Journal of Mobile Multimedia, Vol. 11, No.3&4 (2015) 330-338

ZERO PADDING AND CYCLIC PREFIX FOR OFDM ON MULTIPATH RAYLEIGH FADING CHANNEL

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This article report simulation of OFDM over various multipath Rayleigh fading channel, with dicussion on the guard interval method. Techniques of guard interval employed are Cyclic Prefix and Zero Padding, each with a range of ratio from 1:1 to 16:1. The transmission are simulated over Rayleigh fading channel applying 1 to 4 paths in comparison. Observations on BER value for OFDM transceiver is done with 16-QAM as the base modulation. Overall, implementation of zero padding for guard interval in this work has resulted on better performance in compare with those of cyclic prefix. With zero padding of 8:1 on 64 packet data, it is optimum in compare with variety of others. The deviation of BER is however less than 0.001 within each channel type with various guard interval. For Rayleigh environment, the error increased significantly up to 2 paths, but tended to saturate for 3 and 4 paths.

Key words: OFDM, Zero Padding, Rayleigh fading, Multipath, BER

1 Introduction

Orthogonal Frequency Division Multiplexing (OFDM) is the standard applied widely on next generation telecommunication. Based on a parallel data transmission of data scheme, OFDM reduces the negative effect of telecommunications environment, and already settled for WiMax and and the digital TV, for example, and also a trending development on optical communication.

The OFDM process is some notches above basic modulation with choices of alternatives on each subprocess, making it a perfect object for software defined radio (SDR). Various studies were done involving the subprocesses i.e. base modulation schemes, IFFT discussion, and guard interval [1-5]. Others involved the standards related or in which the OFDM scheme is entailed i.e. Wimax and IEEE standard 802.11 [6-8].

One of the effects tackled in OFDM is the Inter-symbol Interferences (ISI), happened mainly in multipath envorenment. Employing cyclic prefix as guard interval (GI) is one subprocess that deal with this problem. In recent years various study were performed on alternating the standardized guard interval [9-13], among others with the use of general prefix or fix prefix.

This paper explore the use of Zero Padding in comparison with the standard Cyclic Prefix (CP). The study also simulate Rayleigh fading channel of various path numbers. While most references applied up to 2 paths to observe the rayleigh fading effect and compare it with mere AWGN [12-15], our project explored until four in number of paths. As starting ground and comparison are several studies of recent years.

The rest of the article is organized as followed: Chapter "System Model" of the paper describe the system simulated and its parameters variation, emphasizing the multipath channel and guard interval.

Chapter "Performance Analysis" show and discuss the simulation results. The article is closed in chapter Conclusion.

2 System Model

Simulation within the project is done among other under GNU Radio, using C++ as development languange for some functions. The system comprised OFDM transmitter and receiver, as well as the transmission channel. The block diagram for the whole project is shown in Figure 1. The shaded area on the right highlight the area discussed in this paper.

Attributed as part of OFDM processes are a base modulation, and inverse fast fourier transform (IFFT). 16-QAM is used as base modulation in this study. The IFFT employed here as encoding is implemented for package of 64 data. The guard interval dan channel are the varied for observation. Bit error rate (BER) value is used as observation variable and sysmbol error rate (SER) is also monitored as control variable of simulation scenarios. Random signals are generated and used for the performance test, as well as fixed sequences of data as control and pretest.

The simulation is developed as modules of processes, following those in Figure 1. Therefore the BER value is calculated at the end, simply based on the difference between the input and output signal of the whole process.

