Performance Evaluation of Punctured Convolutional Codes for OFDM-WiMAX System

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Abstract: **Errors occur in information during transmission, due to noise on the communication channel. In this paper, we study the unequal error protection capabilities of convolutional codes belonging to the family of rate-compatible punctured convolutional codes. Puncturing is the process of deleting some parity bits from the code-word according to a puncturing matrix. Puncturing increases code rate without increasing complexity. The bandwidth efficiency decreases with increase in redundant bits in coding. By removing these redundant bits through puncturing improves the bandwidth efficiency. Puncturing is the trade-off between rate and performance. In this paper, simulation model of OFDM based WIMAX system has been developed using punctured convolutional codes. The bit error rate performance has been carried out for different code rates like 1/2, 2/3, 3/4, 5/6, 7/8, 11/12 for modulation techniques BPSK and QPSK.**

Keywords: **BPSK; Convolutional codes; MATLAB; OFDM-WiMAX; QPSK; Puncturing.**

I. INTRODUCTION

After years of development and uncertainty, a standards-based interoperable solution is emerging for wireless broadband. WiMAX is a wireless broadband solution that offers a rich set of features with a lot of flexibility in terms of deployment options and potential service offerings [1]. The IEEE 802.16 group subsequently produced 802.16a, an amendment to the standard, to include NLOS applications in the 2GHz–11GHz band, using an orthogonal frequency division multiplexing (OFDM)-based physical layer. OFDM is the transmission scheme of choice to enable high-speed data, video, and multimedia communications and is used by a variety of commercial broadband systems, including DSL, Wi-Fi, Digital Video Broadcast-Handheld (DVB-H), and MediaFLO, besides WiMAX. OFDM is an elegant and efficient scheme for high data rate transmission in a non-line-of-sight or multipath radio environment [2].

The aim of OFDM is to divide the wide frequency selectivity of fading channels into multiple flat fading channels. The OFDM uses the spectrum more efficiently by making the entire sub carrier orthogonal to one another, preventing interference between the sub carriers. One of the main attractions of OFDM are handling the multi-path interference, and mitigate inter-symbol interference (ISI) causing bit error rates in frequency selective fading environments [3].

In recent years, there has been an increasing demand for efficient and reliable digital data transmission and storage systems. This demand has been accelerated by emergence of large-scale, high-speed data networks for the exchange, processing and storage of digital information in the commercial, governmental and military spheres. A merging of communications and computer technology is required in the design of these systems. A major concern of the system designer is the control of errors so that the data can be reliably reproduced.

In 1948, Shannon demonstrated in a landmark paper that, by proper encoding of information, errors induced by a noisy channel or storage medium can be reduced to any desired level without sacrificing the rate of information transmission or storage, as long as the information rate is less than the capacity of the channel. After Shannon's work, much effort has been extended on the problem of devising efficient encoding and decoding methods for error control in a noisy environment. Recent developments have contributed towards achieving the reliability required by today's high-speed digital systems, and the use of coding has become an integral part in the design of modern communication and digital storage systems [4].

By adding redundant information to the data to be transmitted, it is possible to detect and even correct the errors. This principle is called forward error control. One method to add redundant information is by using a convolutional code. This code is generated by a finite state machine that is fed with the data to be transmitted. Due to the finite state behaviour of the convolutional code, many information bits have influence on a single channel bit. The received channel bit sequence can be decoded using the Viterbi algorithm (VA), which computes the most likely transmitted sequence. Due to the finite state behaviour of the convolutional encoder, the memory requirement is relatively low for VA, which is especially important in a mobile communication environment, where computational and memory requirement should be kept as low as possible.

It is clear that more redundant information will result in larger ability to detect and correct errors and therefore will result in a lower block error probability and lower bit error probability. By adjusting the amount of redundant information, the error protection given can be modified depending on the channel and/or source characteristics. In a mobile environment the system resources at the hand-held side are limited so the same decoder should be used independent of the amount of redundant information added. One of the variable rate convolutional encoding schemes is the punctured convolutional codes, where redundant information at the encoder output is deleted [5].

II. SYSTEM MODEL

The WIMAX based OFDM system model is composed of a transmitter, AWGN communication channel and receiver.

