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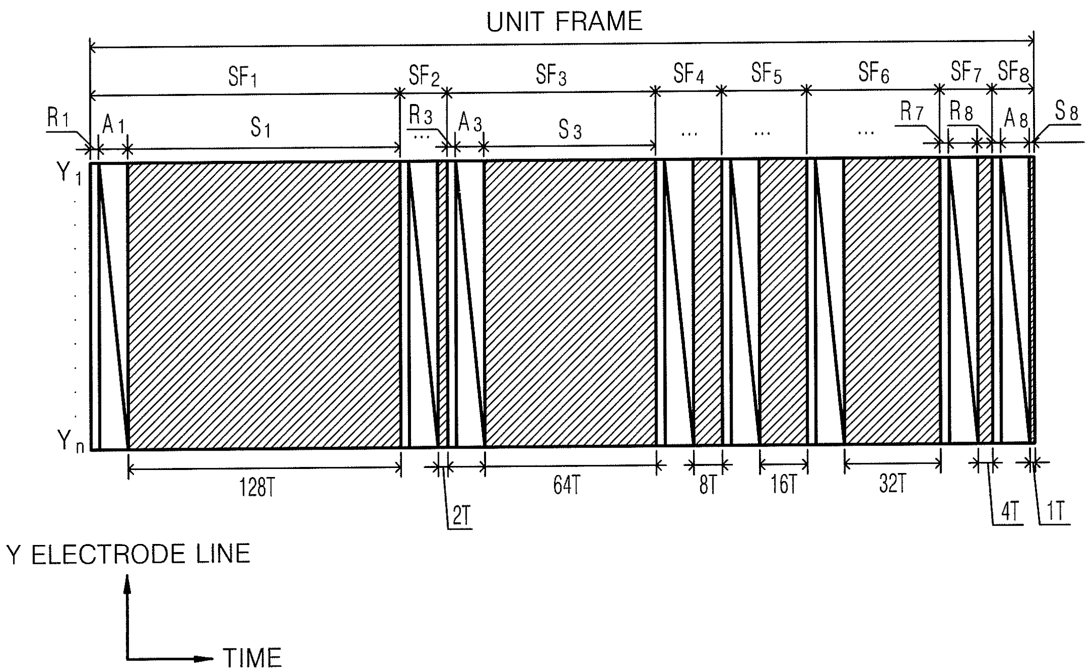
(54) **Method of driving discharge display panel for reducing audible noise**

(57) Provided is a method of driving a discharge display panel, in which sub fields of a unit frame are allocated different gray-scale weights and are time-division driven. Here, at least one other sub field is present between a sub field given a maximum gray-scale weight and a sub field given a second largest gray-scale weight.

FIG. 14



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Description

[0001] The present invention relates to a method of driving a discharge display panel, and more particularly, to a method of driving a discharge display panel, in which sub fields of a unit frame having different gray-level weights are time-division driven.

[0002] In a discharge display panel, such as a plasma display apparatus disclosed in US Patent No. 5,541,618, a unit frame is divided into a plurality of sub fields for time-division gray scale display, each of the sub fields including a reset period, an address period, and a sustain period. A unique gray-scale weight is allocated to each of the sub fields, and a sustain period is set to be proportional to the allocated gray-scale weight.

[0003] FIG. 1 is a view of a 3-electrode surface discharge plasma display panel 1 which is a conventional discharge display panel. FIG. 2 illustrates an example of a display cell of the plasma display panel 1 illustrated in FIG. 1.

[0004] Referring to FIGS. 1 and 2, address electrode lines A_{R1} through A_{Bm}, dielectric layers 11 and 15, X electrode lines X_1 through X_n that are sustain electrode lines, Y electrode lines Y_1 through Y_n that are scan electrode lines, phosphor layers 16, barrier ribs 17, and a MgO layer 12 that is a protective layer are formed between front and rear glass substrates 10 and 13 of the conventional 3-electrode surface discharge plasma display panel 1.

[0005] The address electrode lines A_{R1} through A_{Bm} are formed on a front surface of the rear glass substrate 13 in a predetermined pattern. The lower dielectric layer 15 is formed to cover the front surface of the rear glass substrate 13 and the address electrode lines A_{R1} through A_{Bm}. The barrier ribs 17 are formed in parallel with the address electrode lines A_{R1} through A_{Bm}, on a front surface of the lower dielectric layer 15. The barrier ribs 17 define discharge regions of display cells, and prevent optical crosstalk from occurring between the display cells. The phosphor layers 16 are applied to cover the display cells.

[0006] The X electrode lines X_1 through X_n (sustain electrode lines) and the Y electrode lines Y_1 through Y_n (scan electrode lines) are alternately formed in parallel on a rear surface of the front glass substrate 10 so that they intersect the address electrode lines A_{R1} through A_{Bm}. Display cells are defined at the points where a pair of the X electrode lines X_1 through X_n and the Y electrode lines Y_1 through Y_n intersect each of the address electrode lines A_{R1} through A_{Bm}. Each of the X electrode lines X_1 through X_n and each of the Y electrode lines Y_1 through Y_n are made by combining transparent electrode lines X_{na} and Y_{na} shown on FIG. 2 formed of a transparent conductive material, such as indium tin oxide (ITO), and metal electrode lines X_{nb} and Y_{nb} shown on FIG. 2 in order to increase conductivity. The front dielectric layer 11 is formed to cover the rear surface of the front glass substrate 10, the X electrode lines X_1 through X_n and the Y electrode lines Y_1 through Y_n. The protective layer 12, such as an MgO layer, which protects the plasma display panel 1 from a strong electric field, is formed on a rear surface of the front dielectric layer 11. A discharge space 14 is sealed and filled with a gas for generating plasma.

In a method of driving such a discharge display panel, a reset period, an address period, and a sustain period are sequentially included in a unit sub field. In the reset period, the states of electric charges in all display cells are equalized. In the address period, a predetermined wall potential is generated in selected display cells. In the sustain period, predetermined ac voltage is applied to all pairs of X and Y electrode lines in order to generate sustain discharge in the display cells in which the wall potential was generated in the address period. In the sustain period, plasma is generated by the gas for generating plasma included in the discharge space 14 of each of the selected display cells in which sustain discharge occurs, and then, ultraviolet rays are emitted to excite the phosphor layer 16, thus generating light. Referring to FIG. 3, an apparatus which drives the plasma display panel 1 illustrated in FIG. 1 includes an image processor 61, a controller 62, an address driver 63, an X driver 64, and a Y driver 65.

[0007] The image processor 61 transforms an external analog image signal into an internal digital image signal including 8-bit red (R), green (G), blue (B) image data, a clock signal, and a vertical and horizontal synchronization signal.

[0008] The controller 62 generates driving control signals S_A, S_Y, and S_X in response to the internal digital image signal received from the image processor 61.

[0009] The address driver 63 generates display-data signals by processing the address signal S_A of the driving control signals S_A, S_Y, and S_X received from the controller 62, and applies the generated display-data signals to the address electrode lines A_{R1} through A_{Bm} of FIG. 2. The X driver 64 drives the X electrode lines X_1 through X_n of FIG. 2 which are sustain electrode lines, in response to the X driving control signal S_X of the driving control signals S_A, S_Y, and S_X received from the controller 62. The Y driver 65 drives the Y electrode lines Y_1 through Y_n of FIG. 2 which are scan electrode lines, in response to the Y driving control signal S_Y of the driving control signals S_A, S_Y, and S_X received from the controller 62.

[0010] FIG. 4 illustrates a method of driving the plasma display panel 1 illustrated in FIG. 1 by using the apparatus of FIG. 3. Referring to FIG. 4, for time-division gray-scale display, each unit frame is divided into eight sub fields SF_1 through SF_8 to which gray-scale weights are allocated in ascending order. Also, each of the sub fields SF_1 through SF_8 are divided into reset periods R_1 through R_8, address periods A_1 through A_8, and sustain periods S_1 through S_8.

[0011] Discharge conditions for all display cells are equalized in the reset periods R_1 through R_8, and also, they are adjusted to be suitable for addressing to be performed in a subsequent period.

[0012] In the address periods A_1 through A_8, a display-data signal is applied to the address electrode lines A_{R1} through A_{Bm} of FIG. 1, and at the same time, scan pulses corresponding to the Y electrode lines Y_1 through Y_n are sequentially applied thereto. Accordingly, when the display-data signal is of a high-level during application of the scan pulses, addressing discharge occurs in a corresponding discharge cell thus generating wall charges therein, but wall charges are not generated in the other discharge cells.

[0013] In the sustain periods S_1 through S_8, a sustain pulse is alternately applied to all the Y electrode lines Y_1 through Y_n and all the X electrode lines X_1 through X_n, thus causing sustain discharge to occur in discharge cells where the wall charges were formed in the corresponding address periods A_1 through A_8. Thus, the output brightness in one of the display cells is proportional to the total length of the sustain periods in the unit frame which can be selected from any possible combination of sustain periods S_1 through S_8 available in each unit frame. In the present embodiment, the length of the sustain periods S_1 through S_8 in a unit frame is 255T (T denotes a unit duration). Therefore, 256 gray-scales can be displayed, including a case where display is not performed in a unit frame.

[0014] Here, a duration 1T corresponding to 2° is set for the sustain period S_1 of the first sub field SF_1, a duration 2T corresponding to 2^1 is set for the sustain period S_2 of the second sub field SF_2, a duration 4T corresponding to 2^2 is set for the sustain period S_3 of the third sub field SF_3, a duration 8T corresponding to 2^3 is set for the sustain period S_4 of the fourth sub field SF_4, a duration 16T corresponding to 2^4 is set for the sustain period S_5 of the fifth sub field SF_5, a duration 32T corresponding to 2^5 is set for the sustain period S_6 of the sixth sub field SF_6, a duration 64T corresponding to 2^6 is set for the sustain period S_7 of the seventh sub field SF_7, and a duration 128T corresponding to 2^8 is set for the sustain period S_8 of the first sub field SF_8.

[0015] Thus, when a subfield to be displayed is properly selected from among the eight sub fields SF_1 through SF_8, 256 gray-scales, including a zero gray scale where nothing is displayed in any subfield, can be displayed.

