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Credelle

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(54) **COLOR FLAT PANEL DISPLAY SUB-PIXEL ARRANGEMENTS AND LAYOUTS FOR SUB-PIXEL RENDERING WITH SPLIT BLUE SUB-PIXELS**

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This patent is subject to a terminal disclaimer.

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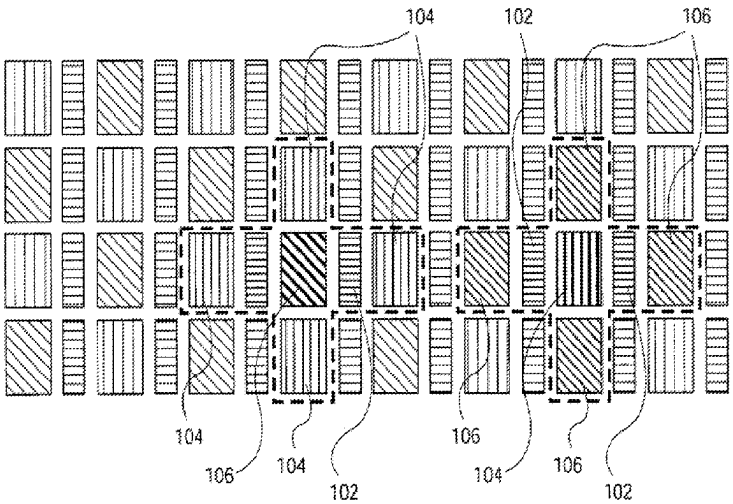
(57) **ABSTRACT**

Various embodiments of a sub-pixel octal grouping are disclosed. The octal grouping may comprise three-color (red, green and blue) sub-pixels with blue colored subpixel comprising twice the number of positions within the octal sub-pixel grouping as the red and green colored sub-pixels. Various embodiments for performing sub-pixel rendering on the sub-pixel groupings are disclosed.

8 Claims, 21 Drawing Sheets



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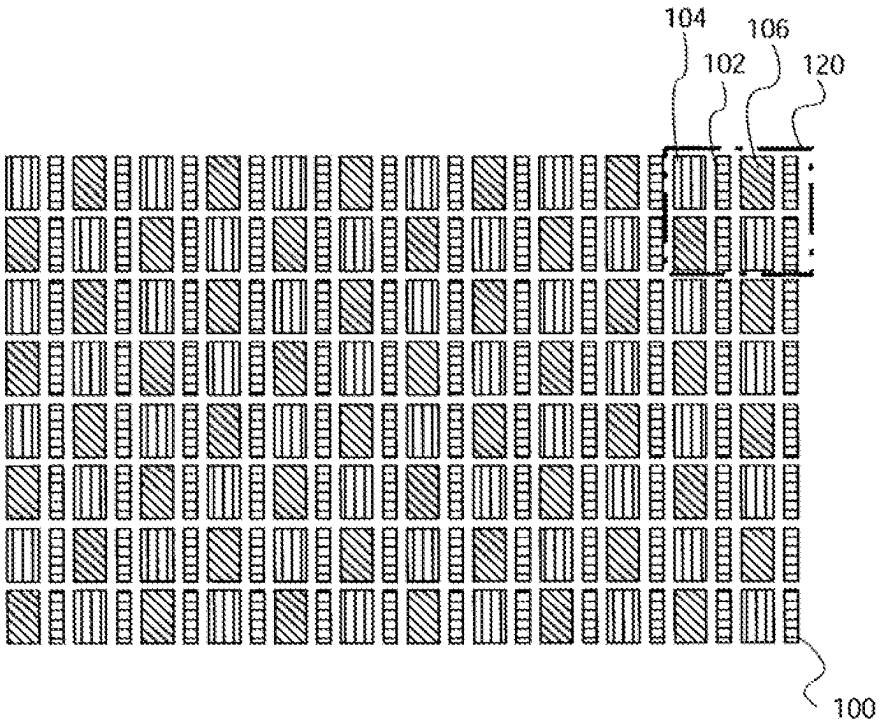

