개선된 Anti-cloche Filter와 BPF 그리고 오차가 없는 제곱근기를 사용한 SECAM Encoder와 Decoder의 설계

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Design of Digitalized SECAM Video Encoder with Modified Anti-cloche filter and SECAM Video Decoder with BPF and Error-free Square Root

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요 약

본 논문은 개선된 Anti-cloche filter를 사용하는 SECAM video encoder와 오차가 없는 제곱근기와 BPF를 사용하는 SECAM video decoder를 제안하고자 한다. SECAM video encoder는 ITU-R BT.470에 의해 지정된 Anti-cloche filter를 사용하지만, Anti-cloche filter가 가지는 특성이 주파수에 따라 매우 급격히 변하기 때문에 디지털회로의 설계에 적용하기가 어렵다. 이러한 문제를 해결하기 위해서 본 논문에서는 Anti-cloche filter의 주파수 특성이 좌우대칭이라는 점을 이용하여서 좌우대칭의 중심이 되는 주파수인 4.286MHz를 0MHz로 이동하여 Anti-cloche filter를 High Pass Filter(HPF)로 변환한다. 변환된 HPF는 Anti-cloche filter에 비해 구조가 간단하기 때문에 설계가 비교적 용이하다. 또한 본 논문에서 제시한 SECAM video decoder는 주파수 변조된 신호로부터 색차신호(Db, Dr)를 복원하기 위해서 오차가 없는 제곱근기와 두 개의 미분기 그리고 삼각함수를 이용하며 색상신호의 잡음을 제거하고 CVBS(Composite Video Baseband Signal)로부터 색상신호와 밝기신호를 분리하기 위해서 BPF를 사용한다. 제안된 시스템은 Altera FPGA인 APEX20KE EP20K1000EBC652-3와 TV를 이용하여 실시간 검증을 수행하였다.

ABSTRACT

In this paper, we propose the Sequentiel Couleur Avec Memoire or Sequential Color with Memory (SECAM) video encoder system using modified anti-cloche filters and the SECAM video decoder system using a band pass filter (BPF) and an error-free square root. The SECAM encoder requires an anti-cloche filter recommended by International Telecommunication Union-Recommendation (ITU-R) Broadcasting service Television (BT) 470. However, the design of the anti-cloche filter is difficult because the frequency response of the anti-cloche filter is very sharp around rejection-frequency area. So, we convert the filter into a high pass filter (HPF) by shifting the rejection frequency of 4.286MHz to 0Hz frequency. The design of HPF becomes very easy, compared to that of the anti-cloche filter. The proposed decoder also uses an error-free square root, two differentiators and trigonometric functions to extract color-component information of Db and Dr accurately from frequency modulation (FM) signals in SECAM systems. Also, the BPF in decoder is used for removing color noise in chrominance and dividing CVBS into chrominance and luminance. The proposed systems are experimentally demonstrated with Altera FPGA APEX20KE EP20K1000EBC652-3 device and TV sets.

키워드

SECAM, video encoder, video decoder, ITU-R BT.470

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Ⅰ. Introduction

Current television broadcasting standards such as NTSC, PAL and SECAM use the composite video baseband signals (CVBS) of luminance and chrominance signals to transfer color images through a broadcasting channel. The video encoders take component video signals (e.g., RGB or YCbCr) and encode those into the CVBS. The RGB represents red, green and blue signals. The YCbCr represents the luminance signal of Y and two color-component signals of Cb and Cr. The encoded CVBS is converted into YCbCr by the video decoder[1].

SECAM encoder system requires two filters such as anti-cloche filter and pre-emphasis filter. Because the system uses frequency modulation (FM), Pre-emphasis and Anti-cloche filter must be designed for emphasizing the amplitude of transferring signal suppressing band width[2]. The frequency response of the Anti-cloche filter has sharp and symmetric characteristic which makes it difficult to design Anti-cloche filter. So we changed the characteristic of Anti-cloche filter. In other words, the band suppressed filter is converted into high pass filter. Also, the group delay of the modified filter is minimized to perform high quality.

