

行政院國家科學委員會專題研究計畫成果報告

於混合傳送類此與數位頻道之次載波光纖系統中降低數位頻道誤碼率的方法研究

Methods for reducing M-QAM channel bit-error-rate in hybrid AM/QAM systems

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一、中文摘要

本計畫是提出一個大幅降低在 hybrid AM/QAM CATV 系統中數位 QAM 頻道錯碼率的方法，並以電腦模擬來驗證其可行性。

關鍵詞：CATV, AM, QAM, Bit-error-rate

Abstract

We propose and verify through computer simulations the use of a preceding technique to eliminate the nonlinear distortions in an M-QAM channel, which is transported along with multiple AM-VSB channels by a laser diode. We show that the preceding technique can completely remove the clipping-induced bit-error-rate (BER) floor at a cost of a 3-dB signal-to-noise ratio reduction.

Keywords: Hybrid AM-VSB/M-QAM, preceding, subcarrier-multiplexed systems.

二、緣由與目的

In this letter, we propose a novel preceding technique to solve the problem. This technique was previously adopted by digital spectrum-compatible high definition television broadcast system to reject cochannel NTSC visual, color, and aural carriers [4], and can be realized in an M-QAM modem by digital signal processing techniques. We have modified the preceding technique in [4] to reject discrete interferences located at fixed frequencies such as $6nH1.25$ MHz where composite-triple beat (CTB) occurs (n is an integer), and

$6nH1.25f1.25$ and $6nH1.25f1.75$ MHz where composite second-order (CSO) beat occurs [5].

三、The Precoding Technique

Fig. 1 (a) shows the received M-QAM spectrum interfered by CSO's and CTB due to laser clipping or other nonlinear mechanisms. A possible method to remove the CSO's and CTB is to utilize a comb filter with notches at $6nH0.25k$ MHz where $0 \leq k \leq 23$ [Fig. 1(b)]. This comb filter, which has a transfer function $H_c(f) = \sum_{k=0}^{23} e^{-j2\pi k f T}$ With a delay time $T = 4$ us, must be used in combination with a pre-equalizer [Fig. 1 (c)] whose transfer function is given by $H_e(f) = 1/H_c(f)$ in order to have an overall flat frequency response. However, the pre-equalizer with feedback may become unstable (e.g., when the input signal has a dc component). In addition, the combiner in the pre-equalizer increases the number of possible levels in case of quantized inputs and the required dynamic range in case of analog inputs.

A modification of Fig. 1 (c) by utilizing modulo reductions [4], shown in Fig. 1 (d), can avoid all the above disadvantages and still retain the operation of the comb filtering. The output of the precoder is now confined to the same range of the input data by a modulo operator. Therefore, the precoded data will be stable and has the same dynamic range as the input data.

In the receiver, another modulo operator at the output of the comb filter is required to recover the original data. To show that the

overall coding system works, assume that the input data symbol a_n , $n=0,1,2,\dots,L-1$, i.e., an L-pulse amplitude modulation (L-PAM) signal, where L is a positive integer. The precoded symbol b_n is then given by

$$b_n = \sum_{k=0}^{D-1} a_{n-k} \quad (1)$$

where D is the number of delayed symbols. Similarly, after the comb filter and the modulo operator, the recovered symbol d_n is

$$d_n = \sum_{k=0}^{D-1} b_{n-k} \quad (2)$$

After combining (1) and (2), we obtain

$$d_n = \sum_{k=0}^{D-1} a_{n-k} \quad (3)$$

Since both a_n and d_n are elements of the set $\{0,1,2,\dots,L-1\}$, we can conclude that $a_n = d_n$. Therefore, once an end-to-end transmission is established, the decoded data symbol will be the same as the original data symbol without any timing delay.