FIG. 1

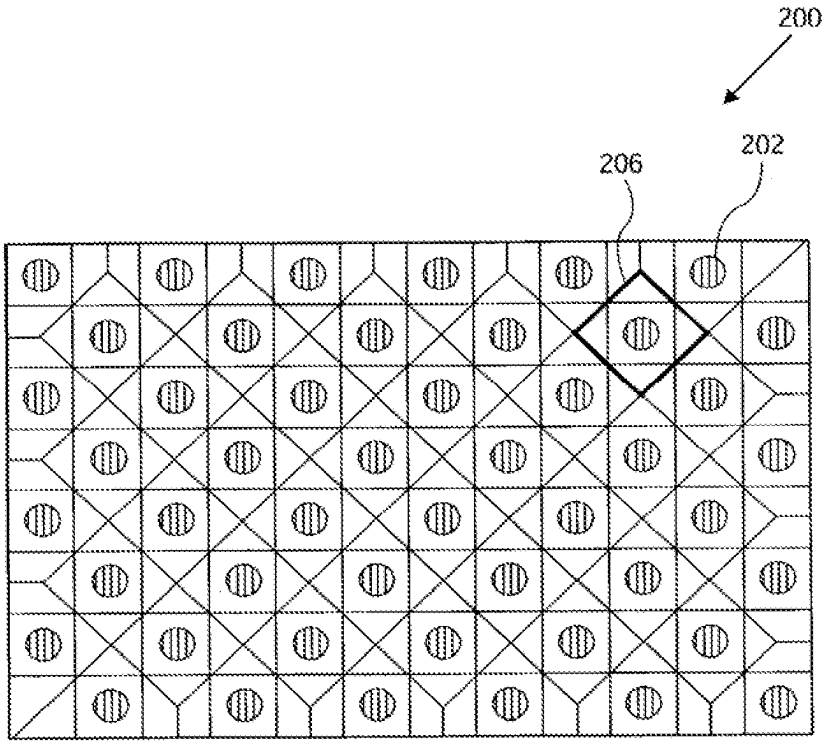

FIG. 2

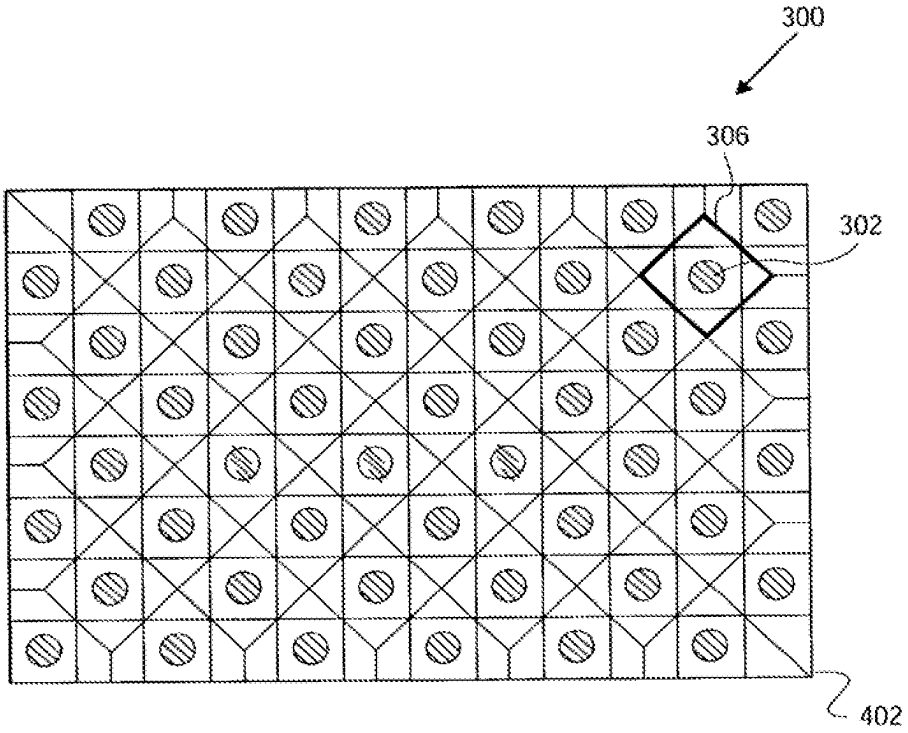

FIG. 3

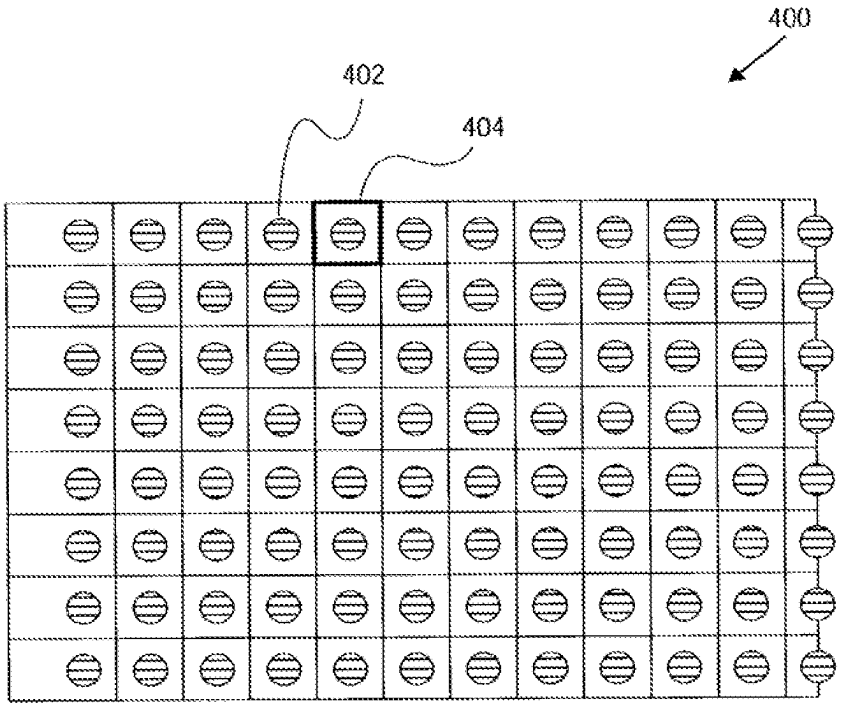

FIG. 4

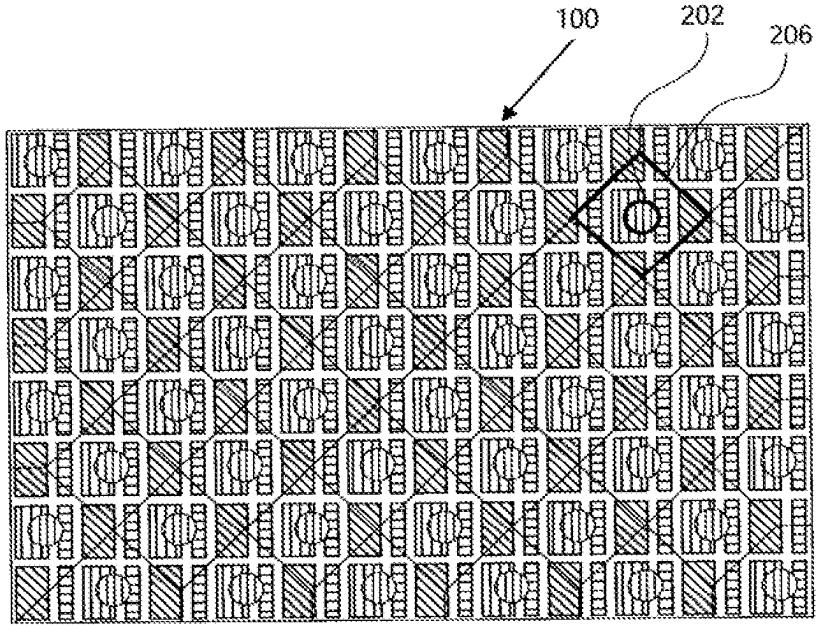

FIG. 5

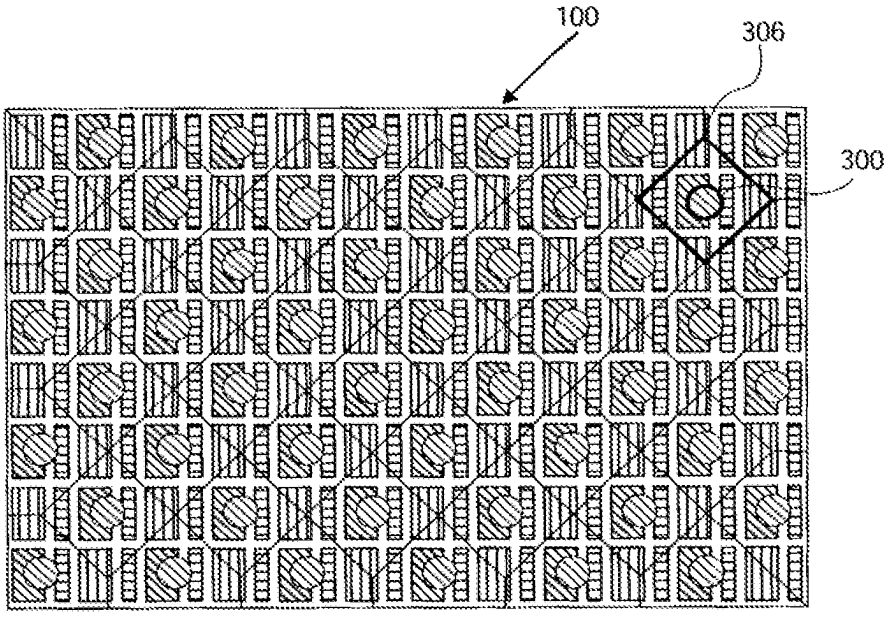

FIG. 6

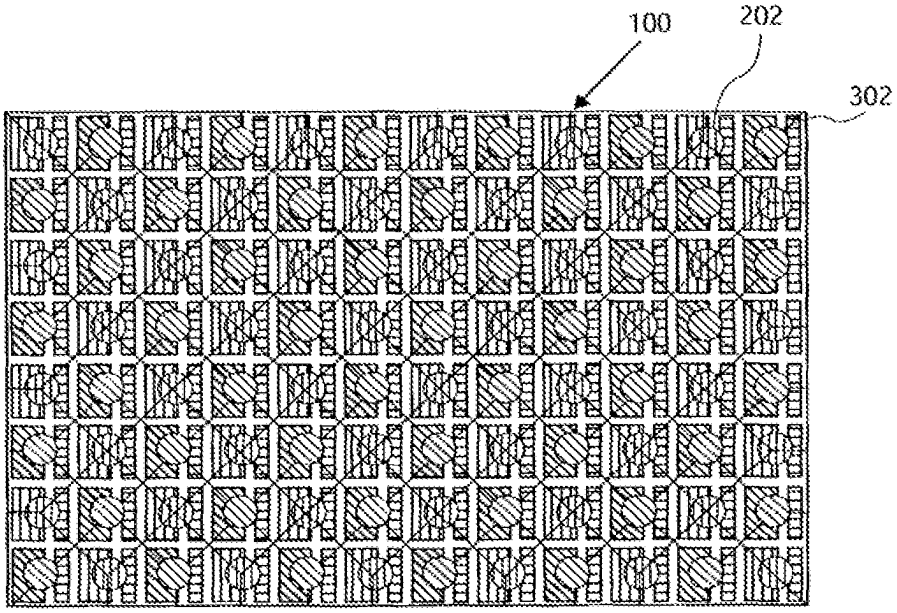

FIG. 7

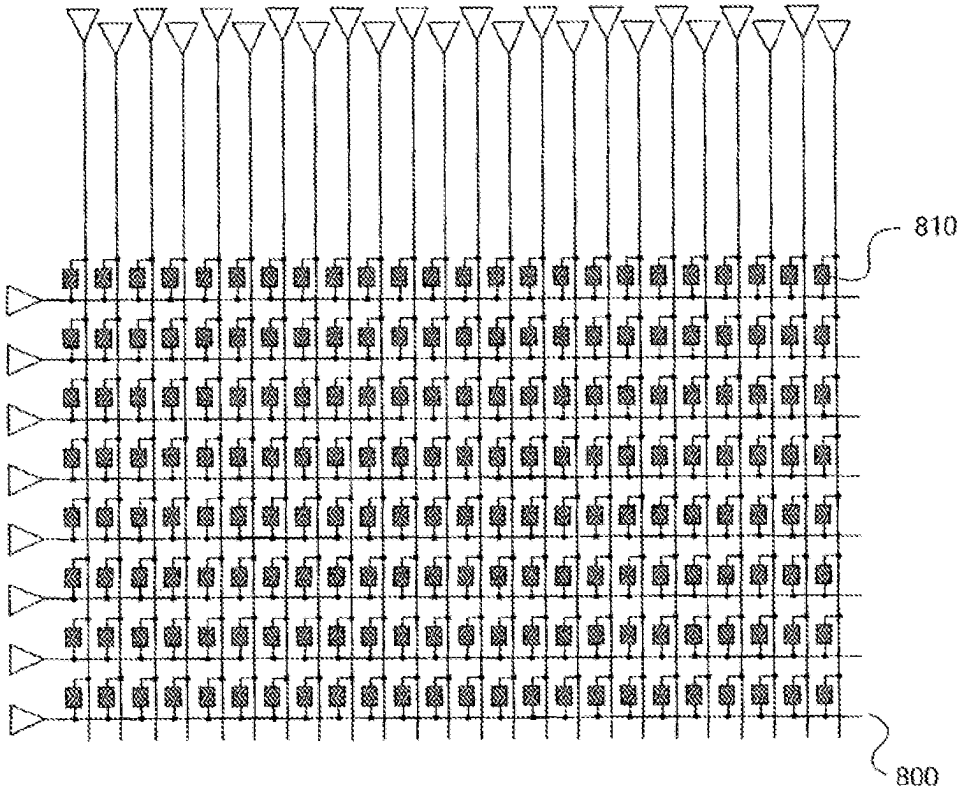

FIG. 8A

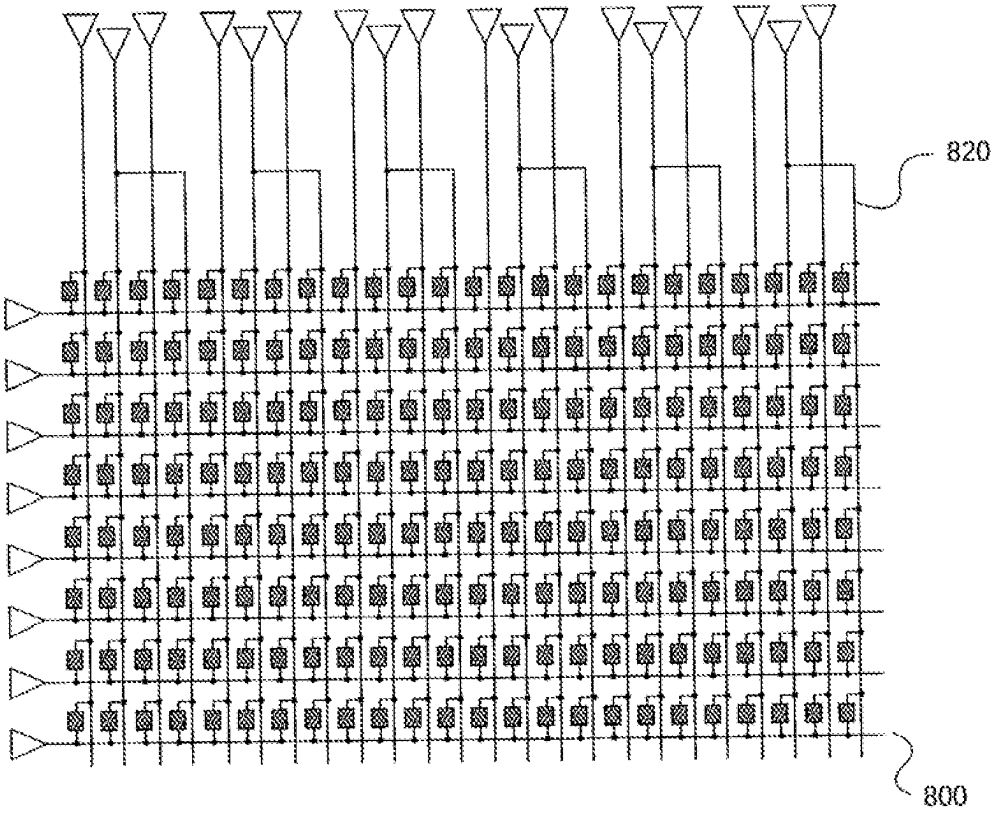

FIG. 8B

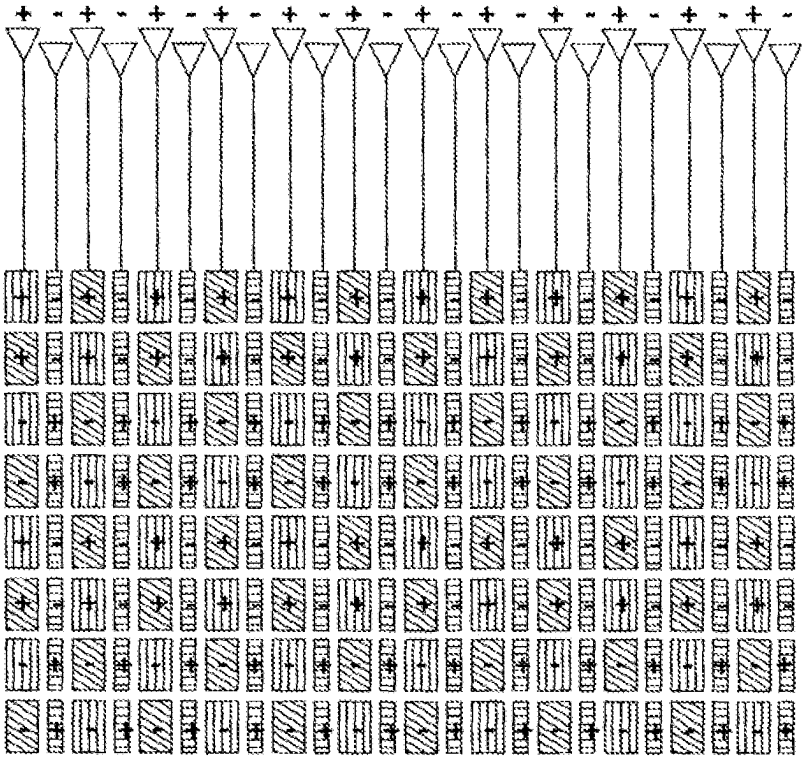

FIG. 9

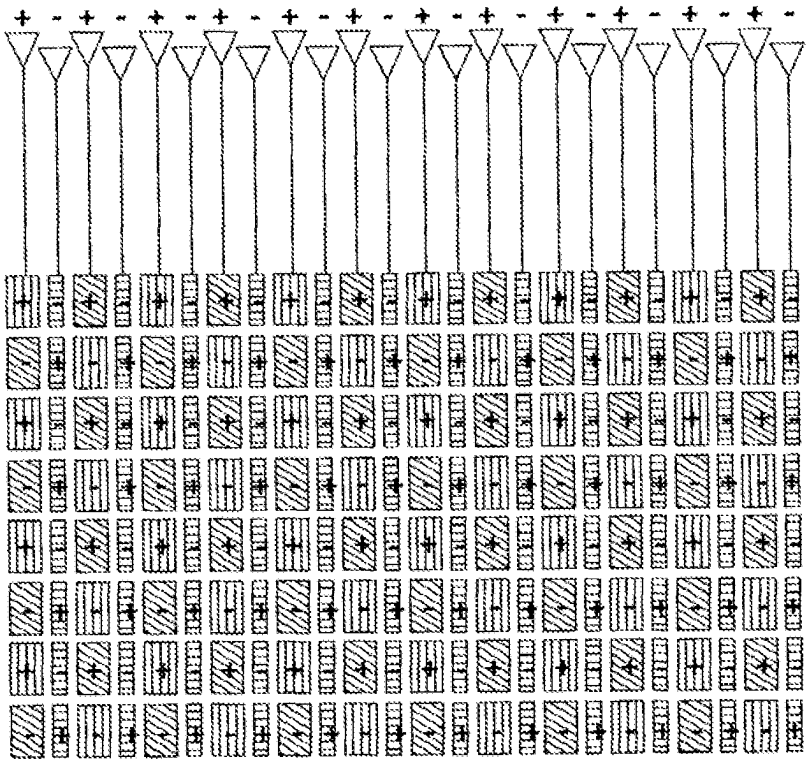

FIG. 10

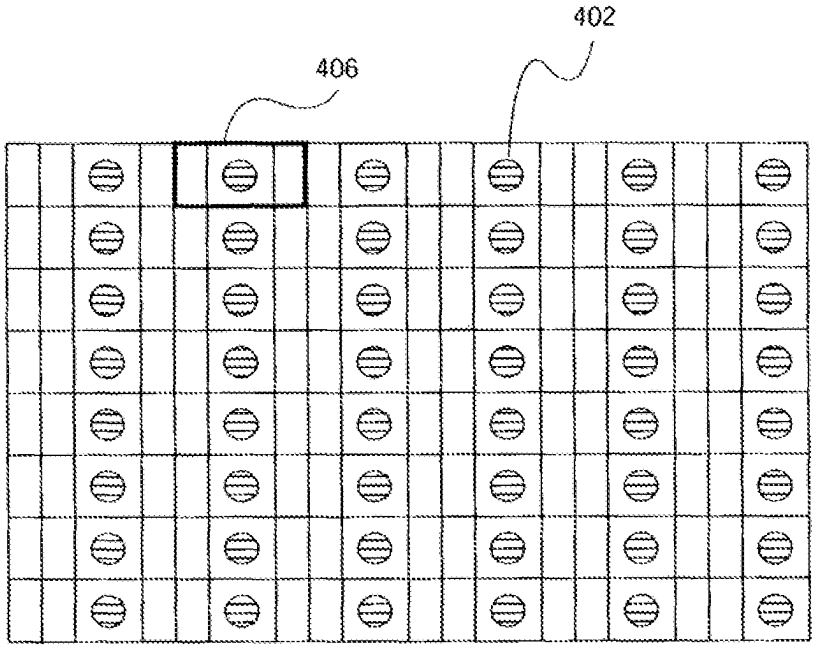

FIG. 11

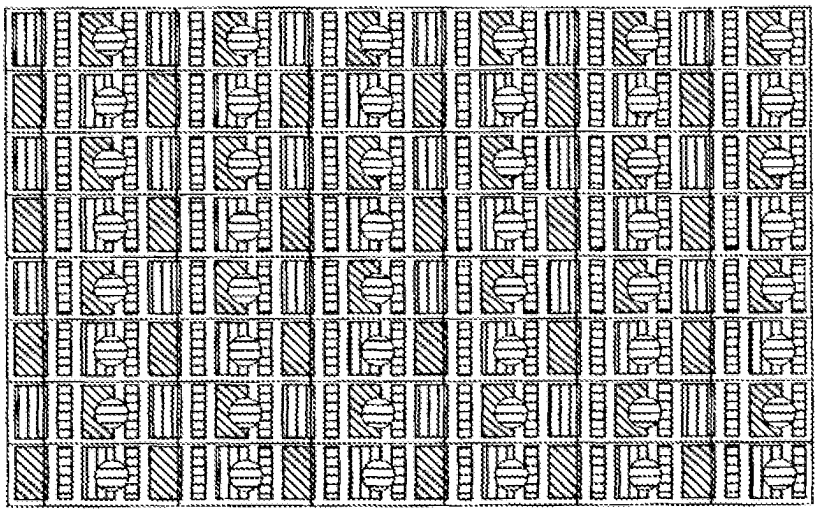

FIG. 12

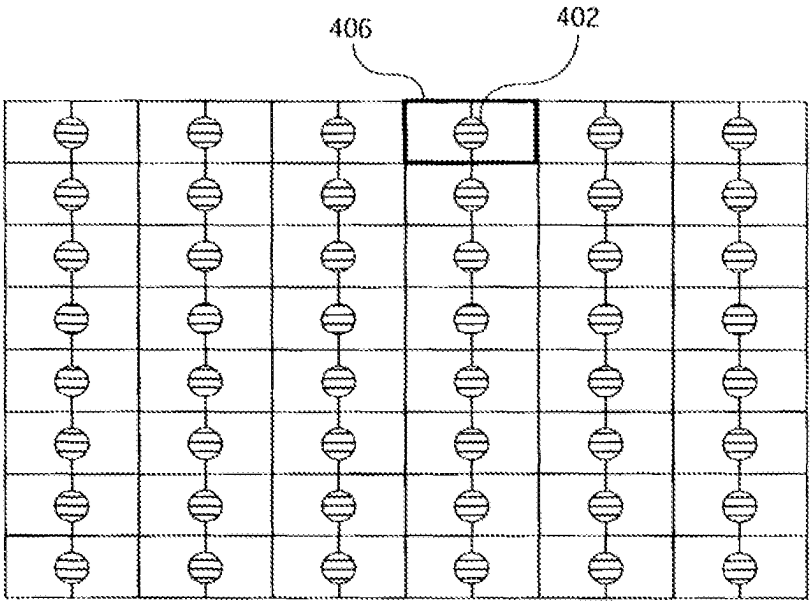

FIG. 13

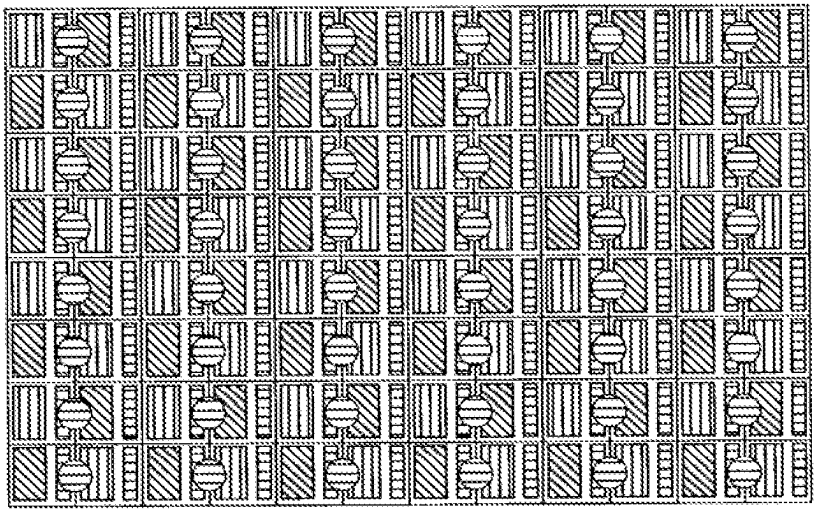

FIG. 14

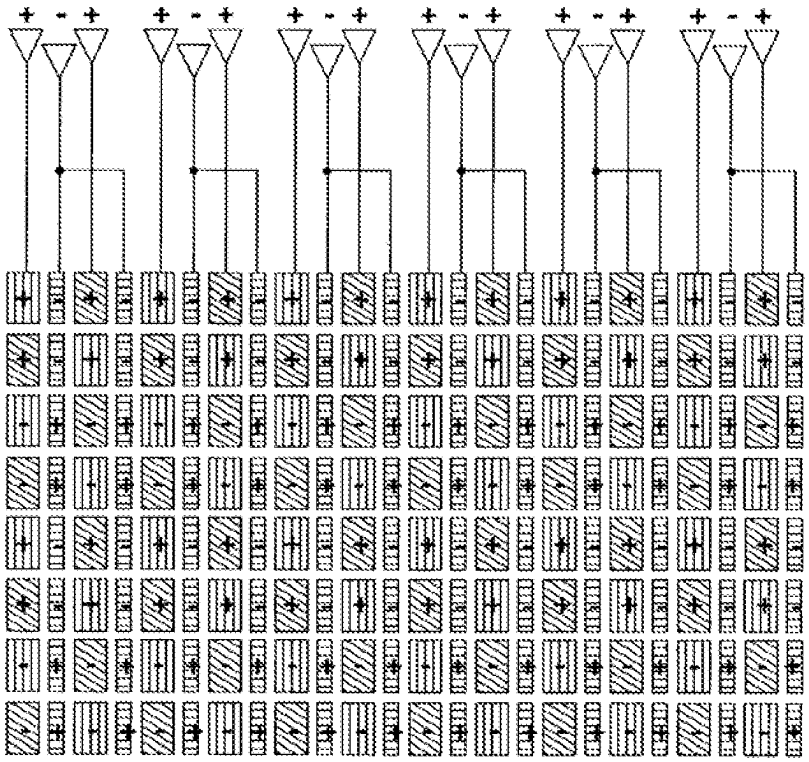

FIG. 15

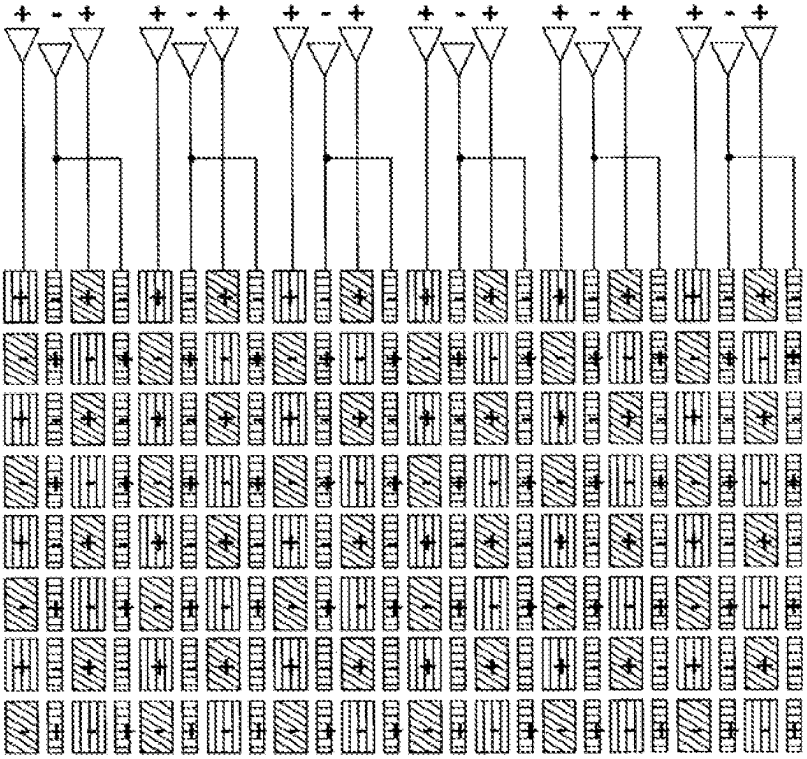

FIG. 16

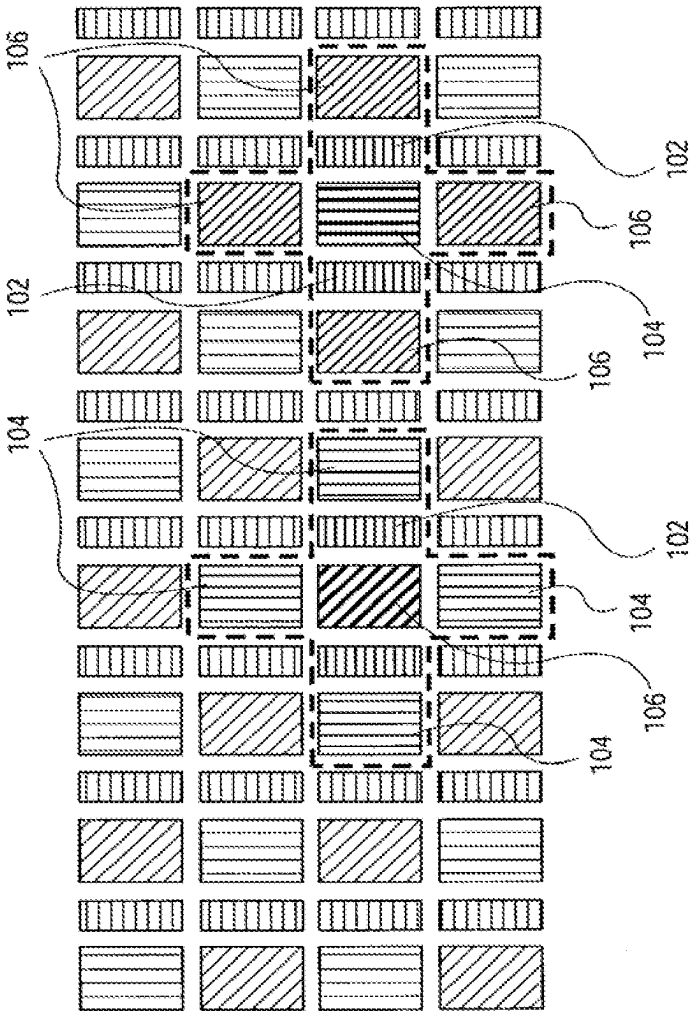

FIG. 17

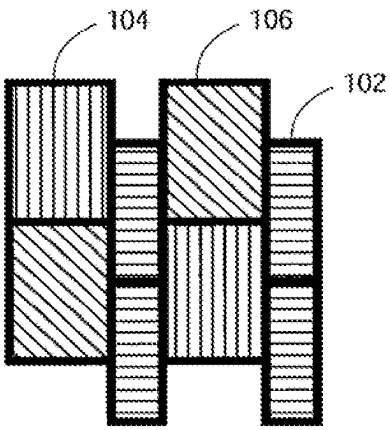

FIG. 18A

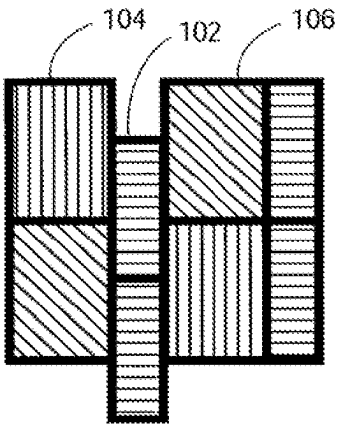

FIG. 18B

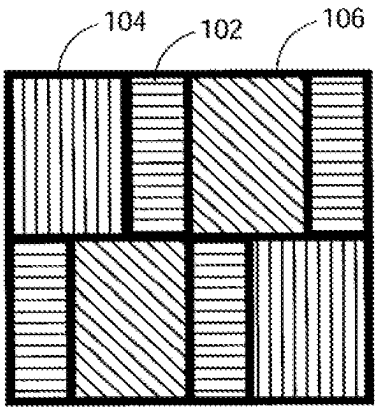

FIG. 19A

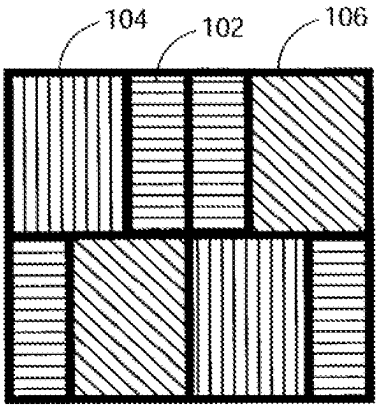

FIG. 19B

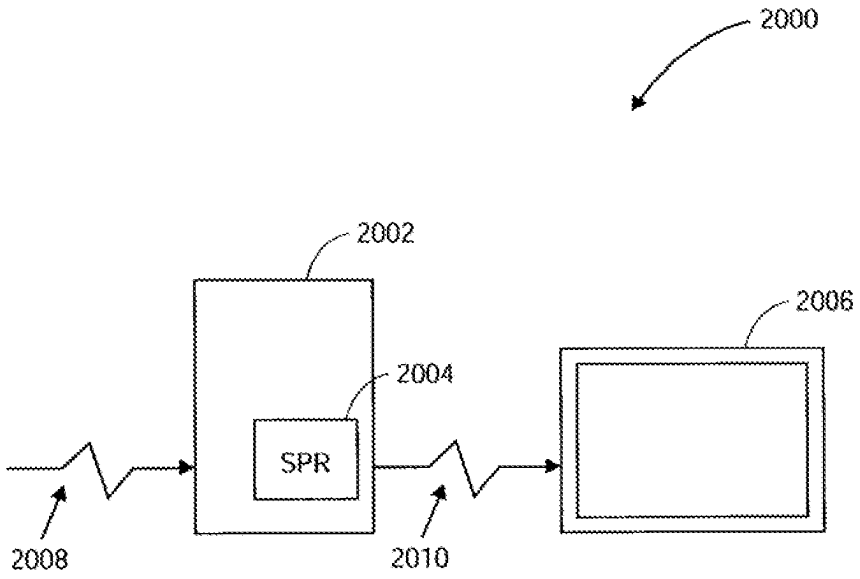

FIG. 20

COLOR FLAT PANEL DISPLAY SUB-PIXEL ARRANGEMENTS AND LAYOUTS FOR SUB-PIXEL RENDERING WITH SPLIT BLUE SUB-PIXELS

RELATED APPLICATIONS

This application is a continuation of and claims priority to U.S. patent application Ser. No. 12/189,462, entitled "IMPROVEMENTS TO COLOR FLAT PANEL DISPLAY SUB-PIXEL ARRANGEMENTS AND LAYOUTS FOR SUB-PIXEL RENDERING WITH SPLIT BLUE SUB-PIXELS," filed on Aug. 11, 2008, (now U.S. Pat. No. 8,134,583, having an issue date of Mar. 13, 2012), which application is hereby incorporated by reference herein for all that it contains and teaches.

