QUANTIZATION METHOD OF FILTER COEFFICIENTS FOR IMPROVING BER CHARACTERISTICS IN DIGITAL MODULATION SCHEME

Hideaki MUNEMASA[1], Koichi ICHIGE[2]

[1]*Department of Electrical and Computer Engineering, Yokohama National University*
79-5 Tokiwadai, Hodogaya-ku, Yokohama 240-8501, Japan
and E-mail: mune@ichilab.dnj.ynu.ac.jp
[2]*As (1) above, but E-mail: koichi@ynu.ac.jp*

Abstract

This paper proposes a new SPT (Signed Power-of-Two) allocation scheme for filter coefficients in order to improve BER characteristics in communication system. Digital communication system should reduce interference of adjacent channels and improve BER characteristics within a limited frequency band. The accuracy of filter coefficients becomes worse if we implement the filter on a fixed-point digital device with shorter bit length. SPT term expresses each coefficient as a sum of signed 2^n terms, and leads better filter characteristics in comparison with normal quantization. The performance of the present algorithm is evaluated through the comparison of BER characteristics for digital modulation.

1 Introduction

Mobile communication techniques are developing toward next generation technologies that enable very high-speed and large-capacity communication. The communication system, especially transmitter and receiver, should achieve a high BER (Bit Error Rate) characteristic for such purpose. Digital signals used for mobile communication are generally multi-bit binary pulse signals with wideband spectrum. Many users in a same transmission path may cause interference between channels. Digital communication system must reduce interference of adjacent channels and improve BER characteristics for the efficiently use of limited frequency band. When a signal is transmitted in radio path with a limited finite frequency band, its waveform is distorted by Inter Symbol Interference (ISI). Impulse response must cross 0 at every symbol interval T to transmit signals without ISI. The digital filters which satisfy this condition is called Nyquist filters. Cosine Rolloff Filter (CRF) and root CRF are often used as a Nyquist filter for communication applications. However, the accuracy of filter coefficients becomes worse if we implement the filter on a fixed-point calculation digital device such as DSP and FPGA with shorter bit length. High accuracy by short bit length filtering is desired for communication applications.

As an effective quantization method of filter coefficients, the technique which uses SPT terms (Signed Power-of-Two terms) has already been proposed [1]. Using SPT terms, each coefficient is expressed as a sum of signed 2^n terms. Because multiplication of 2^n is equivalent to just a shift operation, the filter can be implemented without multipliers. This quantization method can be suitable for high-speed processing communication techniques. The way to allocate SPT terms to obtain better frequency response is discussed in [1], however, this allocation scheme is not always the best for communication systems evaluated through BER characteristics.

This paper focuses SPT term allocation to improve BER characteristics in communication system. When the coefficients in the edge of the impulse response are quantized to 0, the cutoff response and stopband characteristics becomes worse and they tend to lead worse BER characteristics. Therefore we propose a new SPT allocation scheme to improve BER characteristics for communication systems. Our method allocates more SPT terms in the edge and less SPT terms in the vicinity of the center by weighted coefficients of the filter. We designed root CRF for the validity of these weight to allocate and evaluate BER characteristics given by quantization using SPT term allocation scheme.

2 Filtering between transmitter and receiver

When digital signal processing systems are implemented in ASIC or FPGA, quantization error makes problems like overflow, noise and oscillation. Quantization error remarkably appears in the fixed-point calculation compared with the floating-point calculation. The fixed-point calculation has advantages over the floating-point calculation at low cost and high speed. In this section, we explain filtering between transmitter and receiver.

Filters are used to bandlimit modulated digital signals and to suppress interference signals. Those filters are often used in transmitting and receiving systems like Fig.1 as matched filters.

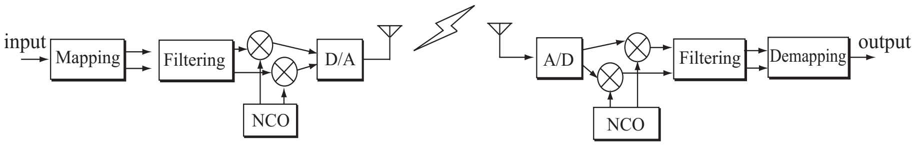

Figure 1: Filtering between transmitter and receiver

3 Quantization techniques

In this section, we first show the SPT allocation scheme of [1] briefly as a previous work, and then present a new SPT allocation scheme to design filters which achieve better BER characteristics.

