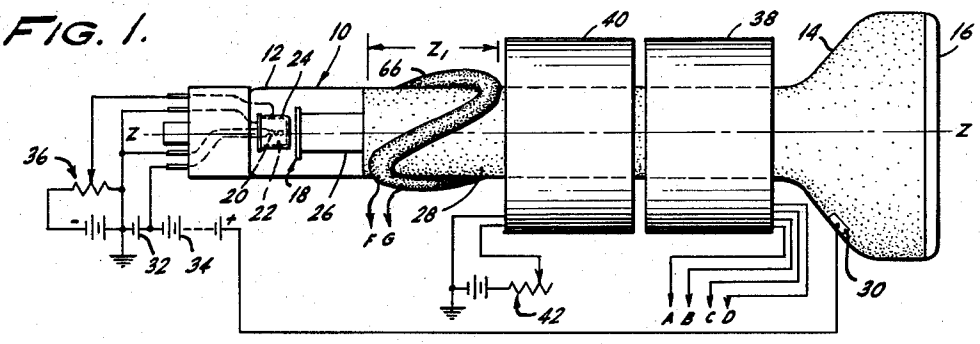
Sept. 22, 1964 C. P. COMEAU 3,150,284

APPARATUS FOR USE IN CONJUNCTION WITH A CATHODE RAY TUBE TO REDUCE DEFOCUSING AND ASTIGMATISM OF AN ELECTRON BEAM THEREOF

Filed Sept. 17, 1962

FIG. 1.



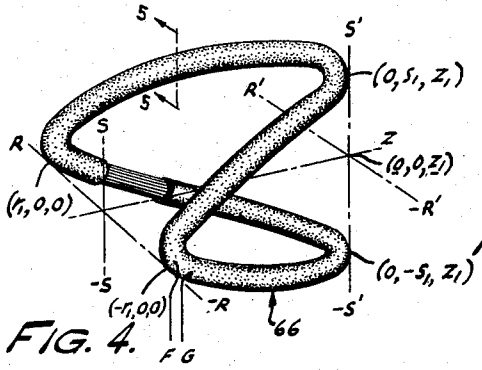


FIG. 4.

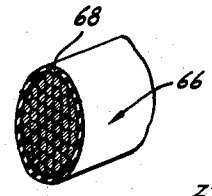


FIG. 5.

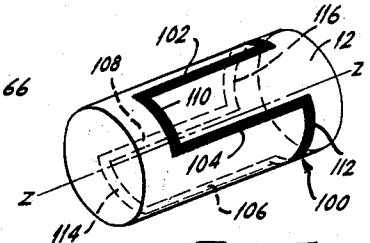
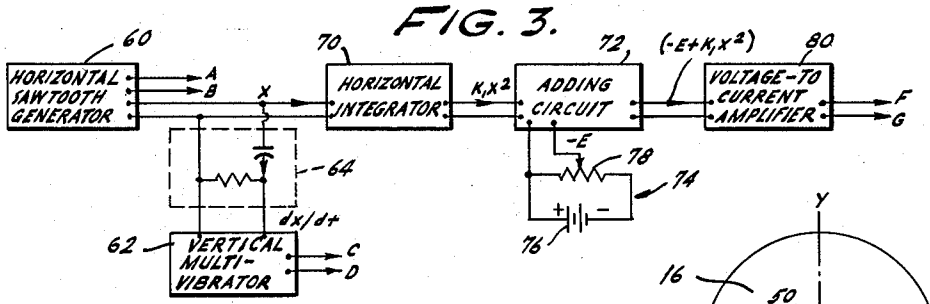


FIG. 7.

FIG. 3.