This application also claims priority to U.S. patent application Ser. No. 10/278,352, entitled "COLOR FLAT PANEL DISPLAY SUB-PIXEL ARRANGEMENTS AND LAYOUTS FOR SUB-PIXEL RENDERING WITH SPLIT BLUE SUB-PIXELS," filed on Oct. 22, 2002, issued as U.S. Pat. No. 7,417,648 on Aug. 26, 2008 and published as U.S. Patent Application Publication No. 2003/0128179 which claims priority to U.S. Provisional Patent Application No. 60/346,738 entitled "ARRANGEMENT OF SUBPIXELS WITH DOUBLE BLUE STRIPES," filed on Jan. 7, 2002, which applications are hereby incorporated by reference herein for all that they contain and teach.

BACKGROUND

The present application relates to improvements to display layouts, and, more particularly, to improved color pixel arrangements, means of addressing used in displays, and to data format conversion methods for these displays.

Full color perception is produced in the eye by three-color receptor nerve cell types called cones. The three types are sensitive to different wavelengths of light: long, medium, and short ("red", "green", and "blue", respectively). The relative density of the three differs significantly from one another. There are slightly more red receptors than green receptors. There are very few blue receptors compared to red or green receptors.

The human vision system processes the information detected by the eye in several perceptual channels: luminance, chromanance, and motion. Motion is only important for flicker threshold to the imaging system designer. The luminance channel takes the input from only the red and green receptors. In other words, the luminance channel is "color blind." It processes the information in such a manner that the contrast of edges is enhanced. The chromanance channel does not have edge contrast enhancement. Since the luminance channel uses and enhances every red and green receptor, the resolution