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A CRT FOR A VERTICAL SCAN HDTV DISPLAY AND METHOD OF OPERATING THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

5 This application claims the benefit under 35 U.S.C. 119(e) of U.S. Provisional Patent Application Serial No. 60/613,155, entitled "DIGITAL ORTHOGONAL SCAN HDTV DISPLAY", filed September 24, 2004, which is incorporated by reference herein in its entirety. This application also claims the benefit under 35 U.S.C. 119(e) of U.S. Provisional Patent Application Serial No. 60/640,875, entitled "A CRT FOR A VERTICAL SCAN
10 HDTV DISPLAY AND METHOD OF OPERATING THE SAME", filed December 31, 2004, which is incorporated by reference herein in its entirety.

FIELD OF THE INVENTION

 The invention relates to a cathode ray tube (CRT) for a High Definition Television
15 (HDTV) display operating in a vertical scan mode and a method of operating the CRT.

BACKGROUND OF THE INVENTION

 The popularity of HDTV has prompted an increased demand for television sets capable of displaying HDTV images. Such demand has prompted an increase in demand for
20 larger aspect ratio, true flat screen displays having a shallower depth, increased deflection angle and improved visual resolution performance.

 The demand for shallow, flat screen displays has led to efforts to improve spot performance so that spot size and shape exhibit greater uniformity across the entire screen for improved visual resolution performance. To this end, most displays now make use of
25 dynamic focus. Increasing the deflection angle also yields an improvement in spot

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performance in the central area of the screen because increasing the deflection angle results in a decreased gun-to-screen distance, hereinafter referred to as the "throw" distance. Figure 1 illustrates the basic geometrical relationship between throw distance and deflection angle for a typical CRT. Increasing the deflection angle (A) reduces the throw distance, thus allowing
5 for production of a shorter CRT and ultimately, a slimmer television set.

As the deflection angle increases, the throw distance decreases and spot size decreases in a non-linear relationship. The following formula mathematically approximates relationship between spot size and throw distance:

$$\text{Spot Size} \approx B * \text{Throw}^{1.4} \quad (\text{Equation 1})$$

10 where the exponent 1.4 represents an approximation taking into consideration the effects of magnification and space charge effects over a useful range of beam current. The term B represents a system-related proportionality constant. Considering this relationship, for a tube having a diagonal dimension of 760 mm, increasing the deflection angle from 100 degrees to 120 degrees while decreasing the center throw distance, for example, from 413mm to 313mm
15 yields a 32% reduction in spot size at the center of the screen.

Increasing the deflection angle in these displays gives rise to increases in obliquity, which is defined as the effect of a beam intercepting the screen at an oblique angle, thereby causing an elongation of the spot. The problem of obliquity becomes especially apparent in CRTs having a standard horizontal gun orientation, i.e., a CRT whose guns have a horizontal
20 alignment along the major axis of the screen. As obliquity increases, a spot having a generally circular shape at the center of the screen becomes oblong or elongated as the spot moves toward edges of the screen. Based on this geometrical relationship, in a large aspect ratio screen, such as a 16 x 9 screen, the spot appears most elongated at the edges of the major axis

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and at the screen corners. The obliquity effect causes the spot size to grow. The following equation defines the spot size radius SS_{radial} :

$$SS_{\text{radial}} = SS_{\text{normal}} / \cos(A) \quad (\text{Equation 2})$$

where A represents deflection angle, as measured from Dc to De as shown in Figure 1 and

5 nominal spot size SS_{normal} represents the spot size without obliquity.

In addition to the obliquity effect, yoke deflection effects in self-converging CRTs having a horizontal gun orientation can compromise spot shape uniformity. To achieve self-convergence, CRT's typically include a horizontal yoke that generates a pincushion shaped field and a vertical yoke that generates a barrel shaped field. These yoke fields cause the spot
10 shape to become elongated. This elongation adds to the obliquity effect by further increasing spot distortion at the three-o'clock and nine o'clock positions (referred to as the "3/9" positions) and at corner positions on the screen.

Various attempts have been made to address spot distortion and obliquity. For example, U.S. Patent No. 5, 170,102 describes a CRT with a vertical electron gun orientation
15 whose undeflected beams appear parallel to the short axis of the display screen. The deflection system described in this patent includes a signal generator for causing scanning of the display screen in a raster-scan fashion, thereby yielding a plurality of lines oriented along the short axis of the display screen. The deflection system also comprises a first set of coils for generating a substantially pincushion-shaped deflection field for deflecting the beams in
20 the direction of the short axis of the display screen. A second set of coils generates a substantially barrel shaped deflection field for deflecting the beams in the direction in the long axis of the display screen. The deflection system's coils generally distort spots by elongating them vertically. This vertical elongation compensates for obliquity effects, thereby reducing spot distortion at the 3/9 and corner positions on the screen. The barrel shaped field required

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to achieve self convergence at 3/9 screen locations overcompensates for obliquity and vertically elongates the spot at the 3/9 and corner locations as shown in Figure 10 of the U.S. Patent No. 5, 170,102. (In effect, the barrel shaped field overcompensates, thus making the spot shape at the 3/9 position and the screen corners a vertically oriented ellipse.) Orienting
5 the electron guns along the vertical or minor axis will yield improvements in a self-converging system, but spot distortion remains problematic at the 3/9 positions and at the corner screen locations.

Thus, a need exists for a CRT system that overcomes the aforementioned disadvantages.

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SUMMARY OF THE INVENTION

Provided is a cathode ray tube and a method of operating the cathode ray tube for a display system which has a picture display area and an electron gun assembly with inline guns being aligned vertically. The display system includes a deflection system for the cathode ray
15 tube to provide line rate scanning in a vertical direction. A video signal processing system serves to transpose video signals supplied to the deflection system. The deflection system includes a first picture correction circuit for reducing picture distortion in at least part of the picture display area. The video signal processing system also includes a second correction circuit for reducing picture distortion in at least of part of picture display area coextensive
20 with the part of the picture display area in which the first picture correction circuit reduces picture distortion.

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BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described by way of example with reference to the accompanying figures of which:

FIGURE 1 is a diagram depicting the basic geometrical relationship between the throw
5 distance and deflection angle in a typical CRT;

FIGURE 2 is a diagrammatic cross sectional view of a CRT according to an embodiment of the present principles;

FIGURE 3 is a diagram of the screen of the CRT of FIG. 2 illustrating a mis-convergence pattern in accordance with the present principles;

10 FIGURE 4 is a diagram depicting optimization of spot shape in accordance with the present principles;

FIGURE 5 is a block diagram of a first illustrative embodiment of the associated signal processing and electronic drive system for driving the CRT of FIG. 2 in accordance with the present principles in accordance with the present principles;

15 FIGURE 6 is a block diagram of a second illustrative embodiment of the associated signal processing and electronic drive system for driving the CRT of FIG. 2 in accordance with the present principles;

FIGURE 7 is a block diagram of a third illustrative embodiment of the associated signal processing and electronic drive system in accordance with the present principles;

20 FIGURE 8 is a block diagram of a modification of the CRT display system shown of FIG. 6;

FIGURE 9 is a block diagram showing a second modification of the CRT display system of FIG. 6.

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FIGURE 10 is a diagram depicting a portion of a CRT display screen subject to image distortion;

FIGURE 11 is a block diagram of a video correction system within the CRT display system of FIGS. 5-9; and

5 FIGURE 12 is a characteristic graph for a polyphase filter within the video correction system of FIG. 11.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Prior to discussing the CRT display system of the present principles, a brief discussion
10 of the facets of a typical cathode ray tube will prove helpful. Figure 2 illustrates a cathode ray tube (CRT) 1, for example a W76 wide screen tube, having a glass envelope 2 comprising a rectangular faceplate panel 3 and a tubular neck 4 connected by a funnel 5. The funnel 5 has
an internal conductive coating (not shown) that extends from an anode button 6 toward the faceplate panel 3 and to the neck 4. The faceplate panel 3 comprises a viewing faceplate 8
15 and a peripheral flange or sidewall 9, which is sealed to the funnel 5 by a glass frit 7. The inner surface of the faceplate panel 3 carries a three-color phosphor screen 12. The screen 12
comprises a line screen with the phosphor lines arranged in triads. Each triad includes a phosphor line of three primary colors, typically Red, Green and Blue, and extends generally
parallel to the major axis of the screen 12.

20 A mask assembly 10 lies in a predetermined spaced relation with the screen 12. The mask assembly 10 has a multiplicity of elongated slits extending generally parallel to the major axis of the screen 12. An electron gun assembly 13, shown schematically by dashed lines in Figure 2, is centrally mounted within the neck 4 to generate three inline electron beams, a center beam and two side or outer beams, directed along convergent paths through

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the mask assembly 10 to strike the screen 12. The electron gun assembly 13 has three vertically oriented guns, each generating an electron beam for a separate one of the three colors, Red, Green and Blue. The three guns lie in a linear array extending parallel to a minor axis of the screen 12.

5 The CRT 1 employs an external magnetic deflection system comprised of a yoke 14 situated in the neighborhood of the funnel-to-neck junction. When activated with a drive signal in a manner discussed hereinafter, the yoke 14 generates magnetic fields that cause the beams to scan over the screen 12 vertically and horizontally in a rectangular raster. The external magnetic system or electronic deflection system can be driven by drive circuits and
10 applies a high frequency deflection in a short direction to electron beams emitted from the electron guns of the electron gun assembly 13.

1. —ELECTRON-BEAM SPOT SHAPING AND CONVERGENCE WITH YOKE FIELDS AND QUADRUPOLE COILS

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A. Yoke Fields

In accordance with one aspect of the present principles, the electron beam undergoes spot shaping. To understand spot shaping, a discussion of the yoke 14 and the effect of the yoke
20 fields will prove helpful. As discussed, the yoke 14 lies in the neighborhood of the funnel-to-neck junction on the CRT 1 as shown in Figure 2. In the illustrated embodiment, the yoke 14 has first deflection coil system (not shown) that generates a horizontal deflection yoke field that is substantially barrel-shaped. The yoke 14 has a second deflection coil system (not shown) electrically insulated from the first deflection coil system for generating a vertical

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yoke field that is substantially pincushion-shaped. These yoke fields affect beam convergence and spot shape. Rather than adjust for self-convergence, the horizontal barrel field shape associated with the first deflection system undergoes an adjustment (e.g., a reduction), to yield an optimized spot shape at the sides of the screen. The barrel shape of the yoke field attributable to the second deflection coil system undergoes a reduction. The combined effects of the barrel-shaped field and the dynamic astigmatism correction provided by the dynamic focus associated with the electron guns yields an optimized, nearly round spot shape at the 3/9 position and at the corner screen locations. The use of pincushion vertical field and a barrel horizontal field, where the barrel horizontal field is adjusted to improve spot shapes and allow some misconvergence of the electron beams along the screen edges is characterized as quasi-self-convergent deflection fields.

