Development of Zero-Padded Conjugate Cancellation Transmission with Adaptive Receiver for ICI Cancellation

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Abstract: ***OFDM (Orthogonal Frequency Division Multiplexing) system is the high bandwidth efficient technique mainly used for high data transmission over the multipath fading environment. The major challenges faced by OFDM/OFDMA systems are sensitivity to frequency selective fading and ICI due to Doppler shift and CFO when subcarrier spacing becomes smaller. So we implement the zero padded conjugate technique with Adaptive receiver to cancel out the ICI. Adaptive receiver has the frequency tracking capability by adopting the normalized block least mean-squared algorithm. Zero padding makes the signal more robust to errors and also increases the subcarrier spacing. In this paper proposed design methodology is discussed in detail and performance is evaluated for AWGN fading channel for BPSK, QPSK and 16-QAM modulation techniques in terms of BER.***

Keywords: Block least mean-squared (BLMS) algorithm; frequency offset; inter-carrier interference (ICI); orthogonal frequency division multiplexing.

1. Introduction

Orthogonal Frequency Division Multiplexing (OFDM) is the multi-carrier transmission technique used for high data rate transmission [1] over the broadband wireless communication systems. OFDM is a Multi-Carrier Modulation technique in which a high rate bit-stream is split into (say) N parallel bit-streams of lower rate and each of these are modulated using one of N orthogonal sub-carriers.

In OFDM the basic idea is to divide the available spectrum into many orthogonal narrowband sub channels so that each sub channel experience almost flat fading. OFDM can provide large data rates with sufficient resistance to radio channel impairments like multipath fading.

So it becomes very efficient technique for data transmission over multipath fading environment due to its properties like a) high bandwidth efficiency and b) resistance to multipath fading. OFDM has been adopted in the European digital audio and video broadcast radio system and is being investigated for broadband indoor wireless communications. Standards such as HIPERLAN2 (High Performance Local Area Network) and IEEE 802.11a and IEEE 802.11gIts implementation becomes easier with the help of Fast Fourier Transform and Inverse Fast Fourier Transform for demodulation and modulation respectively [2]. The major problem of such a highly efficient modulation system is the sensitivity to the frequency offset, which may result either from mismatch between the oscillator and the Doppler shift. In such situations, the orthogonality of the carriers is no longer maintained, which results in Intercarrier Interference (ICI). If ICI is not properly compensated it results in power leakage among the subcarriers, thus degrading the system performance.

The ICI can be removed by using various techniques like conventional self cancellation methods [3]-[5]. One major problem reported with these kinds of methods is that the bit error rate (BER) performance is limited due to the constant phase error generated at the coherent detection process. Another methods used for ICI cancellation are based on performing correlative coding [6]-[7] before the inverse Fast Fourier transform (IFFT) block of OFDM transmitter. Such types of methods are more suitable for BPSK transmissions.

In Conjugate cancellation (CC) method [8] of ICI cancellation, the first path represents the standard OFDM signal and the second one is formed by a conjugate of the first paths. CC method is not performing effectively for high offset frequency situations. Another effective method used for ICI cancellation is general phase rotated conjugate cancellation (PRCC) [9]. Simply an artificial phase rotation is introduced which is determined by the frequency offset estimate in the training mode. The optimal phase rotation is derived with the criterion of maximizing the carrier-to-interference ratio (CIR), to achieve better performance. To determine optimal phase rotation frequency offset estimate has to feedback from receiver to transmitter and this is the major drawback of phase rotated conjugate cancellation (PRCC) scheme.

In this paper to further enhance the performance of PRCC method for time-varying frequency offset situations the concept of Zero padding is used with Adaptive receiver. As the main problem of ICI occurs due to frequency mismatching between transmitter and receiver oscillator, so the main advantage of zero padding is it provide better Time and Frequency synchronization by making non-information carriers to zero. Also the zero padded signals are more robust to fading. Adaptive receiver has the advantage to adapt the frequency offset by using the BLMS algorithm. So by use of zero padding with adaptive receiver we can achieves better BER performance to mitigate ICI in OFDM systems.

