DESIGN OF COFDM SYSTEM IN DIGITAL MOBILE COMMUNICATION

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ABSTRACT

In this paper I proposed a model for COFDM (coded orthogonal frequency division multiplexing) based on OFDM structure with TCM coding block and with Higher constellation modulation schemes (BPSK, QPSK, 16-QAM, QASK)
Computer simulation models with Matlab system for performance assessment over the effects of channel like noise (AWGN) and multi-path fading channel such as (Rayleigh distribution)

As a result these models of proposed COFDM have better gains in dB at the receiver output under ideal and Rayleigh fading channel and some features like high data rate up to 20MHz at carrier frequency 1GHz, robust to channel propagation effects, increasing resistance to types of interferences, and provide the security by hid the signal from eavesdropper.

These features make the proposed model more suitable to use with wireless communication for 4G (fourth generation) digital mobile communication.

Keywords: COFDM (coded orthogonal frequency division multiplexing), TCM (Trellis coded modulation, BPSK (binary phase shift keying).

تصميم نظام COFDM للاتصالات الرقمية المتنقلة

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الخلاصة

في هذه البحث، اقترحت نموذج COFDM ترميز التقسيم الترددي المتعامد والمستند على تقنية OFDM بتشفير الكتلة مضافا الى ذلك الترميز نوع TCM للنموذج المقترح واستخدمت في هذا النموذج المقترح عدة انواع من تقنيات التضمين الرقمي هي (BPSK, QPSK, 16-QAM, QASK) .

تم إعتماد برنامج MATLABلمحاكاة وإختبار أداء النموذج المقترح COFDM في هذا البحث وملاحظة تأثيرات القناة عليها مثل ، الضوضاء البيضاء AWGN وتأثيرات توهين تعدد المسار Multi-Path Fading Channel مثل (Rayleigh distribution) حيث بينت النتائج ان النموذج COFDM وباستخدام نوع التضمين QPSK ونظام الترميز TCM code هو الافضل والاقوى في العمل ويعطي معامل ربح للنظام اكثر من غيرة تحت تأثيرات القناة المتعددة والتداخلات وبالنتيجة فان تقنية COFDM تمتلك بعض المميّزات منها القدرة العالية على نقل البيانات تقدر حوالي 20MHz فما فوق ، متانة تجاه تاثيرات القناة ، ممانعة عالية لانواع التداخلات وتزودنا كذلك بإمكانية الحماية الامنية للمعلومات وذلك بإخفاء الاشارة عن المتنصتين. هذه المميّزات تجعل النموذج المقترح مناسباً بشكل كبير لغرض الاستعمال في انظمة الجيل الرابع 4G للاتصالات اللاسلكية النقالة .

INTRODUCTION

As wireless communications have experienced great success and are widely used everywhere, the demands for good quality and variety of service have increased. To fulfill these desires development for high speed wireless communication systems has been investigated. One successful approach to an achieving reliable and efficient high speed data transmission scheme is OFDM (Jonghyun,2003).

Orthogonal Frequency Division Multiplexing (OFDM) was discovered by chang in his pioneering paper in 1966. The basic idea is that dispersive transmission media can be rendered nondispersive, if the transmission channel is subdivided in a high number of parallel, low-rate, nondispersive channels.

Multiple Access (MA) scheme for 4G must also be low complexity, robust against several wireless channel and resilient to interference. Thus, OFDM stands a good chance to become the prime technology for 4G .Pure OFDM or Hybrid OFDM will be most likely the choice for physical layer multiple access technique in the future generation of telecommunications systems (Anibal,2000).

OFDM is a method of digital modulation in which a signal is split into several narrowband channels at different frequencies and it has been widely used in broadcast systems. It is being used for digital audio broadcasting (DAB) and for digital video broadcasting (DVB) in Europe and Australia(Sheungl,2005). It was selected for these systems primarily because of its high spectral efficiency and multipath tolerance Signals are orthogonal if they are mutually independent of each other. Orthogonally is a property that allows multiple information signals to be transmitted perfectly over a common channel and detected, without interference. Loss of orthogonally results in blurring between these information signals and degradation in communications(Georgios,2005). Many common multiplexing schemes are inherently orthogonal. Time division multiplexing (TDM) allows transmission of multiple information signals over a single source is transmitted preventing any interference between the multiple information sources. In the frequency domain most FDM system are orthogonal as each of the separate transmission signals are well spaced out in frequency preventing interference (Aero et al 2003).

