A DOUBLE-FIELD 1000-SCANNING-LINE CONVERSION SYSTEM FOR MULTIMEDIA IMAGE SOURCES

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A new 1000-scanning-line conversion system having compatibility and harmonization with new-generation display systems for multimedia image sources such as a conventional TV image source with 525/30 (480i) interlaced scanning, a personal computer image source with 525/60 (480p) progressive scanning and a high-definition image source with 1125/30 (1080i) interlaced scanning has been studied.

A single-scanning technology with a scan conversion method has already been investigated by authors to realize a single display system for all existing kinds of TV image formats with different scanning-lines, indicating-channels and so on. From the researches it has been confirmed that the proposed 1000-scanning-line double-field wobbling method can obtain a minimum deterioration of the vertical response and no degradation of the motion of an image, and that the aliasing and flickering effects caused by the use of a conventional interlaced scanning can be eliminated in the system.

In this paper it has been mentioned that the same advantages due to a newly developed scan conversion, which employs a double field-rate, double scanning-line and wobbling method similarly, can be well introduced for a large-area display with higher brightness and contrast to attain a higher picture-quality of not only the 480i scanning image source but also the 480p and 1080i scanning image sources whose degradation of the vertical resolution has to be brought on account of the high-density scanning system with a narrow scanning-line interval.

1. INTRODUCTION

The new-generation television system such as the high-definition TV, advanced TV, digital TV and three dimensional TV are expected to be in widespread practical use for the realization of various image media leading the age of information. These new TV systems have two kinds of scanning methods. One is the interlaced scanning method which is mainly applied to broadcasting TV systems (BCTVs), and the other is the progressive scanning method which is mostly used to personal computer display systems (PCTVs).

An analog form of the high-definition TV called as Hi-Vision which has the 1125/30 interlaced scanning system is already applied in such fields as broadcasting, promotion, publication and medicine in Japan. In case of a digital form of the digital TV (DTV), which are already under standardization and some parts of which have been tested in a broadcasting field of U.S., Japan and other areas in the world, some kinds of image formats such as the digital high-definition TV (HDTV) and digital standard-definition TV (SDTV) have been recommended and under world-wide practical use.

In the recommendation above, the HDTV includes so-called 1080i system with 1080 interlaced active-lines, which is same as that of the Hi-Vision. And in the SDTV there is so-called 480i system with 480 interlaced active-lines, which is same as that of the current analog TV system such as the NTSC. These systems are mainly used for BCTV image sources. The other system of the HDTV is called 720p system which has 720 active-lines with progressive scanning. And the other of the SDTV is called 480p system

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which has 480 active-lines with a progressive scanning. They will also be applied to PCTV image sources besides BCTVs.

Therefore, the next-generation TV platform should naturally be required to equip plural kinds of scanning-lines and different scanning-forms to display various kinds of image information. It means that a multimedia display system using multi-scanning method which brings cost-disadvantage in usual will become necessary.

To realize a harmonization and compatibility of display system for both BCTVs and PCTVs in the near future, this paper describes about new technologies using a single-scanning method which provides cost-advantage and better performance of picture-quality.

2. VERTICAL RESPONSE OF CRT DISPLAY

In the papers [1], [2], [3] it has been clarified that by the physical characteristics of cathode-ray tube (CRT) display [6], [7] the vertical response deteriorates as the scanning-line interval in one field becomes narrower. The deterioration is owing to a spread of beam spot on each scanning-line which causes interference between some neighboring scanning-lines. The beam spot profile can be approximated to the gaussian response, and an increase of beam currents for getting higher brightness of the display makes a fat and bottom-up profile, which causes a degradation of the vertical response and contrast. From a display model in which a gaussian pulse with a half-amplitude duration of z_o is displayed so as to be sampled in a vertical direction with a scanning-line interval of $z_o/2$, the vertical response of display has been elucidated in the papers.

In case of 525/30 interlaced scanning system including the 480i system with a scanning-line interval of x_o=2/525, which corresponds to $z_o/2= x_o/s$, the vertical response has been given by

$$F_1(\nu) = K\,exp\,[-k(K^2-1)(2\alpha\nu x_0)^2] \qquad (1)$$

where $k=4\,ln\,2,\ \alpha=\pi/k,\ K=z_h/z_o,\ z=x/s$

ν : vertical spatial frequency

x : displacement in vertical direction

s : beam spot diameter at 50% luminance level

z : vertical displacement normalized by s

z_h: half-amplitude duration of the image which is perceived by the eyes as spread from z_o to z_h

In case of 525/60 progressive scanning system including the 480p system and the 525/60 system scan-converted from NTSC with a scanning-line interval of $x_o/2$=1/525, which corresponds to $z_o/2= x_o/2s$, the vertical response has been given by

$$F_2(\nu) = K\,exp\,[-k(K^2-1)(\alpha\nu x_0)^2] \qquad (2)$$

From a result of the calculation of K as shown in the papers [2], [3], the responses of $F_1(\nu)$ and $F_2(\nu)$ have been shown respectively in Fig. 1 and Fig. 2 with parameters of x_o/s.

These properties clarify that the 480p progressive scanning system (or the 1080i interlaced scanning system) having twice the number of scanning-lines than that of the 480i interlaced scanning system in one field cannot avoid a deterioration of the vertical response, and the deterioration becomes more remarkable by the use of a fat profile of beam spot having a smaller value of xo/s to get higher brightness of the display. For example, in case of a display with x_o/s=2.0, the 480p (or 1080i) system makes the response degrade by –6dB at ν=525/2 in contrast with the 480i system. From this, it should be aroused that the traditional 480i interlaced scanning system is more suitable to get higher brightness and contrast in a large-area display than the 480p (or 1080i) system.

