IJDACR
ISSN: 2319-4863

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 12, July 2017)

Performance Analysis of OFDM System in Multipath Fading Environment

Kratika Gupta
riyagupta180@yahoo.com

Pratibha Nagaich
pratibha.nagaich@trubainstitute.ac.in

Abstract – **A detailed study of the OFDM technique is developed in this paper, followed by a general overview of the systems used to implement it. To support these studies, several systems were simulated modeled under MATLAB. The systems produced are versatile and can be used to study the performance that results from the variation of a large number of parameters. These variations can be used to improve or optimize the performance of the system within a given framework. The simulation developed can thus be a valuable tool for the research, design, and development of OFDM systems.**

Keywords –**Multipath Fading, OFDM, QAM, QAM.**

I. Introduction

In recent years orthogonal frequency division multiplexing (OFDM) has gained a lot of involvement in diverse digital communication applications. It is a new ensuring transmission scheme for broadband communications over a wireless channel. In OFDM data is transmitted simultaneously through multiple frequency bands [1]. It offers many advantages over single frequency transmission such as high spectral efficiency, robustness to channel fading, immunity to impulse interference, and the capability to handle frequency-selective fading without resorting to complex channel equalization schemes. OFDM also uses small guard interval, and its ability to combat the ISI problem. So, simple channel equalization is needed instead of complex adaptive channel equalization.

In the conventional serial data transmission system, the information symbols are transmitted sequentially where each symbol occupies the entire available spectrum bandwidth. But in an OFDM system, the information is converted to N parallel sub-channels and sent at lower rates using frequency division multiplexing. The subcarrier frequency spacing is selected carefully such that each subcarrier is located on the other subcarriers zero crossing points [2]. This implies that there is overlapping among the subcarriers but will not interfere with each other, if they are sampled at the sub carrier frequencies. This means that all subcarriers are orthogonal. Due to the orthogonality of the subcarriers the transmission bandwidth is used efficiently as the subcarriers are allowed to overlap each other and still be decoded at the receiver.

OFDM has been used for Digital Audio Broadcasting (DAB) and Digital Video Broadcasting (DVB) in Europe, and for Asymmetric Digital Subscriber Line (ADSL) high data rate wired links. OFDM has also been standardized as the physical layer for the wireless networking standard 'HIPERLAN2' in Europe and as the IEEE 802.11a,g standard in the US, promising raw data rates of between 6 and 54Mbps. OFDM has various properties that make it desirable over existing single carrier systems, the main advantage is OFDM's immunity to frequency selective fading.

Multicarrier networks such as Frequency Division Multiplexing (FDM) have been around since the late 1950's [3], however due to their implementation complexity and inefficient use of the frequency band they were restricted to military applications. A multicarrier system is basically a number of information bearing carriers transmitted in parallel. Multicarrier systems in wireless applications are less susceptible to channel induced distortions than single carrier systems at corresponding data rates.

Chang [4] and Saltzberg [5] further developed FDM in the mid 60's by introducing multiple carriers which overlap in the frequency domain without interfering with each other, utilizing the frequency spectrum more efficiently, hence OFDM. However the complexity issue still remained.

In the 1970's Weinstein and Ebert [6] used an Inverse Discrete Fourier Transform (IDFT) and Discrete Fourier Transform (DFT) to perform the modulation and demodulation respectively, exploiting the sinusoidal nature of the Fourier Transform and significantly reducing the complexity of an OFDM system.

In the last 10 years more advances in practical OFDM systems have been made, particularly in Europe where various projects and prototypes were initiated such as Digital Video Narrowband Emission (HD-DIVINE), System de Television En Radio diffusion NumeriquE (STERNE), and digital Terrestrial Television broadcasting (dTTb). This has led to the adoption of OFDM in many European standards.

IJDACR
ISSN: 2319-4863
IJDACR
International Journal Of Digital Application & Contemporary Research
International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 12, July 2017)

OFDM has progressed to the point where it has now been used for various communication applications such as Digital Audio Broadcasting (DAB) and Digital Video Broadcasting (DVB) in Europe. It has also been adopted as the physical layer modulation scheme for wireless networking standards such as Hiperlan2 in Europe and the Institute of Electrical and Electronic Engineers (IEEE) 802.11a, standards in the United States [7-9]

The objective of this paper is to describe different modulation schemes (Quadrature Phase-shift keying and Quadrature amplitude modulation) in OFDM using Rayleigh multipath fading channel and evaluate the performance using Bit Error Rate (BER) and Signal-to-Noise Ratio (SNR).

