ICI Reduction Technique for OFDM Systems using Combining Weight Technique: A Survey

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***Abstract*- This paper is a detail survey of the ICI reduction technique for OFDM systems using combining weight technique. The paper reviews a lot of combining weight techniques as well as compare different types of combining weight technique based on ICI reduction performance and cost constraint. In ICI reduction, optimum combining and near-optimum combing methods are reviewed. These methods are highly compatible with most existing data detection, equalization, and channel estimation methods. It has also very low complexity.**

Key Words: Bit-error rate (BER), Inter-carrier-interference (ICI), Optimum combining weight, Orthogonal frequency division multiplexing (OFDM), Near optimum combining weights, Signal to noise ratios (SNRs)

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a special form of multicarrier modulation scheme [1]. In OFDM the individual carriers are mutually orthogonal to each other. OFDM provides high spectral efficiency, low implementation complexity. It has less vulnerability to echoes and non-linear distortion. Due to increase in symbol duration, there is a reduction in delay spread. Addition of guard band, almost removes the ISI in the system. OFDM can be efficiently implemented by using IFFT.

With the increasing demand for wireless multimedia applications, it is desirable to design the wireless system with higher data rates. Furthermore, the frequency spectrum has a limited and valuable source, making it necessary to utilize the available spectrum efficiently and co-exist with other wireless systems. Thus, future wireless technology is required to operate at high data rates, at high carrier frequencies under the environment of high mobility and large spectrum interference, while the data transmission still remains reliable and supports multiple users. Orthogonal frequency division multiplexing (OFDM) technology is at the core of multicarrier systems that play a crucial role in fulfilling the above requirements [2].

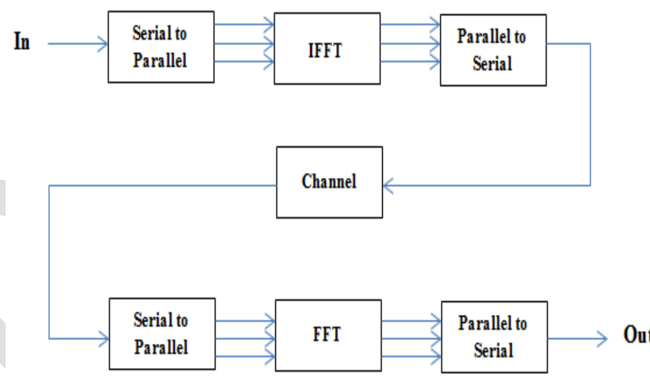

Fig 1: Block Diagram of OFDM Systems

In a communication system based on OFDM technique, a receiver needs to synchronize with a transmitter in frequency, phase and time to faithfully reproduce the transmitted signal. Frequency offset in OFDM system is introduced by the mismatch between transmitter and receiver sampling clocks and misalignment between the reference frequency of the transmitter and receiver stations. The sampling clock error appears in two ways.

(1) A slow variation in sampling time instant causes rotation of sub-carriers and subsequent loss of signal-to-noise ratio (SNR) due to ICI.

(2) It causes the loss of orthogonally among sub-carriers due to energy spread and adjacent sub-carriers

Let us defined the normalized sampling error as

$$t_\Delta = \frac{T' - T}{T} \qquad (1)$$

Where, T and T' are transmitting and receiving sampling periods respectively.
And the power is approximated by

$$Pt_\Delta \approx \frac{\pi^3}{3}(Kt_\Delta)^2, \text{ where, K = sub-carrier index} \qquad (2)$$

Hence, the degradation grows as the square of offset t_{Δ} and the sub-carrier index K. This means that the outermost sub-carriers are most severely affected. The OFDM system with a large number of sub-carriers are very sensitive to the sampling offset.

II. WIRELESS COMMUNICATION CHANNEL

The wireless channel is the defined as a link between a Transmitter and a receiver and classified considering the coherence bandwidth and coherence time. The multipath channel generally has a bandwidth where channel variations are highly correlated [3]. This bandwidth is called the coherence bandwidth $(\Delta f)c$.