However, there is other deterioration of picture-quality in the conventional 480i interlaced scanning system, that is such disturbances of time domain as the line crawling, line flickering and field flickering are remarkable [8], [9]. The line crawling is notably apparent in a large area and a slow movement of an image. The line flickering includes an interline flickering and an edge flickering appeared in a large area and at a vertical edge respectively. The field flickering appears mainly in a large and bright area. These effects are caused by the use of a low number of scanning-lines and interlaced method.

In the PCTV often sighted at very near distance, particularly, to avoid these disturbances the progressive scanning system (480p, 720p) is made worn-out measures.

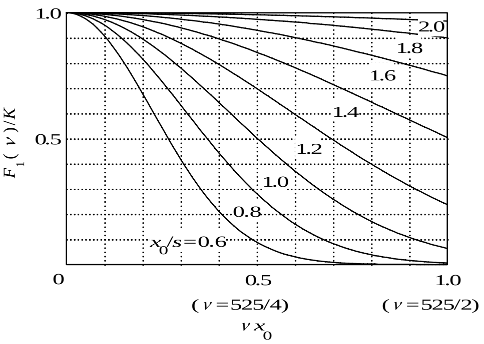


Fig. 1 Vertical responses of interlaced scanning

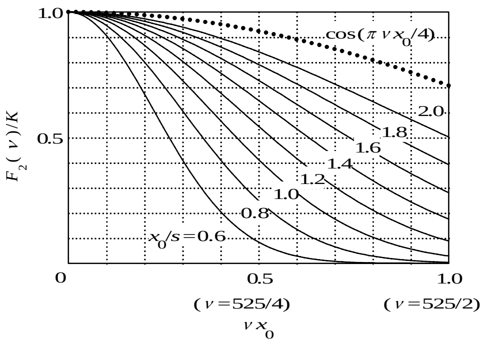


Fig. 2 Vertical responses of progressive scanning

3. SCANNING CONVERSION SYSTEM FOR 480i INTERLACED SCANNING IMAGE

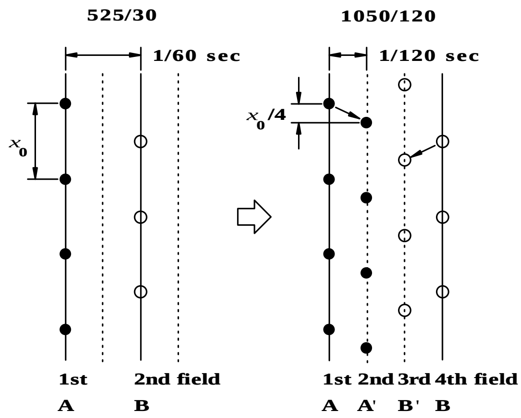
It has already been studied in the papers [2], [3], [4], [5] by authors that the proposed double-field wobbling method by which a conventional interlaced 525-scanning-line signal is converted to a 1050-scanning-line signal has brought a better performance of picture-quality than that of the normal 480i system. In this 1050-scanning- line double-field wobbling system which is called as 1050w system, especially, no perceived noise of the line structure, line crawling, field flickering and line flickering can be obtained, hence, the new 1050w wobbling scanning system makes possible to get a good-performance close to that of the 480p progressive scanning system without flickering.

This 1050w scanning conversion system is shown in Fig. 3, in which (a) shows scanning patterns, and (b) and (c) show frequency responses of two-dimensional main- and sub-spectrum respectively where λ and ν are temporal frequency and vertical spatial frequency respectively.

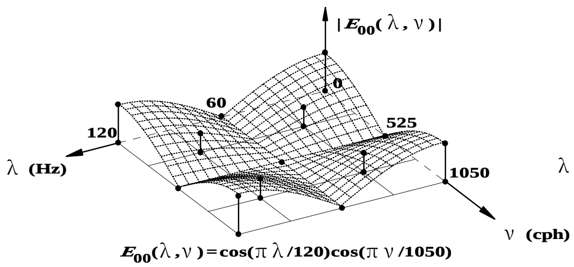
In this method, one frame with a time period of 1/30 sec contains four fields. The first and the fourth fields are indicated on the same spatial-displacement as original two true fields, which are shown by A and B respectively. And the second and the third fields are replaced by the true fields, furthermore, the second and the third fields are offset by a quarter of scanning-line interval in a vertical direction, which are shown by A' and B' respectively.

The 1050w scanning conversion method introduces a vertical filtering effect of $\cos(\pi\nu/1050)$ and a temporal filtering effect of $\cos(\pi\lambda/120)$ independently, as a result the line structure and field flickering caused by the carrier (λ, ν)=(0, 525) and (60, 0) respectively can be eliminated perfectly. These effects, further, lead to the exclusion by –6dB of the interline flickering caused by the carrier (30, 525/2) and to the improvement by −3dB of the edge flickering caused by aliasing in the neighborhood of a point (30, 0).

