Inter Carrier Interference (ICI) Cancellation in OFDM Systems: A Review

Er. Sukhjit Singh

AP in ECE, GJIET, Banur, India

Abstract: **In the area of wireless communications, the demand for high data rate transmission is rapidly increasing. Orthogonal frequency division multiplexing (OFDM) is known to be a promising technique for high-rate transmission that can overcome the inter symbol interference (ISI) which results from the time dispersive nature of wireless channels. For OFDM communication systems the orthogonality is lost among the sub-carriers due to frequency offset which results in Inter carrier Interference (ICI). This ICI rapidly degrades the performance of OFDM system. We have so many ICI cancellation methods like time windowing and frequency equalization to improve the BER performance of OFDM systems. In this an efficient ICI cancellation methods termed ICI self-cancellation (SC) scheme, extended Kalman filter (EKF) method and another ICI cancellation scheme, named Total ICI Cancellation scheme are proposed. However the total ICI cancellation scheme has does not lower the transmission rate or reduce the bandwidth efficiency. It is shown that for high values of the frequency offset and for higher order modulation schemes, the EKF method perform better than the SC method.**

Keywords**—Orthogonal frequency divison multiplexing (OFDM) Inter carrier interference(ICI), self cancellation (SC),Extended Kalman filtering (EKF) .**

I. INTRODUCTION

As the demand for high data rate communication has been increasing rapidly, it is required to overcome the problems associated with high speed communications. As the transmission signal passes through the channel it effects by many degradations, such as noise, attenuation, multipath, interference, time variation, non-linearity‘s. for a particular channel the communication designer must decide how to efficiently utilize the available channel bandwidth in order for reliable transmission within the transmitted power constraint and receiver complexity constraint. In case of low speed communications, the degradation parameter effects are small. In single carrier communication, degradation can be reduced by signal processing techniques at the receiver . Different methods like adaptive equalization and channel coding can be used toincrease the performance. However it is difficult use these methods at high data rate because inherent delay also increases with bit rate. Therefore alternative approach is multicarrier communication. Orthogonal frequency division multiplexing (OFDM) is an example of multicarrier communication and is preferred modulation scheme in modern high data rate wireless communication systems.The basic principle of OFDM technique is to split the available spectrum into N number of sub-channel bandwidths and transmission of signal using orthogonal carriers through these sub-channels. OFDM converts the frequency selective channel to frequency flat channel so that it can completely eliminate Inter symbol interference (ISI). This is the major advantage of OFDM (which is multi carrier communication) over single carrier communication In OFDM, the multiple frequency channels (sub-carriers) are orthogonal to each other. But the major problem of OFDM is frequency offset sensitivity between the transmitted and received signals, may be due to Doppler shift of the channel, or the difference between the transmitter and receiver local oscillator frequencies. This carrier frequency offset causes loss of orthogonality among sub-carriers and then signals carried by sub-carriers becomes dependent on each other, which leads to inter-carrier interference. Researchers have proposed various techniques to combat the ICI in OFDM systems . In this research, the effects of ICI have been analyzed and three solutions to combat ICI have been discussed. The first method is a self-cancellation scheme, the other two techniques are extended Kalman filter (EKF) and Total ICI Cancellation approach. In the self-cancellation scheme The ICI between adjacent sub-carriers is reduced at the receiver by using redundant data transmission onto adjacent sub-carriers and it is very simple method. The main idea is to modulate one data symbol onto a group of subcarriers with predefined weighting coefficients. Hence the ICI signals generated within a group can be “self-cancelled” each other. Furthermore, simulation results under different conditions are presented which shows its advantages in certain conditions.

In this approach first we quantize the normalized frequency offset into M discrete values, leading to M spreading code matrices as candidates. Next, by decoding the received signal using these M spreading code matrices, M decisions are made on the data symbols. Using these M data symbols to recreate the received signal with ICI and measuring the Euclidean distance of the M recreated signals with the actual received signal, the best normalized frequency offset is chosen and the best corresponding data symbols are determined. Simulation results over AWGN channel and mobile multi-path fading channel demonstrate that the proposed method eliminates the ICI with less computational complexity.[1][2]

II OFDM DISCUSSION

OFDM is a combination of modulation and multiplexing. Multiplexing generally refers to Independent signals, those produced by different sources. In OFDM the question of Multiplexing is applied to independent signals but these

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independent signals are a sub-set of the one main signal. In OFDM the signal itself is first split into independent channels, modulated by data and then re-multiplexed to create the OFDM carrier. The sub-carriers should be orthogonal to each other to improve spectral efficiency. At the receiver side it is easy to recover data in each sub-carrier as long as carriers are orthogonal to each other. As more and more carriers are added, the bandwidth approaches (N+1)/N Bits per Hz. Largernumber of carriers gives better spectral efficiency. The main concept in OFDM is Orthogonality of the sub-carriersThe Orthogonality among the carriers can be maintained if the OFDM signal is defined by using Fourier transform procedures. The OFDM system transmits a large number of narrowband carriers, which are closely spaced. Note that at the central frequency of the each sub channel there is no crosstalk from other sub channels. 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, synchronous sub-carriers. The sub-carriersare spaced by 1/NTs in frequency, thus they are orthogonal over the interval (0, Ts). First, aserial-to-parallel (S/P) converter groups the stream of input bits from the source encoder into groups of log2M bits, where M is the alphabet of size of the digital modulation scheme employed on each sub-carrier. A total of N such symbols, Xm, are created. Then, the N symbols are mapped to bins of an inverse fast Fourier transform (IFFT). These IFFT bins correspond to the orthogonal sub-carriers in the OFDM symbol. Therefore, the OFDM symbol can be expressed as

$$x(n) = \frac{1}{N}\sum_{m=0}^{N-1} X_m\, e^{j\frac{2\pi mn}{N}} \qquad 0 \le n \le N-1$$