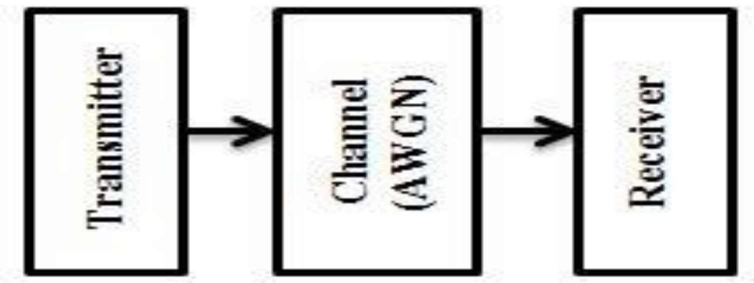


Figure.1. OFDM-WiMAX system model

A. Transmitter

The transmitter of OFDM-WiMAX system is given as follow:

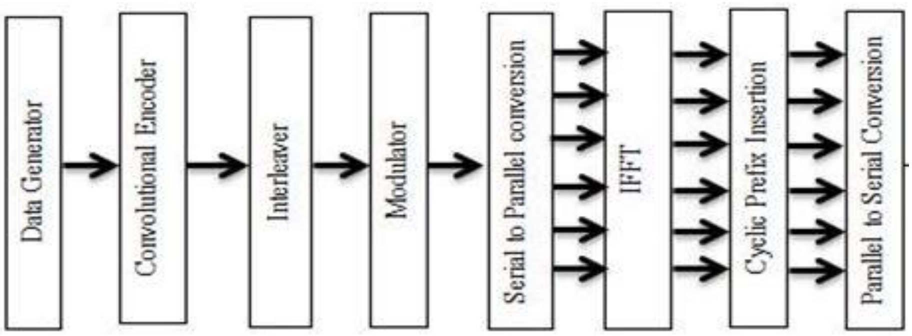


Figure.2. Transmitter for OFDM-WiMAX system

Information is generated by source which may be human speech, data source, video or a computer. This information is then transformed to electric signals by source encoder which is convolutional encoder. Here binary input data is encoded by a rate 1/2 convolutional encoder. The rate may be increased to 2/3, 3/4, 5/6 or 7/8 by puncturing the coded output bits.

After interleaving, the binary values are converted into modulated values. IFFT 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. To make the system robust to multipath propagation, a cyclic prefix is added.

B. AWGN Channel

High data rate communication over additive white Gaussian noise channel (AWGN) is limited by noise .The received signal in the interval $0 \leq t \leq T$ may be expressed as

$r(t)=Sm\ (t) + n(t)$

Where n(t) denotes the sample function of additive white Gaussian noise(AWGN) process with power- spectral density [6].

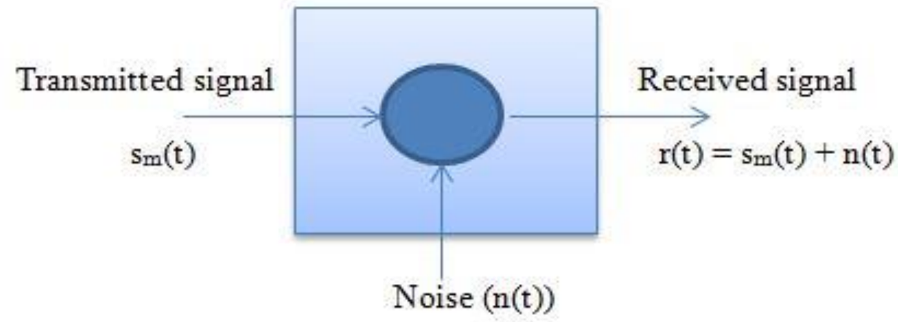


Figure.3. Model for received signal passed through AWGN channel

C. Receiver

The receiver of OFDM-WiMAX system is given as follow:

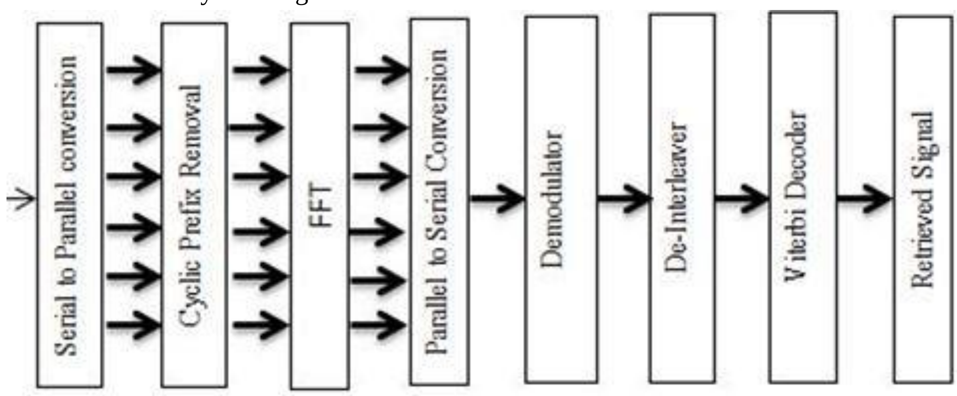


Figure.4. Receiver for OFDM-WiMAX system

After converting serial data into parallel form, the cyclic prefix is removed from the received signal. FFT converts back the time domain signal into frequency domain complex data points. After converting these data points back into serial form, the signal is demodulated back to its binary form. The signal is de-interleaved to its original form. Viterbi decoding algorithm is mostly applied to convolutional encoder and it uses maximum likelihood decoding technique. Noisy channels cause bit errors at receiver. Viterbi algorithm estimates actual bit sequence using trellis diagram. Commonly, its decoding algorithm is used in two different forms. This difference results from the receiving form of the bits in the receiver. Decoded information is received with hard decision or soft decision. Decoded information is explained with ±1 on hard decision operation while soft decision decoding uses multibit quantization. Hard decision and soft decision decoding refer to the type of quantization used on the received bits. Hard decision decoding uses 1 bit quantization on the received channel values while soft decision decoding uses multi bit quantization on the received channel values. For hard decision decoding, the symbols are quantized to one bit precision while for soft decision decoding, data bits are quantized to three or four bits of precision. The selection of quantization levels is an important design decision because of its significant effect on the performance of the link [6].

III. CONVOLUTIONAL CODING

The principle of a convolutional code is based on Shannon's statement that information should not be transmitted one information bit at a time, but should be encoded such that each information bit has some influence on many bits transmitted over the channel. In a convolutional code this is obtained by a shift register, which contents is a linear function of the previous input bits. On its turn, each output of the convolutional encoder is a linear function of the current input and the shift register contents. The convolutional code has a finite state behaviour, due to the shift register [5].

Convolution codes are specified by three parameters (n, k, K), where n, k, K are length of the code word, number of input bits and constraint length respectively. The constraint length K, defines the past number of input bits in the memory register that affect the output code word. The relation R=k/n is The rate of Convolution code, which defined as the ratio of number of output bits to the number of input bits and is denoted by 'R'.

In general, k data bits may be shifted into the register at once, and n code bits generated. In practice, it is often the case that k=1 and n=2, giving rise to a rate 1/2 code.

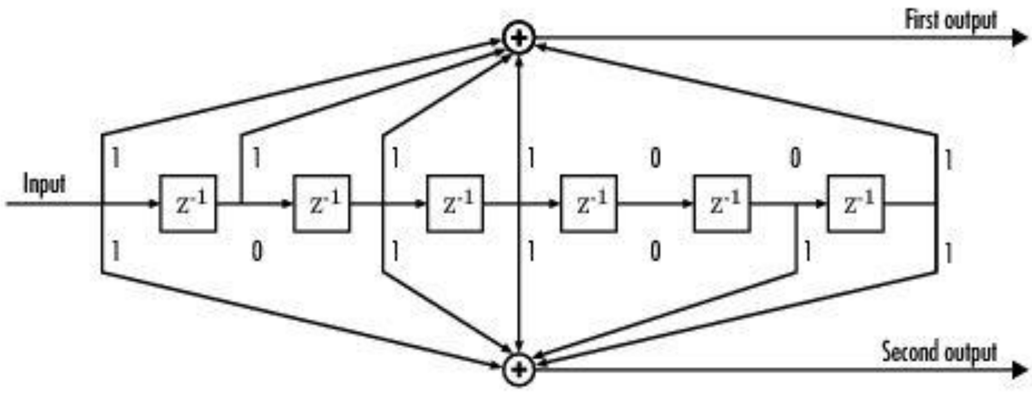


Figure.5. Convolution encoder with K=7, R=1/2, generator polynomial [171, 133]

A. Punctured Convolutional codes

A punctured convolutional code is a high-rate code obtained by the periodic elimination (i.e., puncturing) of specific code symbols from the output of a low-rate encoder. The resulting high-rate code depends on both the low-rate code, called the original code, and on both the number and specific positions of the punctured symbols. The pattern of punctured symbols is called the perforation pattern of the punctured code, and is conveniently described in a matrix form called the perforation matrix [7].

