Turbo-COFDM System over Multipath Rayligh Selective Fading Channel

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Abstract

OFDM system operates at high speed data rate over selective fading channel. In this paper a Turbo Coded OFDM (COFDM) system was presented and simulated over Rayleigh selective fading mobile radio channel. The type of the turbo code used is a parallel concatenated convolutional code (PCCC). The simulation results include a comparison between coded and uncoded OFDM system with different number of subcarrier. Furthermore, the number of iterations and input frame lengths effects on the performance were investigated. The result shows that the performance of OFDM system is enhanced when using turbo code in the OFDM system. Furthermore, the performance enhancement is increased as the number of iterations and input frame length is increased.

الخلاصة

أن نظام مزج تقسيمات التردد المتعامد (OFDM) المصمم يعمل على إرسال المعلومات عالية السرعة خلال قناة الحبو الانتقائي. في هذا البحث تم عرض ومحاكاة نظام OFDM المرمز عبر قناة الراديوية المتنقلة ذات الحبو الانتقائي نوع رالي أن نوع الترميز المستخدم هو الترميز المتوازي (PCCC). النتائج تتضمن مقارنه بين نظام OFDM المرمز وغير المرمز مع أعداد حاملات مختلفة. أضافتا إلى ذلك تم اختبار تأثير عدد الدورات و طول هيكل الإدخال. بينت النتائج إن أداء النظام يتحسن باستخدام الترميز. بالاضافه إلى ذلك فان النظام Turbo-COFDM يتحسن مع زيادة عدد الدورات و طول هيكل الإدخال.

1.Introduction

Orthogonal Frequency Division Multiplexing (OFDM) has been considered as a promising candidate to a high rate data transmission in a frequency selective channels environment, since many data streams are modulated and mapped on orthogonal carriers. Thus many low bit rate signals are transmitted in parallel, instead of one high bit rate signal. The low bit rate signals hardly suffer from intersymbol interference (ISI) in frequency selective channels, and because of orthogonality of the sub-carriers, it is possible to demodulate the received signal without cross talk between the information on the subcarriers [1,2].

Although OFDM is relatively immune to ISI, it can still be affected and equalization will help to combat the ISI and the Intercarrier interference (ICI). Moreover, equalizers for OFDM system will much less complex due to the reasons described above [3,4]. An elegant and simple method is to use a so-called guard interval between the

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transmitted symbols. This is also referred as cyclic prefix (CP) extension. A number of symbols from the end of each block can be appended to the beginning of the block as cyclic prefix (CP). Thus, after the convolution with the channel memory is cleared at the end of each block this cyclic prefix insertion is, however, is just redundancy and decrease the information rate [3,5]. There are two major obstacles in using OFDM in transmission system. First it is very sensitive to frequency offset caused by misalignment in carrier frequencies or Doppler shift. These imperfections will destroy sub-carrier orthogonality and introduce inter-carrier interference (ICI) among sub-carrier in addition to attenuation and rotation of each of the sub-carriers phase. The second disadvantage is that the peak power of the signal can be up to N times the average power (where N is the number of carriers) [2].

2. The OFDM System Modeling

The simulated OFDM system model is shown in Fig. (1). The input serial data stream is formatted into the word size required for transmission. The data is then transmitted in the parallel by assigning each data word to one carrier in the transmission. The data to be transmitted on each carrier is modulated into a BPSK format. After the required spectrum is worked out, an inverse Fourier transform (IFFT) is used to find the corresponding time waveform. The guard period is then added to the start of each symbol. A cyclic prefix is used here as a guard period. The effect of the channel is then introduced to the transmitted signal. This channel model allows the signal to noise ratio and the multipath effect to be controlled.

The receiver basically does the inverse operation to the transmitter. The cyclic prefix is removed. The FFT of each symbol is then taken to find the original transmitted spectrum. Single tap frequency domain equalizer is used to enhance the detection performance. Each transmitted carrier is then evaluated and converted back to the data word by demodulating the received symbol. The data words are then combined back to the same word size as the original signal.

3. Turbo Coding and COFDM System

A turbo code encoder with two component codes is shown in Fig.(2). Special types of convolutional codes, called Recursive Systematic Convolutional Codes (RSC), are used as the building blocks of turbo code encoder. The encoder ENC1 and ENC2 of the two components RSC, encode the same input information bits (U_k) but in different order, because of the interleaver before the ENC2 gives appropriate puncturing of parity bits from two encoders. This will produce a turbo code of desired rate. A fired Peseudo-random interleaver is used. It has been selected from a many types of random interleaver, which maps low-weight output code words to weight-two sequence. Fig. (3) shows the structure of turbo code decoder. The two decoder SISO1 and SISO2 corresponding to the contained encoders ENC1 and ENC2 are serially connected through the sum interleaver that used in the encoder.