The rest of the paper is organized as follows: In Section II OFDM system and related work is described, In Section III, the improved design methodology is proposed. In Section III, paper is concluded.

2. System Model

2.1 OFDM System Model

In an OFDM system, the input bit stream is multiplexed into N symbol streams, each with symbol period Ts, and each symbol stream is used to modulate parallel sub-carriers. These sub-carriers are spaced by 1/NTs in frequency. After applying inverse Fast Fourier transform baseband discrete-time OFDM signal is given as;

$$x_m = \frac{1}{N}\sum_{k=0}^{N-1} X_l e^{j\frac{2\pi}{N}mk} \quad 0 \le m \le N-1 \quad (1)$$

where N is the total number of subcarriers, and X_l is the a symbol modulating the l_{th} subcarrier. After passing through an additive white Gaussian noise (AWGN) channel, with the presence of frequency offset a linear phase rotation is produced, which is given as;

$$y_m = x_m e^{j\frac{2\pi}{N}m\varepsilon} + w_m \quad 0 \le m \le N-1 \quad (2)$$

where ε is the frequency offset by subcarrier frequency spacing, and w_n is the AWGN noise. After performing the fast fourier transform (FFT), the frequency domain signal on received signal is as shown;

$$Y_k = \frac{1}{N}\sum_{m=0}^{N-1} y_m e^{-j\frac{2\pi}{N}mk}$$

$$= \sum_{m=0}^{N-1} (x_m e^{j2\pi m\varepsilon/N} + w_m) e^{-j2\pi mk/N}$$

$$= \frac{1}{N}\sum_{k=0}^{N-1} X_l \sum_{m=0}^{N-1} e^{-j2\pi m(k-m-e)/N}$$

$$+ \sum_{m=0}^{N-1} w_n e^{-j2\pi mk/N} \quad (3)$$

Expression (3) can also be written as follows;

$$X_k S(-\varepsilon) + \sum_{l=0, l\neq k}^{N-1} X_l S(k-l-\varepsilon) + W_k \quad k = 0, 1 \ldots N-1 \quad (4)$$

Here W_k is the Fourier transform of w_m.
where the term *s(k-l+ε)* referred as the ICI coefficient. The first term in the expression (4) is the desired information signal i.e. X_k, and second term is regarded as sum of interferences from X_k.

2.2 CC Scheme [8]

In Conjugate cancellation (CC) method, the first path represents the standard OFDM signal and the second one is formed by a conjugate of the first paths. At the receiver side, the received time-domain signal of first path is same as given in expression (2) and second path signal is given as;

$$y'_{k,cc} = X_k[S(\varepsilon) + S(-\varepsilon)] + \sum_{l=0, l\neq k}^{N-1} X_l (S(k-l+\varepsilon) + S(k-l-\varepsilon)) + W_k^* \quad (5)$$

At receiver side, combination of first and conjugate of second path achieves the ICI cancellation. The combined output and the CIR are given as below;

$$\text{CIR}_{cc} = \frac{|s(-\varepsilon) + s(\varepsilon)|}{\sum_{k=0}^{N-1} |s(k-\varepsilon) + s(k+\varepsilon)|} \quad (6)$$

3. Motivation and Objective

As today's era is of digital wireless communication, so Third Generation (3G) and Fourth Generation (4G) are intended to provide high speed, high capacity, low cost per bit, IP based services. So, in wireless communication to fulfill all these requirements, concept of parallel transmission of symbols is used to achieve high throughput and better transmission quality. Orthogonal Frequency Division Multiplexing (OFDM) is one of the techniques used for parallel transmission. It becomes very efficient technique for data transmission over multipath fading environment due to its properties like high bandwidth efficiency and resistance to multipath fading. The main disadvantage of ODFM system is its sensitivity to synchronization error, such as frequency or phase offsets, Frequency offset results from Doppler effects i.e. due to mismatch between the transmitter and receiver local oscillators, due to which the orthogonality of subcarriers is not longer maintained, and results in Intercarrier Interference (ICI). So main motive of this thesis work is to implement highly efficient system to mitigate the effect of ICI.