of the luminance channel is several times higher than the chromanance channels. Consequently, the blue receptor contribution to luminance perception is negligible. The luminance channel thus acts as a resolution band pass filter. Its peak response is at 35 cycles per degree)(cycles/°). It limits the response at 0 cycles/° and at 50 cycles/° in the horizontal and vertical axis. This means that the luminance channel can only tell the relative brightness between two areas within the field of view. It cannot tell the absolute brightness. Further, if any detail is finer than 50 cycles/°, it simply blends together. The limit in the horizontal axis is slightly higher than the vertical axis. The limit in the diagonal axes is significantly lower.

The chromanance channel is further subdivided into two sub-channels, to allow us to see full color. These channels are quite different from the luminance channel, acting as low pass filters. One can always tell what color an object is, no matter how big it is in our field of view. The red/green chromanance sub-channel resolution limit is at 8 cycles/°, while the yellow/blue chromanance sub-channel resolution limit is at 4 cycles/°. Thus, the error introduced by lowering the red/green resolution or the yellow/blue resolution by one octave will be barely noticeable by the most perceptive viewer, if at all, as experiments at Xerox and NASA, Ames Research Center (see, e.g., R. Martin, J. Gille, J. Larimer, Detectability of Reduced Blue Pixel Count in Projection Displays, SID Digest 1993) have demonstrated.

