A Review on Various Approaches to Reduce ICI in MIMO OFDM System

Vaibhav Chaudhary
Research Scholar
FET-SSGI, Junwani, BHILAI (INDIA)

Rakesh Mandal
Assistant Professor
FET-SSGI, Junwani, BHILAI (INDIA)

Abstract

The vast usage of mobile applications have emerged a need for high speed data transmission and efficient and error free data transmission. For the purpose the use of multiple antenna systems at both the transmitting and receiving end is formulated known as MIMO Systems. It provides improved Spectral Efficiency and link reliability as compared to conventional systems. When it is combined with OFDM systems; it eliminates the fading effect and with requirement of lower Bandwidth it provides high Throughput. Yet having a number of advantages; it suffers from some limitations like ISI, ICI and PAPR. These are the factors which degrades the System Performance.

Keywords: Orthogonal Frequency Division Multiplexing (OFDM), Multiple Input Multiple Output (MIMO) ,Inter Carrier Interference (ICI).

I. INTRODUCTION

MIMO-OFDM (multiple input multiple output- orthogonal frequency division multiplexing), a novel wireless broadband technology, has achievedimmenseesteem for its potential of high rate transmission and its robust-ness against multi-path fading and other channel impairments.[1] Orthogonal frequency division multiplexing has gained considerable attention due to its high speed data applications. It is rising as most favorite digital modulation systemdue to its high bandwidth efficiency and strength to handle multipath interference. OFDM is a multicarrier transmission system in which transmission bandwidth is divided into many narrowband sub channels which are transmitted into parallel.[2] As a result the symbol duration is increased and inter-symbol interference is mitigated. OFDM systems require precise frequency synchronization otherwise inter-carrier interference (ICI) occurs. ICI has a negative impact on data throughput .in OFDM communication systems, the frequency offsets in mobile radio channels deteriorate the orthogonality between subcarriers resulting in Inter Carrier Interference (ICI). ICI causes power outflowbetween subcarriers consequently degrading the system performance.[3] A renownedsetback of an OFDM is its compassion to frequency offset between the transmitted and received carrier frequencies. This survey paper work investigates three bandwidth efficient methods for combating the effects of ICI.

II. ICI MECHANISM OF STANDARD OFDM SYSTEM

Frequency offset is main drawback of OFDM system that can be caused by Doppler shift due to relative motion between the transmitter and receiver, or by differences between the frequencies of the local oscillators at the transmitter and receiver [4]

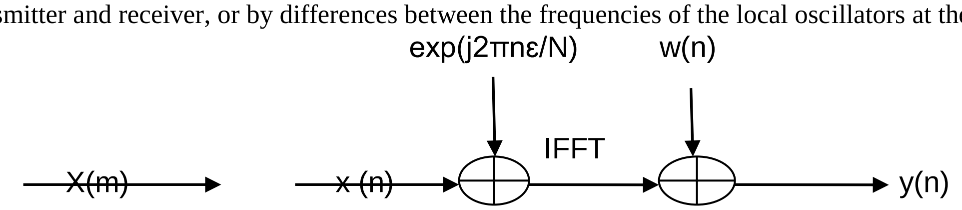

Fig. 1: Model of Frequency Offset

In OFDM system, the high data rate serial input bit stream is fed into serial to parallel converter to get low data rate output parallel bit stream. The low data rate parallel bit stream is modulated. Modulation is a process by which a carrier signal is altered according to information in a message signal. The modulated data are served as input to inverse fast Fourier transform so that each subcarrier is assigned with a specific frequency. The frequencies selected are orthogonal frequencies. As the modulated data is sent to an IFFT and are transformed and multiplexed to x(n).

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

Where the X_m are the baseband symbols on each sub-carrier. 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 an N-point fast Fourier transform (FFT) operation at the receiver. The demodulated symbol is given as

$$Y(m) = \sum_{n=0}^{N-1} y(n) e^{\frac{j2\pi mn}{N}} + W(m) \quad (2)$$

W(m) is the FFT of the samples ofw(n). Because of the low data rate transmission, a narrowband signal sent at a high data rate through a multipath channel will experience greater negative effects of the multipath delay spread, because the symbols are much closer together. Multipath distortion can also cause inter-symbol interference (ISI) where adjacent symbols overlap with each other. This is prevented in OFDM by the insertion of a cyclic prefix between successive OFDM symbols. This cyclic prefix is discarded at the receiver to cancel out ISI. It is due to the robustness of OFDM to ISI and multipath distortion.

