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AN IMPROVED SLOT BASED FILTERATION APPROACH TO REDUCE THE ICI IN OFDM

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Abstract- The demand for high data rate services has been increasing very rapidly and there is no slow down in sight. Orthogonal Frequency Division Multiplexing (OFDM) is a promising technique for achieving high data rate in mobile environment and ability to convert the frequency selective fading channel into several nearly flat fading channels. OFDM provides the high spectrum efficiency over the network because it allows the overlapping of subcarrier in frequency domain. A problem with OFDM is that its sensitivity to the frequency offset between transmitter and receiver signals, which may be caused by Doppler shift in the channel or by difference between the transmitter and receiver local oscillator frequency. This carrier frequency offset causes the loss of orthogonality between the sub-carrier and signal transmitted on each carrier are not independent to each other, leading to the inter-carrier interference (ICI). The interference results the high signal to noise ratio (SNR) as well as high bit error rate (BER). It affects both the reliability as well as the efficiency. The proposed approaches that have been developed to reduce the ICI can be categorized as self-cancellation scheme and kalman filter.

Keywords: OFDM, ICI, Self-Cancellation and kalman filter.

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I. INTRODUCTION

The ever increasing demand for very high rate wireless data transmission calls for technologies which make use of the available electromagnetic resource in the most intelligent way. Key objectives are spectrum efficiency (bits per second per Hertz), robustness against multipath propagation, range, power consumption and implementation complexity. These objectives are often conflicting, so techniques and implementations are sought which offer the best possible trade off between them. The Internet revolution has created the need for wireless technologies that can deliver data at high speeds in a spectrally efficient manner. However, supporting such high data rates with sufficient robustness to radio channel impairments requires careful selection of modulation techniques. Currently, the most suitable choice appears to be OFDM (Orthogonal Frequency Division Multiplexing). One of the main reasons to use OFDM is to increase the robustness against frequency selective fading or narrowband interference. In a single carrier system, a single fade or interferer can cause the entire link to fail, but in a multicarrier system, only a small percentage of the subcarriers will be affected. Error correction coding can then be used to correct for the few erroneous subcarriers. The concept of using parallel data transmission and frequency division multiplexing was published in the mid-1960s [1, 2].

II. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING

Orthogonal Frequency Division Multiplexing (OFDM) has grown to be the most popular communications systems in high speed communications. OFDM technology is the future of wireless communications. OFDM has been adopted in the European digital audio and video broadcast radio system and investigated for broadband indoor wireless communications. Standards such as HIPERLAN2 (High Performance Local Area Network) and IEEE 802.11a and IEEE 802.11g have emerged to support IP-based services. Such systems are based on OFDM and are designed to operate in the 5 GHz band [3].OFDM is a special case of multi-carrier modulation. Multi-carrier modulation is the concept of splitting a signal into a number of signals, modulating each of these new signals to several frequency channels, and combining the data received on the multiple channels at the receiver [4]. In OFDM, the multiple frequency channels, known as sub-carriers, are orthogonal to each other [5]. Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier transmission technique, which divides the bandwidth into many carriers, each one is modulated by a low rate data stream. In term of multiple access technique, OFDM is similar to FDMA in that the multiple user access is achieved by subdividing the available bandwidth into multiple channels that are then allocated to users. However,

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OFDM uses the spectrum much more efficiently by spacing the channels much closer together. This is achieved by making all the carriers orthogonal to one another, preventing interference between the closely spaced carriers.

III. EVOLUTION OF OFDM

Chang proposed the original OFDM principles in 1966, and successfully achieved a patent in January of 1970. OFDM is a technique for transmitting data in parallel by using a large number of modulated sub-carriers. These sub-carriers divide the available bandwidth and are sufficiently separated in frequency so that they are orthogonal. The Orthogonality of the carriers means that each carrier has an integer number of cycles over a symbol period. Weinstein and Ebert [6], 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 [7], 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. Hirosaki [8], 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. Cimini [9] 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

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OFDM operating at even much higher frequencies nowadays. For example, the IEEE 802.16 standard proposes yet higher carrier frequencies ranging from 10 GHz to 60 GHz.

IV. PRINCIPLE OF OFDM

The total signal bandwidth, in a classical parallel data system, can be divided into N non-overlapping frequency sub-channels. Each sub-channel is modulated with a separate symbol and then the N sub-channels are frequency multiplexed. The general practice of avoiding spectral overlap of sub-channels was applied to eliminate inter-carrier interference (ICI). This is shown in Fig 1 (a). This resulted to insufficient utilization of the existing spectrum. An idea was proposed in the mid-1960s to deal with this wastefulness through the development of frequency division multiplexing (FDM) with overlapping sub-channels. The sub-channels were arranged so that the sidebands of the individual carriers overlap without causing ICI. This principle is displayed in Fig 1 (b). To achieve this the carriers must be mathematically orthogonal. From this constraint the idea of OFDM (orthogonal frequency division multiplexing) was born. Bandwidth saved in case of OFDM [10].

