Frequency Offset Sensitivity Reduction in OFDM Mobile Communication System

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Abstract-**In OFDM, it is difficult to set up perfect synchronization between the transmitter and the receiver due to intercarrier interference (ICI). A new technique that is combination of self ICI cancellation scheme and windowing method is proposed for frequency offset reduction in mobile environment. Simulations have been carried out for multipath fading channels to compare the performance improvement of the proposed scheme relative to self ICI cancellation scheme.**

Keyword: OFDM, Intercarrier interference, Bit error rate.

I. INTRODUCTION

OFDM has been applied in European digital audio broadcasting (DAB) system and is being considered for other applications such as digital video broadcasting (DVB) and high-speed wireless broadband local area networks (WLAN). A proposal to use OFDM in radio mobile environment has been analyzed [1].

The appealing aspect of OFDM system is that its capability to combat the multipath fading compared to single carrier system. Then we can consider the reliable communication in rayleigh fading channels by using OFDM transmission.

In Rayleigh fading channel the Doppler effect will caused the frequency offset that is a major obstacle for synchronization at the front end of the receiver. A number of method for mitigate the effect of frequency offset were introduced in the literature.

Among them self ICI cancellation scheme enables the system to have an increased carrier to interference ratio enhanced by about 10 dB [2]. Beside, if the OFDM signals are shaped by suitable windowing function the result signals will give better performance [3].

Next section effect of frequency offset to performance of OFDM system will be discussed. In section III, self ICI cancellation scheme is summarized as well as windowing method. In section IV a new scheme called advanced self ICI cancellation is introduced. Section V describes the simulation results to verify the performance of the proposed scheme. Section VI concludes the paper.

II. FREQUENCY OFFSET EFFECT

The effect of frequency offset to the OFDM system can be considered as the reduction in signal amplitude at the output of matched filter to each of the subcarrier and introduction of ICI from the other subcarriers.

Assume the signal sequence $a_{i,0}, a_{i,1}, \ldots, a_{i,N-1}$ in OFDM system, which contain N subcarrier and the symbol period T. The IFFT output signal sequence of OFDM transmitter in the ith transmitted symbol is given by

$$X(t) = e^{j2\pi f_c t} \sum_{k=0}^{N-1} b_{k,i}\, p(t - \frac{kT}{N}) \quad (1)$$

Where f_c is the carrier frequency and p(t) is the impulse response of the low pass filter in the transmitter and $b_{i,k}$ are IFFT output samples. If the received signal suffers a Doppler frequency shift of f_D the demodulated signal can be represented as,

$$X(t) = e^{(j2\pi f_D t + \theta_0)} \sum_{k=0}^{N-1} b_{k,i}\, q(t - \frac{kT}{N}) \quad (2)$$

Where q(t) is the combined effect of the channel and of the transmitter and receiver filters. θ_o is the different between the phase of the receiver local oscillator and carrier phase at the start of the receiver symbol.

For perfect recovery of the signal, input signal to the receiver should be sampled at the sampling frequency $\frac{N}{T}$. The sampled input to the receiver is given by,

$$y_{k,i} = e^{j\theta_0} b_{k,i} e^{j\frac{2\pi k f_D T}{N}} \quad (3)$$

Received Fourier transformed signal on m[th] subcarrier is given by

$$z_{m,i} = \sum_{k=0}^{N-1} y_{k,i} e^{\frac{-j2\pi km}{N}} \quad (4)$$

Using properties of geometric series,

$$z_{m,i} = \frac{1}{N} e^{j\theta_0} \sum_{l=0}^{N-1} a_{l,i} \sum_{k=0}^{N-1} e^{\frac{-j2\pi k(l-m+f_D T)}{N}} \quad (5)$$

$$z_{m,i} = e^{j\theta_0} \sum_{l=0}^{N-1} c_{l-m} a_{l,i} \quad (6)$$

Where

$$c_{l-m} = \frac{1}{N} \frac{\sin(\pi(l-m+f_D T))}{\sin(\frac{\pi(l-m+f_D T)}{N})} e^{j\frac{N-1}{N}(l-m+\Delta f T)} \quad (7)$$

Rearranging the equation (6) , we get

$$z_{m,i} = e^{j\theta_0} a_{m,i} + e^{j\theta_0} \sum_{l=0, l\neq m}^{N-1} c_{l-m} a_{l,i} \quad (8)$$

When $\Delta f = 0$ the received signal is only have the first term which is simply the phase rotation of transmitted signal.

When $\Delta f \neq 0$ the second term which corresponds to the ICI occur and each output data symbol will depend on all of the input values.

III. SELF ICI CANCELLATION SCHEME

Zhao and Haggman [2] proposed a method called self ICI cancellation for reducing sensitivity to frequency offset errors. Here the data to be transmitted are mapped into adjacent pair of subcarriers, with 180^0 phase difference between them, rather than into a single subcarrier. This scheme improve the BER of 10 dB. The disadvantage of this method is that it is less bandwidth efficient as two subcarriers are used to transmit one data symbol due to repetition .

Windowing method proposed by Muschallick [3], the author consider FFT as the filter bank therefore we need a filter bank with improved frequency response to keep orthogonality and easy implement. Above requirement may be fulfilled by using a nyquist windowing that is a windowing which reduces the side lobes and conserves the carrier orthogonality characteristic.

The nyquist window reduces the amplitude of the filter side lobe depending on the roll off factor α, e.g C/N improvement of up to 1.3 dB for Gaussian channel when α equal 1.