(a) Scanning patterns



(b) Frequency response of main-spectrum



(c) Frequency response of sub-spectrum

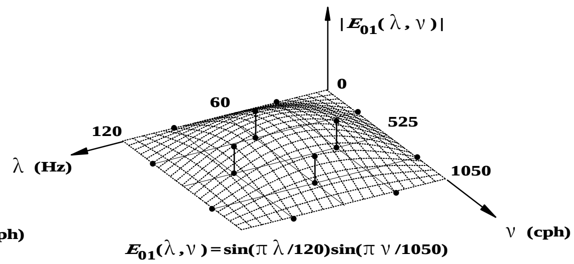


Fig.3 1000-scanning-line double-field wobbling method

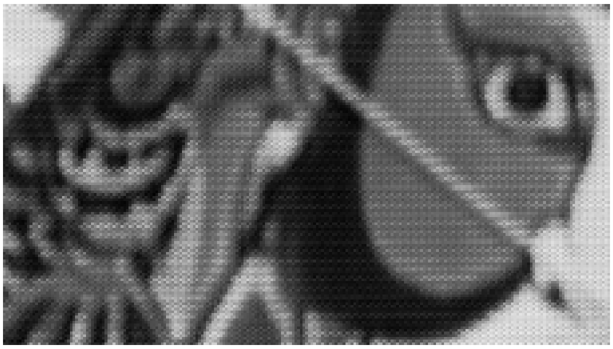
Moreover, the line crawling is suppressed sufficiently because of a wobbling effect that acts on the human visual system, by which the disturbance appears as responses of −6dB at the carrier (30, 525/2) and null at the carrier (60, 525) alternately on the axis of $\nu=(525/60)\lambda$. The effects can be confirmed by an experimental evaluation of picture-quality in contrast with other scanning methods as shown by pictures in Fig. 4.

In the pictures, (a) shows the 525-scanning-line 30-frame-rate image picture with a normal interlaced scanning such as the 480i system, (b) shows the 525-scanning-line 60-field-rate image picture with a normal progressive scanning such as the 480p system, and (c) shows the 1050-scanning-line 120-field-rate image picture with the above-mentioned 1050w wobbling scanning to which the normal 525/30 image shown in (a) has been converted. In addition, for the impartial and proper evaluation this experiment employs only a multi-scanning display for PCTV whose parameter value of x_0/s is approximately given by 3.5, which means that the 525/60 (480p or 1080i) system makes easy to obtain a higher resolution but difficult to get a higher brightness and contrast by reason of using slim beam spot profile, and also means the line structure cannot be avoided as appeared in not only (a) but also in (b).

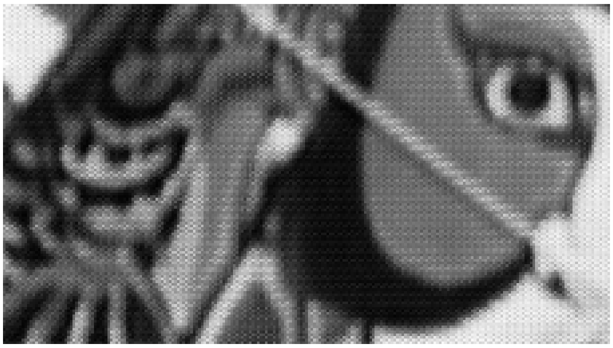
The 525/60 system as shown in (b) causes a degradation of the vertical response slightly from the

525/30 system in (a). The origin is owing to the physical factor of display shown in Fig. 2 by Eq.2.

(a) 525/30 interlaced scanning picture



(b) 525/60 progressive scanning picture



(c) 1050/120 double-field wobbling scanning picture

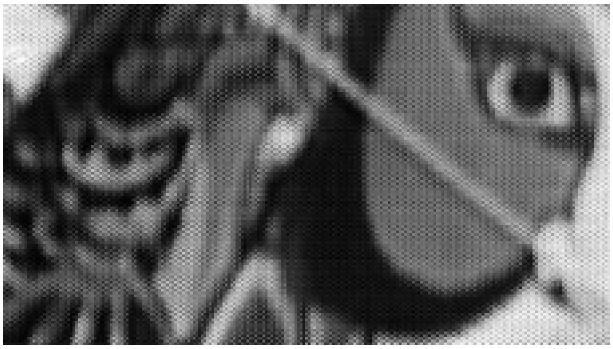


Fig.4 Pictures using different scanning methods

Also due to the slim beam spot, the advantage of vertical response attained by the use of the 1050w scanning conversion system is not remarkably perceived in (c) as compared with the 525/60 system in (b). Or rather it is allowed as if the vertical response is performed with a slight decrease from the 525/60 system. The cause is due to a smoothing effect and the filtering factor shown by dotted line in Fig. 2 which corresponds to a parameter value of x_O/s =2.4 approximated by calculation, whose value is smaller than the display's parameter value of 3.5. But the slight degradation can be easily amended by using a new vertical enhancement system described later in Fig. 9.

By the way, the line structure disturbance, which is awfully conspicuous in (a) and (b), has been eliminated perfectly as shown in (c). This advantage leads to an image with a smoothed flat and no jagged edge, which particularly makes the image glossy just as a photographic picture. Furthermore, by using this 1050w system, other various disturbances such as the line crawling, line flickering and field flickering can be suppressed sufficiently in (c) as compared with the 480i interlaced scanning system in (a).

4. SCANNING CONVERSION SYSTEM FOR 480p PROGRESSIVE SCANNING IMAGE

The same concept and advantage of the 1050w scanning conversion method can be applied for the 525/60 (480p) progressive scanning image as shown in Fig. 5. In the system each true field of the original 525/60 signal is divided into double-field alternated by line so that the first true field A is set to the first field A' and the second field A", and the second true field B to the third field B" and the fourth field B', in which moreover the second field A" and the third field B" are offset by a half of scanning-line interval, that is xo/4 (=1/1050), in the vertical direction for the first field A' and the fourth field B' respectively.

