends 64 of these lines are connected to the output of the converter 28 or 32 whereby the voltage difference between the two lines 60 and 62 will be equal to the analog deflection signal produced by the converter. The output ends 66 of the lines 60 and 62 are connected to the input to the power amplifier 30 or 34 so as to provide a voltage signal to the power amplifier that is a corrected analog deflection signal including the analog deflection signal and a compensating signal.

A voltage dropping resistor 68 may be serially disposed in one of the lines 60. The input end 70 of this resistor 68 will thus have a voltage that differs from the voltage on the second line 62 by the magnitude of the analog deflection signal. The resistor 68 is in series with the input to the power amplifier 30 or 34 whereby any voltage drop across this resistor 68 will be effective to reduce the signal fed to the power amplifier. In order to make the voltage drop across the resistor 68 equal to the compensating signal, a network 72 is provided that extends from the output end 74 of the resistor 68 to the second line 62.

This network 72 is a non-linear load which is effective to vary as a higher order function of the current. More particularly, the network 72 includes a limiting resistor 76 that has one end thereof connected directly to the line 60. The opposite end of the resistor 76 is connected to a junction 78 formed between a pair of parallel branches 80 and 81 that include resistors 82 and 84 and diodes 86 and 88. The two diodes 86 and 88 are disposed in opposed polarities whereby current will alternatively flow through one or the other of the branches 80 and 81 but not simultaneously through both.

A pair of identical biasing resistors 90 and 92 may be connected to the junction of the resistor 82 and the diode 86, and to the junction of the resistor 84 and the diode 88, respectively. The first resistor 90 leads to a source of a negative biasing voltage while the second resistor 92 leads to a source of a positive biasing voltage.

Normally, the two bias voltages and the resistors 90 and 92 are adjusted so that the junction 78 will be maintained at ground potential or at the potential on the line 60 that produces a zero deflection of the electron beam 18. It may thus be seen that when the electron beam 18 is centered, both ends of the resistor 76 will be at the same potential and no current will flow through the resistor 76. However, if the analog deflection signal varies so as to cause the voltage on the line 60 to become more positive, or more negative, there will be a voltage drop across the resistor 76. This will cause a current to flow through the resistor 76 with at least a portion of this current flowing through the resistor 68.

In addition, the current flowing through the resistor 76 will unbalance the network 72 and cause the potential at the junction 78 to vary either more positive or more negative. As may be seen in FIGURE 5c, the potential at the junction will normally bias the two diodes 86 and 88 at a point where no current will flow therethrough. However, if the voltage at junction 78 increase in a positive direction, the diode 88 will be cut off while the diode 86 will be biased conductive.

The amount of the current flowing through the diode 86 will correspond to the curve 94 in FIGURE 5c. In the initial conductive regions of this curve 94, the curve 94 will have an exponential shape. By a careful selection of diodes, the shape of the curve may be made to follow a higher order function such as a cubic function.

The parameters of the network 72 are chosen so that diode 86 will be biased within an operating range that is of a higher order nature corresponding to the factor dI^3 .

The diode 88 is biased reversely to the diode 86. As a consequence, if the junction 78 becomes more negative the diode 86 will cut off and the diode 88 will conduct according to curve 96. This curve 96 will be substantially identical to the curve 94 whereby this current will also vary similar to the factor dI^3 .

In order to employ the present display system 10 for producing a visual display, the two inputs for the horizontal and vertical deflection channels 22 and 26 may be operatively interconnected with a suitable source of digital deflection signals. It will thus be seen that a horizontal digital signal will be fed into the horizontal digital-to-analog converter 28 so as to produce an analog signal having an amplitude proportional to the desired amount of horizontal deflection. This signal will flow from the converter 28 to the two inputs 64 into the compensator 58. The signal will then travel along the two conductors 60 and 62 and the resistor 68 in the compensator 58 to the power amplifier 30. The amplifier 30 will then produce a current in the horizontal yoke 20 which will deflect the electron beam 18 through an angle θ whereby the bright spot 19 will be displaced right or left by a distance D. Similarly, the horizontal deflection signals will be changed to an analog signal in the converter 32. The analog signal will then flow along the two conductors 60 and 62 to the power amplifier 34. The power amplifier 34 will in turn energize the vertical yoke 24 and deflect the electron beam 18 vertically of the face 14.

