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ICI Cancellation using Self Cancellation Method

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Abstract: In these recent years, with the increase in the growth of digital communication, there has been a huge need for high speed data transmission. Likewise, there is a huge demand for the communication systems that support a wide range of services which include video, data and voice. OFDM (Orthogonal Frequency Division Multiplexing) is an efficient method of communication to achieve high speed data rates in mobile environment since it supports multicarrier modulation and has feature of converting frequency selective fading into flat fading channel. However OFDM has its sensitivity against carrier frequency offset which causes Inter Carrier Interference (ICI). In this paper we have tried to give an efficient ICI cancellation method termed as ICI self cancellation.

Keywords: OFDM, Interference, Inter Carrier Interference, Doppler shift, Frequency miss match.

I. INTRODUCTION

Exponential increase in the demand for high rate wireless data communication calls for the technique that makes use of electromagnetic resources in the most efficient way. Some objectives like power consumption, spectrum efficiency, implementation complexity, multipath propagation, range, robustness should be considered while designing such systems. The revolution in the internet has been the driving factor for such wireless technologies that can deliver information at high speeds.

Hence OFDM is most suitable for such systems since it can provide large data rates with robustness. But as mentioned earlier OFDM might get affected by Inter carrier interference. The main reason for such interference is Doppler shift in the channel or the oscillator frequency mismatch at transmitter and receiver. Because of this, Orthogonal property of carriers is not maintained which results in ICI. This undesired ICI degrades the performance of the system. OFDM is mainly observed in many communication standards, such as IEEE 802.11a, MMAC (Multimedia mobile access communication).

II. MOTIVATION

OFDM is robust in adverse channel conditions and hence allows high level of spectral efficiency. While working with wireless systems we may encounter some problems like multipath fading, time dispersion leading to Inter carrier Interference, lower bit rate capacity, less spectral efficiency.

But in OFDM, the above mentioned problem could be reduced to some extent. Hence such division multiplexing method can be selected for systems like Digital Audio Broadcasting (DAB), Digital subscriber Lines (DSL), Digital Video Broadcasting (DVB). By analysing above lines we can come to conclusion that OFDM is best suited for Wireless Mobile Communication

III.LITERATURE SURVEY

In 1971, Weinstein and Ebert proposed a modified OFDM system in which the discrete Fourier Transform (DFT) was applied to generate the orthogonal subcarriers waveforms instead of the banks of sinusoidal generators. Their scheme reduced the implementation complexity significantly, by making use of the inverse DFT (IDFT) modules and the digital-to-analog converters. In their proposed model, baseband signals were modulated by the IDFT in the transmitter and then demodulated by DFT in the receiver. Therefore, all the subcarriers were overlapped with others in the frequency domain, while the DFT modulation still assures their orthogonality.

Cyclic prefix (CP) or cyclic extension was first introduced by Peled and Ruiz in 1980 for OFDM systems. In their scheme, conventional null guard interval is substituted by cyclic extension for fully-loaded OFDM modulation. As a result, the orthogonality among the subcarriers was guaranteed. With the trade-off of the transmitting energy efficiency, this new scheme can result in a phenomenal ISI (Inter Symbol Interference) reduction. Hence it has been adopted by the current IEEE standards. In 1980, Hirosaki introduced an equalization algorithm to suppress both inter symbol interference (ISI) and ICI, which may have resulted from a channel distortion, synchronization error, or phase error. In the meantime, Hirosaki also applied QAM modulation, pilot tone, and trellis coding techniques in his high-speed OFDM system, which operated in voice-band spectrum.

In 1985, Cimini introduced a pilot-based method to reduce the interference emanating from the multipath and co-channels. In the 1990s, OFDM systems have been exploited for high data rate communications. In the IEEE 802.11 standard, the carrier frequency can go up as high as 2.4 GHz or 5 GHz. Researchers tend to pursue OFDM operating at even much higher frequencies nowadays. For example, the IEEE 802.16 standard proposes yet higher

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carrier frequencies ranging from 10 GHz to 60 GHz. However, one of the main disadvantages of OFDM is its sensitivity against carrier frequency offset which causes intercarrier interference (ICI). The undesired ICI degrades the performance of the system. ICI self-cancellation is a scheme that was introduced by Yuping Zhao and Sven-Gustav Haggman in 2001 to combat and suppress ICI in OFDM.