In Fig. (3) an interleaving is denoted by (π) whereas (π^{-1}) denotes the inverse permutation (deinterleaving). In this paper iterative turbo decoding is implemented using Log-MAP algorithm Soft Input Soft Output (SISO) decoders. Appropriate soft outputs from the demodulator $\lambda\ (C_k)$ are used as distortion for information bits $\lambda\ (U_k)$ which initialized for the first iteration by assuming information bits to be equally probable. However, after the first decoding step $\lambda\,(U_k)$ apriori will be available from soft outputs of information bits computed in the previous decoding stage. The SISO decoder can be used to compute extrinsic information corresponding to both information bits and coded bits in general. For iterative decoding of a turbo code only $\lambda\,(C_k)$ is required. It is passed to the next decoder after each decoding step to improve the correction capacity of the decoding. Detection is made after the final iteration by adding the a posteriori probability values of information bits from the output of the last decoding stage to the values of a priori distributions [6, 7, 8].

The presented turbo-COFDM system model is shown in Fig. (4). The binary data is input to the parallel turbo encoder shown in Fig. (2). The coded data was input to the OFDM system shown in Fig. (1). Then, the output data from OFDM system was input to the parallel turbo decoder shown in Fig. (3) to find the received data.

4.Computer Simulation Tests and Results

The Turbo coded OFDM (Turbo-COFDM) and the original OFDM systems were simulated under the same conditions using MATLAB version 7 to allow various parameters of the system to be varied and tested. The performance of turbo code at single carrier system was tested too. Two fingers Rayleigh selective fading channel was used in the simulation process.

The parameters and the system configuration used in the simulation can be summarized by the following ;

Source data rate	2 Mbps
Modulation scheme	BPSK
Number of subcarrier	128
Number of FFT points	128
OFDM symbol duration	$16*10^{-6}$ sec
Guard interval	$1.6*10^{-6}$ sec
Guard interval type	Cyclic prefix
Required bandwidth	2 MHz
Model of simulated channel	Jacks Model [10]
Number of path	8 paths
Number of finger	2 finger
Multipath delay Spread	$3*10^{-6}$ sec
Doppler frequency	150 Hz
Type of channel coding	PCCC
Code rate	1/3
Transfer function	$[1,7,5]_2$
Number of iterations	2, 4, 6, and 8 iterations
Frame length	1000 bits and 2000 bits
Bit error rate	10^{-4}

The comparison between performance of turbo coded and uncoded single carrier system over 2-finger Rayliegh selective fading mobile radio channel is shown in Fig.(5). It is clear that the performance of turbo coded system is better than the performance of uncoded system by about 24 dB at bit error rate 10^{-4}. This advantage in gain is due to the cancellation of error by error correcting code.

To investigate the effect of number of iterations on the turbo code system extra test was carried out as shown in Fig. (6). From Fig. (6), it is clear that the performance of the system is enhanced as the number of iterations increased. This test is carried out when the input frame length equal to 1000 bits. Fig. (7) shows the performance of coded system at 2000 bits/frame. The performance of system is enhanced with the increasing the input frame length as shown in Fig. (8) at 4 iterations.

The relation between the number of iterations and Eb/No (in dB) with

different frame lengths, at bit error rate 10^{-4} is shown in Fig. (9). The Eb/No (in dB) decreased as the number of iterations increased.
A comparison between performance of presented turbo coded OFDM (Turbo-COFDM) system and simulated OFDM system (N=128) over 2-finger Rayliegh selective fading mobile radio channel is shown in Fig.(10). It is clear that the performance of turbo-COFDM system better than the performance of uncoded system by about 22 dB at bit error rate 10^{-4}. Furthermore, the performance of turbo-COFDM system gives advantage by about 27 dB compared with uncodede single carrier system, and about 3 dB compared with turbo coded single carrier system.
The performance of presented of the turbo-COFDM system with different number of iterations is as shown in Fig.(11). This test has been carried out at 128 subcarrier and 1000 bits/frame. It is clear that the performance is enhanced with the increased number of iterations.
Fig. (12) shows the effect of increasing the number of subcarrier on the performance of turbo-COFDM system at 2-iterations and frame length 1000 bits. The figure shows that the performance is better with increasing of the number of subcarrier. The performance of turbo-COFDM with different number of subcarrier at 2-iteration and 2000 bits/frame was shown in Fig. (13)
The relation between the number of subcarrier and Eb/No (in dB) with different frame lengths, at bit error rate 10^{-4} is shown in Fig. (14). The best performance occurs with largest number of subcarrier.