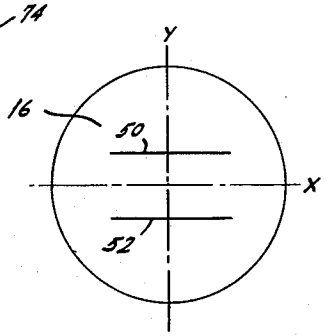
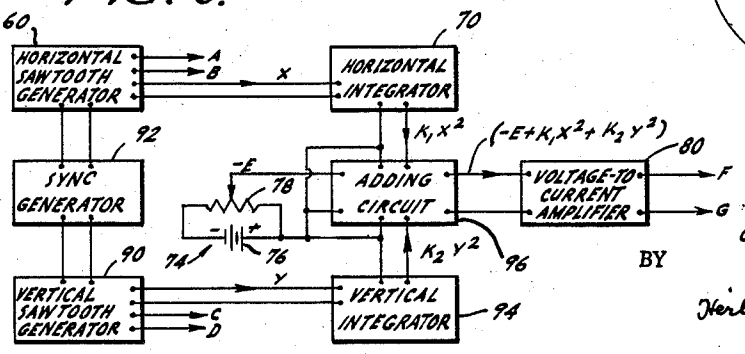


FIG. 2.

FIG. 6.



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3,150,284

APPARATUS FOR USE IN CONJUNCTION WITH A CATHODE RAY TUBE TO REDUCE DEFOCUSING AND ASTIGMATISM OF AN ELECTRON BEAM THEREOF

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11 Claims. (Cl. 315—22)

This invention relates to a system for simultaneously correcting the focus and astigmatism of a cathode-ray beam while the beam is being scanned across the screen of a cathode-ray tube.

Flying-spot scanner systems typically comprise a cathode-ray tube, a lens for imaging the screen of this tube onto the surface of an object and a photomultiplier tube. The beam of the cathode-ray tube is scanned over successive portions of its screen. The moving spot of light so produced is projected by the lens onto the object, and the portion of the projected light reflected or transmitted by the object is directed onto the photocathode. The signal produced by the phototube in response to this light is representative of the scanned object.

For such a system to be able to resolve successive portions of the object most accurately, the projected spot of light must have as small a diameter as possible. To obtain such a spot, the cathode-ray beam must be substantially anastigmatic and substantially prefectly focused on all scanned portions of the screen. However several factors militate against such perfect focus and freedom from astigmatism. In particular, the screen of a typical flying-spot scanner tube is substantially plane. Consequently, as the beam is deflected away from the center of the screen, the distance between the electron gun and the screen (i.e. the throw distance of the beam) increases. Hence, even if the beam when undeflected is perfectly focused at a given point on the screen, it becomes progressively more defocused as it is deflected farther from this point. Such defocusing undesirably increases the diameter of the spot of light. Moreover where the beam is deflected by a magnetic field, non-uniformities in the deflection field may introduce astigmatism into the beam. Indeed such astigmatism may be present even in the undeflected beam, e.g. by reason of non-uniformities in the focusing field. Astigmatism is undesirable because it either elongates the spot or increases the minimum diameter to which it can be focused.

Heretofore astigmatism and focus have been dynamically corrected in three-gun color television systems by a system comprising two planar, elliptical coils, the major axes of which lie in mutually perpendicular planes. Both coils are positioned concentric with the neck of the picture tube and are respectively supplied with horizontal and vertical correction signals. This system is disadvantageous because it requires at least two coils and because the planar, elongated coils require a substantial amount of space transverse to the tube neck.

Accordingly it is an object of the invention to provide a system for simultaneously correcting both astigmatism and focus of a cathode-ray beam during scansion thereof.

Another object is to provide such a system which is particularly well adapted to correct astigmatism of the type which is most pronounced when the beam impinges the screen off-center along an axis of deflection.

Another object is to provide such a system which requires only one correction coil.

The foregoing objects are achieved, in a system comprising a cathode-ray tube having means for projecting an electron beam along a given line and an electron-responsive structure positioned so as to be impinged by said beam, by providing a correction coil comprising at least

one continuous electrical conductor substantially completely surrounding a segment of the line along which the beam is projected and having a non-planar, undulatory shape. When appropriately energized, such a coil produces a longitudinal magnetic field component parallel to said given line, which correct errors in the focus of the beam, and simultaneously produces a quadrupole magnetic field component transverse to said line, which corrects the astigmatism of the beam.

