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Multipath Fading Channel, Various Modulation Schemes, and Cyclic Prefix, the OFDM-Based Wimax Physical Layer's Performance Evaluation

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ABSTRACT

To deliver high transmission data rates across broader regions and to users in places without broadband service, the IEEE 802.16 standard for broadband wireless access (BWA), also known as worldwide interoperability for microwave (WiMAX), was established. In this study, we examine the WiMAX Physical Layer in the context of multipath propagation channels using various modulation techniques and cyclic prefixes (CP). The multipath propagation channel has been selected as stanford university interim (SUI). Evaluation of Physical Layer performance is done by analyzing bit error rate (BER) *vs* signal-to-noise ratio (SNR) charts. Compared to QPSK, 16QAM, and 64 QAM, Physical Layer performance using BPSK modulation technique is much superior. Additionally, BER performance is improved with a higher cyclic prefix (CP) value.

Keywords
OFDM, SUI, WiMAX, BWA, Physical Layer.

INTRODUCTION

The need to develop new communication networks with greater data rates is a direct result of the exponential rise in the use of digital information networks.A wider variety of services, such video conferencing or apps with multimedia contents, are driving change in the telecom business. High capacity and reliable broadband wireless communications systems are becoming more important as the need **for** connection to be given "any where, any time" grows in response to people's growing dependence on computer networks and the Internet. New wireless broadband standards and technology will quickly cover more ground, allowing high-performance access to more than one billion consumers throughout the globe. There is a growing need for innovative approaches to acquiring large capacity wireless networks due to factors such as the very rapid adoption of mobile phone technology, wireless interoperability for microwave access (WiMAX), and the exponential expansion of the Internet When other broadband technologies, like cable or DSL, are not viable due to high deployment and maintenance costs, WiMAX will step in as a great alternative. This will allow for the widespread use of the famous last mile infrastructures in areas where they are currently unavailable. Thus, WiMAX will link underserved metropolitan regions with rural areas in emerging nations. Carriers, business campuses, and Wi-Fi hotspots may all benefit from its backhaul capabilities. Due to its quick deployment and cost-effectiveness, WiMAX is an excellent solution for these problems.

WiMAX PHYSICAL LAYER

Orthogonal frequency division multiplexing is the foundation of the WiMAX physical layer. Many commercial broadband systems that provide high-speed data, video, and multimedia communications employ orthogonal frequency division multiplexing (OFDM). This includes Digital Video, Wi-Fi, and DSL. Broadcast-Held (DVB-H), MediaFLO, and WiMAX are also available. one-frequency division multiplexing (OFDM) is a sophisticated and effective method for transmitting data at high rates in a multipath or nonline-of-sight radio environment.

OFDM Technology

To efficiently overcome the obstacles of non-line-of-sight propagation, operators may use orthogonal frequency division multiplexing (OFDM) technology. Through orthogonal frequency division multiplexing (OFDM), several signals may be sent in simultaneously by

first being separated into separate frequency bands, or subcarriers. By eliminating the guard bands while maintaining the orthogonality of the modulated signals, orthogonal frequency division multiplexing (OFDM) offers a more efficient use of the spectrum. In order to turn serial data into multiple channels, OFDM makes use of the fast fourier transform (FFT) and the inverse FFT. Due to the fact that the FFT size is 256, OFDM is defined with a total of 256 sub channels, also known as carriers. OFDM involves sending the initial signal in parallel with 256 separate subcarriers. So, a multicarrier modulation method is what OFDM is called. Because OFDM uses smaller subcarriers with low bit rates, which results in extended symbol periods, it is more resilient against multipath propagation delay than single-carrier systems. To further reduce the impact of multipath delay spread, a guard period is added to each OFDM symbol. One benefit of the WiMAX OFDM waveform is its ability to function in an NLOS scenario with a greater delay spread. The OFDM waveform does away with adaptive equalization's complexity and inter-symbol interference (ISI) issues by virtue of its symbol time and cyclic prefix. A portion of the OFDM waveform's carriers is comparatively easier to equalize in the event of selective fading due to the waveform's composition of several narrowband.