5. Conclusion

From the above results, it can be concluded that the presented turbo-COFDM gives advantages as compared with turbo coded single carrier system by abut 3 dB at BER=10^{-4}. Furthermore, the performance of the presented turbo-COFDM system better than the performance of OFDM system by about 22 dB at BER=10^{-4}. The performance of the coded system is enhanced with the increased the number of iterations, while the performance is degraded as the number of bits per frame is decreased. Furthermore, increasing the number of subcarrier leads to performance enhancement of the presented turbo-COFDM system.

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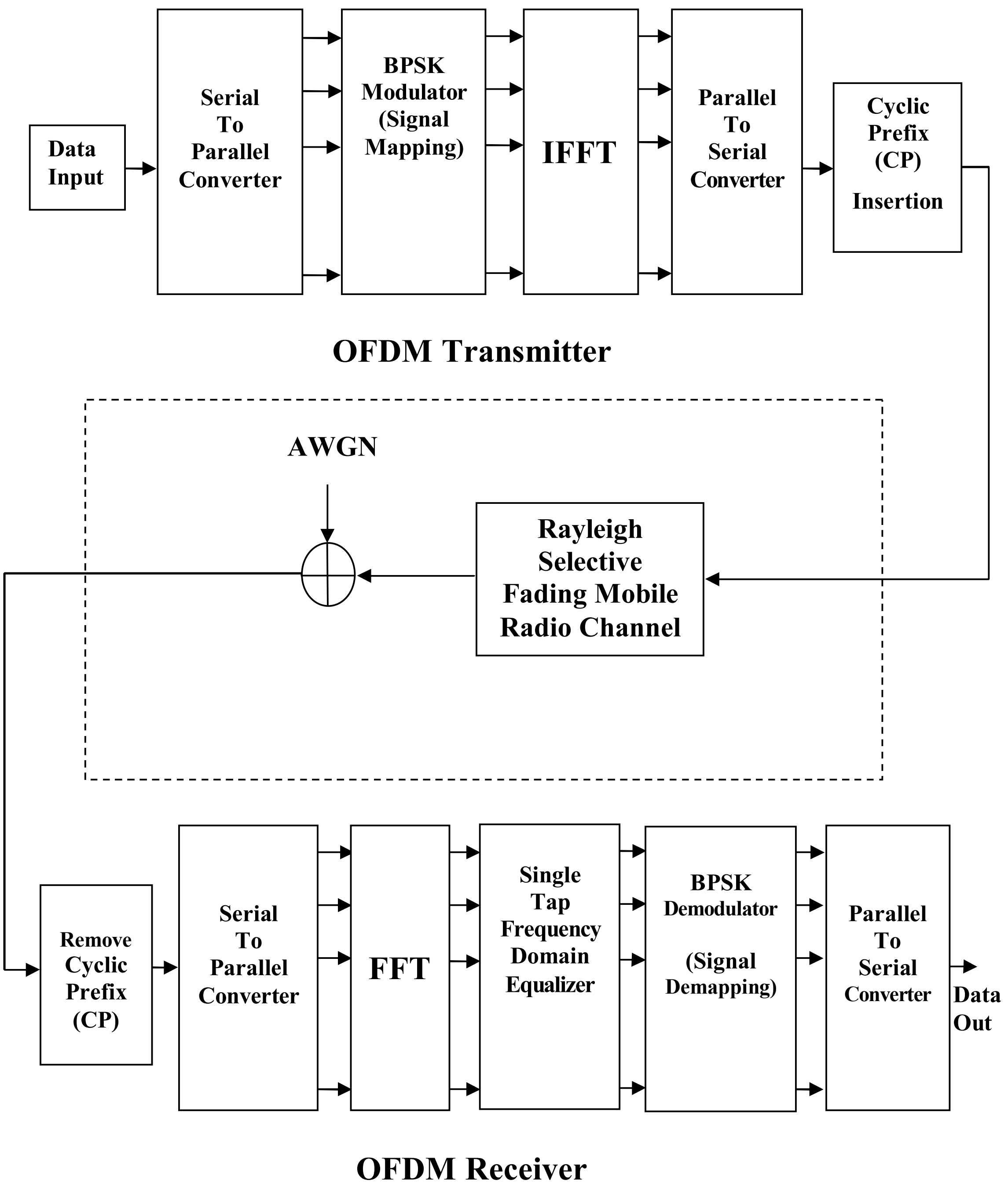
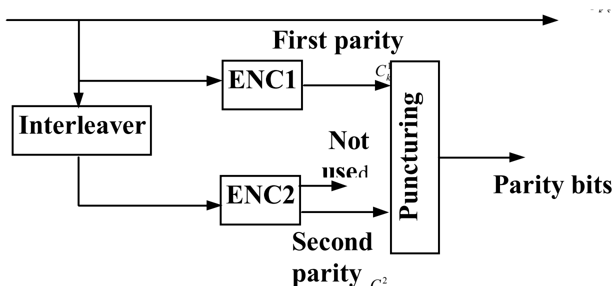


