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(54) Device and method for scattered conversion of display signals

(57) An apparatus and a method for data signal scattering conversion. The apparatus includes a scattering multiplexer, a digital-to-analog converter, and a scattering demultiplexer. The scattering multiplexer is for receiving p digital data signals and outputting the q-th digital data signal of the p digital data signals. The digital-to-analog converter is to perform digital-to-analog conversion of the q-th digital data signal and output an analog data signal. The scattering demultiplexer has p output terminals, and is used for outputting the analog data signal through the q-th output terminal. Offset voltages output from the digital-to-analog converter are scattered over a number of data lines so that undesired points with abnormally deep or light colors due to the output offset voltages, are difficult to perceive.

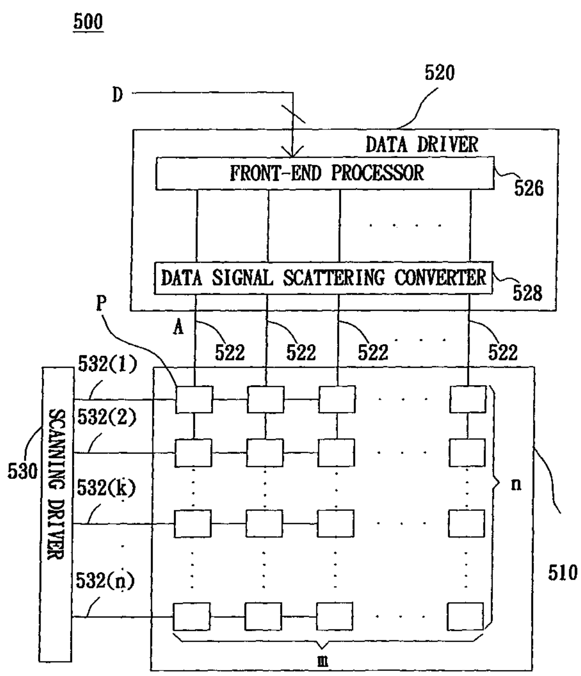

FIG. 5

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Description

[0001] This application incorporates by reference Taiwanese application Serial No. 90109219, filed on Apr. 17, 2001.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] The invention relates in general to an apparatus and method for data signal conversion, and more particularly to an apparatus and method for data signal scattering conversion.

Description of the Related Art

[0003] A display apparatus is used as means of communication between humans and machines. Two kinds of display apparatus, the cathode ray tube (CRT) display and the liquid crystal display (LCD), are available in the market. For CRT displays, since their technology and manufacture are well developed, their cost is relatively low even for providing high quality color images, so that they are widely used. However, CRT displays are large in size and emit high levels of radiation. On the other hand, LCDs can be made more compact, with low emissions of radiation. Therefore, LCDs, such as thin-film transistor liquid crystal displays (TFT-LCDs), are being substituted for CRT displays.

[0004] Referring to the block diagram of FIG. 1, a TFT-LCD 100 is illustrated to include a display panel 110, a data driver 120, and a scanning driver 130. Display panel 110 includes a plurality of pixel units P configured to form an m by n array, wherein each pixel unit P includes a thin film transistor and a liquid crystal device (not shown). For the pixel units in each column, source terminals of the thin film transistors are electronically coupled, forming m data lines 122 stretched out within the display panel 110. Likewise, for the pixel units in a row, gate terminals of the thin film transistors are electronically coupled, forming n scan lines 132 stretched out within display panel 110. Data driver 120 includes a front-end processor 126 and a data signal converter 128, and is used to receive digital image data D and output analog data signals A. Front-end processor 126 is employed to receive the digital image data D and output digital data signals D'. Data signal converter 128 is coupled to front-end processor 126 and display panel 110, and is used to receive the digital data signals D', perform digital-to-analog (D/A) conversion of the digital data signals D' so as to produce analog data signals A, and then output them to display panel 110. Scanning driver 130 is coupled to scan lines 132 and is to receive a horizontal synchronization (HSYNC) signal and a vertical synchronization (VSYNC) signal.

[0005] According to the VSYNC signal, scanning driver 130 sequentially selects each of the scan lines 132 (scan line 132(k), k = 1 to n), so as to turn on all the thin film transistors of the selected scan line. When all the thin film transistors of the scan line 132(k) are turned on, the analog data signals A from data driver 120 are applied to the liquid crystal devices of the scan line 132 (k) through source and drain terminals of the thin film transistors of scan line 132(k) for control of the gray levels of the liquid crystal devices. In this manner, data driver 120 controls the gray levels of the liquid crystal devices according to the analog data signals A. When scanning driver 130 receives the VSYNC signal, scanning driver 130 re-starts to turn the scan lines 132 sequentially on at a time from the first (k=1) to the last (k=n). Generally, the time period between two successive HSYNC signals is denoted as a horizontal scanning time, while the time period between two successive VSYNC signals is denoted as a vertical scanning time. For displaying a frame, it takes one horizontal scanning time to complete one horizontal line of the frame, and takes one vertical scanning time to complete the entire frame.

[0006] In practice, the liquid crystal device is easily damaged when voltages of the same polarity are continuously applied to the liquid crystal devices. Accordingly, data driver 120 may apply polarity inversions to avoid such damage on liquid crystal device. Polarity inversion such as dot inversion or column inversion is to alternately output positive and negative voltages to the liquid crystal devices.

[0007] FIG. 2 illustrates details of the data signal converter 128 shown in FIG. 1. Data signal converter 128 includes a digital-to-analog (D/A) converter. The D/A converter is to receive the digital data signal D', perform polarity inversion of the digital data signals D', and output the analog data signals A. The D/A converter includes m demultiplexers 202, m multiplexers 204, m+1 digital-to-analog conversion devices 206, and m+1 output buffers 210. For instance, demultiplexer 202(i) is used to receive digital data signal D'(i) and to output digital data signal D'(i) to D/A conversion device 206(i) or 206(i+1) according to the polarity inversion method. If *i* is an odd number, D/A conversion device 206(*i*) is to output converted data signal S(*i*) with positive polarity. If *i* is an even number, D/A conversion device 206(*i*) is to output converted data signal S(*i*) with negative polarity. Output buffer 210(i) is used to receive converted data signal S(i), output buffered data signal S'(i), and feed buffered data signal S'(i) into multiplexers 204(i-1) and 204(i). Multiplexer 204(i) is employed to receive buffered data signals S'(i) and S'(i+1) from output buffers 210(i) and 210(i+1) respectively, and to selectively output digital data signal A(i) according to demultiplexer 202(i), where A(i) is either S'(i) or S'(i+1). For example, demultiplexer 202(i) outputs digital data signal D'(i) to D/A conversion device 206(i+1) so that multiplexer 204 (i) outputs S'(i+1) as analog data signal A(i). In this way, by using demultiplexers 202 and multiplexers 204, the polarities of individual analog data signals A can be changed according to the polarity inversion method, and analog data signals A after polarity inversion are associated with appropriate data lines 122. If demultiplexer 202(i) and multiplexer 204(i) are to change the polarity of analog data signal A(i) according to the HSYNC signal, the dot inversion is therefore achieved. If demultiplexer 202(i) and multiplexer 204(i) are to change the polarity of analog data signal A(i) according to the VSYNC signal, the effect of column inversion is achieved.

[0008] However, the analog data signals from the data driver may have different offset voltages, which correspond to gray lines displayed on the LCD and affects the uniformity of the brightness of each pixel displayed. Generally, the data driver produces the offset voltages due to variations of output voltage levels of the operational amplifiers in output buffers 210. The offset of output voltage level of an operational amplifier is commonly in the range of 50mV to 60mV, while offset voltage tolerated by the LCD is within 10mV. If the offset in the output of the operational amplifier exceeds the tolerance by too much, the associated liquid crystal device of display panel 110 may become a pixel unit with undesired deep color or light color.

[0009] FIG. 3A illustrates a frame 300 displayed by TFT-LCD 100, wherein each rectangle represents a pixel unit and the output buffer 210(j) has an output offset voltage. Output buffer 210(j) outputs analog data signal A(j) to data line 122(j) so that the pixel units controlled by data line 122(j) displays a light gray line. FIG. 3B shows a graph of gray level intensity versus data line, wherein the data lines shown in FIG. 3A are indicated along the X-axis, while the gray level intensities perceived by humans are measured along the Y-axis, and wherein data driver 120 outputs image data by the column inversion method. Since light stimulus will be integrated in the human visual system, the gray line corresponding to output buffers 210 (j) occurs as shown in FIG. 3A.

[0010] FIG. 4A illustrates another frame 400 displayed by the TFT-LCD 100, wherein each rectangle represents one pixel unit and data driver 120 outputs image data by the dot inversion. Output buffer 210(j) has an output offset voltage. Thus, when output buffer 210 (j) outputs analog data signal A(j) to data line 122(j) or outputs analog data signal A(j-1) to data line 122(j-1), the pixel units controlled by data lines 122(j) and 122(j-1) displays light gray points indicated in FIG. 4A. By the integration effect of the human visual system described above, these light gray points are actually perceived by humans as light gray lines displayed on the LCD panel, as shown in FIG. 4B. The X-axis in FIG. 4B indicates the data lines of FIG. 4A while the Y-axis indicates the gray level intensities perceived by human eyes.

[0011] For resolving the problem of degradation of the uniformity of display brightness due to the variation in output signal level, one way is to improve the output precision of the operational amplifiers to be used. However, this solution greatly increases the difficulty in the design and manufacture of LCDs.

SUMMARY OF THE INVENTION

[0012] It is therefore an object of the invention to provide an apparatus and a method for data signal scattering conversion. By the invention, the degradation of uniformity of brightness that on a display can be effectively avoided.

[0013] This object of the invention of the invention is satisfied by an apparatus for data signal scattering conversion for use in a display with signal scattering conversion. A display with signal scattering includes a display panel and a data driver. The display panel includes multiple pixel units, wherein the pixel units are arranged to form an m by n array. The pixel units on each row are electrically coupled, forming a scan line; the pixel units on each column are electrically coupled, forming a data line. The data driver, coupled to the display panel, is used for outputting m analog data signals to the pixel units according to digital image data. The data driver includes a front-end processing device and the apparatus for data signal scattering conversion. The front-end processing device is used for receiving the digital image data and outputting m digital data signals. The apparatus for data signal scattering conversion is used for receiving the digital data signals and outputting the m analog data signals to the pixel units. The apparatus for data signal scattering conversion includes a scattering multiplexer, a digital-to-analog converter, and a scattering demultiplexer. The scattering multiplexer is for receiving p digital data signals and outputting the q-th digital data signal of the p digital data signals by a scattering method, wherein p and q are positive integers and q is not greater than p. The digital-to-analog converter is coupled to the scattering multiplexer, and is used for performing digital-to-analog conversion of the q-th digital data signal and outputting an analog data signal. The scattering demultiplexer is coupled to the digital-to-analog converter, has p output terminals, and is employed to output the analog data signal through the q-th output terminal by the scattering method.

[0014] Since the output buffers of the digital-to-analog converter may have different output offset voltages due to the variations in the output voltage levels of the individual output buffers, light gray lines associated with the output buffers will be formed on the display. According to the invention, the relation between the D/A converter's output buffers and the data lines is changed. Thus, the effect of the output offset voltages of the digital-to-analog converter on individual data lines is scattered over a number of data lines, so that undesired points with abnormally deep or light colors due to this effect are almost imperceptible on the display.

[0015] According to the object of the invention, a method for image display with signal scattering is provided for use in a display, wherein the display includes a plurality of pixel units arranged to form an m by n array. The method includes the following steps. First, p digital data signals are provided. Next, according to a scattering method, the q-th digital data signal is selected from the p digital data signals. According to the q-th digital data signal, an analog data signal is then produced. Finally, according to the scattering method, the analog data signal is fed into the pixel unit of the r-th row, q-th column for image formation, wherein m, n, p, q, and r are positive integers, q is not greater than p, and r is not greater than m.