3.1 SPT term allocation scheme

If each coefficient of digital filters is represented by the sum of signed SPT terms, the filter can be implemented without multipliers. The number of SPT terms allocation to the coefficients is determined by the statistical quantization step-size of those coefficients. To allocate SPT terms to the coefficients, it is necessary to have an estimate of the magnitude of each coefficient. The SPT term allocation score $c(n)$ is defined for each coefficient $a(n)$ as follows:

$$c(n) = 0.36 \log_2 |a(n)| \tag{1}$$

This is an effective design method, but not always optimum to design quantized filters for wireless communication.

3.2 Proposed method

The filter which has good stopband characteristics is used to remove interference signals lying on the neighboring frequency range. The shorter filter length is desired for communication system, but shorter filters are difficult to reduce those interference. It is required to consider the quantization technique to improve the characteristics around the stopband edge for the filters that have small circuit scale. The circuit scale of the filter is designed smaller, the number of SPT terms which are allocated to the filter coefficients are reduced, it leads worse frequency response. The method in [1] allocates more SPT terms to large coefficient than small coefficients. If SPT terms are allocated mainly to the center of the impulse response, coefficients in the edge of the impulse response are quantized to 0. It leads worse cutoff characteristics and the filter cannot remove interferences.

Therefore, cutoff characteristic is improved by weighting to the edge of the impulse response. The weights which increase the both edges make truncation error large, we use the weights of the edge and the center which are small; the weights of the edge are large. Therefore we represent the weights as third-order function in (2). In allocation, moduli of amplitude response are weighted by (2).

$$w_k = (M - |k|)^3 + M \tag{2}$$
$$a_w(k) = (w_k * h)(k) \tag{3}$$

Let denote w_k as the weight for k-th impulse response away from the center of impulse response. If filter length N is odd, $-\frac{N-1}{2} \le k \le \frac{N-1}{2}$, $M = \frac{N-1}{2} + 1$, and if N is even, $-\frac{N}{2} \le k \le \frac{N}{2}$, $M = \frac{N}{2}$. Denote $a_w(k)$ is the value assigned to (1) instead of $a(k)$ as given by (3). Our method can improve frequency response of the filter coefficients quantized one SPT. Deterioration of the center of the impulse response by allocation SPT terms to the edge of the impulse response leads worse frequency response of between the passband edge and the stopband edge. But our method keeps filter length, frequency response of the stopband is better than other methods. The proposed method can improve the stopband characteristics, effective for communication systems. The coefficient to receive an SPT term is the one with the largest $c(k)$. After a coefficient has received an SPT term, its corresponding value of $c(k)$ is decreased by one. Our algorithm using weighted coefficients runs follows.

Step1: Let R be the total number of SPT terms to be allocated. Let $u(k)$ is the number of SPT to be assigned to $a(k)$. Initialize $u(k) = 0$.

Step2: Calculate w_k and $a_w(k)$ for all k.

Step3: Evaluate $c(k) = 0.36 \log_2 |a_w(k)|$ for all k.

Step4: Let $c(i)$ be the largest $c(k)$ for all k. Search $c(i)$.

Step5: If $c(i)$ is found, replace $u(i)$ by $u(i) + 1$, replace $c(i)$ by $c(i) - 1$, then replace R by $R - 1$.

Step6: If $R = 0$, finish to allocate. Otherwise, go back to Step3.

4 Simulation results

In this section, BER characteristics of the proposed method in section 3 are evaluated through computer simulation in comparison of those by the method in [1].

4.1 BER characteristics for modulated wave

Table 1 shows specifications of the simulation. In order to examine their BER characteristics, we designed root CRF of which coefficients are quantized by 2 bit, Ref.[1] and the proposed method. Fig.4 and 5 shows the comparison of the BER characteristics in QPSK, 16QAM, respectively. We examined BER characteristics at the same number of SPT terms, in other words, same number of calculation. The band-limited 8PSK signal arrives in contiguous band of the desired wave. How the filters eliminate the interference of contiguous band is evaluated in this simulation. The computational effort of allocation SPT terms equals to 2 bit quantization. 2bit quantization cannot remove the interference of contiguous band, its BER characteristics becomes worse. The proposed method can eliminate the interference of contiguous band, and yields good BER characteristics close to infinite precision. To obtain fine BER characteristics in the case of the same number of the SPT terms, our method keeps filter length is effective.

