BER PERFORMANCE ANALYSIS OF OFDM IN COGNITIVE RADIO NETWORK IN RAYLEIGH FADING CHANNEL

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ABSTRACT: Orthogonal frequency division multiplexing (OFDM) now a day is becoming a popular modulation technique for cognitive radio networks (CRN). It is only because it can provide large data rates and is sufficiently robust in the face of radio channel impairments. Digital modulation techniques provide efficient evolution for our wireless mobile communications by increasing the capacity, speed and quality of a wireless networks. In this paper, we concentrate on digital modulation schemes, such as QPSK and BPSK over an Rayleigh fading channel to analyze the performance of an OFDM system in terms of bit error rate (BER). Inter carrier interference (ICI) is the major drawback of OFDM. We have chosen pulse shaping schemes, improved sinc power pulses and raised cosine filter for ICI cancelation. All simulation work is done using MATLAB and results shows improvement in BER when ICI cancelation schemes are applied.

Keywords – Cognitive radio network (CRN), OFDM, Rayleigh fading, BPSK, QPSK, Inter carrier interference (ICI).

1. INTRODUCTION

Wireless technology is embedded in our daily routine life. These devices use a finite amount of radio spectrum. As the number of devices increase, they compete for bandwidth and they have to face bandwidth scarcity problem. Moreover, traditional fixed spectrum allocation policy can no longer meet the needs and services of the wireless users. According to Federal Communications Commission (FCC), temporal and geographical variations in the utilization of the assigned spectrum range from 15% to 85% in current spectrum allocation policies [1]. To combat this problem J Motila first time proposes the concept of Cognitive Radio Network (CRN). Cognitive radio technology has opened new doors to emerging applications. This technology can serve as a facilitator of communications for other devices which may operate in different band and/or have incompatible wireless interfaces. Similarly, this technology can also be used to provide opportunistic access to large parts of the underutilized spectrum in cellular networks. In his paper J. Motila Define Cognitive Radio as

"The point in which wireless personal digital assistants and the related networks are sufficiently computationally intelligent about radio resources and related computer to computer communications to detect user communication needs as a function of use context, and to provide radio resources and wireless services most appropriate to those needs" [2].

As wireless applications are becoming more sophisticated and are widely used, the demand for high data-rate communications will increase substantially. Therefore, in addition of being frequency agile, a communication system should be able to achieve high data-rates for transmission. The Multicarrier modulation (MCM) approach can support huge data-rates by dividing the stream into several parallel bit streams, each with a lower bit rate, and modulating these sub-streams with different subcarriers [3].

In this paper we will study orthogonal frequency division multiplexing (OFDM), which is a multicarrier modulation scheme. CRN uses OFDM for data transmission at lower bit rate (BER). In this paper we will study BER analysis of OFDM system in cognitive radio network. Several schemes are also proposed so that BER can be improved and inter carrier interference (ICI) can be minimized.

2. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM)

OFDM is a multi-carrier transmission technique that divides the available spectrum into subcarriers, with each subcarrier containing a low rate data stream. The subcarriers have appropriate spacing and pass band filter shape to satisfy orthogonality. As compared to classical parallel data system, frequency division multiplexing (FDM), where a guard band is necessary between the subcarriers which results in an inefficient usage of spectrum.
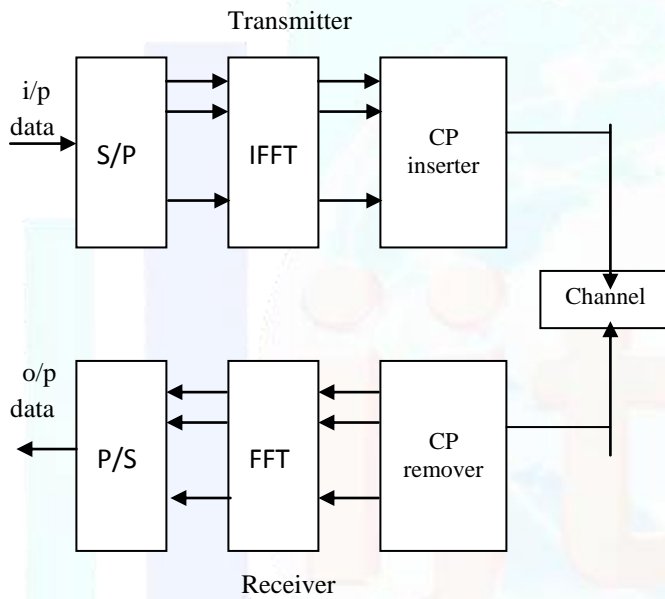