The field reduction that results in improved spot shape from self-convergence actually causes mis-convergence at certain locations on the screen. FIGURE 3 illustrates a display screen showing the resulting misconvergence from such a reduced barrel-shaped field. For example, when the barrel field undergoes a reduction to achieve an optimized spot at the 3/9 positions and at the corner locations of the screen, the beams over-converge at the sides of the screen. Overconvergence as used here refers to a condition that results from the red and blue beams crossing over each other prior to striking the screen. The amount of overconvergence varies as a function beam deflection. Thus, the resultant pattern appears converged at the center of the screen while appearing mis-converged at the sides of the screen. Assuming the electron gun assembly 13 of FIG 2 has its red, green, and guns orientated from top to bottom, the overconvergence causes the electron beams to generate a blue, green, red convergence pattern at the sides of the screen as seen in FIG. 3. The resultant overconvergence at the screen sides in this example was measured at 15 millimeters. Other CRT designs having

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different geometries, or different yoke field distributions will result in more or less overconvergence, for example, in the range of 5 to 35 millimeters.

b. Multipole Coils

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The addition of multipole coils, such as the quadrupole coils 16 shown in FIG. 2, can correct for mis-convergence, or over-convergence that results from the yoke effect described above. In particular, locating the quadrupole coils 16 on the gun side of the yoke 14 will dynamically correct for the yoke effect. The quadrupole coils 16 are fixed to the yoke 14 or alternatively, can be applied to the neck and have their four poles oriented at approximately 90° angles relative to each other as is known in the art. The adjacent poles of the coils 16 have alternating polarity and the orientation of their poles lies at 45° from the tube axes so that the resultant magnetic field displaces the outer (red and blue) beams in a vertical direction to provide correction for the mis-convergence pattern shown in FIG. 3. Alternatively, the quadrupole coils 16 can lie behind the yoke 14 approximately at or near the dynamic astigmatism correction point of the guns of the electron gun assembly 13.

Operating under dynamic control, the quadrupole coils 16 create a correction field for adjusting miscoverage on the screen. The quadrupole coils 16 in this embodiment are driven in synchronism with the horizontal deflection. The signal driving the quadrupole coils 16 has a magnitude selected to correct the overconvergence described above. In an illustrated embodiment, the quadrupole coil signal has a waveform whose shape approximates a parabola.

The electron gun assembly 13 of the CRT 1 has electrostatic dynamic focus astigmatism correction to achieve optimum focus in both the horizontal and vertical directions

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of each of the three beams. This electrostatic dynamic astigmatism correction occurs separately for each beam, thereby allowing for correction of the horizontal-to-vertical focus voltage differences without affecting convergence. Although the quadrupole coils 16 affect beam focus, their location near the dynamic astigmatism point of the guns of the electron gun assembly 13 allows for correction of this effect by adjusting the electrostatic dynamic astigmatism voltage so that there is a minimal effect on the spot. This enables correction of misconvergence at selected locations on the screen without affecting the spot shape. Advantageously, modification of the yoke field design can optimize spot shape and the dynamically driven quadrupole coils 16 can correct for any resultant misconvergence.

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c. Yoke Field and Quadrupole Coils

FIGURE 4 illustrates one quadrant of the screen of a W76 CRT with an aspect ratio of 16:9 and a 120° deflection angle and shows the improvement in spot shape and size obtained by the design of the yoke 14 and the use of the quadrupole coils 16 as discussed above. The spots illustrated by the dotted lines represent the effects of throw distance and obliquity referenced to a round center spot. Optimized spots obtained in accordance with the present principles appear with solid lines. Significant improvements in spot size and shape appear at the sides and corners of the screen. Table 1 lists experimental results for an illustrative embodiment in accordance with the present principles, with H representing the horizontal dimension of each spot, and V representing the vertical dimension of each spot normalized to the center spot. Table 1 compares the cumulative effect of gun orientation, yoke field effects and dynamically controlled quadrupole coils with dynamic astigmatism correction applied to traditional horizontal inline gun CRTs.

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TABLE 1

Spot Location	Guns aligned horizontally 120 degree deflection H x V normalized to center	Guns aligned vertically 120 degree deflection H x V normalized to center
Bottom and Top	1.1 x 1.5	0.8 x 1.6
Sides	3.0 x 0.6	2.0 x 1.5
Corners	3.0 x 0.9	1.6 x 2.0

The center column of Table 1 lists the spot dimensions for a prior art standard

5 horizontal gun orientation CRT with self-convergent beams, whereas the right-hand column represents the results for a CRT with vertical gun alignment in accordance with the present principles wherein the beams undergo dynamically controlled convergence. Although spot shape suffers a slight compromise at the 6 O'clock and 12 O'clock screen positions (6/12 or otherwise as the top and bottom), spot size uniformity shows great improvement at the 3

10 O'clock and 9 O'clock positions (3/9 or otherwise as the side) and at the corner locations. The present technique advantageously provides more uniform spot shape across the screen, thus enhancing visual resolution. Although the invention is applicable to CRTs having deflection angles at 100 or above, the invention has particular applicability to much larger deflection angles such as systems exceeding 120 degrees.

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2. TIMING CONSIDERATIONS

Another facet of the CRT display system of the present principles involves the timing of the electron beam scanning in the CRT display. In this regard Table 2 provides a comparison of the clock frequency, scan line count, and pixel per scan line value for a conventional CRT having horizontal aligned electron guns versus a vertical scan CRT display in accordance with the present principles.

TABLE 2

		Standard horizontal scan		Vertical scan
		HDTV1	HDTV2	HDTV
Visual scan lines and pixels				
	Horizontal	1920	1280	720
	Vertical	1080	720	1280
	Refresh (field) rate	60 Hz	60 Hz	60 Hz
	Interlace or progressive	Interlace	Progressive	Interlace
Timing and circuit considerations				
	Scan line direction	Horizontal	Horizontal	Vertical
	Total scan lines including retrace	1125	750	1375
	Pixels per scan line inc. retrace	2475	1650	900
	Scan frequency	33.75 kHz	45 kHz	41.25 kHz
	Pixel clock rate	83.5 MHz	74.25 MHz	37.125 MHz

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The number of scan lines and pixel data listed in the Table 2 under the heading "Timing and circuit considerations" exceed the visual scan lines and pixel data, respectively, and take account of overscan and retrace. For the vertical gun alignment CRT in the Table 2, the visible image field contains 1280 vertical scan lines with 720 addressable points (i.e. 720 pixels/line) on each scan line.

The three different scan systems in Table 2 afford excellent visual performance. Any visual differences due to the number of scan lines or pixels appear insignificant on a screen size having a diagonal dimension of less than 1 meter at normal viewing distances of larger than 1 meter. The vertical scan system, however, provides a significantly better image because of the better spot size/resolution of the electron beam. While the high speed scan frequency remains about the same for all systems, the vertical scan system requires significantly less scan power because the deflection angle in the vertical direction is much smaller than horizontal direction for a 16 x 9 aspect ratio systems. Further, the pixel clock rate for the vertical scan system is much less than the other systems. A particularly advantageous arrangement utilizes 1280 interlaced visual scan lines, which significantly reduces the deflection power requirements with no detrimental effect when displaying HDTV images.

The CRT display system of the present principles can operate at scan rates other than those listed in Table 2. A scan rate that yields vertical scan lines in the range of approximately 700 to 3000 for 16:9 format tubes in the diagonal dimensional range between approximately 20 cm and 1 m provide excellent HDTV displays under normal home viewing conditions (approximately 2 meter viewing distance).

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3. VIDEO PROCESSING SYSTEM FOR TRANSPOSING AND ADJUSTING INCOMING VIDEO SIGNAL FOR DISPLAY

As described in greater detail with respect to FIGS. 10-12, the CRT display system of the present principles makes use of digital video correction that maps digital video signal information to the appropriate scan location to correct convergence and geometry. This video mapping does not affect the spot shape and affords an effective tool for achieving small corrections. For large corrections, video correction can cause some loss in light output since all the beams must scan all the areas of the screen for the video mapping to work. For example, employing video correction to compensate for the 15 mm of red-to-blue misconvergence shown in FIGURE 3 typically would require an additional overscan of 7.5 mm at the top (for the red) and also at the bottom (for the blue) resulting in a light output loss of about $15/372$ or 4% along the sides.

Employing video correction to yield improved convergence affords the possibility of eliminating multipole correction, by obviating the use of the quadrupole coils 16 of FIG. 2. Eliminating the quadrupole coils 16 will reduce the cost of the CRT display system. An alternative embodiment of the present principles makes use of both the quadrupole coils 16 and video correction to improve convergence.

Conventional video signal transmission assumes a pixel-by-pixel time sequence such that transmission of Red, Green and Blue images effectively occurs as a series of scan lines proceeding from the left edge to the right edge of the image along a scan line and then moving down to the next scan line where again the signal sequence proceeds from left to right. This process continues from top to bottom, in either a progressive scan mode or an interlaced scan mode, as is known in the art. To achieve a vertical scan display, the image must undergo a

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translation into a vertical scan pattern such that the signal sequence starts at the upper left hand corner of the image. The subsequent signal elements then follow along a vertical line from top to bottom along the left edge. After an appropriate blanking interval, generation of a signal element at the top edge of the image at the second scan line occurs, followed by the
5 signal elements corresponding to a sequence from top to bottom along the second scan line. Similarly the third scan line starts at the top and proceeds to the bottom of the image, and thus the corresponding top to bottom signal element must be provided. This process continues through the last scan line at right vertical edge of the image.

To effect vertical scanning, a horizontal scan sequence must undergo a change from a
10 conventional left-to-right and stepwise top-to-bottom regimen to a top-to-bottom and stepwise left to right transposed sequence. For the purposes of the following discussion, the terms "Digital Orthogonal Scan" or DOS refer to the above-described transposition operation.

In general, CRT displays exhibit raster distortions. The commonest raster distortions pertain to geometric errors and to convergence errors. A geometric error results from non-
15 linearities in the scanned positions of the beams as the raster traverses the screen.

Convergence errors occur in a CRT display when the Red, Green and Blue rasters do not align perfectly such that over some portion of the image, a Red sub-image appears offset with respect to the Green sub-image and the Blue sub-image appears offset to the right of the Green sub-image. Convergence errors of this type can occur in any direction and can appear
20 anywhere in the displayed image.

With known color CRT displays, both convergence and geometric errors occur despite perfect alignment of the center region during the original manufacture of the CRT display, assuming that the deflection signals applied to the deflection coils ramp linearly. Traditional, analog circuit techniques compensate for such distortions by modifying the deflection signals

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from linear ramps to more complex wave shapes. Also, adjustment in the details of the yoke design can reduce convergence errors and geometry errors. As the deflection angle increases beyond 100°, traditional methods of geometry and convergence corrections become more difficult to implement.