Puncturing has the effect of reducing the number of encoded digits corresponding to the information digits, i.e., of increasing the code rate. Thus, a low-rate encoder can be used to generate many high-rate codes by appropriately selecting the puncturing pattern. If a rate- 1/n original encoder is punctured by deleting some of the nP encoded bits corresponding to P information bits, then P is called the puncturing period. The puncturing pattern can be represented as an n × P matrix P whose elements are 1's and 0's, with a 1 indicating inclusion and a 0 indicating deletion [7].

The advantage of using punctured codes is that a high rate punctured codes can be decoded using decoder for the low-rate original code, thereby requiring a smaller number of computations. Puncturing is the trade-off between rate and performance. Puncturing increases code rate without increasing complexity for code rate and at the same time provides bandwidth efficiency but the performance of system is comparatively degraded [8].

IV. SIMULATION

Different Punctured convolutional codes have been used for the simulation of the OFDM-based WiMAX system using modulation techniques - BPSK and QPSK. High-rate punctured codes have been derived from rate 1/2 convolutional codes. The simulation results have been compared by plotting their BER versus E_b/N_0 through MATLAB.

The different punctured patterns used to get different punctured code-rates are shown in table 1.

TABLE.1. PUNCTURING MATRICES

Code-rate	Punctured-pattern
2/3	1 1 0 1
3/4	1 1 1 0 0 1
5/6	1 1 0 1 0 1 0 1 0 1
7/8	1 1 0 1 1 0 1 0 1 0 1 0 1 0

TABLE.2. SIMULATION PARAMETERS

Parameters	Values
FFT size	256
No. of data sub-carriers	256
OFDM symbols	192
Guard time	64
Modulation	BPSK, QPSK
Code Rates	1/2, 2/3, 3/4,5/6,7/8,11/12
Constraint Length	7
Code Generator	171,133

The following section shows the simulated results of OFDM based WIMAX system for different punctured code rates. The simulation depicts the comparison of performance of system corresponding to different values of code rates for different modulation techniques.

Code-rate 1/2 with BPSK and QPSK: The simulation results shows that, for BPSK without puncturing; only 96 numbers of bits per OFDM symbol are sent over the channel. On the other hand for QPSK, only 192 numbers of bits per symbol could be sent over the channel. But the performance of the system is best at code rate 1/2 for both BPSK and QPSK. As for BPSK, approximately BER of 10e-6 is achieved at 2dB EbN0 and for QPSK; BER of 10e-5 is achieved at approximately 4.5dB.

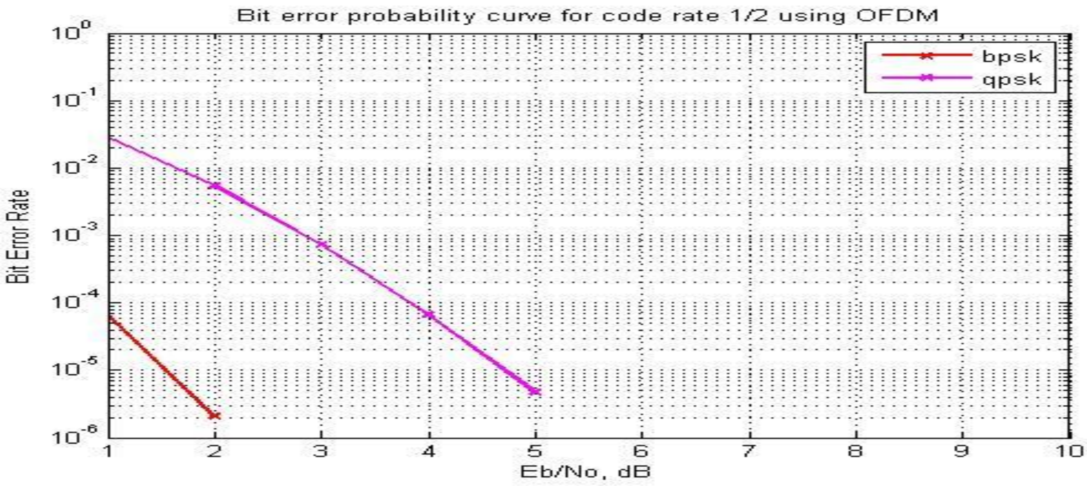


Figure.6. BER v/s EbN0 curve for code-rate 1/2

A. Code-rate 2/3 with BPSK and QPSK:

The simulation results for punctured code-rate 2/3 shows that, for BPSK; 128 numbers of bits per OFDM symbol could be sent over the channel and for QPSK, 256 numbers of bits per symbol could be sent over the channel with puncturing. But the performance of the system has been degraded for both BPSK and QPSK. As for BPSK, BER of slightly lower than 10e-4 could be achieved at 2dB EbN0 and for QPSK; BER of 10e-5 is achieved at approximately 5.5dB.