[0016] Other objects, features, and advantages of the invention will become apparent from the following detailed description of the preferred but non-limiting embodiments. The following description of the invention is made with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017]

FIG. 1 (Prior Art) is a block diagram illustrating a TFT-LCD.

FIG. 2 (Prior Art) is a block diagram illustrating the data signal converter shown in FIG. 1.

FIG. 3A (Prior Art) illustrates a frame displayed by the LCD.

FIG. 3B (Prior Art) is a graph of gray level intensity versus data line for the frame shown in FIG. 3A.

FIG. 4A (Prior Art) illustrates another frame displayed by the LCD.

FIG. 4B (Prior Art) is a graph of gray level intensity for the frame shown in FIG. 4A.

FIG. 5 illustrates a display apparatus with signal scattering conversion according to a preferred embodiment of the invention.

FIG. 6 is a block diagram illustrating the data signal scattering converter in FIG. 5.

FIG. 7A (Prior Art) illustrates a displayed frame with a gray line.

FIG. 7B illustrates a frame displayed by using a method of space scattering according to a preferred embodiment of the invention.

FIGS. 8A-8D illustrate a successive frames displayed by applying a time scattering method.

FIGS. 9A-9D are graphs of gray level intensity for the frames shown in FIGS. 8A-8D.

FIG. 10 is a graph of gray level intensity perceived by humans for the frames shown in FIGS. 8A-8D.

FIG. 11 is a block diagram illustrating another example of data signal scattering converter 528 in FIG. 5.

FIG. 12A (Prior Art) illustrates a displayed frame with a gray line.

FIG. 12B illustrates a frame displayed by application of a space scattering method according to a preferred embodiment of the invention.

FIGS. 13A-13E illustrate successive frames displayed by application of a time scattering method.

FIGS. 14A-14D are graphs of gray level intensity for the frames shown in FIGS. 13A-13D.

FIG. 15 is a graph of gray level intensity perceived by humans for the frames shown in FIGS. 13A-13D.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0018] Referring to FIG. 5, it shows a block diagram illustrating a display apparatus with signal scattering conversion according to a preferred embodiment of the invention. Display apparatus with signal scattering conversion 500 includes display panel 510, data driver 520, and scanning driver 530. Display panel 510 includes a plurality of pixel units P configured to form an m by n array, wherein each pixel unit P includes a thin film transistor and a liquid crystal device. For the pixel units in each column, source terminals of the thin film transistors are coupled electronically, forming m data lines 522 stretched out in the display panel 510. Likewise, for the pixel units in a row, gate terminals of the thin film transistors are coupled electronically, forming n scan lines 532 stretched out in display panel 510. Data driver 520 includes front-end processor 526 and data signal scattering converter 528, and is used to receive digital image data D and output analog data signals A. Front-end processor 526 is employed to receive the digital image data D and output digital data signals D'. Data signal scattering converter 528 is coupled to front-end processor 526 and data lines 522, and is used to receive the digital data signals D', perform digital-to-analog (D/A) conversion of the digital data signals D' so as to produce analog data signals A, and output them to data lines 522. Scanning driver 530 is coupled to scan lines 532 and is to receive a horizontal synchronization (HSYNC) signal and a vertical synchronization (VSYNC) signal.

[0019] According to the VSYNC signal, scanning driver 530 selects one of scan lines 532, such as scan line 532(k), sequentially, where k is an positive integer not greater than n, so that all of the thin film transistors of the scan line are turned on. When all the thin film transistors of scan line 532(k) are turned on, the analog data signals A from data driver 520 can be applied to the liquid crystal devices of scan line 532(k) through source and drain terminals of the thin film transistors of scan line 532(k), whereby data driver 520 controls the liquid crystal device in gray scales according to the analog data signals A When scanning driver 530 receives the VSYNC signal, scanning driver 530 re-starts to turn on one of scan lines 532 sequentially from the first one.

[0020] FIG. 6 is a block diagram of the data signal scattering converter 528 of FIG. 5. Data signal scattering converter 528 includes digital-to-analog (D/A) converter 600, scattering multiplexers 640, and scattering demultiplexers 642. In this embodiment, scattering multiplexers 640 are 3-to-1-line multiplexers; that is, each of them has three input terminals and one output terminal. Besides, scattering demultiplexers 642 are 1-to-3-line demultiplexers; that is, each of them has one input terminal and three output terminals. In practice, at least 2-to-1-line multiplexers and 1-to-2-line demultiplexers can act as the scattering multiplexers and scattering demultiplexers, respectively, according to the invention. Scattering multiplexer 640(i) is used to receive digital data signals D'(i), D'(i+1) and D'(i+2), and, according to a scattering method to be described later, select one out of digital data signals D'(i), D'(i+1) and D'(i+2) as scattering data signal D"(i). Digital-to-analog converter 600 is coupled to scattering multiplexers 640, and is used to receive scattering data signals D", perform digital-to-analog conversion on scattering data signals D", and output analog data signals T. Digital-to-analog converter 600 includes digital-to-analog conversion devices 606 and output buffers 610, and is used to output analog data signals T. Digital-to-analog conversion devices 606 are coupled to scattering multiplexers 640, while output buffers 610 are coupled to digital-to-analog conversion devices 606. Scattering demultiplexer 642(i), coupled to D/A converter 600, is used to receive analog data signal T(i) and to output analog data signal T(i) to one of data lines 522(i), 522(i+1), and 522(i+2) according to scattering multiplexers 640. For instance, if scattering data signal D"(i) from scattering multiplexers 640 is digital data signal D'(i+2) so that analog data signal T(i) is equal to analog data signal A(i+2), scattering demultiplexers 642 output analog data signal T(i) to data line 522(i+2). In this way, analog data signals A can be associated with data lines 522 correctly. Besides, all scattering multiplexers 640 are synchronized; that is, if scattering multiplexer 640(i) selects digital data signal D'(i+2) and outputs it as scattering data signal D"(i), scattering multiplexer 640(i-1) selects digital data signal D'(i+1) as scattering data signal D"(i-1).

[0021] Through the operation of scattering multiplexers 640 and scattering demultiplexers 642, each output of the output buffers of D/A converter 600 is to be scattered over three data lines. Therefore, if some of the output buffers have output offset voltages, undesired points due to the output offset voltages will be scattered within the three data lines. Since the scattered undesired points cannot form light gray lines on the display and they are almost imperceptible, the display quality is improved.

[0022] By the invention, a scattering method is used to change the correspondence between output buffers 610 and data lines 522. Undesired points with abnormally deep or light colors due to output offset voltages from output buffers 610 are scattered according to the scattering method so that the undesired points are almost imperceptible. Hence, the degradation of uniformity of display brightness can be reduced effectively. The scattering method can be space scattering, time scattering, or time-and-space scattering, for example.

[0023] Space scattering is used to change the relation between output buffers 610 and data lines 522 for each horizontal line. Referring to FIG. 7A, it illustrates a frame displayed without using the scattering method. In FIG. 7A, each of the rectangles represents one pixel unit, and the numbers in the rectangles indicate corresponding output buffers that apply gray level voltages to the pixel units. When the pixel unit is drawn as a shaded rectangle, an output buffer corresponding to the number in the shaded rectangle for that pixel unit has an output offset voltage. As can be observed from FIG. 7A, output buffer j has an output offset voltage so that a light gray line is formed through data line 522(j). Referring now to FIG. 7B, it illustrates a frame displayed by using space scattering, wherein output buffer 610(j) has an output offset voltage. Besides, scattering multiplexer 640(j) successively selects digital data signals D' in the sequence D'(j), D'(j+1), D'(j+2), D'(j+1), D'(j), D'(j+1), and so on. When the scattering data converter receives the HSYNC signal, the relation between output buffers 610 and data lines 522 is changed; that is, undesired points having originally occurred on the same line of a frame are scattered over different data lines of the same frame so that they are difficult to perceive.

[0024] Time scattering is used to change the relation between output buffers 610 and data lines 522 for each frame. Referring to FIGS. 8A to 8D, they illustrate a series of frames displayed by using time scattering, wherein output buffer 610(j) has an output offset voltage. Besides, scattering multiplexer 640(j) successively selects digital data signals D' in the sequence D'(j), D'(j+1), D'(j+2), D'(j+1), D'(j), D'(j+1), and so on. FIG. 8A illustrates the first frame, where one vertical line with light gray color is formed associated with data line 522(j). FIG. 8B illustrates the second frame, where one vertical line with light gray color is formed associated with data line 522 (1-1). FIG. 8C illustrates the third frame, where one vertical line with light gray color is formed associated with data line 522(j-2). FIG. 8D illustrates the fourth frame, where one vertical line with light gray color is formed associated with data line 522(j-1). In brief, output buffer 610(j) is associated with a different data line for each of the successive frames. Thus, the light gray lines due to output offset voltages are scattered so that they are difficult to perceive.

[0025] Time-and-space scattering is used to change the relation between output buffers 610 and data lines 522 for each frame with each horizontal line. That is, undesired points originally associated with the same data line for one frame can be scattered over different frames and different data lines. Thus, the undesired points caused by the output offset voltages of output buffers 610 are scattered equally and are almost imperceptible.

[0026] Scattering multiplexer 640(j) can be configured to select one out of digital data signals D'(j), D'(j+1), and D'(j+2) according to a predetermined sequence, a random sequence, or a weighted curve. In the case of a weighted curve, digital data signals D' outputted to scattering multiplexer 640(j) are associated with different weight values respectively. In this way, scattering multiplexer 640(j) selects one out of digital data signals D'(j), D'(j+1), and D'(j+2) according to their associated weight values so as to change the relation between output buffers 610 and data lines 522. If scattering multiplexer 640 (j) changes the relation between output buffers 610 and data lines 522 according to a weighted curve, the display to be perceived is equivalent to the result of convolving the weighted curve with the light gray intensities. For example in FIGS. 8A to 8D, digital data signals D'(j), D' (j+1), and D'(j+2) are associated with weight values 1/4, 2/4, and 1/4 respectively. Referring to FIGS. 9A to 9D, they shows graphs of gray level intensity for the frames shown in FIGS. 8A-8D respectively. FIG. 10 is a graph of gray level intensity perceived by humans for the successively; equivalently frames shown in FIGS. 8A-8D, this graph shows the result of convolving the weighted curve with gray level intensity of a light gray line. In this way, the undesired points are scattered so that their gray level intensities as perceived by humans, are reduced. Besides, as can be seen from FIG. 10, the gray level intensities are distributed in such a way that the line in the middle has higher intensity than the lines on the both sides. As a whole, the image looks smoother while the undesired points are difficult to perceive. Thus, the display quality is improved.

[0027] Referring to FIG. 11, it shows a block diagram of another example of the data signal scattering converter 528 of FIG. 5. In FIG. 11, the data signal scattering converter is capable of outputting analog data signals with different polarities. Data signal scattering converter 528 includes digital-to-analog (D/A) converter 1100, (m+3) scattering multiplexers 1140, and (m+3) scattering demultiplexers 1142. In this embodiment, scattering multiplexers 1140 are 3-to-1-line multiplexers; that is, each of them has three input terminals and one output terminal. Besides, scattering demultiplexers 1142 are 1-to-3-line demultiplexers; that is, each of them has one input terminal and three output terminals. In practice, at least 2-to-1-line multiplexers and 1-to-2-line demultiplexers can act as the scattering multiplexers and scattering demultiplexers, respectively, according to the invention. Scattering multiplexer 1140(i) is used to receive digital data signals D'(i), D'(i+2) and D'(i+4), and, according to a scattering method be described later, select one out of digital data signals D'(i), D'(i+2) and D'(i+4) as scattering data signal D"(i). Digital-to-analog converter 1100 is coupled to scattering multiplexers 1140, and is used to receive scattering data signals D", perform digital-to-analog conversion on scattering data signals D", and output analog data signals T. Scattering demultiplexer 1142(i), coupled to D/A converter 1100, is used to receive analog data signal T(i) and output analog data signal T(i) to one of data lines 522(i), 522(i+2), and 522 (i+4) according to scattering multiplexers 1140. For instance, if scattering data signal D"(i) from scattering multiplexers 1140 is digital data signal D'(i+2), then analog data signal T(i) is equal to analog data signal A(i+2) and scattering demultiplexers 1142 outputs analog data signal T(i) to data line 522(i+2). In this way, analog data signals A can be associated with data lines 522 correctly. Besides, all scattering multiplexers 1140 are synchronized; that is, if scattering multiplexer 1140(i) selects digital data signal D'(i+2) and outputs it as scattering data signal D"(i), scattering multiplexer 1140(i-1) selects digital data signal D'(i+1) as scattering data signal D"(i-1).