Figure 1- ODFM system block

The schematic diagram of the OFDM system is depicted in Figure 1. Each OFDM symbol can be generated as follows [4]. The bit stream is split into parallel data streams using the serial-to- parallel (S/P) converter. Afterwards, the parallel streams are passed into an inverse fast Fourier transformation (IFFT) to generate a time sequence of the streams. Subsequently, the OFDM symbol time sequences are extended by adding a cyclic extension called the cyclic prefix (CP). The CP is a copy of the last part of the symbol that is added in the beginning of the sequences and should be larger than the network delay spread in order to mitigate the inter-symbol interference (ISI) generated by the arrival of different OFDM symbols with different delay. The resulting digital signal is converted into an analogue one and transmitted through the channel.

At the receiver side, the signal is reconverted again into digital one and the fast Fourier transformation (FFT) is performed on the received streams after removing the CP. Finally, the parallel streams are gathered into single stream as the original transmitted one. The OFDM baseband equivalent is formed by taking the inverse discrete Fourier transform (IDFT) to a set of complex input symbols $\{X_k\}$ and adding a cyclic prefix [5]. This can be written mathematically as

$$x(n) = \sum_k \sum_{l \in Z} X_{k,l g_T}(n - lT) e^{j2\pi(n - lT - c)k/N}$$

(1)

Where $\{k\}$ is the set of data subcarrier indices and is a subset of the set $\{0, 1, \cdots, N-1\}$, N is the IDFT size, C is the length of the cyclic prefix in number of samples, and T = C + N is the length of the OFDM symbol in number of samples. l denotes the lth OFDM symbol while gT (n) is a rectangular pulse shape that can be expressed as

$$g_T(n) = \begin{cases} 1 & n = 0, 1, \ldots, T-1 \\ 0 & otherwise \end{cases}$$

(2)

any two subcarriers in OFDM are orthogonal in the time interval T.

3. OFDM SIGNAL TO NOISE RATIO (SNR) ANALYSIS IN RAYLEIGH FADING CHANNEL

The SNR is defined as the ratio of the desired signal power to the noise power [6]. The SNR indicates reliability of transmission link between the transmitter and receiver, and is accepted as a standard measure of signal quality. The mean SNR can be given by the ratio of the mean signal power and mean noise power as follows [7]:

$$E(\gamma_i^f) = \frac{E(|X_i|^2 \cdot |H_i|^2)}{E(|\hat{n}_i|^2)} = \frac{E(|X_i|^2) \cdot (|H_i|^2)}{E(|\hat{n}_i|^2)}$$ (3)

where $E(\cdot)$ denotes an expectation operator and γ_i^f denotes the SNR at i'th subchannel. Suppose we consider a frequency non-selective slow fading channel, i.e. flat channel response, where the channel magnitude response $E(|Hi|2)$ is flat over the spectrum band. The deactivation of subcarriers due to incumbent users will result in a non-zero ISO. This would also filter out a portion of the channel magnitude response,

which results in an increase in the magnitude of $E(/Hi/2)$. Then, the SNR gain is given by:

$$SNR_{gain} = 10\,log_{10}\left(\frac{E(X_i)^2 \cdot E(H_i)^2/(1-\alpha)}{N_o(1-\alpha)B}\right) - 10\,log_{10}\left(\frac{E(X_i)^2 \cdot E(H_i)^2}{N_oB}\right)$$

$$= -10\,log_{10}(1-\alpha)$$

(4)

Where N_o = Noise power spectral density

B = Bandwidth

α = Incumbent Spectral occupancy (ISP)

In case of frequency selective multipath channel, the channel magnitude response $E(/Hi/2)$ is not flat over the spectrum. Thus, deactivating a portion of the spectrum would also flatten a portion of the channel magnitude response, which results in a random increase in the magnitude of $E(/Hi/2)$.