[0016] FIG. 5 is a timing diagram of driving signals to be applied to the plasma display panel 1 illustrated in FIG. 1 in a single sub field SF of the subfields illustrated in FIG. 4. In FIG. 5, S_{AR1}, ..., $_{ABm}$ denote driving signals to be respectively applied to address electrode lines A_{R1} through A_{Bm} of FIG. 1, S_{X1}, ...,$_{Xn}$ denote driving signals to be respectively applied to the X electrode lines X_1 through X_n of FIG. 1, and S_{Y1} through S_{Yn} denote driving signals to be respectively applied to the Y electrode lines Y, through Y_n of FIG. 1.

[0017] FIG. 6 is a diagram illustrating the distribution of wall charges in a display cell at an instant of time t_5 of FIG. 5. FIG. 7 is a diagram illustrating the distribution of wall charges in a display cell at an instant of time t_8 of FIG. 5. In FIGS. 6 and 7, the reference numerals that are the same as those of FIG. 2 denote the same elements. Referring to FIG. 5, in wall charge accumulation durations t1 through t5 of a reset period R of a sub field SF of FIG. 4, an electric potential applied to Y electrode lines Y_1 through Y_n is increased from a ground electric potential V_G to a first electric potential V_{SET} + | V_{SCL}-V_{SCH} | having positive polarity, e.g., 355 V, which is a maximum electric potential that is the addition of a sixth electric potential V_{SET} and a third electric potential | V_{SCL}-V_{SCH} | The third electric potential | V_{SCL}-V_{SCH} having positive polarity is generated due to the difference between the second electric potential V_{SCL} having negative polarity and the fourth electric potential V_{SCH} having negative polarity.

[0018] A ground electric potential V_G is applied to X electrode lines X_1 through X_n and address electrode lines A_{R1} through A_{Bm}.

[0019] Accordingly, discharge occurs among the Y electrode lines Y_1 through Y_n and the X electrode lines X_1 through X_n, and among the Y electrode lines Y_1 through Y_n and the address electrode lines A_{R1} through A_{Bm}. As a result, wall charges having negative polarity are formed around all the Y electrode lines Y_1 through Y_n, wall charges having positive polarity are formed around all the X electrode lines X_1 through X_n, and wall charges having positive polarity are formed around all the address electrode lines A_{R1} through A_{Bm} (see FIG. 6).

[0020] Next, in wall charge distribution durations t5 through t8 of the reset period R of a sub field SF of FIG. 4, an electric potential applied to the Y electrode lines Y_1 through Y_n is reduced from the first electric potential V_{SET} + | V_{SCL}-V_{SCH} to the second electric potential V_{SCL} having negative polarity while an electric potential applied to the X electrode lines X_1 through X_n is maintained to be equal to a fifth electric potential V_{E1}. Here, a ground electric potential V_G is applied to the address electrode lines A_{R1} through A_{Bm}. Thus, discharge occurring among the X electrode lines X_1 through X_n and the Y electrode lines Y_1 through Y_n allows some of the wall charges formed around the Y electrode lines Y_1 through Y_n to be appropriately moved around the X electrode lines X_1 through X_n (see FIG. 8). Also, the ground electric potential V_G is applied to the address electrode lines A_{R1} through A_{Bm}, and thus, the wall charges having positive polarity formed around the address electrode lines A_{R1} through A_{Bm} are appropriately reduced (see FIG. 7).

[0021] Accordingly, in a subsequent address period A, display-data signals $S_{AR1,}$ ..., $_{ABm}$ are applied to the address electrode lines A_{R1} through A_{Bm}, and a scan pulse of the second electric potential V_{SCL} having negative polarity is sequentially applied to the Y electrode lines Y_1 through Y_n which are biased to the fourth electric potential V_{SCH} having negative polarity, thereby smoothly performing addressing.

[0022] For display-data signals to be respectively applied to the address electrode lines A_{R1} through A_{Bm}, the first address electric potential V_A having positive polarity is applied when a display cell is selected, and the ground electric potential V_G is applied otherwise. Thus, when display-data pulses of first address electric potential V_A having positive polarity are applied during application of scan pulses of the second electric potential V_{SCL} having negative polarity, addressing discharge occurs in corresponding display cells, thus generating a wall potential equal to or higher than a set electric charge therein, but a wall potential equal to or higher than the set electric potential are not formed in the other display cells. Here, the fifth electric potential V_{E1} having positive polarity is applied to the X electrode lines X_1 through X_n in order that X electrode lines in selected display cells are influenced by the addressing discharge.

[0023] In a sustain period S, sustain pulses of a seventh electric potential V_S having positive polarity are alternately applied to all the Y electrode lines Y_1 through Y_n and X electrode lines X_1 through X_n. Therefore, in the sustain period S, sustain discharge occurs in the display cells in which the wall potential equal to or greater than the set electric potential was formed during the corresponding address period A_A.

[0024] A conventional discharge display apparatus as described above has a basic problem that comparatively loud noise is generated since it is driven by high ac voltage.
In particular, such a noise problem becomes serious, considering a recent trend that substrates of a discharge display apparatus (the front and rear glass substrates 10 and 13 of FIG. 1) become thinner and a driving voltage becomes higher due to partial pressure of discharge gas for high driving efficiency.

[0025] For example, the intensity of audible noise in a plasma display apparatus is significantly increased, when the thickness of the front glass substrate 10 of the plasma display panel 1 illustrated in FIG. 1 is less than 1.8 mm and the electric potential Vs, illustrated in FIG. 5, of the sustain pulses is greater than 200 V.

[0026] The present invention provides a method of driving a discharge display panel while efficiently reducing audible noise generated in the discharge display apparatus. According to an aspect of the present invention, there is provided a method of driving a discharge display panel, in which sub fields of a unit frame are given different gray-scale weights and are time-division driven, wherein at least one other sub field is present between a sub field given a maximum gray-scale weight and a sub field given a second largest gray-scale weight.

[0027] According to the above method, it is possible to efficiently reduce basic noise generated in a discharge display apparatus. Actually, it was proved that noise generated in a discharge display apparatus has frequency characteristics that the intensity of audible noise in a most sensitive low-frequency band of human audible frequency bands diminishes when at least one sub field is present between a sub field given a maximum gray-scale weight and a sub field given a second largest gray-scale weight.

[0028] The above and other features and advantages of the present invention will become more apparent by describing in detail exemplary embodiments thereof with reference to the attached drawings in which:

FIG. 1 is a perspective view illustrating the internal structure of a 3-electrode surface discharge plasma display panel which is a conventional discharge display panel;
FIG. 2 is a cross-sectional view of one of display cells of the plasma display panel illustrated in FIG. 1;
FIG. 3 is a block diagram of an apparatus for driving the plasma display panel illustrated in FIG. 1;
FIG. 4 is a timing diagram illustrating a method of driving the plasma display panel of FIG. 1 by using the apparatus illustrated in FIG. 3;
FIG. 5 is a waveform diagram of driving signals applied to the plasma display panel of FIG. 1 in one of sub fields illustrated in FIG. 4;
FIG. 6 is a diagram illustrating the distribution of wall charges formed in a display cell at an instant of time t_5 illustrated in FIG. 5;
FIG. 7 is a diagram illustrating the distribution of wall charges formed in a display cell at an instant of time t_8 illustrated in FIG. 5;
FIG. 8 is a graph illustrating noise characteristics in two models of plasma display apparatus, over frequency;
FIG. 9 is a graph illustrating the frequency characteristics of driving signals applied to the plasma display panel 1 of FIG. 1 under various conditions, when the method of FIG. 4 is performed;
FIG. 10 is a graph illustrating the frequency characteristics of driving signals applied to the plasma display panel 1 of FIG. 1 and the frequency characteristics of resultant noise, when the method of FIG. 4 is performed;
FIG. 11 is a graph illustrating the frequency characteristics of driving signals applied to the plasma display panel of FIG. 1 by using only the three sub fields, of the subfields illustrated in FIG. 10, to which first through third largest gray-scale weights are allocated, and the frequency characteristics of resultant noise.
FIGS. 12 and 13 are graphs illustrating the frequency characteristics of driving signals applied to the plasma display panel of FIG. 1 by using the structure of sub fields in which at least one other sub field is present between a sub field given a maximum gray-scale weight and a sub field given a second largest gray-scale weight and between a sub field given the second largest gray-scale weight and a sub field given a third largest gray-scale weight, and the frequency characteristics of resultant noise;
FIG. 14 is a timing diagram illustrating a method of driving a discharge display panel based on experiment results illustrated in FIGS. 8 through 13, according to an embodiment of the present invention; and
FIG. 15 is a timing diagram illustrating a method of driving a discharge display panel based on experiment results

illustrated in FIGS. 8 through 13, according to another embodiment of the present invention.

[0029] Hereinafter, exemplary embodiments of the present invention will be described in detail with reference to the accompanying drawings. Here, descriptions with reference to FIGS. 8 through 13 are related to experiments that are important to perform exemplary embodiments of the present invention. The above descriptions with reference to FIGS. 1 through 3 are also applicable to the present invention.

FIG. 8 is a graph illustrating the audible noise characteristics of two models of plasma display apparatus taken over frequency. That is, in FIG. 8, reference numeral C81 denotes a plot showing the frequency characteristics of noise in a first model of plasma display apparatus, and reference numeral C81denotes a plot showing the frequency characteristics of noise in a second model of plasma display apparatus.

Referring to FIG. 8, the intensity of audible noise generated in a plasma display apparatus is increased of human audible frequency bands. Thus, the intensity of audible noise in the most sensitive low-frequency band of the human audible frequency bands must be reduced in order to efficiently reduce noise in the plasma display apparatus. For this, it is required to find out the factors that can change the frequency characteristics of noise in the plasma display apparatus.

[0030] When the thickness of the front glass substrate 10 of a plasma display panel, such as the plasma display panel 1 illustrated in FIG. 1, is less than 1.8 mm and the electric potential V_S of sustain pulses, such as those shown in FIG. 5, is greater than 200 V, the intensity of the above noise is significantly increased.

[0031] FIG. 9 is a graph illustrating the frequency characteristics of driving signals applied to the plasma display panel 1 of FIG. 1 under various conditions when the method of FIG. 4 is performed.