The SECAM system uses FM modulation to transmit the Db and Dr color difference information, with each component having its own sub-carrier. The two pieces of color information (Db and Dr) added to the monochrome signal could be transmitted on alternate line to avoid the possibility of crosstalk. So the color information and monochrome signal interfere with each other and then the distributed signals make color noise. In order to solve the problem, the proposed SECAM decoder system uses BPF which is dividing CVBS into chrominance and luminance signal. The divided signals make the decoded image more vivid and more distinct. The color information is represented by various frequencies which are assigned by emphasized Db and Dr. The proposed decoder system uses two differentiators, some trigonometric functions and error-free square root for getting color information from FM modulated CVBS[3]. Also, SECAM decoder uses two kinds of IIR filter such as cloche filter and de-emphasis filter which compensate the amplitude emphasized by SECAM encoder.

Ⅱ. Proposed SECAM encoder system

The incoming YCbCr signals are converted into YDbDr signals which are color space for encoding. The YDbDr represents the luminance signal of Y and two color-component signals of Db and Dr. Equations (1) and (2) are to generate CVBS of the SECAM system [4]. The SECAM system transmits Db and Dr each line alternatively.

$$\mathrm{CVBS} = Y + G\sin 2\pi\left\{f_{OR} + \Delta f_{OR}\int_0^t Dr(\tau)d\tau\right\}\text{for Dr line} \quad (1)$$

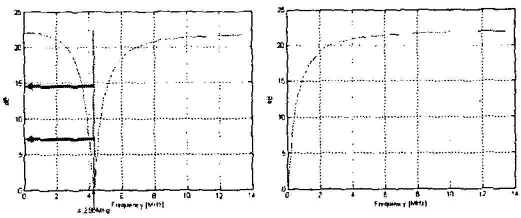
$$\mathrm{CVBS} = Y + G\sin 2\pi\left\{f_{OB} + \Delta f_{OB}\int_0^t Db(\tau)d\tau\right\}\text{for Db line} \quad (2)$$

where G=23IRE, f_{OR}=4.40625MHz, $\triangle f_{OR}$=280 kHz, f_{OB}=4.25MHz, $\triangle f_{OB}$=230kHz.

After modulation of Db and Dr, sub-carrier pre-emphasis is applied and changing the amplitude of the sub-carrier as a function of the frequency deviation. The intention is to reduce the visibility of the sub-carriers in low bandwidth of luminance and to improve the signal-to-noise ratio of highly saturated colors[4]. This anti-cloche is given as:

$$\mathrm{G} = \mathrm{M}\frac{1 + j16\mathrm{F}}{1 + j1.26\mathrm{F}} \quad (3)$$

where F=(f/4286)-(4286/f), f=instantaneous sub-carrier frequency in kHz, and 2M=23IRE±2.5% of luminance amplitude.



(a) (b)

Fig. 1 Symmetry of Anti-cloche filter and the modified anti-cloche filter

그림. 1 Anti-cloche 필터의 대칭성과 개선된 Anti-cloche 필터

At digital SECAM encoder system, it is difficult to design anti-cloche filter. Curve of the filter is so sharp that we change anti-cloche filter into HPF by using symmetrical characteristic. Figure 1-(a) shows the curve which is described by using Eq. (3) and MATLAB [5]. The filter is symmetry at 4.286MHz by Eq. (3). We shift an axis of symmetry to the point of 0Hz. So, anti-cloche filter can be modified such as Fig. 1-(b). The high pass filter like Fig. 1-(b) is easy to design as digital. If anti-cloche filter is modified like Fig. 1-(b), modulation method should be changed. To use the modified anti-cloche filter, Eq. (1) and (2) are converted into Eq. (4) and (5), respectively. The term $f_o t - f_o t$ is added to the brace of Eqs. (1) and (2). The added equation is represented by trigonometric function. So frequency modulation signal, $\sin 2\pi\{f_{OR} + \Delta f_{OR}\int_0^t Dr(\tau)d\tau\}$, is converted to $\sin 2\pi\{(f_{OR} - f_O)t + \Delta f_{OR}\int_0^t Dr(\tau)d\tau$. Because the term f_{OR} is replaced to $f_{OR} - f_O$, the modified filter of Fig. 1-(b) can be used. The Db path is the same as Dr path.