4. PULSE SHAPING APPROACH IN OFDM

In spite of various advantages OFDM suffer from one major drawback Inter Carrier Interference (ICI) [8]. When ICI is increased than orthogonality in OFDM transmission can no longer be maintained. Various researchers are working to minimize the effect of ICI in OFDM transmission. We are going to discuss two pulse shaping approach in OFDM so that ICI can be minimized.

4.1 IMPROVED SINC POWER PULSE (ISP)

The purpose of pulse shaping is to reduce the main lobe as well as side lobe, as the side lobes contain the ICI power and the main lobe contains peak power. The improved sinc power pulse (ISP) is inspired from the conventional SP pulse shape [9]. The conventional sinc pulse is defined below.

$$P_{SP}(f) = sinc^m\,(fT)$$

(5)

The Fourier transform of the continuous time Improved Sinc power pulse (ISP) is described by modifying SP as follows.

$$P_{ISP}(f) = exp\{-a(fT)^2\}sinc^m\,(fT)$$

(6)

Where 'a' is a design parameter to adjust the amplitude and m is the degree of the sinc function. It is

observed that the magnitude spectral of side lobe is maximum for rectangular pulse and minimum for ISP pulse shapes.

4.2 RAISED COSINE FILTER

The raised-cosine filter is, a good candidate to be used for OFDM sidelobe suppression due to its ability to minimize inter carrier interference (ICI) as well as its relatively straightforward implementation based on mathematically tractable expressions. The ideal raised-cosine filter impulse response is defined as [6]:

$$h(t) = sinc\left(\frac{t}{T}\right)\frac{cos\left(\frac{\pi\beta t}{T}\right)}{1-\frac{4\beta^2t^2}{T^2}}$$

(7)

Where T is the reciprocal of the symbol rate.

The frequency response of an ideal raised-cosine filter consists of unity gain at low frequencies, a raised-cosine function in the middle frequencies, and really total attenuation at high frequencies. The width of the middle frequencies is defined by the roll off factor β, where $0 < \beta < 1$. The term β is a measure of the excess bandwidth (BW) of the filter, i.e., the BW occupied beyond the Nyquist BW of 1/2T. Mathematically, the frequency response of a raised-cosine filter can be written as [11]

$$H(f) = \begin{cases} T & |f| \le \frac{1-\beta}{2T} \\ \frac{T}{2}\left[1 + cos\left(\frac{\pi T}{\beta}\left[|f| - \frac{1-\beta}{2T}\right]\right)\right], & \frac{1-\beta}{2T} < |f| \le \frac{1+\beta}{2T} \\ 0 & otherwise \end{cases}$$

(8)

Using the Fourier transform pair $h(t) \leftarrow F \rightarrow H(f)$, we can modulate $H(f)$ to the center frequency f_c by multiplying $h(t)$ by a factor of $e2\pi fct$. Therefore, the new raised-cosine filter impulse response becomes

$$h_{new}(t) = sinc\left(\frac{t}{T}\right)\frac{cos\left(\frac{\pi\beta t}{T}\right)}{1-\frac{4\beta^2t^2}{T^2}}e^{2\pi f_c t}$$

(9)

5. SIMULATION RESULTS

In this paper, we have evaluated the BER performance of an OFDM system with two digital modulation schemes, namely

BPSK (Binary Phase Shift Keying) and QPSK (Quadrature Phase Shift Keying) [10], over a Rayleigh fading channel. OFDM is a powerful modulation technique to achieve high data rate and is able to eliminate inter symbol interference (ISI). It is computationally efficient due to its use of FFT techniques for implementing modulation and demodulation functions. The simulation parameters used for the model are as given below.