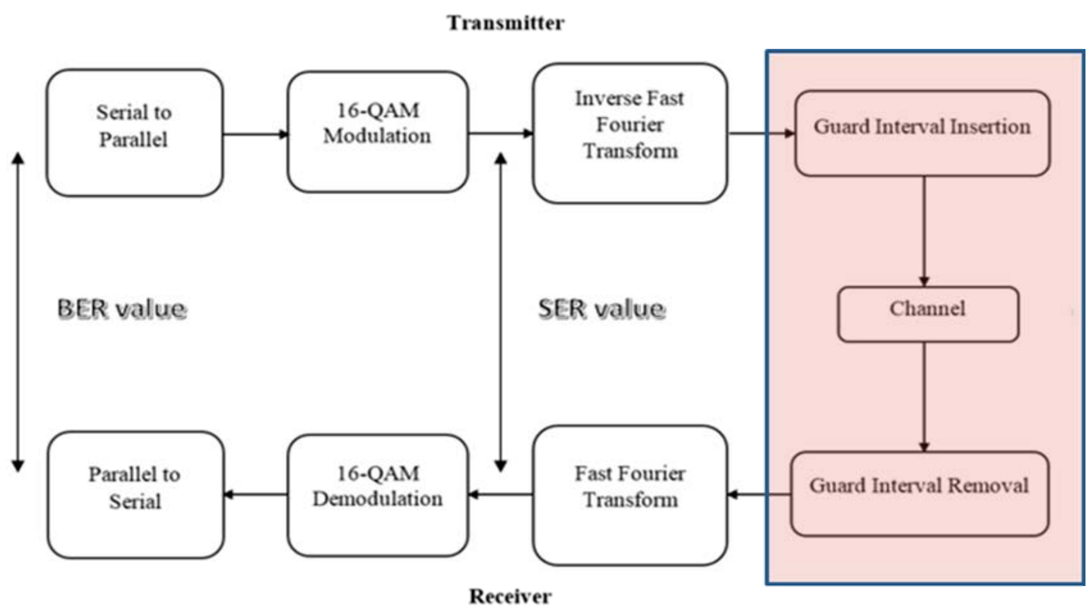

Figure 1. Block diagram of OFDM transmission simulated.

2.1. Channel Model

In multipath propagation environment, a spot receives not only the direct wave from the transmitting but also delayed waves caused by reflection, diffraction and scattering that reach the time later than the direct wave. Model of these is shown in Figure 2. It illustrated four paths, the direct wave put in number 1 and path 2, 3, and 4 are assumed of scattering and reflection.The amplitude has a Rayleigh distribution, and the phase has a uniform distribution when observe the received signal at the time arrival.

In this project, multipath Rayleigh fading is applied as the channel in the simulation including one-path, two-path, three-path, and four-path. Each path already contained multiwaves of considerable number. In this multipath propagation environment, a station receives not only the direct wave but also delayed waves caused by reflection, diffraction and scattering that reach the time later than the direct wave. Model of these is shown in Figure 2 as adopted from [15]. It assumed four paths, the direct wave put in number 1 and path 2, 3, and 4 are assumed of scattering and reflection.The amplitude has a Rayleigh distribution, and the phase has a uniform distribution when observe the received signal at the time arrival. Any number of waves arriving within the same time is classified as having the same path. Accordingly with four paths, our channel model for simulation comprises four groups of waves, having four various delay to compare with the direct wave.

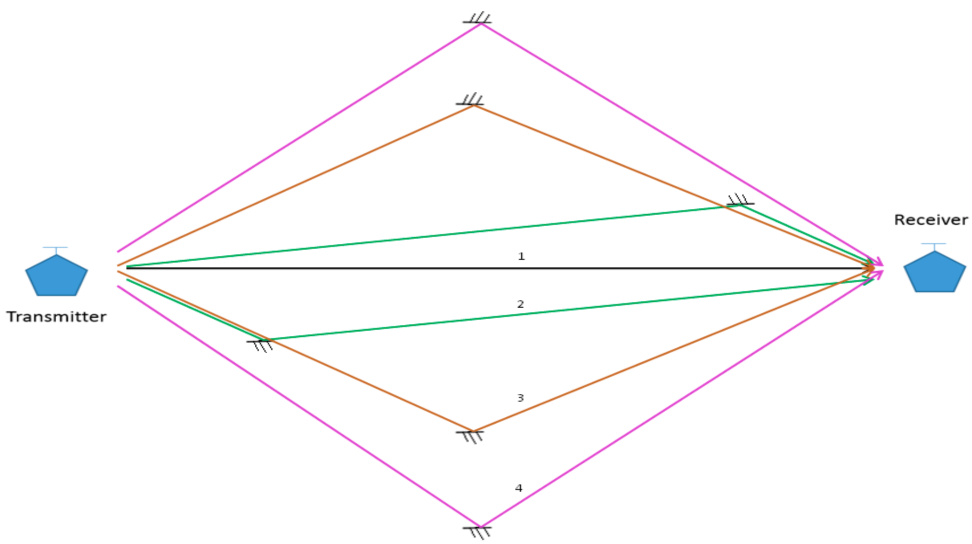

Figure 2. Multipath fading channel

Implementing the notion to simulation, notions of incident angles, doppler shift and delays are incorporated in the channel model. The transmission within one path are of complex signal *r*(*t*), consisting of the real part *x*(*t*) and *y*(*t*) as in equation 1. Each of these parts is an envelope of waves regarded to one path.