For the analysis in a frequency domain, the original progressive scanning source signal is described by

$$P(\lambda,\nu)=A_p\sum_{m=-\infty}^{\infty}\sum_{n=-\infty}^{\infty}\delta(\lambda-2m/T,\nu-2n/\gamma) \tag{3}$$

where T=1/30, γ = 2/525

A_P : amplitude of image source

To perform the 1050w wobbling conversion, the fourier transform $W(\lambda)$ for a field switch signal $w(t)$ alternated by field and $S(\nu)$ for a line switch signal $s(t)$ alternated by line respectively are defined as following

$$W_1(\lambda)=\sum_{k=-\infty}^{\infty}C_k\,\delta(\lambda-k/T) \tag{4}$$

$$W_2(\lambda)=\sum_{k=-\infty}^{\infty}(-1)^k C_k\,\delta(\lambda-k/T)$$

$$C_k=\begin{cases}1/2 & (k=0)\\ (-1)^i/(2i+1)\pi & (k=2i+1)\end{cases}$$

$$S_1(\nu)=\sum_{h=-\infty}^{\infty}D_h\,\delta(\nu-h/\gamma) \tag{5}$$

$$S_2(\nu)=\sum_{h=-\infty}^{\infty}(-1)^h D_h\,\delta(\nu-h/\gamma)$$

$$D_h=\begin{cases}1/2 & (h=0)\\ (-1)^i/(2i+1)\pi & (h=2i+1)\end{cases}$$

Using the convolution denoted by an asterisk (∗) for these Eq.3, Eq.4 and Eq.5, frequency responses of this system can be given by

$$\begin{aligned}
E_p(\lambda,\ \nu) &= P(\lambda,\ \nu)*W_1(\lambda)*S_1(\nu) \\
&+P(\lambda,\ \nu)*W_1(\lambda)*S_2(\nu)\exp\{-j2\pi(\lambda T/4-\nu\gamma/4)\} \\
&+P(\lambda,\ \nu)*W_2(\lambda)*S_1(\nu)\exp\{-j2\pi(-\nu\gamma/4)\} \\
&+P(\lambda,\ \nu)*W_2(\lambda)*S_2(\nu)\exp\{-j2\pi(\lambda T/4)\} \\
&=\sum_{h=-\infty}^{\infty}\sum_{k=-\infty}^{\infty}C_k D_h P(\lambda-k/T,\nu-h/\gamma) \\
&+\sum_{h=-\infty}^{\infty}\sum_{k=-\infty}^{\infty}C_k(-1)^h D_h P(\lambda-k/T,\nu-h/\gamma) \\
&\quad \exp\{-j2\pi(\lambda T/4-\nu\gamma/4)\} \\
&+\sum_{h=-\infty}^{\infty}\sum_{k=-\infty}^{\infty}(-1)^k C_k D_h P(\lambda-k/T,\nu-h/\gamma) \\
&\quad \exp\{-j2\pi(-\nu\gamma/4)\} \\
&+\sum_{h=-\infty}^{\infty}\sum_{k=-\infty}^{\infty}(-1)^k C_k(-1)^h D_h P(\lambda-k/T,\nu-h/\gamma) \\
&\quad \exp\{-j2\pi(\lambda T/4)\}
\end{aligned} \tag{6}$$

From Eq.6 the frequency responses of this scanning conversion method can be shown in Fig. 5 (b)~(e). The main-spectrum response as shown in Fig. 5 (b), whose outline resembles closely to that of the above-mentioned wobbling conversion method shown in Fig. 3 (b), denotes that the carriers (0, 525), (60, 0) and (60, 525) unique to the progressive scanning are suppressed to null so that the line structure and field flickering can not be perceived.

On the other hand, some disturbances are caused by new carriers of sub-spectrum as shown in Fig. 5 (c), (d) and (e). Fig. 5 (c) indicates a generation of a new carrier (60, 525/2) and Fig. 5 (d) teaches a new carrier (30, 525), whose amplitude responses given by –3dB are quite same as that of the wobbling conversion method shown in Fig. 3 (c). These carriers made by an irregular interlaced scanning conversion with a double-field rate bring another disturbance which strictly speaking should appear as a line flickering. However, the line flickering can seldom be perceived because the new carriers have frequencies of 60Hz and 525cph which is twice as high as that of the 525/30 system having frequencies of 30Hz and 525/2cph respectively. The quite same effect as shown in Fig. 3 (c) can be certified by the experimental result in Fig. 4 (c).

Fig. 5 (e) denotes a generation of another new carrier (30, 525/2) which should be result in the line crawling. But, this is also quite same as that of the wobbling conversion method shown in Fig. 3 (b). Hence, with not only the same amplitude response of –6dB but also the wobbling effect, the perceived noise can be avoided in human eyes. It has been also verified by the experiment.

In addition, the vertical response of the system having a certain small value of x_o/s can be improved in theory as compared with the original 525/60 progressive scanning system. It is the reason that the scanning-line interval in one field becomes twice as much from $x_o/2$ (=1/525) to x_o (=2/525), which is brought by the alternated double-field conversion. That is, the vertical response factor of display is amended by $F_1(\nu)$ of Eq.1 instead of $F_2(\nu)$ of Eq.2 which are shown in Fig. 1 and Fig. 2 respectively.

In case that a display with higher brightness and contrast has a beam spot profile of x_o/s =2.0, by applying these properties the frequency response of the 1050/120 conversion system which is given by $E_p(\lambda,\ \nu)F_1(\nu)$ can be shown in Fig. 6 (a) in contrast with the original 525/60 system which has a response given by $P(\lambda, \nu)F_2(\nu)$ as shown in Fig. 6 (b). As a result, at the frequency of ν=525/2cph, the new 1050/120 system teaches a higher vertical response of +3dB than that of the conventional 525/60 (480p) system.