5 The basic idea of Video Correction (VC) relies on the assumption that the CRT causes geometry and/or convergence distortion of the incoming image. If prior to display, the incoming signal undergoes processing in a manner to actually distort the signal inverse to the distortion inherent in the CRT, then the signal, when displayed, will appear distortion-free. With reference to the example given above for convergence errors, VC performs inverse
10 distortion by displacing the Red sub-image in the opposite direction (e.g., to the right) by the same amount with respect to the Green sub-image to counteract the CRT distortion which effectively displaces the Red Sub-image to the left and similarly displaces the Blue sub-image to the left, resulting in good Red-to-Green convergence. Similarly, the VC displaces the Blue sub-image to the left, compensating for the CRT convergence distortion. It should be
15 appreciated that VC can also be used to reshape all sub-images (including the Green sub-image) to reshape the entire overall raster geometry. Further, VC can be used in conjunction with the yoke field to achieved desired raster geometries.

Prior art optimized CRT display systems commonly employ Image Processing (IP) techniques which cause the displayed image, as seen by the human eye, to appear superior to
20 the same image in the absence of any processing. Edge enhancement constitutes a typical example of image processing, and serves to enhance brightness transition gradients so that the image appears sharper.

The foregoing DOS and VC operations according to the invention herein described are preferentially executed in the digital domain. IP operations can be executed in analog or

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digital forms. The digital form for IP is preferred when digital signals are available in the signal path. The various signal processing tasks associated with DOS, VC and IP operations can be effectively executed in a programmable gate array and associated memory. The programmable gate array can take several alternative forms including field programmable gate arrays (which are commonly referred to as FPGAs), mask programmable gate arrays, and Application-specific Integrated Circuits and other forms of circuits suitable for digital signal processing.

FIGS. 5, 6, and 7 illustrate alternate embodiments of a vertical-scan CRT display system that performs a combination of DOS, VC, and IP operations in accordance with the present principles. As will become better understood, some embodiments perform one or more of the DOS, VC, and IP operations in the digital domain while other embodiments perform one or more operations in the analog domain.

FIG. 5 illustrates a first embodiment of a vertically transposed scan CRT display system in accordance with the present principles. The display system receives input signals from a source such as a Set-Top Box (STB) 100, for example, an RCA Model DTC 210 set top box. The STB 100 provides horizontal and vertical progressive sync [H&V(p)Sync] signals and Red, Green, and Blue component analog signals [RGB(p)]. These signals undergo processing by a Digital Signal Processing (DSP) system that comprises elements 110, 120 and 130. Element 110 comprises an analog-to-digital (A/D) converter that converts the RGB(p) analog signals into three digital signal arrays for the R, G, and B progressive rasters, respectively.

Element 120 comprises firmware, typically in the form of a programmable gate array that operates on the RGB(p) signal set to perform VC operations described in greater detail with respect to FIGS 10-12. Alternatively, the element 120 could take the form of a

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programmed processor. The individually corrected R, G, and B arrays typically undergo storage in a memory (not shown) comprising part of the gate array 120. The memory reads out individual R, G and B signals as transposed vertical scan signal (DOS) in an interlaced manner. Thus, the output of the gate array 120 comprises a set of interlaced digital R, G, and B signals. Furthermore, the gate array also provides H and V interlaced sync signals corresponding to the timing associated with the transposed, vertically scanned, interlaced signal format.

Element 130 in FIG. 5 comprises a digital-to-analog (D/A) converter for converting the R, G, and B signals into corresponding interlaced analog R, G, and B signals, respectively.

Element 140 comprises a matrix operator that converts the R, G, and B signals into a YPbPr format through standard matrix operations. Alternatively, the matrix operator 140 could convert the R, G, and B signals to other formats such as YUV or YCbCr. Thus, the term “YPbPr format” includes any type of component signal encoded into a luminance channel and two color difference channels in either digital or analog form. Similarly, luminance “RGB” as used herein, refers to the three color field components, whether in digital or analog form. When the formats (i.e. YPbPr, YCbCr, etc.) do not bear an explicit description as being digital or analog, the context will make clear the status of the signal.

An image processing unit 150 receives the DOS-modified component video from the matrix operator 140. The image processing element 150 performs image processing and optimization operations known in the art, such as edge enhancement. Further, the image processing element 150 possesses the ability to convert the YPbPr format signals back to an RGB format to adjust CRT parameters such as contrast, brightness, Automatic Kine Bias (AKB), and Automatic Beam Limit (ABL). Each of the R, G, and B signals from the image processing element 150 passes to a separate one of a set of video output amplifiers 160 that

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provides the input signals to the electron gun assembly of the CRT 170. The sync signals produced by the gate array 120 undergo further processing by sync processor 180 prior to input to the dynamic focus element 190 to generate a dynamic focus signal. A quad drive circuit 200 receives the processed sync signals from the sync processor 180 to generate the CRT deflection yoke signals. A deflection signal generator 210 processes the sync signals from the sync processor 180 to generate the H and V signals that drive the deflection coils of CRT 170.

FIG. 6 shows an alternative embodiment of a vertical scan CRT display system in accordance with the present principles. A front-end processor element 300 receives incoming HDTV signals and provides a digital video output signal in a progressive scan YPbPr format. The front-end processor 300 also generates horizontal and vertical progressive sync. A transpose operator element 310 receives the output signals from the front-end processor and performs a DOS operation to yield a progressive vertically scanned YPbPr signal. An image processor 320 performs image processing on the vertically scanned YPbPr signal. For example, the image processor 320 can perform a basic set of IP functions, such as edge enhancement. A format converter 330 performs YPbPr to RGB format conversion to enable a video correction element 340 to accomplish Video Correction (VC). The video correction element 340 also accomplishes a conversion from progressive to interlaced vertical scanning. The digital RGB(i) interlaced vertical scan signal output by the video correction element 340 undergoes a conversion by a digital-to-analog (D/A) converter 350 yielding analog RGB(i) signals. An image processor 360 accomplishes final generation of the interlaced vertical scan signal by providing contrast, brightness, AKB, and ABL functions.

A video amplifier element 370 drives the three electron guns of CRT 380 in accordance with the RGB(i) signals from the image processor 360. A sync processor 390

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provides sync signals to the dynamic focus generator 400, quad drive 410, and deflection signal generator 420 in accordance with the H&V(i) signals received by the sync processor from the video correction element 340.

While the CRT display systems of FIGS. 5 and 6 share common elements, they differ
5 in several ways. Note that the CRT display system of FIG. 5 completes all IP operations after the DOS function and after the incoming signal has undergone Video Correction. The CRT display system of FIG. 6 performs the DOS function followed by Image Processing (IP). Such an arrangement allows for use of an image processor, such as image processor 320, designed to process the DOS signal prior to the VC operation which is especially desirable
10 when VC is utilized for large convergence errors.

FIG. 7 depicts yet another embodiment of a CRT display system in accordance with the present principles. The CRT display system of FIG. 7 includes elements in common with the CRT display system of FIG. 6 and like reference numbers reference like elements. As discussed above, the CRT display system of FIG. 6 utilizes a single image processor 320
15 downstream of the transpose operator element 310. By comparison, the CRT display system of FIG. 7 employs two image processors 320' and 360'. As seen in FIG. 7, the first image processor 320' lies downstream of the front end processor 300 and provides pre-processing of the digital YPbPr signals prior to input to the image transpose operator element 310. The second image processor 360' lies downstream of the D/A converter 350 and provides post
20 processing of the interlaced analog RGB(i), as well as setting the brightness, AKB, and ABL. In all other respects, the CRT display system of FIG. 7 operates the same as that of FIG. 6.

An advantage can arise by doing some image pre-processing prior to preparing the signals for the specific addressing requirements associated with a particular display. Within the CRT display system of FIG. 7, the first image processor 320' performs such pre-

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processing prior the DOS operation by the transpose operator element 310. Alternatively, the CRT display system of FIG. 7 could include yet another image processor (not shown) residing downstream of the transpose operator element 310 and upstream of the format converter 330.

A particular type of image pre-processing of general interest involves the pre-
5 processing of 50 Hz HDTV images for display on a CRT operated in the transposed vertical scan mode. To minimize flicker, 50 Hz interlaced images commonly undergo conversion into another format. Digital signal processing methods allow conversion from 50 Hz to 60 Hz. The utilization of a pre-processor for accomplishing 50 Hz to 60 Hz conversion would allow the CRT display system of the present principles to operate at 60 Hz worldwide irrespective of
10 whether the incoming signal utilizes a frequency of 50 Hz or 60 Hz. Alternatively, 50 Hz signals often undergo conversion to 75 Hz to eliminate flicker. Such a conversion to 75 Hz could occur within the first image processor 320' in FIG. 7 and the remainder of the display chain, beginning with transpose operator element 310, could operate in a 75 Hz. mode.

FIGURE 8 illustrates yet another embodiment of a CRT display system that optimizes
15 image quality. The CRT display system of FIG. 8 shares elements in common with the display system of FIGS. 6 and 7 and like reference numerals refer to like elements. As described hereinafter, the CRT display system of FIG. 8 executes a series of image enhancement operations on the final RGB sub-images prior to display on the CRT 380. Common operations of this kind include peaking and edge enhancement by individual colors.
20 The CRT display system of FIG. 8 accomplishes such enhancement by way of image enhancement element 355 situated downstream of the D/A converter 350 and upstream of the image processor 360. By virtue of being downstream from the D/A converter 350, the image enhancement element 355 accomplishes color-by-color post-processing in the analog domain. In other words, the enhancement element 355 and the image processor 360 can be

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characterized as a post-image processing element which sets contrast, brightness, AKB, and ABL and modifies RGB(i) analog signals, whereby at least one of the functions is performed from the group consisting of peaking, black stretch, color stretch and edge enhancement of individual colors.

5 FIGURE 9 depicts an alternative embodiment of a CRT display system, which like the CRT display system of FIG. 8, provides optimized image quality. The CRT display system of FIG. 9 employs many of the same elements as the display system of FIG 8 and like numbers reference like elements. As compared to the CRT display system of FIG. 8 which performs color-by-color enhancements in the analog domain, the CRT display system of FIG. 9
10 performs such enhancements in the digital domain. To that end, the CRT display system of FIG. 9 employs a digital image enhancement element 355' downstream of the Video Correction element 340 and upstream of the D/A converter 350. Thus, within the CRT display system of FIG. 9, the enhancement element 355' accomplishes RGB image enhancements in the digital domain. Only after completion of the color by color image
15 enhancements does digital-to-analog conversion take place.