IV. OFDM

OFDM is a special form of multi carrier modulation technique which is responsible for generation of waveforms which are orthogonal to each other. In such schemes, a large number of orthogonal, overlapping, narrow band sub-carriers are transmitted in parallel. The separation of these sub-carriers is such a way that there is a very compact spectral utilization. After more than four decades of research, OFDM is now available for implementation of high-speed digital communications.
The basic principle of OFDM is to divide the available spectrum into many orthogonal sub channels such that each narrow band sub channels experience flat fading. The main advantage of OFDM is its way of handling multipath interference at the receiver. Basically multipath phenomenon generates two effects a) frequency selective fading b) Inter symbol interference.
By using suitable error correcting code, we can achieve more robustness which decreases frequency selective fading. Usage of FFT (Fast Fourier Transform) technique in modulation and demodulation technique makes it more efficient.

A. OFDM system description

In an OFDM system, the input bit stream is multiplexed into N symbol streams, each with symbol period Ts, each symbol stream is used to modulate parallel, synchronous sub-carriers. These are spaced 1/NTs in frequency, thus they are orthogonal in nature over the interval (0, Ts). The high speed data rate for OFDM are accomplished by simultaneous transmission of data at a lower rate on each of the orthogonal sub-carriers. Because of this, distortion in received signal induced by multipath delay is not significant.

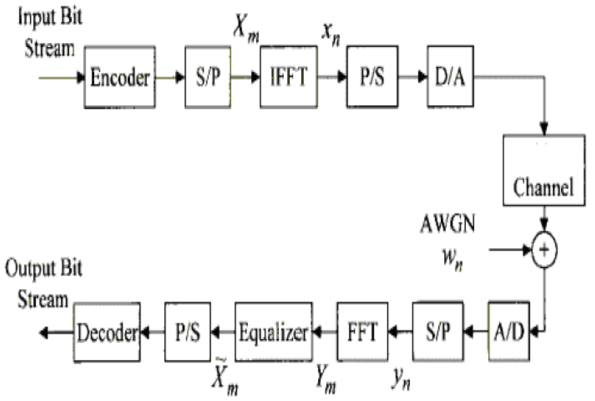

Fig. 1 Baseband OFDM Transceiver system

The figure shows the basic block diagram of OFDM transceiver system. Initially an input bit stream of predefined bits is fed into the encoder present in the transmitter. The output from the encoder is fed into the block in which Inverse FFT of the signal takes place. After that block the signal is sent to digital to analog converter and added some noise called AWGN (Additive White Gaussian Noise). At the receiver end we have Analog to digital converter and sent to the block where FFT takes place. At the end of the receiver we have decoder which decodes the encoded data.

B. Intersymbol and intercarrier interference

In a multipath environment, a transmitted symbol takes different times to reach the receiver through different propagation paths. From the receiver‘s point of view, the channel introduces time dispersion in which the duration of the received symbol is stretched. Extending the symbol duration causes the current received symbol to overlap previous received symbols and results in intersymbol interference (ISI). In OFDM, ISI usually refers to interference of an OFDM symbol by previous OFDM symbols. For a given system bandwidth the symbol rate for an OFDM signal is much lower than a single carrier transmission scheme. For example for a single carrier BPSK modulation, the symbol rate corresponds to the bit rate of the transmission. However for OFDM the system bandwidth is broken up into N subcarriers, resulting in a symbol rate that is N times lower than the single carrier transmission. This low symbol rate makes OFDM naturally resistant to effects of Inter-Symbol Interference (ISI) caused by multipath propagation. Multipath propagation is caused by the radio transmission signal reflecting off objects in the propagation environment, such as walls, buildings, mountains, etc. These multiple signals arrive at the receiver at different times due to the transmission distances being different. This spreads the symbol boundaries causing energy leakage between them.
In OFDM, the spectra of subcarriers overlap but remain orthogonal to each other. This means that at the maximum of each sub-carrier spectrum, all the spectra of other subcarriers are zero. The receiver samples data symbols on individual sub-carriers at the maximum points and demodulates them free from any interference from the other subcarriers. Interference caused by data symbols on adjacent sub-carriers is referred to intercarrier interference (ICI).
The orthogonality of subcarriers can be viewed in either the time domain or in frequency domain. From the time domain perspective, each subcarrier is a sinusoid with an integer number of cycles within one FFT interval. From the frequency domain perspective, this corresponds to each subcarrier having the maximum value at its own center frequency and zero at the center frequency of each of the other subcarriers. The orthogonality of a subcarrier with respect to other subcarriers is lost if the subcarrier has nonzero spectral value at other subcarrier frequencies. From the time domain perspective, the corresponding sinusoid no longer has an integer number of cycles within