When a signal is transmitted through a channel, if $(\Delta f)c$ of the channel is small compared with the bandwidth of the transmitted signal, the channel is called to be frequency selective. In this case, the signal is severely distorted by the channel. And, if $(\Delta f)c$ is much larger compared with the bandwidth of the transmitted signal, the channel is called to be frequency non selective or flat. For the measure of frequency selectivity of the channel, there are two important parameters:

(1) The average excess delay.

(2) The root mean square (RMS) delay spread.

The Rayleigh distribution is commonly used to describe the statistical time varying nature of the envelope of a frequency non selective (flat) fading signal, or the envelope of an individual multipath component. In this case, the channel is called a Rayleigh fading channel. On the other hand, when a direct path is available or the channel signal reflectors, in this case the envelope as a Rice distribution and the channel is called, a Ricean fading channel.

The time variation of a channel is determined by a lot of factors, such as the height of the transmitter/receiver antenna, the speed of transmitter/receiver in motion, the shape of the antenna, the height of surrounding structures The three factors to describe the fading characteristics that a transmitted signal experiences in a channel, the p.d.f. of the envelope, frequency selectivity, and time selectivity. They are independent, so there are many combinations to consider. For instance, when no line-of-sight component is available in a channel, the data transmission rate is very high. The receiver is installed in a high-speed cruising vehicle, the channel will be a frequency selective fast Rayleigh fading channel, and the data transmission rate is very low. Then the receiver is installed in a stationary terminal, the channel will be a frequency non selective slow Ricean fading channel.

When the symbol transmission rate, channel frequency selectivity, and channel time selectivity are given, the transmission performance becomes more selective to the time selectivity as the number of sub-carriers increases because the wider symbol duration is less robust to the random noise, whereas it becomes poor as the number of sub-carriers decreases because the wider poor spectrum of each sub-carriers is less robust to the frequency selectivity [4]. Fig. 2 shows the relation among the number of sub-carriers, frequency selectivity, and the time selectivity

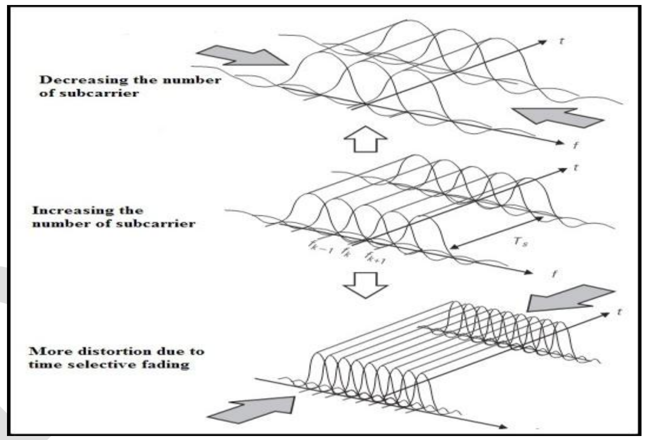

Fig. 2: Relations among number of Subcarriers [2]

III. INTER-CARRIER –INTERFERENCE

Presence of Doppler shifts, frequency and phase offsets in an OFDM system, causes loss in orthogonality of the sub-carriers. This phenomenon is known as inter-carrier interference (ICI). ICI degrades the performance of OFDM systems and error floor occurs. ICI suppressed by equivalently reducing the channel time variation of information part will turn into a constant which means no ICI occurs.

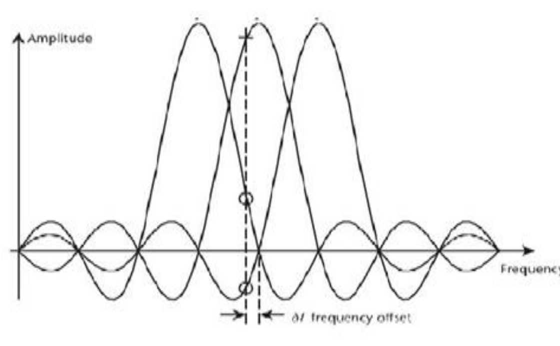

Fig.3: Loss of Orthogonality due to Sampling Offset [5]