The CRT display system of FIG. 9 can include the application of beam scan velocity modulation (BSVM) in the fast vertical scan direction. BSVM constitutes a sharpness enhancement method that involves local changes in the scan velocity of the electron beam based on brightness transitions in the video signal inputs. With reference to FIG. 9, either the
20 video correction element 340 or the digital enhancement unit 355' could provide a suitable BSVM signal.

In a generalized embodiment of the invention the CRT comprises a plurality image processors to accomplish image enhancement operations to improve perceived image quality with respect to one or more attributes like edge sharpness, reduce noise, adjust color, and

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contrast in the displayed image. A first image processor receives an input signal and then feeds the signal to the transposition operation, and such first image processor may be an analog processor operating on an analog component YPbPr signal which, after processing, is fed to an analog-to-digital converter preceding the transposition operation, or such first

5 processor could be a digital circuit operating on a digital component YCbCr signal, in which case first image processor input is either a component digital signal or a component analog signal which is then passed through an analog-to-digital converter which precedes first image processor. A second image processor following the digital transposition operation and preceding the video correction operation is utilized to cause further image enhancements

10 subsequent to the image transposition, such second image processor is implemented in digital circuitry and operates on a transposed component video stream like YCbCr and such second image processor output is fed to a digital matrixing means which converts the digital component YCbCr signal to a digital RGB-signal, which then is operated on by the video correction system. Further, a third image processor may be utilized and such third image

15 processor is located in the signal stream subsequent to the video correction operation and such third image processor executes image enhancement operations on the individual RGB transposed and video corrected color signals; such third image processor may be of an analog type, in which case the digital RGB outputs are first converted by a digital-to-analog converter to analog RGB signals, or it may be of a digital type, in which case the digital RGB signals

20 are directly fed to such third image processor and the output of this third image processor is then fed to a digital-to-analog converter whose RGB analog output is then available as input to the final elements in the video chain that drive the CRT and provide the appropriate signal levels to obtain optimized brightness, contrast, beam cut-off, and black level. Appropriate horizontal and vertical sync signals associated with the transposed and appropriately scanned

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image can be generated, and such sync signals provide input to a sync processor, which in turn provides appropriate inputs for sub-systems associated with the focusing, scanning, and other functions required for the operation and performance optimization functions of the vertically scanned CRT.

5 As discussed above, the CRT display systems of FIGS. 5-9 include video correction performed by the gate array element 120 of FIG. 5 and by the video correction element 340 of FIGS 6-9. In accordance with the present principles, the video correction occurs by first determining the geometric raster distortion of each color, and then establishing the necessary horizontal and vertical displacement (i.e., Δx and Δy) needed to correct the individual raster
10 distortions. The video then undergoes displacement by Δx and Δy to correct for such distortions.

To better understand the process by which such video correction occurs, refer to FIGURE 10, which depicts an example of image distortion appearing on a CRT screen. Within the encircled area, the image appears distorted by the amounts Δx and Δy (shown as
15 ΔV_x and ΔV_y in the FIG. 10). Note that the distortion over the image is not homogeneous and differs for each color.

FIG. 11 provides a general overview of video correction for distortion in accordance with the present principles. First, a measuring device (not shown) determines the x and y offsets (Δx and Δy), typically with a grid of 9 x 9 or a 5 x 5 points spaced over the entire
20 image, yielding Δx and Δy offset matrices 400 and 401. The Δx and Δy offset matrices undergo interpolation, via elements 402 and 403 in FIG. 11. In practice, the elements 402 and 403 can take the form of a programmed processor, application specific integrated circuit, field programmable gate array or digital signal process as an example. A re-sampling filter 404 re-samples video from an incoming source, such as the progressive RGB(p) signals from the

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format converter 330 of FIGS. 6-9 or the A/D converter 110 of FIG. 5 to yield a video image 405 that is distorted by an amount inverse to the distortion that arises from the geometric raster distortion of each color. Thus, the distortion created by video correction cancels the original distortion, yielding a substantially distortion free-image 406. As discussed, the

5 horizontal Δx and vertical Δy displacements are measured or computed on a 9x9 grid. Interpolation of Δx and Δy samples becomes necessary to know the displacement at each point of the re-sampled image typically by the well known two dimensional cubic interpolation.

The result of the interpolation is a distortion vector comprising integer and non-integer components in both the x and y direction. The re-sampling filter 404 consists of a simple
10 remapping of the pixels for the integer component of the distortion vector and of a polyphase filter for the non-integer component. The remapping is conveniently accomplished by reading out a video source memory with adjusted addresses, whereas the integer part of the above interpolation, typically cubic interpolation, is used for the address adjustment.

For performing the non-integer component of the re-sampling operation, filter 404 of
15 FIG. 11 can take the form of a five tap polyphase filter as described in graph of FIG. 12. The graph of Fig 12 shows coefficient values on its y-axis and tap values on its x-axis. The polyphase filter adapts its coefficients to the non-integer shift between the original and the final pixels. The non-integer component of the interpolation can assume values between -0.5 and +0.5, corresponding to interpolated pixel positions +/-0.5 sample spaces from the closest
20 integer value. In Fig. 12 the computed five tap-weights are shown for two non-integer interpolated pixels. The non-integer components computed from the interpolation, shown here are +0.05 and -0.4 pixels from the closest integer position, these are referred to as Phase = 0.05 and Phase = -0.4 in figure 12 respectively. The five element tables associated with each indicated Phase gives the weights for the filter tap summations, indicated in Fig. 12 as

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coefficients. Typically look-up tables are used to store the coefficients for a finite number of non-integer interpolated values. A common approach is to store the coefficients for 64 discrete phases and select the phase closest to the interpolated value.

While the foregoing describes a High Definition Television (HDTV) CRT display
5 operating in a vertical scan mode it should be understood that these principles may be applied to other types of CRTs and that the foregoing only illustrates some of the possibilities for practicing the invention. Particularly, the invention is applicable to a 16:9 screen aspect ratio, but can be applied to systems having a wide variety of aspect ratios like 4:3 or even higher than 16:9, such as 2:1. Many other embodiments are possible within the scope and spirit of the
10 invention. It is, therefore, intended that the foregoing description be regarded as illustrative rather than limiting, and that the scope of the invention is given by the appended claims together with their full range of equivalents.

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What is claimed is:

1. A cathode ray tube system comprising:

vertical in-line electron guns which emit electron beams;

a deflection yoke and drive signals to scan a raster, said raster having a vertical
5 component that is scanned faster than a horizontal component, said deflection yoke and
drive signals scan electron beams vertically;

quasi-self-convergent deflection fields including a pincushion vertical field and a
barrel horizontal field;

said barrel horizontal field being adjustable to improve spot shapes of said electron
10 beams along screen edges, whereby misconvergence of said electron beams can occur by
adjusting said barrel horizontal field;

means to correct misconvergence caused by said barrel horizontal field and maintain
said spot shapes along said screen edges;

means to correct geometry errors of said electron beams and maintain said spot shape;
15 and

means to transpose video signals so that the signal timing is adjusted to meet vertically
scanned electron beam modulation requirements and means to apply image processing to
further correct said geometry errors and further correct said misconvergence.

2. The cathode ray tube system according to claim 1, wherein said means to
20 correct misconvergence includes quadrupole coils driven by dynamic waveforms or video
correction.

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3. The cathode ray tube system according to claim 1, wherein said means to correct geometry errors includes modifying deflection raster waveforms or video correction.

4. The cathode ray tube system according to claim 1, wherein said cathode ray tube system has a 16:9 aspect ratio or greater.

5. The cathode ray tube system according to claim 1, wherein said cathode ray tube system has a deflection angle which exceeds 100 degrees.

6. The cathode ray tube system according to claim 1, wherein said cathode ray tube system contains 700 to 3000 vertical lines.

7. The cathode ray tube system according to claim 6, wherein said raster scanning is either progressive or interlaced.

8. The cathode ray tube system according to claim 1, wherein said cathode ray tube system contains 1280 visible vertical scan lines with 720 visible addressable points or 1375 total vertical scan lines with 900 total addressable points.

9. The cathode ray tube system according to claim 1, wherein said cathode ray tube system includes dynamic focus means.

10. The cathode ray tube system according to claim 2, wherein said means to correct misconvergence utilizes a programmable gate array and associated memory.

11. The cathode ray tube system according to claim 3, wherein said means to correct geometry errors utilizes a programmable gate array and associated memory.

12. The cathode ray tube system of claim 10, wherein the programmable gate array and associated memory is executed in the form of an Application Specific Integrated

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Circuit which is either directly integrated with memory, packaged-integrated with memory or configured to utilize external memory components for its associated memory.

13. The cathode ray tube system of claim 11, wherein the programmable gate array and associated memory is executed in the form of an Application Specific Integrated

5 Circuit which is either directly integrated with memory, packaged-integrated with memory or configured to utilize external memory components for its associated memory.

14. A cathode ray tube comprising:

vertically oriented inline guns, a deflection yoke, designed to shape electron beams spot shape and control image resolution;

10 means to control convergence and raster geometry by appropriately mapping video signals applied to electron beams as a function of screen location.

15 15. The cathode ray tube according to claim 14, wherein said means to control convergence includes one or more operators from the group consisting of dynamic waveform correction, quadrupole coils, and video signal processing.

16. The cathode ray tube according to claim 14, wherein said means to control raster geometry includes scan waveform correction or video signal processing.

17. The cathode ray tube according to claim 14, wherein said means to control raster geometry includes scan waveform correction and video signal processing.

18. The cathode ray tube according to claim 14, wherein said cathode ray tube has a deflection angle exceeding 100 degrees.

19. The cathode ray tube of claim 14, wherein said CRT display system has a 16:9 aspect ratio or greater.

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20. A method of operating a CRT including the steps of:

-providing a CRT having a faceplate wherein the screen elements are oriented horizontally and the electron guns are oriented in a vertical plane;

-providing an electron deflection means that scans electron beams in a vertical raster pattern and signal processing means;

-providing convergence correction means;

-feeding video signal in the signal processing means;

-converting the video signal with the signal processing means to a predetermined vertical scan format having a predetermined refresh rate, wherein the signal processing means appropriately maps individual electron beams to adjust convergence of the electron beams on the screen elements; and

-scanning said electron beams emitted from the guns in a vertical direction at the predetermined scan format at the predetermined refresh rate, wherein the scanning utilizes the electron deflection means and the convergence correction means.

21. The method of claim 20, wherein the scanning of the electron beams is performed in an interlaced fashion.

22. The method of claim 20, wherein the signal processing means also calculates and maps to change the raster shape.

23. A method of operating a CRT including the steps of:

providing, within the CRT, vertically aligned guns, a faceplate on which the screen elements are oriented horizontally and an electron deflection system that scans electron beams in a vertical raster pattern;

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performing signal processing of an input video signal, said signal processing including
a conversion of the video signal to a predetermined vertical scan format;

performing convergence correction of the electron beams; and,

scanning said electron beams in a vertical direction at a predetermined scan format and
at a predetermined refresh rate, wherein the signal processing and convergence operate to
appropriately map and converge the electron beams onto the screen.