Frequency offset is main drawback of OFDM system that can be caused by Doppler shift due to relative motion between the transmitter and receiver, or by differences between the frequencies of the local oscillators at the transmitter and receiver
The received signal is given by

$$y(n) = x(n).e^{\frac{j2\pi n\varepsilon}{N}} + w(m) \quad (3)$$

Where ε is the normalized frequency offset, and is given by $\Delta f NT$.Δf is the frequency difference between the transmitted and received carrier frequencies and $T_s$is the subcarrier symbol period. w(n) is the AWGN introduced in the channel. The effect of this frequency offset on the received symbol stream can be understood by considering the received symbol Y(k) on the kth sub-carrier.

$$y(k) = X(k)S(0) + \sum_{l=0, l\neq k}^{N-1} X(l)S(l-k) + n_k \quad (4)$$

k=0,1,2,…N−1

Where N is the total number of subcarriers, X(k) is the transmitted symbol for the kth subcarrier, n_k is the FFT of w(n), and S(l-k) are the complex coefficients for the ICI components in the received signal. The ICI components are the interfering signals transmitted on sub-carriers other than the kth sub-carrier. The first term is desired signal, with ε=0, S(0) has maximum value S(0)=1. The second term is ICI component. The complex coefficients are given as

$$S(l-k) = \frac{\sin(\pi(l+\varepsilon-k))}{N\sin(\pi(l+\varepsilon-k)/N)} e^{(j\pi(1-\frac{1}{N})(l+\varepsilon-k))} \quad (5)$$

The carrier to interference ratio is ratio of signal power to the power in the interference components. The CIR expression for subcarrier 0<k<N-1 can be expressed as

$$CIR = \frac{|S(k)|^2}{\sum_{l=0,l\neq k}^{N-1} |S(l-k)|^2} = \frac{|S(0)|^2}{\sum_{l=1}^{N-1} |S(l)|^2} \quad (6)$$

III. METHODS PROPOSED FOR ICI MITIGATION:

(1) FREQUENCY DOMAIN EQUALIZATION
(2) TIME-DOMAIN WINDOWING
(3) MAXIMUM LIKLIHOOD ESTIMATION
(4) ICI SELF CANCELLATION

These methods are discussed as below

A. FREQUENCY DOMAIN EQUALIZATION

The fading distortion in the channel causes ICI in the OFDM demodulator. Compensation for fading distortion in the time domain introduces the problem of noise enhancement. So frequency domain equalization process is used 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 below:[5]

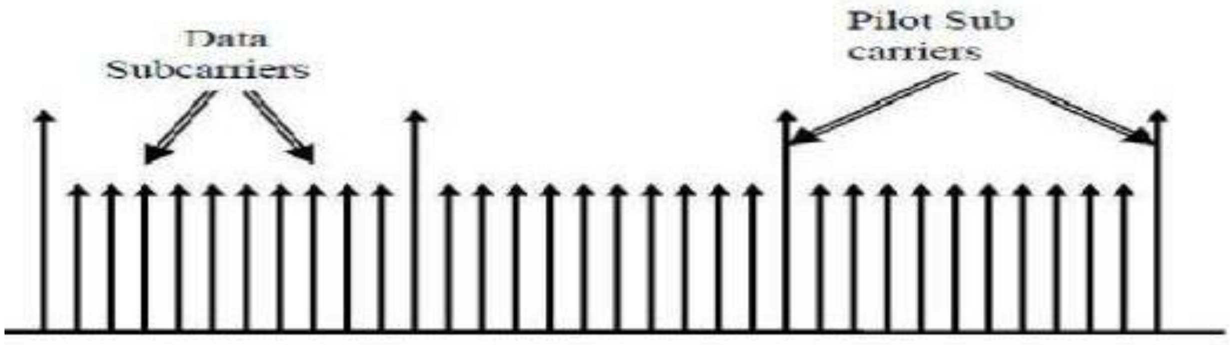

Fig. 2: Arrangement of Pilot Subcarriers

The pattern of the Pilot symbols is able to produce the co-efficient needed for elimination of ICI in frequency domain and so it is possible to design a suitable Equalizer for the purpose. It can only reduce the ICI caused by fading distortion but it does not deal the problems of frequency mismatch between transmitter and receiver and Doppler shift which is the main 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 this method is not effective one.

