BER PERFORMANCE OF AWGN CHANNEL USING DIFFERENT CYCLIC PREFIX OF WIMAX

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Abstract:

This paper developed a model of a WiMAX system using simulation in Matrix laboratory language (MATLAB) for finding the impact of cyclic prefix on which BER calculations is carried out. The WiMAX signal was transmitted over the AWGN channel various signal-to-noise ratio (SNR) values. To evaluate the performance, for each SNR level, the received signal was demodulated and the received data was compared to the original information. The result of the simulation is shown in the plot of the bit error rate versus Eb /No, which provides information about the system's performance. The convolution coding and interleaving is applied to improve BER performance of WiMAX system for various digital modulation schemes like BPSK, QPSK, and QAM.

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1. INTRODUCTION

The demand for high data rate services has been increasing very rapidly and there is no slowdown in sight. Currently Global System for Mobile telecommunications (GSM) technology is being applied to wireless phone systems. But GSM uses time division multiple access (TDMA), which has a high symbol rate leading to problems with multipath causing inter-symbol interference. Several techniques are under consideration for the next generation of digital phone systems, with the aim of improving cell capacity, multipath immunity, and flexibility [1-3].

These include CDMA and OFDM. In the beginning of 3G (Third Generation) era, CDMA technique was widely employed for most systems. But their capability of supporting much higher data rate is limited [4,5]. This is because they use multiple codes simultaneously, which may result in self-interference. So B3G (Beyond 3G), OFDM is used instead of CDMA. In IEEE802.11 series, the low date rate is working on CDMA (802.11b) but high date rate uses OFDM (802.11g and 802.11a). WiMAX is also using OFDM. OFDM is currently being used in several new radio broadcast systems including high definition digital television (HDTV) and digital audio broadcasting (DAB). Research has been done into the use of OFDM as a transmission method for mobile telecommunications systems. [2, 6-9]

WiMAX, the IEEE 802.16e standard has brought a revolution in wireless broadband technology. Fixed Broadband Wireless Access (FBWA) systems that are capable to transmit higher data rates over larger geographical areas are not fulfilling the QOS needs [10]. WiMAX is a substitute to wired DSL technology for last-mile solutions for providing backhaul services, thus increasing the data rate for large area [11,12]. IEEE standard 802.16e provides fixed, nomadic and mobile wireless broadband connectivity without the need for direct line-of-sight with the base station [13-16].

There are numerous works done in this area [17-21]. Some of important ones are summarized here. The authors of [17] presented higher level of modulations (i.e., M-PSK and M-QAM for different values of M) with different code rates and on WiMAX-MIMO system for Rayleigh channel by focusing on spatial multiplexing MIMO technique. In [18,19] authors evaluate a WiMAX system under different combinations of digital modulation (BPSK, QPSK, 4-QAM and 16-QAM) and different communication channels AWGN and fading channels (Rayleigh and Rician). The works in [20,21] paper explained the performance of mobile WIMAX physical layer for

OFDMA on different channel condition. The authors are motivated to study the implementation of WIMAX and to compare the results by varying parameters like cyclic prefix and modulation schemes.

2. SYSTEM MODEL

This subsection describes the system model as depicted in figure 1 used for the simulation.

1. **Modulation:** We passed the random values through the adaptive modulation schemes according to the constellation mapped. The data was modulated depending their size and on the basis of different modulation schemes like BPSK, Gray-mapped QPSK, 16 QAM and 64 QAM. The modulation has done on the basis of incoming bits by dividing among the groups of i. That is why there are $2^{\boldsymbol{i}}$ points. The total number of bits represented according to constellation mapped of different modulation techniques. The size of i for BPSK, QPSK, 16 QAM and 64QAM is 1, 2, 4 and 16 respectively.

