A Bit Error Rate Model of M-ary PSK OFDM Satellite Communication Systems for Educational Purpose

I. Bacic, K. Malaric

University of Zagreb, Faculty of Electrical Engineering and Computing
Department of Wireless Communication, Zagreb, Croatia
Email: iva.bacic@fer.hr

Abstract. *In this work, after a basic theoretical background on orthogonal frequency division multiplexing, our virtual bit error rate mode of M-ary PSK OFDM satellite communication systems, realised in Matlab, is presented. Elementary guide for the program is given: by simply typing the wanted parameters, communication system is defined. BER for this system can be plotted. This program is especially suitable for educational propose. Furthermore, in this work, influence of different PSK modulation, number of subcarriers and length of cyclic prefix on the signal performance and communication quality is analysed. It was shown that the BPSK gained the best signal performance, number of subcarriers has no influence on the transmission quality and by increasing the cyclic prefix BER is smaller.*

Keywords: OFDM, M-ary PSK, Subcarrier, Cyclic Prefix, BER, Matlab

1. Introduction

In satellite communication high transmission quality and availability are essential [1]. For measuring signal performance, a criterion called the bit error rate, BER is used. BER represents the number of incorrectly received bits to the number of transmitted bits and is, commonly plotted against E_b / N_0, where E_b stands for energy per bit and N_0 is the noise power spectral density. To improve communication quality in a communication system, a parallel-data transmission of symbols such as Orthogonal Frequency Multiplexing, where the total transmission bandwidth is split into a number of orthogonal subcarriers is used [2].

In this work, software for analysing the signal performance and communication quality is represented. After defining the elementary parameters for an OFDM system the program results with a BER versus E_b / N_0 graph. Described program was developed in Matlab.

2. Theoretical background

OFDM involves sending several signals at a given time over different frequency channels, or subcarriers which are orthogonal indicating there is a precise mathematical relationship between carrier frequencies ensuring that the modulation symbol can be recovered from the transmitted signal without intersymbol interference, ISI [3] [4]. OFDM divides serial data stream into several parallel streams, one for each subcarrier. Each subcarrier is modulated with a conventional modulation scheme. M-ary PSK scheme used in satellite communication systems [5] [6], is a digital phase modulation of a sinusoidal carrier:

$$s_i(t) = \sqrt{\frac{2E_S}{T}} \cos(2\pi f_C t) \cos(\frac{2\pi i}{M} + \frac{\pi}{4}) - \sqrt{\frac{2E_S}{T}} \sin(2\pi f_C t) \sin(\frac{2\pi i}{M} + \frac{\pi}{4}) \quad (1)$$

where *Es* is the symbol energy and *i* is the imaginary number $i = \sqrt{-1}$. Parameter *M* is chosen as a power of 2 since the data to be converted are usually binary [7]. PSK data bits are grouped into unique pattern to form symbols, represented by a particular phase which is sent across the channel after modulating the carrier. Receiver determines phase of received signal and maps it to the symbol it represents. Usually Gray mapping is used for allocating bits to a

symbol providing that adjacent symbols differ by only one bit [8]. This gives the best immunity to corruption. OFDM treats the PSK symbols as though they are in the frequency-domain. These symbols are feed to an Inverse Fast Fourier Transform, IFFT block which brings the signal into the time-domain and is defined with [9]:

$$X_k = \sum_{n=0}^{N-1} x_n e^{-\frac{2\pi i}{N} nk} \qquad n = 0,1,2...N-1 \tag{2}$$

where N is the IFFT size, chosen as a power of 2 and has to be significantly larger than the number of subcarrieres (like show in Tab.1) to ensure that the edge effects are neglectible at half the sampling frequency [4]. After IFFT is taken, the cyclic prefix, CP can be added. CP is a copy of the last part of the OFDM symbol which is appended to the front of transmitted OFDM symbol and is introduced because of no perfect synchronization between transmitter and receiver (therefore, wrong messages may be received) [10]. Its duration is determined by the expected duration of the multipath channel in the operating environment and is usually set to 1/32, 1/16, 1/8 or 1/4 of duration of whole OFDM symbol [10]. Extended message is transmitted through the channel. At the receiver's side, after removing the cyclic prefix, the Fast Fourier Transform block performs the reveres process on the received signal and brings it back to frequency domain to be demodulated [12].