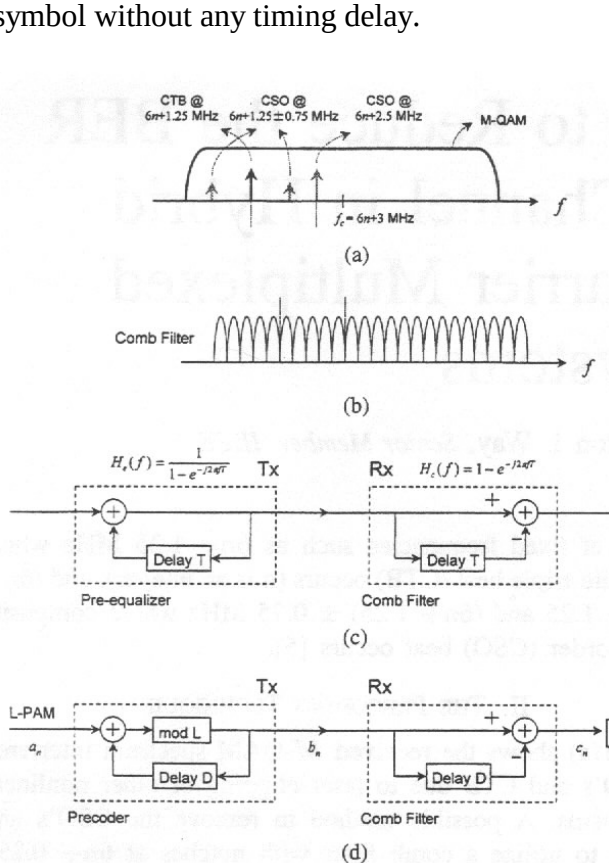


Fig.1. (a) Frequency locations of CSO's and CTB in an M-QAM channel whose center frequency f_c is at $6n+3$ MHz. (b) A comb filter with notches at $6n+0.25k$, where $0 \leq k \leq 23$. (c) A pre-equalizer and a comb filter, with their respective transfer functions shown. (d) A precoder, a comb filter, and a modulo

operator.

We note that the only penalty of the preceding technique is the 3-dB degradation in SNR [4]. This is because that the equivalent noise power after the comb filter is

$$\frac{N_0}{2} \int_{-B}^B |H_c(f)|^2 df = \frac{N_0}{2} \int_{-B}^B |1 - e^{j2\pi fT}|^2 df = 2N_0B \quad (4)$$

where B is the equivalent noise bandwidth of the receiver without comb filter, and $N_0/2$ is the two-sided spectral noise density. Therefore, when the comb filter is added to the system, the equivalent noise power is twice the original equivalent noise power of NOB. However, for the transmitted data, the output of the modulo operator d_n and the input of the comb filter b_n have the same power level. Consequently, a 3-dB SNR reduction results.

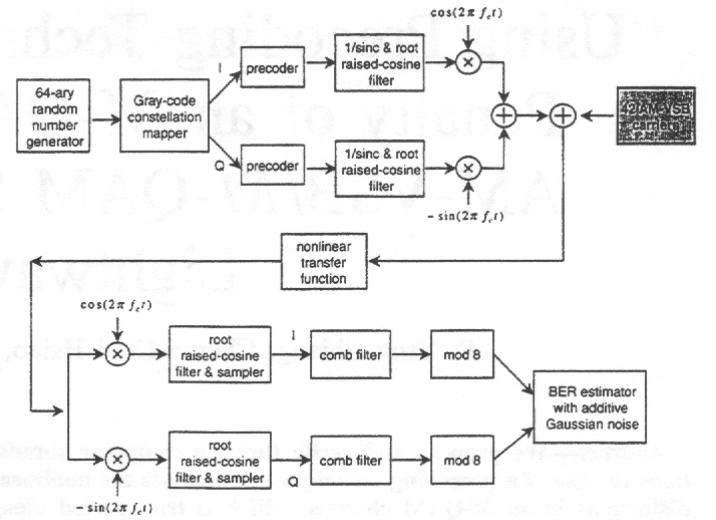


Fig. 2. Simulation block diagram.