24. The method of claim 23, wherein the signal processing includes applying a
distortion to the video signal yielding a video image that is distorted by an amount
approximately inverse to a distortion that arises from a geometric raster distortion of each
electron beam.

25. The method of claim 24, wherein the signal processing also calculates and
maps to change the raster shape.

26. The method of claim 23, wherein the scanning of the electron beams is
performed in an interlaced fashion.

27. The method of claim 23, wherein the conversion of the video signal is from a
horizontal scan sequence to the predetermined vertical scan format.

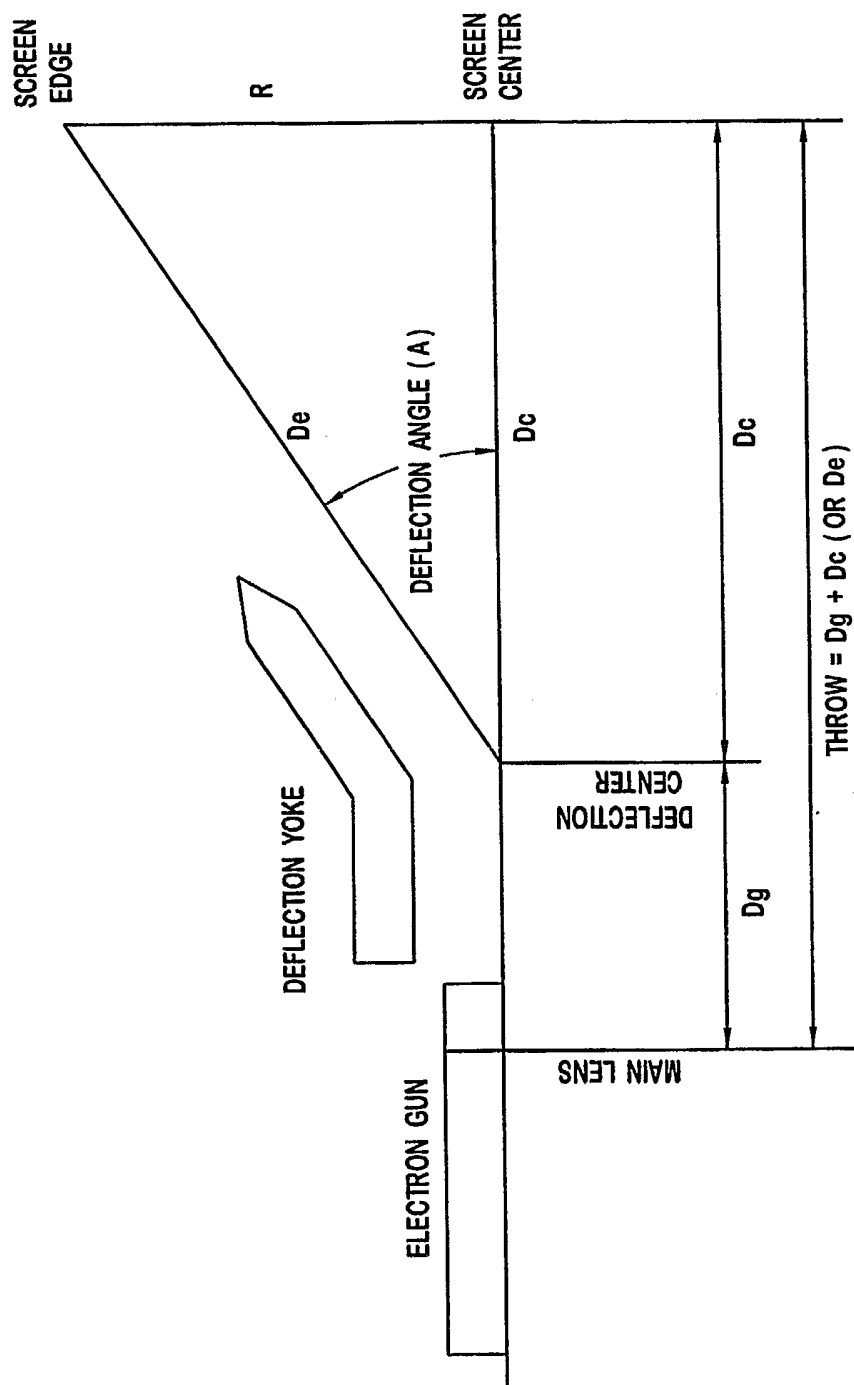


Fig. 1

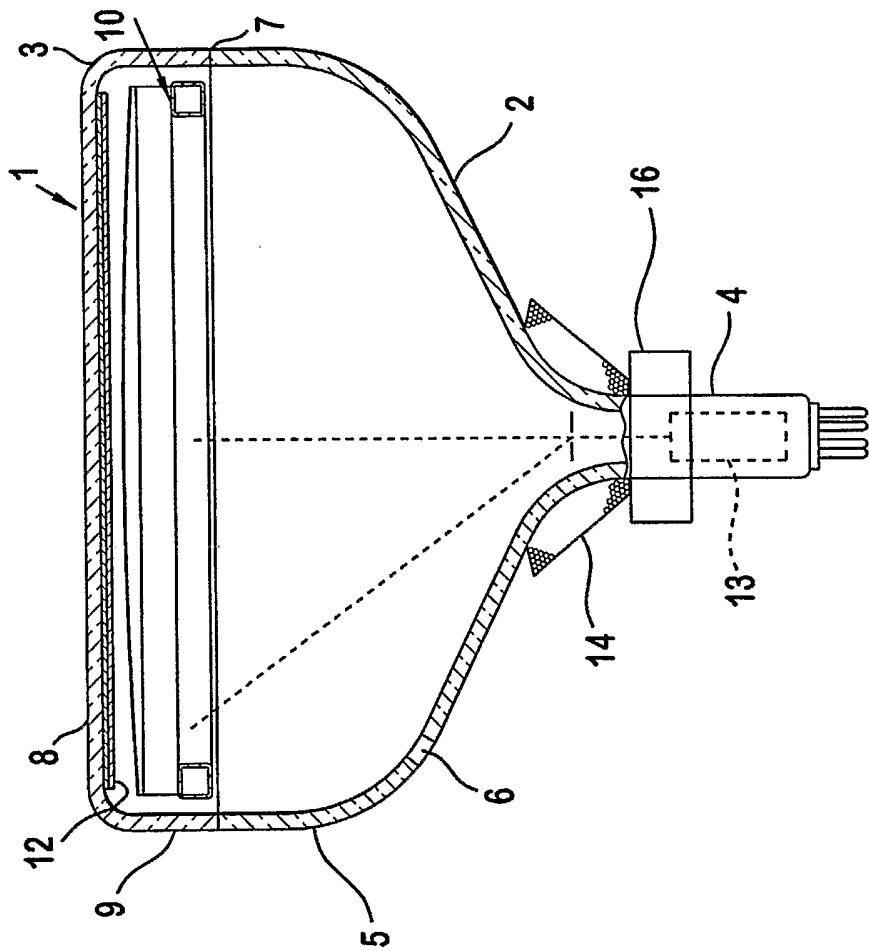


FIG. 2

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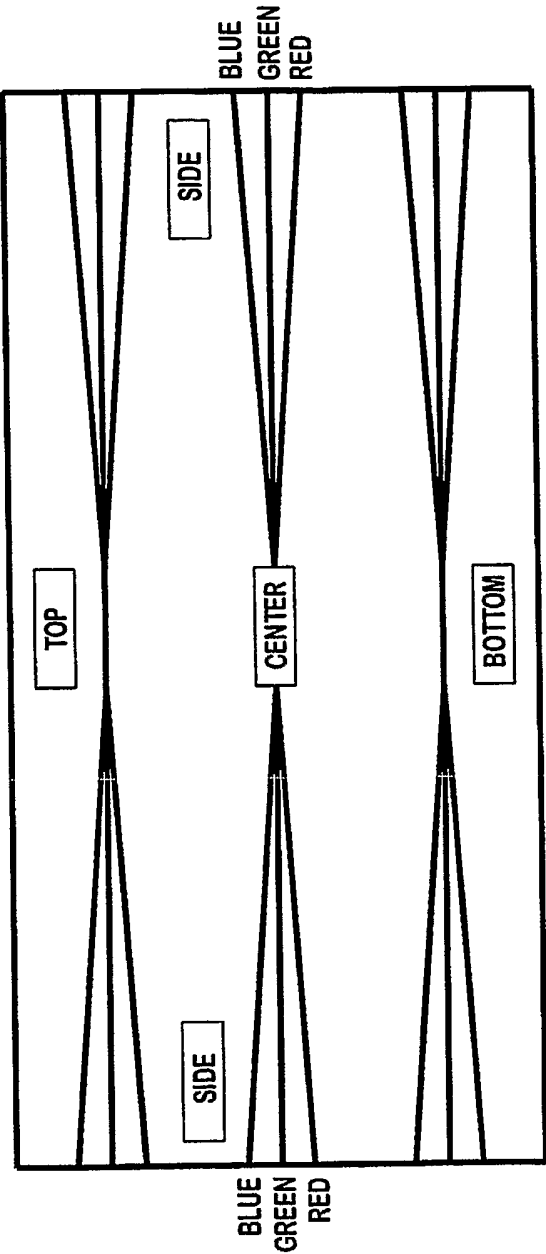