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the FFT interval. ICI occurs when the multipath channel varies over one OFDM symbol time. When this happens, the Doppler shift on each multipath component causes a frequency offset on the subcarriers, resulting in the loss of orthogonality among them. This situation can be viewed from the time domain perspective, in which the integer number of cycles for each subcarrier within the FFT interval of the current symbol is no longer maintained due to the phase transition introduced by the previous symbol. Finally, any offset between the subcarrier frequencies of the transmitter and receiver also introduces ICI to an OFDM symbol

V. ANALYSIS OF INTER-CARRIER INTERFERENCE

The main disadvantage of OFDM, however, is its susceptibility to small differences in frequency at the transmitter and receiver, normally referred to as frequency offset. This frequency offset 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. In this project, the frequency offset is modelled as a multiplicative factor introduced in the channel as shown in the below figure.

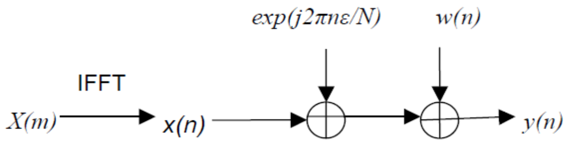

Fig. 2 Frequency Offset Model

The effect of this frequency offset on the received symbol stream can be understood by considering the received symbol Y(k) on the k th sub-carrier. By analysing the formulas and block diagram of frequency offset model, we can plot the ICI co-efficient for wide range of values of k versus sub carrier index as given in the figure 3.

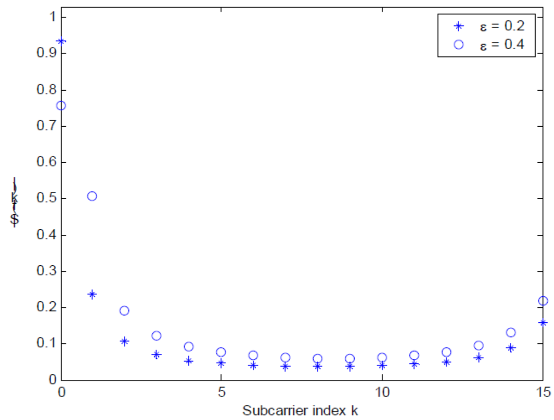

Fig. 3 ICI Co-efficient for N=16 carriers

This figure shows that for a larger ε, the weight of the desired signal component, S(0), decreases, while the weights of the ICI components increases. The authors also notice that the adjacent carrier has the maximum contribution to the ICI. This fact is used in the ICI self-cancellation technique.

The carrier-to-interference ratio (CIR) is the ratio of the signal power to the power in the interference components. It serves as a good indication of signal quality. The derivation assumes that the standard transmitted data has zero mean and the symbols transmitted on the different sub-carriers are statistically independent.

VI. ICI CANCELLATION SCHEME

Basically Inter carrier interference can be reduced using four methods. Frequency domain equilization, Time domain windowing, Pulse shaping and ICI self cancellation. From the above four methods the first two methods are the initial approach, where as the last two methods are very effective.

ICI self-cancellation is a scheme that was introduced by Yuping Zhao and Sven-Gustav Häggman in 2001 in to combat and suppress ICI in OFDM. Succinctly, the main idea 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.

A. ICI Cancelling Modulation

The ICI self-cancellation scheme requires that the transmitted signals be constrained such that X (1) = -X (0), X (3) = -X (2)......... X (N-1) = -X (N-2). This assignment of transmitted symbols allows the received signal on subcarriers k and k + 1 to be written as

$$Y'(k) = \sum_{l=0}^{N-2} X(l)\ [S(l-k)-S(l+1-k)]$$

$$Y'(k) = \sum_{l=0}^{N-2} X(l)\ [S(l-k+1)-S(l-k)]$$

and the ICI coefficient S'(l-k) is denoted as S'(l-k) = S(l-k) – S(l+1-k).