The luminance channel determines image details by analyzing the spatial frequency Fourier transform components. From signal theory, any given signal can be represented as the summation of a series of sine waves of varying amplitude and frequency. The process of teasing out, mathematically, these sine-wave-components of a given signal is called a Fourier Transform. The human vision system responds to these sine-wave-components in the two-dimensional image signal.

Color perception is influenced by a process called "assimilation" or the Von Bezold color blending effect. This is what allows separate color pixels (also known as sub-pixels or emitters) of a display to be perceived as a mixed color. This blending effect happens over a given angular distance in the field of view. Because of the relatively scarce blue receptors, this blending happens over a greater angle for blue than for red or green. This distance is approximately 0.25° for blue, while for red or green it is approximately 0.12°. At a viewing distance of twelve inches, 0.25° subtends 50 mils (1,270μ) on a display. Thus, if the blue pixel pitch is less than half (625μ) of this blending pitch, the colors will blend without loss of picture quality. This blending effect is directly related to the chromanance sub-channel resolution limits described above. Below the resolution limit, one sees separate colors, above the resolution limit, one sees the combined color.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in, and constitute a part of this specification illustrate various implementations and embodiments.

FIG. **1** shows an arrangement of sub-pixel emitters comprising threes colors—red, green, and blue—in groupings that create a larger rectilinearly repeating cell group of eight sub-pixels wherein the blue sub-pixels are "split".

FIGS. **2**, **3** and **4** illustrate one embodiment of red, green, and blue resample area arrays for the red, green and blue color planes respectively to match the sub-pixel arrangement of FIG. **1**.