Frequency offsets are typically introduced by a frequency mismatch in the local oscillators of the transmitter and the receiver. The impact of a frequency error can be seen as an error in the frequency instants where, the received signal is sampled during demodulation by the FFT. Fig.3 depicts this twofold effect. The amplitude of the desired sub-carrier (SC) is reduced (“+”), and ICI arises from the adjacent SCs (“0”).Mathematically, a carrier offset can be accounted for by frequency shift δf and a phase offset θ in the low-pass equivalent received signal.

$$r_{(t)}{}' = r_{(t)}\, e^{j(2\pi\delta f t+\theta)} \tag{3}$$

It is required to reduce this inter-carrier-interference to a minimum for proper performance. There are two techniques has been proposed.

A. Optimum combining weights.
B. Near-optimum combining weights.

IV. OPTIMUM COMBINING WEIGHTS AND NEAR OPTIMUM COMBINING WEIGHTS

Optimum combining weights and near-optimum combining weights are such techniques which achieves a better performance with the same computation complexity [6]. In this technique the performance can be improved if the delay spread is large. This technique also has the following advantages.

(1) The proposed methods have very low complexity.

(2)They are highly compatible with most existing data detection, equalization, and channel estimation methods.

(3) This technique can be directly applied to other cyclic prefix (CP) communication systems, e.g., orthogonal frequency-division multiple access, single carrier frequency-division multiple access and CP-aided code division multiple access.

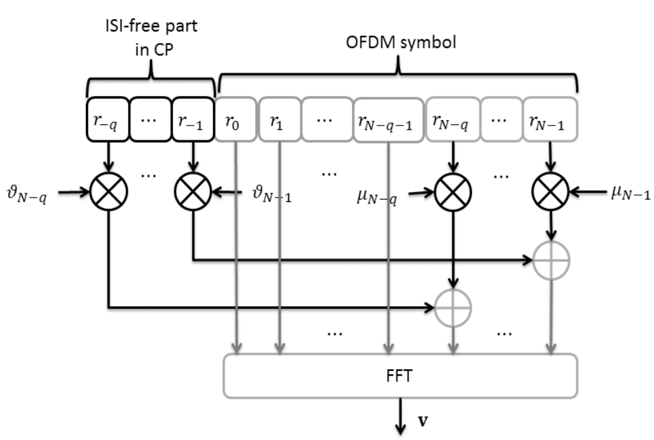

Fig.4: Implementation of the CP combining [7]

Optimum combining weights and near-optimum combining weights are based on the cyclic prefix (CP) recycling scheme. The CP recycling scheme is motivated by the fact that in some situations the specified CP length is much longer than the delay spread and there are a considerable number of ISI-free samples in CP. Conventionally, these ISI-free samples are simply discarded, and apparently it is a waste of resources. Therefore, the core idea of this scheme is to design a method to recycle the ISI –free samples in CP to improve the system performance. Originally, the CP recycling scheme was used to maximize signal-to-noise ratio (SNR) in the presence of frequency offset, and it was also applied to suppress the ICI caused by time-varying channels and directly applied the combining weights to suppress the phase noise effect.

The CP recycling scheme is applied to suppress the ICI power incurred by phase noise, although this idea has already been used in [8,9], nevertheless, the heuristic combining weights adopted in are apparently not optimum in the sense of ICI minimization. The optimum combining methods can be incorporated with other phase noise mitigation methods since the output of the optimum combining method can be treated as a Cleaner (less ICI-polluted) input to the traditional phase noise mitigation methods.

V. CONCLUSIONS

This paper described an optimum combining weights and near optimum combining weights of ICI reduction in OFDM systems. These methods conclude robust performance and improve BER performance with negligible amount of additional computational complexity. These methods can be incorporated with other phase noise mitigation methods, since the output of the optimum combining method can be treated as a cleaner (less ICI polluted) input to the traditional phase noise mitigation methods.

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BIOGRAPHIES

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