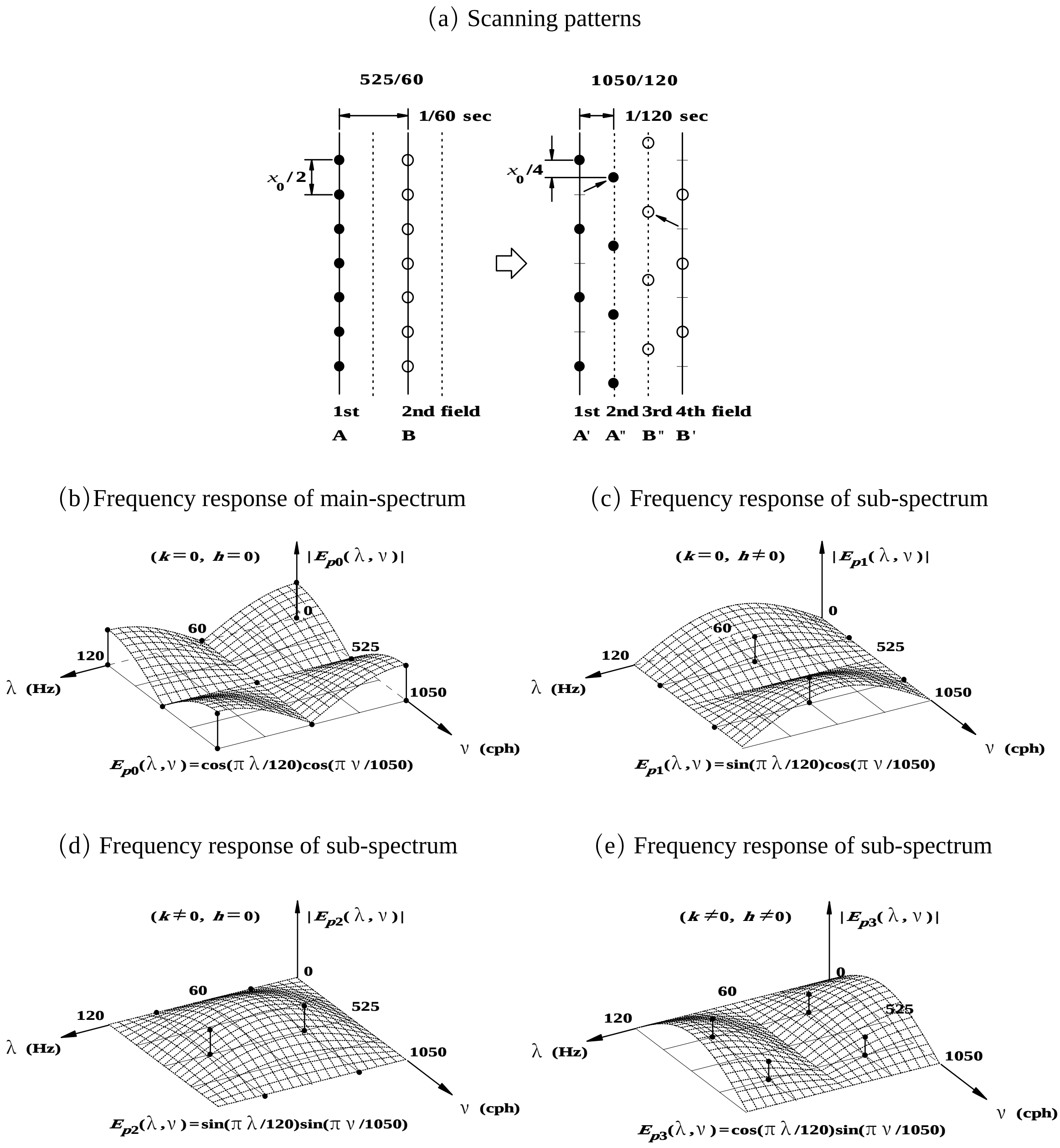
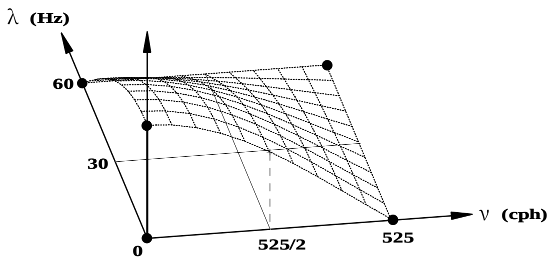


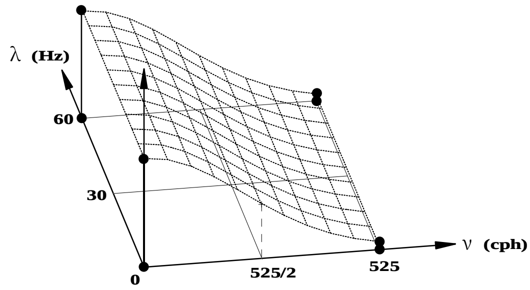
Fig.5 Scanning patterns and frequency responses of 1050w wobbling scanning conversion for 480p image source

(a) 1050/120 wobbling scanning conversion



main-spectrum response of $E_p(\lambda,\ \nu)F_1(\nu)$

(b) 525/60 progressive scanning



main-spectrum response of $P(\lambda,\ \nu)F_2(\nu)$

Fig.6 Frequency responses of display with x_O/s =2.0

5. SCANNING CONVERSION SYSTEM FOR 1080i INTERLACED SCANNING IMAGE

The 1050w scanning conversion technique, furthermore, is applicable to the high-definition image source such as the Hi-Vision and HDTV by employing the similar procedure, which is called as 1125w system that converts 1125/30 interlaced scanning to 1125/120 wobbling scanning.

