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Review On Ici Reduction Techniques In Ofdm System

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Abstract : *Orthogonal frequency division multiplexing (OFDM) is a promising technique for the broadband wireless communication system. However, the inter-carrier-interference (ICI) produced by the phase noise of transceiver local oscillator is a serious problem. The variations in Time Offset (TO) can lead to inter-symbol-interference (ISI) in case of frequency selective channel. Literature survey of any research filed or subject is must required, before contributing in the research of that field. The literature review gives a detailed study of existing published material for clear understanding of that area. Therefore, this Paper presents a detailed literature survey of the area taken (i.e., OFDM). The study in this paper highlights different problems or issues of OFDM system like high PAPR, synchronization, and Inter-Carrier-Interference (ICI). This review also summarizes the methods available in the literature to overcome these problems.*
Keywords: *OFDM, ICI, SC, MLE,PS*

I. Introduction

Orthogonal Frequency Division Multiplexing (OFDM) has grown to a popular communication technique for high speed communication in the last decade. Being an important member of the multicarrier modulation (MC) techniques, Orthogonal Frequency Division Multiplexing (OFDM), is also called Discrete Multitone Modulation. It is based upon the principle of frequency division multiplexing (FDM) where each frequency channel is modulated with simpler modulation scheme. It splits a high rate data stream into a number of lower rate streams that are transmitted simultaneously over a number of orthogonal subcarriers. Orthogonal Frequency Division Multiplexing is a form of multi carrier modulation technique with high spectral efficiency, robustness to channel fading, immunity to impulse interference, uniform average spectral density capacity of handling very strong echoes and non-linear distortion. Despite of its many advantages, OFDM suffers from two main drawbacks, i.e., high peak to average power ratio (PAPR) and inter-carrier interference (ICI), which may be caused by Doppler shift in the channel or by the difference between the transmitter and receiver local oscillator frequencies . In such situations, the orthogonally of the carriers is no longer maintained, which result in Inter-carrier Interference (ICI).

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), Pulse Shaping and ICI self cancellation technique. This paper discusses all the prominent ICI reduction technique described above.

II. Ofdm System Model

The discrete time baseband OFDM system model with N subcarriers is shown in Figure 1.1 It consists of transmitter, channel and receiver blocks which are described below.

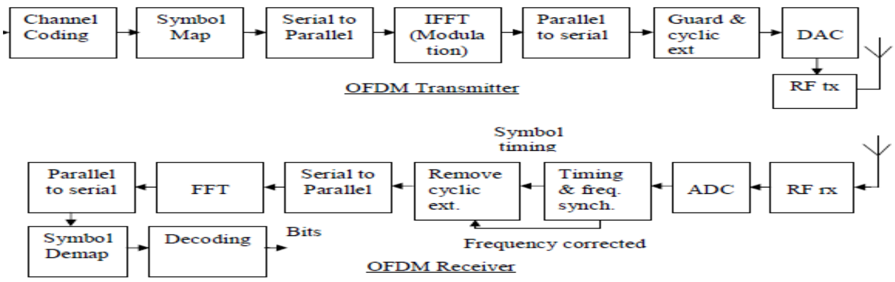

Fig 1.1 OFDM System Block Diagram

At the transmitter, the user information bit sequence is first subjected to channel encoding to reduce the probability of error at the receiver due to the channel effects. Usually, convolution encoding is preferred. Then the bits are mapped to symbols of either 16-QAM or QPSK. The symbol sequence is converted to parallel format and IFFT (OFDM modulation) is applied and the sequence is once again converted to the serial format.

Guard time provided between the OFDM symbols and the guard time filled with the cyclic extension of the OFDM symbol. Windowing is applied to the OFDM symbols to make the fall-off rate of the spectrum steeper. The resulting sequence is converted to an analog signal using a DAC and passed on to the RF modulation stage. The resulting RF modulated signal is, then, transmitted to the receiver using the transmit antennas. Here, directional beam-forming can be achieved using antenna array, which allows for spectrum reuse by providing spatial diversity. Therefore OFDM symbol can be expressed as,

$$x(n) = \frac{1}{N}\sum_{m=0}^{n-1} x(m)e^{j2\Pi nm/N} \tag{1}$$

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.

At the receiver, first RF demodulation is performed. Then, the signal is digitized using an ADC and timing and frequency synchronization are performed. The guard time is removed from each OFDM symbol and the sequence is converted to parallel format and FFT (OFDM demodulation) is applied. The output is then serialized and symbol demapping is done to get back the coded bit sequence. Channel decoding is, then, done to get the user bit sequence. The demodulated symbol stream is given by,

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

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

III. Ici Reduction Techniques

Frequency Domain Equalization: The fading distortion in the channel causes ICI in the OFDM demodulator. The pattern of ICI varies from frame to frame for the demodulated data but remains invariant for all symbols within a demodulated data frame. Compensation for fading distortion in the time domain introduces the problem of noise enhancement. So frequency domain equalization process is approached for reduction of ICI by using suitable equalization techniques. We can estimate the ICI for each frame by inserting frequency domain pilot symbols in each frame as shown in figure 1.2.

