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A Survey of ICI Reduction Techniques in OFDM System

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Abstract: In Today's world OFDM plays very important role for wireless communication systems. OFDM has over lapping subcarrier spectrum[1] due to this overlapping spectrum OFDM has very high spectral efficiency. OFDM is also known as Multi carrier modulation technique and this OFDM system is very sensitive to carrier frequency offset [1,2], which cause loss of orthogonality and amplitude reduction of OFDM signal and lead to Inter Carrier Interference(ICI)[2] ,which is one of the major weakness of OFDM system. In this paper various ICI reduction techniques are discussed. Techniques like Time domain windowing, Frequency domain equalization, Maximum likelihood estimation (MLE), Extended kalman filtering (EKF) and ICI self cancellation technique.

Keywords: OFDM, ICI, MLE.

I. INTRODUCTION

Now a Days OFDM is very useful for high speed data transmission systems, because it has several unique features like Robustness to multipath fading, high spectral efficiency, and immunity to impulse interference, flexibility and easy equalization over single carrier communication system. The basic Principle of OFDM system is to divide the available bandwidth into 'N' narrow sub-channel [1] at equidistance frequency .the sub channel spectrum overlap each other but the subcarriers signal are still orthogonal. But one of the major weaknesses of OFDM system is ICI [2], which result from Doppler shift in the channel or by difference between the Transmitter and Receiver local oscillator frequency this ICI destroy the orthogonality of the spectrum and signal can't be received without interference. The problem of ICI can be solved by various techniques proposed by various researchers which include Time domain windowing, Frequency domain equalization, Maximum Likelihood estimation (MLE), Extended, Pulse Shaping and ICI self cancellation technique. This paper discusses all the prominent ICI reduction technique described above. The rest paper is organized as follows section II. Discusses OFDM system model and ICI .section III describes various ICI reduction techniques and in section IV conclusion is given.

II. OFDM SYSTEM MODEL

A basic OFDM system contains modulation scheme, serial to parallel transmission, parallel to serial transmission and IFFT/FFT. Fig.1, illustrate the block diagram of OFDM system. The input data stream is converted into parallel data stream and mapped with modulation scheme. Then the symbols are mapped with Inverse Fast Fourier Transform (IFFT) and converted to serial stream. The complete OFDM symbol is transmitted through the channel.

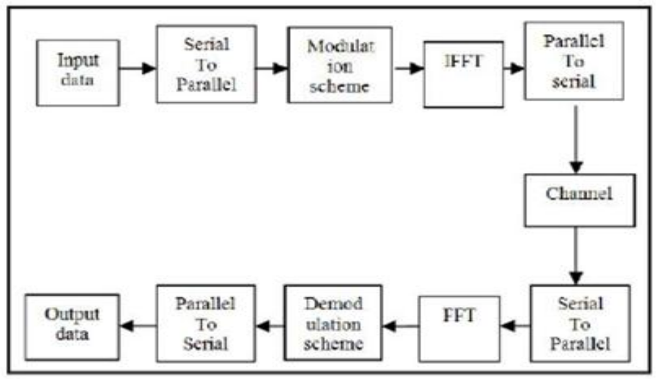

Fig.1. Block diagram of FFT based OFDM system.

Therefore OFDM symbol can be expressed as

$$x(n) = \frac{1}{N}\sum_{m=0}^{n-1} X(m)e^{j2\pi nm/N} \quad \textbf{(1)}$$

Where x (n) denotes the sample of the OFDM signal, X(m) denotes the modulated symbol within subcarrier and N is the number of subcarriers.

On receiver side this symbol are converted back to parallel stream and mapped with FFT then with demodulation scheme and converted to serial data as output data.

The demodulated symbol stream is given by

$$y(m) = \sum_{n=0}^{N-1} y(n)e^{-j2\pi nm/N} + w(m) \quad \textbf{(2)}$$

Where w (m) corresponds to the FFT of the samples of the w (n).

III. ICI REDUCTION TECHNIQUES

A. Frequency Domain Equalization

Frequency domain equalization process is approached for reduction of ICI by using suitable equalization techniques [4]. We can estimate the ICI for each frame by inserting frequency domain pilot symbols in each frame as shown in bellow Fig.2. It can only reduce the ICI caused by fading distortion which is not the major source of ICI. Again it is only suitable for flat fading channels, but in mobile communication the channels are frequency selective fading in nature because of multipath components. Here also the channel needs to be estimated for every frame. Estimation of channel is complex, expensive & time consuming. Hence the method is not effective one.