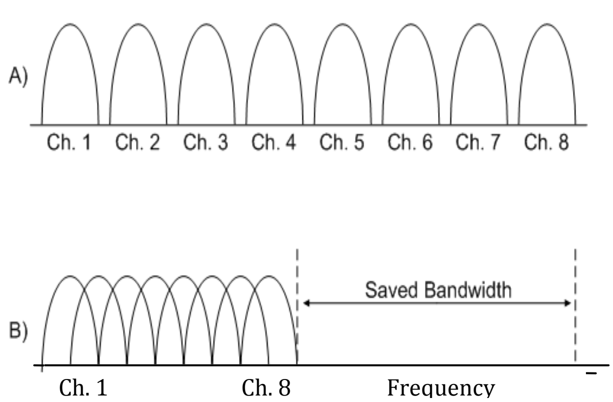

Figure 1:(A) The frequency spectrum of eight channels shown utilizing frequency division multiplexing. Parallel transmitters are employed in which guard bands are placed between subcarriers. (B) The frequency spectrum of OFDM is shown where sub-channels are orthogonal to the adjacent channels. The percentage of bandwidth used to transmit the same data is reduced by 50%.

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A non linearity that affects the OFDM system can be categories as Peak-to-average-power-reduction (PAPR) and Inter-Carrier-Interference (ICI). I have focus on the problem of ICI in OFDM system.

V. RELATED WORK

In this section we briefly review the proposed work related to ICI reduction in OFDM system. Jagan Naveen et. al. [11], proposed a work. The effects of ICI have been analyzed and two solutions to combat ICI have been presented. The first method is a self cancellation scheme, in which redundant data is transmitted onto adjacent subcarriers such that the ICI between adjacent sub carriers cancels out at the receiver. The other technique the Extended Kalman Filter (EKF) method statistically estimate the frequency offset and correct the offset using the estimated value at the receiver.

Miao-Wen Wen et. al. [12], performed a work. A novel type of inter-carrier-interference (ICI) self-cancellation method using mirror mapping is proposed to combat these impairment. Based on the proposed novel method and by adopting two widely used mapping operations, we altogether derive two different mirror mapping schemes. Analysis and simulation results verify that the proposed mirror mapping schemes not only inherit the efficiency of the existing self-cancellation schemes in suppressing ICI caused by CFO but also have the ability of compressing or even eliminating in-phase/quadrature-phase (I/Q) imbalance.

F. Prianka et al. [13, 14], performed a work. In orthogonal frequency division multiplexing (OFDM) system, the frequency offset in mobile radio channel leads to the loss of sub-carrier orthogonality which causes inter-carrier interference (ICI). As a result, the performance of the system will degrade. The authors have proposed an efficient scheme for ICI cancellation. Through a detailed analysis and simulation, it is shown that the performance of the proposed scheme gives better BER (Bit Error Rate) and CIR (Carrier to Interference Ratio) than the conventional self cancellation scheme.

Qiang Shi et. al. [15], proposed a novel self cancellation technique to mitigate the ICI effect. Although the bandwidth efficiency of the scheme is reduced by half due to the redundant symbols, it can be solved by increasing the number of subcarriers or using large signal alphabet size. The performance of ICI self cancellation are analyzed in the term of CIR

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and BER. Simulation result demonstrate that proposed ICI self cancellation scheme outperforms other existing self cancellation method and robustness to large frequency offset.

Karthik Muralidhar et. al. [16], proposed a vector state-scalar observation (VSSO) Kalman filter for channel estimation in doubly-selective orthogonal frequency division multiplexing (OFDM) systems. Author show how the observed pilot symbol vector can be de-correlated or decoupled into uncorrelated multipath scalars. This aspect (proposed Kalman filter) is similar in spirit to that of a quasi-static channel.

Yuan Jing et. al [17] performed a work. An extended $H\infty$ filter-based carrier frequency offset (CFO) estimator is proposed for orthogonal frequency division multiplexing (OFDM) systems. The design criterion of the proposed estimator is to minimize the effect of worst-case disturbances (noise and model error) on the CFO estimation errors. This data-aided CFO estimator does not require any statistical knowledge of the disturbances. Moreover, its computational complexity is similar to that of the extended Kalman filter (EKF) method.

Yi-Hao Peng et. al. [18], proposed a new scheme to cancel the effect of ICI. The system performances are evaluated based on carrier-to interference ratio and bit error rate. The simulation results show that the effect of phase error with the proposed scheme is lighter than with Zhao's scheme. Hence, the BER performance of proposed scheme is better than that of Zhao's scheme even in a large frequency offset.