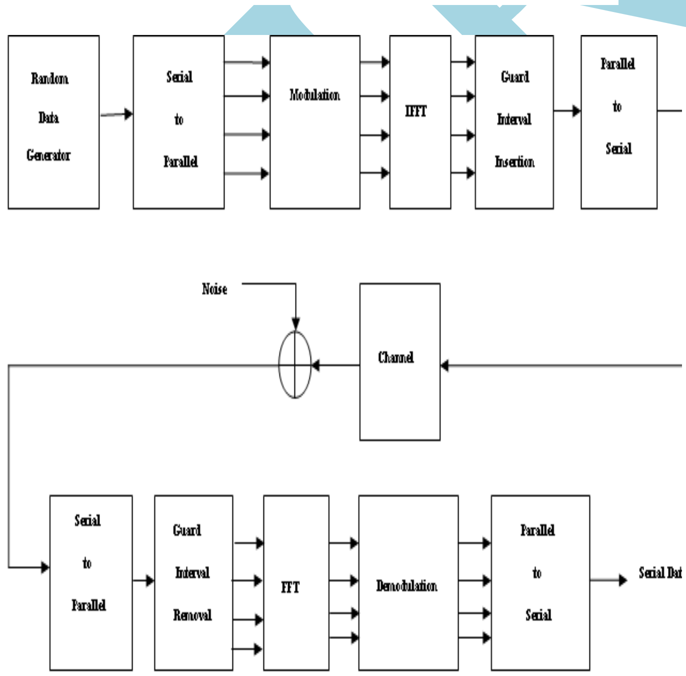

Fig 1. OFDM

Orthogonal Frequency Division Multiplexing (OFDM) is a modern technique that eliminates a need for the complex equalizers. OFDM is robust in various channel conditions and gives high spectral efficiency. It effectively reduces performance degradations due to multipath and is capable of combating deep fades in part of the spectrum. OFDM reduces Inter symbol Interference (ISI) by handling with large delay spreads, also by including the guard band in each OFDM symbol ISI can be eliminated completely. But the ICI is the maindrawback of OFDM system, in this project various methods are studied to reduce IC component.[9][10][11]

III. ICI CANCELLATION SCHEMES

ICI Self- Cancellation Method : In ICI Self- Cancellation method, 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. [3]

Maximal Likelihood Estimation : This method was suggested by Moose. This method estimates the frequency offset and cancels this offset at the receiver. In this technique, an OFDM symbol stream of *N* symbols is replicated such that the duplicate symbols are *N* positions apart in the symbol stream. These symbols are then modulated using a 2*N*-point inverse fast Fourier transform. At the receiver, the first set of *N* symbols are demodulated using an N-point fast Fourier transform to yield the sequence Y_{1k}, and the second set is demodulated with another N-point FFT to yield the sequence Y_{2k}. The frequency offset is the phase difference between Y_{1k} and Y_{2k}, that is, $Y_{2k} = Y_{1k} e^{j2\pi}$.

Once the frequency offset is known, the ICI distortion in the data symbols can be reduced by multiplying received symbols with a complex conjugate of the frequency shift. [4]

Extended Kalman Filter : The Extended Kalman Filtering (EKF) technique is another method to estimate the frequency offset in the received signal. The received symbols are

$$Y(n) = X(n).e^{\frac{j2\pi n'\varepsilon(n)}{N}} + W(n) \qquad (2)$$

There are two stages in the EKF scheme to mitigate the ICI effect: the offset estimation scheme and the offset correction scheme.[5]

IV. DRAWBACKS

It 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, and the Doppler shift. 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 the method is not effective one.

V. CONCLUSION AND FUTURE SCOPE

In this research, three methods were explored for mitigation of the ICI. The ICI self-cancellation (SC) and the extended Kalman filtering (EKF) method and Total ICI cancellation schemes are proposed. The choice of which method to employ depends on the specific application. For example, self cancellation does not require very complex hardware or software for implementation. For small alphabet sizes (BPSK) and for low frequency offset values, The SC scheme delivers good performance in terms of BER. However, for higher order modulation schemes, the EKF and perform better. The self-cancellation technique does not completely cancel the ICI from adjacent sub-carriers. However, it is not bandwidth efficient as there is a redundancy of 2 for each carrier.On the other hand, the EKF method does not reduce bandwidth efficiency as the frequencyoffset can be estimated from the preamble of the data sequence in each OFDM frame.However, it is more complex implementation method compared to SC method. In addition,this method requires a training sequence to be sent before the data symbols for estimation of the frequency offset. It can be adopted for the receiver design for IEEE 802.11a because this standard specifies preambles for every OFDM frame. The preambles are used as the training sequence in estimating the frequency offset. There are some other methods to reduce the ICI and improve the performance of system like channel estimation techniques. The further work can be done by extending the concept of channel estimation and by performing the simulation to investigate the performance of these ICI cancellation schemes in multipath fading.

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