四、電腦模擬

The computer simulation system block diagram is shown in Fig. 2, where the nonlinear transfer function represents a laser diode with an arbitrary light output versus current I curve. The simulation parameters and conditions are as follows. 1) The I/Q data were precoded with L=8 (i.e., 8-PAM) and D=20 (i.e., a delay of 20 symbols). 2) 42 random-phased unmodulated carriers (from 55.25 to 307.25 MHz) were

combined with an up-converted 5-Ms/s 64-QAM signal centered at 417 MHz, and the simulation results were averaged over 6000 different phase combinations of the 42 AM channels. The reason why we chose 417 MHz as the center frequency of the QAM channel is to calibrate our simulation results with those of a theoretical analysis [6]. In general, the center frequency of a QAM channel can be allocated at $m f_a$ MHz, where m is an integer and f_a is the frequency separation between notches, in order to suppress all the CTB and CSO's. 3) The sampling frequency was 5 GHz, which is high enough to remove the spectral aliasing error. 4) Root raised-cosine (RRC) filters with a rolloff factor of 0.2 were used as band-limiting pulse-shaping filters in the transmitter, and as matched filters in the receiver, respectively. 5) In the receiver, ideal carrier and timing recoveries were assumed.

CHIANG *et al.*: USING PRECODING TECHNIQUE

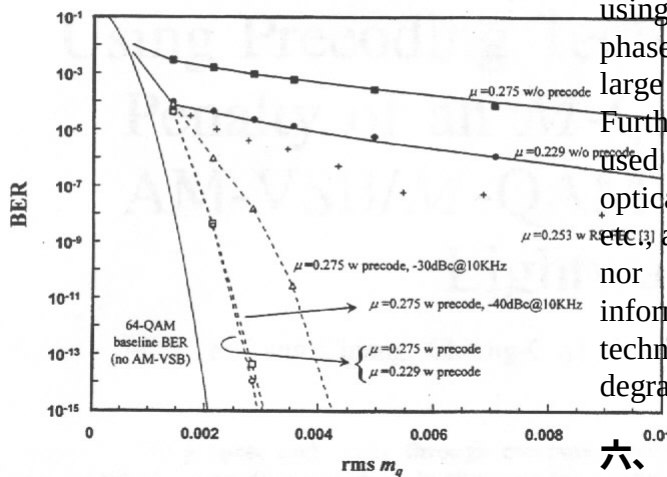


Fig.3. 64-QAM BER versus its rms optical modulation index m_q .

Fig. 3 shows the BER versus rms optical modulation index (OMI) of the 64-QAM channel. As a calibration of our simulation technique, we first note that if the preceding technique is not used, the simulated BER performances due to laser clipping (solid squares and circles) are about the same as those calculated from theory (lines) [6] for total rms OMI $\mu = 0.275$ and

0.229, respectively. When the preceding technique is used, it is observed that the noise floors are completely removed for both μ 's (open circles). The deviation from the baseline BER curve is due to the 3-dB signal-to-noise ratio (SNR) degradation of the comb filtering, as was explained in Section B.

The experimental results which used (204 188) RS-FEC and $\mu = 0.253$ [31] are also shown in Fig. 3 for comparison. We can see that there still exists a BER floor when using this RSFEC. In contrast, when preceding technique is used, the BER is decreased significantly even when a larger μ of 0.275 is used.

五、結論

A novel preceding technique which can be used to eliminate CTB/CSO's in hybrid AM-VSB/M-QAM SCM Lightwave systems is proposed and its feasibility is verified by computer simulations. The BER floor due to laser clipping-induced CSO/CTB in an M-QAM channel can be completely removed by using the preceding technique, even when the phase noise in each AM-VSB carrier is as large as -40 dBc at 10 kHz offset. Furthermore, this preceding technique can be used to eliminate CTB/CSO's induced by optical fiber dispersions, optical reflections, etc., and presents neither bandwidth overhead nor timing delay of the transported information. The only penalty in using this technique is that there is a 3-dB SNR degradation due to the comb filtering.

六、自我評估

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