Although these methods are orthogonal the term OFDM has been reserved for a special form of FDM and the subcarriers in an OFDM signal are spaced as close as is theoretically possible while maintain orthogonally between them and OFDM can be easily generated orthogonally by using an Inverse Fast Fourier Transform (IFFT) and received using a Fast Fourier Transform (FFT). **Fig.(1)** shown the orthogonally between OFDM carriers(Kihira,2007).

Principles of OFDM

An OFDM signal is the result of the addition of several subcarriers that are modulated by means of phase shift keying (PSK) or quadrature amplitude modulation (QAM).**Fig (2)** illustrate OFDM transmitter, and if we have a (K) complex symbols modulated in QAM or PSK.
From figure above, with input sequence (a[k]), where $0 \le k \le N-1$, the frequency spacing Δf between the different sub-carriers and the symbol interval T_u, the transmitted can be expressed as:

$$\mathbf{x}(t) = \sum_{k=0}^{N-1} \mathbf{a}[\mathbf{k}] h_k(t)$$

$$\mathbf{x}[\mathbf{n}] - \sum_{k=0}^{N-1} \mathbf{a}[\mathbf{k}]\, e^{j2\pi k \Delta f t} \qquad 0 \le t \le T_u \qquad (1)$$

If the signal is sampled at rate of T_u/N then we can rewrite the equation (1) as:

$$\mathbf{x}[\mathbf{n}] = \mathbf{x}\left(\frac{n}{N} T_u\right) = \sum_{k=0}^{N-1} \mathbf{a}[\mathbf{k}] e^{j2\pi k \Delta f T_{u/N}} \qquad (2)$$

$$\mathbf{x}[\mathbf{n}] = \sum_{k=0}^{N-1} \mathbf{a}[\mathbf{k}]\, e^{j2\pi nk/N} \qquad (3)$$

After taking inverse Fourier transform (IDFT) for the symbols, the encoded data can be expressed as: (Georgios,2005).

X[n] = N.IDFT {a[k]}

$$\mathbf{x}[\mathbf{n}] = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} a[k]\, e^{j2\pi nk/N} \quad , n=0,1,\dots,N-1 \qquad (4)$$

To immunity from multipath, OFDM used Cyclic Prefix (CP). The CP is a copy of the last Npre symbols.The CP makes the transmitted signal periodic with period N. We can express the encoded data with a cyclic prefix as: (Moray,2008).

X(n) = X(n+N) , n=-Npre,……..,-1 (5)

At the receiver the Fourier transform (DFT) as shown in **Fig. (3)** implement to find the approximate signal â[k]. Then can be expressed as: (Leonardo et al 2008).

â[k] = DFT {X[n]}

$$= \mathbf{a}[\mathbf{k}] \qquad (6)$$

The equation (6) above is defined as (Laith,2006) :

There are two most important features of the OFDM technique, which are different from the traditional FDM systems.

1) Each sub-carrier has different center frequency. These frequencies are chosen so that the following integral over a symbol period is satisfied :

$$\int_0^{T_u} a_m e^{jw_m t} a_1 e^{jw_1 t}\, dt = 0 \quad , m \neq 1 \qquad (7)$$

The sub-carrier signals in an OFDM system are mathematically orthogonal to each other.

2) IDFT and DFT function can be exploited to realize the OFDM modulation and demodulation instead of the filter banks in the transmitter and receiver to lower the system implementation complexity and cost. This feature is attractive for practical use.

The IFFT and FFT algorithms can be used to calculate the IDFT and DFT efficiently. IFFT and FFT are used to realize the OFDM modulation and demodulation to reduce the system implementation complexity and to improve the system running speed (Laith,2006).

SYSTEM MODEL

In this paper the proposed computer model of COFDM is simulated by using MATLAB program to allow various parameters of these systems to be varied and tested. COFDM is essentially a new method of transmitting high data rate digital signals over 4G mobile communication systems that means the bandwidth would be much wider (100 MHz) and data would be transferred at much higher rates up to 1GHz and it's a robust technique in fading environment [Fernando et al 1998]. **Fig.(4)** shows the transceiver structure used for COFDM model. After generate data the Encoder is placed at the first stage and used TCM code .

Trellis – coded modulation (TCM)

Trellis coded modulation TCM is amalgamation of coding and modulation that provides a coding gain of 3 to 6 dB without the additional bandwidth necessary for the redundant coding symbols. This was an important innovation that was quickly adopted in many areas of wireless communications.