The complex fading model applied as one path in simulation is [15]

$$r(t) = x(t) + jy(t) \qquad (1)$$

where

$$x(t) = \left[\sqrt{\frac{2}{N+1}}\sum_{n=1}^{N} sin\left(\frac{\pi n}{N}\right)cos\left\{2\pi f_d\ cos\left(\frac{2\pi n}{N}\right)t\right\} + \frac{1}{\sqrt{N+1}}cos2\pi f_d t\right] \qquad (2)$$

$$y(t) = \sqrt{\frac{2}{N_1}}\sum_{n=1}^{N} sin\left(\frac{\pi n}{N}\right)cos\left\{2\pi f_d\ cos\left(\frac{2\pi n}{N}\right)t\right\} \quad (3)$$

in which N is the number of wave within one path, enveloping waves number n ; and f_d indicate the doppler shift. When simulating various path, the same model is applied with different delay time for each path.

2.2. Zero Padding and Cyclic Prefix

The guard interval can be implemented as prefix or sufix to the packet data. Figure 3 illustrade the method applied in the project with guard interval as prefix added to the packet. With Zero Padding, the prefix are simply as zeros of certain length. With Cyclic Prefix however, the prefix is taken from end part of the symbol itself.

The length of guard interval can be chosen and reflected as the ratio between the packet length and the GI length, as

$$\text{GI ratio} = T_P : T_{GI} \quad (4)$$

For this project the GI ratio are chosen to be varied from 1:1 to 16:1, each were applied to various length of packet data i.e. 32, 64 and 128 bit. The lower ratio of 1:1 and 2:1 were applied for low packet data only.

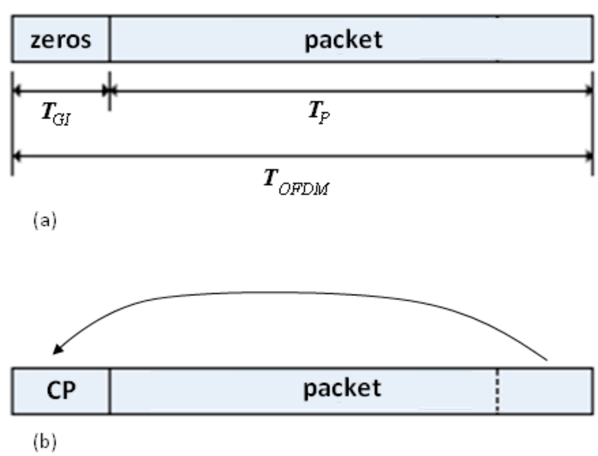

Figure 3. Prefix Guard Interval with (a) Zeros padding; (b) Cyclic prefix

3 Performance Analysis

The transmission was observed for 5 conditions of channel, i.e. 1-4 paths Rayleigh and AWGN only. Each of the Rayleigh paths are simulated with 6 waves. The Rayleigh and transceiver parameters are set as in the table 1.

Parameter 1-6 of table 1 are used to define the multipath Rayleigh, for 1 to 4 paths. Time arrival essentially describe the delay created by each path, with path 1 having time entry of zero. Each path also has diferent levelof signal power as they reach the receiver, set in parameter Mean Power. As mentioned above, within each path were generated a number of fading waves according to Rayleigh fading, which number is set to six. The initial phase is set to zero, and Doppler frequency is set to 200 as a maximum value.

Parameter 7-12 of Table 1 presents the OFDM transmitter parameter as well as those of the receiver. A fixed FFT length of 64 is set for the observation. Guard interval length and ratio is varied as the observed states. 16-QAM is fixedly used in this simulation for base modulation, implementing Gray code in it [8].

The observation is divided in two parts. The first is on various multipath, and the second with variations on the guard interval. A third part present the effect of guard interval ratios in variations of channel.

