Comparative Analysis of Various Wireless Digital Modulation Techniques with different Channel Coding Schemes under AWGN Channel

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ABSTRACT
Wireless communication is the heart of all the modern communications techniques. The future communication is mostly all about related to wireless communications. In wireless communication, different modulation methods are playing the vital roles. To combat the error in transmission channel coding techniques are very much necessary. In this paper, theoretical BER (bit error rate) analysis with E_b /No (Energy per Bit to Noise Power) has been done for various digital modulations techniques such as 8-PSK, 16-QAM and 64-QAM. The paper has also included various channel coding schemes such as block code and convolutional code in the analysis. For all the analysis, AWGN (Additive White Gaussian Noise) channel has been considered.

General Terms
Modulation methods, error control coding, wireless communication, Bit error rate analysis.

Keywords
PSK, QAM, block code, convolutional code, AWGN, BER etc..

1. INTRODUCTION
In telecommunications, modulation is the method of varying one or more properties of a waveform which is called ‘carrier signal’ along with a modulating signal which contains information to transmit. A carrier signal is a periodic signal with constant height (amplitude) and frequency (Hz), where information can be added to the carrier by varying its amplitude, frequency or phase. There are mainly two types of modulation techniques: analog modulation and digital modulation. If the modulating signal is analog then we use analog modulation and when the modulating signal is digital then we use digital modulation. In digital modulation, PSK, QAM, ASK, FSK modulation are popularly used [1].

While transmitting the signal through the wireless channel there might be some bit errors. To combat this bit error, various channel coding methods have been used such as convolutional coding, block coding, cyclic coding and so on [2]. In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel that has been altered due to noise, interference, distortion or bit synchronization errors. It is the number of bit errors per unit time. It is a unit less performance measure, often expressed as a percentage. It is a great tool to analyze the performance of the various modulation techniques [3].

E_b/N_o (the energy per bit to noise power spectral density ratio) is a very important parameter in digital communication. It is a normalized signal-to- noise ratio (SNR) measure, also known as SNR per bit. It is especially useful when comparing the bit error rate (BER) performance of different digital modulation schemes without taking bandwidth into account [4].

AWGN (Additive White Gaussian Noise) Channel is a basic channel model used in analysis. It is the commonly used to transmit signal while signals travel from the channel and simulate background noise of the channel. Mathematical expression in received signal passed through the AWGN channel is:

$$r(t) = s(t) + n(t) \qquad (1)$$

where $s(t)$ is transmitted signal and $n(t)$ is background noise [5]. It is flat and not “frequency-selective” as in the case of other fading channel.

There are several researches have been done on the performance comparisons of the various modulation techniques and channel coding schemes with the lie of E_b /N_o vs BER.

In [6], the authors have investigated the effect of multipath channels on bandpass modulation by simulating a selective frequency fading channel with 6 rays in MATLAB Environment. The authors in [7] have analyzed BPSK and QPSK Modulation with Convolution Coding under AWGN and Rician channel. Similar works have been found in [8-12].

The paper has been organized as: section 1 introduce the paper, section 2 will describe the modulation schemes while section 3 will describe the channel coding. The results have analyzed in section 4 and section 5concludes the paper.

2. MODULATION TECHNIQUES
Modulation is the method of varying one or more properties of a waveform which is called ‘carrier signal’ along with a modulating signal which contains information to transmit. A carrier signal is a periodic signal with constant height (amplitude) and frequency (Hz), where information can be added to the carrier by varying its amplitude, frequency or phase.