TCM uses a rate k/n convolutional encoder and directly maps those points onto a set of signal constellation points using a technique called mapping by set partitioning (Harry,2006).

Serial To Parallel Converter And Digital Modulator

The output serial bit stream {(b_i), which $b_i= \pm1$ and i=0, 1, 2, with bit duration T_b seconds} is converted to parallel bit stream into blocks of N bit which represented as:

$$C_{(k,p)}$$

Where k=0,1,2,…. And p= 0, 1, 2… N-1 the N denotes the number of carriers and

=±1.And then sent the parallel bit stream to the digital modulator that outputs a complex number which represented as (Imran et al 2006).

$$C_{[k,p]} = cos(\theta_{k,p}) + jsin(\theta_{k,p}) \quad (8)$$

$$C_{k,p} = C_{k,p}\pi h + \pi h \sum_{q=0}^{k-1} C_{q,p} + \emptyset \quad (9)$$

Where h defines the PSK mapper and Ø represents to the initial mapping point that is assumed to be zero. The modulator could be BPSK, QPSK, 16-PSK, 16-AM, and QASK.

IFFT Block

The output signal sent to Inverse Fast Fourier Transform (IFFT) block which applied those results in orthogonal signals on the sub channels. The modulated by orthogonal carrier and finally summed to give the transmitted OFDM symbol, the IFFT yield the OFDM symbol consisting the sequence

$X_{[n]} = X_{[0]}, X_{[1]}, \dots, X_{[N-1]}$ Of length N, where.

$$X_{[n]} = \frac{1}{\sqrt{N}} \sum_{i=0}^{N-1} X_{[i]} e^{j2\pi ni/N} \quad ,0 \le n \le N-1 \quad (10)$$

The orthogonal signals are then converted back into a serial stream and after converting from parallel to serial stream will adding cyclic prefix and then converted from digital to analog signal after this stage the signal converting up to the desired carrier frequency to transmit signals. The output from the transmitter is:

$$S(t) = \sum_{L=-\infty}^{\infty} S_L(t) = \sum_{L=-\infty}^{\infty} \sum_{k=0}^{N-1} X_{k,L} \emptyset_k(t-LT) \quad (11)$$

Where L is OFDM symbol number and.

$$\emptyset_k(t) = \begin{cases} \frac{1}{\sqrt{T - T_{cp}}} e^{j2\pi \frac{w}{N} K(t - T_{cp})} & \text{if } t \in [0,T] \\ 0 & \text{otherwise} \end{cases} \quad (12)$$

T is the symbol length (second) =N/W+ T_{cp}, N is the number of subcarrier, W is bandwidth (Hz), T_{cp} is length of the cyclic prefix (second).

The Channel

COFDM output transmitter is applied to the channel, should be noted that channel consist of AWGN and multi-path fading as a Rayleigh distribution.

The receiver

At the receiver, the signal received *r(t)* pass through analog to digital (A/D) converter and then removed cyclic prefix, the data sequence converted .

$$FFT\{X_{[n]}\} = X_{[i]} = \frac{1}{\sqrt{N}} \sum_{i=0}^{N-1} X_{[i]} e^{j\frac{2\pi ni}{N}} \qquad ,0 \le n \le N-1 \qquad (13)$$

Back to parallel sequence (S/P) and it's applied to Fast Fourier Transform (FFT), the N-point FFT of $X_{[n]}$ can expression as:

Then the output signal will be make demodulation and convert it from parallel to data sequence, in finally, the decoding block will be decoded by minimizing Euclidean distance between the received signal point and the points of the constellation according to the modulation scheme (Stever et al 2009).

SIMULATION RESULTS

Computer simulation tests have been carried out to evaluate the performance of different types of digital modulation of proposed models COFDM and the improvements of the (SNR) against (BER) are be calculated in the digital receiver output also assumed the signal will affect by the frequency selective fading which has been chosen a Rayleigh distribution channel addition to AWGN. The procedure contains initialization parameters input data. The parameters that can be set at the time of initialization are the number of simulated OFDM symbols, cyclic prefix length, modulation, coding rate, range of signal to noise ratio (SNR) values, and channel model for simulation.