Figure 4 shows a comparison between |S'(l-k)| and |S(l-k)| on a logarithmic scale.

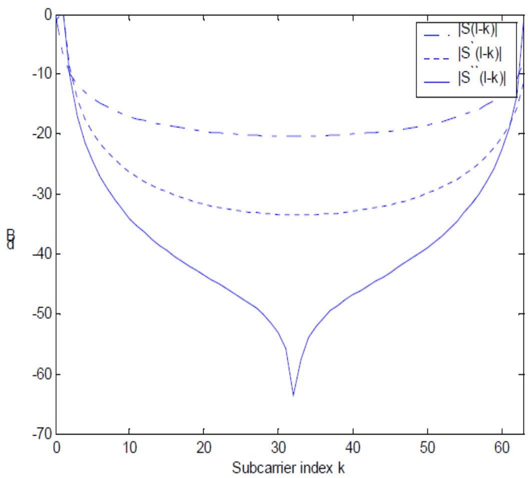

Fig. 4 Comparison between |S(l-k)| and |S'(l-k)|

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C. ICI Cancelling Demodulation

ICI modulation introduces redundancy in the received signal since each pair of subcarriers transmit only one data symbol. This redundancy can be exploited to improve the system power performance, while it surely decreases the bandwidth efficiency. To take advantage of this redundancy, the received signal at the (k + 1) th subcarrier, where k is even, is subtracted from the k th subcarrier.

This is expressed mathematically as

$$Y''(k) = Y'(k) - Y'(k+1)$$
$$=\sum_{l=0}^{N-2} X(l)\ [-S(l-k-1)+2S(l-k)-S(l-k+1)]$$

Subsequently, the ICI coefficients for this received signal becomes

$$S''(l-k) = -S(l-k-1)+2S(l-k)-S(l-k+1)$$

When compared to the two previous ICI coefficients |S(l-k)| for the standard OFDM system and |S'(l-k)| for the ICI canceling modulation, |S''(l-k)| has the smallest ICI coefficients, for the majority of l-k values, followed by |S'(l-k)| and |S(l-k)|. This is shown in Figure 4.1 for N = 64 and ε = 0.4. The combined modulation and demodulation method is called the ICI selfcancellation scheme.

As mentioned above, the redundancy in this scheme reduces the bandwidth efficiency by half. This could be compensated by transmitting signals of larger alphabet size. Using the theoretical results for the improvement of the CIR should increase the power efficiency in the system and gives better results for the BER. Hence, there is a tradeoff between bandwidth and power tradeoff in the ICI self-cancellation scheme.

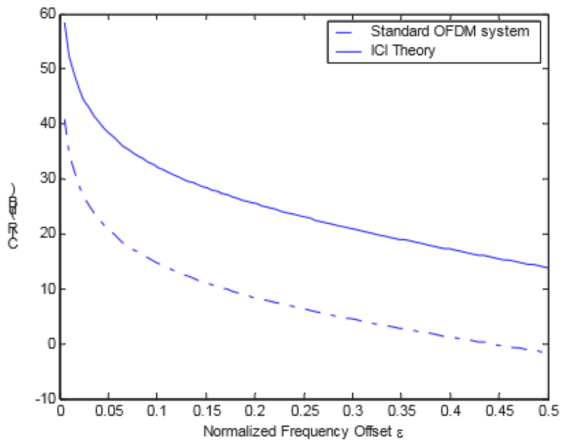

Fig. 5 CIR versus ε for a standard OFDM system

VII. CONCLUSION

In this project, the performance of OFDM systems in the presence of frequency offset between the transmitter and the receiver has been studied in terms of the Carrier-to-Interference ratio (CIR) and the bit error rate (BER) performance. Inter-carrier interference (ICI) which results from the frequency offset degrades the performance of the OFDM system. 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. However, it is not bandwidth efficient as there is a redundancy of 2 for each carrier.

VIII. FUTURE WORKS

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 for estimation of the frequency offset. In this project, the simulations were performed in an AWGN channel. This model can be easily adapted to a flat-fading channel with perfect channel estimation. Further work can be done by performing simulations to investigate the performance of these ICI cancellation schemes in multipath fading channels without perfect channel information at the receiver. In this case, the multipath fading may hamper the performance of these ICI cancellation schemes.

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