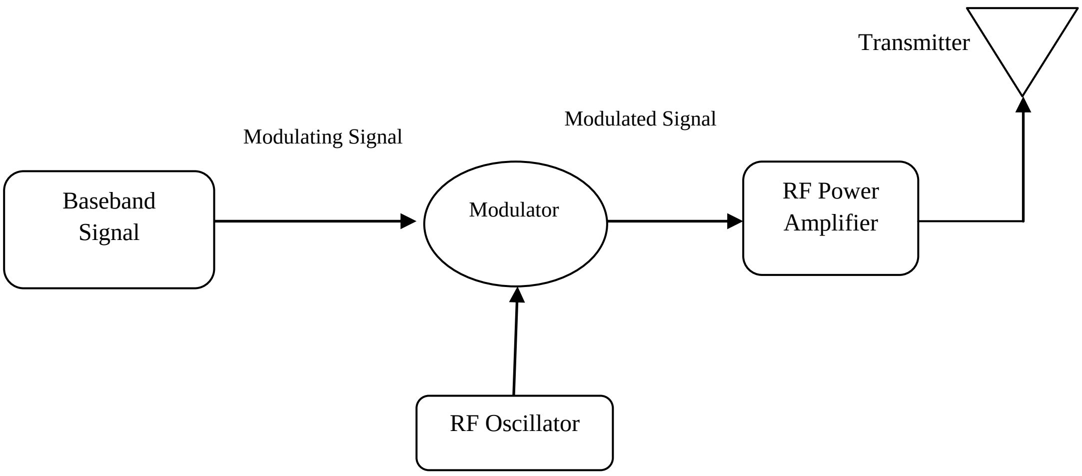

Fig 1: Modulation Block Diagram

2.1 Modulation types

There are several types of modulation techniques. They have been discussed below:

Analog Modulation: Analog modulation refers to the process of transferring an analog baseband (low frequency) signal, like an audio or TV signal over a higher frequency signal such as a radio frequency band. The three main types of analog modulation are Amplitude Modulation (AM), Frequency Modulation (FM), Phase Modulation (PM).

Digital Modulation: Digital Modulation and is a generic name for modulation techniques that uses discrete signals to modulate a carrier wave. The three main types of digital modulation are Frequency Shift Keying (FSK), Phase Shift Keying (PSK) and Amplitude Shift Keying (ASK).

2.1.2 Digital Modulation Types

FSK (Frequency Shift Keying): Frequency-shift keying (FSK) is a frequency modulation scheme in which digital information is transmitted through discrete frequency changes of a carrier signal, e.g. amateur radio, caller ID and emergency broadcasts.

ASK (Amplitude Shift Keying): Amplitude-shift keying (ASK) is a form of amplitude modulation that represents digital data as variations in the amplitude of a carrier wave, e.g. used in our infrared remote controls & in fiber optical transmitter and receiver.

PSK (Phase Shift Keying): Phase-shift keying (PSK) is a digital modulation scheme that conveys data by changing (modulating) the phase of a reference signal (the carrier wave), e.g. widely used for wireless LANs, RFID and Bluetooth communication, ADSL broadband modem, satellite communication, mobile phones.

8-PSK

8-PSK modulation basics or multilevel PSK modulation which is a type of digital modulation based on carrier phase change. In 8PSK there are 8 different phase changes defined, each phase change represents the transmission of 3 bits. 8PSK is used in e.g. EDGE, broadcast video systems, aircraft and satellite systems. In BPSK modulation digital data of 1 and 0 is represented by 180 degree phase change. In QPSK by phase shift of 90 degree, here 2 bits are mapped on each signal. In Multilevel PSK (8-PSK) more than 2 bits are mapped using different phase angles. 8-PSK equation:

A complex baseband M-PSK signal is represented by,

$$S_n(t)=\sqrt{(2Es/T)}\cos(\omega t+\theta_n),\ n=1,2,..M \quad (2)$$

where Es is the symbol energy of each M-PSK Symbol, T is the bit period, $\theta_n$is the phase shift for each of the symbol. For 8-PSK, M=8.

QAM (Quadrature Amplitude Modulation)

QAM is a method of combining two amplitude modulated (AM) signals into a single channel, thereby doubling the effective bandwidth. QAM is used with pulse amplitude modulation (PAM) in digital systems, especially in wireless applications.

Types of QAM: These are the types of QAM:8-QAM, 16-QAM, 32-QAM, 64-QAM, 128-QAM, 256- QAM.

QAM bits per symbol

The advantage of using QAM is that it is a higher order form of modulation and as a result it is able to carry more bits of information per symbol. By selecting a higher order format of QAM, the data rate of a link can be increased. The table below gives a summary of the bit rates of different forms of QAM (16, 64) and 8-PSK.

Table 1: Modulation methods with bit per symbol and symbol rate

Modulation	Bit per symbol (BPS)	Symbol rate
8-PSK	3	1/3 bit per rate
16 QAM	4	1/4 bit per rate
64 QAM	6	1/6 bit per rate

3. CHANNEL CODING

The purpose of channel coding theory is to use detect and/or correct the bit error which have been found while transmitting.

