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Comparison of Three Different Cancellation Schemes for Orthogonal Frequency Division Multiplexing (OFDM) System

Ma Khin Saw, Aye Aye Khine

Department of Electronic Engineering, Technological University, Yamethin, Myanmar

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ABSTRACT

Orthogonal Frequency Division Multiplexing (OFDM) is an exceptional case of Frequency Division Multiplexing. The dilemma of OFDM is its sensitivity to frequency offset between the transmitted and received carrier frequencies. This frequency offset establishes Inter-Carrier Interference (ICI) Cancellation in the OFDM symbol. ICI reduction methods have been had by OFDM. This research considers three ICI self-cancellation (SC), maximum likelihood (ML) estimation, and extended Kalman filter (EKF) method. These three methods are compared in terms of bit error rate performance, bandwidth efficiency, and computational complexity. For high values of the frequency offset and for higher order modulation schemes, the SC method does not as well as the ML and EKF methods. Simulation results using MATLAB software.

Keywords: *OFDM, ICI cancellation, Bit Error Rate, BPSK Modulation, Additive white Gaussian noise (AWGN). MATLAB*

I. INTRODUCTION

This Orthogonal Frequency Division Multiplexing (OFDM) is appearing as the desired modulation scheme in modern high data rate wireless communication systems. OFDM has been espoused in the digital audio and video broadcast radio system and is being investigated for broadband indoor wireless communications. Standards such as HIPERLAN 2 and IEEE-802.11 a have come into support IP-based services. OFDM can be seen either a modulation technique or a multiplexing technique. One of the main reasons to use OFDM is to enlarge the robustness against frequency selective fading.

In OFDM, the multiple frequency channels are called sub-carriers, are orthogonal to each other. The problem of OFDM is its sensitivity to frequency offset between the transmitted and received signals, this may be caused by Doppler shift in the channel, or by the difference between transmitter and receiver local oscillator frequencies. This carrier frequency offset causes loss of orthogonally between sub-carriers and the signals transmitted on each carrier are dependent of each other, OFDM is a valuable technique to conflict multipath effect, Inter- Symbol Interference (ISI) and frequency selective fading. But in application, a major problem of OFDM is very sensitive to the frequency offset which causes Inter- Carrier Interference (ICI). By using MATLAB Simulation, this research purposing to see how the Bit Error Ratio (BER) of a transmission varies when Signal to Noise Ratio (S/N) and Orthogonal Frequency Division Multiplexing transmission channel. The Bit Error Rate (BER) caused by Inter Carrier Interference (ICI) raises greatly with the increase of frequency offset in Orthogonal Frequency Division Multiplexing systems. Researchers have proposed various methods to combat the ICI in OFDM systems. The existing approaches have been expanded to decrease ICI can be grouped frequency-domain equalization, time-domain windowing and ICI self-cancellation (SC) scheme. In this research, the effects of ICI have been analyzed and three solutions to combat ICI have been presented. The first method is a self-cancellation scheme, in which unnecessary data is transmitted on to close sub-carriers. The ICI between adjacent sub-carriers cancels out at the receiver. The other two techniques, maximum likelihood (ML) estimation and the extended Kalman filter (EKF) method, estimate the frequency offset and correct the offset using the estimated value at the receiver.

II. DESCRIPTION OF OFDM SYSTEM

In an OFDM system, the input bit stream is multiplexed into N symbol streams, each with symbol period T_s, and each symbol stream is used to modulate parallel, synchronous sub-carriers. The sub-carriers are spaced by $1/NT_s$ in frequency, thus they are orthogonal over the interval $(0,T_s)$. Figure 1. shows a typical discrete-time baseband OFDM transceiver system. First, serial-to-parallel(S/P) converter groups the stream of input bits from the source encoder into groups of $\log_2 M$ bits, where M is the alphabet of size of the digital modulation scheme employed on each sub-carrier. A total of N such symbols, X_m, are created. Then, the N symbols are mapped to bins of an inverse fast Fourier transform (IFFT). These IFFT bins communicate to the orthogonal sub-carriers in the OFDM symbol. Therefore, the OFDM symbol can be expressed as

$$x(n)=\frac{1}{N}\sum_{m=0}^{N-1}X_m e^{j\frac{2\pi nm}{N}} \quad \text{----------(1)}$$

where the X_m's are the baseband symbols on each sub-carrier. The digital-to-analog (D/A) converter then creates an analog time-domain signal which is transmitted through the channel.