In a preferred embodiment the correction coil is used in conjunction with a tube having a screen shaped so that the throw distance of the beam increases as the beam is deflected, e.g. a tube having a flat screen. This system also comprises a static focusing coil and a deflection coil producing a nonuniform deflection field such that the beam is most astigmatic when it impinges off-center on an axis of deflection and becomes progressively less astigmatic when deflected from this position. To correct focus and astigmatism during scansion in such a system, the respective intensities of both the total longitudinal field component (produced by both the static focusing coil and the correction coil) and the quadrupole field component (produced solely by the correction coil) must have their greatest value when the beam impinges said axis of deflection off-center, and must both decreases as the beam is increasingly deflected therefrom. To produce longitudinal and quadrupole field components simultaneously varying in this manner, means are provided for supplying to the correction coil a correction current which is strongest when the beam impinges said axis of deflection off-center and which becomes progressively weaker as the beam is deflected from this position.

Other advantages and features of the invention will become apparent from a consideration of the following detailed description taken in connection with the accompanying drawings, in which:

FIGURE 1 is a diagram of a cathode-ray tube system according to the invention;

FIGURE 2 is a diagram of the screen of the cathode-ray tube of FIGURE 1;

FIGURE 3 is a block diagram of a circuit for supplying deflection and correction signals to the system of FIGURE 1;

FIGURE 4 is a diagram partially in section of the correction coil employed in the system of FIGURE 1;

FIGURE 5 is a cross-sectional view of the coil shown in FIGURE 4;

FIGURE 6 is a block diagram of another circuit for supplying deflection and correction signals to the system of FIGURE 1, and

FIGURE 7 is a diagram of another form of correction coil usable in the system of FIGURE 1.

The system of FIGURE 1 comprises a cathode-ray tube 10 of a type conventionally used in a flying-spot scanner system. This tube comprises a circularly cylindrical neck 12 having an axis Z—Z and a coaxial bulb portion 14 having a plane faceplate 16. The interior of faceplate 16 is coated with a phosphor layer forming a screen. To project a cathode-ray beam along the Z—Z axis toward the screen, tube 10 comprises an electron gun 18 of conventional form supported coaxially within neck 12. Gun 18 comprises a heater 20, a cathode 22, a control grid 24, and an accelerating anode 26. In addition, a region of the interior surface of neck 12 and bulb 14 is coated with a conductive film 28 composed for example of colloidal graphite. Anode 26 is connected to film 28 by metal spring fingers (not shown) pressing thereagainst. A connector button 30 provides an external electrical connection to film 28 and anode 26. A low voltage source 32 supplies heater voltage to heater 20, and a high voltage source 34 supplies beam-accelerating voltage to anode 26 and film 28. A source 36 com-

prising a battery and a potentiometer supplies negative grid-biasing voltage to grid 24.

To deflect the cathode-ray beam, a deflection yoke 38 comprising horizontal and vertical windings (not shown) is provided. The terminals of the horizontal winding are designated A–B and the terminals of the vertical-deflection winding are designated C–D. To focus the beam statically, an iron-cored focusing coil 40 of conventional form is provided. This coil is energized by a source 42 comprising a battery and a rheostat connected in series relationship with coil 40, and produces in response to energization a magnetic field the predominant component of which is parallel to the Z—Z axis.

In one form of character-recognition system, the cathode-ray beam is scanned alternately along a different one of two linear paths which are parallel to, on opposite sides of, and equidistant from the horizontal axis of the phosphor screen and bisected by its vertical axis. These two scanning paths are shown in FIG. 2 at 50 and 52.

To produce such a scanning pattern, a periodic sawtooth current which varies during each cycle continuously between a given intensity in one sense to the same intensity in the opposite sense is supplied to terminals A–B of the horizontal winding by a horizontal sawtooth generator 60 (see FIG. 3). The latter may have a conventional structure. To displace the beam alternately above and below the horizontal axis on successive horizontal scansions, a current of constant intensity and alternating sense is supplied to terminals C–D by a bistable multivibrator 62 which also may have a conventional structure. To synchronize the horizontal and vertical deflections of the beam, a sawtooth output voltage produced by generator 60 in synchronism with its output current is differentiated by a conventional resistor-capacitor circuit 64 to form sharp pulses coincident with the termination of each sawtooth of current. The time constant of differentiating circuit 64 is substantially less than the periodicity of the sawtooth wave. The sharp pulses are supplied as a trigger signal to multivibrator 62.