[0032] In FIG. 9, reference numeral C91 denotes a first frequency characteristic curve showing the frequency characteristics of driving signals obtained by performing Fourier transform on a combination of waveforms of driving signals when the plasma display panel 1 is driven according to the method of FIG. 4. The first frequency characteristics curve C91 shows that the levels of signal are comparatively high in a low-frequency band A9 which is a sensitive frequency band, as indicated by the frequency characteristics curves C81 and C82 of FIG. 8. That is, the frequency characteristics of noise vary depending on the frequency characteristics of the driving signals.

[0033] Reference numeral C92 denotes a second frequency characteristic curve showing the frequency characteristics of driving signals obtained by performing Fourier transform on a combination of waveforms of driving signals when the plasma display panel 1 is driven according to the method of FIG. 4, using only the sustain periods S_1 through S_8 of the sub field SF_1 through SF_8 while removing the reset periods R_1 through R_8 and the address periods A_1 through A_8 thereof. The second frequency characteristic curve C92 is similar to the first frequency characteristic curve C91 in the low-frequency band A9 which is a sensitive frequency band. Accordingly, noise characteristics in the most sensitive low-frequency band A9 of the human audible frequency band are highly dependent on the sustain periods S_1 through S_8.

[0034] Reference numeral C93 denotes a third frequency characteristic curve showing the frequency characteristics of driving signals obtained by performing Fourier transform on a combination of waveforms of driving signals when the plasma display panel 1 is driven according to the method of FIG. 4, using only the seventh and eighth sustain periods S_7 and S_8 while removing the reset periods R_1 through R_8, the address periods A_1 through A_8, and the first through sixth sustain periods S_1 through S_6 of sub field SF_1 through SF_8. The third frequency characteristic curve C93 is similar to the first and second frequency characteristic curves C91 and C92 in the low-frequency band A9 which is a sensitive frequency band.

[0035] Accordingly, the noise characteristics of the most sensitive low-frequency band A9 of the human audible frequency bands are significantly dependent on the sustain periods S_1 through $S_{8,}$ and particularly, sustain periods, such as the sustain periods S_7 and S_8, which are given a high gray-scale weight.

[0036] More specifically, the noise characteristics of the most sensitive low-frequency band A9 of the human audible frequency bands are significantly dependent on time intervals (time intervals R_8 and A_8) between sustain periods (the sustain periods S_7 and S_8), which are given a high gray-scale weight, and the durations of the sustain periods (durations 64T and 128T). However, since it is difficult to adjust the time intervals between the sustain periods and the durations of the sustain periods, it is needed to determine whether the intensity of audible noise in the sensitive low-frequency band A9 is reduced by changing the arrangement of the sustain periods S_1 through S_8.

[0037] FIG. 10 is a graph illustrating the frequency characteristics C101 of driving signals applied to the plasma display panel 1 of FIG. 1 and the frequency characteristics C102 of resultant noise when using the structure of sub fields to which gray-scale weights are allocated in ascending order as in the conventional method of FIG. 4.

FIG. 11 is a graph illustrating the frequency characteristics of driving signals applied to the plasma display panel of FIG. 1 by using only the three sub fields, of the subfields illustrated in FIG. 4, to which first through third largest gray-scale weights are allocated, and the frequency characteristics of resultant noise.

[0038] FIG. 12 is a graph illustrating the frequency characteristics of driving signals applied to the plasma display panel 1 of FIG. 1, when using the structure of subfields in which another sub field is present between a sub field given a maximum gray-scale weight and a sub field given a second largest gray-scale weight and between the sub field given the second largest gray-scale weight and a sub field given a third largest gray-scale weight, and the frequency characteristics of resultant noise.

[0039] FIG. 13 is a graph illustrating the frequency characteristics of driving signals applied to the plasma display panel 1 of FIG. 1, when using the structure of subfields in which two other sub fields are present between a sub field given a maximum gray-scale weight and a sub field given a second largest gray-scale weight and between the sub field given the second largest gray-scale weight and a sub field given a third largest gray-scale weight, and the frequency characteristics of resultant noise. Table 1 shows gray-scale weights allocated to 11 sub fields SF_1 through SF_{11} used to obtain the frequency characteristics curves illustrated in FIGS. 10 through 13.

[Table 1]

	SF_1	SF_2	SF_3	SF_4	SF_5	SF_6	SF_7	SF_8	SF_9	SF_{10}	SF_{11}
FIG. 10	1	3	7	16	28	48	80	128	180	236	292
FIG. 11	1	1	1	1	1	1	1	1	290	333	388
FIG. 12	292	3	236	1	180	7	128	16	80	28	48
FIG. 13	292	3	1	236	7	16	180	128	80	48	28

[0040] A comparison of FIGS. 10 and 11 reveals that the frequency characteristics C101 and C111 of driving signals are similar in most sensitive low-frequency bands A10 and A11 of human audible frequency bands, and thus, the frequency characteristics C102 and C112 of noise are also similar to each other. That is, the noise characteristics in the most sensitive low-frequency bands A10 and A11 are significantly dependent on the sub fields SF_9 through SF_{11} allocated high gray-scale weights sustain periods.

[0041] Further, a comparison of FIGS. 10 and 12 reveals that the frequency characteristics C101 and C121 of driving signals are different from each other, and thus, the frequency characteristics C102 and C122 of noise are also different from each other. More specifically, the intensity of audible noise illustrated in FIG. 12 is lower than that of noise illustrated in FIG. 10 in the most sensitive low-frequency bands A10 and A121 of human audible frequency bands. Thus, FIG. 12 and Table 1 show that audible noise in a plasma display apparatus is efficiently reduced when the sub field SF_2 is present between the sub field SF_1 allocated a maximum gray-scale weight and the sub field SF_3 allocated a second largest gray-scale weight and the sub field SF_4 is present between the sub field SF_3 allocated the second largest gray-scale weight and a sub field SF_5 allocated a third largest gray-scale weight. Of course, the intensity of audible noise in a middle and low frequency region A122 of FIG. 12 is slightly greater than that of a middle and low frequency region of FIG. 10. However, although the intensity of audible noise in the region A122 is slightly increased, this region is not audible by humans, and thus, the noise in this region can be neglected.

[0042] Similarly, a comparison of FIGS. 10 and 13 reveals that the frequency characteristics C101 and C131 of driving signals are different from each other, and thus, the frequency characteristics C102 and C132 of audible noise are also different from each other. More specifically, the intensity of audible noise illustrated in FIG. 13 is lower than that of audible noise illustrated in FIG. 10 in the most sensitive low-frequency bands A10 and A131 of the human audible frequency bands. Thus, FIG. 13 and Table 1 show that audible noise in the plasma display apparatus is efficiently reduced when two other sub fields SF_2 and SF_3 are present between the sub field SF_1 given a maximum gray-scale weight and a sub field SF_4 given a second largest gray-scale weight and two other sub fields SF_5 and SF_6 are present between the sub field SF_4 given the second largest gray-scale weight and the sub field SF_7 given a third largest gray-scale weight plasma display apparatus. Of course, the intensity of audible noise in a middle and low frequency region A132 of FIG. 13 is slightly greater than that of a middle and low frequency region of FIG. 10. However, although the intensity of audible noise in the region A132 is slightly increased, this region is not audible to humans, and thus, the noise in this region can be neglected. FIG. 14 is a timing diagram illustrating a method of driving a discharge display panel based on the experiment results illustrated in FIGS. 8 through 13, according to an embodiment of the present invention. Referring to FIG. 14, for time-division gray-scale display, each of all unit frames is divided into 8 sub fields SF_1 through SF_8. Also, the sub fields SF_1 through SF_8 are divided into reset periods R_1 through R_8, address periods A_1 through A_8, and sustain periods S_1 through S_8.

[0043] Here, the sub field SF_2 is present between the sub field SF_1 given a maximum gray-scale weight and the sub field SF_3 given a second largest gray-scale weight. Also, the two sub fields SF_4 and SF_5 are present between the sub field SF_3 given the second largest gray-scale weight and the sub field SF_6 given a third largest gray-scale weight. Accordingly, it is possible to efficiently reduce audible noise in a plasma display apparatus, as described above with reference to Table 1 and FIGS. 10 through 13. FIG. 15 is a timing diagram illustrating a method of driving a discharge display panel based on the experiment results illustrated in FIGS. 8 through 13, according to another embodiment of the present invention. Referring to FIG. 15, for time-division gray-scale display, each of all unit frames is divided into 8 sub fields SF_1 through SF_8. Also, the sub fields SF_1 through SF_8 are divided into reset periods R_1 through $R_{8,}$ address periods A_1 through A_8, and sustain periods S_1 through S_8.

[0044] Here, the two sub fields SF_2 and SF_3 are present between the sub field SF_1 given a maximum gray-scale weight and the sub field SF_4 given a second largest gray-scale weight. Also, the sub field SF_5 is present between the sub field SF_4 given the second largest gray-scale weight and the sub field SF_6 given a third largest gray-scale weight. Accordingly, it is possible to efficiently reduce audible noise in a plasma display apparatus, as described above with reference to Table 1 and FIGS. 10 through 13. As described above, according to a method of driving a discharge display panel according to the present invention, noise in a discharge display apparatus can be efficiently reduced. The reason is that the intensity of audible noise is significantly reduced in the most sensitive low-frequency band of human audible frequency bands by arranging at least one sub field to be present between a sub field given a maximum gray-scale weight and a sub field given a second largest gray-scale weight. While this invention has been particularly shown and described with reference to exemplary embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the invention as defined by the appended claims.

Claims

1. A method of driving a discharge display panel, in which sub fields of a unit frame are given different gray-scale weights and are time-division driven, wherein at least one other sub field is present between a sub field given a maximum gray-scale weight and a sub field given a second largest gray-scale weight.

2. A method of driving a discharge display panel to control grey scale comprising applying a driving signal using a unit time frame divided into a plurality of sub fields, each having a different duration corresponding to a different grey scale amount, wherein the driving signal is applied in one or more of the subfields corresponding to a required total grey scale amount, **characterised in that** the sub fields are arranged in the unit time frame such that at least one other sub field is present between a sub field having a longest duration, and a sub field having a second longest duration.

3. A method according to claim 1 or 2, wherein at least one other sub field is present between the sub field having the second longest duration and a sub field having a third longest duration.

4. A method according to claim 1, 2 or 3, wherein each sub field comprises a reset period having the same duration for each sub field, an address period having the same duration for each sub field and a sustain period having a different duration for each sub field.