$$\begin{aligned} \text{CVBS} &= Y + G\sin 2\pi\left\{f_{OR}t + \Delta f_{OR}\int_0^t Dr(\tau)d\tau\right\} \\ &= Y + G\sin 2\pi\left\{f_O t + (f_{OR}t - f_O t + \Delta f_{OR}\int_0^t Dr(\tau)d\tau)\right\} \\ &= Y + G[\cos 2\pi f_O t \cdot \sin 2\pi\{(f_{OR} - f_O)t + \Delta f_{OR}\int_0^t Dr(\tau)d\tau\} \\ &\quad + \sin 2\pi f_O t \cdot \cos 2\pi\{(f_{OR} - f_O)t + \Delta f_{OR}\int_0^t Dr(\tau)d\tau\}] \end{aligned} \tag{4}$$

$$\begin{aligned} \text{CVBS} &= Y + G\sin 2\pi\left\{f_{OB}t + \Delta f_{OB}\int_0^t Db(\tau)d\tau\right\} \\ &= Y + G\sin 2\pi\left\{f_O t + (f_{OB}t - f_O t + \Delta f_{OB}\int_0^t Db(\tau)d\tau)\right\} \\ &= Y + G[\cos 2\pi f_O t \cdot \sin 2\pi\{(f_{OB} - f_O)t + \Delta f_{OB}\int_0^t Db(\tau)d\tau\} \\ &\quad + \sin 2\pi f_O t \cdot \cos 2\pi\{(f_{OB} - f_O)t + \Delta f_{OB}\int_0^t Db(\tau)d\tau\}] \end{aligned} \tag{5}$$

Ⅲ. proposed SECAM decoder system

To get $Dr(\tau)$ and $Db(\tau)$ from Eqs. (4) and (5), we should shift FM modulated signals to low frequency. Equations (6) and (7) are the result of multiplying Eq. (4) by $cos2\pi f_o t$ and $sin2\pi f_o t$, respectively.

$$\begin{aligned} &\text{Eq.(4)} \times \cos 2\pi f_O t = \\ &Y \times \cos 2\pi f_O t + \frac{1}{2} \times G \times [\sin 2\pi\{(f_{OR} - f_O)t + \Delta f_{OR}\int_0^t Dr(\tau)d\tau\} \\ &+ \sin 2\pi\{2f_O t + (f_{OR} - f_O)t + \Delta f_{OR}\int_0^t Dr(\tau)d\tau\}] \end{aligned} \tag{6}$$

$$\begin{aligned} &\text{Eq.(4)} \times \sin 2\pi f_O t = \\ &Y \times \sin 2\pi f_O t + \frac{1}{2} \times G \times [\cos 2\pi\{(f_{OR} - f_O)t + \Delta f_{OR}\int_0^t Dr(\tau)d\tau\} \\ &- \cos 2\pi\{2f_O t + (f_{OR} - f_O)t + \Delta f_{OR}\int_0^t Dr(\tau)d\tau\}] \end{aligned} \tag{7}$$

Equation (8) and (9) are given by low pass filtering Eqs. (6) and (7), respectively. The band width of low pass filter is 1.5MHz.

$$\frac{1}{2} \times G \times [\sin 2\pi\{(f_{OR} - f_O)t + \Delta f_{OR}\int_0^t D_R(\tau)d\tau\}] \tag{8}$$

$$\frac{1}{2} \times G \times [\cos 2\pi\{(f_{OR} - f_O)t + \Delta f_{OR}\int_0^t D_R(\tau)d\tau\}] \tag{9}$$

Now, we use a differentiation rule in Eq. (10) for getting $Db(\tau)$ and $Dr(\tau)$.

$$\frac{dy}{dx} = \frac{dy}{du} \cdot \frac{du}{dx} = f'(u) \cdot g'(x) \tag{10}$$

When $y=f(u)$ and $u=g(x)$ are the differentiable function, the composite function $y=f(g(x))$ is differentiable by using 'x' [6] and the differential function is given like as Eq. (10).

$$\pi \cdot G \cdot \{(f_{OR} - f_O) + \Delta f_{OR}D_R(t)\} \cdot \cos 2\pi\{(f_{OR} - f_O)t + \Delta f_{OR}\int_0^t Dr(\tau)d\tau\} \tag{11}$$

$$-\pi \cdot G \cdot \{(f_{OR} - f_O) + \Delta f_{OR}D_R(t)\} \cdot \sin 2\pi\{(f_{OR} - f_O)t + \Delta f_{OR}\int_0^t Dr(\tau)d\tau\} \tag{12}$$

Equations (11) and (12) show the differentiated Eqs. (8) and (9) by using Eq. (10). As you can see, Eqs. (11) and (12) have same phase, so Eqs. (11) and (12) could be arranged and simplified by using Eq. (13).