II. PROPOSED METHODOLOGY

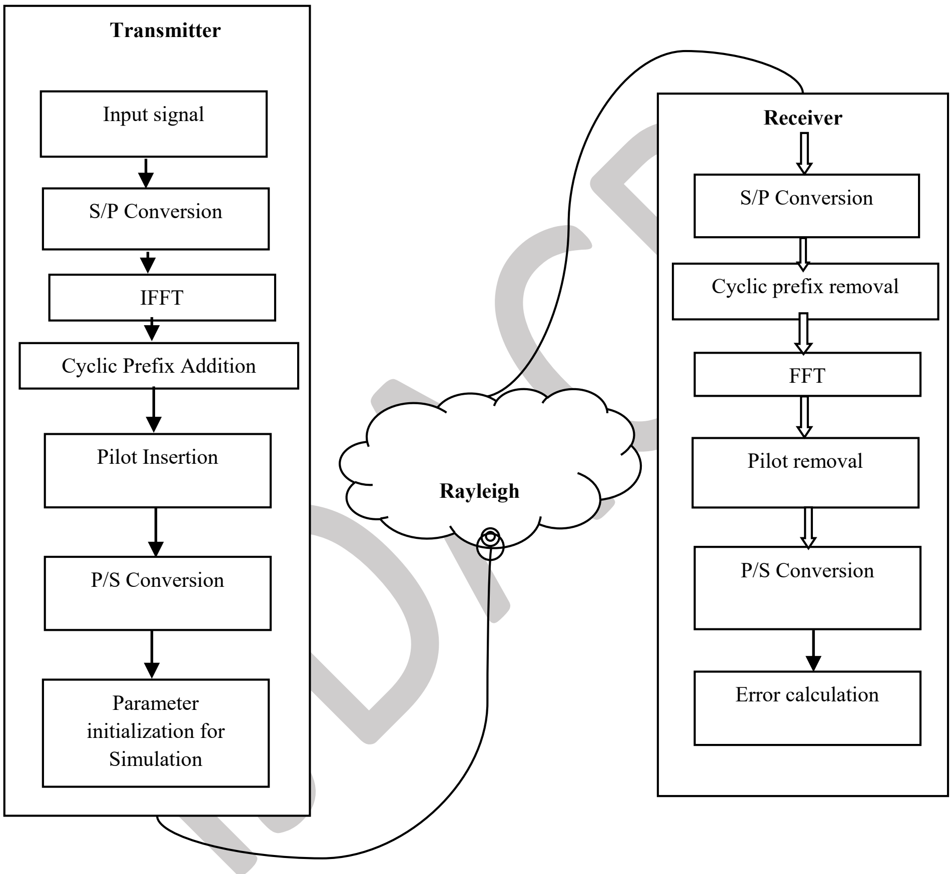

Figure 1: Flow diagram for proposed work

As per the flow diagram (Figure 1), it is clear that there are three sections namely; transmitter section, channel section and receiver section. In transmitter section, data input is used to insert data which is then modulated in the next section. After that serial to parallel conversion is done. Cyclic prefix (CP) is added to the output of this section. Then IFFT is applied on parallel data stream. Pilot Insertion is performed and then the data is again converted from parallel to serial stream. Thereafter, channel coding is performed and parameter initialization is done. This data is transferred through channel section. At the receiver section the reverse process of transmission section is applied to get the data from the data output.

Figure 1 shows a baseband transceiver structure for OFDM utilizing the Fourier transform. Here the serial data is modulated to complex data symbols (QPSK and QAM) with a symbol rate of $\frac{1}{T_s}$. The data is then T_s demultiplexed by a serial to parallel converter resulting in a block of N complex symbols, X_0 to X_{N-1}. The parallel samples are then passed through a N point IFFT (in this case no oversampling is assumed) with a rectangular window of length $N.T_s$, resulting in complex

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 12, July 2017)

samples x_0 to x_{N-1}. Assuming the incoming complex data is random it follows that the IFFT is a set of N independent random complex sinusoids summed together. The samples, x_0 to x_{N-1} are then converted back into a serial data stream producing a baseband OFDM transmit symbol of length $T = N.T_s$.

A Cyclic Prefix (CP), which is a copy of the last part of the samples is appended to the front of the serial data stream before Radio Frequency (RF) up conversion and transmission. The CP combats the disrupting effects of the channel which introduce Inter Symbol Interference (ISI).

In the receiver the whole process is reversed to recover the transmitted data, the CP is removed prior to the FFT which reverses the effect of the IFFT. The complex symbols at the output of the FFT, $Y_0 \,..\, Y_{N-1}$ are then demodulate and the original bit steam recovered.