Table 1. The FFT size and number of subcarriers used in communication systems

IFFT/FFT size	128	256	512	1024	2048
Number of subcarriers	72	192	360	720	1440

3. Virtual bit error rate model program

OFDM system explained in previous section is implemented in a test program for analysing the bit error rate. For deal the problem, Matlab was used.

Program's environment is user friendly: simply by typing the wanted parameters (type of PSK modulation, number of subcarriers and length of cyclic prefix) into the graphical user interface, the communication system is defined. Clicking on button *plot*, the result, a BER versus E_b / N_0 graph with its legend is plotted on the right side of the GUI. After changing parameters, another graph may be plotted at the same figure for comparison the influence of different parameters on the signal performance. Our program provides up to seven curves at the same figure (more than that would be confusing). By clicking the button *clear* the whole figure is deleted, and a new analysis is available. Optionally, grid can be added to the graph (button *grid*).

Thus defined, our test program is especially suitable for educational propose.

4. Results

In the following, the computational results of BER model of M-PSK OFDM satellite communication system are introduced.

First the influence of M is observed. For every pair in Tab. 1 BER versus E_b / N_0 graphs with different modulations are plotted and for all, the same conclusion was made: lower parameter M gives better communication quality. For measuring the same BER level, the BPSK ($M = 2$) allows the highest level (E_b / N_0 is lower) in the channel. For illustration Fig.1 with

the results for three modulations; $M = 2, 4, 8$ for the first values of IFFT size and number of subcarriers in Tab. 1 is given.

IFFT size, N is chosen as a power of 2 (first row in Tab.1). Let's observe the influence of number of data subcarriers in an OFDM system with fixed IFFT size and only one modulation type. A representative result is given on Fig. 2. It is seen that the number of subcarriers has no influence on the transmission quality but their amount is directly related with the transmission rate. The more carriers used, transmission rate is higher [4]. Limitations on number of subcarriers are date rate defined by norms and also the highest possible power of the signal (signal power is higher if there are more subcarriers) [4] [12].

On Fig. 3 can be seen that increasing the cyclic prefix duration improves the BER performance of the OFDM system and the best results were gained with length of CP set to 1/4 of the whole OFDM symbol length. Although this length gained lowest data rate, it's mostly used because of providing best protection.

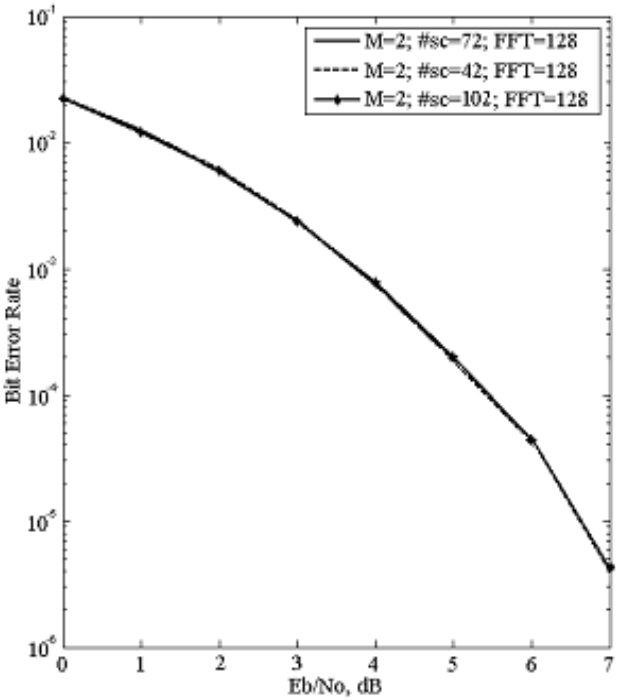

Fig.2. BER vs. E_b / N_0 graph:
influence number of subcarriers (right)