At the receiver, the signal is converted back to a discrete N point sequence y(n), corresponding to each sub-carrier. This discrete signal is demodulated using and N point fast Fourier transform (FFT) operation at the receiver. The demodulated symbol stream is given by:

$$Y(m) = \sum_{m=0}^{N-1} y(n) e^{-j\frac{2\pi nm}{N}} + W(m) \qquad \text{---------(2)}$$

where, W (m) corresponds to the FFT of the sample of w(n), which is the Additive White Gaussian Noise (AWGN) introduced in the channel.

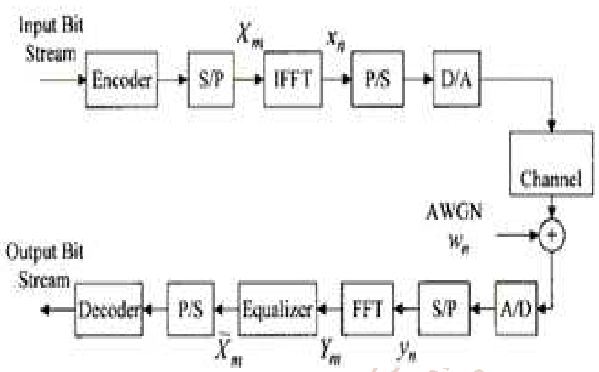

Figure1. Baseband OFDM transceiver system

III. Comparison Of Three Different Cancellation Schemes

To compare the three different cancellation schemes, BER curves were used to evaluate the performance of each scheme. By using MATLAB simulation, the results are expressed in this research. The OFDM transceiver system was implemented as specified by figure 1. Modulation schemes of binary phase shift keying (BPSK) and 4-ary quadrature amplitude modulation (QAM) were chosen because they are used in many standards such as 802.11a. The normalized frequency offsets of simulations equal to 0.05, 0.15, and 0.30 are given in figure 2(a) and (b).

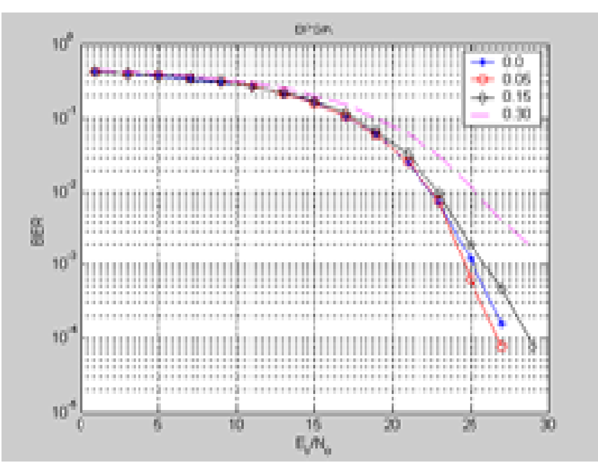

Figure2 (a) BER performance of a standard OFDM system without ICI cancellation for BPSK.

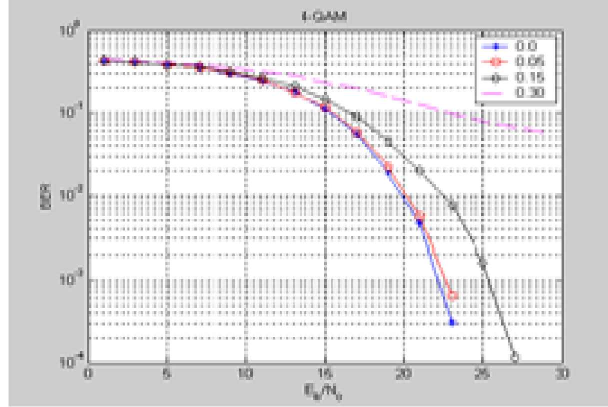

Figure2 (b) BER performance of a standard OFDM system without ICI cancellation for 4-QAM

These results show that debasement of performance increases with frequency offset. In case of binary phase shift keying, the frequency offset of 0.30 does not get worse the performance too greatly. When frequency offset is small, the 4-QAM system has a lower BER than the BPSK system. But the BER of BPSK diverse more dramatically with the decrease the frequency offset than that of 4-QAM. Therefore, it is terminated that larger alphabet sizes are more sensitive to ICI. The comparisons of performance of the SC, ML and EKF schemes for different alphabet sizes and different values of the frequency offset show in figure 3(a) and (b). It is examined in the figures that each method has its own advantages. The presence of small frequency offset and binary alphabet size, self-cancellation gives the best results. Although, for larger alphabet sizes and larger frequency offset such as 4- QAM and frequency offset of 0.05, self cancellation offers much decrease in performance. The best overall results are given by the maximum likelihood method. The Kalman filter method indicates that for very small frequency offset, it performs very badly, as it barely improves BER. However, for high frequency offset the Kalman filter does perform extremely well. It gives a significant high to performance.