3.1 Linear Block code

A linear block code (LBC) is an error-correcting code for which any linear combination of code words is also a codeword. Linear codes are traditionally partitioned into block codes and convolution codes, although turbo codes can be seen as a hybrid of these two types.

3.2 Convolutional code

A convolutional code is a type of error-correcting code that generates parity symbols via the sliding application of a Boolean polynomial function to a data stream.

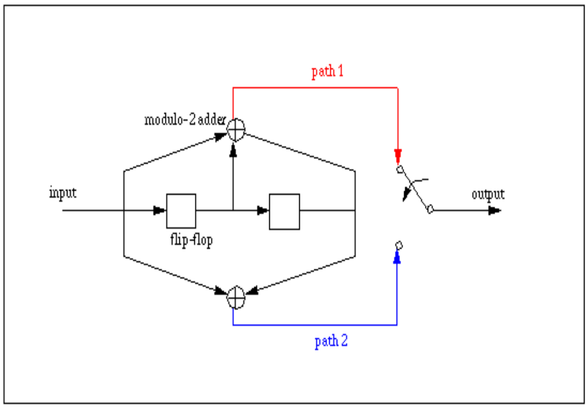

Fig.2: Convolutional code Block Diagram

4. SNR, BER, E_b/N_o and AWGN

Signal-to-noise ratio (abbreviated SNR or S/N) is a measure used in science and engineering that compares the level of a desired signal to the level of background noise. It is defined as the ratio of signal power to the noise power, often expressed in decibels

The bit error rate (BER) is the number of bit errors per unit time. The bit error ratio (also BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval. BER is a unit less performance measure, often expressed as a percentage

Eb/No (the energy per bit to noise power spectral density ratio) is an important parameter in digital communication or data transmission. It is a normalized signal-to-noise ratio (SNR) measure, also known as the "SNR per bit".

Additive white Gaussian noise (AWGN) is a basic noise model used in Information theory to mimic the effect of many random processes that occur in nature. The modifiers denote specific characteristics: Additive because it is added to any noise that might be intrinsic to the information system.

5. RESULTS AND ANALYSIS

This section will discuss and analysis the results obtained from MATLAB 2016a. In various figures we have presented the performances of various modulation techniques with and without channel coding.

In Fig. 3, it has been found that the performance of 8-PSK increases tremendously when convolutional coding has been incorporated. Though for low Eb/No case, block performs better. Say for 4 dB Eb/No, block code's BER is less than without channel coding case and much better than convolutional coding case. But increasing the value of Eb/No, convolutional coding improves much better. Say in 10 dB Eb/No, with convolutional coding, BER is around 10-6 , while for block code it is around 10-4 and without coding it is around 10-3.

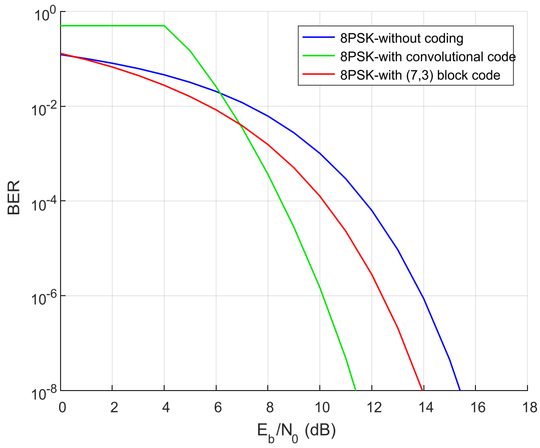

Fig. 3 BER analysis of 8PSK with or without channel coding

In Fig. 4, it has been found that the performance of 16-QAM increases greatly when convolutional coding has been integrated. Though for low E_b/N_o case, block performs better. Say for 4 dB E_b/N_o, block code's BER is less than without channel coding case and much better than convolutional coding case. But increasing the value of $E_b/N_{o,}$ convolutional coding improves much better. Say in 10 dB $E_b/N_{o,}$ with convolutional coding, BER is around 10^{-5} , while for block code it is less than 10^{-3} and without coding it is near 10^{-2}.