$$\sin^2 x + \cos^2 x = 1 \tag{13}$$

Equation (14) is the result of Eq. (13) by using Eq. (11) and (12), respectively.

$$\pi^2 \times G^2 \times \{(f_{OR} - f_O) + \Delta f_{OR}D_R(t)\}^2 \tag{14}$$

And then, Eq. (14) should be treated by using error-free square root which does not have any error. Equation (15) shows the treated Eq. (14) by using error-free square root.

$$\pi \times G \times \{(f_{OR} - f_O) + \Delta f_{OR} D_R(t)\} \quad (15)$$

In Eq. (15), π, G, $(f_{OR} - f_O)$ and Δf_{OR} are constant, so $D_R(t)$ is gotten by using simple calculations such as the four arithmetical operations. However, before calculating Eq. (15), we should consider the sign compensation because values treated by square root are always positive. The methods of sign compensation are shown below in Eq. (16) and Eq. (17).

$$[\sin\{f(x)\}]' = f'(x) \cdot \cos\{f(x)\} \quad (16)$$

$$[\cos\{f(x)\}]' = -f'(x) \cdot \sin\{f(x)\} \quad (17)$$

By Eqs. (16) and (17), we could know the sign generated by sine and cosine differentiation. When Eqs. (8), (9) and (15) are rearranged by Eqs. (16) and (17), the final equation is shown below.

$$\text{Eq.(8)}' = \frac{2}{G} \times \text{Eq.(15)} \times \text{Eq.(9)} \quad \text{Eq.(9)}' = -\frac{2}{G} \times \text{Eq.(15)} \times \text{Eq.(8)} \quad (18)$$

Because we know already the signs of Eq. (8) and (9), the signs of Eq. (15) could be known easily. After sign compensation, the Dr is gotten by using the four arithmetical operations. The Db is calculated by the same manner of Dr processing.

In the SECAM system, we know that the chrominance and luminance signals use the same channel, so the different frequencies interfere with each other. The below equation represents the color noise effect.

$$\text{Luminance} = Y_1 + Y_2 \cdot sin(2\pi \cdot f_x \cdot t) \quad (19)$$

Y_1 is DC level of luminance and Y_2 is AC amplitude of luminance. The term, f_x, is any luminance frequency. Equation (20) shows the Dr line with luminance of Eq. (19).

$$\begin{aligned} \text{CVBS} &= \text{Luminance} + \text{Chrominance} \\ &= Y_1 + Y_2 \cdot sin(2\pi \cdot f_x \cdot t) + G \cdot sin2\pi\{f_{OR} \cdot t + \Delta f_{OR} \int_0^t Dr(\tau)d\tau\} \end{aligned} \quad (20)$$

After multiplying Eq. (19) by sub-carrier (sine and cosine) and treating the results by using chrominance LPF, the converted equations are shown like as below.

$$\frac{1}{2} \cdot Y_2 \cdot \sin\{2\pi \cdot (f_x - f_o) \cdot t\} + \frac{1}{2} \cdot G \cdot \sin 2\pi\{(f_{OR} - f_o) \cdot t + \Delta f_{OR} \int_0^t Dr(\tau)d\tau\} \quad (21)$$

$$\frac{1}{2} \cdot Y_2 \cdot \cos\{2\pi \cdot (f_x - f_o) \cdot t\} + \frac{1}{2} \cdot G \cdot \cos 2\pi\{(f_{OR} - f_o) \cdot t + \Delta f_{OR} \int_0^t Dr(\tau)d\tau\} \quad (22)$$

In Eq. (21) and (22), the term, $f_x - f_o$, is the frequency of color noise. To remove the color noise, the proposed SECAM decoder system uses BPF whose dB response is shown in Fig. 2. Figure 3 shows the luminance and chrominance processing with BPF. The color noise can be removed by subtracting original CVBS from CVBS filtered by BPF.