OFDM Parameters in WiMAX

Earlier it was noted that the OFDM physical layer is implemented somewhat differently in the stationary and mobile WiMAX variants. A 256 FFT-based OFDM physical layer is used by Fixed WiMAX, which is derived from IEEE 802.16-2004. The scalable OFDMA-based physical layer is used by Mobile WiMAX, which is derived from the IEEE 802.16e-20055 standard. There is a wide range of possible FFT widths for mobile WiMAX, from 128 bits all the way up to 2,048 bits.

Fixed WiMAX OFDM-PHY

With this update, the FFT size remains at 256, with 192 subcarriers serving as data carriers, 8 as pilot subcarriers for channel estimation and synchronization, and the remaining subcarriers serving as guard bands.6 Due to the constant FFT size, the subcarrier spacing changes as the channel bandwidth does. Subcarrier spacing rises and symbol duration reduces as bandwidths become bigger. A bigger proportion has to be set aside as guard time to compensate for delay spread if symbol time decreases. With WiMAX, designers may choose from a variety of guard times, letting them strike a balance between spectral efficiency and delay spread resilience.

Mobile WiMAX OFDMA-PHY

The FFT size may be adjusted from 128 to 2,048 in mobile WiMAX. Here, the subcarrier spacing is always 10.94 kHz since the FFT size is raised in tandem with the available bandwidth. Because the length of the OFDM symbol remains constant, the fundamental resource unit, scaling has no effect on higher levels. Saving money is another benefit of a scalable design. The subcarrier spacing of 10.94 kHz was selected because it met the needs of both fixed and mobile situations in terms of delay spread and Doppler spread. When operating in 3.5 GHz, this subcarrier spacing can handle vehicle mobility up to 125 kmph and delay spread values up to 20 μs.

SIMULATION MODEL

Figure 1 shows the implementation model of WIMAX Physical Layer used as for simulation. SUI channel has been employed for transmission purpose. The mandatory Channel coding modulation parameters for the simulation model are specified in the IEEE 802.16 Standard document.4 The simulation parameters used in the system model are given in Table 1.

The simulation model is composed of a transmitter, SUI communication channel and receiver. Transmitter consists of data generator, channel encoder, bit to symbol mapper, modulator, inverse fourier transform (IFFT) and cyclic prefix addition blocks. Using the data generator, Random data is fed into the transmitter in form of binary pulses. The channel encoder acts upon the input data and helps to improve the capacity of a channel by adding some carefully designed redundant information to the data being transmitted through the channel. The bit to symbol mapper helps to convert the data bits into symbols. This is needed because the higher order modulation techniques operate on symbols but not on bits. There is a need of pilot carriers in data carriers for channel estimation and used in receiver detection. Pilot carrier insertion is followed by an IFFT which converts a number of complex data points, of length which is a power of 2, into the time domain signal of the same number of points. Cyclic prefix is the most effective guard period attached in front of every OFDM symbol. The cyclic prefix is the copy of

Figure 1. *Wimax Physical Layer simulation Model*

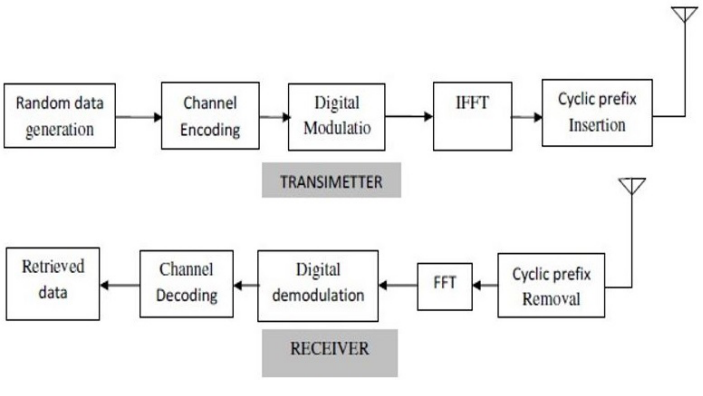


Table 1. *Parameters for SUI Channel*

Parameter	SUI-1	SUI-2	SUI-3	SUI-4
P (Power in each path in dB)	[0 -15 -20]	[0 -12 -15]	[0 -5 -10]	[0 -4 -8]
K (Ricen Distribution) (linear scale)	[4 0 0]	[2 0 0]	[1 0 0]	[0 0 0]
Tap Delay (μses)	[0.0 0.4 0.9]	[0.0 0.4 1.1]	[0.0 0.4 0.9]	[0.0 0.5 0.9]
Dop (maximum Doppler frequency) (Hz)	[0.4 0.3 0.5]	[0.2 0.15 0.25]	[0.4 0.3 0.5]	[0.2 0.15 0.25]
Auto-corr (Coefficient of antenna Correlation factor)	0.7	0.5	0.4	0.3
Normalized factor of gain (dB)	-0.1771	-0.3930	-1.5113	-1.9218