The analog signal applied to the two inputs 64 will be effective to determine the amount of voltage difference between the two lines 60 and 62. In the event there is a voltage difference, the difference will cause a current to flow through the dropping resistor 68 and the network 72. The current flowing through the network 72 will be a function of the voltage between the two input terminals and the resistance of the network 72. If the voltage on the line 60 is equal to the voltage at the junction, no current will flow through the resistor 76. As a result, no current will be drawn through the resistor 68 and no voltage drop will be produced. This condition will occur when the deflection is 0 and there is no error. However, if the beam 18 is to be deflected, the voltage on line 60 will differ from the voltage on the junction 78. A current will then flow through the dropping resistor 68 and the resistor 76. Depending upon whether the voltage is plus or minus, the current will flow through the diode 86 or diode 88.

The magnitude of the current will vary similar to the line 94 or the line 96 in the graph of FIGURE 5c. As may be seen when the voltage difference increases the amount of current will increase. However, the amount of increase in the current will not be linear but will be exponential and by a careful choice of the values of the resistors 76, 82 and 84, can be made to closely approximate a third order function corresponding to the error produced in the deflection of the beam. If the resistor 76 is made adjustable, the magnitude of the current may be changed. More particularly, the current may be varied so that it will vary according to one of the solid lines 98 in FIGURE 5b. If the resistors 82 and 84 in the branches 80 and 81 are made variable, these resistors 82 and 84 may be varied so as to cause the current to vary as the dotted family of curves 100 in FIGURE 5b. Thus, the resistor 76 will control the amount of current and the resistors 82 and 84 will control the rate at which it changes.

As the current flows through the resistor 68 and the network 72, it will produce a voltage drop. Thus, the voltage at the end 74 will differ from the analog voltage signal at the end 70. The voltage at the end 74 corresponds to the dashed curve 102 in FIGURE 5a. By properly adjusting the resistors 76, 82 and 84 the current

can be made so that the voltage on the end 74 will follow a curve 102 that is symmetrically disposed with respect to the line 36.

It will thus be seen that as the voltage of the deflection signal varies in a positive or negative direction, the amplitude of the signal fed into the power amplifier and supplied to the deflection yoke will be decreased by the voltage drop across the resistor 76. The magnitude of this drop will, in turn, be substantially identical to the amount of voltage that would produce the non-linear distortion. As a consequence, if the signals supplied to the display system are suitable for drawing the square 48 in FIGURE 3, the compensating yoke 15 in the drift section will isolate the vertical and horizontal deflections from each other whereby the sides of the square will be straight. In addition, the vertical and horizontal compensators 58 will be effective to decrease the amplitude of the signal fed to the power amplifiers 30 and 34 and to the deflection yokes 20 and 24 so that the error produced in the deflection or displacement of the bright spot 19 will be exactly offset. This, in turn, will cause the sides of the square to be exactly positioned irrespective of the size of the square.

While only a single embodiment of the present invention is disclosed and described herein, it will be readily apparent to persons skilled in the art that numerous changes and modifications may be made without departing from the scope of the invention. Accordingly, the foregoing disclosure and description thereof are for illustrative purposes only and do not in any way limit the invention which is defined only by the claims which follow.

What is claimed is:

1. In a display system including

a cathode ray tube having a fluorescent face and an electron gun for directing a beam of electrons toward the face and having a drift space between the face and the electron gun,

a vertical deflection yoke disposed between the gun and the face for deflecting the electron beam vertically of the face,

a vertical deflection channel interconnected with the yoke,

an input to said channel for receiving a vertical deflection signal, said channel being effective to feed a current through the yoke to deflect the beam vertically in response to the vertical deflection signal through a distance that is a combination of a linear function of the current and a particular non-linear higher order function of the current,

a horizontal deflection yoke disposed between the gun and the face, said horizontal yoke being normal to the first yoke to deflect the signal horizontally of the face,

a horizontal deflection channel interconnected with the horizontal yoke,

an input to the horizontal channel for receiving a horizontal deflection signal, said horizontal channel being effective to feed a current through the horizontal yoke so as to deflect the beam horizontally of the face in response to the horizontal deflection signal through a distance that is a combination of a linear function of the current and a particular non-linear higher order function of the current, said vertical and horizontal yokes being positioned to produce an interaction between the vertical and horizontal deflections, an isolating yoke positioned on the tube adjacent the vertical and horizontal yokes and in the region of the drift space to isolate the vertical and horizontal deflections produced by the two yokes and minimize any interaction between such deflections,

a pair of voltage dropping resistors each being connected in a different one of said horizontal and vertical deflection channels to provide a voltage having characteristics dependent upon the characteristics of the deflection signal in the respective channel,