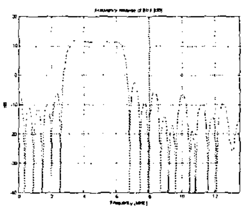


Fig. 2 dB response of band pass filter
그림. 2 Band Pass Filter의 dB 응답

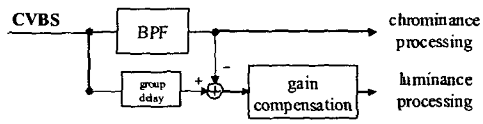


Fig. 3 Signal separation processing using BPF
그림. 3 BPF를 사용한 신호 분리

Ⅳ. Experimental Results

Figures 4 and 5 show the block diagram of the digital SECAM encoder and decoder system, respectively. The proposed systems satisfy the operating frequency of 27 MHz in the hardware designs.

Figure 6 shows the demonstration results without BPF and separating chrominance signal from CVBS in luminance processing. As you can see, Fig. 6-(a) shows the FM noise in displayed image because of remaining chrominance signal in luminance signal and Fig. 6-(b) shows color noise over 2 MHz because luminance signal is remaining in chrominance signal. Figure 7 shows the result decoded by proposed SECAM decoder with BPF and separating chrominance from CVBS in luminance processing. As you can see, Fig. 7-(a) does not show any FM noise and Fig. 7-(b) shows the color noise over 3.125 MHz which is higher than 2 MHz. Thus, Fig. 7 proves the effectiveness of the proposed SECAM decoder system.

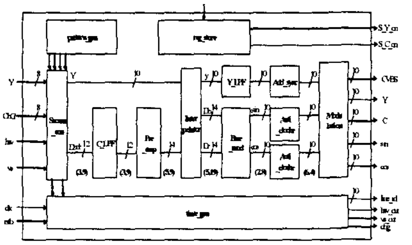


Fig. 4 Block diagram of the proposed encoder
그림. 4 제안한 부호화기의 블럭도

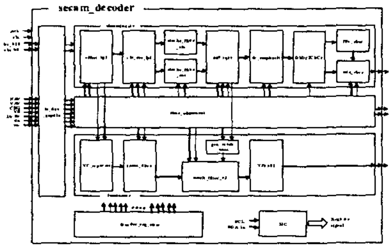
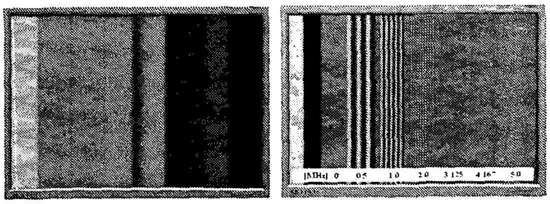
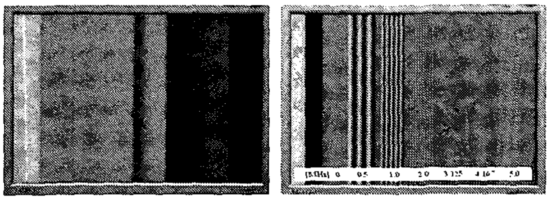


Fig. 5 Block diagram of the proposed decoder
그림. 5 제안한 복호화기의 블럭도



(a) Demodulated Color bar (b) Demodulated multi-burst

Fig. 6 Decoded result without BPF and separating chrominance from CVBS in luminance processing
그림. 6 BPF 없이 밝기신호처리과정에서 CVBS로부터 색차신호를 제거하는 방법을 사용한 복호결과



(a) Demodulated Color ba (b) Demodulated multi-burst

Fig. 7 Decoded result with BPF and separating chrominance from CVBS in luminance processing
그림. 7 BPF와 밝기신호처리과정에서 CVBS로부터 색차신호를 제거하는 방법을 사용한 복호결과

V. Conclusions

In this paper, we proposed the SECAM encoder system using the modified anti-cloche filter. By using the modified anti-cloche filter, the hardware complexity of SECAM encoder system increases, but the filter design is easy and the structure of filter is simple. Also, we proposed the advanced SECAM decoder system using error-free square root, BPF and separating chrominance from CVBS in luminance processing. The error-free square root makes it possible for SECAM decoder to get color information from CVBS by using trigonometric function in chrominance processing. The BPF removes color noise in chrominance processing and the reduced color noise makes luminance band width enlarged. The separating chrominance from CVBS in luminance processing removes FM noise of displayed image. Thus, the proposed SECAM decoder system can provide more vivid and more distinct image. We expect that the proposed SECAM encoder and decoder system can be applied to various display systems such as DVD player, Camcorder, digital camera, and so on available for SECAM.

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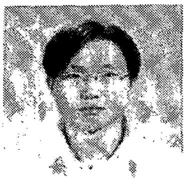

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