[0028] Digital-to-analog converter 1100 includes demultiplexers 1102, multiplexers 1104, D/A conversion devices 1106, and output buffers 1110. Demultiplexer 1102(i) is coupled to scattering multiplexer 1140(i), D/A conversion device 1106(i), and 1106(i+1), and is used to receive scattering data signal D"(i). In addition, according to either dot inversion or column inversion, demultiplexer 1102(i) outputs the received scattering data signal D"(i) to either D/A conversion device 1106(i) or D/A conversion device 1106(i+1). Further, all demultiplexers 1102(i) are synchronized. That is, if demultiplexer 1102(i) outputs scattering data signal D"(i) to D/A conversion device 1106(i+1), demultiplexer 1102(i-1) outputs scattering data signal D"(i+1) to D/A conversion device 1106(i). Digital-to-analog conversion device 1106(i) is coupled to demultiplexers 1102(i) and 1102(i-1), and used to receive D"(i-1) or D"(i) and output converted data signal S(i). In addition, if *i* is an odd number, D/A conversion device 1106(*i*) is to output converted data signal S(*i*) with positive polarity; if *i* is an even number, D/A conversion device 1106(*i*) is to output converted data signal S(*i*) with negative polarity. Output buffer 1110(i), coupled to D/A conversion device 1106(i), is used to receive converted data signal S(i), output buffered data signal S'(i) according to converted data signal S(i), and feed buffered data signal S'(i) into multiplexers 1104(i) and 1104(i-1). Multiplexer 1104(i) is coupled to output buffers 1110(i) and 1110(i+1), and is used to receive buffered data signals S'(i) and S'(i+1), and to output analog data signal T(i) according to demultiplexer 1102(i), wherein analog data signal T(i) is either S'(i) or S'(i+1). For instance, when demultiplexer 1102(i) outputs scattering data signal D"(i) to D/A conversion device 1106 (i+1), multiplexer 1104(i) outputs buffered data signal S' (i+1) as analog data signal T(i).

[0029] Through the operation of scattering multiplexers 1140, demultiplexers 1102, scattering demultiplexers 1142, and multiplexers 1104, the output of output buffer 1110(i) is scattered over six data lines, 522(i-1) to 522(i+4). Therefore, if output buffer 1110(i) has an output offset voltage, the undesired points due to the output offset voltage are scattered within the six data lines. Since the scattered undesired points cannot form light gray lines on the display and are humanly almost imperceptible, the display quality is improved.

[0030] By the invention, a scattering method is used to change the relation between output buffers 1110 and data lines 522. Thus, undesired points with abnormally deep or light colors due to output offset voltages from output buffers 1110 are scattered so that the undesired points are almost imperceptible. Hence, the degradation of uniformity of display brightness can be reduced effectively. The scattering methods including space scattering, time scattering, and time-and-space scattering are described as follows.

[0031] Space scattering is used to change the relation between output buffers 1110 and data lines 522 for each horizontal line. Referring to FIG. 12A, it illustrates a frame displayed without using a scattering method, wherein polarity inversion, such as column inversion, is employed. In FIG. 12A, each of the rectangles represents one pixel unit while the numbers in the rectangles show the corresponding output buffer, which outputs the gray level to the corresponding pixel unit. In addition, signs preceding the numbers in the rectangles are indicative of the polarities of output signals from the output buffers associated with the numbers. When the pixel unit is drawn as a shaded rectangle, an output buffer corresponding to the number in the rectangle has an output offset voltage. As can be observed from FIG. 12A, output buffer 1110(j) has an output offset voltage so that a light gray line is formed through data line 522 (j). Referring now to FIG. 12B, it illustrates a frame displayed by using space scattering, wherein output buffer 1110(j) has the output offset voltage. Scattering multiplexer 1140(j) successively selects digital data signals D' in the sequence D'(j), D'(j+4), D'(j+2), D'(1), D'(j+4), D'(j+2), and so on. When the scattering data converter receives the HSYNC signal, the relation between output buffers 1110 and data lines 522 is changed; that is, undesired points which originally occur on the same line of a frame are scattered over different data lines of the same frame so that they are difficult to perceive.

[0032] Time scattering is used to change the relation between output buffers 1110 and data lines 522 for each frame. FIGS. 13A to 13E illustrate a series of frames displayed by using time scattering, wherein column inversion is employed to perform polarity inversion and output buffer 1110(j) has an output offset voltage. Besides, scattering multiplexer 1140(j) successively selects digital data signals D' in the sequence D'(j), D'(j+2), D'(j+4), D'(j+2), D'(j), D'(j+2), and so on. FIG. 13A illustrates the first frame, where one vertical line with light gray color is formed associated with data line 522(1-1). FIG. 13B illustrates the second frame, where one vertical line with light gray color is formed associated with data line 522(j-2). FIG. 13C illustrates the third frame, where one vertical line with light gray color is formed associated with data line 522(j-5). FIG. 13D illustrates the fourth frame, where one vertical line with light gray color is formed associated with data line 522(j-2). FIG. 13E is equivalent to FIG. 13A. In brief, output buffer 1110 (j) is associated with a different data line for each of the successive frames. Thus, the light gray lines due to output offset voltages are scattered so that they are almost imperceptible.

[0033] Time-and-space scattering is used to change the relation between output buffers 1110 and data lines 522 for each frame with each horizontal line. That is, undesired points originally associated with the same data line for one frame can be scattered over different frames and different data lines. Thus, the undesired points caused by the output offset voltages of output buffers 1110 are scattered equally and much more difficult to be perceived.

[0034] Scattering multiplexer 1140(j) can be configured to select one out of digital data signals D'(j), D'(j+2), and D'(j+4) according to a predetermined sequence, a random sequence, or a weighted curve. In the case of a weighted curve, digital data signals D' outputted to scattering multiplexer 1140(j) are associated with different weight values respectively. In this way, scattering multiplexer 1140(j) selects one out of digital data signals D'(j), D'(j+2), and D'(j+4) according to their associated weight values so as to change the relation between output buffers 1110 and data lines 522. If scattering multiplexer 1140(j) changes the relation between output buffers 1110 and data lines 522 according to a weighted curve, the display to be perceived is equivalent to the display resulting from convolving the weighted curve with the light gray intensities. For example in FIGS. 13A to 13E, digital data signals D'(j), D'(j+2), and D'(j+4) are associated with weight values 0.25, 0.5, and 0.25 respectively. FIGS. 14A to 14D show graphs of gray level intensity for the frames shown in FIGS. 13A-13D respectively. In addition, FIG. 15 is a graph of gray level intensity as perceived by humans for the frames shown in FIGS. 13A-13D successively. Equivalently, this graph shows the result of convolving the weighted curve with gray level intensity of a light gray line. In this way, the undesired points are scattered so that their gray level intensities perceived by humans are reduced. Besides, as can be seen from FIG. 15, the gray level intensities are distributed in the way such that the lines on the both sides have lower intensity than the line in the middle. As a whole, the display looks smoother, while the undesired points are difficult to perceive. Thus, the display quality is improved.

[0035] As disclosed above, the data signal scattering converter according to the invention scatters undesired points with abnormally deep or light colors due to output offset voltages from output buffers in the D/A converter, by changing the relation between the output buffers in the D/A converter and data lines so that the undesired points are not easy to perceive. Therefore, the degradation of uniformity of display brightness is reduced effectively and the display quality is improved.

[0036] While the invention has been described by way of example and in terms of the preferred embodiment, it is to be understood that the invention is not limited to the disclosed embodiment. To the contrary, it is intended to cover various modifications and similar arrangements and procedures, and the scope of the appended claims therefore should be accorded the broadest interpretation so as to encompass all such modifications and similar arrangements and procedures.

Claims

1. An apparatus for data signal scattering conversion, the apparatus comprising:

a scattering multiplexer for receiving p digital data signals and outputting a q-th digital data signal of the p digital data signals by a scattering method, wherein p and q are positive integers and q is not greater than p;

a digital-to-analog converter, coupled to the scattering multiplexer, for performing digital-to-analog conversion of the q-th digital data signal and outputting an analog data signal; and

a scattering demultiplexer having p output terminals, coupled to the digital-to-analog converter, for outputting the analog data signal through a q-th output terminal of the p output terminals by the scattering method.

2. An apparatus according to claim 1, wherein p is not less than 2.

3. An apparatus according to claim 1, wherein the digital-to-analog converter is capable of performing polarity inversion of signal.

4. A display apparatus with signal scattering conversion, comprising:

a display panel comprising a plurality of pixel units, wherein the pixel units are arranged to form an m by n array, m and n being positive integers greater than one, and
a data driver, coupled to the display panel, for outputting m analog data signals according to digital image data, the data driver including

a front-end processing device for receiving the digital image data and outputting m digital data signals, and

a data signal scattering converter, coupled to the front-end processing device, for receiving the digital data signals and outputting the m analog data signals, the data signal scattering converter including

a scattering multiplexer for receiving p digital data signals and outputting a q-th digital data signal of the p digital data signals by a scattering method, wherein p and q are positive integers and q is not greater than p,

a digital-to-analog converter, coupled to the scattering multiplexer, for performing digital-to-analog conversion of the q-th digital data signal and outputting an analog data signal, and

a scattering demultiplexer having p output terminals, coupled to the digital-to-analog converter, for outputting the analog data signal through a q-th output terminal of the p output terminals by the scattering method.

5. A display apparatus according to claim 4, wherein p is not less than 2.

6. A display apparatus according to claim 4, wherein the digital-to-analog converter is capable of performing polarity inversion of signal.

7. A method for image display with signal scattering, for use in a display, the display comprising a plurality of pixel units, the pixel units being arranged to form an m by n array, the method comprising the steps of

providing p digital data signals;

selecting a q-th digital data signal from the p digital data signals by a scattering method;

producing an analog data signal according to the q-th digital data signal; and

feeding the analog data signal into the pixel unit of the r-th row, q-th column according to the scattering method for image display, wherein m, n, p, q, and r are positive integers, q is not greater than p, and r is not greater than m.

8. A method according to claim 7, wherein selecting the q-th digital data signal from the p digital data signals is performed randomly.

9. A method according to claim 7, wherein selecting the q-th digital data signal from the p digital data signals is performed according to a weighted curve.