5. A method according to claim 4, wherein the discharge display panel comprises address electrode lines formed to intersect scan electrode lines between a front substrate and a rear substrate and sustain electrode lines are formed between and parallel to the scan electrode lines and wherein, in the sustain period, sustain pulses are alternately applied to the scan electrode lines and the sustain electrode lines, the number of pulses applied being proportional to the grey scale amount corresponding to the sub field.

6. A method according to claim 5, wherein the thickness of the front substrate is less than 1.8mm and the electric potential of the sustain pulses is greater than 200V.

7. A discharge display apparatus comprising:

   a discharge display panel; and
   a grey scale controller configured to control a driving signal using a unit time frame divided into a plurality of sub fields, each having a different duration corresponding to a different grey scale amount, and apply the driving signal to the display during one or more of the subfields corresponding to a required total grey scale amount, **characterised in that** the sub fields are arranged in the unit time frame such that at least one other sub field is present between a sub field having a longest duration, and a sub field having a second longest duration.

8. A discharge display apparatus according to claim 7, wherein at least one other sub field is present between the sub field having the second longest duration and a sub field having a third longest duration.

9. A discharge display apparatus according to claim 7 or 8, wherein each sub field comprises a reset period having the same duration for each sub field, an address period having the same duration for each sub field and a sustain

period having a different duration for each sub field.

10. A discharge display apparatus according to claim 9, wherein the discharge display panel comprises:

a front substrate and a rear substrate;
address electrode lines;
scan electrode lines formed between the front substrate and the rear substrate which intersect the address electrode lines to form a grid; and
sustain electrode lines formed between and parallel to the scan electrode lines;
wherein, the grey scale controller is configured to, in the sustain period, alternately apply sustain pulses to the scan electrode lines and the sustain electrode lines, the number of pulses applied being proportional to the grey scale amount corresponding to the sub field.

11. A discharge display apparatus according to claim 10, wherein the thickness of the front substrate is less than 1.8mm and the electric potential of the sustain pulses is greater than 200V.

FIG. 1 (PRIOR ART)

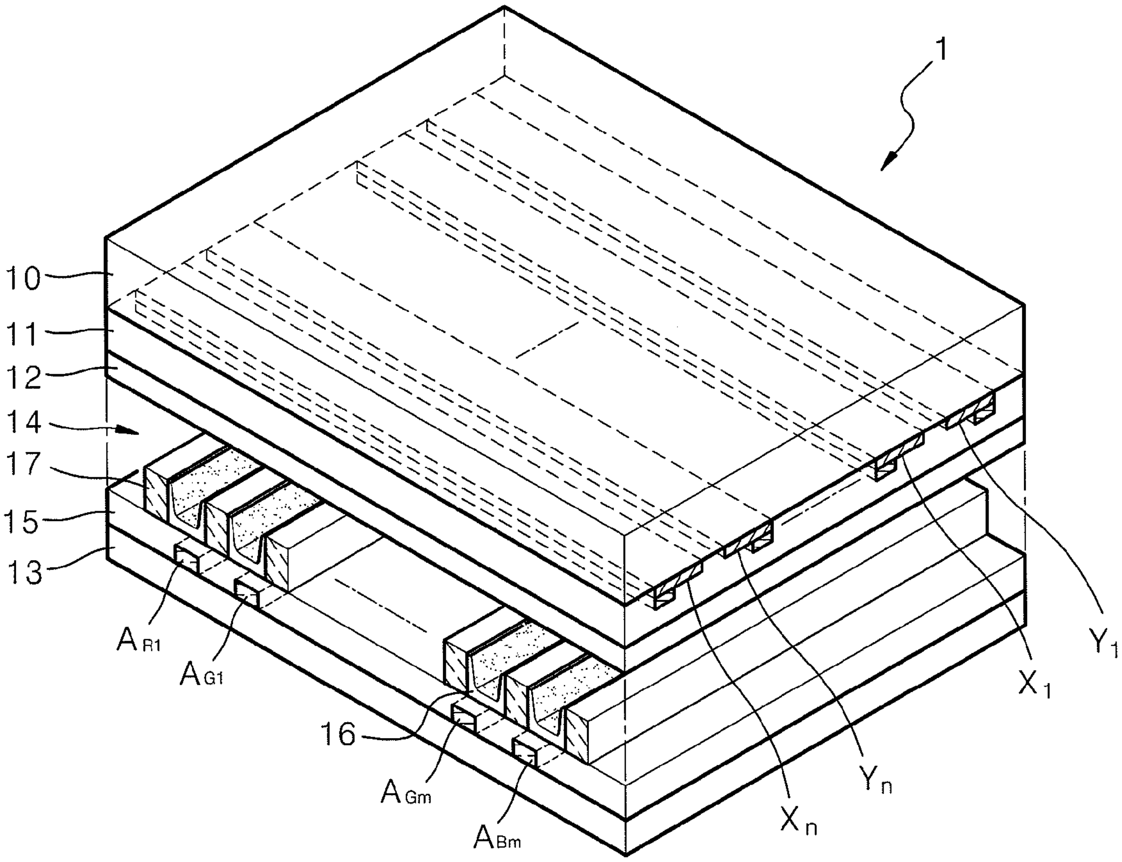


FIG. 2 (PRIOR ART)

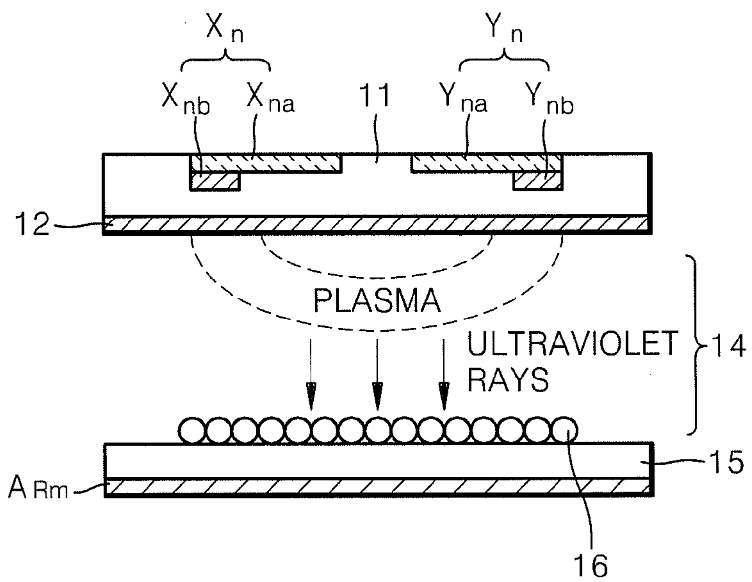


FIG. 3 (PRIOR ART)