In **Fig.(5)** the performance of OFDM system under Rayleigh fading channel shows the BER $=10^{-3}$ required SNR=24dB,while in the proposed model COFDM with TCM code and QPSK modulation over Rayleigh fading channel in **Fig.(6)** the required SNR=5dB at the same BER therefore we can see the performance of proposed model COFDM using BPSK or QPSK have better gains in dB under ideal and Rayleigh fading channel than the others, it is clear the advantage of used encoding TCM code with conventional OFDM system due to mitigate the effects of the multi-path fading channel.

In **Fig.(7)** which represents the performance for proposed model COFDM with QPSK and QAM modulation and two type of coding (TCM, Gray) code respectively and all other parameter as shown in table (4-1), over the same channel condition, it can be seen the SNR required =7.7 dB at BER$=10^{-4}$ for COFDM with Gray code, while in proposed model COFDM with TCM encoding the SNR 6dB. Therefore the proposed model with QPSK modulation and TCM coding is significantly outperforms the others systems for this channel model

Fig.(8) shows the BER performance of different signals, once of them for proposed model COFDM with QASK modulation and TCM coding, the other performance for conventional OFDM with QASK and without coding, the channel effect assumed the effect of Rayleigh fading channel, it can be seen at BER $=10^{-5}$ the SNR required is about 6dB for proposed COFDM using QASK and TCM code, while in OFDM system using QASK without coding the SNR =7.8dB, that's clear the advantage of used coding block (TCM encoding) with conventional OFDM to make the system a robust toward the effects of multi-path fading channel**.**

CONCLUSIONS

In this paper the high data rate COFDM based on OFDM structure was proposed model and tested with Higher constellation modulation schemes (BPSK, QPSK, 16-QAM, QASK) are considered for Rayleigh fading channel with TCM code and GRAY code. The results show that the performance of OFDM with TCM code and QPSK modulation have better gains in dB at the receiver output under ideal and Rayleigh fading channel when compared with OFDM Gray code and without coding. Considered the fact that TCM coding has a lower trellis size.
The proposed COFDM is low sensitivity to time synchronization errors and robust against inter-symbol interference (ISI), inter-carrier interference (ICI) and fading caused by multi-path propagation such as Rayleigh distribution channel.
Finally the proposed COFDM is suitable to use with wireless communication for 4G (fourth generation) digital mobile communication and the loss of efficiency caused by cyclic prefix / guard interval. and it have very large bandwidth.

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Table (1) shows the system parameters.

Parameters	values
Channel Bandwidth, BW	2 GHz
Access scheme	OFDM
Modulation scheme	QPSK, BPSK, 16-QAM, QASK
No. Of symbol	100
Data rate	UP to 20MHz
Ratio of Guard time to useful symbol time (G)	1/4
Coding	TCM
Code rate	1/2
Channel model	Ideal (AWGN only)
	Rayleigh fading