Mathematically the demodulation process (assuming no CP and no channel impairments) using the FFT is equation (1),

$$
\begin{aligned}
Y_{m,k} &= FFT\{x_{m,n}\} \\
&= \frac{1}{N}\sum_{n=0}^{N-1} x_{m,n} e^{-j2\pi nk/N} \\
&= \frac{1}{N}\sum_{n=0}^{N-1}\sum_{d=0}^{N-1} X_{m,d} e^{j2\pi n(d-k)/N} \\
&= \frac{1}{N}\sum_{d=0}^{N-1} X_{m,d} \sum_{n=0}^{N-1} e^{j2\pi n(d-k)/N} \\
&= \frac{1}{N}\sum_{d=0}^{N-1} X_{m,d}\, N\delta[d-k] \\
&= X_{m,k}
\end{aligned}
\tag{1}
$$

Cyclic Prefix

The Cyclic Prefix or Guard Interval is a periodic extension of the last part of an OFDM symbol that is added to the front of the symbol in the transmitter, and is removed at the receiver before demodulation.

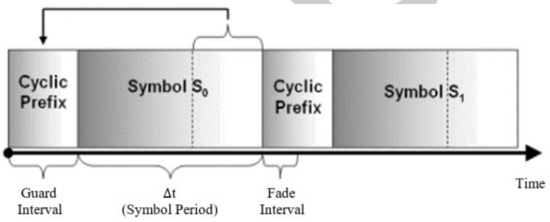

Figure 2: Cyclic Prefix

The cyclic prefix has to two important benefits –

- The cyclic prefix acts as a guard interval. It eliminates the inter-symbol interference from the previous symbol.
- It acts as a repetition of the end of the symbol thus allowing the linear convolution of a frequency – selective multipath channel to be modelled as circular convolution which in turn maybe transformed to the frequency domain. This approach allows for simple frequency – domain processing such as channel estimation and equalization.

Channel Estimation Based On Block-Type Pilot Arrangement

In block-type pilot based channel estimation, the pilot is sent in all sub-carriers with a specific period. Assuming the channel is constant during the block, it is insensitive to frequency selectivity. Since the pilots are sent at all carriers, there is no interpolation error. The estimation can be performed by using either LS or MMSE. The LS estimate is represented by:

$$h_{LS} = X^{-1}y \tag{2}$$

Where, $X = diag\{x_0, x_1, \ldots x_{N-1}\}$, $y = \begin{bmatrix} y_0 \\ \vdots \\ y_{N-1} \end{bmatrix}$

Where x_i is the pilot value sent at the i^{th} subcarrier and y_i is the value received at the i^{th} sub-carrier.

If the time domain channel vector g is Gaussian and uncorrelated with the channel noise, the frequency-domain MMSE estimate of g is given by:

$$h_{MMSE} = FR_{gy}R_{yy}^{-1}y \tag{3}$$

Where, $F = \begin{bmatrix} W_N^{00} & \cdots & W_N^{00(N-1)} \\ \vdots & \vdots & \vdots \\ W_N^{(N-1)0} & \cdots & W_N^{(N-1)(N-1)} \end{bmatrix}$ and

$W_N^{nk} = \frac{1}{N} e^{-j2\pi \frac{n}{N} k}$

Where R_{gy} and R_{yy} is cross covariance matrix between g and y and the auto-covariance matrix of y respectively. When the channel is slow fading, the channel estimation inside the block can be updated using the decision feedback equalizer at each sub-carrier. Decision feedback equalizer for the k^{th} sub-carrier can be described as follows:

The channel response at the k^{th} sub-carrier estimated from the previous symbol $\{H_e(k)\}$ is used to find the estimated transmitted signal $\{X_e(k)\}$.

$$X_e(k) = \frac{Y(k)}{H_e(k)} \quad k = 0,1, \ldots N-1 \tag{4}$$

$X_e(k)$ is mapped to the binary data through “signal demapper” and then obtained back through “signal mapper” as $X_{pure}(k)$.

The estimated channel $\{H_e(k)\}$ is updated by:

$$H_e(k) = \frac{Y(k)}{X_{pure}(k)} \quad k = 0,1, \ldots N-1 \tag{5}$$

Since the decision feedback equalizer has to assume that the decisions are correct, the fast fading channel will cause the complete loss of estimated channel

IJDACR
ISSN: 2319-4863
International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 12, July 2017)

parameters. Therefore, as the channel fading becomes faster, there happens to be a compromise between the estimation error due to the interpolation and the error due to loss of channel tracking. For fast fading channels, as will be shown in simulations, the comb-type based channel estimation performs much better.

Communication Channel

This is the channel through which the data is transferred. Presence of noise in this medium affects the signal and causes distortion in its data content.