FIGS. **5** and **6** illustrate the red and green resample area arrays of FIGS. **2** and **3** overlaid on the sub-pixel arrangement of FIG. **1** respectively.

FIG. **7** illustrates one particular inter-color-plane-phase relationship between the red and green color resample areas overlaid on the sub-pixel arrangement of FIG. **1**.

FIGS. **8**A and **8**B illustrate two possible schematics for a driver arrangement for the arrangement of color emitter sub-pixels in FIG. **1**.

FIGS. **9** and **10** show two "dot inversion" schemes—commonly known as "2×1" and "1×1", respectively—matching FIG. **8**A's schematic.

FIGS. **11** and **13** depict alternative blue color plane resample area arrays to replace the one shown in FIG. **4**.

FIGS. **12** and **14** show how the respective blue color plane resample areas of FIGS. **11** and **13** would map onto the sub-pixel layout as shown in FIG. **1**.

FIGS. **15** and **16** show two "dot inversion" schemes—commonly known as "2×1" and "1×1", respectively—matching FIG. **8**B's schematic.

FIG. **17** illustrates the results of turning on two full color incoming data pixels.

FIGS. **18**A and **18**B show other embodiments of the octal subpixel arrangement with various vertical displacements of the subpixel.

FIGS. **19**A and **19**B show yet other embodiments of the octal subpixel arrangement of various displacements of the split majority subpixel within the subpixel grouping.

FIG. **20** depicts a system incorporating sub-pixel rendering techniques suitable to drive a panel made in accordance with the various embodiments described herein.

DETAILED DESCRIPTION

Reference will now be made in detail to various implementations and embodiments, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts.