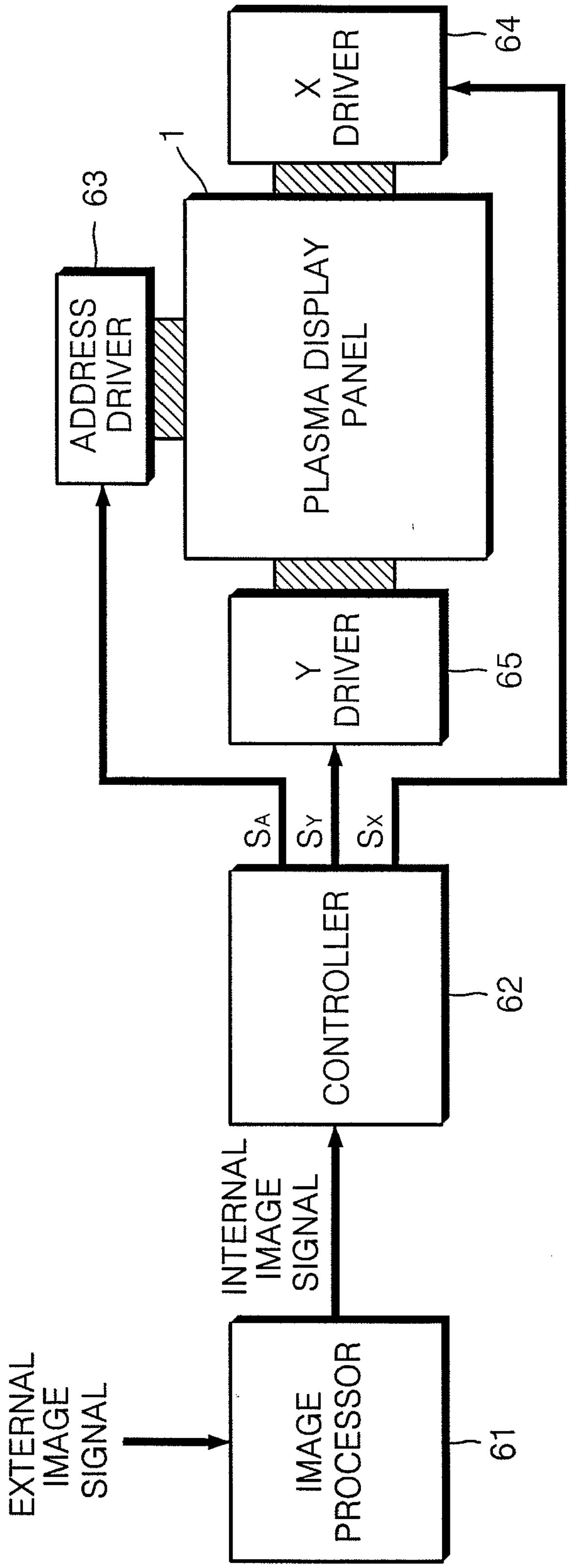


FIG. 4

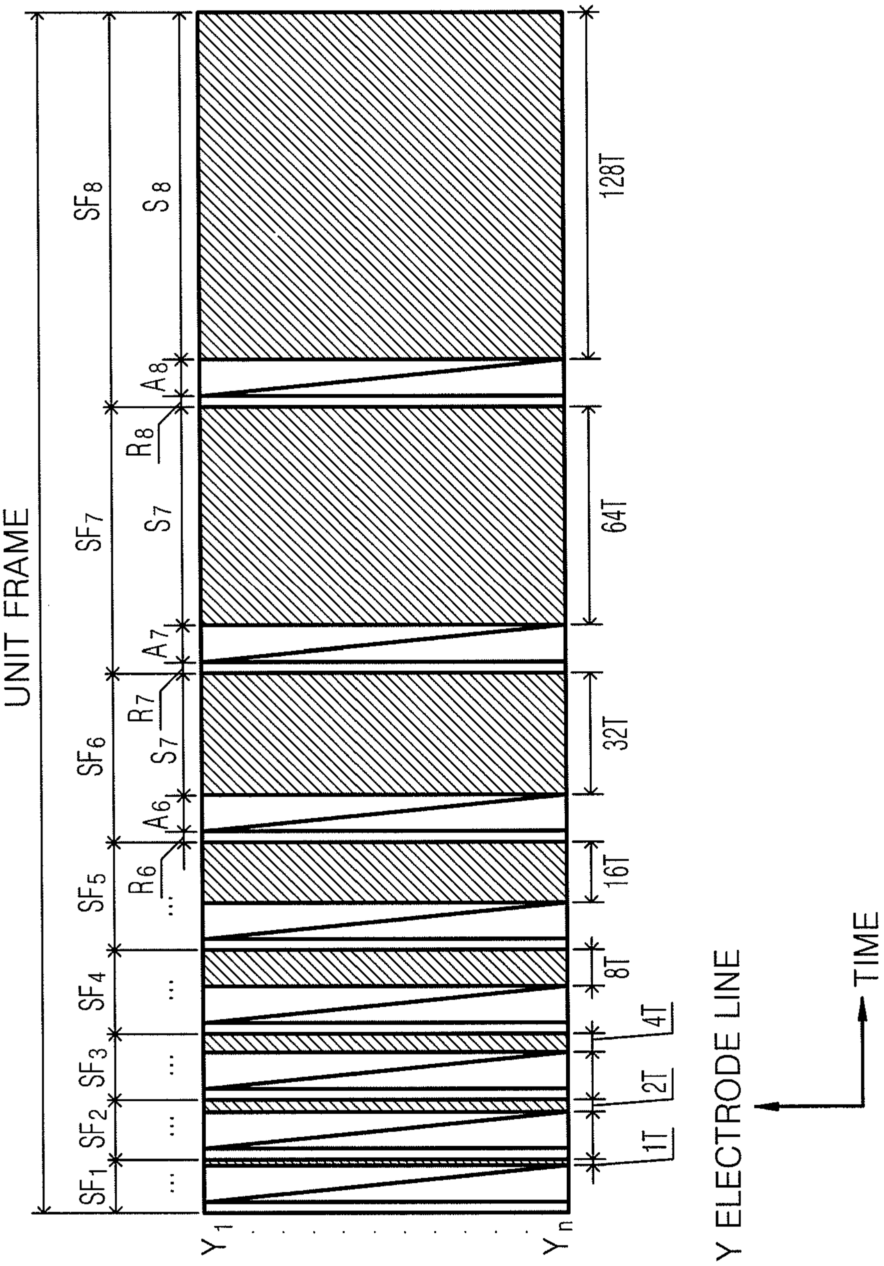

UNIT FRAME
SF_1
SF_2
SF_3
SF_4
SF_5
SF_6
SF_7
SF_8
R_6
A_6
S_7
R_7
A_7
S_7
R_8
A_8
S_8
1T
2T
4T
8T
16T
32T
64T
128T
Y_1
Y_n
Y ELECTRODE LINE
TIME

FIG. 5 (PRIOR ART)

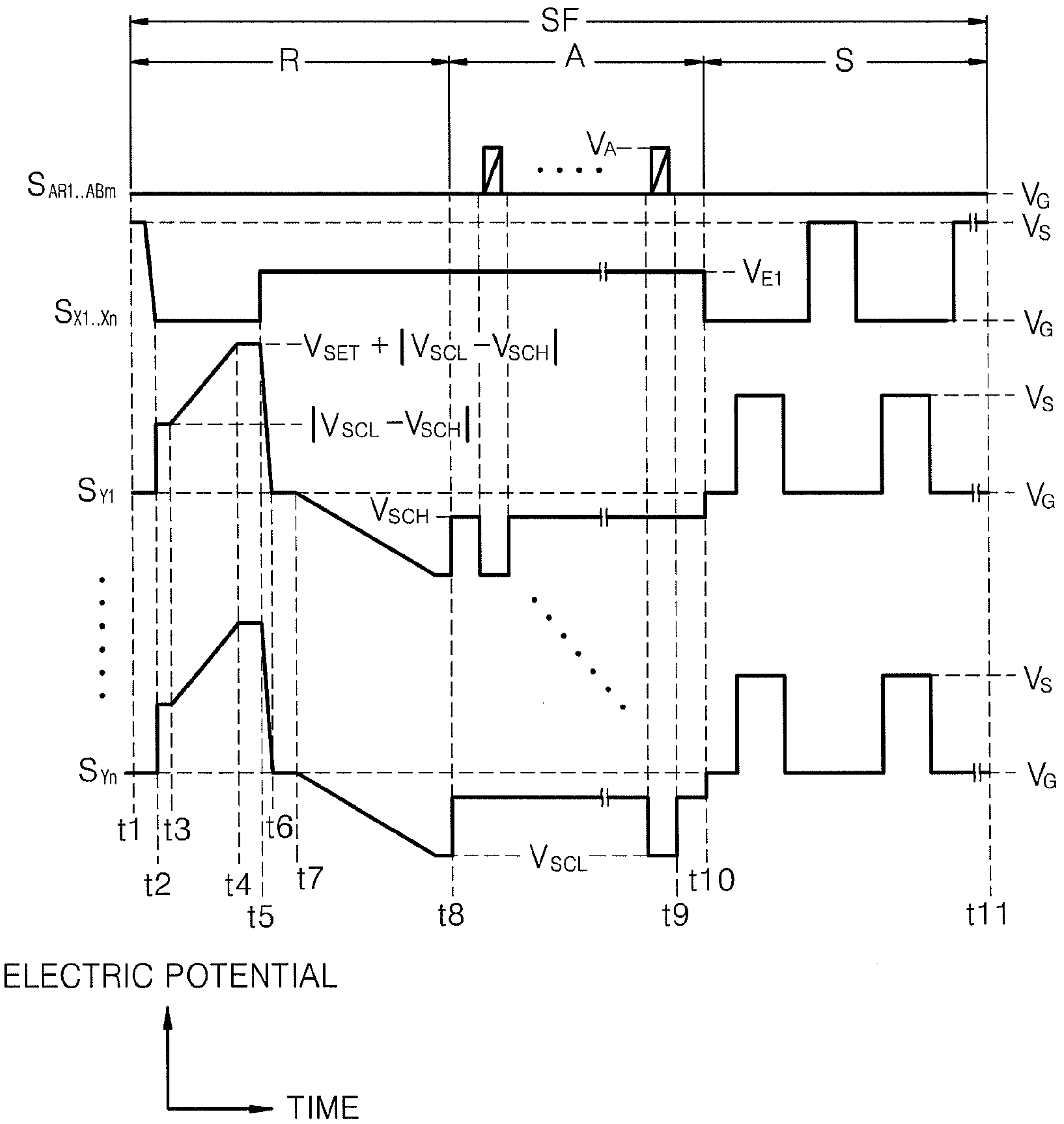


FIG. 6 (PRIOR ART)

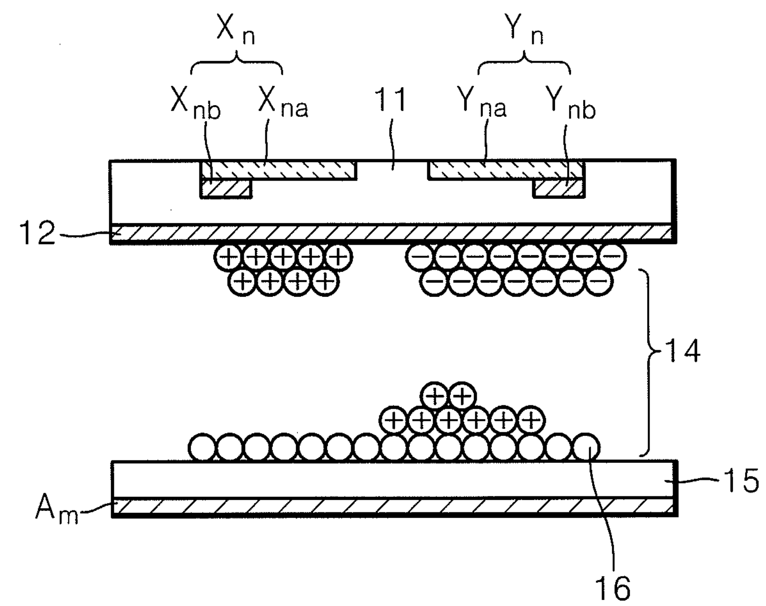


FIG. 7 (PRIOR ART)