the last part of the OFDM symbol added in front of the transmitted symbol, provided that the length is of equal or greater than the maximum delay spread of the channel. The transmitter is followed by SUI channel. At the receiver end the exact reverse process take place to recover the data. This data is used to compute BER from the simulations.

SUI CHANNEL MODEL

An realistic depiction of the wireless channel's propagation environment is necessary for performance assessment of any communication system. Channel modeling relies heavily on the communication system's radio design. Path loss, multipath delay spread, fading characteristics, Doppler spread, cochannel, and neighboring channel interference are the characteristics of the wireless channel.4 Given the completely random nature of the model parameters, the only way to characterize them statistically is in terms of their mean and variance. Wind speed, tree density, antenna height, and beam width are some of the factors that affect them. SUI channel models build upon previous research by AT&T Wireless and others.6 Three distinct kinds of terrain common to the United States' continental interior were considered while developing this model's collection of six channels. Technologies that are well-suited for fixed broadband wireless applications may be designed, developed, and tested using this paradigm.7 Several statistical models informed the parameter selection process for the model. Parametric views of the SUI channels are shown in Tables 1 and 2.

Table 2. *Terrain Type for SUI Channel*

Terrain Type	SUI Channel	Characteristics
C	SUI-1, SUI-2	Mostly flat terrain with light tree densities
B	SUI-3, SUI-4	Hilly terrain with light tree density or flat terrain with moderate to heavy tree density
A	SUI-5, SUI-6	Hilly terrain with moderate to heavy tree density

PERFORMANCE ANALYSIS

The performance analysis was done using simulation in MATLAB. The parameters and their corresponding values used in the simulation are shown in the Table 3. The performance analysis was carried out for two different cases.

In the first case ,for a given modulation scheme like BPSK,QPSK,16QAM,and 64QAM the BER for different SUI channels was obtained by MATLAB simulation, In the second case, for a given cyclic prefix (CP) time like ¼,1/8,1/16 and 1/32, the BER for different modulation schemes was obtained using MATLAB simulation.

RESULTS AND ANALYSIS

The SNR vs BER plots for various modulation schemes for different SUI channel shows that ,in general ,for a given SNR , the higher order modulation schemes have higher BER. That is 64QAM modulation scheme will have highest BER and BPSK modulation scheme will have lowest BER. But at same time spectral efficiency of higher order modulation schemes will be high. For example, 64QAM will have spectral efficiency of 6 bits/sec/Hz, 16QAM BPSK will have spectral efficiency of 1 bit/sec/Hz.

Hence, higher order modulation schemes are more spectral efficient but less power efficient. Also, the SNR VSBER plots for different modulation schemes for a given CP time shows that as cp time is decreased from ¼ to 1/32 the BER increases for all modulation schemes. Also BER plots for all cp times shows QPSK is more tolerant of interference/ QPSK has lowest BER than other modulation schemes for a given SNR value. The BER plot for BPSK for different SUI channels shown in Figure 2 shows that BER performance of BPSK for SUI-1 channel is better than its performance for other SUI channels. For SUI-6 its performance is worst.

Table 3. *Parameters Used in Simulation*

Parameters	Values
Number of OFDM symbols	100
Total data bits	2000
Number of bits per OFDM symbol	96(BPSK),192(QPSK),384(16QAM),768(64QAM)
Number of data sub-carriers	192
Number of FFT points	256
Cyclic prefix	1/4 , 1/8 , 1/16, 1/32
Modulation scheme	BPSK, QPSK, 16QAM, 64QAM
Coding	Convolution Coding, code rate 1/2 and 2/3

Figure 3 shows BER plot for QPSK for different SUI channels. The BER performance of QPSK is inferior than BPSK i.e. for a given value of SNR ,the BER for QPSK is higher than BPSK for all SUI channels.