In FIG. **1**, in the arrangement of sub-pixel emitters **100**, there are three-color emitters in groupings **120** that create a larger rectilinearly repeating cell group of eight sub-pixels. This layout was introduced in the '738 provisional application and included herein by reference. Grouping **120** comprises red sub-pixels **104**, green sub-pixels **106** and blue sub-pixels **102**. As may be seen, blue sub-pixels **102** are "split"—i.e. having a smaller width along the horizontal axis than either red or green sub-pixels but doubled in number per grouping or repeat cell. Such a "split" sub-pixel can refer to a sub-pixel having a smaller area than a non-split sub-pixel. Splitting the blue sub-pixels helps in breaking up the noticeable effect of visible vertical blue stripes down the display, as further discussed in United States Patent Publication No. 2003/0117423 ("the '423 application") also identified as: U.S. patent application Ser. No. 10/278,328 originally entitled "IMPROVEMENTS TO COLOR FLAT PANEL DISPLAY SUBPIXEL ARRANGEMENTS AND LAYOUTS WITH REDUCED BLUE LUMINANCE WELL VISIBILITY," filed on Oct. 22, 2002, and incorporated by reference.

As may additionally be seen in FIG. **1**, the red and the green sub-pixels are placed upon a "checkerboard" pattern with the repeat cell itself. As discussed further in the '225 application, it may be desirable to alter the repeat cell grouping **120** color assignments to have a split green sub-pixel in position of sub-pixels **102** and have the remaining red and blue subpixels form the checkerboard pattern. Likewise, it might be desirable to have the red sub-pixels split and the green and blue sub-pixels on a checkerboard pattern. The alternating "checkerboard" of emitters is similar to the red and green "checkerboard" that was disclosed in co-pending and commonly assigned United States Patent Publication No. 2002/0015110 ("the '110 application"), also identified as: U.S. patent application Ser. No. 09/916,232, originally entitled "ARRANGEMENT OF COLOR PIXELS FOR FULL COLOR IMAGING DEVICES WITH SIMPLIFIED ADDRESSING," filed on Jul. 25, 2001, which is hereby incorporated herein by reference.

It should be appreciate that while FIG. **1** depicts the "split" blue subpixel as narrower than either the red or the green subpixels, another embodiment of the present invention employs blue subpixels of equal area dimensions to the red and green subpixels. To achieve a pleasing white point with all subpixels on in a logical pixel, the relative intensities of the red, green and blue emitters can be changed appropriately as discussed in co-pending and commonly assigned United States Patent Publication No. 2004/0051724 ("the '724 application"), also identified as: U.S. patent application Ser. No. 10/243,094, originally entitled "IMPROVED FOUR COLOR ARRANGEMENTS OF EMITTERS FOR SUBPIXEL RENDERING," filed Sep. 13, 2002, which is hereby incorporated herein by reference.

As shown in FIG. **1**, the subpixels appear to have a substantially rectangular appearance. It should be appreciated that other shapes to the subpixels are also possible and are contemplated within the scope of the present invention. For example, a multitude of other regular or irregular shapes for the subpixels are possible and are desirable if manufacturable. It suffices only that there is an octal grouping of colored subpixels in the fashion herein described that may be addressable for the purposes of subpixel rendering (SPR).

As subpixel shapes may vary under the scope of the present invention, so too may the exact positions of the subpixels be varied under the scope of the present invention. For example, FIGS. **18**A and **18**B depict a similar octal subpixel grouping wherein one or both of the majority stripes **102** are offset (relatively or otherwise) from the other subpixels **104** and **106**. Other vertical offsets are also possible.

Other embodiments of the octal groupings are also possible. FIGS. **19**A and **19**B depict octal groupings wherein the majority subpixels **102** are interspersed within the checkerboard of subpixels **104** and **106**. Other arrangements of majority subpixel placement within such a checkerboard are also possible and are contemplated within the scope of the present invention.

FIGS. **19**A and **19**B may have column electrodes that zigzag across the display. Column driver savings should be one third when compared to the RGB stripe system with the same resolution and the number of subpixels are about two thirds of the number of subpixels when compared to the RGB stripe system.

Yet other embodiments of the present invention are possible. For example, the entire octal subpixel groupings may be rotated 90 degrees to reverse the roles of row and column driver connections to the grouping. Such a horizontal arrangement for subpixels is further disclosed in the co-pending and commonly assigned application United States Patent Publication No. 2003/0090581 ("the '581 application"), also identified as U.S. patent application Ser. No. 10/278,393, filed Oct. 22, 2002, originally entitled "COLOR DISPLAY HAVING HORIZONTAL SUB-PIXEL ARRANGEMENTS AND LAYOUTS," incorporated by reference.

The alternating "checkerboard" of emitters is similar to the red and green "checkerboard" that was disclosed in co-pending United States Patent Publication No. 2002/0015110, also identified as U.S. patent application Ser. No. 09/916,232 ("the '232 application"), originally entitled "ARRANGEMENT OF COLOR PIXELS FOR FULL COLOR IMAGING DEVICES WITH SIMPLIFIED ADDRESSING," filed on Jul. 25, 2001 and hereby incorporated herein by reference.

With the display comprised substantially of repeat cell **120** having the blue sub-pixel split as sub-pixel **102**, it is possible to perform sub-pixel rendering upon this display using the area resampling techniques as described in United States Patent Publication No. 2003/0103058, also identified as U.S. patent application Ser. No. 10/150,355 ("the '355 application"), originally entitled "METHODS AND SYSTEMS FOR SUB-PIXEL RENDERING WITH GAMMA

ADJUSTMENT," filed on May 17, 2002, which is hereby incorporated herein by reference and is commonly owned by the same assignee of this application. One such embodiment of area resampling is shown in FIGS. **2** through **7**.

FIGS. **2**, **3** and **4** illustrate red **200**, green **300**, and blue **400** resample area arrays for the red, green and blue color planes, respectively. It should be noted that each color resample area array **200**, **300**, and **400** comprises of resample areas **206**, **306** and **404** and that each resample area has an associated resample point **202**, **302** and **402**, respectively. The resample points **202**, **302**, and **402** match the relative positions of the red **104**, green **106** and blue **102** sub-pixel locations, respectively, within each color plane; but not necessarily their exact inter-color-plane-phase relationships. Any number of phase relationships are possible, a number of which have useful properties in given data format conversion cases.

FIGS. **5** and **6** illustrate the red and green resample area arrays of FIGS. **2** and **3** overlaid on the sub-pixel arrangement **100** of FIG. **1**, respectively. FIG. **7** illustrates one particular inter-color-plane-phase relationship between the red and green color resample areas overlaid on the sub-pixel arrangement **100**. This particular intercolor-plane-phase relationship depicts converting the conventional fully converged square grid red-green-blue RGB format which is to be displayed "one-to-one" with the square blue **102** sub-pixel grid. In this inter-color-plane-phase relationship, the green **300**, blue **400**, and red **200** resample area arrays are positioned such that the red **202** and green **302** resample points overlap the blue **402** sample points. This treats the blue sub-pixels **102** as though they lay on top of, or intimately associated with, the red **104** and green **106** sub-pixel checkerboard.

FIGS. **11** and **13** depict alternative blue color plane resample area arrays to replace the one shown in FIG. **4**. FIGS. **12** and **14** show how these respective blue color plane resample area would map onto the sub-pixel layout as shown in FIG. **1**. FIGS. **11** and **13** depict two different embodiments of resample areas **406** for blue with the phase shift shown. It should be appreciated that other phase shifts suffice for the purposes of the present invention. Additionally, other resample areas for the blue pixel data could be employed without departing from the scope of the present invention.

These Figures are merely illustrative and only serve to provide an understanding of the relationship between the resample points, reconstruction points, resample areas, and sub-pixel locations for this embodiment.

The sub-pixel rendering techniques as described in the '355 patent application can be used to convert the incoming data format to that suitable for the display. In such a case, the method proceeds as follows: (1) determining implied sample areas for each data point of incoming three-color pixel data; (2) determining the resample area for each color sub-pixel in the display; (3) forming a set of coefficients for each said resample area, the coefficients comprising fractions whose denominators are a function of the resample area and the numerators are a function of an area of each said implied sample areas that may partially overlap the resample areas; (4) multiplying the incoming pixel data for each implied sample area by the coefficient resulting in a product; (5) adding each product to obtain luminance values for each resample area.