Table 1. Selected system parameters

No.	Channel Parameter	Value (path 1,2,3,4)
1	Time arrival of each multipath	0,18,27,36
2	Mean power for each multipath (in dB)	0,3,5,7
3	Number of waves per path	6,6,6,6
4	Initial phase Rayleigh fading	0.0
5	Set fading counter	10^3, 2.10^3, 3.10^3, 4.10^3
6	Doppler frequency	200
	Transceiver Parameter	Value
7	Mapping type	16 QAM
8	FFT length	64
9	Guard interval length	2,4,8,16,32,64
10	Sample rate	25.10^4
11	Bit rate per carrier	10^6
12	Energy per bit and noise power spectral	1 – 12

3.1. Multipath Rayleigh Fading

Figure 4 shows the average BER value for each channel: the AWGN channel, and 1,2,3, and 4 paths of Rayleigh channel. From AWGN channel to 1 path Rayleigh, a significant increase of error is observed throughout the data. As the path added to the number two, the increase continued, the BER value observed was almost doubled up. But from 2-paths to 3 paths and later 4 paths, there are no significant rise on the error level. The addition of error frm 2-paths to 4-paths was less than 10%, as per the average BER value recorded.

3.2. The Guard Interval with zero padding and cyclic prefix

For this part the observations presented were done on AWGN channel. Variations was set on GI ratio, as well as on the length of the data packet. The result is shown in Figure 5 below. The blue bar shown the average BER value for transmission without guard interval. The grey bars indicated the average BER for various condition with Cyclic Prefix. The red bars represented the ones with Zero Padding. Three ratios were observed i.e. Data length : GI length, and applied for different packet length.