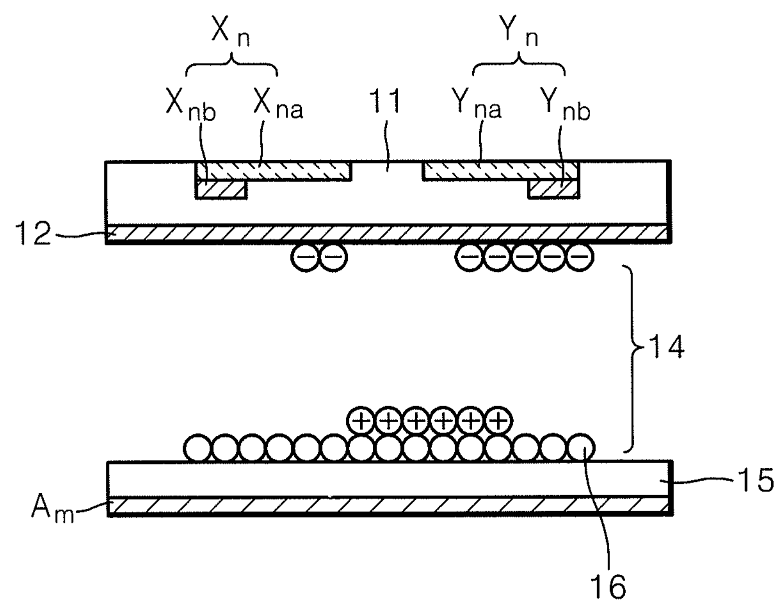


FIG. 8

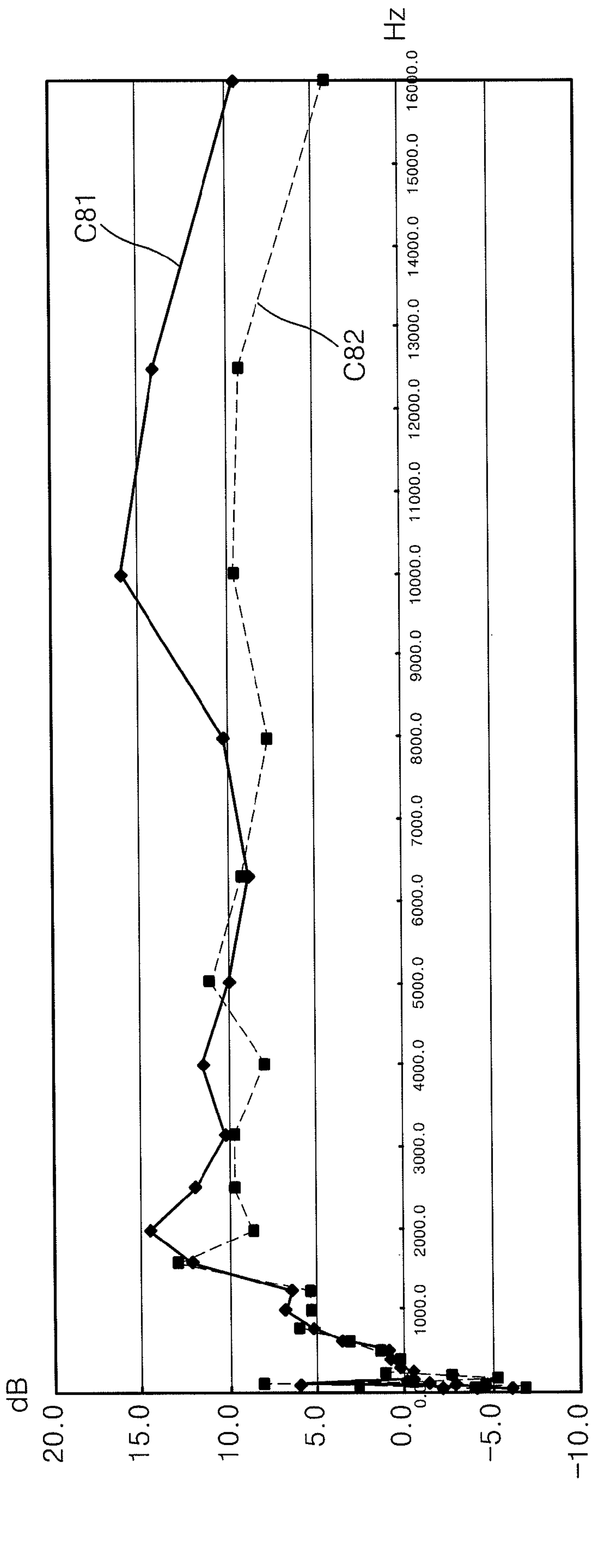
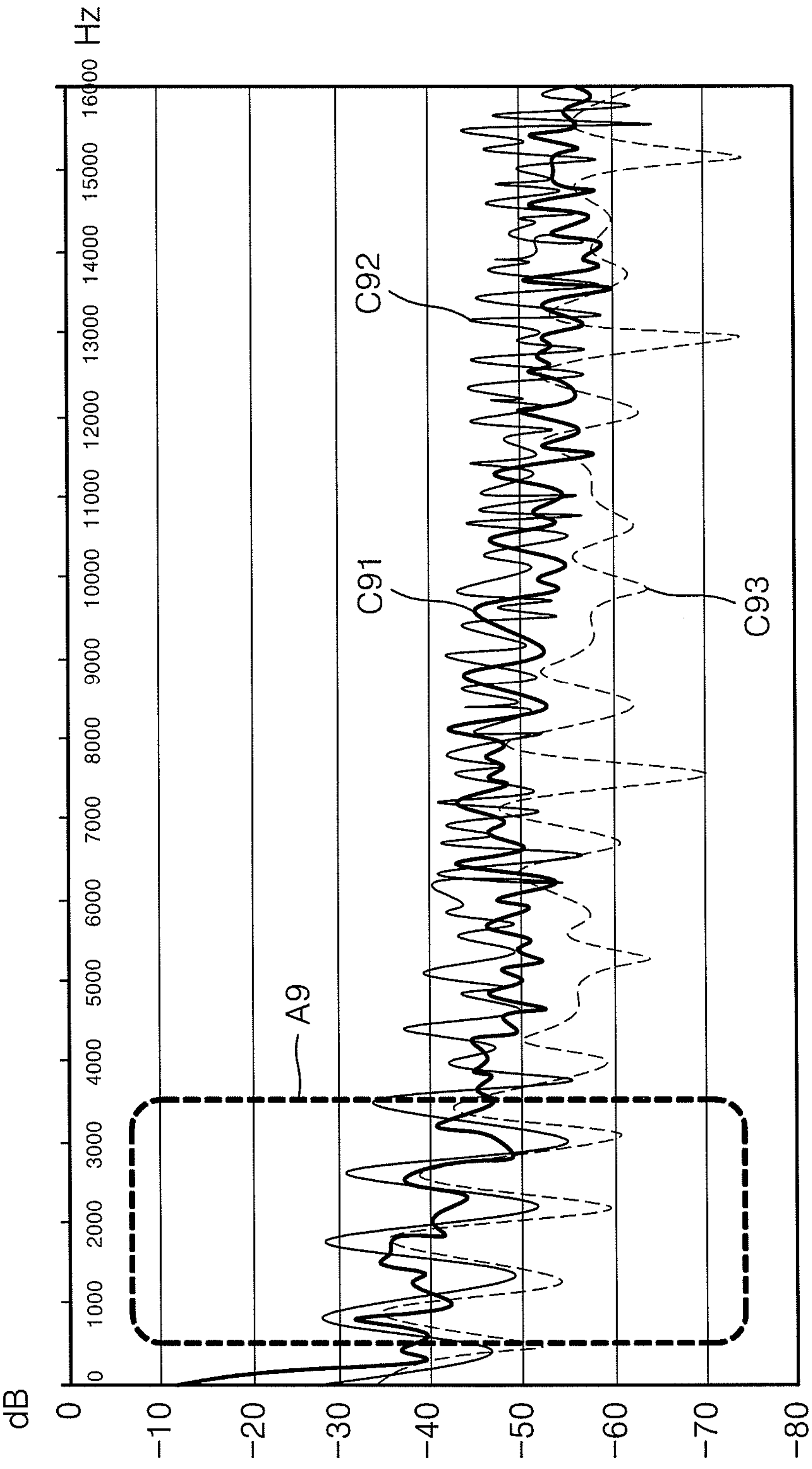

dB
20.0
15.0
10.0
5.0
0.0
-5.0
-10.0
Hz
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
8000.0
9000.0
10000.0
11000.0
12000.0
13000.0
14000.0
15000.0
16000.0
C81
C82

FIG. 9



dB
0
-10
-20
-30
-40
-50
-60
-70
-80
Hz
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000
A9
C91
C92
C93