Objective

- To study a concept of Intercarrier Interference (ICI) for Orthogonal Frequency Division Multiplexing (OFDM) Transmission Technology in multipath fading environment.
- To design and evaluate Orthogonal Frequency Division Multiplexing (OFDM) in a Multipath Fading Channel using computer simulation (MATLAB)
- To compare the results of proposed technique with previous techniques for AWGN and Rayleigh channel to cancel out ICI for Orthogonal Frequency Division Multiplexing (OFDM)
- To obtain and compare the Bit Error Rate (BER) Performance of proposed technique with previous techniques for different frequency offset situations.

4. Methodology

The simulation is carried out using MATLAB software, i.e. product of MathWork Inc. MATLAB is the language of matrix calculation and stands for MATrix LABoratory. The modulation techniques used are BPSK, QPSK, 16-QAM for AWGN multipath fading channels. The proposed scheme works for both time varying and time invariant channels. The flowchart of proposed diagram is as shown in Figure 1.

5. Proposed Scheme

5.1 Signal Model

The modulated symbol X_l (l=0….N-1) are zero padded. The transmitted signal in frequency domain on l^{th} transmitting subcarrier is given by D = (X_0, 0, X_1, 0,….o, X_{N-1}). After passing through the AWGN fading channel, the time domain received signal on first path is given as;

$$y_m = de^{j\frac{2\pi}{N}m\varepsilon} + w_m \quad (7)$$

and signal on second path is denoted as;

$$y'_m = d^* e^{j\frac{2\pi}{N}me} + w'_m \quad (8)$$

After applying FFT to the received signals;

$$Y_k^{1st} = \sum_{m=0}^{N-1} DS(k-l-\varepsilon) + W_k \quad (9)$$

Signal on second path is shown as;

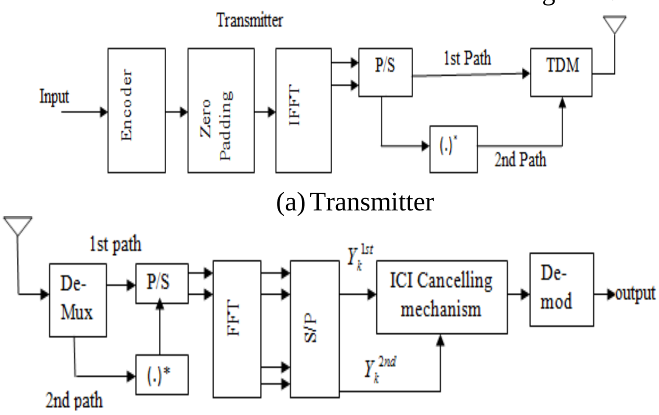
$$Y_k^{2nd} = \sum_{m=0}^{N-1} DS(k-l+\varepsilon) + W'_k \quad (10)$$

Where W_k and W'_k are the Fourier transform of w_m and w'_m respectively. Consider AWGN channel model and two frequency offsets seen in two paths are denoted by ε and Δε respectively, after applying two different phase rotations on both paths, the combining output becomes;

$$Z_{k,proposed} = \left[e^{j\phi} S(e) + e^{-j(\phi+\Delta\phi)} S(-(\varepsilon+\Delta\varepsilon))\right] D$$
$$+ \sum_{l=0, l\neq k}^{N-1} \left[e^{j\phi} S(k-l+\varepsilon) + e^{-j(\phi+\Delta\phi)} S(k-l-(\varepsilon+\Delta\varepsilon))\right] D$$
$$+ \left[W_k + W'_k\right]$$
(11)

5.2 Normalized BLMS

The normalized BLMS is used to update the frequency offset errors, the block size is chosen the same as length of FFT. The error is finout using;
Error = (desired signal)-(received signal)
The step size is taken as 0.08. It process the error block by block rather than sample by sample. The proposed transmitter and receiver structure is as shown in Figure 2.