1) *DRAWBACKS OF FREQUENCY DOMAIN EQUALIZATION*

The main disadvantage of Frequency domain equalization of that It can only reduce the ICI generated due to fading distortion which is not the major cause of ICI. The major cause of interfering ICI is due to the frequency mismatch between the transmitter and receiver, and the Doppler shift. The above mentioned method cannot tackle to it. all over again it is only appropriate for flat fading channels, but in mobile communication the channels are most probably 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.[8]

B. TIME DOMAIN WINDOWING

As OFDM signal have widespread power spectrum so when this widespread signal is transmitted through a band limited channel; some of its portion gets cut-off by default. which leads to inter carrier interference. To lessen the interference the spectrum of the signal should be intense. This can be achieved by windowing technique of signal processing. In this process a transmitting signal is multiplied by a suitable function . The same function is used as reference signal at receiver side to get back the original signal.. The ICI will becancelled out if the product of the window functions satisfies the Nyquist vestigial symmetry criterion. [6] The conventional frame-by-frame time limited orthogonal multicarrier signal s(t) can be expressed as:

$$s(t) = \sum_{k=-\infty}^{\infty} \sum_{n=0}^{N-1} w(t-kT) a_{n,k} \exp(jn\omega_{\Delta}(t-kT)) \qquad (7)$$

In the above equation, $\{a_{n,k}\}$ is a complex sequence, $n\omega_{\Delta}\{n = 0,1,2....N-1\}$ are carrier frequencies and they are equally spaced with ω_{Δ}. The window function w(t) has a length of T and it modifies the waveform of the multicarrier signal in each frame. The ICI for this multicarrier signal can be avoided if the window function w(t) and the carrier separation are correctly chosen. In order to provide a matched receiver for the transmitted signal, the window functions in both the transmitter and the receiver are selected to be equal. The ICI can be determined by examining the cross correlation between two carriers of the transmitted signals. For a complex sequence $\{a_{n,k}\}$, the ICI is given by:

$$a_{n,k} a_{m,k}^{*} \int_{-T/2}^{T/2} w^2(t) \exp(-j\omega_{\Delta}(n-m)t)dt = 0 \qquad (8)$$

1) *DRAWBACKS OF TIME DOMAIN WINDOWING*

It can only decrease the ICI generated due to band limited channel which is also not the key source of ICI. The main source of ICI is due to the frequency mismatch between the transmitter and receiver along with the effect due to theDoppler shift. This mentioned methodis unable to resolve the problem discussed. The Time domain windowing is executed frame by frame & hence it reduces the spectral efficiency to a large extent. Hence the method is not effective one.[8]

C. MAXIMUM LIKLIHOOD ESTIMATION

Moose suggested Maximum Likelihood Estimation method for rectification of frequency offset. According to this method the frequency offset is first analytically anticipated by a maximum likelihood algorithm and then terminated at the receiver. the duplication of an OFDM symbol is included before transmission and evaluation of the phases of each of the subcarriers between the consecutive symbols is processed.[6] When an OFDM symbol of sequence length is simulated, the receiver receives, in the absence of noise, the 2N point sequence r (n) is given by

$$r(n) = \frac{1}{N}\left[\sum_{-K}^{K} X(k)H(k).e^{j2\pi n(k+\varepsilon)/n}\right] \quad (9)$$

k = 0,1,2,.....N-1, N ≥ 2K+1

In the above equation, X(k) are the *2k+1* complex modulation values used to modulate *2k+1* subcarriers, *H(k)* is the channel transfer function for the *kth*carrier and E is the normalized frequency offset of the selected channel. In the method the starting set of N symbols is demodulated using an N-point FFT to yield the sequence R_1(k), and the second set is demodulated using an N-point FFT to yield the sequence R_2(k). The frequency offset is the phase difference between R_1(k),and R_2(k), that is R_2(k)=R_1 (k) $e^{j2\pi\varepsilon}$

Adding the AWGN yields

$Y_1(k) = R_1(k) + W_1(k)$

$Y_2(k) = R_1(k)e^{j2\pi\varepsilon} + W_2(k)$

k= 0,1,2,…N-1

The maximum likelihood estimation of the normalized frequency offset is calculated by:

$$\hat{\varepsilon} = \frac{1}{2\pi}.\tan^{-1}\left\{\frac{\sum_{k=-K}^{K} I_m\left[Y_2(k).Y^*{}_1(k)\right]}{\sum_{k=-K}^{K} R_e\left[Y_2(k).Y^*{}_1(k)\right]}\right\} \quad (10)$$