To achieve maximum character resolution in a character recognition system, the cathode-ray beam of tube 10 must be focused sharply at all scanned points of the screen and must be substantially anastigmatic thereat. However because tube 10 has a flat screen, the throw distance of the beam increases as the beam is deflected farther from the center of the screen. The focal distance of the beam remains constant. Under these conditions, the spot of light produced on the screen by the beam becomes progressively more defocused and diffuse as the beam is deflected farther from the center of the screen. In addition the spot ordinarily becomes more and more elongated in the direction of deflection as it impinges on regions of the screen increasingly distant from its center. To minimize this elongation, deflection yoke 38 may be wound so that the beam is most astigmatic at the intersections of scanning paths 50 and 52 with the Y axis and progressively less astigmatic as the beam is deflected farther from this axis. Nonetheless, any astigmatism in the beam is objectionable since it increases the minimum diameter to which the beam can be focused or elongates the cross section of the beam, and hence reduces the resolution of the character-recognition system.

In accordance with the invention, a correction coil 66 is provided which, when energized as described hereinafter, simultaneously corrects during scansion focus and astigmatism errors of the beam. As shown in FIGS. 1, 4 and 5, coil 66 comprises a plurality of turns of a continuous filamentary conductor, e.g. an insulated metal wire, which lie generally along an undulatory path. This path completely surrounds and conforms to the outer surface of neck 12, undulating between a pair of spaced, parallel planes perpendicular to the Z axis, i.e., the R–S plane and the R'–S' plane. The undulating path successively contacts first one and then another of these planes twice. Thus, as shown in FIG. 4, coil 66 contacts the R axis at the points (r_1, 0, 0) and ($-r_1$ 0, 0) and contacts the S' axis at the points (0, s_1, z_1) and (0, $-s_1$, z_1). Successive undulations of coil 66 are symmetrical with respect to the alternate one of two mutually perpendicular planes, i.e. the R–Z plane and the S–Z plane.

The cross-sectional form of the coil is not critical. In the specifically described embodiment, the cross section is elliptical (see FIG. 5). However the cross sectional form of the coil alternatively may be square, rectangular, kidney-shaped, concave toward the tube neck, or any other desired configuration. As shown in FIG. 5, a coating of insulation 68 surrounds and binds together the turns of the wire forming the coil.

When coil 66 is supplied with current by way of its terminals F–G, the end segments thereof, i.e. those curved segments of coil 66 near its points of tangency with the R and S' axis, produce a magnetic field the predominant component of which is generally parallel to the Z—Z axis. Such a component shortens the distance travelled by the beam from gun 18 to its focal point. Simultaneously the lateral segments of coil 66 interconnecting its end segments produce a magnetic field, the predominant component of which is a quadrupole field transverse to the Z—Z axis. Such a quadrupole field compresses an electron beam projected along the Z—Z axis, along a line perpendicular to the Z axis, and stretches out the beam along another line perpendicular to both the Z—Z axis and the first line, i.e. it introduces astigmatism into the beam. Because a quadruple field distorts an anastigmatic cathode-ray beam in the foregoing manner, it also can be employed both to cancel astigmatism initially existing in the beam and to pre-distort the beam so as to compensate for astigmatism which fields (e.g. focusing and deflection fields) thereafter acting on the beam tend to introduce into it. To achieve either or both of these results, coil 66 must be angularly positioned about neck 12 so that its quadrupole field introduces into the beam a compensating astigmatism of the proper amount and orientation. The appropriate angular position for coil 66 is readily determined by rotating coil 66 about neck 12 until the spot produced by the beam on the screen has minimum astigmatism. Moreover by adjusting appropriately the respective intensities of the constant focusing current supplied to static focusing coil 40 and the maximum current supplied to correction coil 66, the astigmatism of the undeflected beam can be corrected and concurrently the beam can be brought to a sharp focus at the intersection of scanning paths 50 and 52 with the Y axis. During scansion, the beam can be maintained anastigmatic and in sharp focus by simultaneously weakening both the total longitudinal focusing field and the quadrupole field by an amount directly dependent on the distance that the beam is deflected from the Y-axis. By weakening the longitudinal field, i.e. the field parallel to the Z—Z axis, the beam is brought to a focus a longer distance from the gun. This compensates for the longer distance that the beam must travel from gun to screen when deflected from the center of the screen. By weakening the quadrupole field, the amount of compensating astigmatism introduced into the beam is reduced in a manner appropriate to the reduced amount of astigmatism in the beam when deflected. In accordance with the invention, both of these corrections are made by reducing the intensity of the correction current supplied to correction coil 66, in synchronism with the scansion of the beam. Suitable circuits for generating this current are discussed hereinafter.