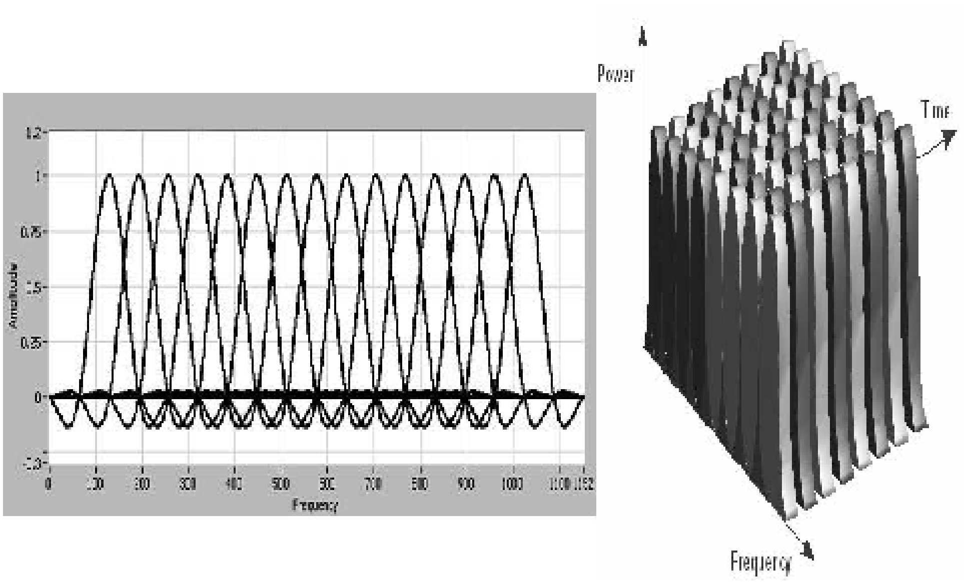

Fig. (1) Orthogonally between OFDM sub-carriers

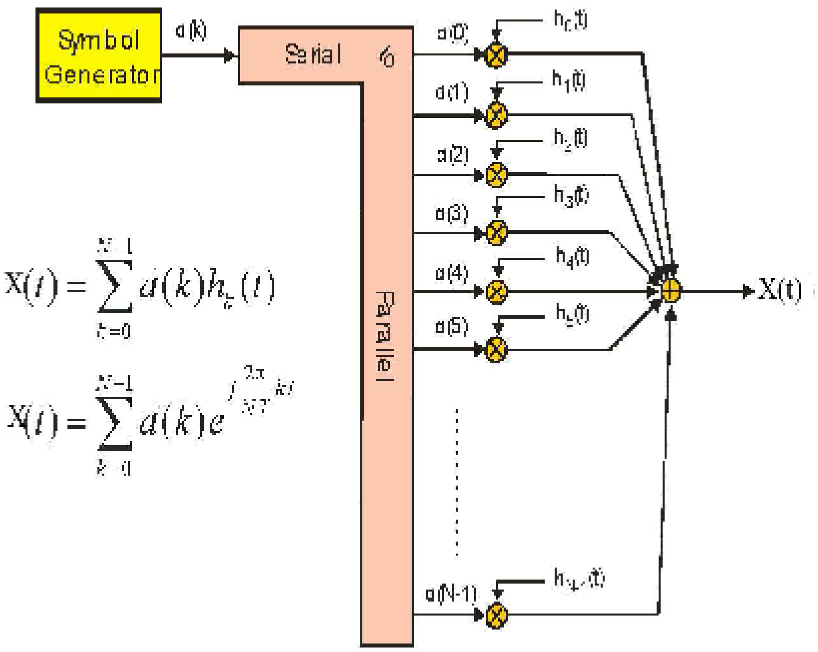

Fig. (2) OFDM Transmitter structure