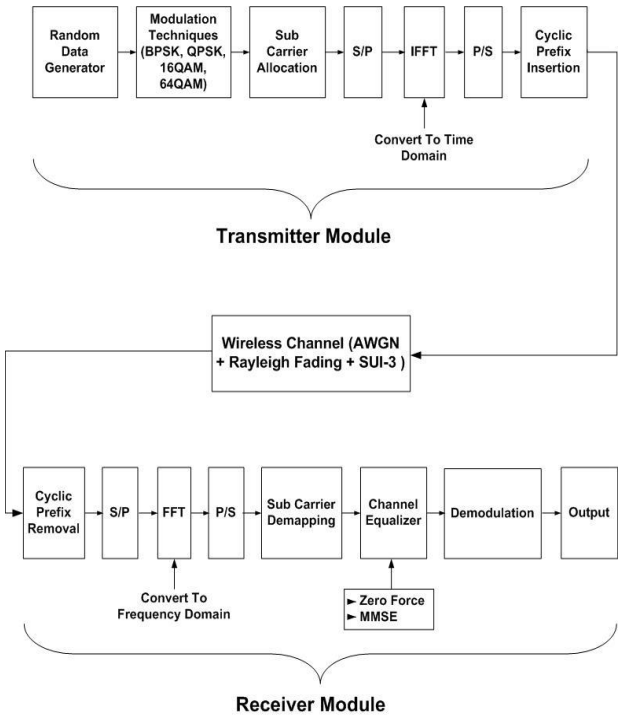

Figure 1: Mobile WiMAX Performance Simulation Block Diagram

2. **IFFT:** The OFDM symbol threats the source symbols to perform frequency-domain into time domain. If we chose the N number of subcarriers for the system to evaluate the performance of WiMAX the basic function of IFFT receives the N number of sinusoidal and N symbols data time. The output of IFFT is the total N sinusoidal signals and makes a single OFDM symbol. The mathematical model of OFDM symbol defined by IFFT which would be transmitted during our simulation as given bellow:

3. **Subcarriers:** In OFDM system, the carriers are sinusoidal. Two periodic sinusoidal signals are called orthogonal when their integral product is equal to zero over a single period. Each orthogonal subcarrier has an integer number of cycles in a single period of OFDM system. To avoid inter channel interference these zero carriers are used as a guard band in this system.
4. **OFDM Symbol Description:** In WiMAX Transmitter, IFFT (Inverse Fast Fourier Transform) used to create OFDM waveform with the help of modulated data streams. On the other hand in WiMAX receiver end, the FFT used to demodulate the data streams. This time duration is defined to as symbol time, T_b. A copy of symbol period, T_g which is termed of Cyclic Prefix (CP) used to collect multipath where, maintaining the orthogonality of the codes. The following figure 2 shows the OFDM symbol in the time domain.

$$x_n = \left(\frac{1}{N}\right)\sum_{k=0}^{N-1} X_k e^{2\pi . jnk/N}; \quad N = 0,1,2,\ldots,N-1$$

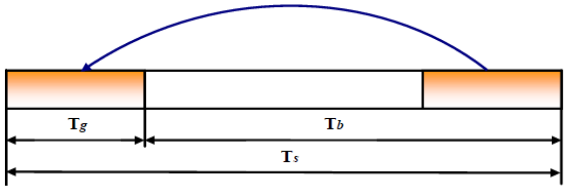

Figure 2: OFDM Symbol Structure in Time Domain

In any OFDM symbol, the transmitted signal voltage to the antenna in time domain can be written as

$$S(t) = Re\left\{ e^{j2\pi f_c t} \sum_{\substack{K=-N_{\frac{usd}{2}} \\ K\neq 0}}^{N_{\frac{usd}{2}}} C_k . e^{j2\pi k\Delta f(t-T_g)} \right\}$$

Where t = Time elapsed with $0 < t < T_s$

C_k =Complex number where k is the frequency offset index of transmitted data

Δf = Carrier spacing

$\Delta f = F_s/N_{fft}$ where F_s = Sampling frequency and N_{fft} = Number of points of FFT/IFFT.

In OFDM system, the number of sub-carriers is 256 which is equal to the FFT size. Each ODFM symbol consists of the following four types of carriers.

- **Data sub-carriers (OFDM) or sub-channels (OFDMA):** used for data transmission.
- **Pilot sub-carriers:** used for various estimation purposes
- **DC sub-carriers:** used as center frequency
- **Guard sub-carriers/Guard bands:** used for keeping space between OFDM and OFDMA signals. The following figure 3 shows the OFDM symbol in frequency domain.

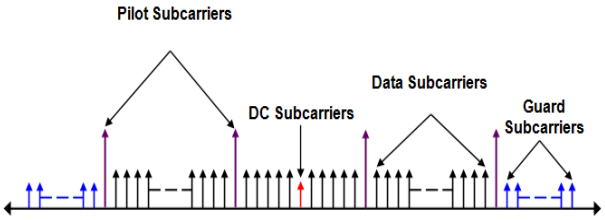

Figure 3: OFDM Symbol in frequency domain

To avoid Inter symbol Interference (ISI) the Cyclic Prefix (CP) is inserted in OFDM system before each transmitted symbol. In wireless transmission the transmitted signals might be distort by the effect of echo signals due to presence of multipath delay. The ISI is totally eliminated by the design when the CP length is greater than multipath delay. After performing Inverse Fast Fourier Transform (IFFT) the CP will be add with each OFDM.