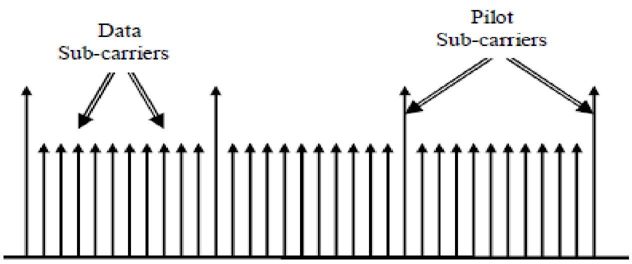

Fig 1.2 Pilot Subcarrier Arrangement

This technique can only reduce the ICI caused by fading distortion which is not the major source of ICI. The major source of ICI is due to the frequency mismatch between the transmitter and receiver. The above method cannot address to it. 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 this method is not an effective one.

Time Domain Windowing: 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. To diminish the interference the spectrum of the signal wave form need to be more concentrated. This is achieved by windowing the signal. 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.

This method only reduces the ICI caused by band limited channel which is not the major source of ICI. The major source of ICI is due to the frequency mismatch between the transmitter and receiver, and the Doppler shift. Further windowing is done frame by frame & hence it reduces the spectral efficiency to a large extent. Hence this method is not an effective one.

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 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,

$$\hat{\varepsilon} = \frac{1}{2\Pi}\left[\frac{\sum_{k=-K}^{K} lmY_2(k)Y_2^*(k)}{\sum_{k=-K}^{K} \mathrm{Re}\,Y_2(k)Y_1^*(k)}\right] \tag{3}$$

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.

$$X(n) = FFT\left\{Y(n)e^{\frac{-j2\Pi ne}{N}}\right\} \tag{4}$$

ICI Self Cancellation Scheme: The self-cancellation schemes works in two very simple steps. At the transmitter side, one data symbol is modulated onto a group of adjacent subcarriers with a group of weighting coefficients. The weighting coefficients are designed so that the ICI caused by the channel frequency errors can be minimized. At the receiver side, by linearly combining the received signals on these subcarriers with proposed coefficients, the residual ICI contained in the received signals can then be further reduced. 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.

In an OFDM communication system, assuming the channel frequency offset normalized by the subcarrier separation is ε , the received signal on subcarrier *k* can be written as,

$$r(k) = X(k)S(0) + \sum_{i=0,l=k}^{N-1} X(l)S(l-k) + n_k \tag{5}$$

where N is the total number of the subcarriers *X* (*k*) denotes the transmitted symbol for the k^{th} subcarrier and n_k is additive noise . The first term in the right-hand side of (5) represents the desired signal. The second term is the ICI components. The sequence *S (l-k)* is defined as the ICI coefficient between l^{th} and k^{th} subcarriers, which can be expressed as,

$$S(l-k) = \frac{\sin\left(\Pi(l+\varepsilon-k)\right)}{N\sin\left(\frac{\Pi}{N}(l+\varepsilon-k)\right)}.\exp\left(j\Pi\left(1-\tfrac{1}{N}(l+\varepsilon-k)\right)\right) \tag{6}$$

Pulse Shaping: The figure 1.3 illustrates the transmitter block diagram of a *N* sub-carrier OFDM system using pulse shaping. Here the incoming data is first modulated in baseband using a bandwidth efficient modulation (QPSK modulation). The baseband modulated stream, with data rate *1/Ts* is then split into *N* parallel streams. Each stream is shaped by a time waveform (pulse shaping waveform) and transmitted over a given subcarrier. Thus the OFDM transmitted signal can be expressed as,

$$x(t) = \sum_{k=0}^{N-1} X_n(k)P_k(t)e^{j2\Pi k\frac{t}{T}} \tag{7}$$

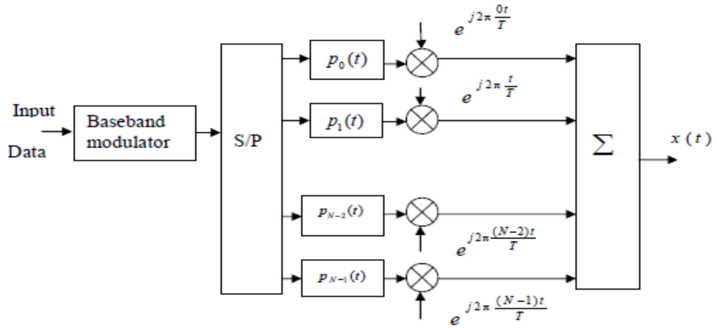

Fig.1.3 OFDM Transmitter Model Using Pulse Shaping

where $X_n(k)$ the modulated data symbol of sub-carrier is k , T is the duration of the OFDM block 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.

IV. Conclusion

After learning all those above techniques, I conclude that conventional technique for ICI Reduction like time domain equalization, windowing technique, self cancelation, maximum likelihood does not properly reduce ICI at the receiver side because in these techniques, ICI reduces only band limited channel which is not a major source of ICI. The major source of ICI is due to frequency mismatch between transmitter and receiver, this problem is reduced by pulse shaping method.

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