I Fig. (1) OFDM system model



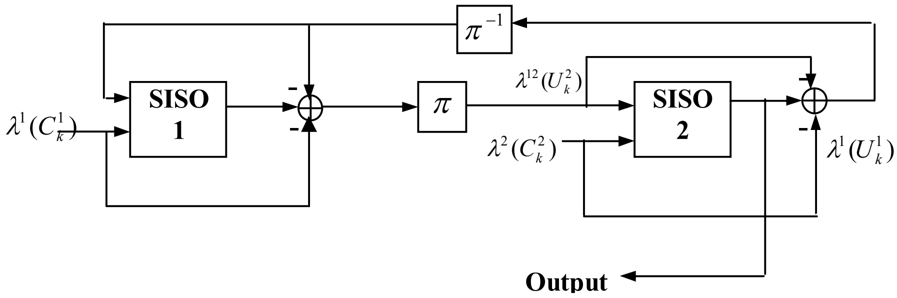


Fig. (3) Block diagram of PCCCs decoder

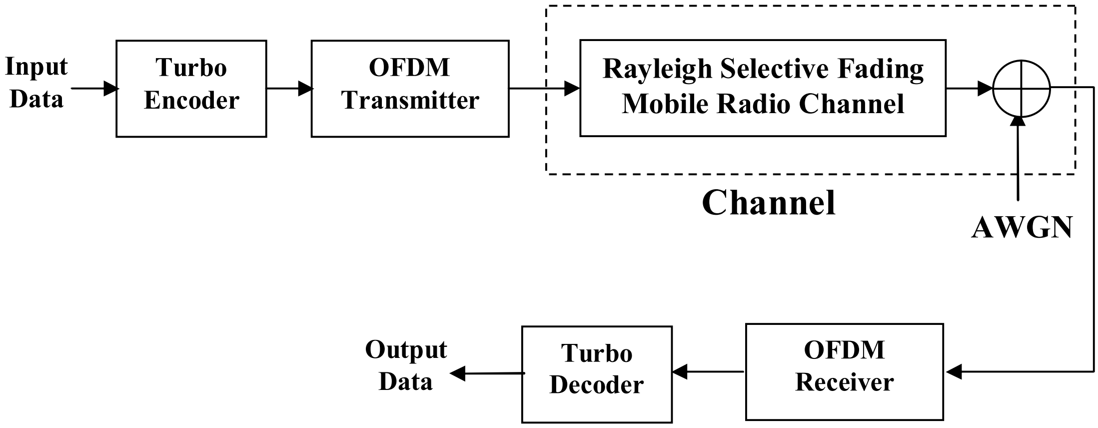


Fig. (4) Presented Turbo-COFDM System

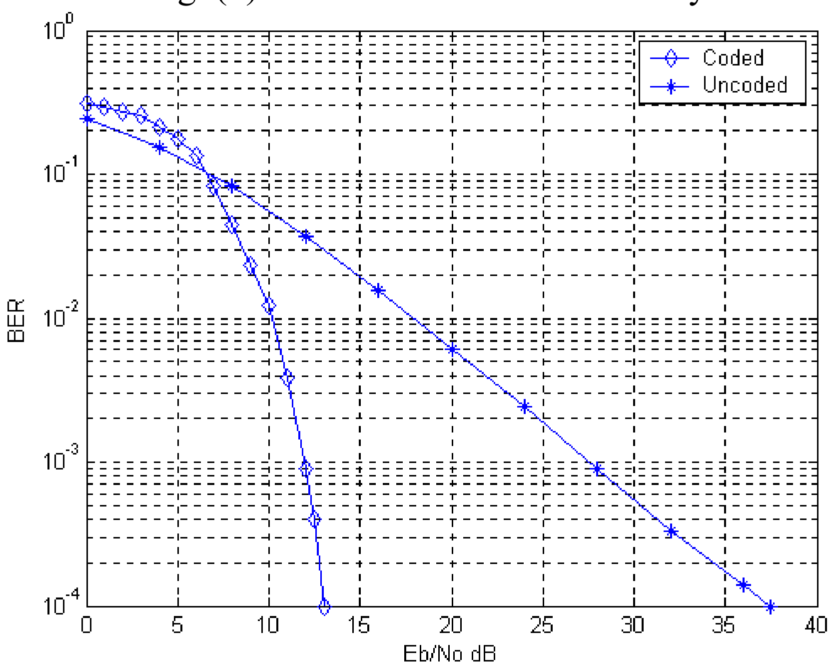


Fig. (5) Comparison between performance of coded and uncoded single carrier system over Raleigh selective fading channel