For a high-definition image source with the 1125/30 (1080i) interlaced scanning, the signal is described by

$$H(\lambda,\ \nu) = A_h \sum_{m=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} \{1 + (-1)^{m+n}\}\,\delta(\lambda - m/T,\ \nu - n/\zeta) \tag{7}$$

where T=1/30, ζ=2/1125

A_h : amplitude of high-definition image source

For the 1125/30 interlaced scanning HDTV signal, the 1125w conversion system is shown in Fig. 7 (a). The scanning pattern obtained by the 1125w conversion bears resemblance to the 1050w conversion system exclusive of the field offset condition.

In the 1050w system the field offset of $x_O/4$ is performed within an inter-double-field interval of 1/120sec, while this 1125w system already has the field offset of $x_O/4$ within an inter-single-field interval of 1/60sec. Therefore each true field of the original 1125/30 signal is simply divided into double-field alternated by line so that the first true field A is set to the first field A' and the second field A" and the second true field B to the third field B' and the fourth field B", but the field offset procedure is no longer required.

Frequency response of the system can be given by

$$\begin{aligned}
E_h(\lambda,\ \nu) =\ & H(\lambda,\ \nu) * W_1(\lambda) * U_1(\nu) + H(\lambda,\ \nu) * W_1(\lambda) * U_2(\nu)\exp(-j2\pi\lambda T/4) \\
& + H(\lambda,\ \nu) * W_2(\lambda) * U_1(\nu) + H(\lambda,\ \nu) * W_2(\lambda) * U_2(\nu)\exp(-j2\pi\lambda T/4) \\
& = \sum_{l=-\infty}^{\infty}\sum_{k=-\infty}^{\infty} C_k B_l H(\lambda - k/T, \nu - l/\varsigma) + \sum_{l=-\infty}^{\infty}\sum_{k=-\infty}^{\infty} C_k (-1)^l B_l H(\lambda - k/T, \nu - l/\varsigma)\exp(-j2\pi\lambda T/4) \\
& + \sum_{l=-\infty}^{\infty}\sum_{k=-\infty}^{\infty} (-1)^k C_k B_l H(\lambda - k/T, \nu - l/\varsigma) + \sum_{l=-\infty}^{\infty}\sum_{k=-\infty}^{\infty} (-1)^k C_k (-1)^l B_l H(\lambda - k/T, \nu - l/\varsigma) \\
& \exp(-j2\pi\lambda T/4)
\end{aligned} \tag{8}$$

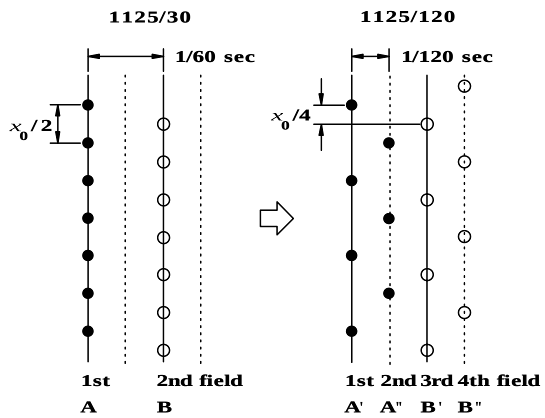
where $U(\nu)$ is given by the following equation which means the fourier transform of line-switch signal

$u(t)$ alternated by each line of the 1125/30 signal.

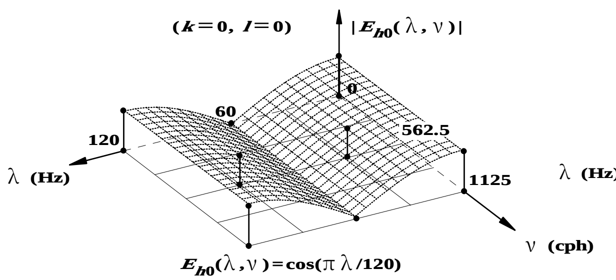
$$
\begin{aligned}
&U_1(\nu) = \sum_{l=-\infty}^{\infty} B_l \delta(\nu - l/\varsigma) \\
&U_2(\nu) = \sum_{l=-\infty}^{\infty} (-1)^l B_l \delta(\nu - l/\varsigma) \\
&B_l = \begin{cases} 1/2 & (l=0) \\ (-1)^i/(2i+1)\pi & (l=2i+1) \end{cases}
\end{aligned}
\qquad (9)
$$

From this the frequency responses can be shown in Fig. 7 (b) and (c). It is obvious that on the main-spectrum in Fig. 7 (b) the field flickering caused by the carrier (60, 0) can be suppressed to null and the carrier (30, 562.5) peculiar to the interlaced scanning, which normally brings no disturbance in eyes because of the twice higher frequency, is reduced to –3dB as compared with the original 1125/30 signal. But another disturbance caused by a new carrier (30, 562.5/2) on the sub-spectrum in Fig. 7 (c) is displayed at the same time, which resembles the line flickering appeared in the traditional 525/30 interlaced scanning. However, the amplitude response of the disturbance carrier is suppressed to –9dB in comparison with the 525/30 system, hence the line flickering is slight enough even if detected.