The amount of astigmatism correction provided by coil 66 per unit of current supplied thereto is directly dependent both on its length (designated z_1 in FIGS. 1 and 4) and the number of turns of wire in coil 66. The amount of focus correction provided by coil 66 per unit of current supplied thereto is directly dependent on the number of turns. The amounts of defocusing and astigmatism concurrently occurring in a given cathode-ray tube when the beam is deflected to any given point of the screen

is dependent on numerous factors, e.g. the distance of electron gun **18** from faceplate **16** the radius of curvature of faceplate **16**, the non-uniformities in direction and intensity of the fields produced by focusing coil **40** and deflection yoke **38**, the angle through which the beam is deflected and the intensity and diameter of the beam. Because these factors will vary in different cathode-ray tube systems, no one design of correction coil **66** can produce perfect correction in all systems. However, the correct design for any given system is readily ascertained by a method of approximation in which a test coil having a given length z_1 and a given number of turns is placed upon the neck of the tube and supplied with a current such that perfect focus is obtained in conjunction with the longitudinal magnetic field provided by the static focusing coil **40**. If the astigmatism is over-corrected, a shorter coil is substituted for the test coil. If the astigmatism is undercorrected, a longer coil is substituted therefor. Alternatively, since the focusing power of coil **66** is more strongly dependent than its astigmatism correction power on the number of turns in coil **66**, a coil having the same length as the test coil but more turns may be substituted therefor in the event that the test coil over-corrects astigmatism. Conversely a coil with fewer turns may be employed where astigmatism is under-corrected.

A suitable correction current for use in the system of FIG. 1 when the beam is scanned as shown in FIG. 2 has an intensity which is a maximum when the beam impinges on the Y axis of the screen and which decreases from this maximum approximately parabolically as the beam is deflected away from the Y axis, i.e. a current of the form $(-I+kx^2)$. In this relationship, I is a constant, k is a positive constant of proportionality, x is the horizontal displacement of the beam from the center of the screen, and the absolute value of I is greater than kx^2. This correction current is generated by the circuit of FIG. 3. In this circuit, a periodic sawtooth voltage produced by horizontal sawtooth generator **60** in synchronism with its sawtooth current is supplied to an integrator **70**. The latter typically comprises a resistor-capacitor integrating circuit having a time constant several times larger than the period of the sawtooth sweep wave. Such an integrator produces a scallop-shaped periodic voltage wave composed of a succession of parabolic segments (k_1x^2). This voltage wave is supplied to an adding circuit **72** within which it is added to a constant voltage $(-E)$ supplied by a source **74** comprising a source of constant, unidirectional voltage **76** and potentiometer **78**. The quantity (k_1x^2) is less than the absolute value of (E) and is of opposite polarity, so that the absolute value of the correction voltage decreases as the beam is deflected farther from the Y axis. The output voltage $(-E+k_1x^2)$ of adding circuit **72** is supplied to a voltage-to-current amplifier **80** to produce the periodic output current $(-I+kx^2)$ having the same waveform as the voltage $(-E+k_1x^2)$. This current is supplied to correction coil **66** via its terminals F–G. Adding circuit **72** and voltage-to-current amplifier **80** may have a conventional structure, e.g. that shown in Fig. 10.12, page 371 of the book, "Cathode Ray Tube Displays," by T. Soller et al. (McGraw-Hill 1948).