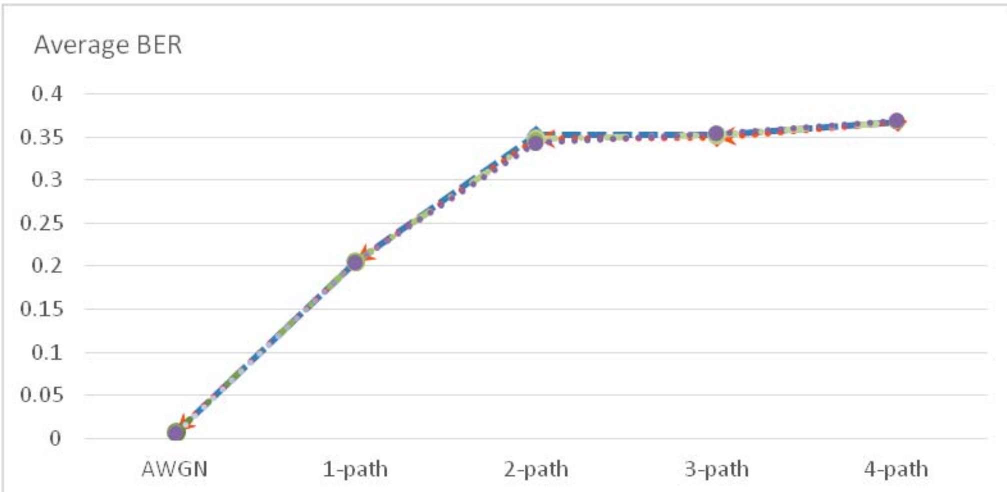

Figure 4. Average BER for various paths

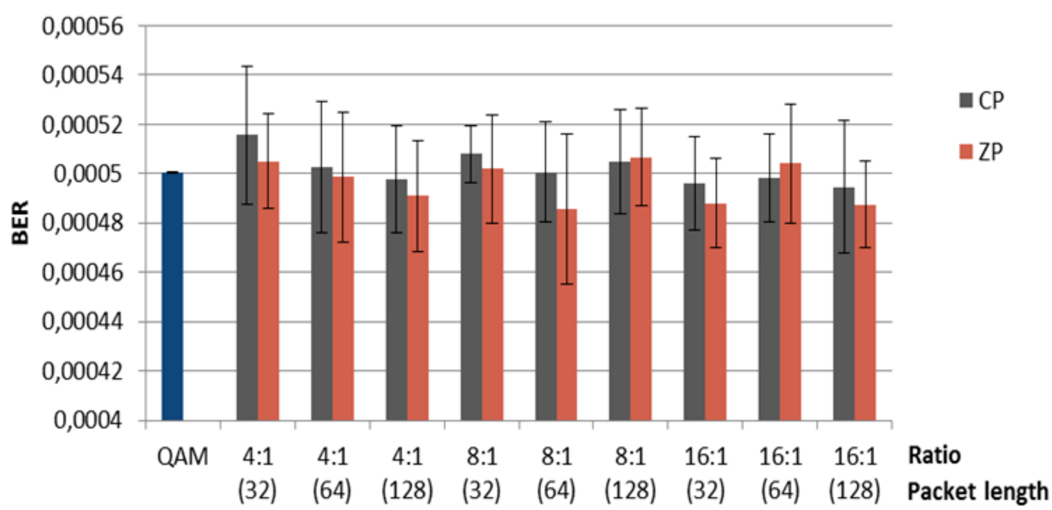

Figure 5. BER average on variation of GI on one type of channel

General observations gives that Zero padding as guard interval technique gave better result than Cyclic Prefix.In addition, zero padding was also easier in implementation. As of the comparison between different ratios and packet length gave off even clear result. The BER value tend to decrease on higher GI ratio, and for longer data packet, but waveringly, so that the average value gathered were indistinct.

Similar data is also extracted for different channel type i.e. the 1path up to 4 paths Rayleigh fading channel model. The deviation of BER from various GI scheme on each path are less than 0.001, akin to those seen in Figure 5.

3.3. Guard interval ratios on Multipath channel

Applying the various parameter of both GI techniques on multipath environment, the observations is shown on Figure 6. The graphic represent average BER value for different ratio on each type of channel. For each channel type, the BER value are decreasing for higher GI ratio. Noted in part 3.2, there were tendencies of decreasing BER value for higher GI ratio, however with deviationof lessthan 0.001 in BER value. Thus seen in bigger picture, the difference in error level are very small. As a result, those diversity of BER value for different GI ratio are barely seen in the chart. This result is bring to a close that generally that variations of GI length and ratio are less significant on observations of various number of paths in Rayleigh channel.

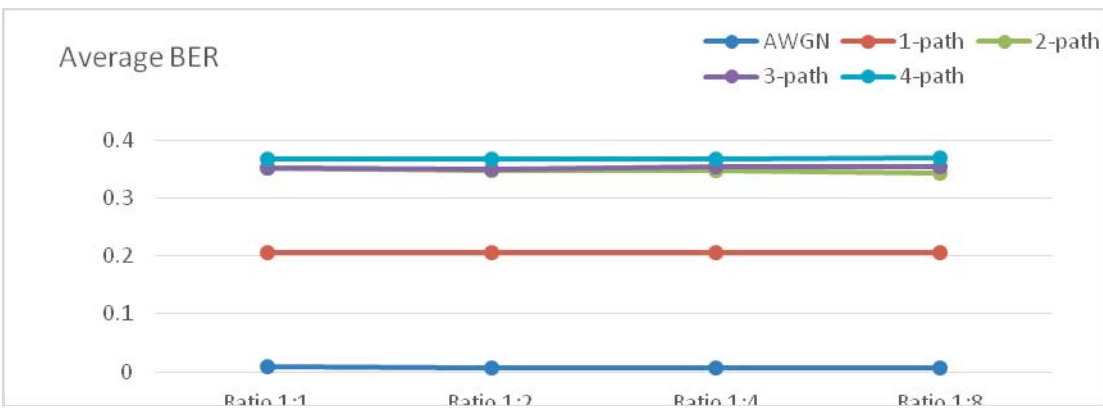

Figure 6. Average BER of various GI ratios in each path

4 Conclusion

The study had made observations on OFDM transmission with Zero Padding and Cyclic Prefix as guard interval variation, and Rayleigh fading channel with 1 to 4 paths.

As GI techniques, Zero Padding performance was observed better than cyclic prefix. Variation on GI ratio had shown tendency to get lower BER value for higher ratio and longer packet.

Variation of channel give significant affect on BER values, from the one-path and four-path Rayleigh fading channel. The lowest BER average value over Rayleigh fading channel is 0.2052, and the highest BER average value over multipath Rayleigh fading channel is 0.3685.

However, variation of the guard interval for different channel were barely recognizable with deviation within one type of channel less than 0.001. Thus BER average values are relatively constant for each n-path Rayleigh fading channel.

Acknowledgements

This article is part of project funded by Ministry of Education Republik Indonesia through Kopertis III under the scheme Hibah Bersaing 2012-2014 administered with 024/SPK/A-01/UAI/V/2014.

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