10. A method according to claim 7, wherein the scattering method is time scattering.

11. A method according to claim 7, wherein the scattering method is space scattering.

12. A method according to claim 7, wherein the scattering method is time-and-space scattering.

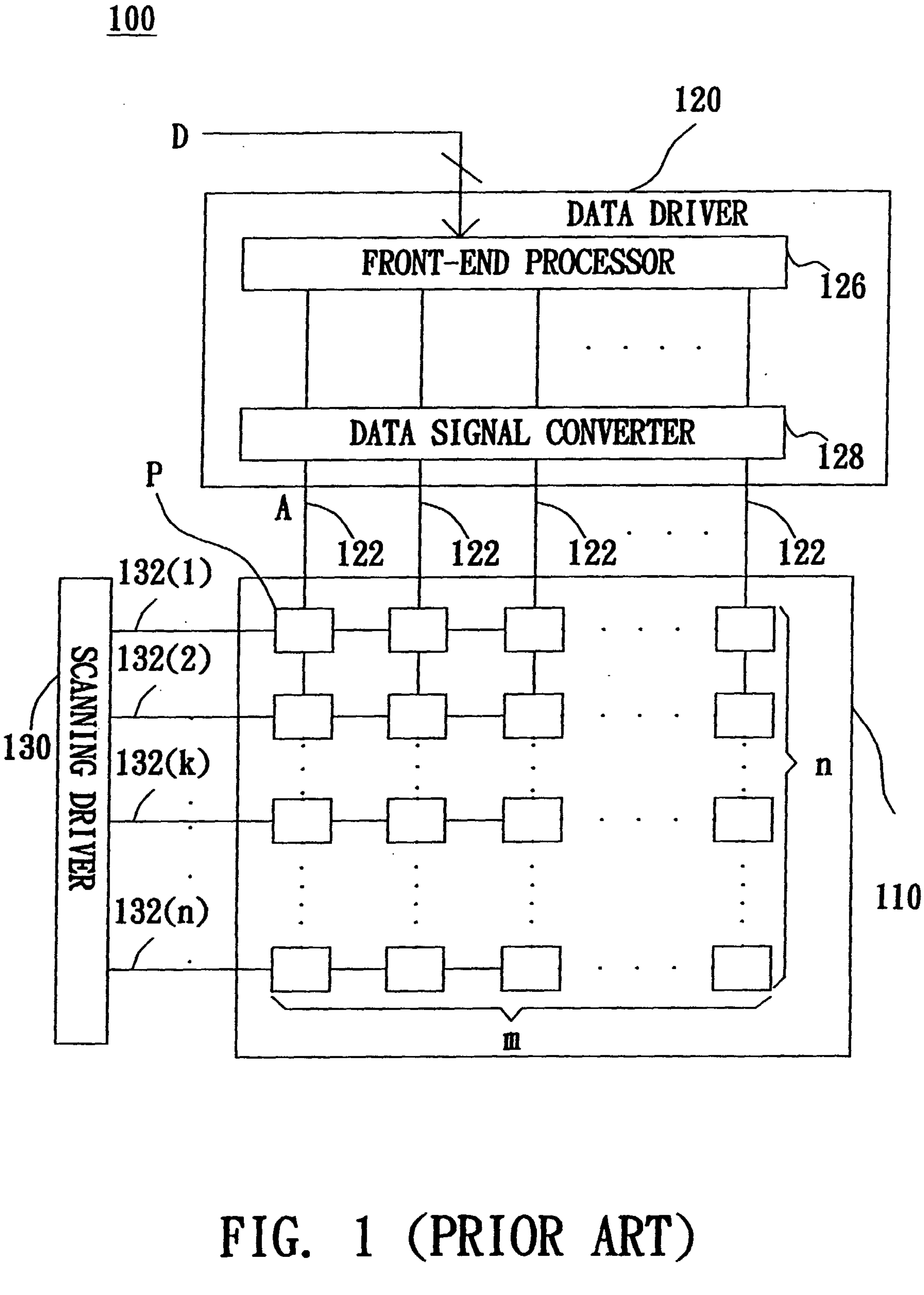

FIG. 1 (PRIOR ART)

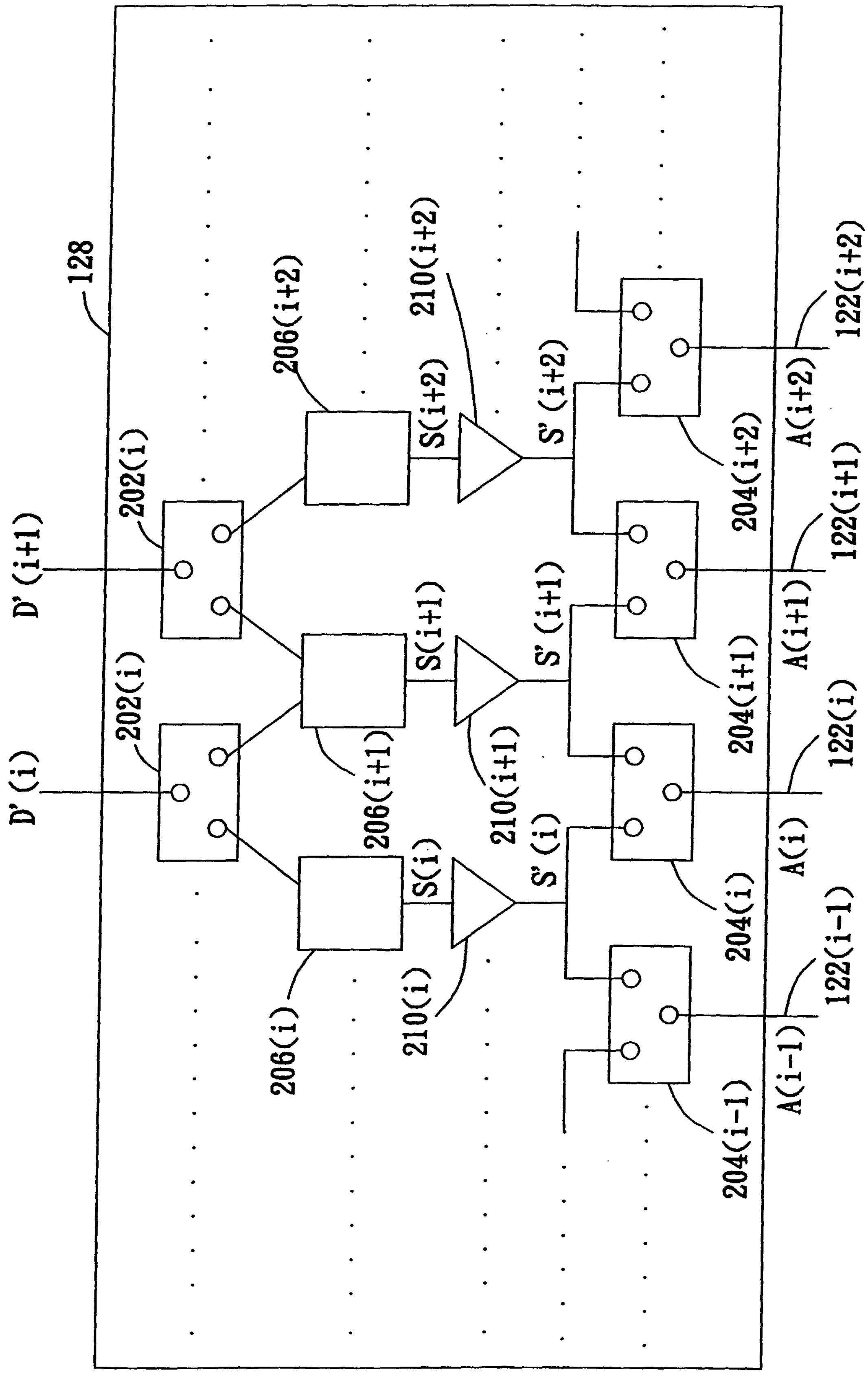

FIG. 2 (PRIOR ART)

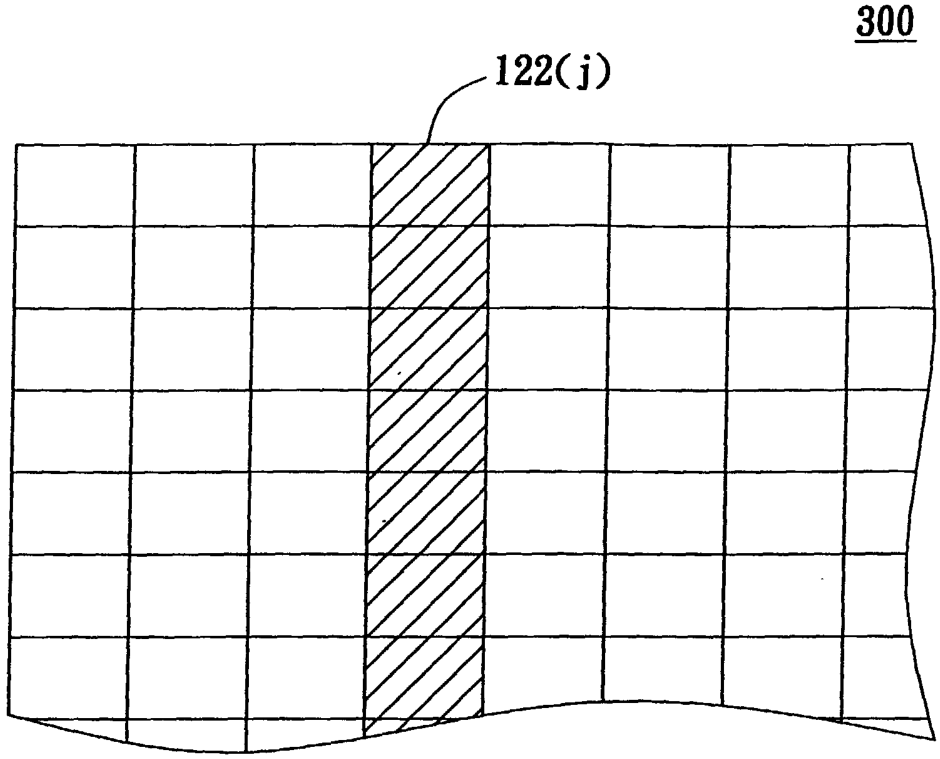

FIG. 3A (PRIOR ART)

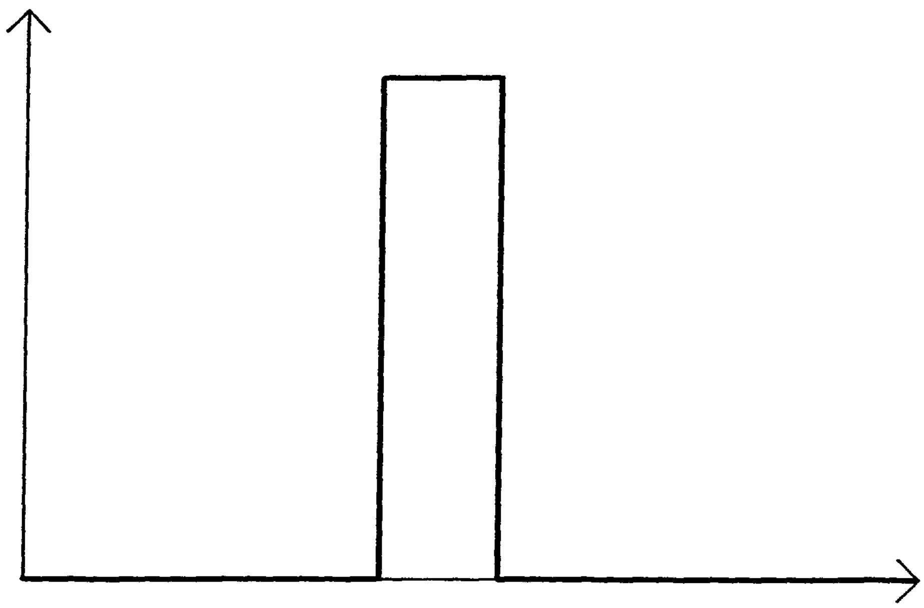

FIG. 3B (PRIOR ART)