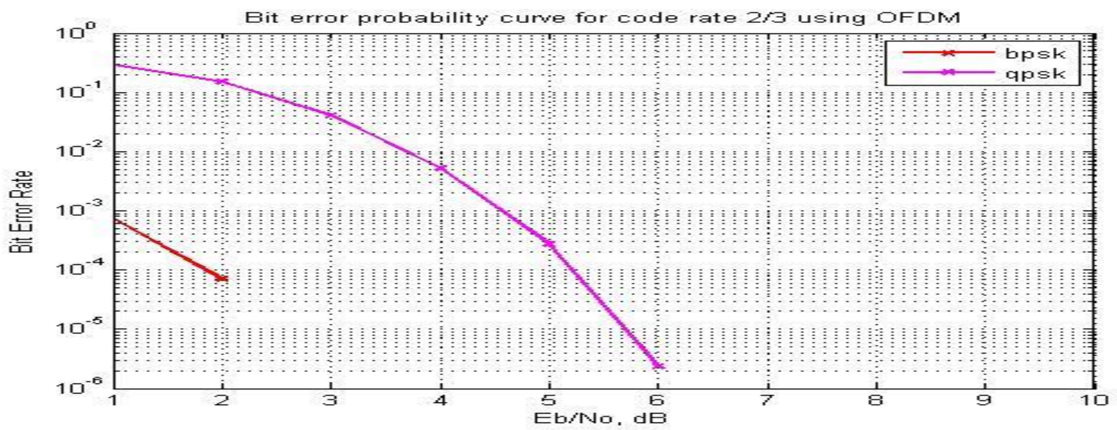


Figure.7. BER v/s EbN0 curve for code-rate 2/3

B. Code-rate 3/4 with BPSK and QPSK:

The simulation results for punctured code-rate 3/4 show that, although the performance of the system has degraded more for both BPSK and QPSK as the rate of the puncturing increases; but 144 and 288 numbers of bits per OFDM symbol could be sent over the channel for BPSK and QPSK respectively, thus providing better bandwidth efficiency.

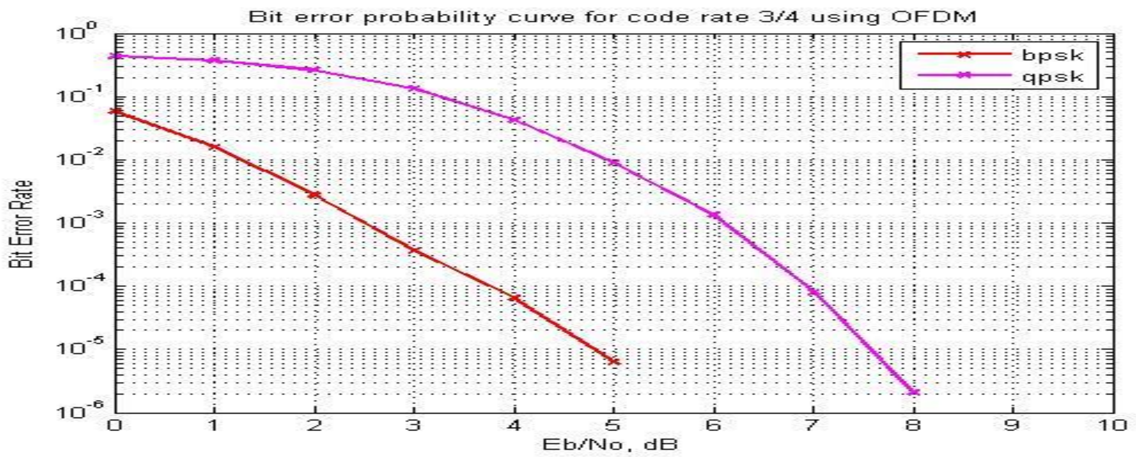
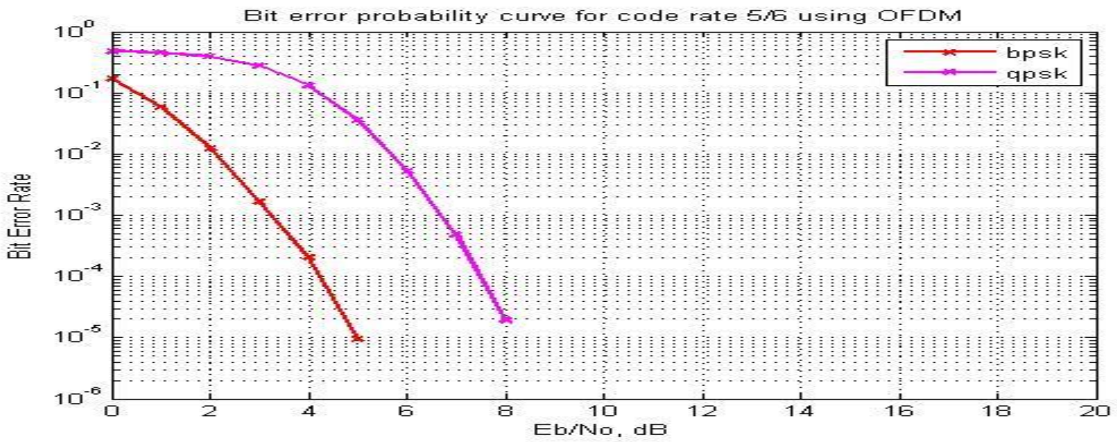