D. SELF CANCELLATION METHOD

ICI self cancellation is a scheme that was introduced by Zhao and Sven-Gustav in 2001 to combat and subdue ICI in OFDM. Briefly, the main indication 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 of the system is self- cancellation. It has been observed that that the difference between the ICI co-efficient of two consecutive sub-carriers are very negligible. This grounds the foundation of ICI self cancellation method. Here one data symbol is not modulated in to one sub-carrier, rather at least in to two consecutive sub-carriers. If the data symbol 'a' is modulated in to the first sub-carrier then '-a' is modulated in to the second sub-carrier. so the ICI thus generatedamong the two sub-carriers almost mutually cancels each other. This process is appropriate for multipath faded channels as here is no need of channel estimation. Because in multipath case channel estimation fails as the channel changes randomly. This method is also suitable for flat channels.[9] 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-carriers. In an OFDM communication system, assuming the channel frequency offset is being normalized by the subcarrier separation is ε, and then the received signal on subcarrier *k* can be written as

$$r(k) = X(k)S(0) + \sum_{l=0, l\neq k}^{N-1} X(l)S(l-k) + n_k \quad (11)$$

$$k = 0,1,2\ldots, N-1$$

Where N is the total number of the sub carriers denotes the transmitted symbol for the *k*th subcarrier and is an additive noise section. The first part in the right-hand side of Equation represents the desired signal. The second part is the ICI component. The sequence is defined as the ICI coefficient between *l*th and *k*th subcarriers.

To further reduce ICI, ICI cancelling demodulation is done. The demodulation is recommended to work in such a way that each signal at the *k*+1th subcarrier (now *k* denotes even number) is multiplied by " -1" and then summed with the one at the *k*th subcarrier. Then the resulting data system is used for making symbol decision. It is represented as

$$r''(k) = \sum_{\substack{l=0 \\ l=even}}^{N-2} X(l)[-S(l-k-1) + 2S(l-k) - S(l-k+)] + n_{k} - n_{k+1} \quad (12)$$

1) *Drawbacks of Self Cancellation*

The major drawback of this method is the reduction in band width efficiency as same symbol occupies two subcarriers.[8]

2) *Merits of this technique*

(1) It is suitable for multipath fading channels

(2) It is also suitable for flat channels
(3) Channel estimation is not required
(4) Channel equalization is not required
(5) It is simple in implementation
(6) It is less complex and effective

IV. CONCLUSION

In this paper, we have analyzed the operation of an OFDM system in the presence of different frequency offset between the transmitter and the receiver sections in terms of the Carrier-to- Interference ratio (CIR) and the bit error rate (BER) performance. Inter-carrier interference (ICI) which occurs because of frequency offset; degrades the performance of the OFDM system. Various methods have been explained in this paper for the cancellation of the ICI. After a lot of research ICI self-cancellation (SC) has been proposed as the most efficient and optimized technique to cope with ICI

REFERENCES

[1] Zhongshan Wu,"mimo-ofdm communication systems: channel estimation and wireless location," May 2006.
[2] Tanvi Chawla, "FFT Factorization Technique for OFDM System,"International Journal of Computer Applications (0975 – 8887) Volume 54– No.5, September 2012.
[3] Sandeep Kaur, Dr. Charanjit Singh, Dr. Amandeep Singh Sappal, "Inter Carrier Interference Cancellation in OFDM System," IJERA, Vol. 2, Issue 3, May-Jun 2012.
[4] S.Driz,M.Bouziani,J.M.Rouvaen,"Inter-carrier Interference cancellation for OFDM Systems,"Mediamira Science Publisher,2009.
[5] Sonika Chouhan, Deepak Sharma,"A Survey of ICI Reduction Techniques in OFDM System," IJCTT, volume 4 Issue 8–August 2013.
[6] Amit Kapoor, Ishan Khurana," Different Channel Estimation and ICI Cancellation Techniques in MIMO-OFDM Wireless Communication Systems," IOSR Journal of Electronics and Communication Engineering, Volume 9, Issue 2, Ver. VII (Mar - Apr. 2014).
[7] Prof. T. S. Rappaport," Inter-carrier interference cancellation for OFDM systems," Spring 2003,May 6,2003.
[8] Naveed Ur Rehman Zhang Lei Muhammad Zahid Hammad," ICI Cancellation in OFDM Systems by Frequency Offset Reduction," Journal of Information Engineering and Applications, Vol.4, No.9, 2014.
[9] B. Rama Rao, K. Srivani, D Sai Prasanna," ICI Cancellation Schemes and Selection Criteria in Orthogonal Frequency Division Multiplexing System: A Review," IJEAT, Volume-2, Issue-3, February 2013.