(a) Transmitter

(a) Receiver

Figure 2: Block diagram of (a) proposed transmitter and (b) proposed receiver

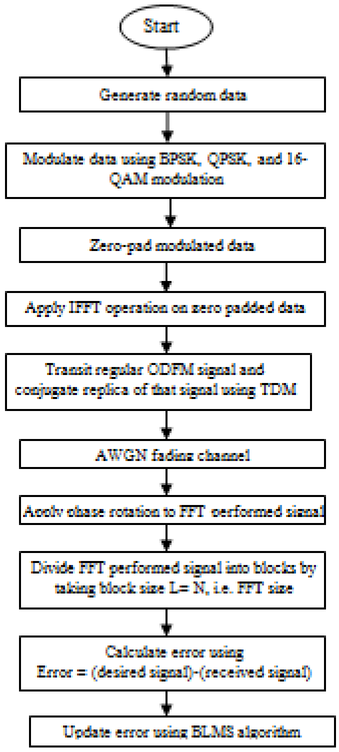


Figure 1: Proposed Methodology

6. Results & Comparison

The purpose of this thesis work is to cancel out the effect of ICI at the receiver side. The effectiveness of proposed scheme is carried out using MATLAB Software. The modulation techniques used are BPSK, QPSK and 16-QAM for AWGN fading channel. Each OFDM symbol is composed of 1024 subcarriers in frequency domain i.e. N=1024. In Figure 3 the BER comparison of proposed scheme is carried out using different modulation i.e. BPSK, QPSK and 16-QAM with standard OFDM signal. It is seen from graph that proposed performs better than standard OFDM signal for fixed frequency offsets.

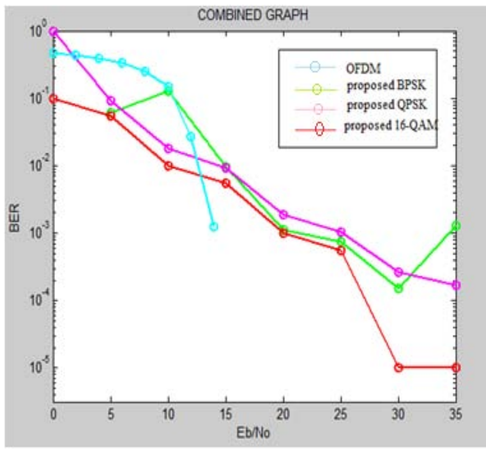


Figure 3: BER comparison of proposed scheme using different modulation schemes with OFDM

In Figure 4. Performance of proposed scheme is comared with previous schemes like CC and PRCC in terms of BER. The BER of proposed scheme is better than CC and PRCC for higher frequency offset variations for AWGN fading environment.

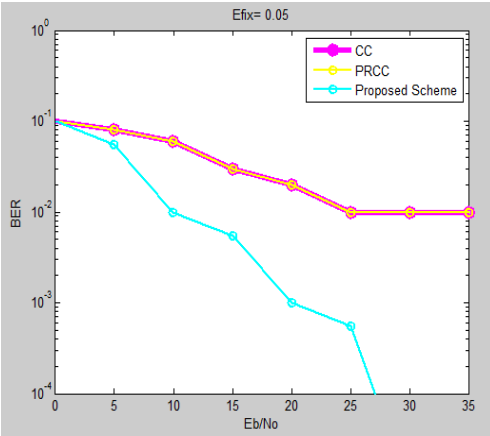


Figure 4: BER comparison of proposed scheme with CC, PRCC using 16-QAM modulation for ε_{fix}=0.05

7. Conclusion

The ICI problem in OFDM system occurs from frequency mismatch between the transmitter and receiver oscillator (constant) and from the Doppler shift (time varying), which results in loss of orthogonality among the subcarriers. The proposed scheme works for both fixed frequency and time varying frequency offsets. So in this paper the consecutive subcarrier are zero padded at transmitter side to make signal more robust to offset errors. The standard signal and its conjugate replica is transmitted using TDM to nullify effect of ICI at receiver and further to enhance the system performance adaptive receiver is used to update frequency offset errors using BLMS algorithm. Simulation results shows that proposed schemes out performs in term of BER than previous techniques for AWGN fading channel.

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