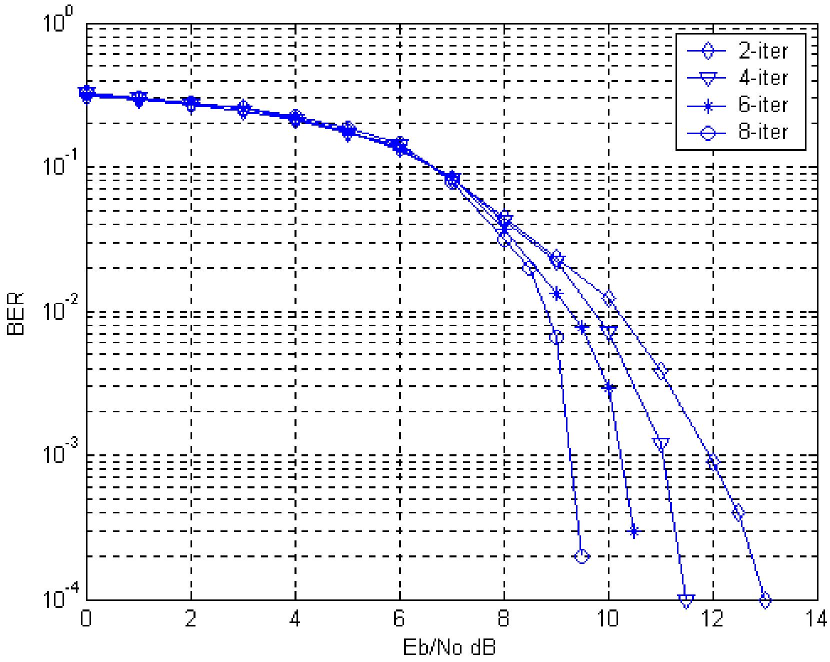


Fig. (6) Performance of turbo code-single carrier system with different number of iterations at frame length 1000 bit

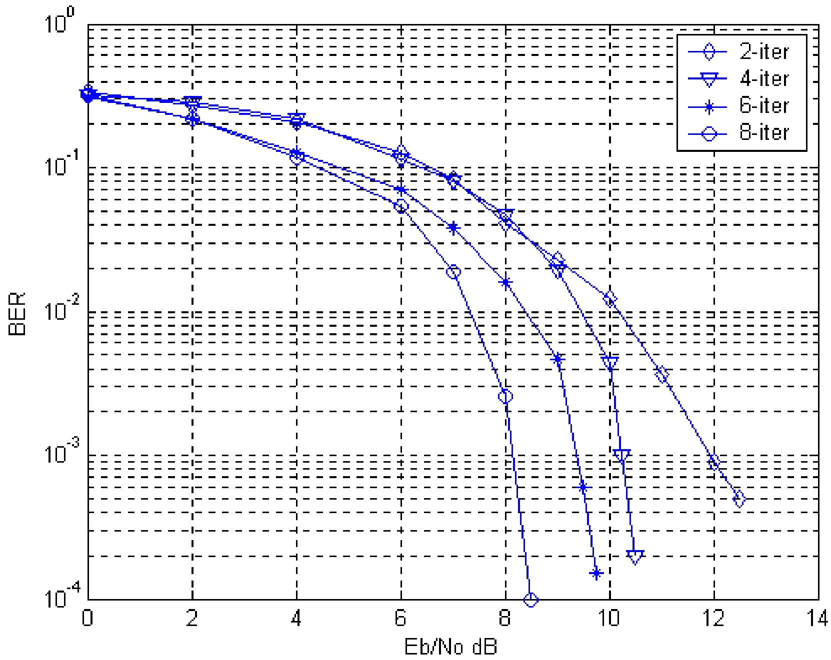


Fig. (7) Performance of turbo code-single carrier system with different number of iterations at frame length 2000 bit