The foregoing discussion has been directed to a character-reading system employing a relatively simple form of scansion. However the invention also is applicable to systems employing more complex forms of scansion, e.g. to a television system in which the beam scans a raster of conventional form and a video signal is applied between grid **24** and cathode **22** of tube **10**. FIG. 6 illustrates a circuit for generating periodic horizontal and vertical sawtooth deflection signals of conventional form and for also generating a periodic correction current. This circuit comprises horizontal sawtooth generator **60** and a vertical sawtooth generator **90** maintained synchronous with generator **60** by signals from a synchronizing generator **92**. Sawtooth generators **60** and **90** and synchronizing generator **92** may all have conventional structures. Horizontal sawtooth generator **60** supplies a sawtooth current of horizontal sweep periodicity, e.g. 15,750 cycles per second, to the horizontal deflection terminals A–B of deflection yoke **38**. Vertical sawtooth generator **90** supplies a sawtooth current of vertical deflection periodicity, e.g. 60 cycles per second, to the vertical deflection terminals C–D of yoke **38**. To generate the correction current for coil **66**, the circuit comprises horizontal integrator **70**, a vertical integrator **94**, constant voltage source **74**, an adding circuit **96** and voltage-to-current amplifier **80**. Each of integrators **70** and **94** typically comprises a conventional series resistor-capacitor circuit having a time constant at least several times larger than the periodicity of the sawtooth voltage supplied thereto by generators **60** and **90** respectively. Horizontal integrator **70** produces at its output a succession of parabolic voltage waves (k_1x^2) and vertical integrator **94** produces at its output a succession of parabolic voltage waves (k_2y^2). Source **74** produces a constant unidirectional voltage $(-E)$. The two parabolic voltage waves and the constant voltage are supplied to adding circuit **96**, and the sum of these three voltages appearing at the output of circuit **96** is supplied to voltage-to-current amplifier **80** which produces an output current having substantially the same waveform as that of the voltage suplied thereto. This output current is supplied to terminals F–G of correction coil **66** to effect the simultaneous correction of the focus and astigmatism of the cathode-ray beam during scansion thereof.

For the scanning rates ordinarily used in flying-spot scanners and television systems, correction coil **66** preferably is an air-core coil, so that its inductance is relatively low and only a small amount of power is needed to drive it. However, where slower scansions are employed, coil **66** may be an iron-core coil and indeed may be incorporated as an additional winding on the iron core of focus coil **40**.

Moreover, coil **66** need not necessarily have the shape shown in FIGS. 1 and 4—a shape achieved in practice by winding the required number of turns of wire onto a circularly cylindrical form having a diameter larger than that of tube neck **12**, placing these turns around a mandrel having the same diameter as the tube neck, squeezing the turns into an approximately elliptical form the minor axis of which coincides with a diameter of the mandrel, bending the turns about this minor axis to the mandrel and then shaping the turns on the mandrel so that the resultant coil conforms to its surface. Alternatively other coil geometries may be employed. A coil **100** having one such different geometry is shown schematically in FIG. 7. The longitudinal segments **102**, **104**, **106** and **108** of coil **100** conform to the surface of neck **12** and are parallel to the Z—Z axis thereof. The end segments **110**, **112**, **114** and **116** of coil **100** also conform to the surface of neck **12**, respectively join longitudinal segments **102–104**, **104–106**, **106–108** and **108–110** and are substantially perpendicular to the longitudinal segments which they join. The end segments produce a predominantly longitudinal magnetic field; the longitudinal segments produce a predominantly quadrupole field.

FIG. 1 shows correction coil **66** positioned behind static focusing coil **40**. However correction coil **66** alternatively may be located between focusing coil **40** and deflection yoke **38** or along substantially the same region of neck **12** as focusing coil **40**.

The coils illustrated in the drawings each have two undulations. However, if desired, coils with eight undulations, producing an octapole field, may be substituted therefor.

In the embodiments described above, the beam of charged particles whose focus and astigmatism are simultaneously and dynamically corrected during scansion has been specifically described as an electron beam. However the invention also can be used to correct the focus and astigmatism of a beam composed of charged particles other than electrons, e.g. alpha particles, protons or other

ions. One such application is in a particle acceleration system of the type employed in atomic research.

Correction coil 66 has been described as conforming to the outside of the circularly cylindrical neck of a cathode-ray tube. However coil 66 need not necessarily conform to a circularly cylindrical surface. Moreover it may be positioned inside the evacuated region along which the beam passes.