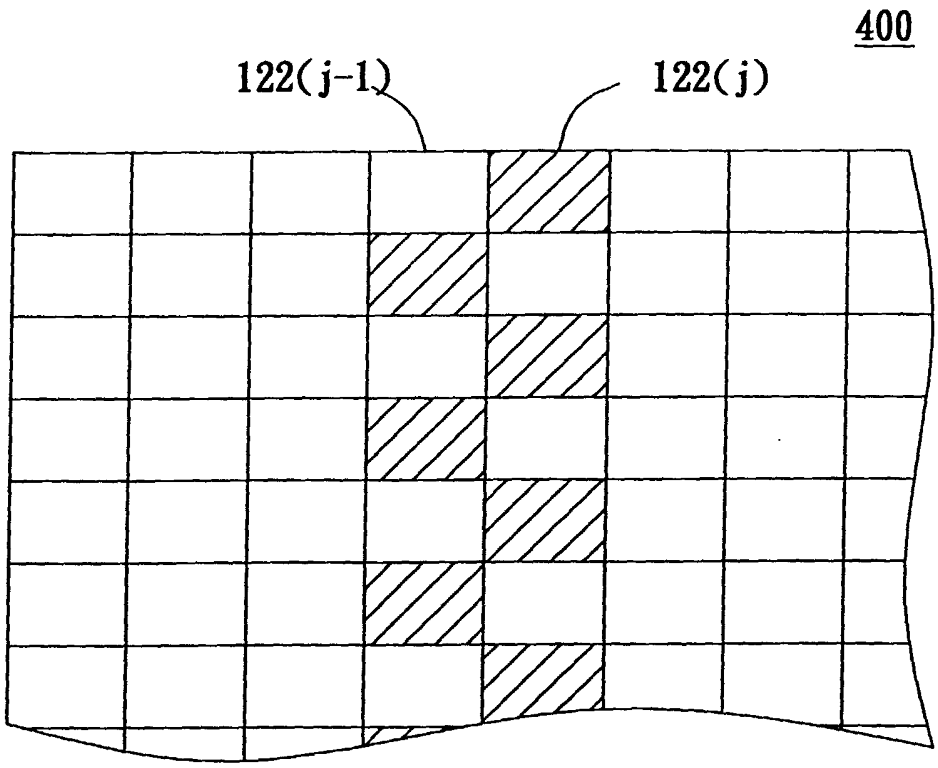

FIG. 4A (PRIOR ART)

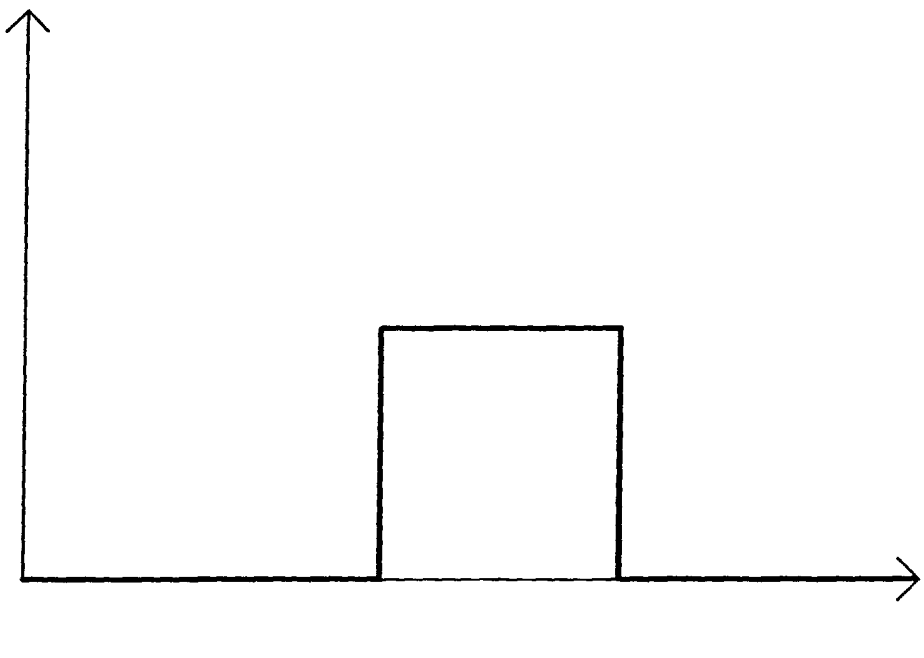

FIG. 4B (PRIOR ART)

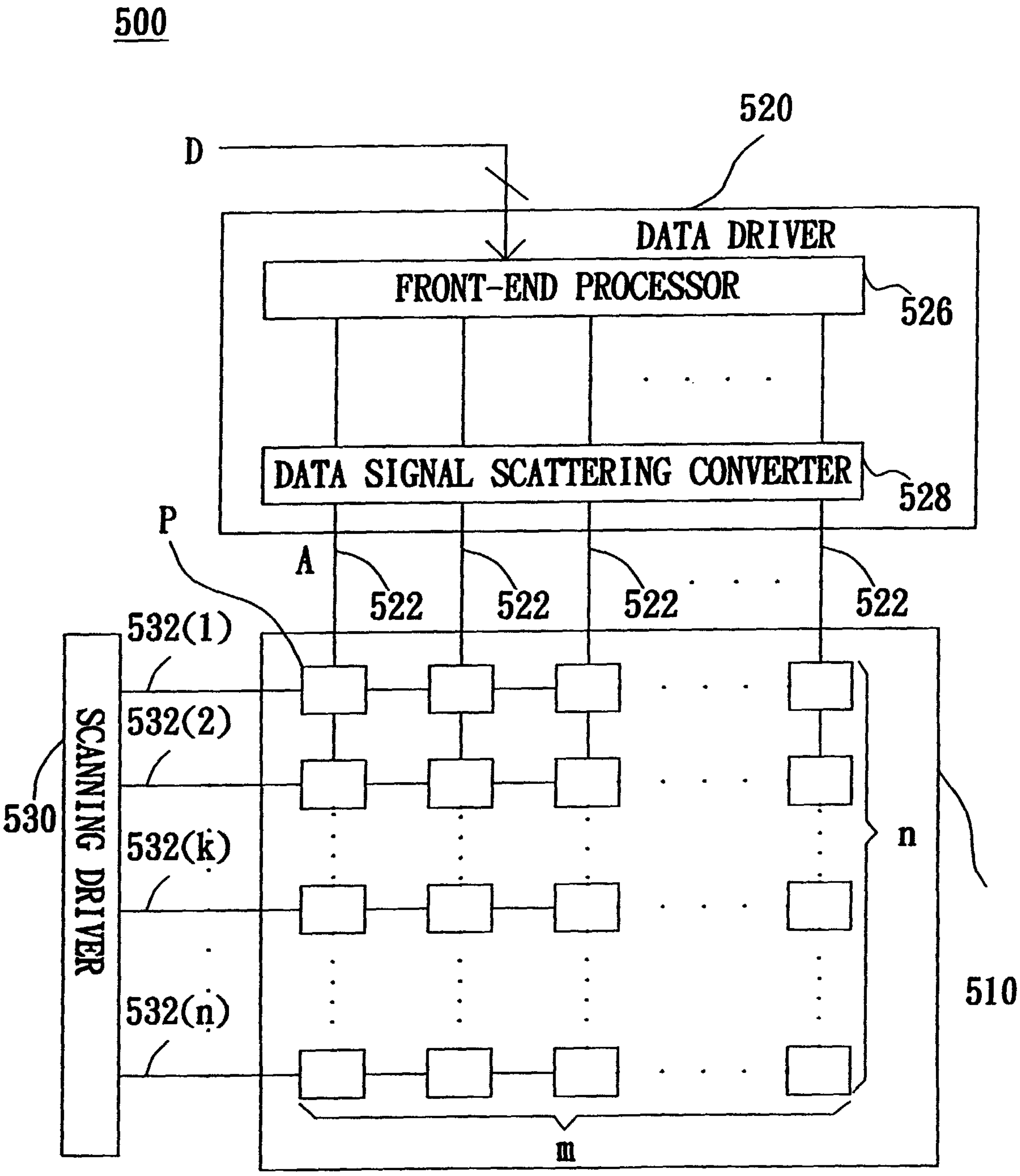
500
520
D
DATA DRIVER
FRONT-END PROCESSOR
526
DATA SIGNAL SCATTERING CONVERTER
528
P
A
522
522
522
522
532(1)
532(2)
530
SCANNING DRIVER
532(k)
532(n)
n
510
m

FIG. 5

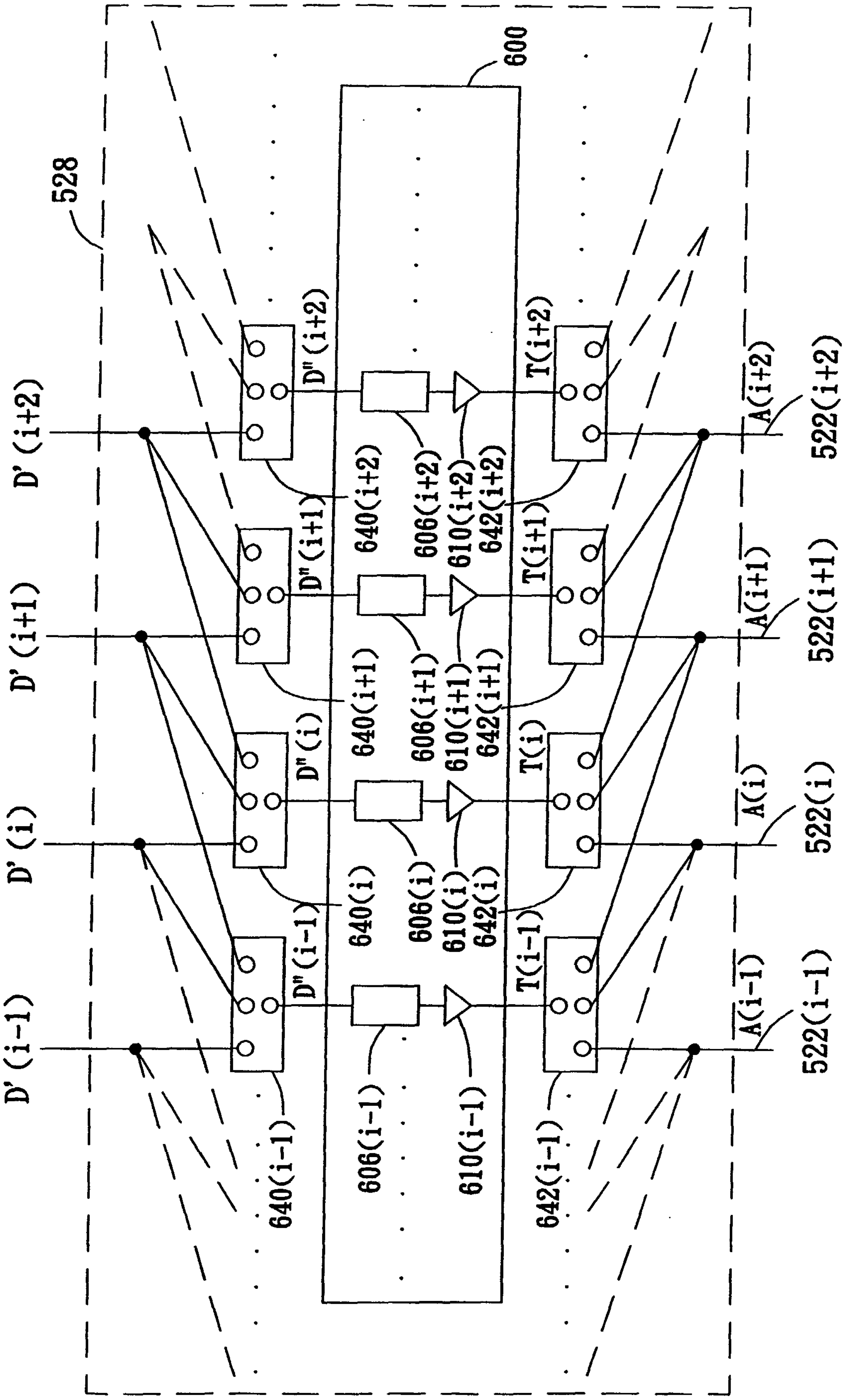
528
600
D'(i-1)
D'(i)
D'(i+1)
D'(i+2)
D"(i-1)
D"(i)
D"(i+1)
D"(i+2)
T(i-1)
T(i)
T(i+1)
T(i+2)
A(i-1)
A(i)
A(i+1)
A(i+2)
522(i-1)
522(i)
522(i+1)
522(i+2)
640(i-1)
640(i)
640(i+1)
640(i+2)
606(i-1)
606(i)
606(i+1)
606(i+2)
610(i-1)
610(i)
610(i+1)
610(i+2)
642(i-1)
642(i)
642(i+1)
642(i+2)