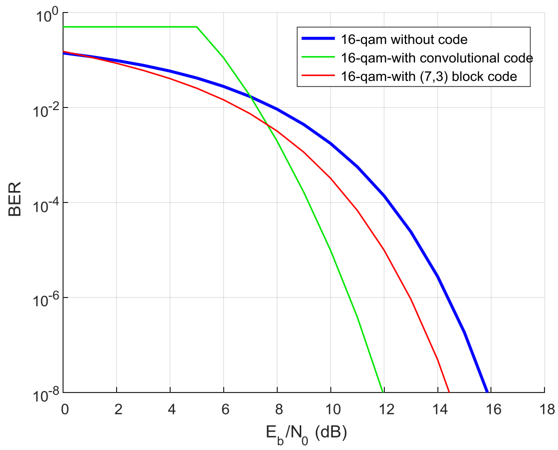

Fig. 4 BER analysis of 16-QAM with or without channel coding

In Fig. 5, it has been found that the performance of 64-QAM increases greatly when convolutional coding has been integrated. Though for low Eb/No case, block performs better. Say for 5 dB Eb/No, block code's BER is less than without channel coding case and much better than convolutional coding case. But increasing the value of Eb/No, convolutional coding improves much better. Say in 15 dB Eb/No, with convolutional coding, BER is less than 10-6 , while for block code it is around 10-4 and without coding it is near 10-3.

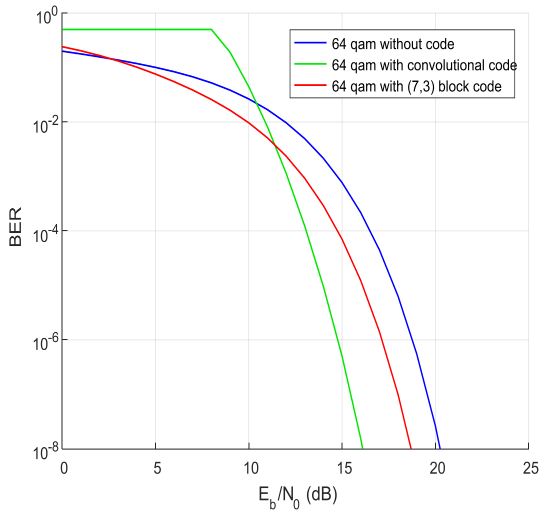

Fig. 5 BER analysis of 64-QAM with or without channel coding

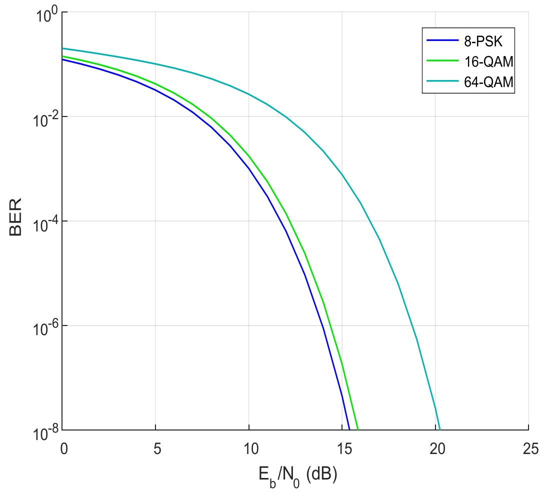

Fig. 6 BER analysis of different modulation techniques without any channel coding

In Fig. 6, the analysis has been done for the performances of 8-PSK, 16-QAM and 64-QAM without considering any channel coding. To achieve BER of 10-8, 8-PSK needs 15.5 dB, 16-QAM needs 16 dB and 64-QAM needs 20.5 dB value of Eb/No.

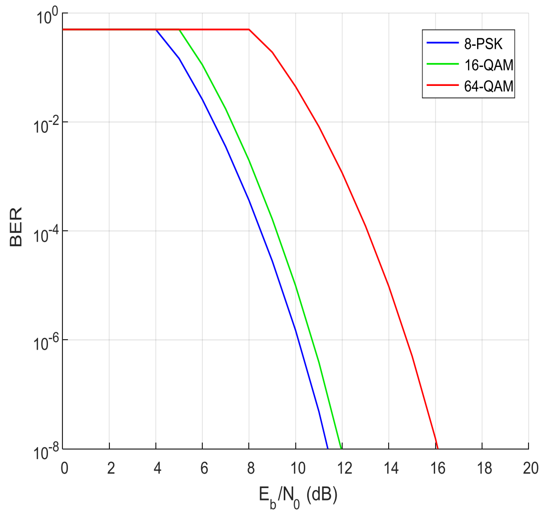

Fig. 7 BER analysis of different modulation techniques with convolutional coding

Similar analysis been done in Fig. 7 for convolutional case. Here to achieve BER of 10-8, 8-PSK needs 11.5 dB, 16-QAM needs 12 dB and 64-QAM needs 16 dB value of Eb/No. 8-PSK performs better here also.