Figure 4 shows BER plot for 16QAM for different SUI channels. The BER performance of 16QAM is inferior as compared BPSK and QPSK. Its BER performance is worst for SUI-6 channel as BER is almost constant for all SNR values.

Figure 5 shows BER plot for 64QAM for different SUI channels. The BER performance of 64QAM is inferior as compared BPSK ,QPSK and 16QAM Its BER performance is worst for SUI-6 channel as BER is almost constant for all SNR values.

Figures. 6, 7, 8 and 9 show the combined BER for BPSK,QPSK,16QAM and 64QAM modulation schemes for CP time of ¼ ,1/8 ,1/16 and 1/32 respectively. For all CP times, the BER performance of QPSK is better as compared to all other modulation schemes. The BER performance of higher modulation schemes like 16QAM and 64QAM is worst than lower modulation schemes like BPSK and QPSK. However, higher modulation schemes have high spectral efficiency(4 and 6 bits/sec./Hz respectively for 16QAM and 64QAM) as compared to lower modulation schemes (1 and 2 bits/sec./Hz respectively for BPSK and QPSK). Hence, QPSK can be considered as a modulation scheme which gives optimum performance with low BER and moderate spectral efficiency. Also, it can

Figure 2. *Wimax Physical Layer simulation Model*

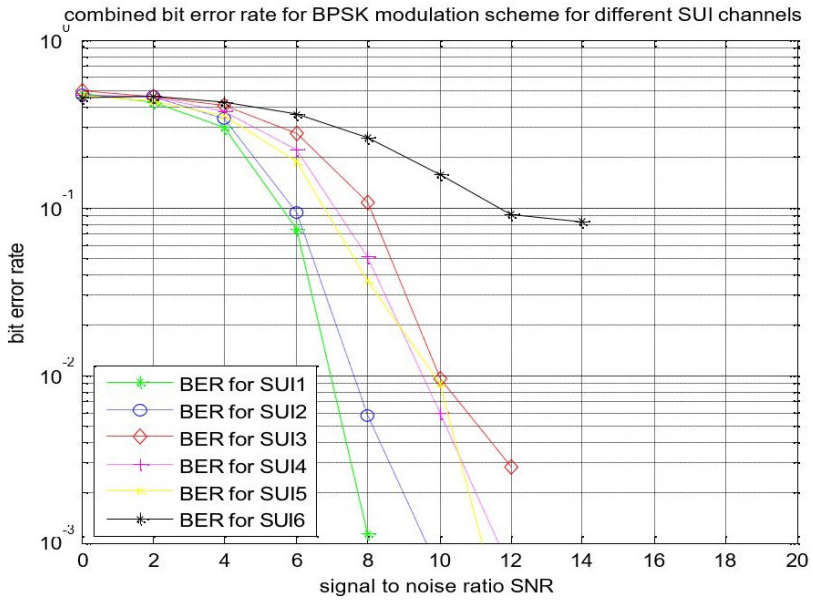


Figure 3. *Combined BER for QPSK Modulation Scheme for Different SUI Channels*

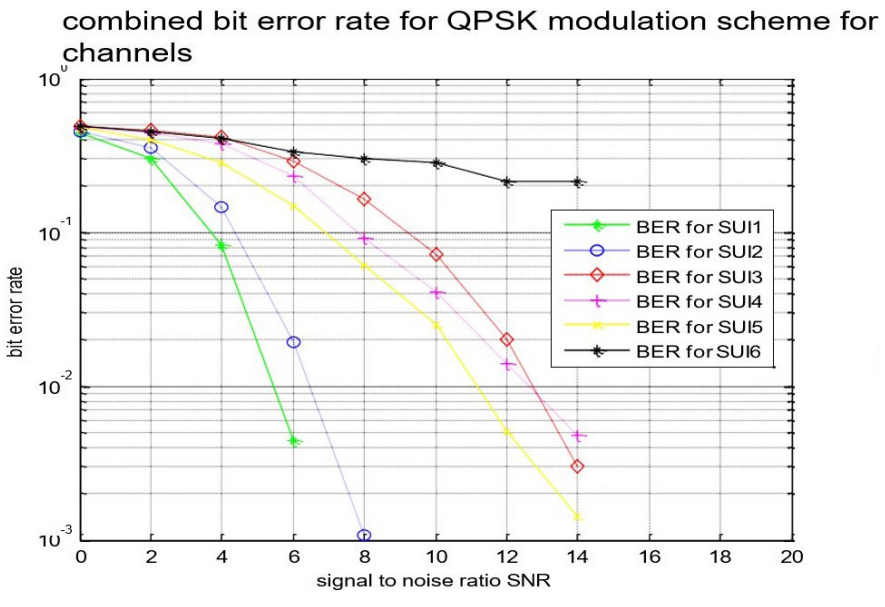


Figure 4. *Combined BER for 16QAM Modulation Scheme for different SUI Channels*

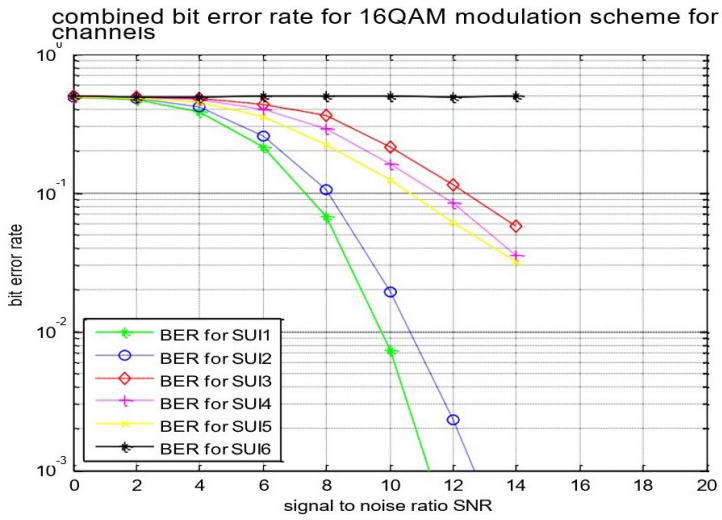
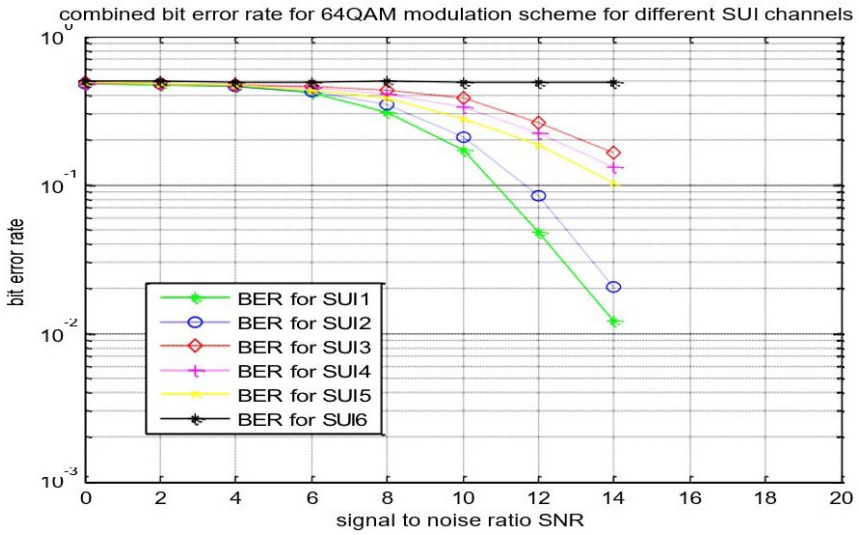


Figure 5. *BER Plot for 64QAM for Different SUI channels*



be considered a trade off between BER and spectral efficiency.

CONCLUSIONS

The WiMAX Physical Layer's performance was tested for several SUI channel models. Since SUI channel considers real-world environmental factors including terrain type, tree density, path loss, and latency, it was used to conduct the performance. These settings define the actual channel in practice. The performance of the Physical Layer with the SUI channel model may be seen as the performance in real-world situations, as the model is based on these properties. The QPSK modulation technique outperforms all others in terms of bit error rate (BER) performance over all CP times.