FIG. 6

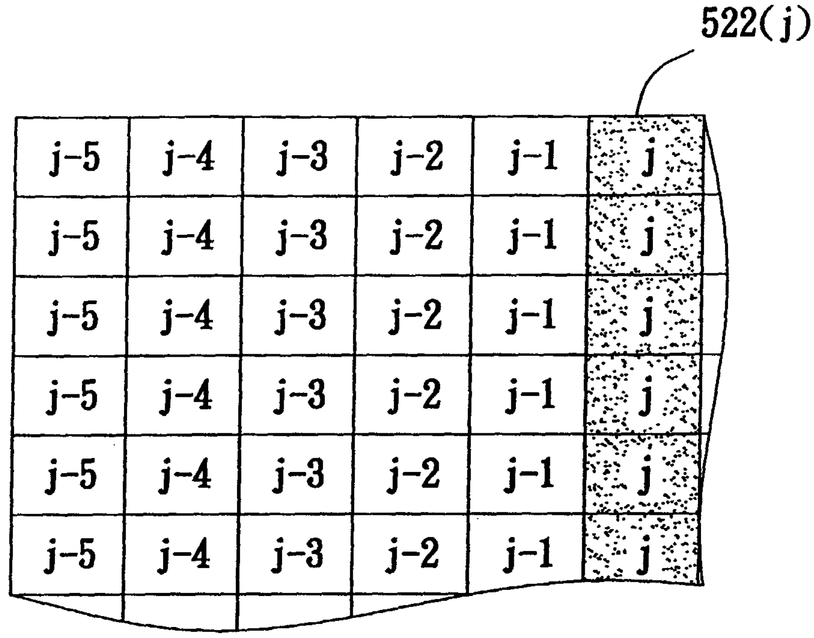

FIG. 7A (PRIOR ART)

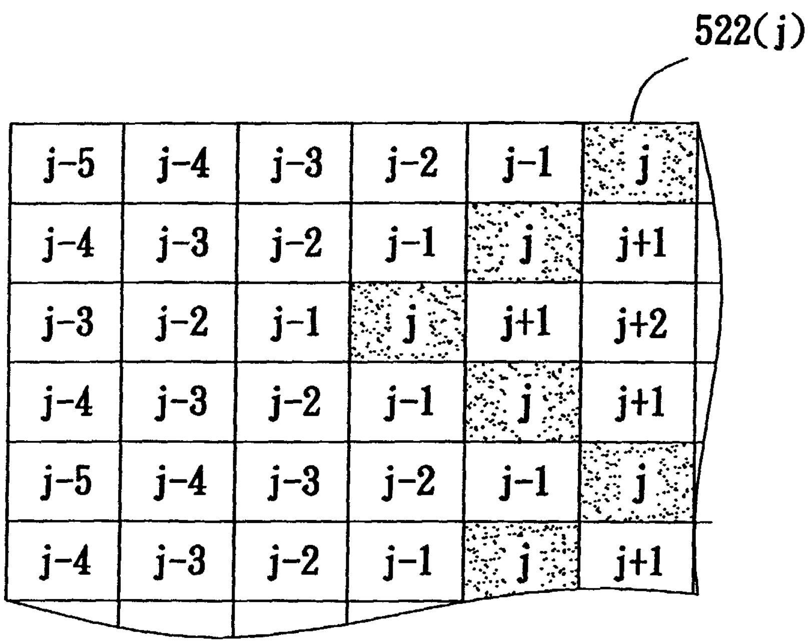

FIG. 7B

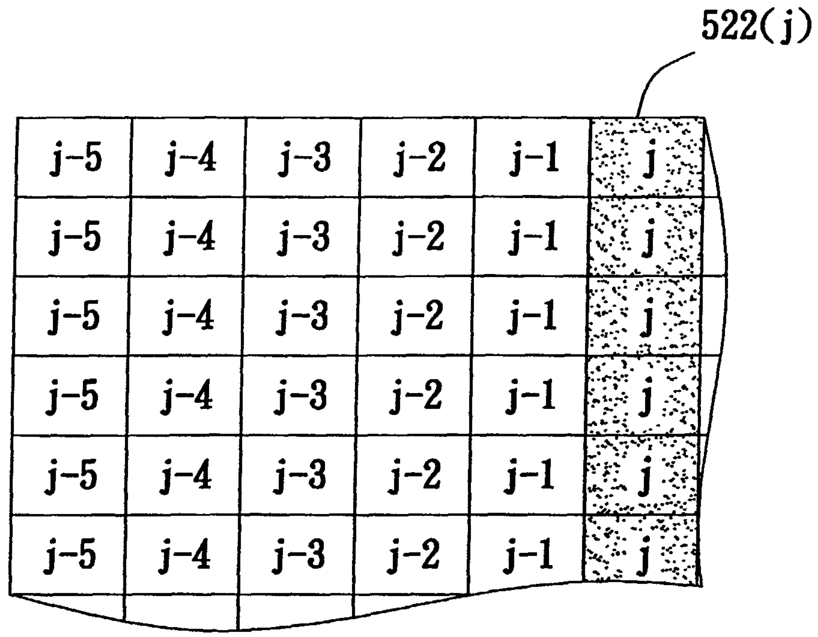
522(j)
j-5 j-4 j-3 j-2 j-1 j
j-5 j-4 j-3 j-2 j-1 j
j-5 j-4 j-3 j-2 j-1 j
j-5 j-4 j-3 j-2 j-1 j
j-5 j-4 j-3 j-2 j-1 j
j-5 j-4 j-3 j-2 j-1 j

FIG. 8A

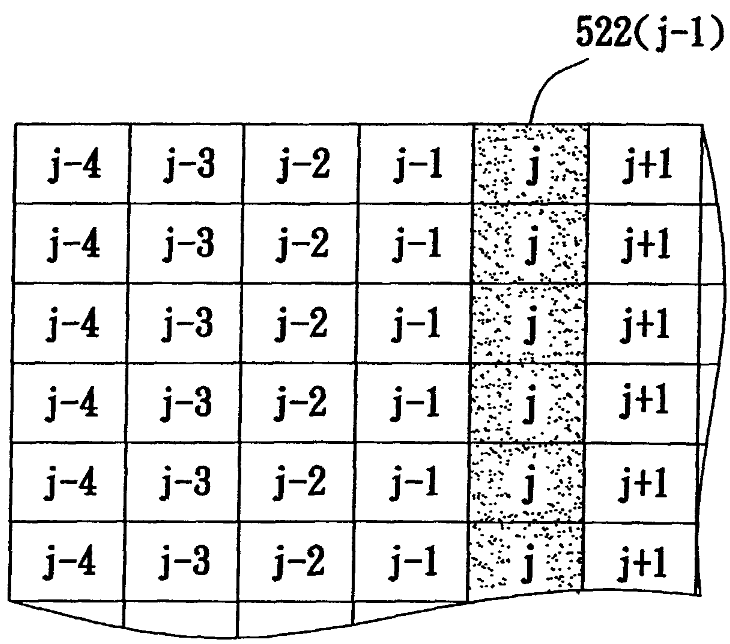
522(j-1)
j-4 j-3 j-2 j-1 j j+1
j-4 j-3 j-2 j-1 j j+1
j-4 j-3 j-2 j-1 j j+1
j-4 j-3 j-2 j-1 j j+1
j-4 j-3 j-2 j-1 j j+1
j-4 j-3 j-2 j-1 j j+1