IV. ADVANCED SELF ICI CANCELLATION SCHEME

OFDM signal contain sum of symbols that are rectangular pulses in time domain or overlapping sinc function in frequency domain. If normal OFDM symbol period is T_u the spectrum of current pulse has zero at frequency instant of $1/T_u$ while it is maximum for spectrum of the next pulse. If orthogonality is destroyed, crossing point between two pulses (at frequency instant $1/T_u$) will be shifted and desired pulse will be detected as the next or previous pulse.

When windowing is performed, result signal is convolution of sinc functions and frequency response of windowing function. Due to the length of windowing are twice of normal OFDM symbol (T_u), the spectrum of current pulse has zero at frequency instant of $1/ 2T_u$ while it is maximum for spectrum of the next pulse. Therefore, the current pulse will not be affected by the other at the crossing point. In another way, the othorgonality characteristic between 2 subcarriers is kept.

When offset increased, the ICI between subcarriers become heavier leading to interfere go beyond the crossing points. In this case, windowing can not keep the orthorgonality and then, the performance obviously reduced. In self ICI scheme, the received signal are subtracted of two consecutive pairs of subcarrier k and k+1. ICI coefficient of received signal on subcarrier k is not much far from ICI coefficient of received signal on subcarrier k+1 leading to reduction of total ICI value on the received signal.

From above ideas we proposed a scheme called advanced self ICI cancellation scheme. This scheme uses the superiority of both windowing and self ICI cancellation method. At the transmitter the signal are coded by self ICI coding and then OFDM signals are shaped by suitable windowing. In this case, rectangular window, Hamming window, Hanning window are investigated. At the receiver 2N points FFT are taken instead of N points. Figure 1 shows an OFDM transmitter based on advanced self ICI cancellation scheme.

V. SIMULATION RESULTS

The simulations have been run for frequency selective Rayleigh fading channels with QPSK modulation. The channels are is modeled by symbol spaced tapped delay line with 4 taps. Amplitude of each tap varies independently from the others according to a Rayleigh distribution with exponential power delay profile. In the simulations, the length of the DFT block is 64 and OFDM system use a carrier frequency of 2 GHz. For urban area 3μs of multipath delay spread is used and mobile speed of 150 km/h is assumed. The simulations shows that effect of diffirent kind of window that is rectangular window, Hamming window, Hanning window are nearly the same.

As depict in figure 2 in fading channel the proposed scheme is the least sensitivity scheme to carrier frequency offset. At BER of 10^{-3} it gets 4 dB improvement to the self ICI scheme.

Figure 3 shows the frequency offset up to 20 percent of subcarrier spacing, the proposed scheme improved up to 6 dB compared to self ICI scheme at BER of 10^{-3}. It is clear that the proposed scheme is better than self ICI scheme at small values of frequency offset. In OFDM system, the offset up to 50 percent of subcarrier spacing is considered in tracking mode. When offset is higher than that the system will change to acquisition mode. Therefore, the proposed scheme will work well in tracking mode when the frequency offset are small enough to compensate.

VI.CONCLUTIONS

A novel frequency offset reduction, which allows better performance than self ICI cancellation alone, for Rayleigh multipath channels, is introduced. Joint of windowing method and self ICI cancellation increases the system performance.

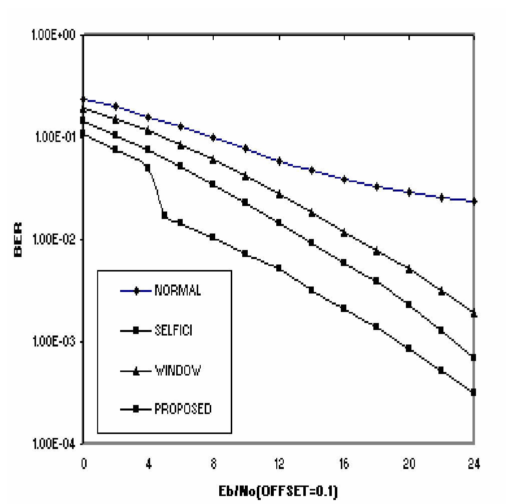

Figure 2: BER Comparison of different schemes for different values of Eb/No with offset 10% of subcarrier spacing in fading channel

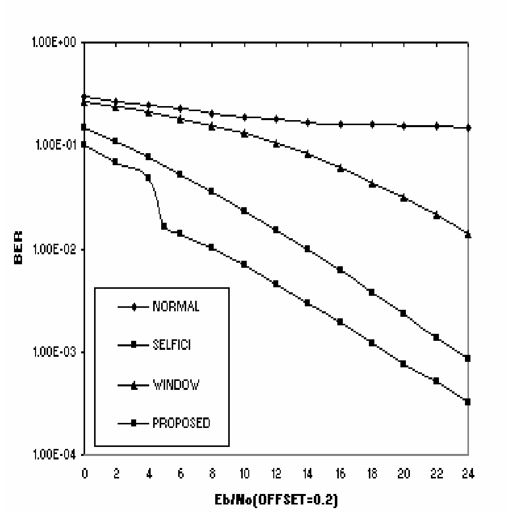

Figure 3: BER Comparison of different schemes for different values of Eb/No with offset 20% of subcarrier spacing in fading channel

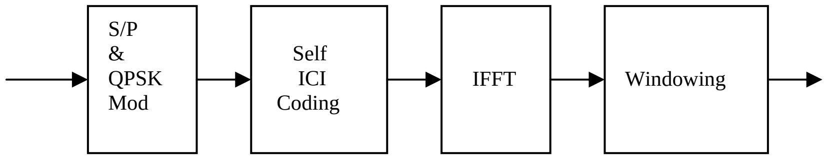

Figure 1: Block diagram of proposed scheme at transmitter side

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