(a) Scanning patterns



(b) Frequency response of main-spectrum (c) Frequency response of sub-spectrum



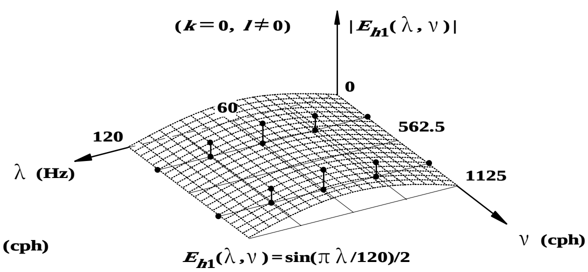
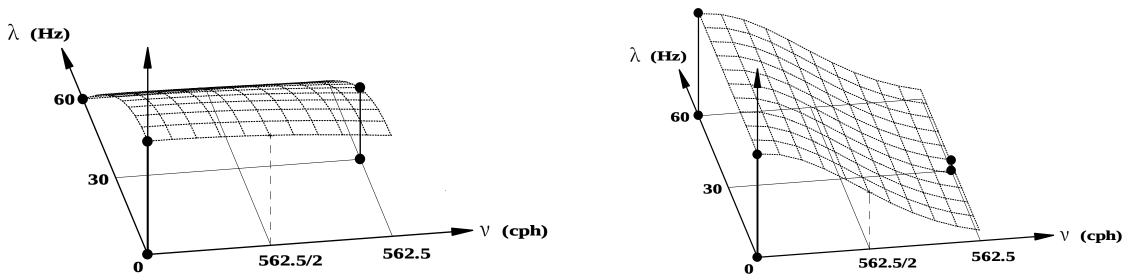


Fig.7 1125w scanning conversion for 1080i image source

By the similar condition as shown in Fig. 3 (b) and Fig. 5 (b), the line crawling which should be caused by the new carriers on the axis of $\nu=(562.5/60)\lambda$, whose disturbance level is –9dB at the carrier (30, 562.5/2) and null at the no carrier (60, 562.5), can also be avoided with no perceived noise. This is also owing to the same wobbling effect. Another new carrier (60, 562.5/2) also gives no disturbance in eyes because of the twice higher frequency and smaller amplitude response of –6dB. The line structure generated in the traditional 525/30 system, needless to say, can be reduced perfectly on account of no carrier (0, 562.5).

From a view point of the vertical response, the 1125/120 (1125w) scanning conversion system brings the same advantage as the above-mentioned 1050/120 (1050w) system shown in Fig. 6 for the resembling high density scanning system with a scanning-line interval of $x_o/2(=1/562.5)$ in a field. The similar response of the 1125/120 conversion system are shown in Fig. 8 as compared with the original 1125/30 interlaced scanning. The new 1125/120 system has no degradation of vertical response caused by the signal processing except the one caused by the physical factor of display which is shown by Eq.1. In case that a display has a beam spot profile of $x_o/s=2.0$, the frequency response of the 1125/120 scanning conversion system is given by $E_h(\lambda,\ \nu)F_1(\nu)$ which is shown in Fig. 8 (a), and that of the original 1125/30 interlaced scanning system is given by $H(\lambda,\ \nu)F_2(\nu)$ as shown in Fig. 8 (b). It is obvious, from this, that at the frequency of ν=562.5/2cph the 1125/120 (1125w) system denotes higher vertical response of +6dB than that of the traditional 1125/30 (1080i) system. Therefore, this system is quite suitable for the HDTV display especially with large area in getting higher brightness and contrast.

(a) 1125/120 wobbling scanning conversion (b) 1125/30 interlaced scanning



main-spectrum response of $E_h(\lambda,\ \nu)F_1(\nu)$ main-spectrum response of $H(\lambda,\ \nu)F_2(\nu)$

Fig.8 Frequency responses of display with x_o/s =2.0

6. APPLICATION OF SCANNING CONVERSION

Now, from a view point of an interpolation technique used by the scanning conversion system, the technique can be applied especially to a new image-detail creation system to obtain an enhancement information of image.

In the scanning pattern of the conversion system shown in Fig. 3 (a), the doubled fields A' and B' are interpolated by each line of the neighboring true fields A and B. Applying this interpolation method, a vertical enhancer in which an image-detail information is generated and supplemented can be realized. The new conception of the image-detail creation system using the double-field wobbling method can be shown with an algorithm in Fig. 9. In this system pixels as indicated by marks (●, ○) have true amplitude responses on the true fields (A, B). And other pixels as indicated by marks (■, □) are interpolated in a vertical direction by neighboring pixels on the true fields (A, B) by each line with a scanning-line interval of $x_0/4$(=1/1050). A level-adaptive prediction coding procedure of the interpolation, by which a pixel on each line of the fields (A', B') is interpolated with an amplitude response predicted according to levels of a plural number of the neighboring pixels, can be employed.