FIG. 8B

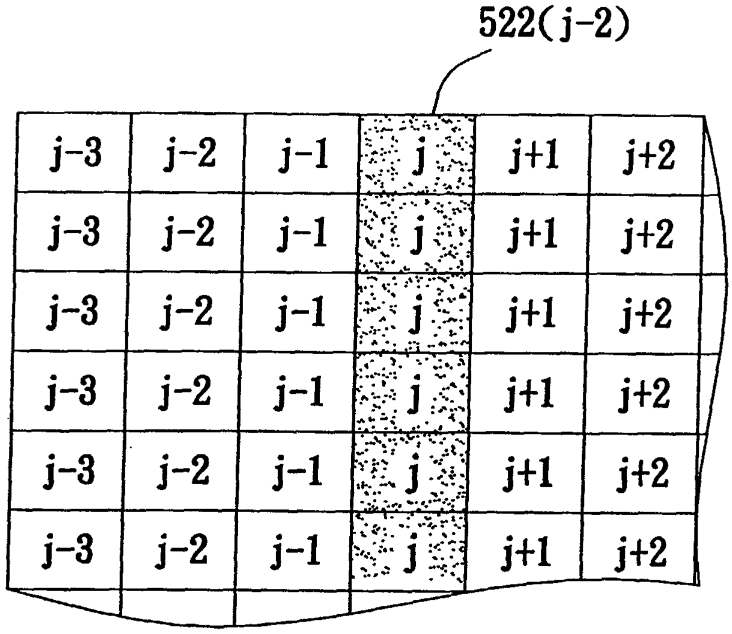

FIG. 8C

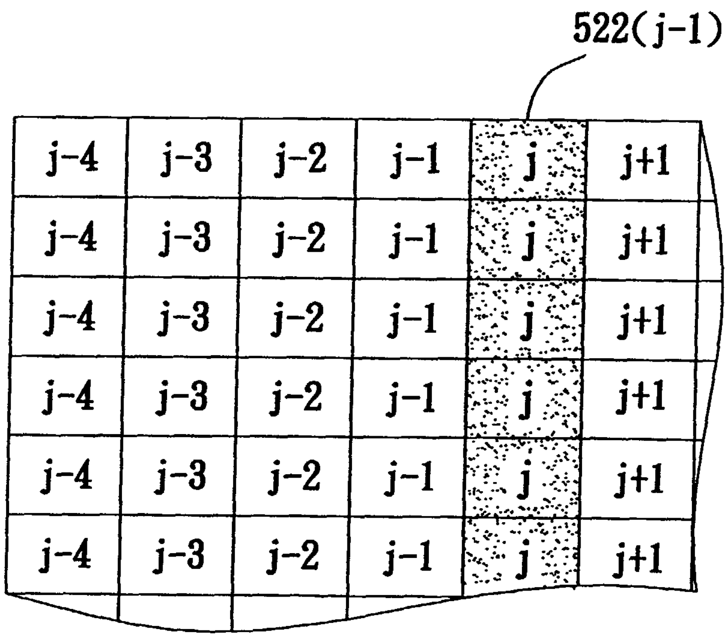

FIG. 8D

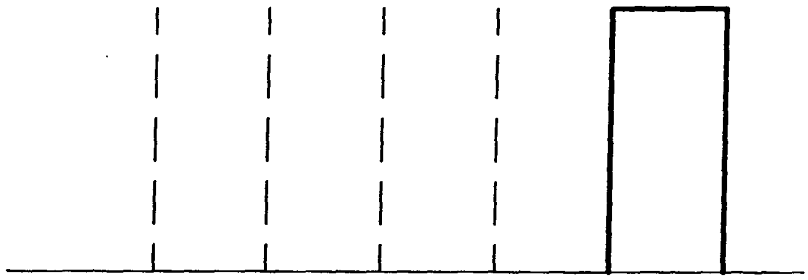

FIG. 9A

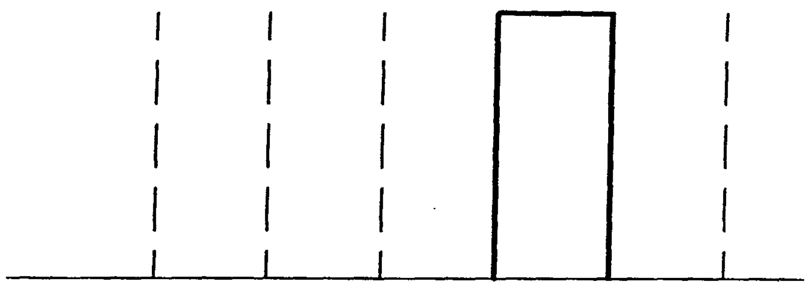

FIG. 9B

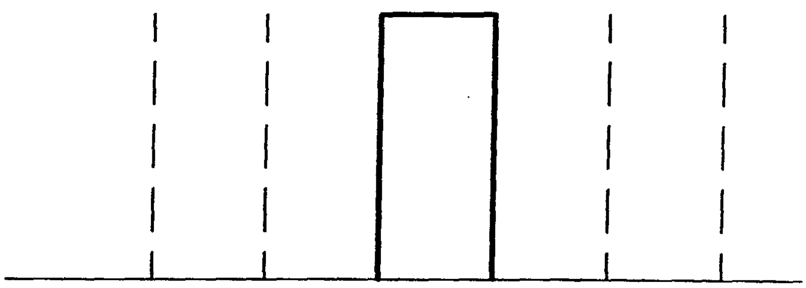

FIG. 9C

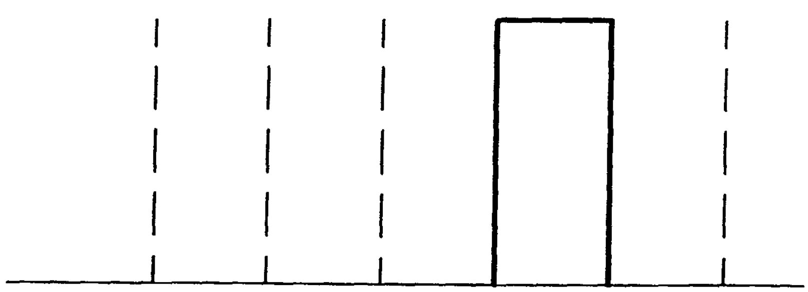

FIG. 9D

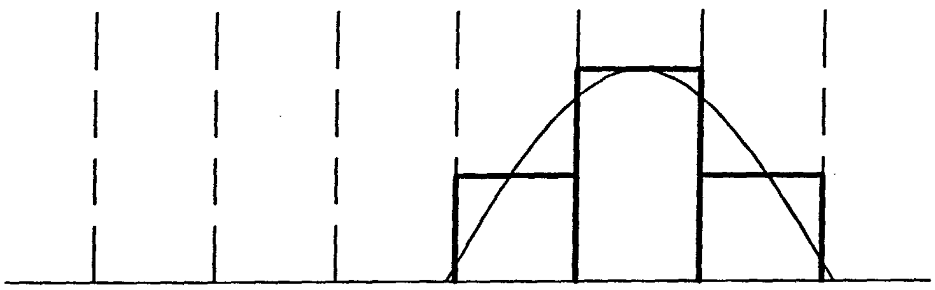

FIG. 10

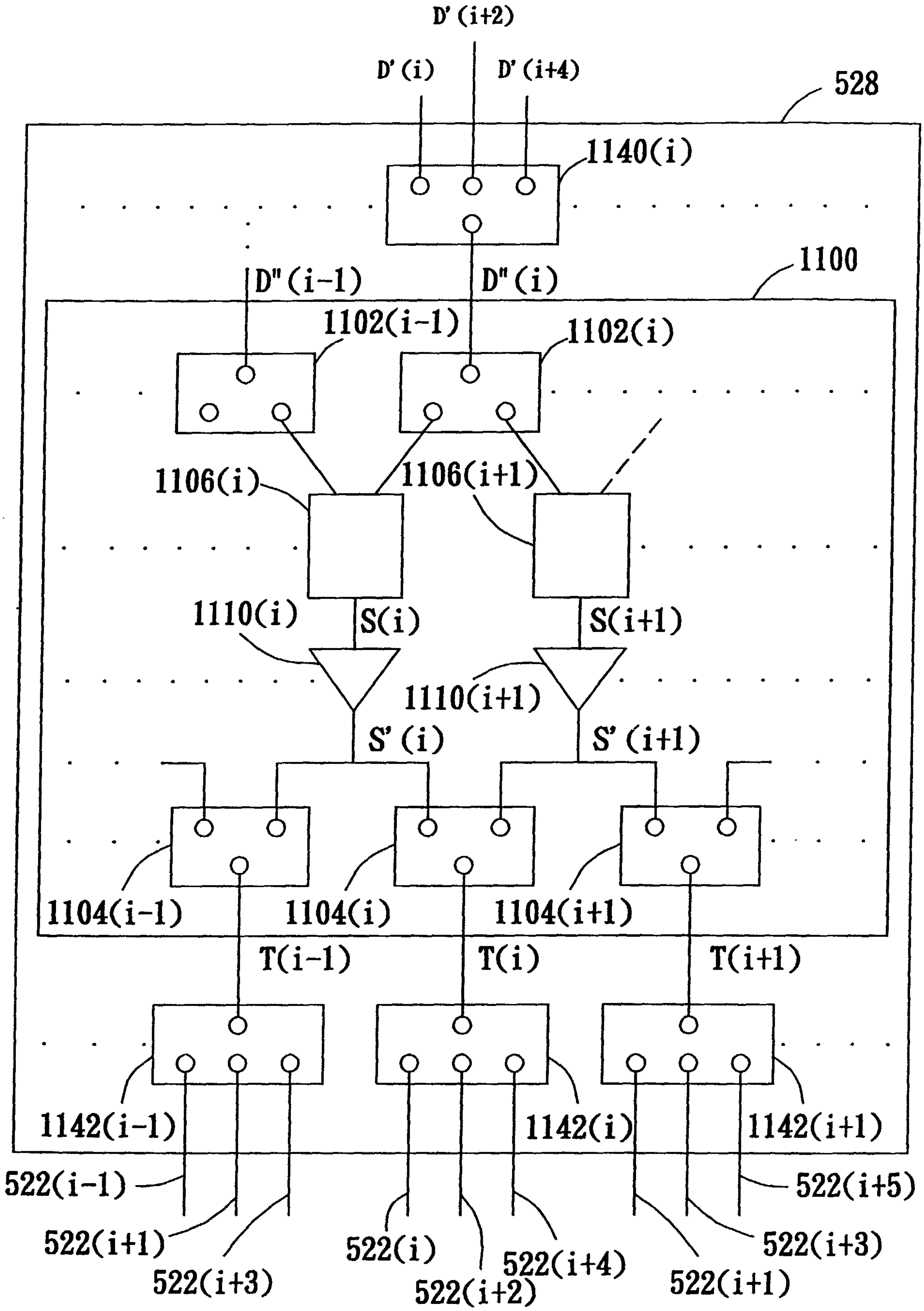
D' (i+2)
D' (i)
D' (i+4)
528
1140(i)
D" (i-1)
D" (i)
1100
1102(i-1)
1102(i)
1106(i)
1106(i+1)
1110(i)
S(i)
S(i+1)
1110(i+1)
S' (i)
S' (i+1)
1104(i-1)
1104(i)
1104(i+1)
T(i-1)
T(i)
T(i+1)
1142(i-1)
1142(i)
1142(i+1)
522(i-1)
522(i+1)
522(i+3)
522(i)
522(i+2)
522(i+4)
522(i+1)
522(i+3)
522(i+5)

FIG. 11

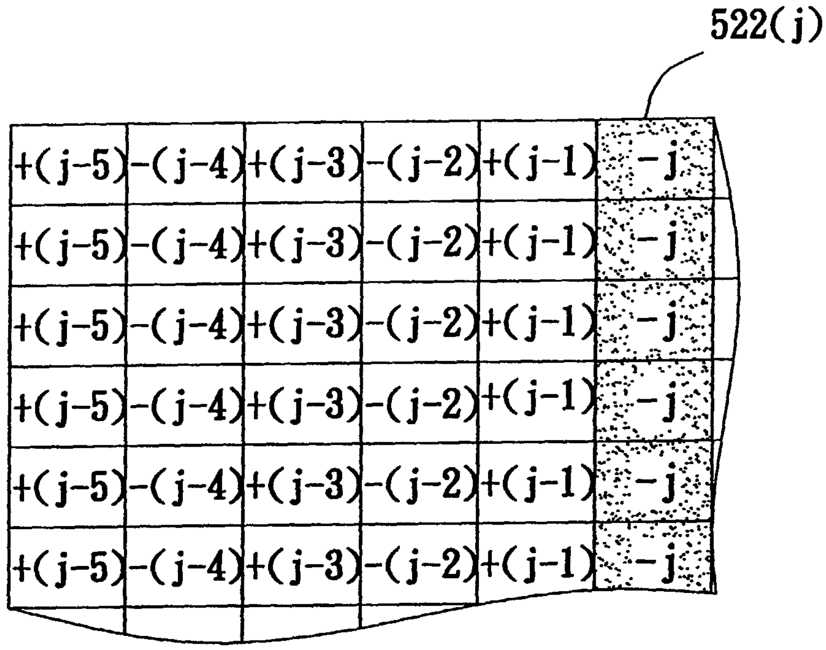

FIG. 12A (PRIOR ART)