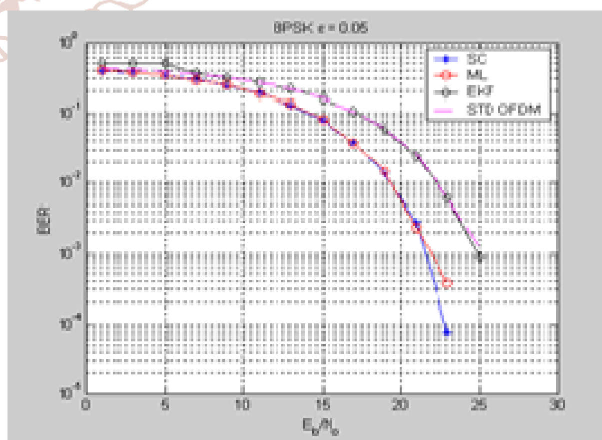

Figure3 (a) BER Performance with ICI Cancellation, ε = 0.05 for BPSK

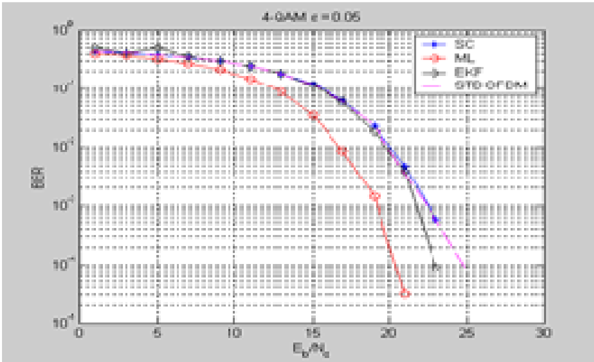

Figure3 (b) BER Performance with ICI Cancellation, ε = 0.05 for 4-QAM.

For small alphabet sizes (BPSK) and for low frequency offset values, the SC and ML techniques have good performance in terms of BER. However, the EKF and ML techniques perform better are higher order modulation schemes. The ML and EKF methods estimate the frequency offset very precisely and cancel the offset using this estimated value. However, the self-cancellation technique does not absolutely cancel the ICI from adjacent sub-carriers. The effect of this residual ICI increases for larger alphabet sizes and offset values.

IV. CONCLUSION

In this research, orthogonal frequency division multiplexing comes out to be a good modulation technique for high performance wireless communications. Between the transmitter and receiver, the performance of OFDM systems in the presence of frequency offset has been studied in terms of the bit (BER) performance and Carrier-to-Interference ratio. Inter-carrier Interference (ICI) which results from the frequency offset corrupts the performance of the OFDM system.

Three methods were discovered in this research for lessen of the ICI. The ICI self-cancellation (SC) and the maximum likelihood (ML) estimation techniques were proposed in prior publications. In this research, the extended Kalman filtering (EKF) method for estimation and cancellation of the frequency offset has been investigated, and compared with the SC and ML techniques. The choice of which method to employ depends on the specific application. Self-cancellation (SC) does not require very complex hardware or software for implementation. The ML method also introduces the same level of redundancy but provides better BER performance. As it accurately estimates the frequency offset. Its implementation is more complex than the SC method. On the other hand, the EKF method does not reduce bandwidth efficiency as the frequency offset can be estimated from the preamble of the data sequence in each OFDM frame. OFDM has the most complex implementation of the three methods. Moreover, this method requires a training sequence to be sent before the data symbols for estimation of the frequency offset. Also, the case of self cancellation modified self cancellation and maximum likelihood methods. In these methods, bandwidth efficiency is reduced. To use a particular Inter-carrier Interference reduction method in OFDM system. There must be a tradeoff between bandwidth efficiency and bit error rate.

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