FIG. 3

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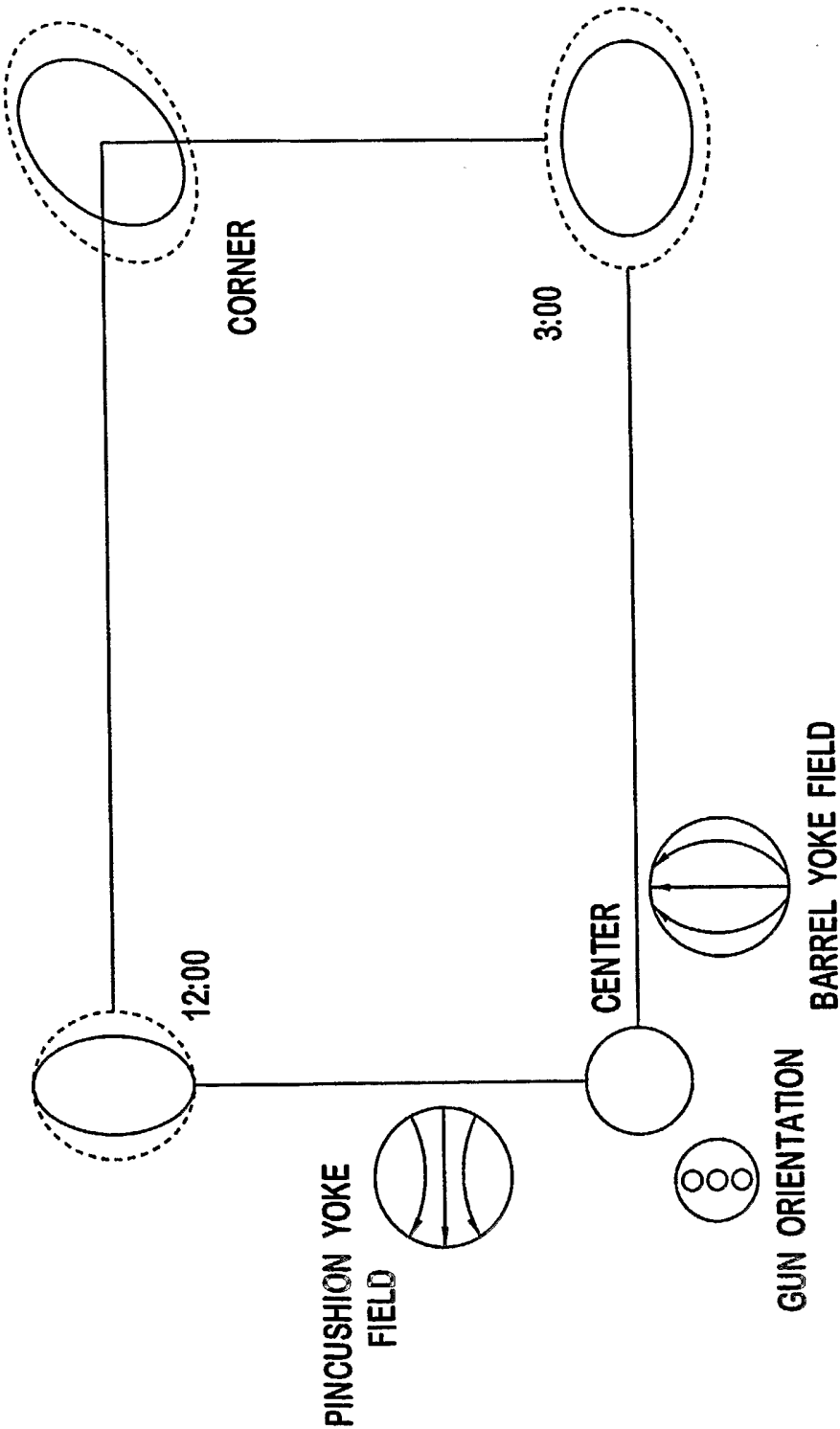