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Figure 6. *Combined BER for Different Modulation Schemes for cp time=1/4*

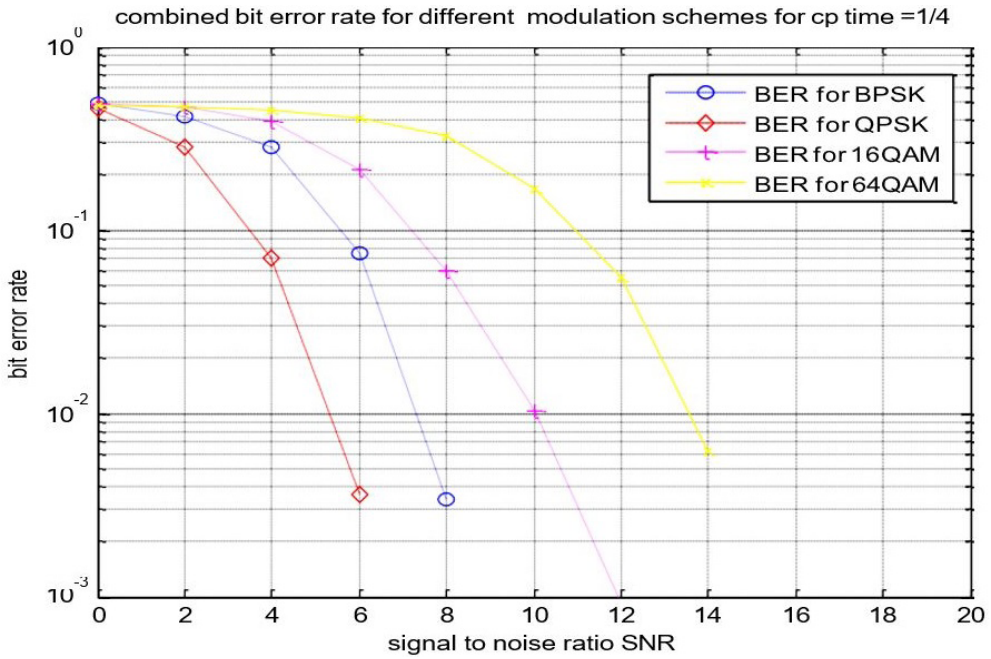
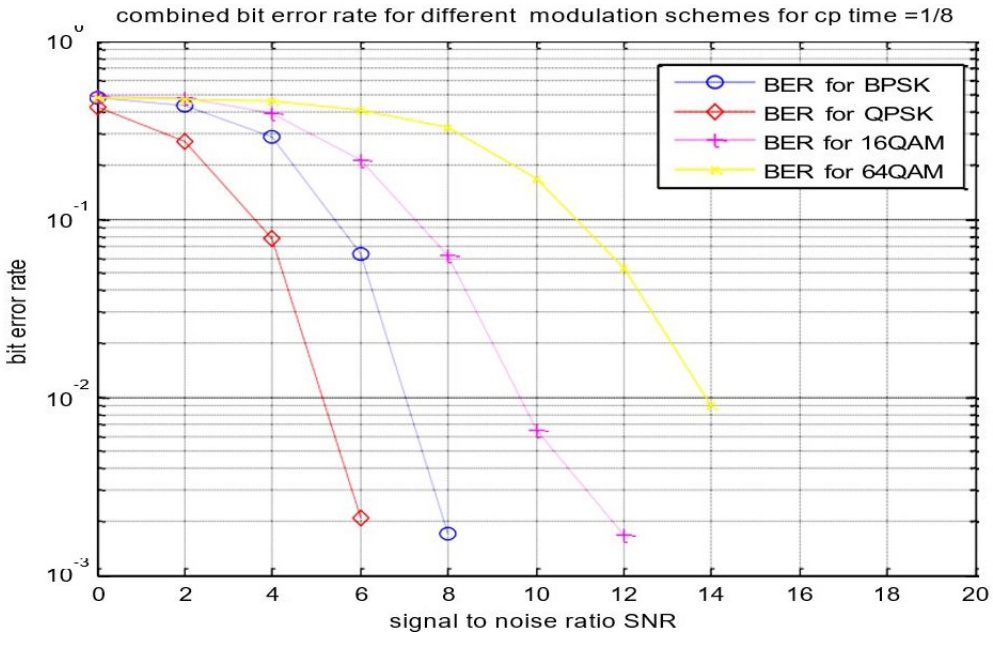


Figure 7. *Combined BER for different Modulation Schemes for cp time=1/8*



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Figure 8. *Combined BER for different Modulation Schemes for cp time=1/16*