FIG. 10

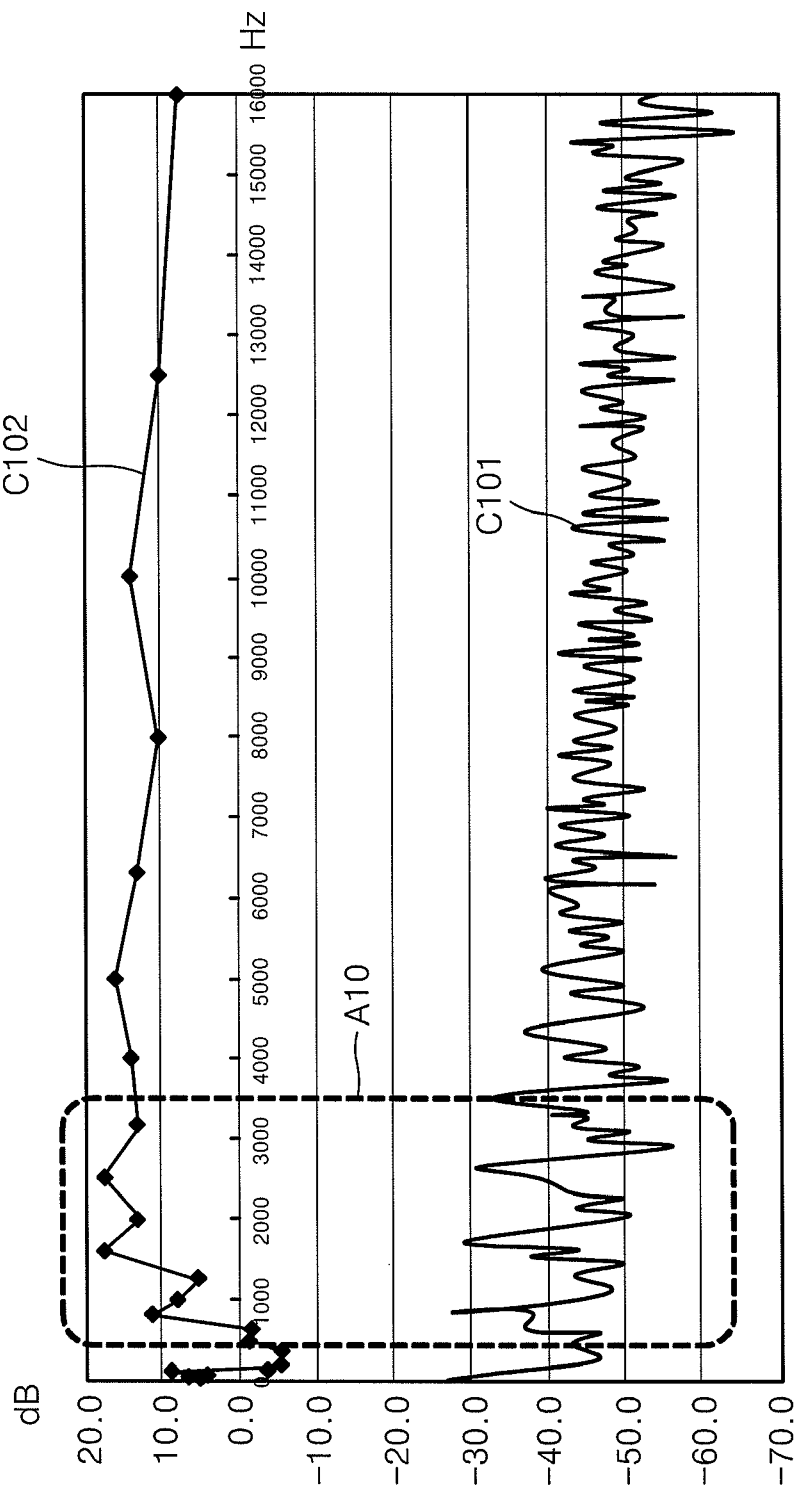
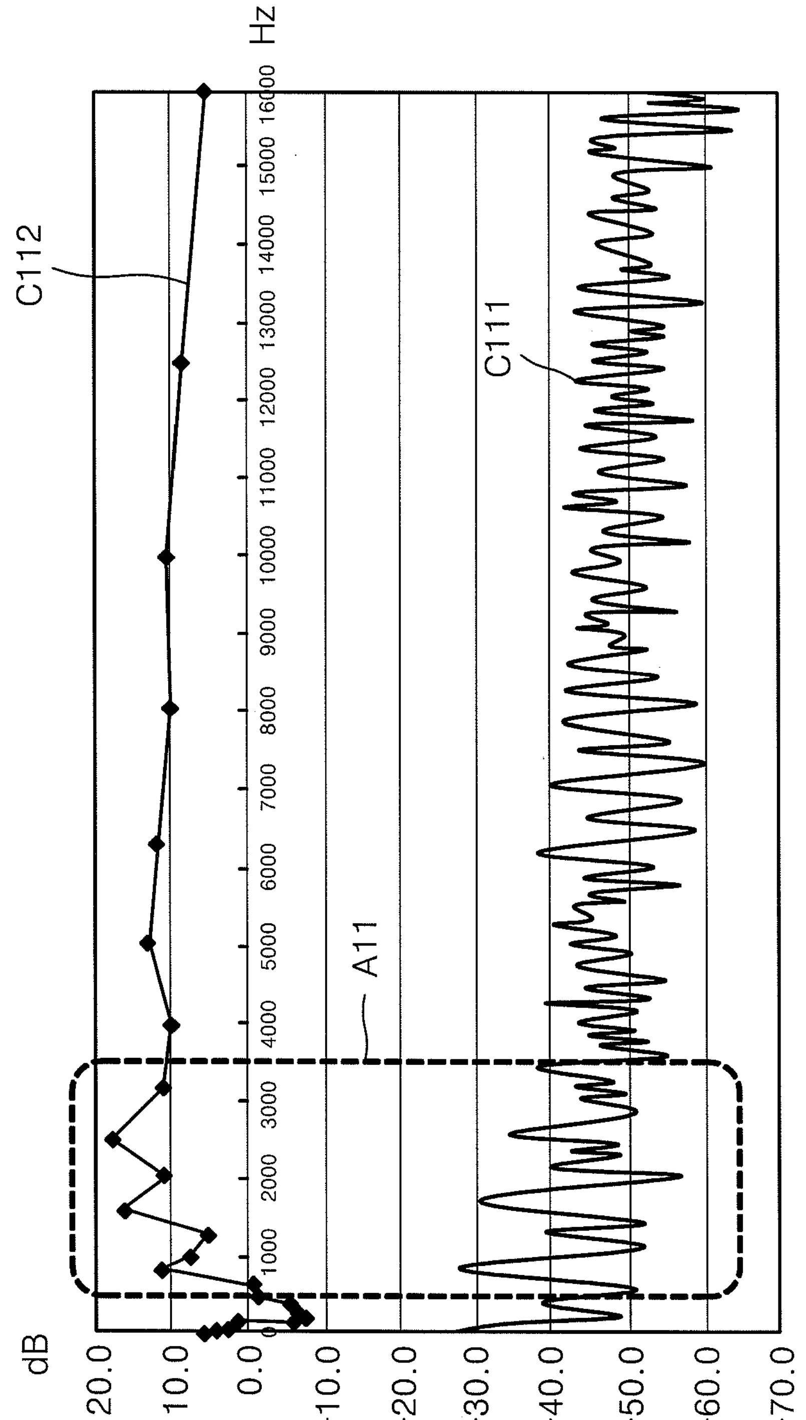

dB
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000
Hz
C102
C101
A10

FIG. 11


dB
Hz
C112
C111
A11
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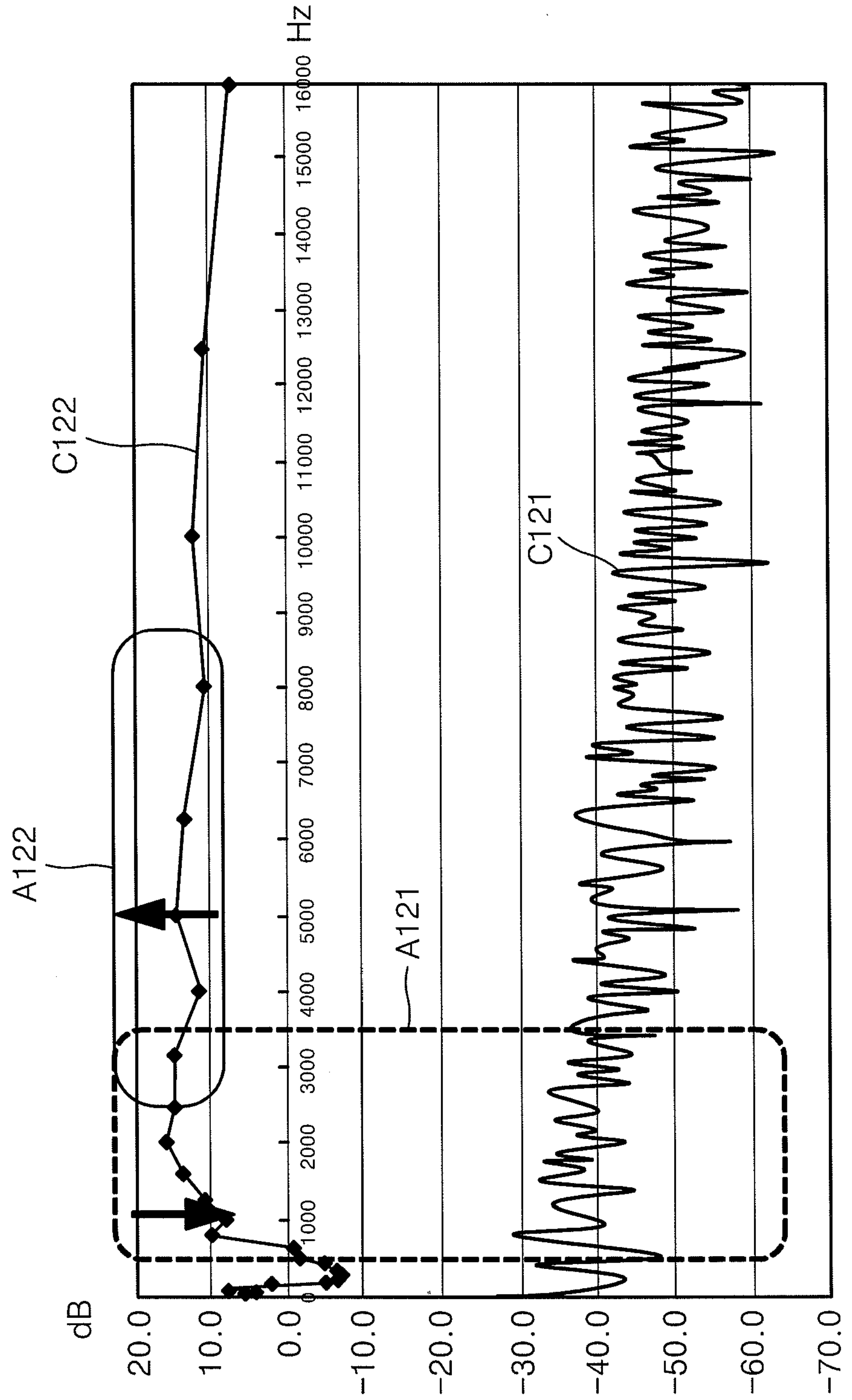
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000

FIG. 12


dB
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-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000
Hz
A122
C122
A121
C121