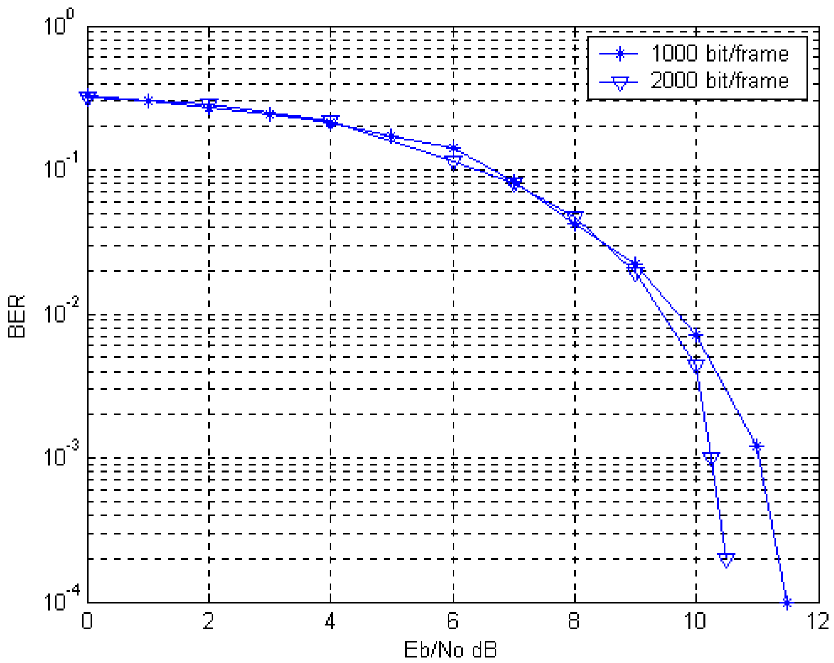


Fig. (8) Performance of turbo code-single carrier system with different number of frame length at 4 iteration

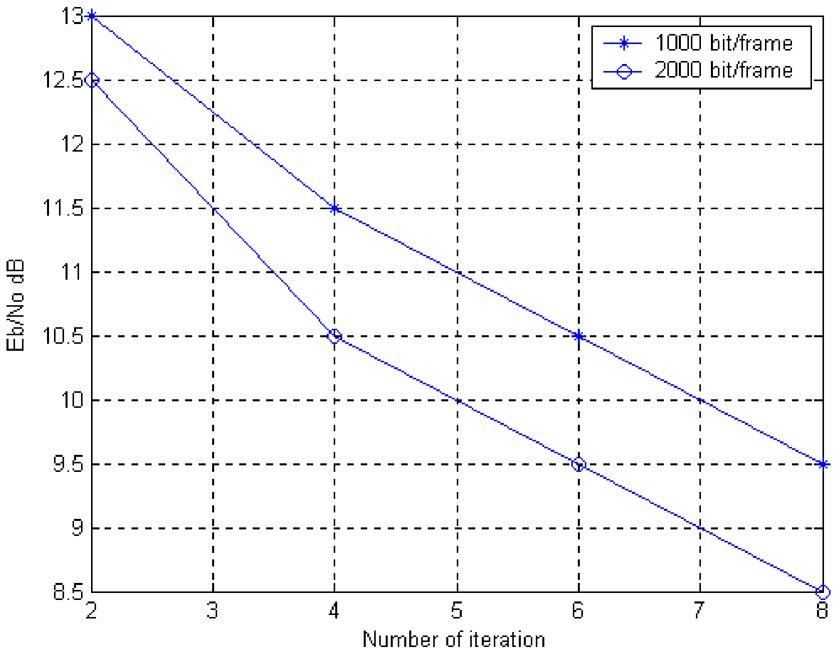


Fig. (9) Relation between number of iteration and Eb/No at different frame length