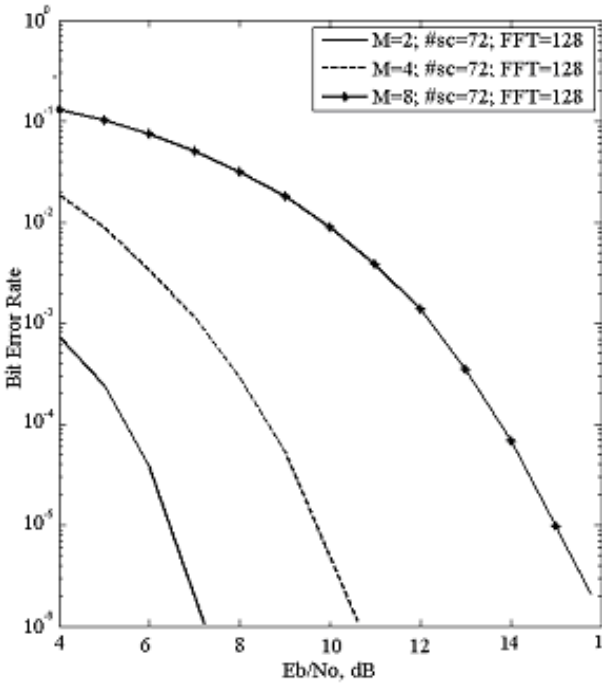

Fig.1. BER vs. E_b / N_0 graph:
influence of modulation parameter M

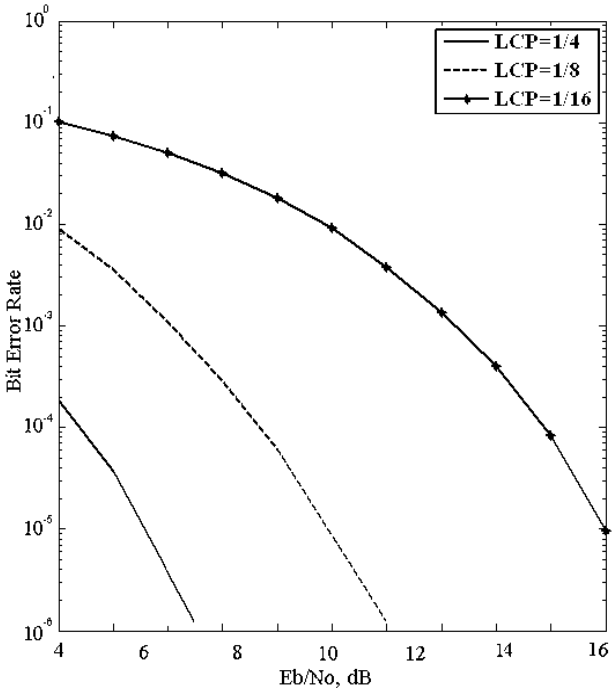

Fig. 3. BER vs. E_b / N_0 graph:
influence of cyclic prefix length

5. Conclusions

This work proposes a virtual BER model for M-ary PSK OFDM satellite communication systems. The program was realised in Matlab. Program's interface is providing a user friendly environment. Simply by typing the wanted parameters, the communication system is defined and the result, a BER versus E_b / N_0 graph is plotted. For comparison of influence of different values of parameter on BER, different graphs may be plotted at the same figure. The test program is especially suitable for educational propose. Furthermore, in this work, analysis of the influence of different types of PSK modulation, number of subcarriers and length of cyclic prefix on the signal performance and communication quality is made. It was shown that the BPSK gained the best signal performance. The number of subcarriers has no influence on the transmission quality but as number of subcarriers increases data rate increases. The limitation on number of subcarriers is the date rate defined by norms and also the highest possible power of the signal. It was shown that increasing the cyclic prefix duration improves the transmission quality, so the cyclic prefix with a length 1/4 of whole OFDM symbol provided best protection but had the lowest data rate.

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