In Fig. 8, the analysis has been done for the performances of 8-PSK, 16-QAM and 64-QAM with considering block coding. To achieve BER of 10-8, 8-PSK needs 14 dB, 16-QAM needs 14.25 dB and 64-QAM needs 18.5 dB value of Eb/No. Here, 8-PSK and 16- QAM acts quite similar while 64-QAM performs poor.

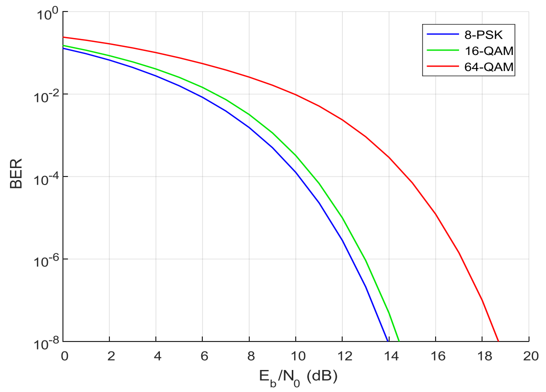

Fig. 8 BER analysis of different modulation techniques with block coding

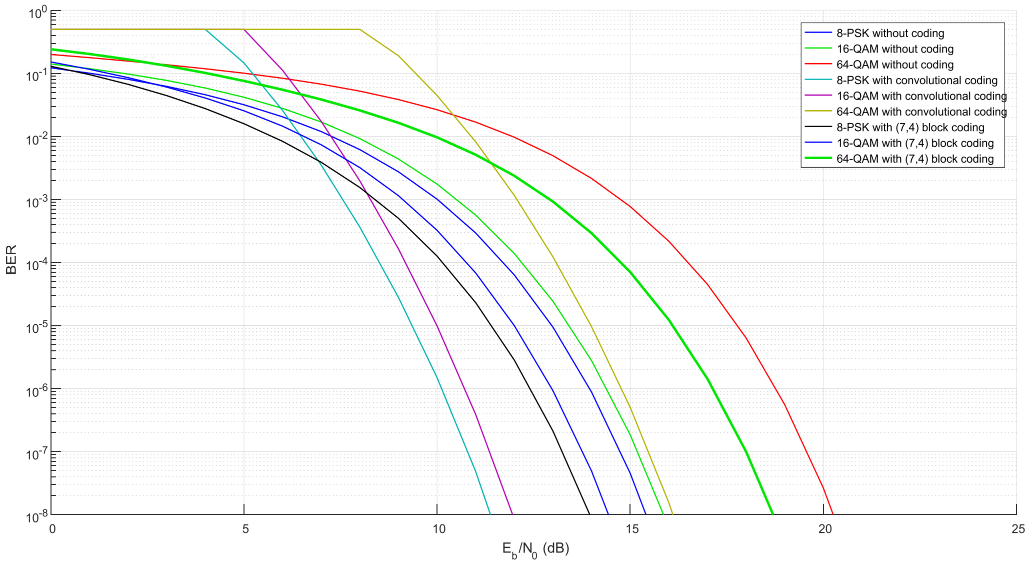

Fig. 9 BER analysis of different modulation techniques with and without channel coding

In Fig. 9, all the above performances analysis have been shown in a figure. From the Fig. 9 it is clear that the performance of 8-PSK with convolutional coding is the best while 64-QAM without any channel coding is the worst. From coding perspective, convolutional coding's overall performance is the best and from the modulation perspective 8-PSK is the best. To achieve the similar BER, 64-QAM needs muchmore value of Eb/No than 8-PSK.

6. CONCLUSION

In this paper, the bit error rate has been theoretically analyzed for various different wireless modulation techniques. In the analysis, it has been found that the performance of 8-PSK with convolutional coding is the best and the 64-QAM without any channel coding is the worst. Though the throughput of the 64-QAM is much better than 8-PSK but BER is high. It is due to sending more bit causes more bit error. To reduce the BER of 64-QAM, several filtering techniques can be used. In future, similar analysis will be done for practical cases with considering some parameters like filters, channel equalizers, other channels and so on.

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