PSEUDO CODE

Define needed variables like number of bits per symbols, Number of symbols, FFT length and SNR value;
{
Generate Binary data form randint according to No. of symbols and No. of bits per symbols;
Convert serial data to parallel streams according to number of sub channels;
Calculate Inverse Fast Fourier transform and convert data into frequency domain;
Add cyclic prefix to IFFT data;
Insert pilot carrier in parallel streams of data;
Until SNR loop expires

Pass data through Rayleigh Multipath channel;
Remove cyclic prefix;
Convert data into time domain by performing Fast Fourier transform;
Remove Pilot carriers;
Convert data into serial bit stream;
Compare generated data and demodulated data to find Bit Error rate;
}
}

III. Simulation and Results

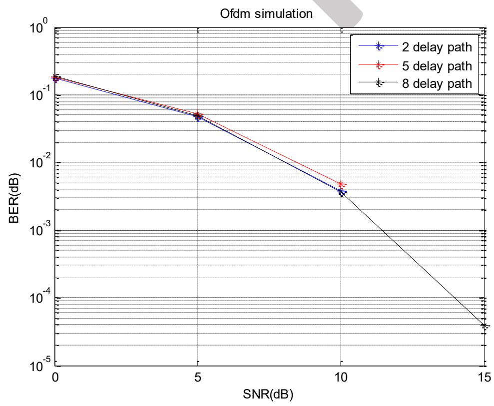

Figure 3: BER v/s. SNR graph for multipath delay in Rayleigh channel

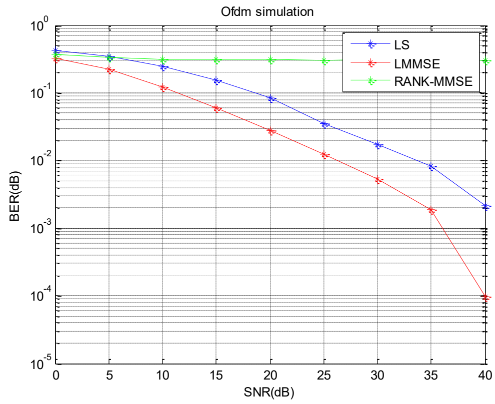

Figure 4: BER vs. SNR performance comparison for different methods

IV. Conclusion

The work is undertaken in this paper firstly discusses the OFDM system and fading channel. The implementation of OFDM model is presented with the analysis of the capabilities of OFDM in Rayleigh fading channel. The simulation uses MATLAB and the effect of different modulation schemes has been evaluated over OFDM system.

On comparing the variations of the BER for different SNR in the MATLAB simulation, it is observed that the BER performance of LMMSE is better than LS and RANK-MMSE schemes. At 30 dB SNR, the BER performance of LMMSE scheme is 4% better than the LS and far better than RANK-MMSE scheme.

Finally it is concluded that the OFDM system with LMMSE scheme is suitable for low capacity short distance applications. While the OFDM with LS and RANK-MMSE techniques are useful for large capacity and long distance applications which slightly increase the BER. The OFDM promises to be a suitable multiplexing technique for high capacity wireless communication application.

Reference

[1] A. D. S. Jayalath, C. Tellambura and H. Wu, "Reduced complexity PTS and new phase sequences for SLM to reduce PAPR of an OFDM signal", IEEE, Vehicular Technology Conference Proceedings, VTC Tokyo, 2000.

[2] W. G. Jeon, K. H. Paik, and Y. S. Cho, "Two-dimensional pilot-symbol-aided channel estimation for OFDM systems with transmitter diversity", IEICE Transactions on Communications, vol. E85B, pp. 840-844, Apr. 2002.

[3] M. L. Doelz, E. T. Heald, and D. L. Martin, "Binary Data Transmission Techniques for Linear Systems", IEEE, Proc. IRE, vol. 45, pp. 656-661, May 1957.

[4] R. W. Chang, "Synthesis of Band Limited Orthogonal Signals for Multichannel Data Transmission", Bell Syst. Tech. Journal., vol. 45, pp. 1,7751,796, Dec 1966.

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 12, July 2017)

[5] B. R. Saltzberg, “Performance of an efficient parallel data transmission system”, IEEE Transactions on Communication Technologies, vol. COM-15, Dec 1967.

[6] S. Weinstein and P. Ebert, “Data transmission by frequency division multiplexing using the discrete fourier transform”, IEEE Transactions on Communication Techniques, vol. COM-19, pp. 628-634, October 1971.

[7] Parul Wadhwa , Gaurav Gupta, “BER Analysis & Comparison of Different Equalization Techniques for MIMO-OFDM System”, International Journal of Advanced Research in Computer Science and Software Engineering, (IJARCSSE), Volume 3, Issue 6, June 2013.

[8] Vishal Anand, Sharmeele Thanagjam, Sukhjeet Kaur, “Analysis of OFDM BER and PAPR using TURBO CODE”, IJCSNS International Journal of Computer Science and Network Security, VOL.12 No.3, March 2012.

[9] Ligata, Haris Gacanin, Fumiyuki Adachi, Miha Smolnikar, and Mihael Mohorcic, “Bit Error Rate Analysis for an OFDM System with Channel Estimation in a Nonlinear and Frequency Selective Fading Channel”, EURASIP Journal on Wireless Communications and Networking, 2011.