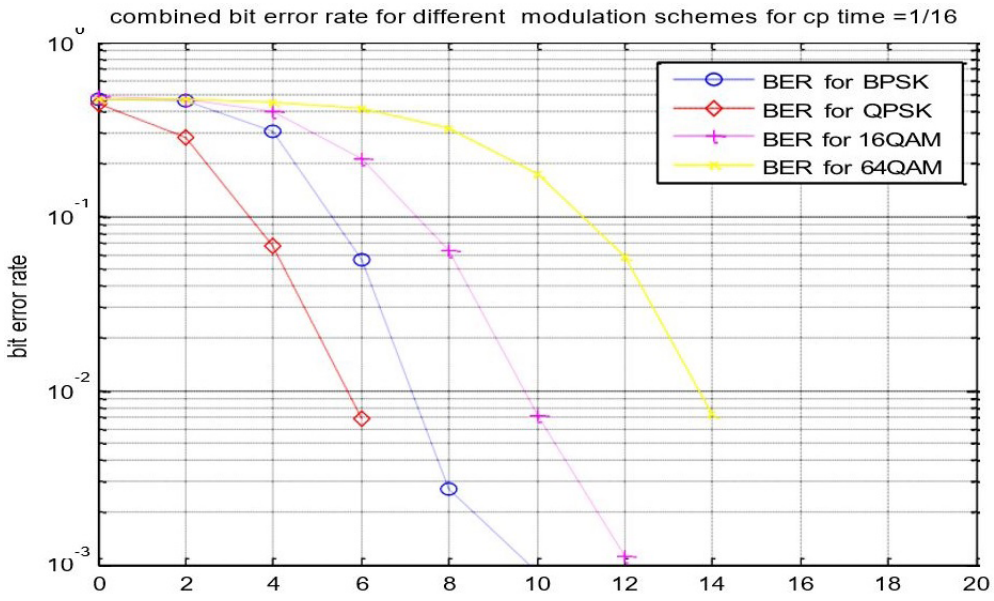
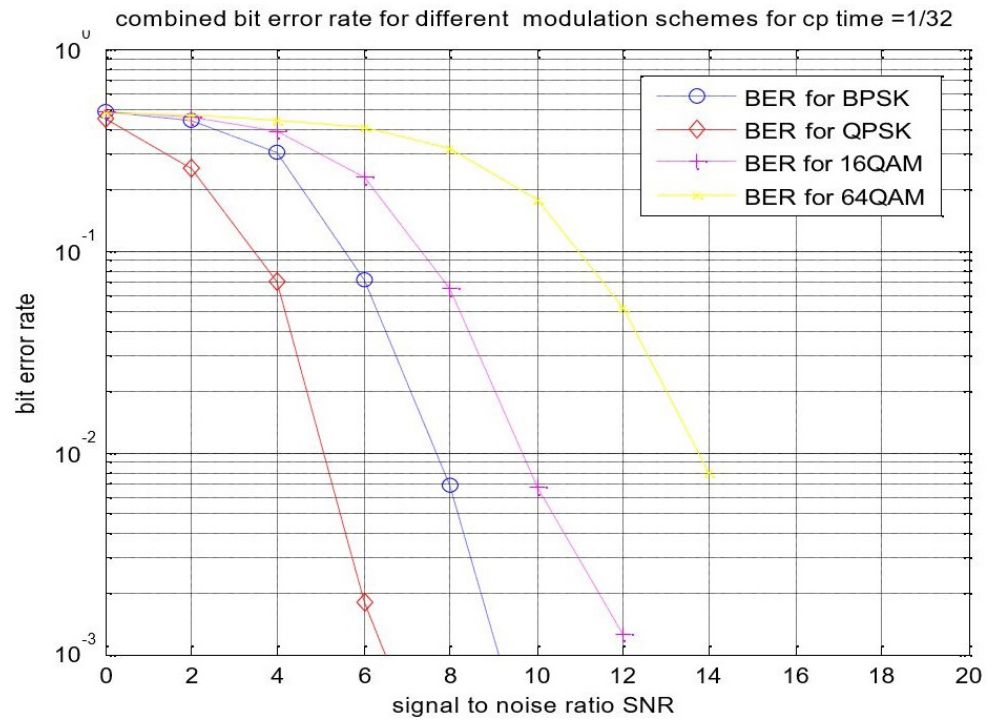


Figure 9. *Combined BER for Different Modulation Schemes for cp time=1/32*



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