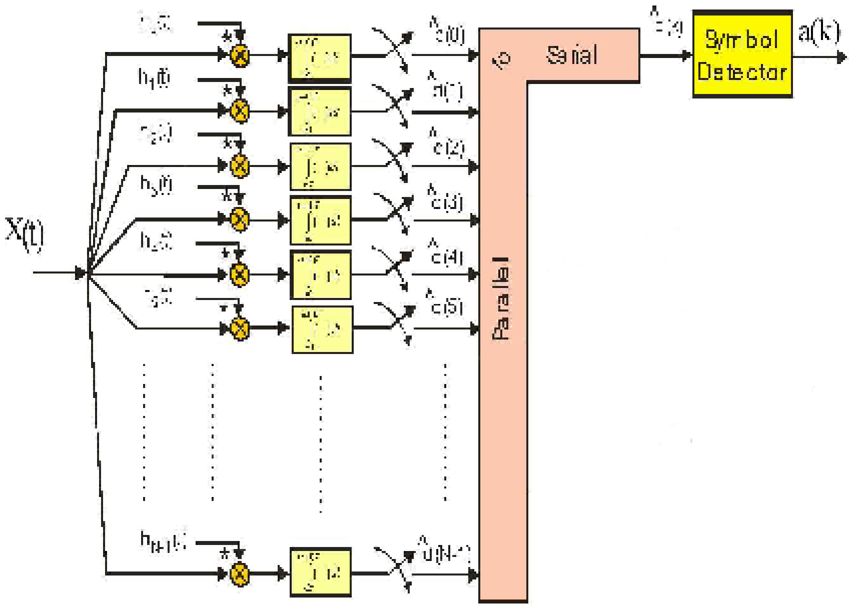

Fig. (3) :OFDM Receiver structure

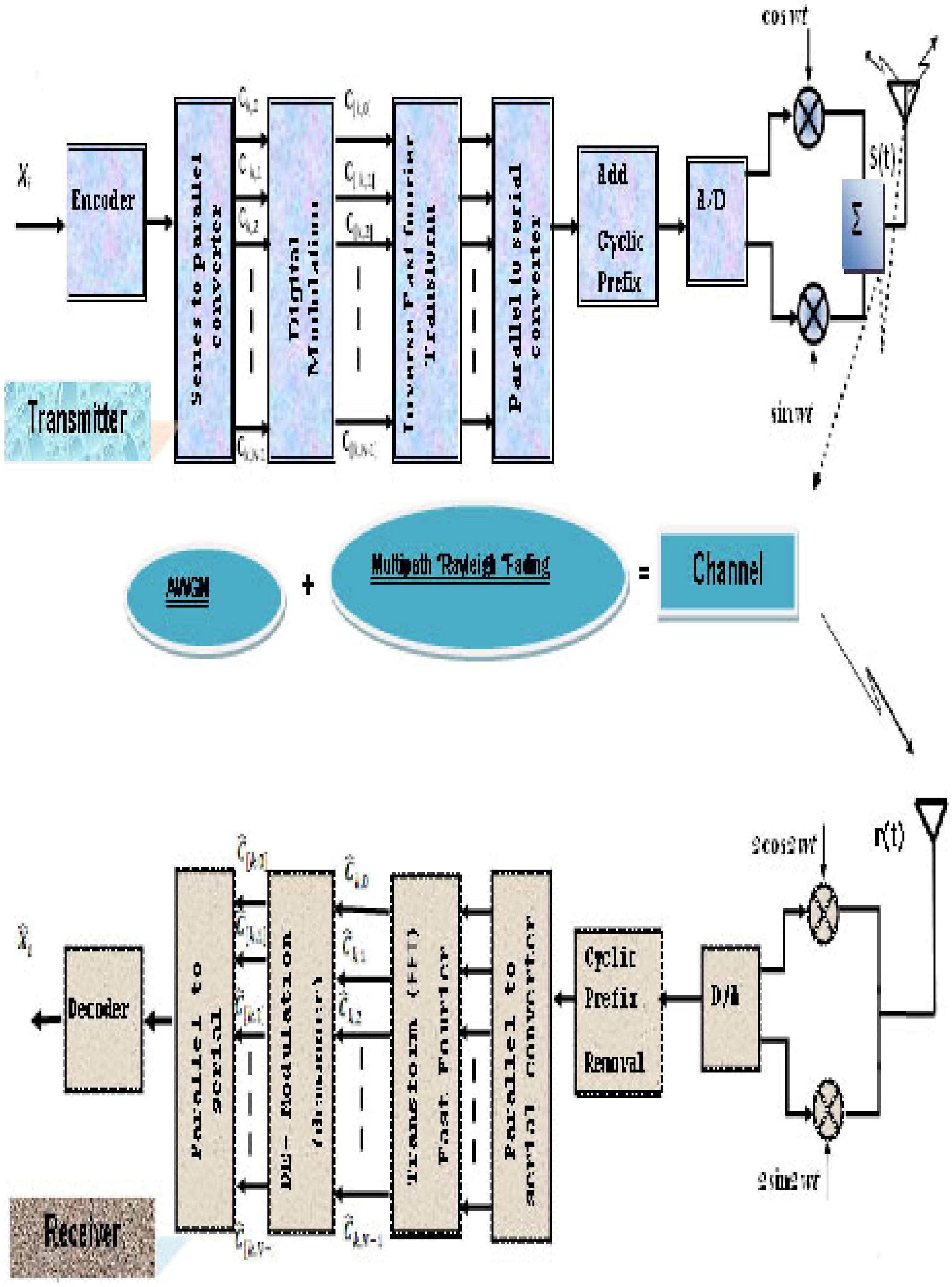

Fig. (4) Block diagram for proposed COFDM model.