FIG. 4

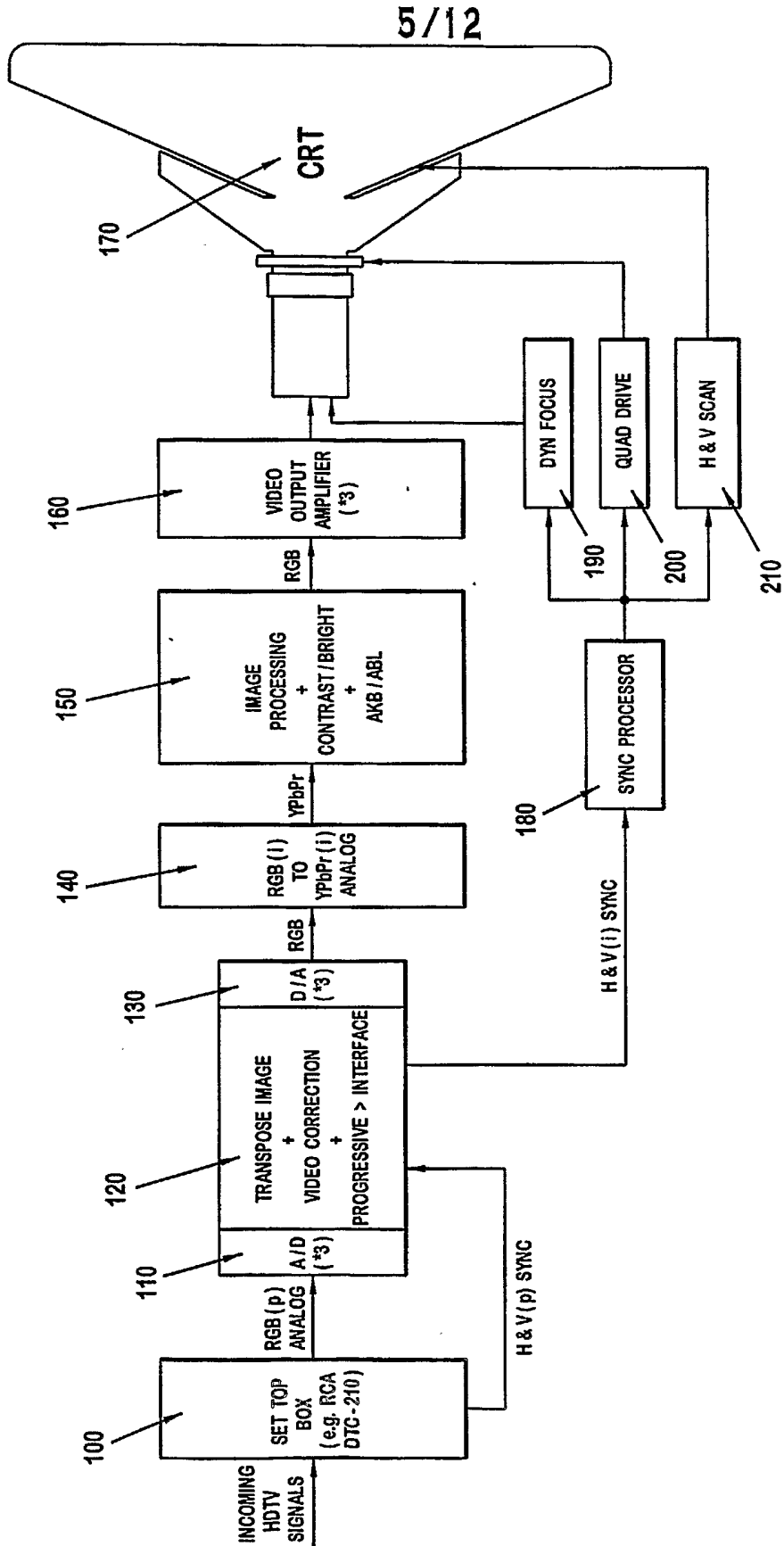


FIG. 5

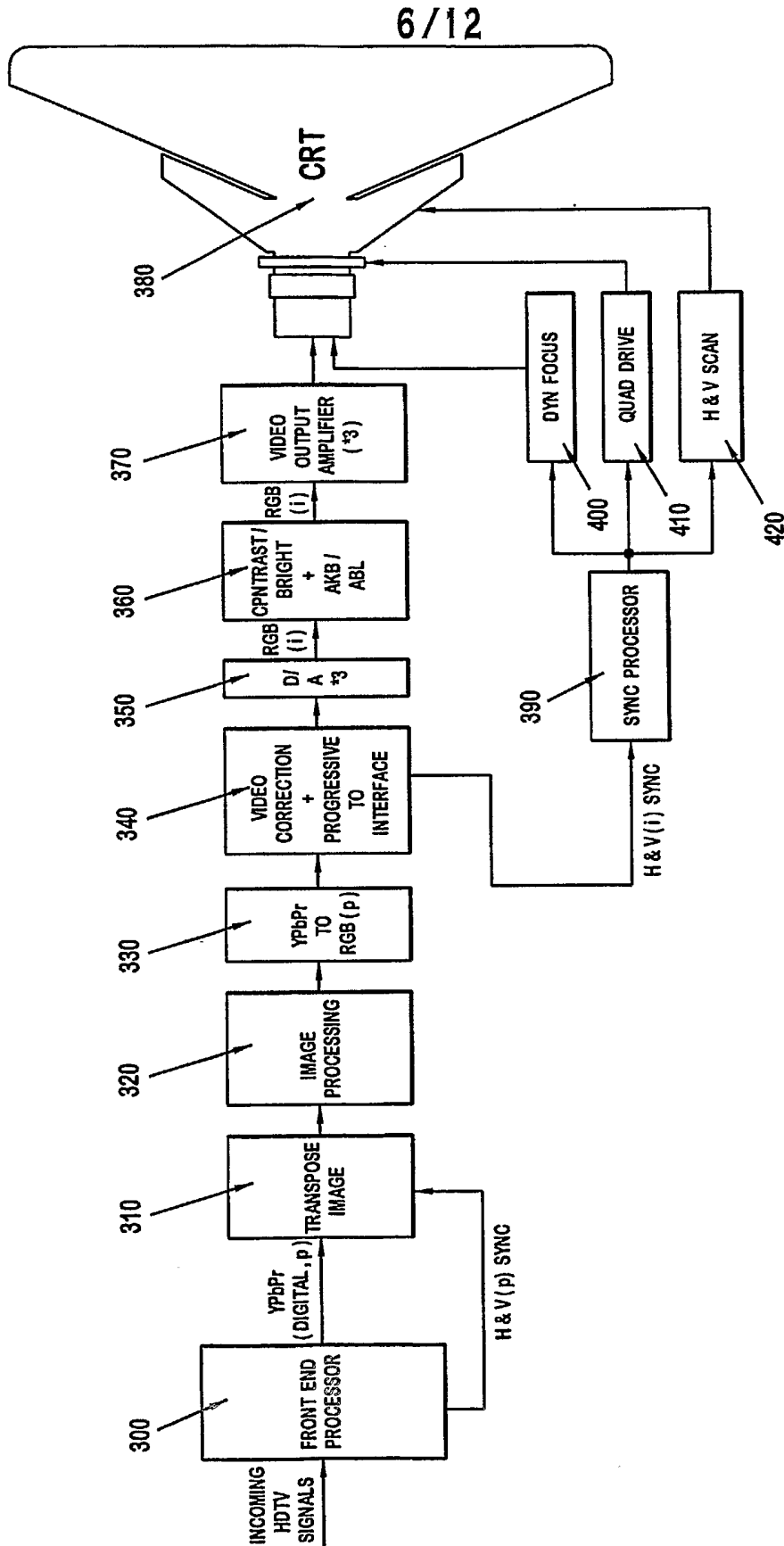


FIG. 6

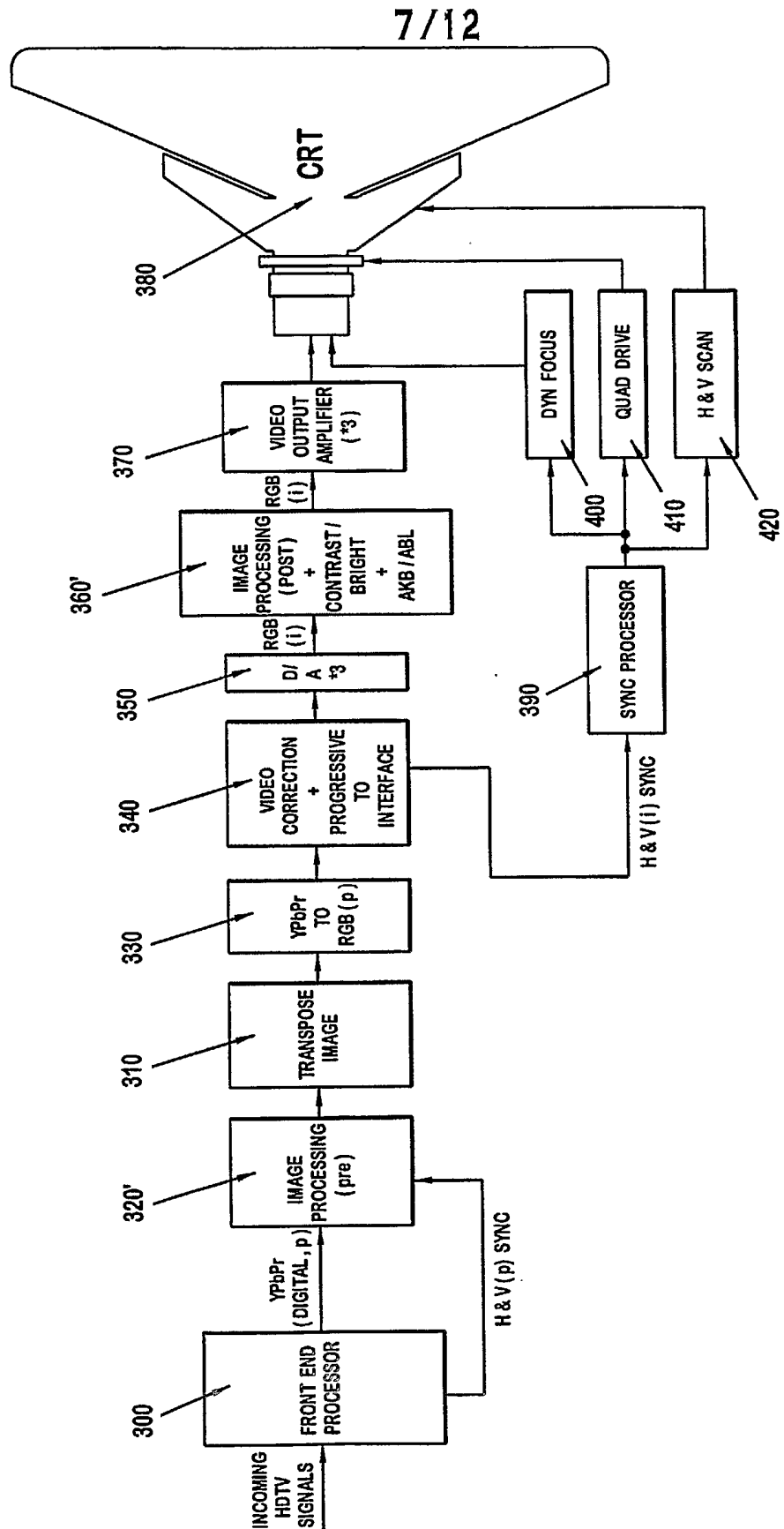


FIG. 7

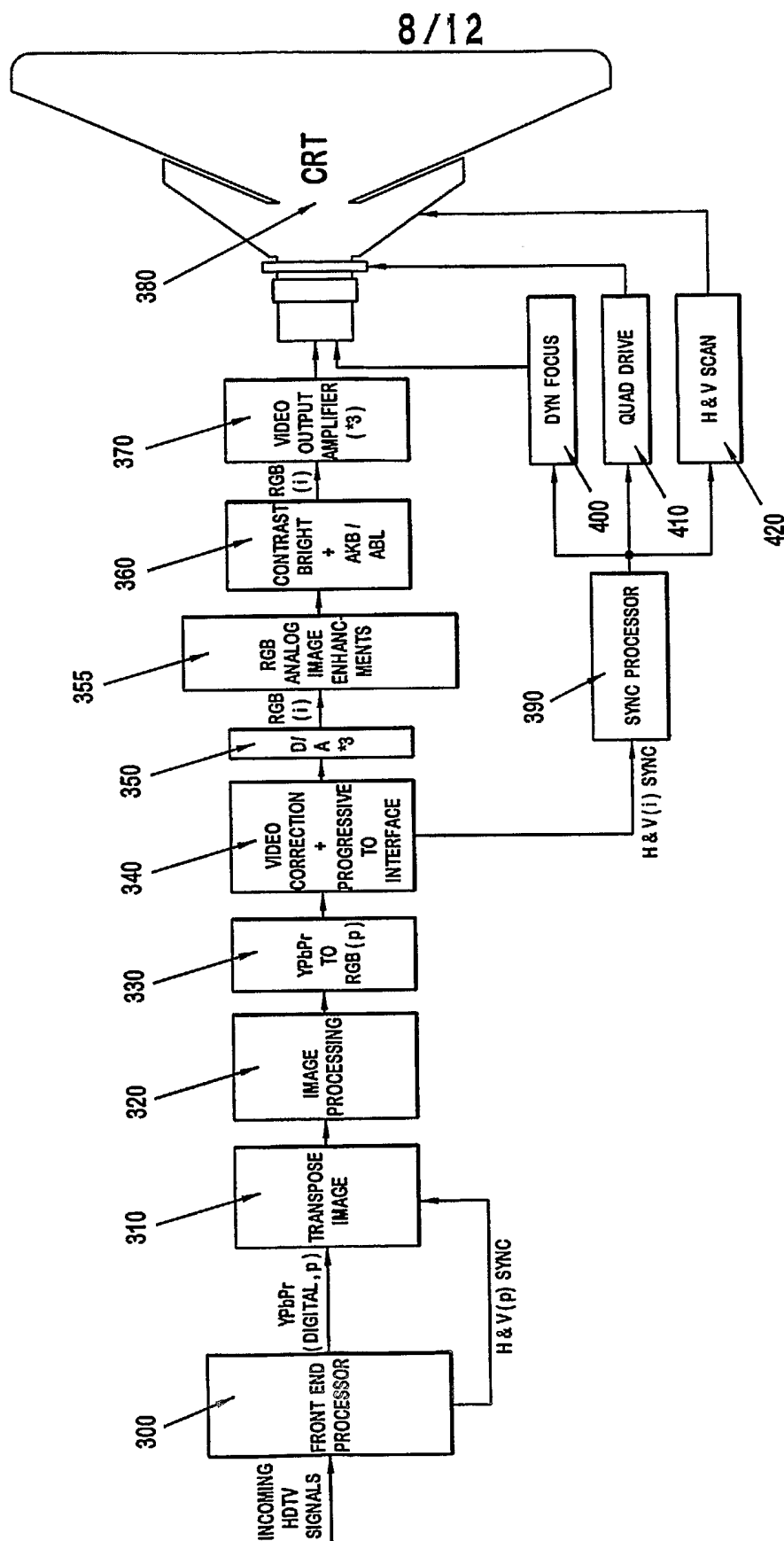


FIG. 8

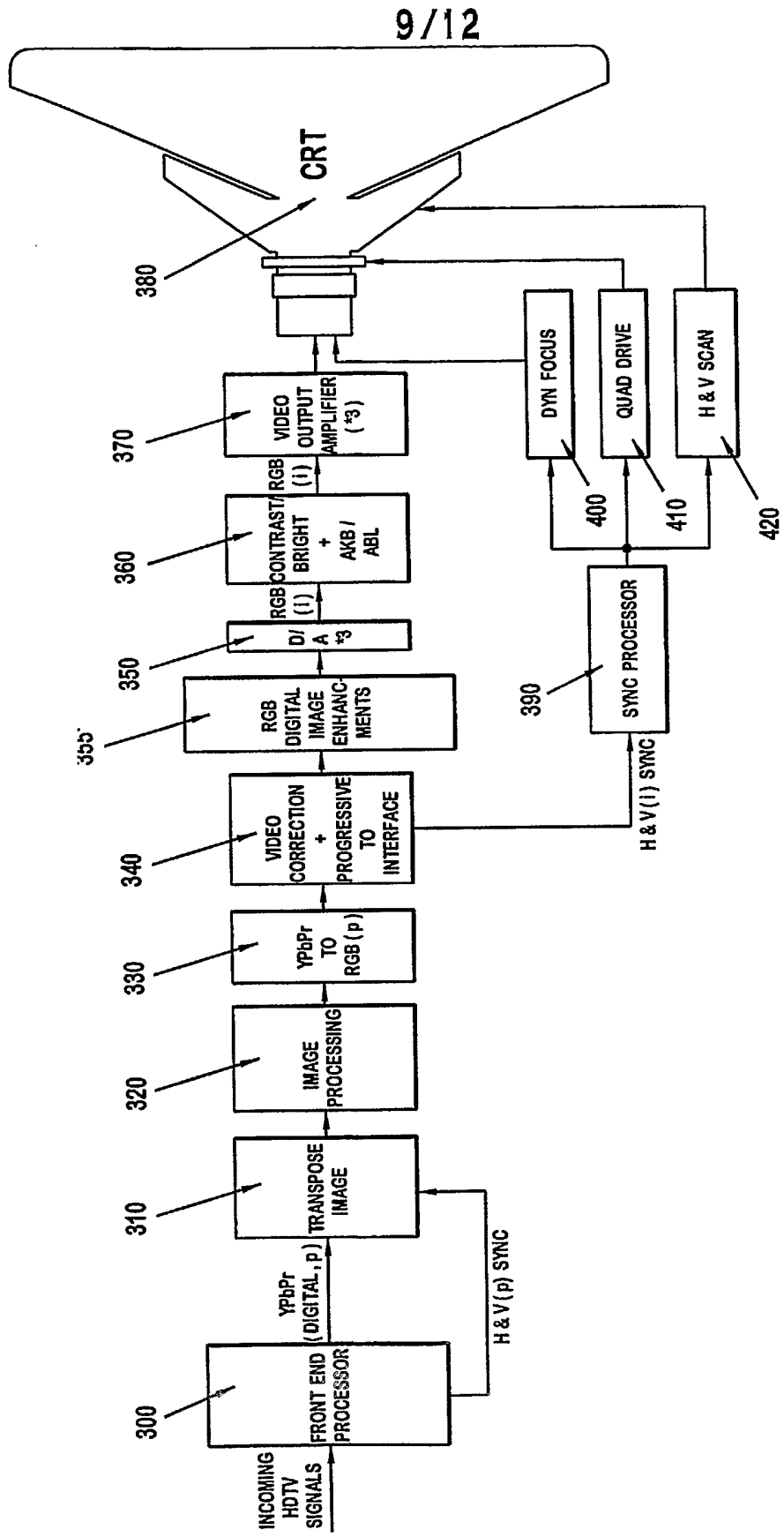


FIG. 9

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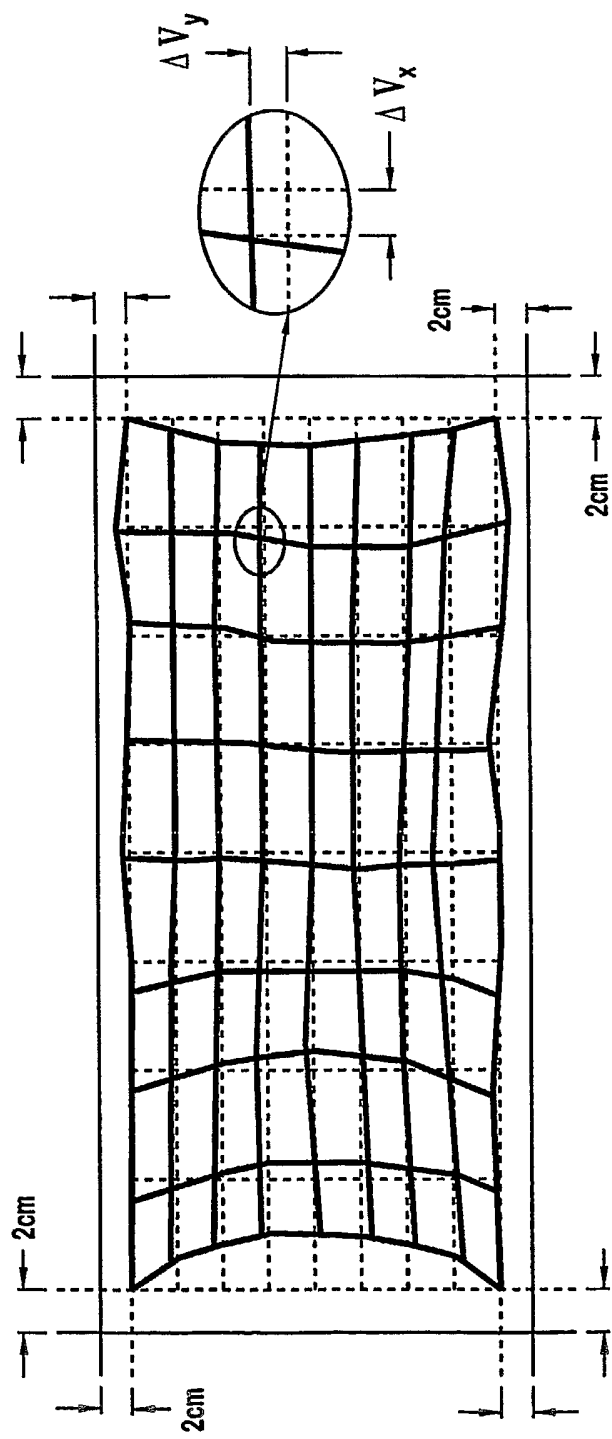


FIG. 10

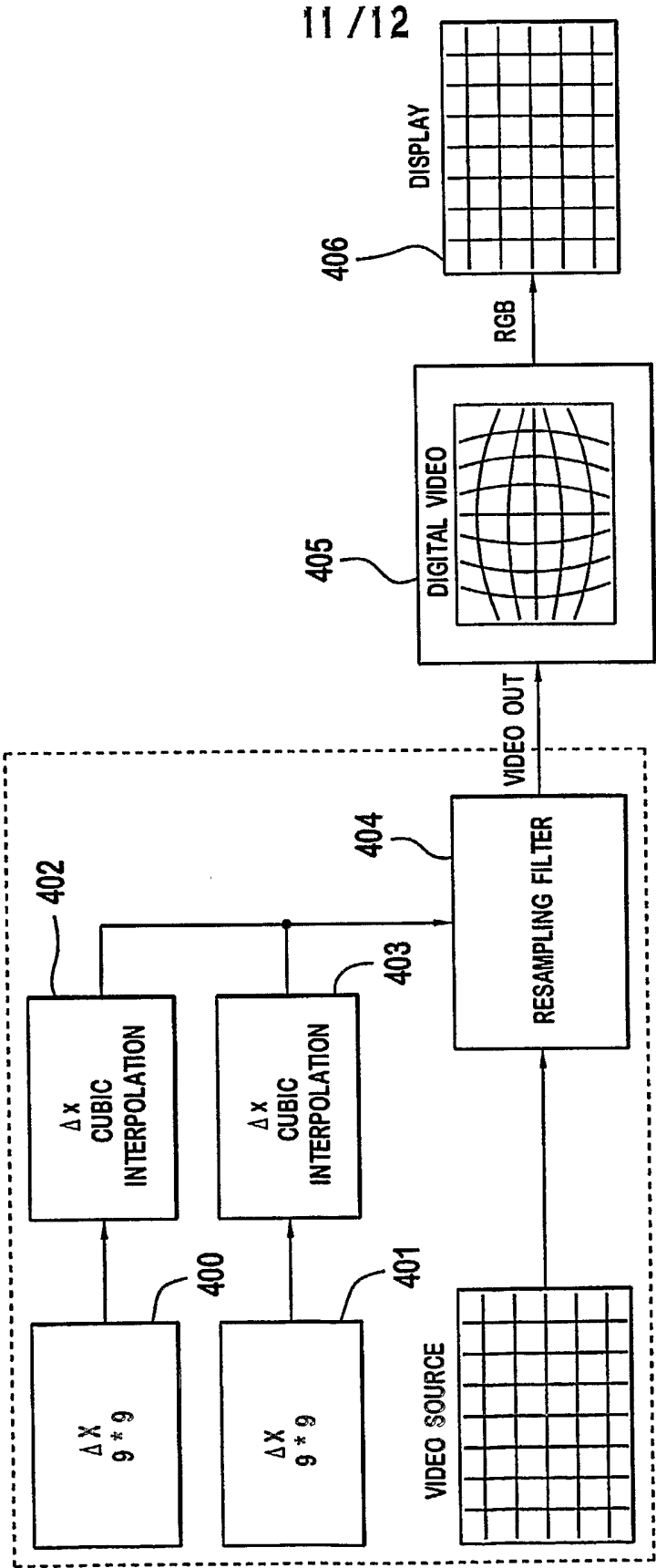


FIG. 11

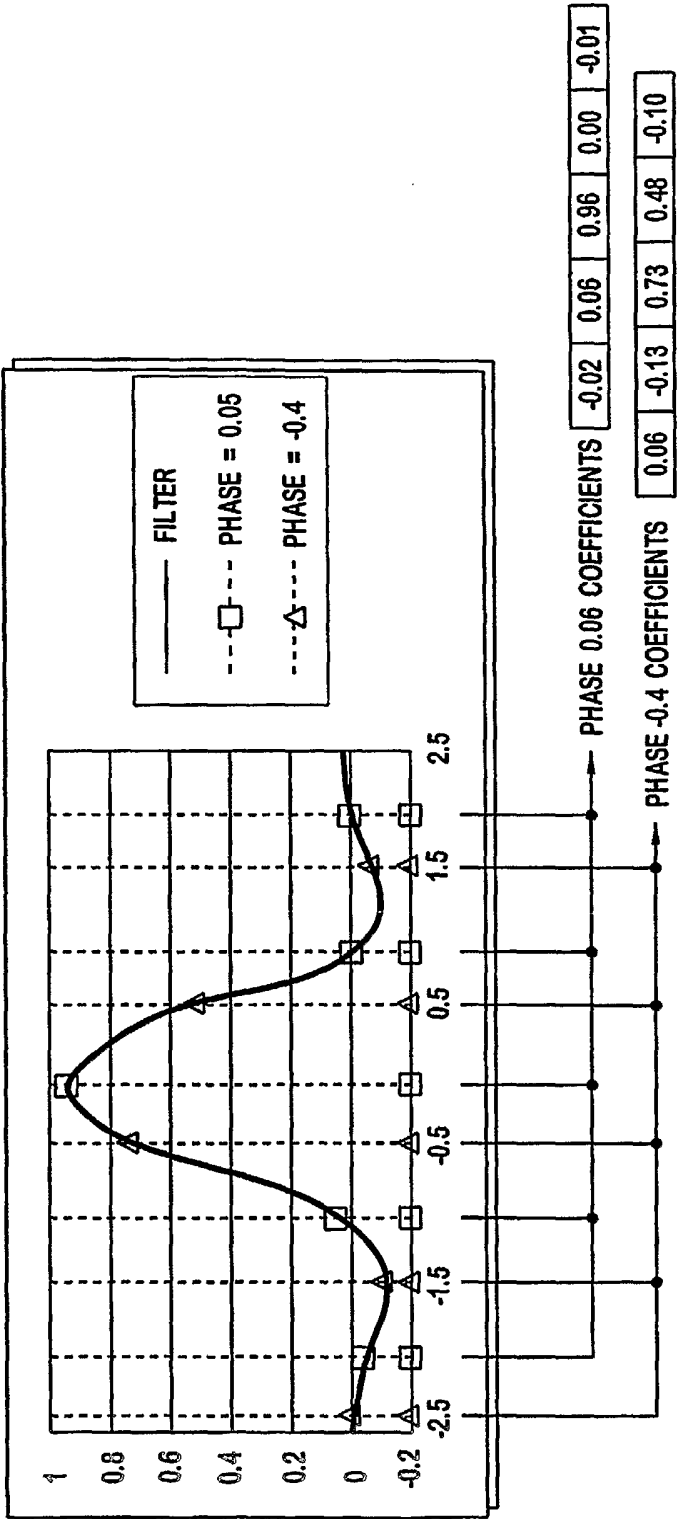


FIG. 12

INTERNATIONAL SEARCH REPORT

Intern: I Application No
PCT/US2005/011397

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 H04N5/44 H04N9/16 H01J29/50 H01J31/20 G09G1/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H04N H01J G09G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 170 102 A (SLUYTERMAN ET AL) 8 December 1992 (1992-12-08) abstract column 4, lines 17-21 column 4, lines 39-41 column 4, lines 47-51 column 4, lines 58-65 column 5, lines 1-8 column 5, lines 20-41 figure 8	1, 3, 4, 6, 14-16, 19, 21, 26, 27
Y		9
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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Date of the actual completion of the international search

22 July 2005

Date of mailing of the international search report

29/07/2005

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INTERNATIONAL SEARCH REPORT

Intern. Appl. Application No
PCT/US2005/011397

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Information on patent family members

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