5. **CP Insertion:** To maintain the frequency orthogonality and reduce the delay due to multipath propagation, cyclic prefix is added in OFDM signals. To do so, before transmitting the signal, it is added at the beginning of the signal. In wireless transmission the transmitted signals might be distort by the effect of echo signals due to presence of multipath delay. The ISI is totally eliminated by the design when the CP length L is greater than multipath delay. After performing Inverse Fast Fourier Transform (IFFT) the CP will be add with each OFDM symbol.
6. **Additive White Gaussian Noise (AWGN):** In wireless communication, the data are transmitting through the wireless channel with respective bandwidth to achieve higher data rate and maintain quality of service. The transmitting data has to take environmental challenges when it is on air with against unexpected noise. That's why data has to encounter various effects like multipath delay spread, fading, path loss, Doppler spread and co-channel interference. This channel effects on the transmitted signals when signals pass through the channel. This noise channel model is good for satellite and deep space communication but not in terrestrial communication because of multipath, terrain blocking and interference. AWGN is used to simulate background noise of channel. The mathematical expression as in received signal $r(t) = s(t) + n(t)$ is shown in figure 4 which passed through the AWGN channel where $s(t)$ is transmitted signal and $n(t)$ is background noise.

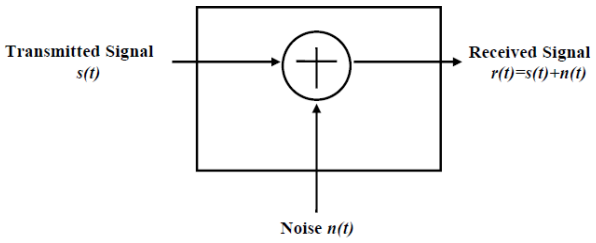

Figure 4: Channel model for AWGN

7. **Receiver Module:** Omni directional Antenna is the most popular antenna in WiMAX, which can be used for point-to-multipoint configuration. This is the limitation of its range and ultimately it shows its signed strength. Omni directional antennas are mostly user friendly when lots of subscribers stay very close to the base station.

   In transmitting module, to deal the frequency orthogonality and reduce the delay, cyclic prefix added in each OFDM signals. That's why, before transmitting the signal, the CP added at the beginning of the

signal. After performing Inverse Fast Fourier Transform (IFFT) the CP will be add with each OFDM symbol. In receiver module, after synchronization the received data contains the Cyclic Prefix of each OFDM signal which is ignored.

By using number of samples FFT converts time domain signal into frequency domain signal. In transmitter module, IFFT converts the OFDM signals from frequency domain to time domain which is exactly reverse work of FFT. To perform of OFDM 256 points, the zeros are padded beginning and ending of the OFDM signal. These zero pads will be removed from the corresponding places at the receiving module.

3. Methodology

MATLAB® is a high-level language and interactive environment for numerical computation, visualization, and programming. Using MATLAB, you can analyze data, develop algorithms, and create models and applications. The language, tools, and built-in math functions enable you to explore multiple approaches and reach a solution faster than with spreadsheets or traditional programming languages, such as C/C++ or Java™. You can use MATLAB for a range of applications, including signal processing and communications, image and video processing, control systems, test and measurement, computational finance, and computational biology. More than a million engineers and scientists in industry and academia use MATLAB, the language of technical computing.

4. Results and discussions

The observations obtained in this work are detailed here. For CP 1/4, 1/8, 1/16, 1/32 BER plots are depicted in Figure 5, 6, 7, 8, respectively, by using modulation schemes BPSK, QPSK, 16QAM, 64 QAM for AWGN channel.