Table 1: Specifications of simulation

Modulation type	QPSK / 16QAM
Signal frequency	10 MHz
Signal bandwidth	10 MHz
Sampling frequency	40 MHz
Modulation type of interference	8PSK
Signal frequency of interference	20 MHz
Signal bandwidth of interference	10 MHz
Filter type	Root CRF
Filter length : N	35
Roll-off factor	0.5
Number of SPT-terms	22, 30

Table 2: Circuit scale

	Circuit Scale	Clock Frequency	DSP blocks
Direct	893	67.92 MHz	33
Proposed	293	74.35 MHz	0

4.2 FPGA Implementation

We simulated to examine circuit scale of the filter in Quartus II, we designed 33-th order root CRF. The FPGA we used is Stratix EP1S40F780 which has 41250 LEs (Logic Elements) and has 112 DSP blocks for calculation. The cost of the filter implemented in Stratix and maximum operating frequency are shown in Table 2. Our method is multiplierless implementation and the filter is designed with SPT terms. Our filter doesn't need to use DSP blocks. Nevertheless, maximum operating frequency of proposal implementation is higher than direct implementation, because multiplierless implementation is simple architecture.

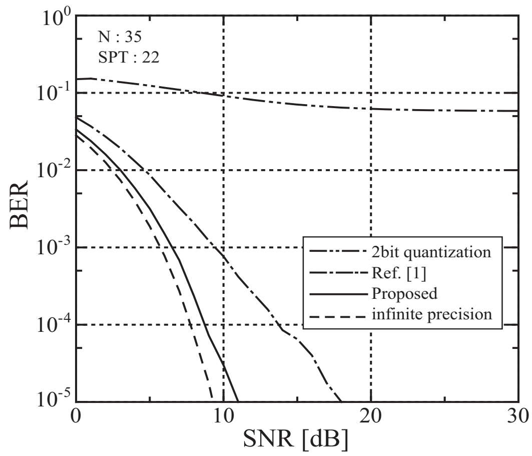

Figure 2: BER characteristics at QPSK

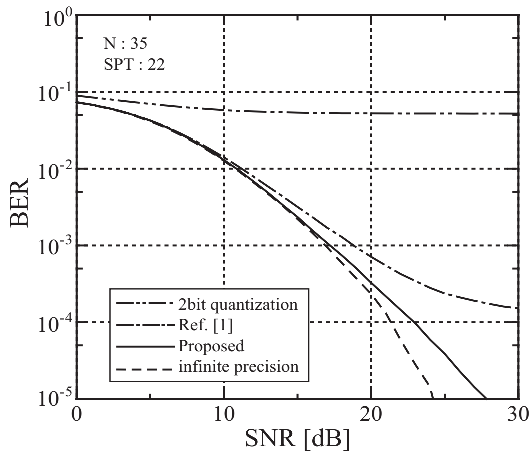

Figure 3: BER characteristics at 16QAM

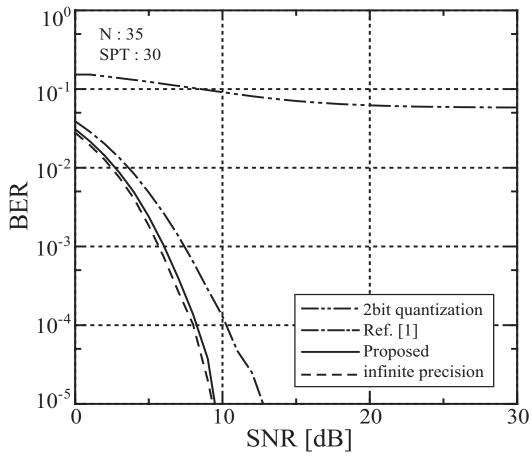

Figure 4: BER characteristics at QPSK

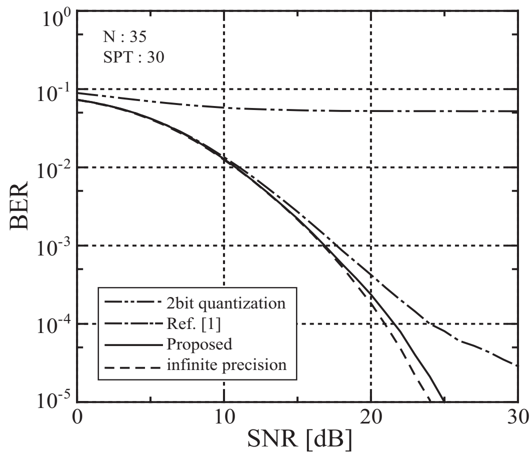

Figure 5: BER characteristics at 16QAM

5 Conclusion

In this paper, we proposed a new SPT-term allocation scheme for filter coefficients which improves BER characteristics in communication system. We have confirmed that BER characteristics could be improved by the proposed SPT term allocation scheme throughout some simulation. The proposed method is very simple and effective in improving BER characteristics in communication system.

References

[1] Y. C. Lim, R. Yang, D. Li and J. Song, ”Signed power-of-two terms allocation scheme for the design of digital filters”, IEEE Trans. Circuits Syst.II vol.46, no.5, pp.577-584, May, 1999.