Jia Tu et. al [19], proposed a turbo equalization based on new Kalman filter for OFDM with time-varying channels. This algorithm uses soft mapping and soft de-mapping to realize information exchange via turbo iteration, realizes the update of channel response, and mitigates the ICI partly. Theoretical analysis and simulation results indicate that the method in this paper can effectively track channel and mitigate ICI. It has good BER performance even the channels are fast varying.

Hye Mi Park et. al [20] performed a work, two channel estimation schemes for OFDM systems are investigated in a time-variant channel. The orthogonality of the subcarriers is destroyed in a time-variant channel, resulting in inter-carrier interference (ICI). To mitigate the ICI, the 2-D Kalman filtering (2-D KF) scheme estimates the channel in time domain by using the Kalman filters in both time and frequency domains and the iterative Wiener filtering (IWF) scheme calculates the ICI through the iteration.

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Jae Yeun Yun et. al [21], proposed a work. Based on the capacity analysis, the optimal windows maximizing the capacity lower bounds are designed numerically with an assumption that the channel is flat fading. The effects of ICI canceling windows on the capacity lower bounds are examined through numerical simulations and results indicate that considerable performance improvement can be achieved by employing the proposed windows, as compared with the conventional systems with/without windowing when the channel varies very rapidly.

Li Zhao et. al. [22], proposed a new ICI self-cancellation scheme using repeated symbol for combating the impact of ICI on OFDM systems. At first, the two repeated symbol blocks on time domain, in which the1st block is formed by inserting zero in the symbol block of a conventional OFDM system, and the 2nd block is formed by inversing and shifting cyclic right from the 1st block, respectively transmitted at the transmitter. At the receiver, the received data symbols are divided into two paths corresponding to the two symbol blocks transmitted, and then the two data symbol streams are combined. Finally, the resultant symbol sequence is detected to obtain the estimation of original data symbols as a conventional OFDM system. By theoretical analysis and calculation for the new scheme, it is obviously shown that the ICI components contained in received signals can be effectively reduced, and the carrier-to interference power ratio (CIR) of this scheme is at least 10dB better than that of a conventional OFDM system.

Alireza Seyedi et. al. [23, 24], proposed a more general approach called the General Self-Cancellation Scheme (GSCS). In this technique, windowing is used to reduce the ICI resulting from frequency shifts. After describing the system, Author uses a numerical method to calculate the bit error rate of the system in presence of a fixed frequency shift and use of Monte Carlo simulations. The results demonstrate that the proposed system performs better than the conventional and the SCS systems, both in presence of an oscillator frequency offset and when ICI is created as a result of channel fading.

Ki-Young Han et. al [25], performed a work. The proposed method is based on a new modified Kalman filter (MKF). The time-varying channel is modeled as an autoregressive (AR) process and the proposed MKF is used to estimate this AR parameter. In addition, to track the time varying channel, a channel predictor using regression analysis and the minimum mean-squared error (MMSE) time domain equalizer are also proposed.

Chuandan Wang et. al [26], proposed a ICI cancellation method termed segment equalization schemes. According to the time-variant nature of the mobile channel, the received OFDM signal and channel impulse response (CIR) is divided

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into many segments before FFT, then equalized every segment in frequency-domain, summed the results to demodulate OFDM signal. Simulations and performance analysis show that OFDM system using the proposed segment equalization can effectively reduce the ICI caused by frequency offset and large Doppler frequencies in mobile radio channels.

Bing Han et. al [27], proposed a work. A new scheme to reduce the frequency-offset sensitivity of orthogonal frequency division multiplexing (OFDM) systems is proposed Without any redundant modulation, and thus no loss of bandwidth efficiency induced, two parallel discrete Fourier transform OFT) modules are inserted in the transmitter side to reduce the sensitivity to frequency offset. The fast implementation of DFT also facilitates the proposed scheme.

B. J. Peiris et. al. [28], proposed a self-cancellation scheme to reduce the ICI and combine maximum likelihood estimation Technique with that scheme to get a better immunity for frequency errors at higher fractional frequency offset values and also discusses the possibility of application of a bandwidth efficient coding scheme for the considered cancellation scheme, to obtain the immunity to channel interference without further reducing bandwidth efficiency.

K. Sathananthan et. al. [29], proposed a Peak Interference-to-Carrier Ratio (PICR) to measure the resulting (ICI) and PICR can be reduced by coding to select only those messages with low PICR as valid codeword. While explicit construction of higher rate, ICI suppressing codes are rather difficult, proposed two new codes that map data on to the three and four adjacent subcarrier. A new ICI reduction scheme, called Tone Reservation Technique.

CONCLUSION

In this section the performance analysis of OFDM has been studied. A brief OFDM system has been given and a review on OFDM performance analysis has also been given. OFDM is key technology which allow for robust, high capacity, high speed wireless broadband multimedia network. In this paper we have been studied self cancellation and kalman filter method to reduce the ICI in OFDM system.

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