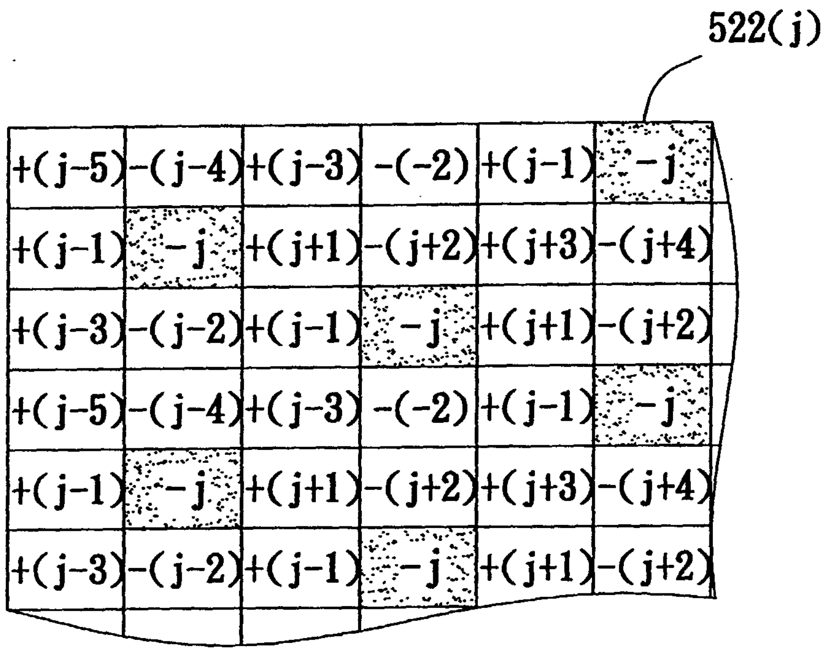

FIG. 12B

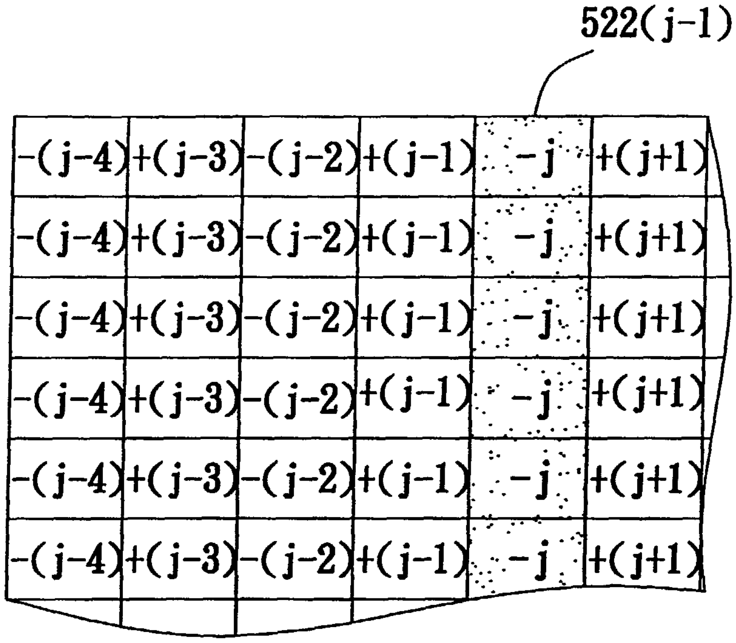

FIG. 13A

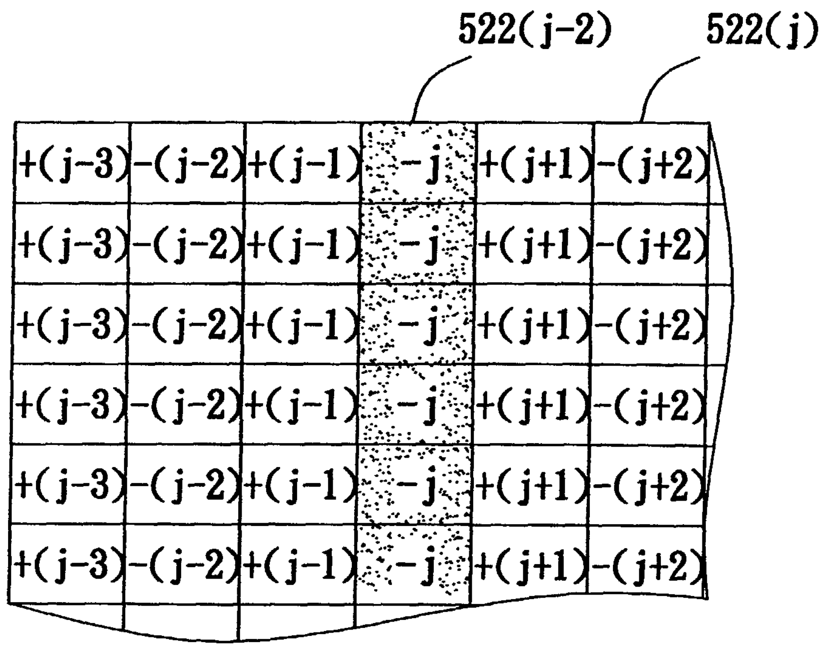

FIG. 13B

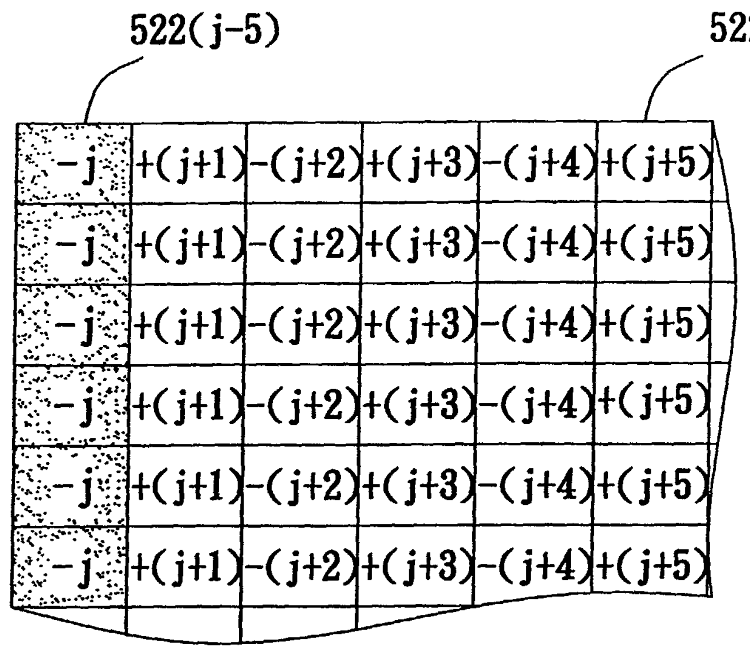

FIG. 13C

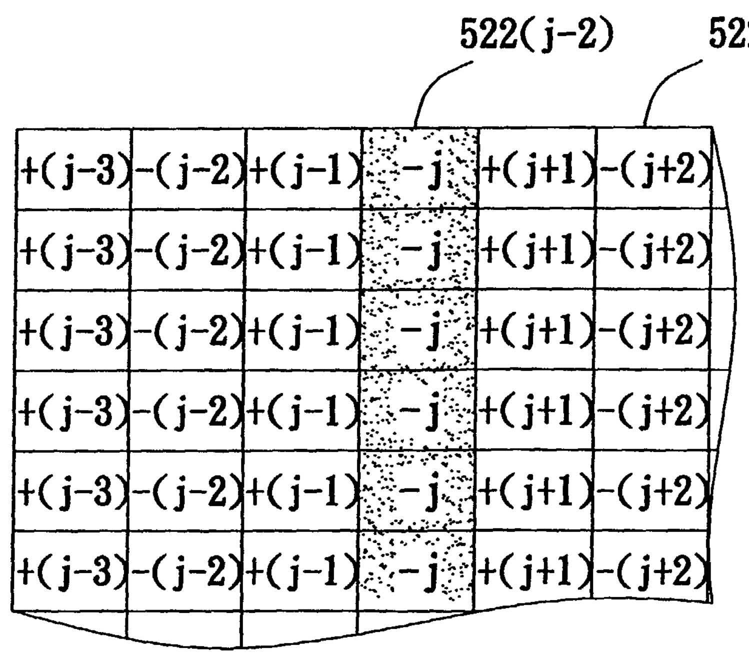

FIG. 13D

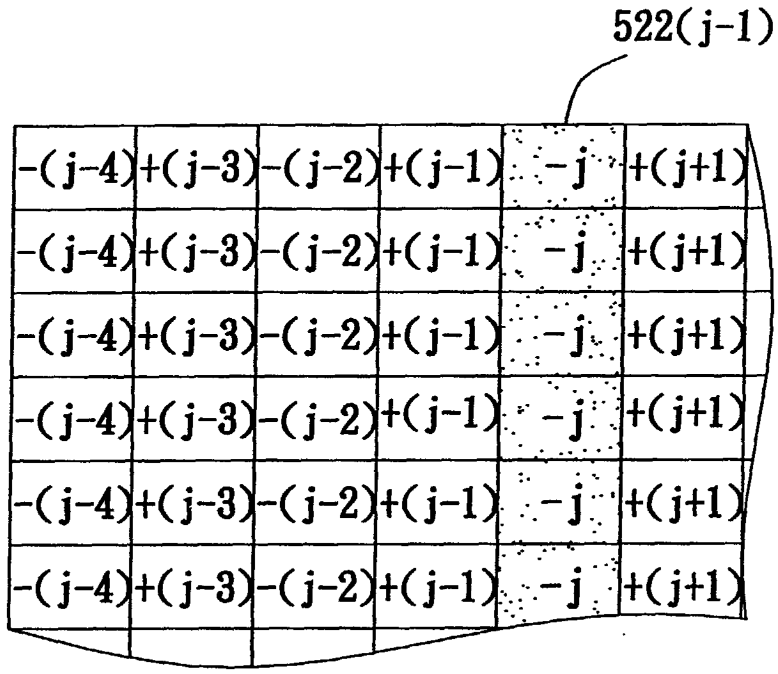
522(j-1)
-(j-4) +(j-3) -(j-2) +(j-1) -j +(j+1)
-(j-4) +(j-3) -(j-2) +(j-1) -j +(j+1)
-(j-4) +(j-3) -(j-2) +(j-1) -j +(j+1)
-(j-4) +(j-3) -(j-2) +(j-1) -j +(j+1)
-(j-4) +(j-3) -(j-2) +(j-1) -j +(j+1)
-(j-4) +(j-3) -(j-2) +(j-1) -j +(j+1)

FIG. 13E

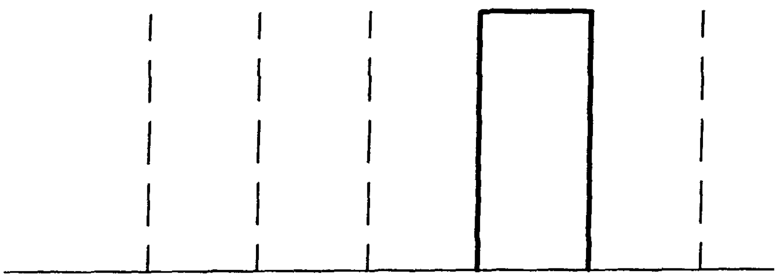

FIG. 14A

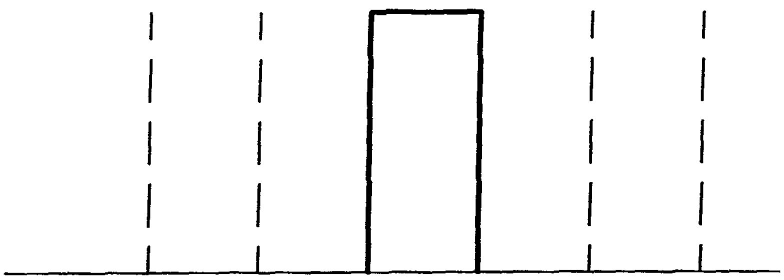

FIG. 14B

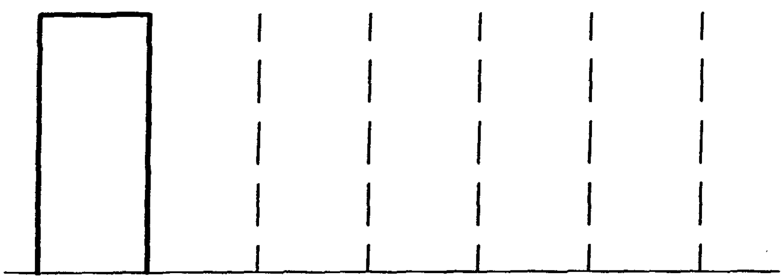

FIG. 14C

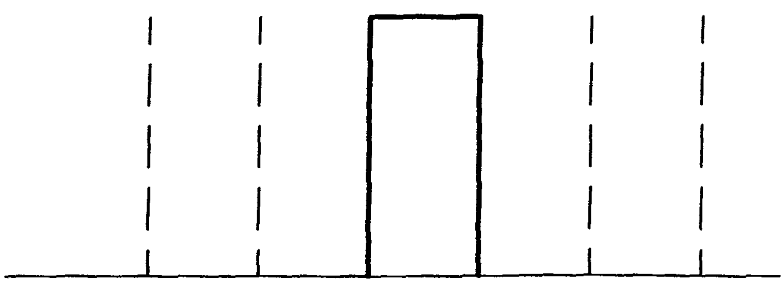

FIG. 14D

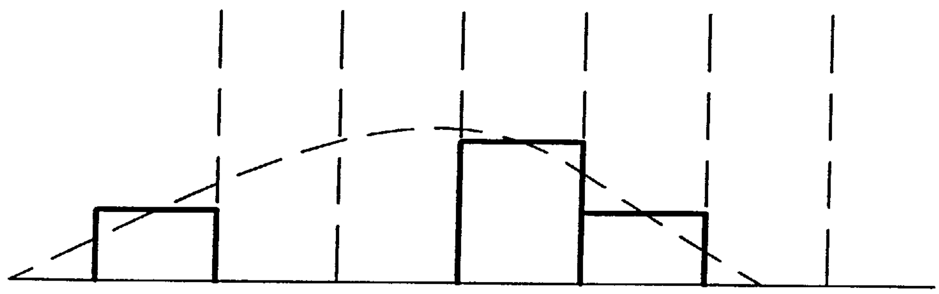

FIG. 15

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 02 00 1270

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	EP 0 837 446 A (CANON KK) 22 April 1998 (1998-04-22) * column 8, line 52 - column 10, line 1 * * column 19, line 56 - column 20, line 44; figure 16 * -----	1-8, 10-12	G09G3/36
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
			G09G

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	3 July 2002	Amian, D

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 02 00 1270

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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03-07-2002

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0837446 A	22-04-1998	JP 10177371 A	30-06-1998
		EP 0837446 A1	22-04-1998
		TW 385418 B	21-03-2000

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82