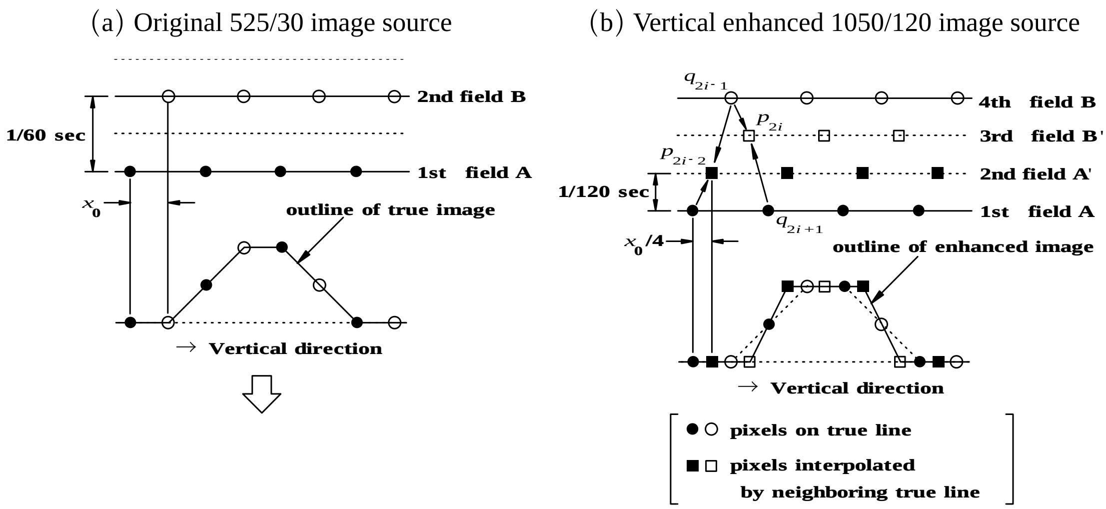


Fig.9 Vertical enhancement system using 1000-scanning-line double-field wobbling method

As an amplitude level and prediction factor of each true pixel on the true fields (A, B) are denoted by q_{2i+1} and k_{2i+1} respectively, an amplitude level of each interpolated pixel on the interpolated fields (A', B') can be given by

$$p_{2i} = \sum_{l=-n}^{n-1} k_{2i+2l+1}\, q_{2i+2l+1} \qquad (10)$$

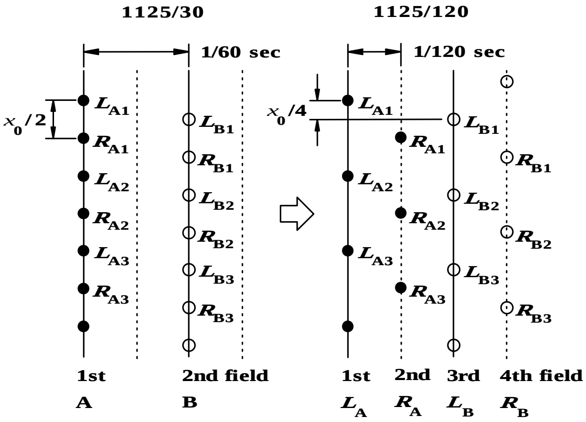
where n denotes a number of pixels used for prediction

By using this level-adaptive procedure for the 1050/120 (1050w) system, the vertical amplitude response of the interpolated image can be changed to achieve a smoother and sharper edge response, which is shown as an outline of enhanced image in Fig. 9 (b), than that of the original 525/30 (480i) image, which is shown in Fig. 9 (a) with an outline. That is, image-details with a vertical sampling interval of $x_0/4$(=1/1050) can be created and appended to bring a higher vertical resolution.

The 1125/120 (1125w) scanning conversion system can be applied to a three-dimensional image display system such as the 3DTV [10], [11], [12], which has already been studied using a field-sequential transmission system by authors in the papers [3] as one of solutions for the realization.

Another solution using a line-sequential transmission system is introduced in Fig. 10 (a), whose experimental evaluation as a stereoscopic (3D) picture is shown in Fig. 10 (b). The two-channel three-dimensional image information, one is based on left-eye information L and the other is right-eye information R, can be alternated and multiplexed by each line so as to have the same format as the 1125/30 interlaced scanning signal. And the multiplexed two-channel signal can be converted to the same 1125/120 (1125w) signal having double-field rate so that the left-eye and right-eye information can be displayed with an alternation of the each double-field. This system, especially, is suitable for transmitting the multi-channel information with a limited bandwidth, therefore it is easy to realize a new image media such as the 3DTV by employing a HDTV-channel of the DTV system.

(a) Scanning patterns



(b) Experimental 3DTV picture

Fig.10 Scanning conversion system for 3DTV using a HDTV-channel

7. CONCLUSION

Nowadays, many kinds of TV image formats, not only the current analog TV but also the digital TV which can supply the SDTV, HDTV and 3DTV etc. with high picture-quality and new image-service, has been proposed to be in world-wide practical use for the next-generation TV system,. However, the mixture of the old and new TV systems may bring a confusion and chaos to the display system because many different scanning systems such as the single-channel 480i (525/30), 480p (525/60), 1080i (1125/30) systems for the existing DTV, and the single-channel 720p, 1080p systems and dual-channel 480i, 480p systems for the next generation DTV and 3DTV are required to display.

In this paper, a single- but not multi-scanning display system has been studied to cope with the current issues. From a view point of realizing a successful compatibility, harmonization and cost-advantage for these new multimedia image sources, a new scanning conversion technique has been proposed, by which the single-channel 480i and 480p TV systems can be displayed with a quite same scanning of 1050w wobbling method and the single-channel 1080i TV system can be displayed with a similar scanning of 1125w wobbling method. This technique is also applicable to the dual-channel 480i TV system and the single-channel 720p, 1080p systems.

Furthermore, by applying the proposed technique a new image-detail creation system which brings higher picture-quality with twice the number of pixels in vertical direction has been investigated. This 1050w/1125w scanning conversion system can be expected for the future digital image platform in which a higher vertical response under no influence of the physical characteristics of CRT display can be realized, which is more valuable for a large-area display with higher brightness and contrast.

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