Other sub-pixel rendering techniques are possible to employ with the various sub-pixel arrangements as disclosed herein. For example, the techniques known as "adaptive filtering" may be employed in the same fashion as described in United States Patent Publication No. 2003/0085906 ("the '906 application"), also identified as U.S. patent application Ser. No. 10/215,843, originally entitled "METHODS AND SYSTEMS FOR SUB-PIXEL RENDERING WITH ADAPTIVE FILTERING," filed on Aug. 8, 2002, which is hereby incorporated herein by reference and is commonly owned by the same assignee of this application. Adaptive filtering can be adopted so as not to require a 3×3 sample of input data, which uses a minimum of two lines of memory. The test may be based on a smaller sample of input data, for example 1×3 or 1×2 matrices. The input data is sampled to test for vertical or diagonal lines, dots and edges, or other high contrast features and then actions are taken, depending on the outcome of the tests.

Test masks may be used and compared to the image data to see if an edge is detected; if detected then take an appropriate action to the red and/or blue data—e.g. apply gamma or apply a new value or different filter coefficient. Otherwise, if no feature is detected, then no action may be taken.

FIG. **17** illustrates the results of turning on two full color incoming data pixels. The two pixels are converted to two clusters of sub-pixels, called "logical pixels", turned on at varying amplitudes. The logical pixel on the left is centered on or near a green sub-pixel **106**. The logical pixel on the right is centered on or near a red sub-pixel **104**. In both logical pixels, the various sub-pixels are turned on to the appropriate illumination such that a pleasing white color is formed and centered on the green and red sub-pixels, respectively.

FIGS. **8**A and **8**B illustrate two possible schematics for a driver arrangement **800** for the arrangement of color emitter sub-pixels in FIG. **1**. FIG. **8**A shows a one to one correspondence of column drivers to columns in the display; however, with the split blue sub-pixels, it may be desirable to tie adjacent columns of split blue sub-pixels via connections **820**. As may be seen in FIG. **8**B, this scheme has the advantage of saving on the number of column drivers.

For convenience, these examples given have the same number of sub-pixels illustrated as FIG. **1**. These drive arrangements may be used for a number of display technologies, as the blocks **810** may represent one or several electrical components. They may represent the capacitive display cell element for passively addressed Liquid Crystal Display (LCD), or ElectroLuminescent (EL) Display. It may represent the gaseous discharge element in a Plasma Display Panel (PDP). It may represent the semiconductor diode element of a passively Inorganic Light Emitting Diode or an Organic Light Emitting Diode Display. It may represent the transistor, storage capacitor, and capacitive cell element of an Active Matrix Liquid Crystal Display (AMLCD). It may represent the multi-transistor, storage capacitor, and light emitting element of an Active Matrix Organic Light Emitting Diode Display (AMOLED). It may represent, in general, the color sub-pixel and its associated electronic elements found in other known or yet to be invented display technologies.

Known drive timing and methods may be used for N×M drive matrices as those shown. However, there may be modifications needed due to the specific color assignments, particularly any checkerboard across the panel or color alternations within a single column. For example, the technique known in the art as Multi-Line Addressing for passive LCD may be modified such that groupings of rows are restricted to odd and even row combinations. This will reduce potential color cross talk since, within a column with two alternating color sub-pixels, only one color will be addressed at a time.

Inversion schemes, switching the electrical field polarity across the display cell to provide a time averaged zero net field and ion current across the cell can be used to the above unique sub-pixel arrangements. FIGS. **9** and **10** (matching FIG. **8**A's schematic) and FIGS. **15** and **16** (matching FIG. **8**B's schematic) show two "dot inversion" schemes—re-

ferred to as "2×1" and "1×1", respectively—on Active Matrix Liquid Crystal Displays, both of which will perform satisfactorily. The scheme shown on FIGS. **9** and **15** may perform better when slight imbalances of light transmission occur between positive and negative polarities, especially when the eye is tracking the motion of displayed images moving across the screen. Each of the Figures shows the polarities during half of the display addressing fields. The polarities are reversed for the other half, alternating every field, resulting in a net zero current (zero DC bias), as is well known in the art.

FIG. **20** depicts a system **2000** in which a display as constructed in accordance with the various embodiments disclosed herein is driven by a sub-pixel rendering technique **2004** which may be resident on a physical device **2002**. An input image data stream **2008** may be input into the sub-pixel rendering technique **2004** and converted in the manner herein disclosed. An output image data stream **2010** is sent to the display device **2006** in order to drive the various sub-pixels to form an image thereupon. As discussed in several references incorporated herein, the sub-pixel rendering (SPR) technique **2004** may be implemented in either hardware and/or software or a combination thereof. For example, SPR techniques **2004** could be resident as logic (either hardware or software) on the display itself or it could reside on a graphics controller chip or board.

While the invention has been described with reference to exemplary embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings without departing from the essential scope thereof. For example, some of the embodiments above may be implemented in other display technologies such as Organic Light Emitting Diode (OLED), ElectroLumenscent (EL), Electrophoretic, Active Matrix Liquid Crystal Display (AMLCD), Passive Matrix Liquid Crystal display (AMLCD), Incandescent, solid state Light Emitting Diode (LED), Plasma Display Panel (PDP), and Iridescent. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

What is claimed is:

1. A display having a display area tessellated by repetition of a sub-pixel repeat group; the sub-pixel repeat group consisting of first through eighth selectively-actuatable light emitting subpixels (sp**1**-sp**8**);

wherein the first through third subpixels (sp**1**-sp**3**) of the sub-pixel repeat group are respectively configured to emit respective and different first, second and third colored lights (c**1**, c**2**, c**3**);

wherein the fourth, sixth and eighth subpixels (sp**4**, sp**6**, sp**8**) of the sub-pixel repeat group are respectively configured to emit the second colored light (c**2**);

wherein the fifth subpixel (sp**5**) of the sub-pixel repeat group is configured to emit the third colored light (c**3**);

wherein the seventh subpixel (sp**7**) of the sub-pixel repeat group is configured to emit the first colored light (c**1**);

wherein the first, third, fifth and seventh subpixels (sp**1**, sp**3**, sp**5**, sp**7**) are positioned within the layout pattern of the sub-pixel repeat group such that their corresponding first and third colored lights (c**1**, c**3**) substantially form a multi-rowed checkerboard pattern;

wherein at least the first, third, fifth and seventh subpixels (sp**1**, sp**3**, sp**5**, sp**7**) are individually selectively-actuatable;

wherein the second and sixth subpixels (sp**2**, sp**6**) are arranged in different rows and in a same column; and

wherein the second, fourth, sixth and eighth subpixels (sp**2**, sp**4**, sp**6**, sp**8**) each has a size smaller than that of the first subpixel (sp**1**).

2. The display of claim **1**, wherein the first colored light has a red color, the second colored light has a green color, and the third colored light has a blue color.

3. The display of claim **1**, wherein the first colored light has a red color, the second colored light has a blue color, and the third colored light has a green color.

4. The display of claim **1**, wherein the first colored light has a green color, the second colored light has a blue color, and the third colored light has a red color.

5. The display of claim **1** wherein the size of each of the second, fourth, sixth and eighth subpixels (sp**2**, sp**4**, sp**6**, sp**8**) is half the size of the first subpixel.

6. The display of claim **1**, wherein the second subpixel (sp**2**) is interposed between the first and the third subpixels.

7. The display of claim **1**, wherein the second and sixth subpixels (sp**2**, sp**6**) are disposed in a same column within the layout pattern of the sub-pixel repeat group.

8. The display of claim **7**, wherein the second and sixth subpixels (sp**2**, sp**6**) which are disposed in the same column are respectively not fully in same respective rows as those in which the first and fifth subpixels (sp**1**, sp**5**) reside within the layout pattern of the sub-pixel repeat group but are instead shifted in a vertical direction with respect to the rows of the first and fifth subpixels.

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