Figure.8. BER v/s EbN0 curve for code-rate 3/4

C. Code-rate 5/6 with BPSK and QPSK:

The simulation results shows that, for BPSK with punctured code rate 5/6; 160 numbers of bits per OFDM symbol are sent over the channel. On the other hand for QPSK, 320 numbers of bits per symbol could be sent over the channel. Although the performance of the system has degraded further but the bandwidth efficiency of the system has also been improved at the same time.



Figur. 9. BER v/s EbN0 curve for code-rate 5/6

D. Code-rate 7/8 with BPSK and QPSK:

With punctured code-rate 7/8, for BPSK; 168 numbers of bits and for QPSK, 336 numbers of bits per OFDM symbol could be sent over the channel; further improving the bandwidth efficiency of the system. But here, BER of approximately 10e-6 is achieved at 7dB EbN0 for BPSK, and for QPSK; BER of approx. 10e-6 is achieved at nearly 11dB.

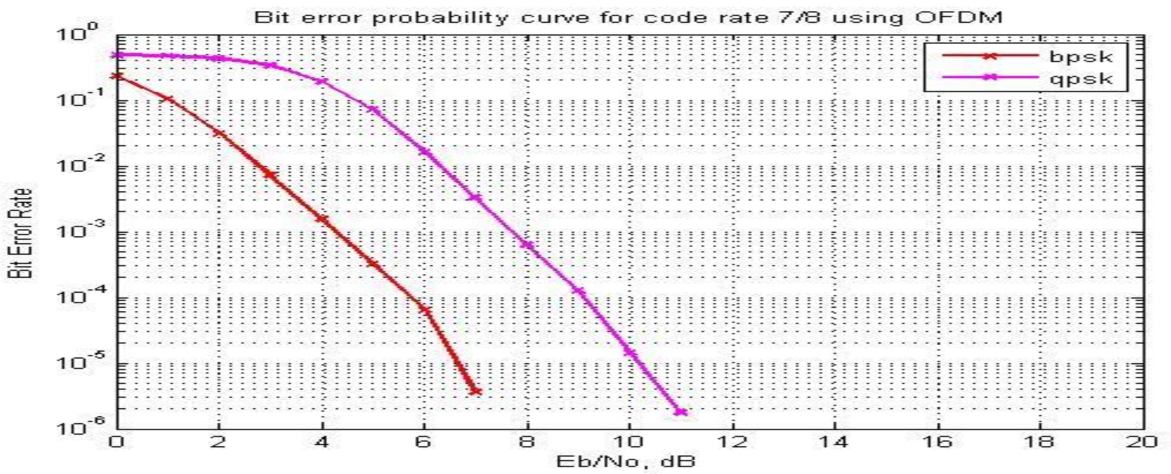


Figure.10. BER v/s EbN0 curve for code-rate 7/8

V. CONCLUSION

The redundant bits in coding decrease the bandwidth efficiency of the system. Puncturing is the process of deleting those redundant bits from the code-word resulting in improved bandwidth efficiency of the system. In this paper, the simulated results conclude that the performance of the punctured code is worse than the performance of the mother code 1/2, especially for noisy channel conditions. On the other hand, for punctured code rates, the system has better bandwidth efficiency. Thus more data could be sent over the same channel bandwidth using puncturing. This concludes that puncturing is a trade-off between bandwidth efficiency and performance of the system.

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