The system of the invention has been described in connection with flying-spot scanner and television display systems employing a single cathode-ray beam. It also can be used to correct focus and astigmatism in multibeam cathode-ray tube systems. In addition it can be used in other types of display systems, e.g. radar displays.

The cathode ray tube system specifically described above is of the type in which the throw distance of the beam increases and its astigmatism decreases as the beam is deflected farther from a deflection axis of the screen. The invention also is applicable to a system in which the throw distance decreases and the astigmatism increases as the beam is deflected farther from a deflection axis of the screen, e.g. in a system in which the screen of the cathode-ray tube is highly curved and non-uniformities in the deflection field introduce increasing amounts of astigmatism into the beam while deflecting it farther from a deflection axis of the screen. In such a system, a correction current increasing in intensity as the beam is deflected farther from a deflection axis of the screen is supplied to the correction coil.

The systems specifically described above have all comprised magnetic focusing and deflection means. However the system of the invention alternatively may comprise electrostatic focusing means, electrostatic deflection means, or both.

The systems described above have all employed a single correction coil 66. However in a television system employing conventional horizontal and vertical deflection, two correction coils of the form of coil 66 may alternatively be used. In such an arrangement, both coils are positioned coaxially on tube neck 10 and are oriented so that their undulations are 180 degrees out of phase, i.e., alternate peaks of one coil are adjacent alternate peaks of the other coil and the other peaks of one coil are remote from the other peaks of the other coil. One coil is supplied with a parabolic horizontal correction current and the other coil is supplied with a parabolic vertical correction current. The latter currents are appropriately phased with the scansion of the beam. Such a system is advantageous in that horizontal and vertical corrections can be made independently of one another.

While I have described my invention by means of specific examples and in specific embodiments, I do not wish to be limited thereto, for obvious modifications will occur to those skilled in the art without departing from the scope of my invention.

What I claim is:

1. Apparatus for use in conjunction with a cathode-ray tube to reduce defocusing and astigmatism of an electron beam thereof, comprising an electrical conductor encircling a region traversed by said beam without intersecting any path of said beam, and describing about said region a path undulating between two surfaces transverse to the axis of said beam, said undulating conductor, when supplied with an electric current, producing an n-pole magnetic field, where n is an integer multiple of four, and said undulations of said conductor having an orientation relative to said beam such that said n-pole magnetic field interacts with said beam to reduce said astigmatism thereof, and means for supplying to said conductor an electric current having an intensity dependent on the position of said beam.

2. Apparatus according to claim 1, wherein said apparatus additionally comprises means positioned adjacent another region traversed by said beam for deflecting said beam and wherein said undulating conductor is positioned so that said beam traverses said region encircled by said undulating conductor before traversing said other region adjacent said deflection means.

3. Apparatus according to claim 1, wherein said surfaces between which said path undulates are parallel and the amplitudes of said undulations are substantially equal to each other.

4. Apparatus according to claim 1, wherein each of said two surfaces is a plane perpendicular to said axis of said beam and said conductor describes between said two planes an undulatory path consisting of two complete cycles, each of said cycles having the same period and form as the other of said cycles.

5. Apparatus according to claim 1, wherein said conductor describes an undulatory path consisting of two complete cycles, wherein said surfaces between which said conductor undulates are parallel and the amplitudes of said undulations are equal to each other, and wherein said apparatus additionally comprises means positioned adjacent another region traversed by said beam for deflecting said beam, and said undulating conductor is positioned so that said beam traverses said region encircled by said undulating conductor before traversing said other region adjacent said deflection means.

6. Apparatus according to claim 5, wherein said surfaces are perpendicular to said axis of said beam and each of said two cycles has the same period and form as the other of said two cycles.

7. Apparatus according to claim 5, wherein said electrical conductor describes said undulatory path a plurality of times.

8. Apparatus according to claim 1, wherein said conductor describes a path undulating through at least two complete cycles.

9. Apparatus according to claim 1, wherein said conductor describes an undulatory path consisting of two complete cycles.

10. Apparatus according to claim 1, wherein said conductor lies on a cylindrical surface.

11. Apparatus according to claim 4, wherein said electrical conductor describes said undulatory path a plurality of times.

No references cited.