- a pair of loads each being interconnected with the voltage dropping resistor in a different one of the horizontal and vertical deflection channels to receive a current dependent upon the characteristics of the deflection signal in the associated channel, and
 non-linear means in said load, said non-linear means being responsive to the voltage across the associated one of the voltage-dropping resistors to vary the current through the load in accordance with the particular non-linear higher function of the current.
2. In a display system,
 a cathode ray tube having a fluorescent face and an electron gun for directing a beam of electrons toward the face,
 a deflection yoke disposed between the gun and the face for deflecting the electron beam across the face of the tube in accordance with the current flowing through the yoke,
 a deflection channel interconnected with the yoke for energizing the yoke,
 an input to said channel for receiving a deflection signal to produce a flow of current through the yoke for a deflection of the beam across the face through a distance that is the combination of a particular linear component of the current and a particular non-linear higher order component of the current,
 a voltage dropping resistor serially connected in said channel to provide a voltage having characteristics dependent upon the characteristics of the deflection signal in the channel,
 a load interconnected with the voltage dropping resistor and connected across said channel to receive a current in accordance with the voltage across the voltage-dropping resistor, and
 non-linear means in said load and responsive to the voltage across the dropping resistor to vary the current through the load and the yoke in the particular non-linear higher order component.
3. In a display system,
 a cathode ray tube having a fluorescent face and an electron gun for directing a beam of electrons toward the face,
 a deflection yoke disposed between the gun and the face for deflecting the electron beam across the face in accordance with the introduction of a signal to the yoke,
 a deflection channel interconnected with the yoke for introducing a signal to the yoke to obtain a deflection of the beam,
 an input to said channel for receiving a deflection signal to provide a deflection of the beam through a distance that is a combination of a particular linear component and a particular non-linear higher order component of the signal, and
 means including a non-linear compensator connected across the channel, said compensator being responsive to the amplitude of the deflection signal in the channel to provide for the deflection signal a compensation corresponding to the particular non-linear higher order function of the deflection signal.
4. In a display system,
 a cathode ray tube having a fluorescent face and an electron gun for directing a beam of electrons toward the face,
 a vertical deflection yoke disposed between the gun and the face for deflecting the electron beam in a vertical direction in accordance with the flow of current through the yoke,
 a vertical deflection channel having a pair of inputs connected to receive a vertical deflection signal and interconnected with the vertical deflection yoke to provide for a flow of current through the yoke in accordance with the linear characteristics of the vertical deflection signal and particular higher-order characteristics of the vertical deflection signal,

- a horizontal deflection yoke disposed between the gun and the face, said horizontal yoke being normal to the first yoke to deflect the electron beam in a horizontal direction in accordance with the flow of current through the yoke,
 a horizontal deflection channel having a pair of inputs connected to receive a horizontal deflection signal and interconnected with the horizontal deflection yoke to provide for a flow of current through the horizontal yoke in accordance with the linear characteristics of the horizontal deflection signal and particular higher-order characteristics of the vertical deflection signal,
 a pair of dropping resistors each connected in series between an individual one of the vertical and horizontal deflection yokes and one of the inputs to the associated one of the vertical and horizontal deflection channels to provide a voltage in accordance with the particular one of the vertical and horizontal deflection signals, and
 a pair of non-linear means each connected across an individual one of the vertical and horizontal deflection yokes, each of said non-linear means being responsive to the amplitude of the voltage across the associated one of the vertical and horizontal deflection yokes to vary the current through the associated yoke in accordance with the particular higher-order characteristics of the deflection signal introduced to the associated yoke.
5. A display system, including:
 a cathode ray tube having a fluorescent face and an electron gun for directing a beam of electrons toward the face,
 a vertical deflection yoke disposed between the gun and the face for deflecting the electron beam in a vertical direction in accordance with the characteristics of a current flowing through the yoke,
 a vertical deflection channel interconnected with the yoke to provide for a flow of current through the yoke,
 an input to said channel for applying a vertical deflection signal to said channel to produce a flow of current through the yoke in accordance with the characteristics of the vertical deflection signal and a particular higher-order function of such signal,
 a horizontal deflection yoke disposed between the gun and the face, said horizontal yoke being normal to the first yoke to deflect the electron beam in a horizontal direction in accordance with the characteristics of a current flowing through the yoke,
 a horizontal deflection channel interconnected with the horizontal yoke to provide for a flow of current through the horizontal yoke,
 an input to the horizontal channel for applying a horizontal deflection signal to said horizontal channel to produce a flow of current through the yoke in accordance with the characteristics of the horizontal deflection signal and a particular higher-order function of such signal,
 first non-linear compensating means connected across the vertical deflection channel, said first compensating means being responsive to the amplitude of the vertical deflection signal to change the amplitude of the current through the vertical deflection yoke by a factor corresponding to the particular higher-order function of such current, and
 second non-linear compensating means connected across the horizontal deflection channel, said second compensating means being responsive to the amplitude of the horizontal deflection signal to change the amplitude of the current through the horizontal deflection yoke by a factor corresponding to the particular higher-order function of such current.
6. In a display system,
 a cathode ray tube having a fluorescent face and an