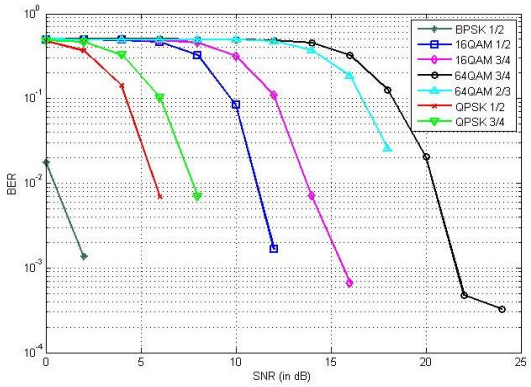

Figure 5: BER of AWGN channel using different modulation schemes having CP 1/4.

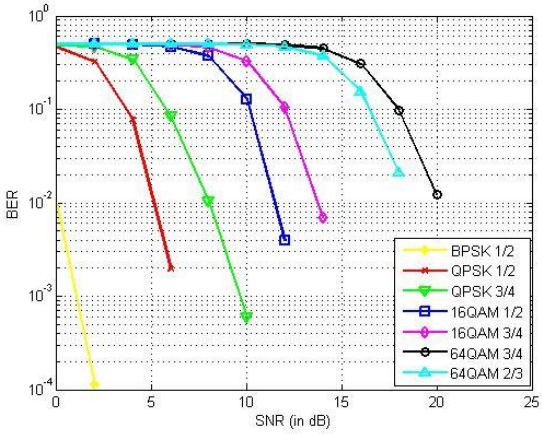

Figure 6: BER of AWGN channel using different modulation schemes having CP 1/8.

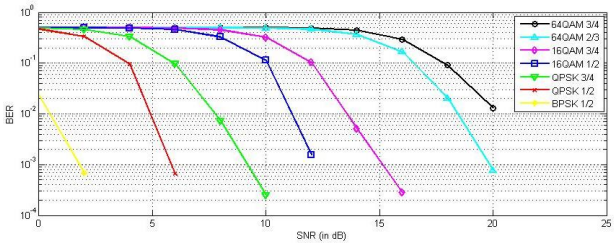

Figure 7: BER of AWGN channel using different modulation schemes having CP 1/16.

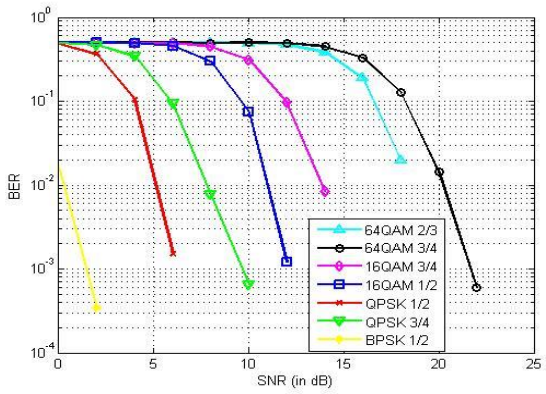

Figure 8: BER of AWGN channel using different modulation schemes having CP 1/32.

From table 1, it is clear that from BER Vs SNR plot, 64 QAM having cyclic prefix 1/32 has highest SNR value, i.e., 20.2. It means 16QAM has minimum noise for AWGN fading channels. The best results are obtained for BPSK followed by QPSK, 16QAM and 64QAM. By increasing cyclic prefix, we are approaching for better output.

Table 1: BER Vs SNR for AWGN channel.

Modulation	Data rate	Cyclic prefix	SNR
BPSK	1/2	1/4	0.7
		1/8	00
		1/16	0.8
		1/32	0.2
QPSK	1/2	1/4	6
		1/8	5
		1/16	5
		1/32	5.1
	3/4	1/4	7.5
		1/8	7.6
		1/16	7.6
		1/32	7.7
16 QAM	1/2	1/4	11
		1/8	11.8
		1/16	11.2
		1/32	10.8
	3/4	1/4	14
		1/8	13.9
		1/16	13.8
		1/32	14
64 QAM	2/3	1/4	18.8
		1/8	17.5
		1/16	18
		1/32	18
	3/4	1/4	20
		1/8	20
		1/16	20
		1/32	20.2

5. Conclusions

The implementation of WiMAX model in simulations ensures BPSK is more power efficient and needs less bandwidth, whereas 64-QAM) has higher bandwidth with very good output. In another case, QPSK and 16-QAM modulation techniques are in middle of BPSK and 64-QAM and having average output.

During all simulations we got, BPSK has the lowest BER and 64-QAM has the highest BER than other modulation techniques. The included Cyclic Prefix (CP) reduced noise resulting lower Bit error Rate (BER) for WIMAX system but increased the complexity in the system.

6. References

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