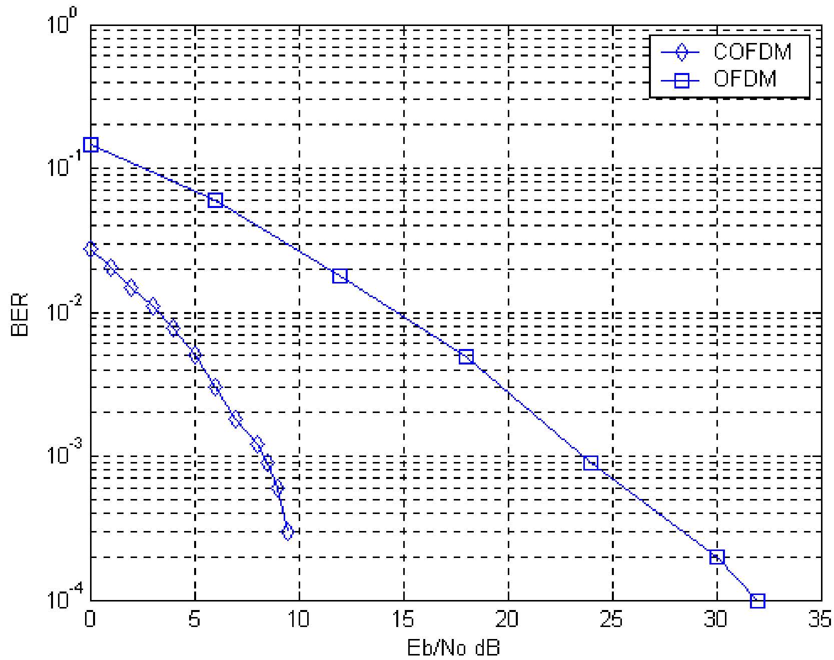


Fig. (10) Comparison between performance of OFDM system and presented turbo-COFDM system over Raleigh selective fading channel

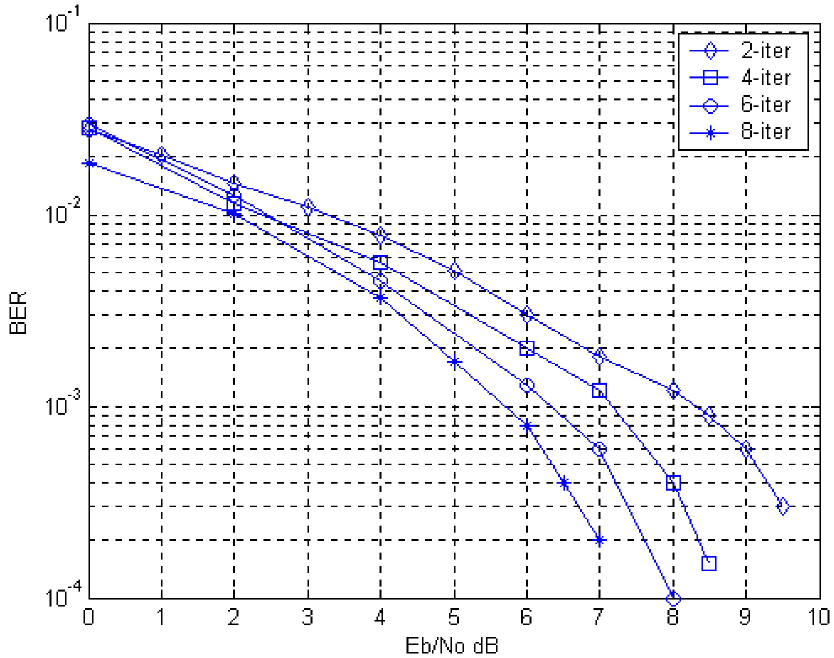


Fig. (11) Performance of presented turbo-COFDM system with different number of iterations at frame length 1000 bit and number of subcarrier 128