- electron gun for directing a beam of electrons toward the face,
deflection means interconnected with said tube for deflecting the beam in a particular direction in response to a deflection current through a distance constituting a combination of a particular linear function and a particular higher-order function of the deflection current,
- a deflection channel having a pair of input terminals interconnected with the deflection means for supplying a deflection signal to the deflection means to produce a flow of current through the deflection means in accordance with the characteristics of the deflection signal,
 - a voltage-dropping resistor connected between one of the input terminals in the deflection channel and said deflection means, said resistor being in series with the channel to provide a voltage that is dependent upon the amplitude of the deflection signal,
 - a non-linear load interconnected across the deflection means to draw through the voltage-dropping resistor and the load a current having characteristics dependent upon the characteristics of the deflection signal, and
 - a unidirectional member electrically connected in the load and having characteristics to vary the current through the deflection means to compensate for the particular higher order function of the deflection current.
7. In the display system set forth in claim 6, a second unidirectional member electrically connected in the load in opposite polarity to the first unidirectional member and having characteristics to vary the current through the deflection means to compensate for the particular higher order function of the deflection current when such deflection current is of opposite polarity to that in which the first unidirectional member is responsive.
8. In a display system,
- a cathode ray tube having a fluorescent face and an electron gun for directing a beam of electrons toward the face,
 - deflection means interconnected with said tube for deflecting the beam in a particular direction in response to a deflection current and through a distance dependent upon a combination of a particular linear function and a particular higher-order function of the deflection current,
 - a deflection channel having a pair of input terminals connected to the deflection means for supplying a deflection signal to the deflection means to produce a deflection current through the deflection means in accordance with the characteristics of the deflection signal,
 - a limiting resistor connected across the deflection means to provide across the deflection means a voltage having characteristics dependent upon the characteristics of the deflection signal, and
 - a non-linear load connected in series with the limiting resistor across the deflection channel to provide a current having characteristics corresponding to the particular higher-order function of the deflection current to compensate for the effect of this function on the electron beam.
9. In the display system set forth in claim 8, the non-linear load constituting a unidirectional member and a second resistor in series with the limiting resistor.
10. A compensator for use in a display system having a cathode ray tube, deflection means and a deflection channel interconnected with said deflection means for supplying

ing a deflection signal to the deflection means to deflect an electron beam in the tube through a distance corresponding to a combination of a particular linear function of the deflection signal and a particular higher-order function of the deflection signal, said compensator including the combination of:

- a limiting resistor electrically connected across the channel for the production of a voltage having characteristics dependent upon the amplitude of the deflection signal in the channel, and
- means including a pair of unidirectional members connected in parallel with each other in opposed polarities and in series with said limiting resistor to vary the signal through the deflection means by a factor corresponding to the particular higher-order function of the deflection signal to compensate for this particular higher-order function.

11. The compensator set forth in claim 10 wherein a pair of resistors are provided and wherein each of such resistors is connected in series with an individual one of the unidirectional members in the pair to provide two parallel branches in series with the limiting resistor with each branch having in series one of the unidirectional members in the pair and one of the resistors in the pair.

12. A compensator for use in a display system having a cathode ray tube, deflection means and a deflection channel interconnected with said deflection means for supplying a deflection signal to the deflection means to deflect an electron beam in the tube in a particular direction through a distance corresponding to a particular linear function and a particular higher order function of the deflection signal, said compensator including the combination of:

- a dropping resistor connected in series with the channel for the production across the resistor of a voltage dependent upon the deflection signal,
- a load connected across the channel to provide a voltage substantially equal to said deflection signal less the voltage across said resistor,
- a pair of unidirectional members in said load, said unidirectional members being connected in opposed polarities to provide for a flow of current through one or the other of the unidirectional members in accordance with the polarity of the deflection signal, and
- means in the load for biasing the unidirectional members to provide the current through the unidirectional members with a compensation corresponding to the particular non-linear function of the deflection signal.

13. The compensator set forth in claim 12 wherein the load includes a pair of resistors each connected in series with a different one of the unidirectional members to form a pair of parallel branches each including an individual one of the unidirectional members in the pair and an individual one of the resistors in the pair.

14. The compensator set forth in claim 13 wherein the load includes an additional resistor in series with each of the parallel branches.

References Cited

UNITED STATES PATENTS

2,749,475	6/1953	Vonderschmitt	315—27 X
2,831,145	4/1958	Albert	315—24
3,023,336	2/1962	Frenkel	313—78

JOHN W. CALDWELL, *Acting Primary Examiner.*

T. A. GALLAGHER, R. L. RICHARDSON,
Assistant Examiners.