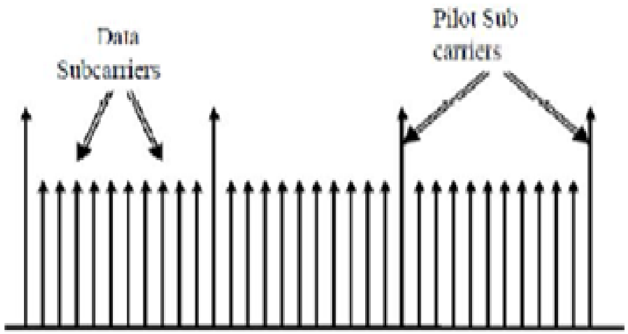

Fig.2. Pilot subcarrier arrangement.

B. Time Domain Windowing

We know that OFDM signal has widely spread power spectrum. So if this signal is transmitted in a band limited channel, certain portion of the signal spectrum will be cut off, which will lead to inter carrier interference. Reduction of interference is achieved by windowing the signal [3]. Basically windowing is the process of multiplying a suitable function to the transmitted signal wave form. The same window is used in the receiver side to get back the original signal. The ICI will be eliminated if the product of the window functions satisfies the Nyquist vestigial symmetry criterion. It can only reduce the ICI caused by band limited channel which is not the major source of ICI. The above method cannot address to it. Windowing is done frame by frame & hence it reduces the spectral efficiency to a large extent. Hence the method is not effective one.

C. Maximum Likelihood Estimation

Another method for frequency offset correction i.e. ML estimation in OFDM systems was suggested by Moose. In this approach, the frequency offset is first statistically estimated using a maximum likelihood algorithm[4,5] and then cancelled at the receiver. This technique involves the replication of an OFDM symbol before transmission and comparison of the phases of each of the subcarriers between the successive symbols. The maximum likelihood estimate is a conditionally unbiased estimate of the frequency offset and can be computed by using received data. The maximum likelihood estimate of the normalized frequency offset is given by

$$\hat{\varepsilon} = \frac{1}{2\pi}\tan^{-1}\left[\frac{\sum_{k=-K}^{K} Im Y_2(k) Y_2^*(k)}{\sum_{k=-K}^{K} Re\, Y_2(k) Y_1^*(k)}\right] \quad \textbf{(3)}$$

Once the frequency offset is known, the ICI distortion in the data symbols is reduced by multiplying the received symbols with a complex conjugate of the frequency shift and applying the FFT.

$$X(n) = FFT\{Y(n)e^{\frac{-j2\pi n\varepsilon}{N}}\} \quad \textbf{(4)}$$

D. ICI Self Cancellation Scheme

The main idea of this scheme is to modulate the input data symbol onto a group of subcarriers with predefined coefficients such that the generated ICI signals within that group cancel each other, hence the name self- cancellation. One data symbol is not modulated in to one sub-carrier, rather at least in to two consecutive sub-carriers [8,9, 10]. If the data symbol ‘a' is modulated in to the 1st sub-carrier then ‘-a’ is modulated in to the 2nd sub-carrier. Hence the ICI generated between the two sub-carriers almost mutually cancels each other. This method is suitable for multipath fading channels as here no channel estimation is required. Because in multipath case channel estimation fails as the channel changes randomly. This method is also suitable for flat channels. The method is simple, less complex & effective. The major drawback of this method is the reduction in band width efficiency as same symbol occupies two Sub-carrier.

E. Pulse Shaping

In the OFDM spectrum that each carrier consist of a main lobe followed by a number of side lobes with reducing amplitude. As long as Orthogonality is maintained there is no interference among the carriers because at the peak of the every carrier, there exist a spectral null. That is at that point the component of all other carriers is zero. Hence the individual carrier is easily separated. When there is a frequency offset the Orthogonality is lost because now the spectral null does not coincide to the peak of the individual carriers. So some power of the side lobes exists at the centre of the individual carriers which is called ICI power. The ICI power will go on increasing as the frequency offset increases. Now the purpose of pulse shaping is to reduce the side lobes [6,7]. If we can reduce the side lobe significantly then the ICI power will also be reduced significantly. Hence a number of pulse shaping functions are proposed having an aim to reduce the side lobe as much as possible.

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