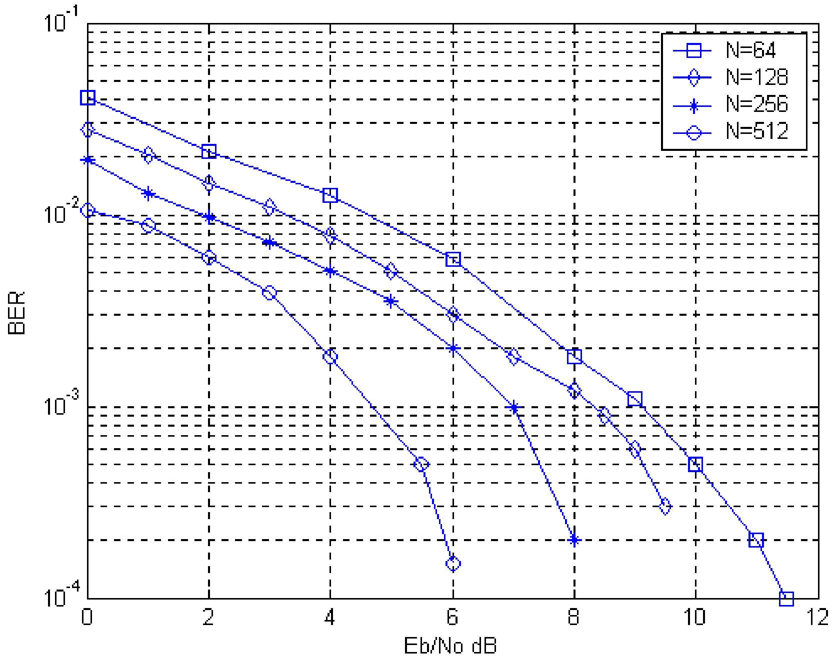


Fig. (12) Performance of presented turbo-COFDM system with different number of subcarriers at frame length 1000 bit and 2 iterations

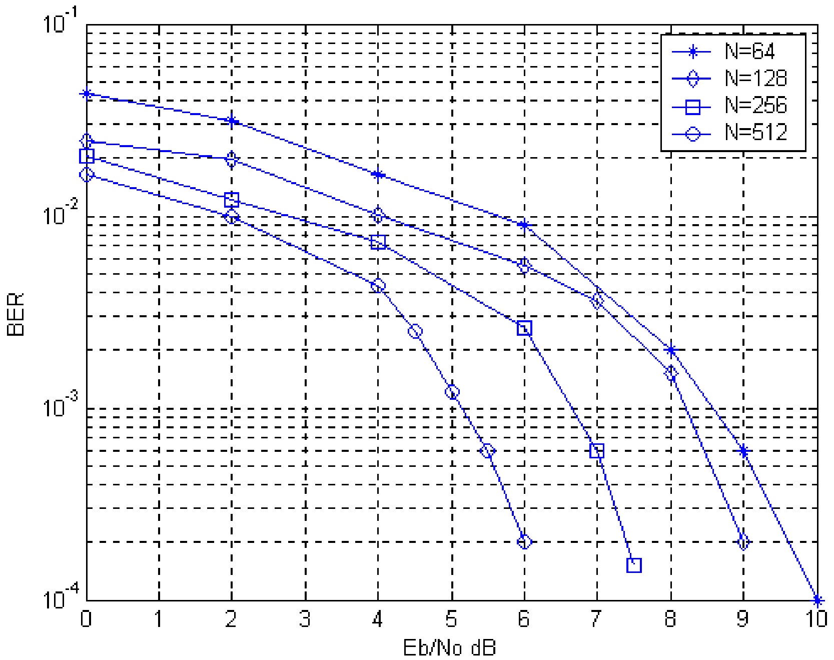


Fig. (13) Performance of presented turbo-COFDM system with different number of subcarriers at frame length 2000 bit and 2 iterations

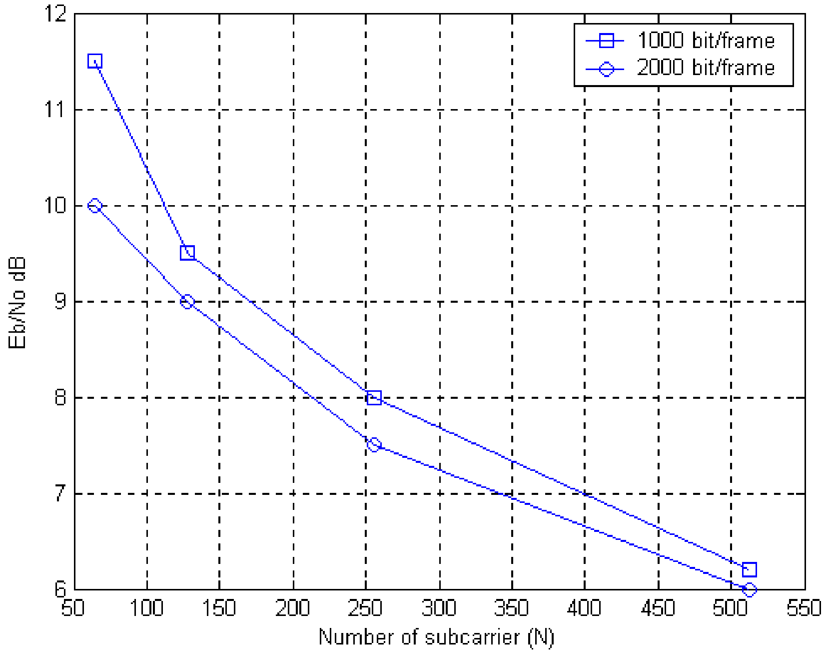


Fig. (14) Relation between number of subcarrier and Eb/No at different frame length and 2 iterations