Simulation work is done using MATLAB. Simulated and theoretical SNR Verses BER curves for BPSK and QPSK modulation schemes are shown in figure 2 and 3. BER performance of QPSK is better than BPSK. It is clear from the report of federal communication commission that using QPSK data can be transmitted at twice of data rate as compared to BPSK modulation. The greatest penalty that is paid for using QPSK is that QPSK transmitters and receivers are very much complicated and costly in comparison to BPSK.

We have chosen BPSK modulation scheme when pulse shaping scheme for ICI cancelation are applied. The pulse shaping technique is applied to OFDM system with a fixed normalized frequency offset value $\Delta fT = 0.25$. Pulse shapes RC with roll off rate $\beta = 0.5$ and ISP with different design parameters (m=2, a=0.5, 1) are considered in this simulation. From figure 4 it is clear that BER can be improved when using raised cosine filter for ICI reduction. Further improvement in BER can be achieved when using ISP. Hence with the proposed pulse shaping approach drawback of OFDM system, i.e. ICI are reduced. So performance enhancement of the OFDM system is observed.

TABLE- 1

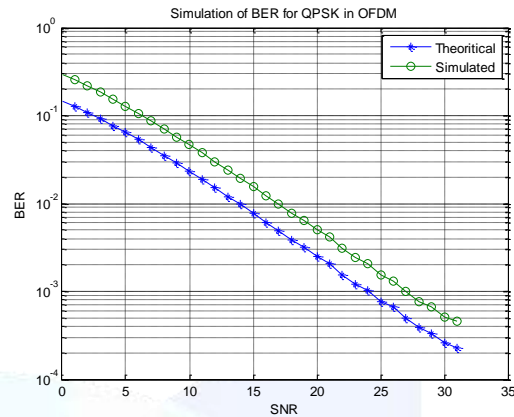| Parameter	Specification
IFFT size	64
No of carrier in OFDM symbol	52
Channel	Rayleigh
Frequency Offset value	0.25
Modulation	BPSK/ QPSK

Figure 2- Simulated and theoretical Bit error rate of QPSK in OFDM in Rayleigh fading channel.
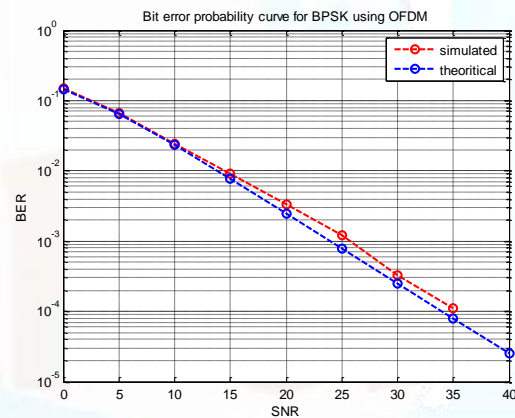

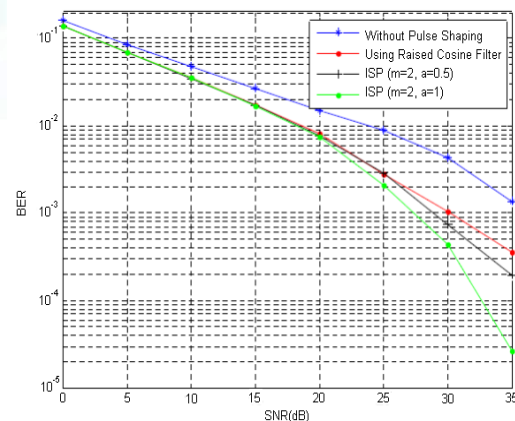Figure 3- Simulated and theoretical Bit error rate of BPSK in OFDM in Rayleigh fading channel.

Figure 4- BER performance of BPSK-OFDM system for without and with Pulse Shaping ΔfT= 0.25.

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