FIG. 13

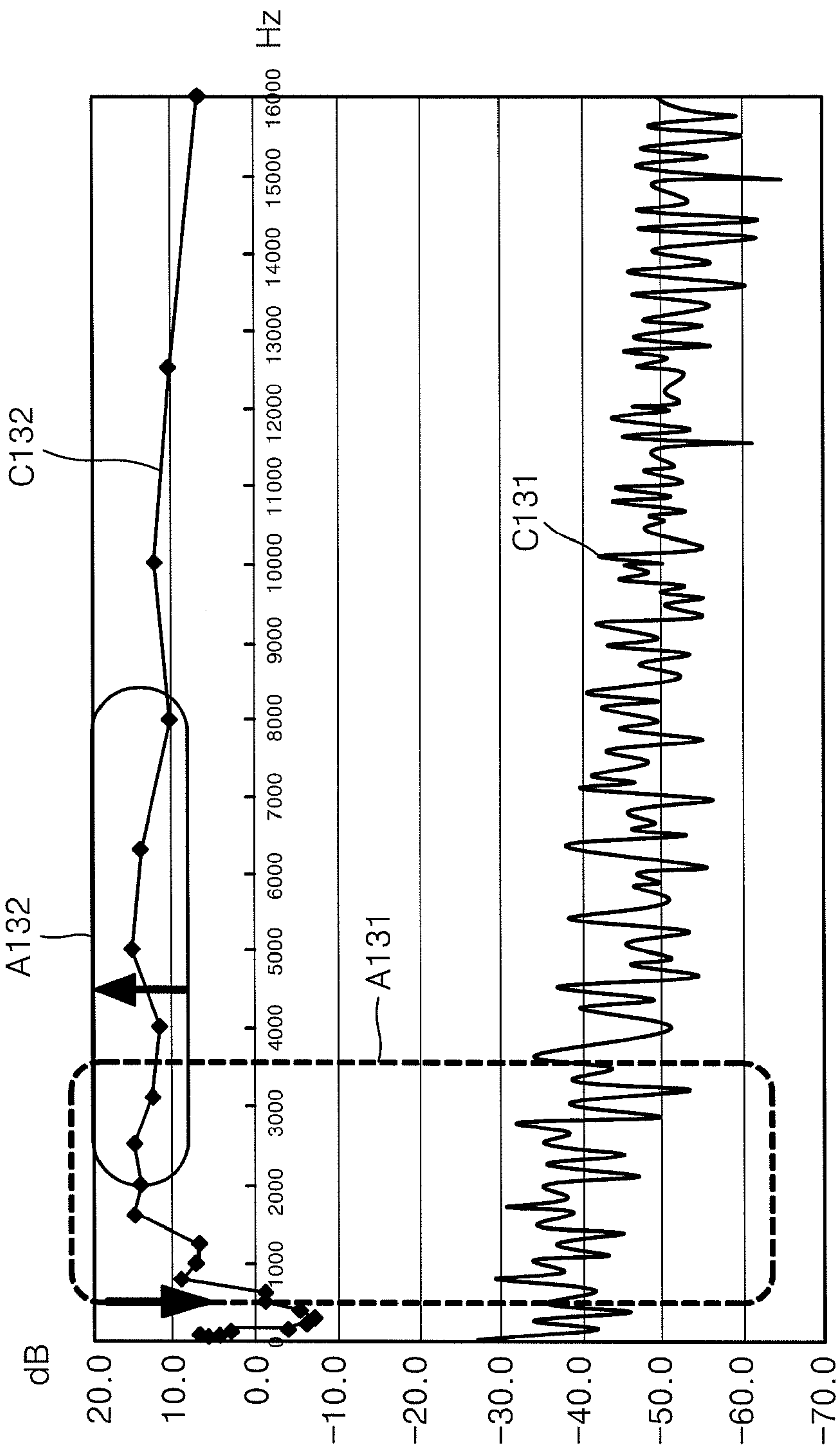

C132
A132
A131
C131
dB
Hz
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000

FIG. 14

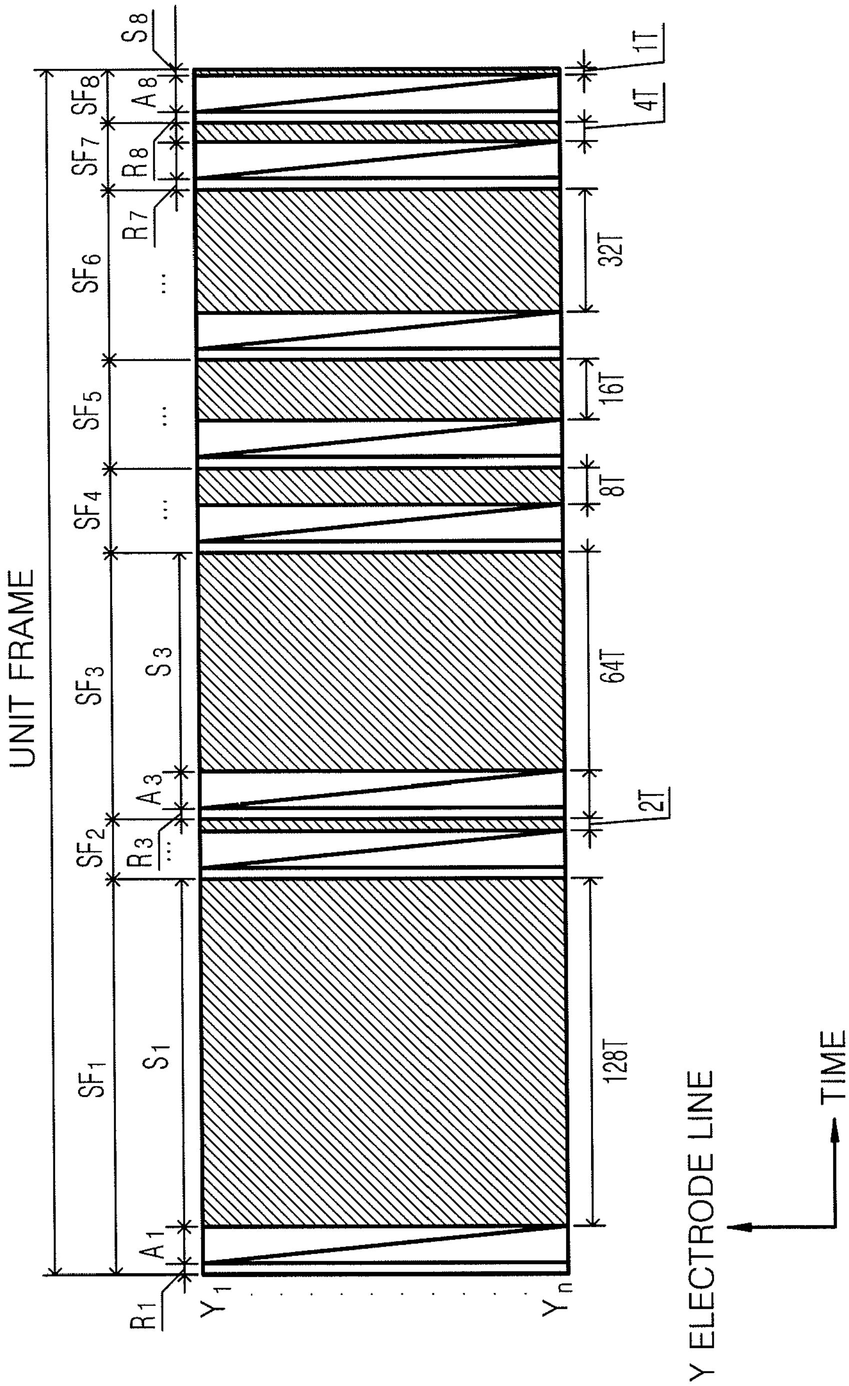
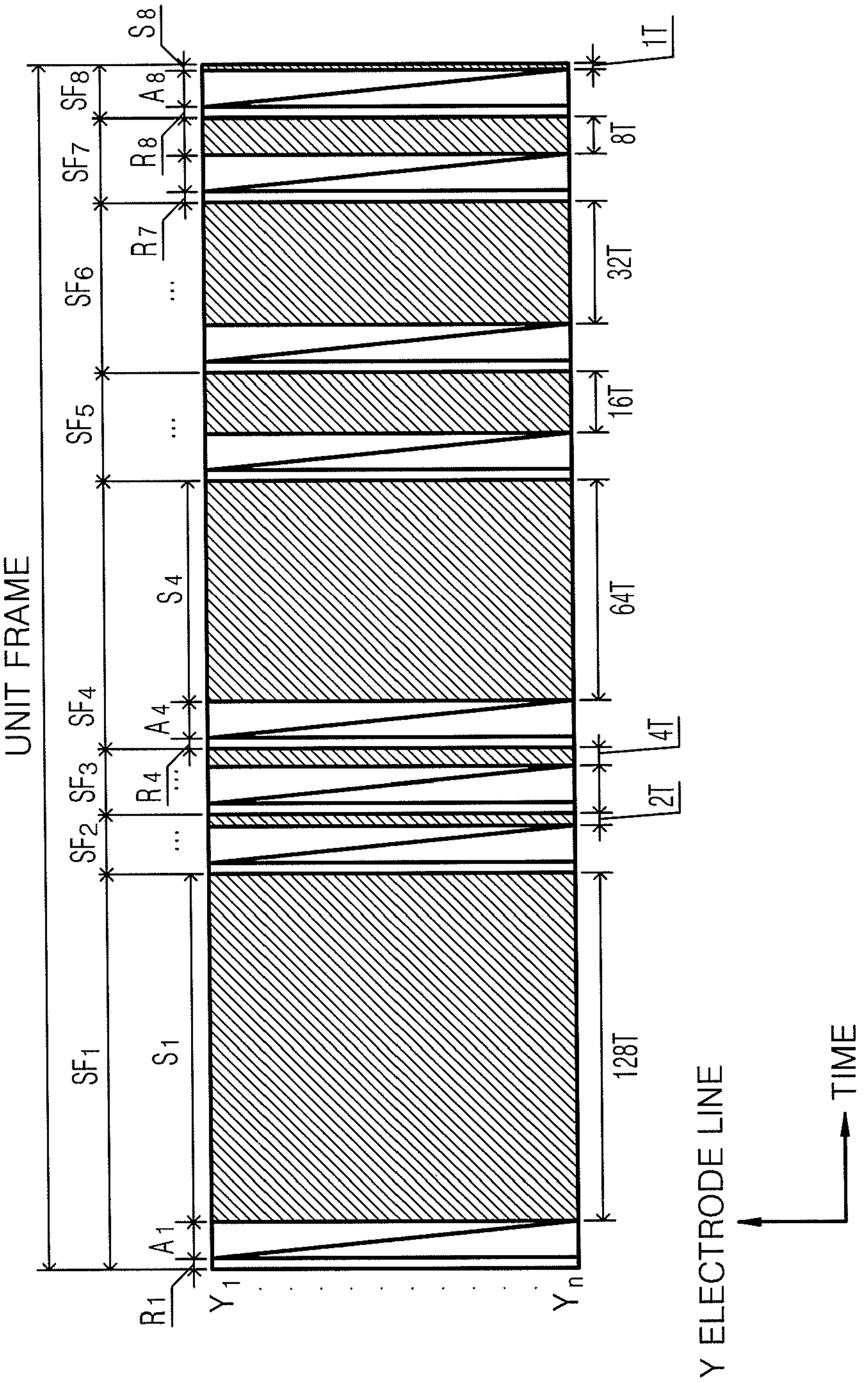

UNIT FRAME
SF1
SF2
SF3
SF4
SF5
SF6
SF7
SF8
S1
S3
S8
A1
A3
A8
R1
R3
R7
R8
128T
2T
64T
8T
16T
32T
4T
1T
Y1
Yn
Y ELECTRODE LINE
TIME

FIG. 15


UNIT FRAME
SF_1
SF_2
SF_3
SF_4
SF_5
SF_6
SF_7
SF_8
R_1
A_1
S_1
R_4
A_4
S_4
R_7
R_8
A_8
S_8
Y_1
Y_n
128T
2T
4T
64T
16T
32T
8T
1T
Y ELECTRODE LINE
TIME

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 5541618 A **[0002]**