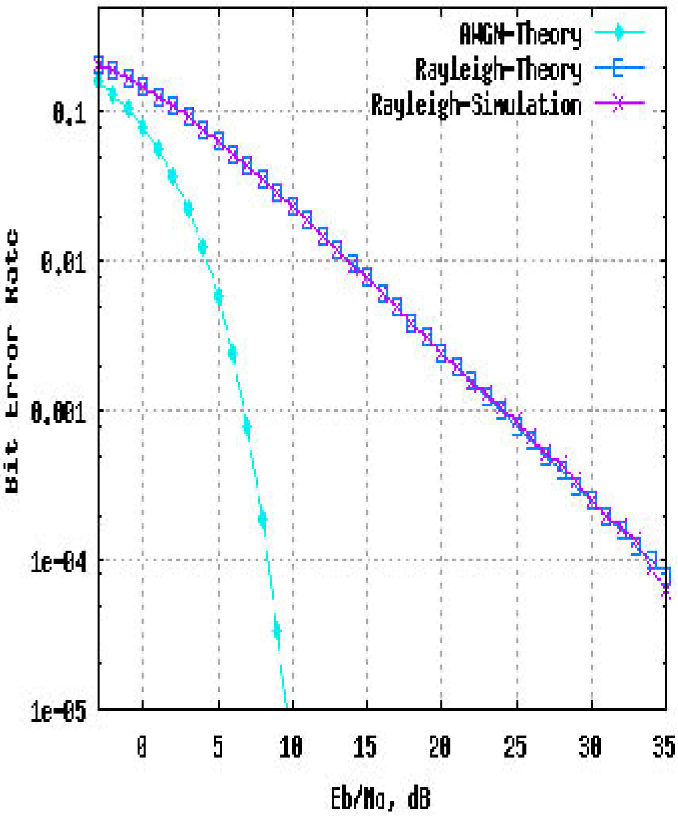

Fig. (5) performance of conventional OFDM with BPSK modulation without coding.

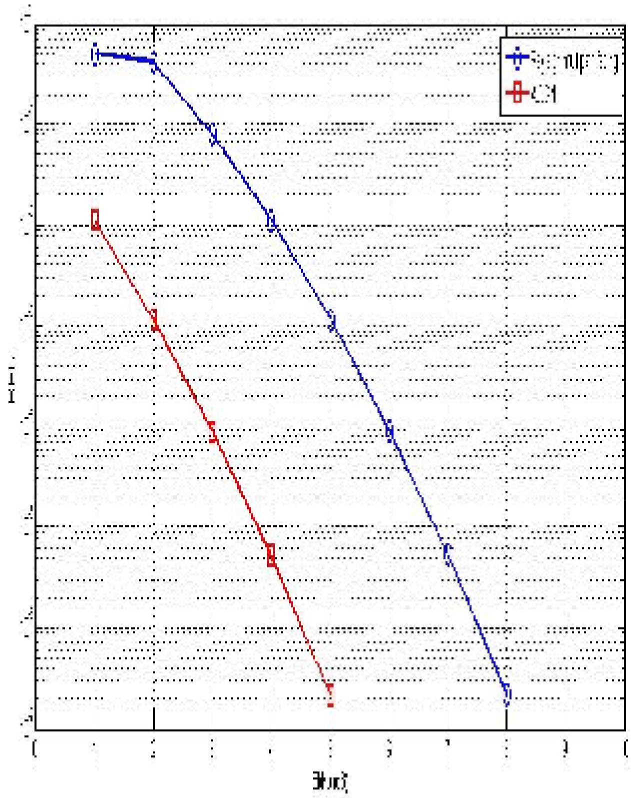

Fig. (6) performance of the proposed model COFDM with QPSK and TCM code over Rayleigh fading channel

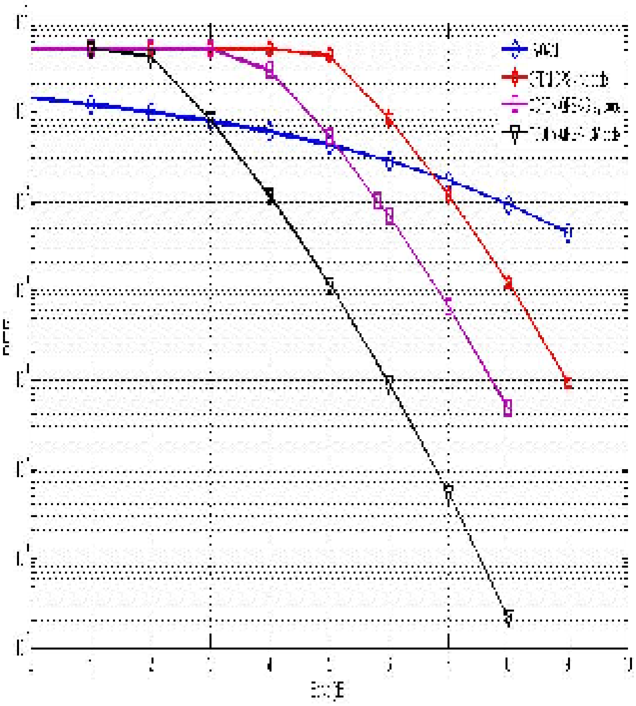

Fig. (7) performance of different systems over Rayleigh fading channel.

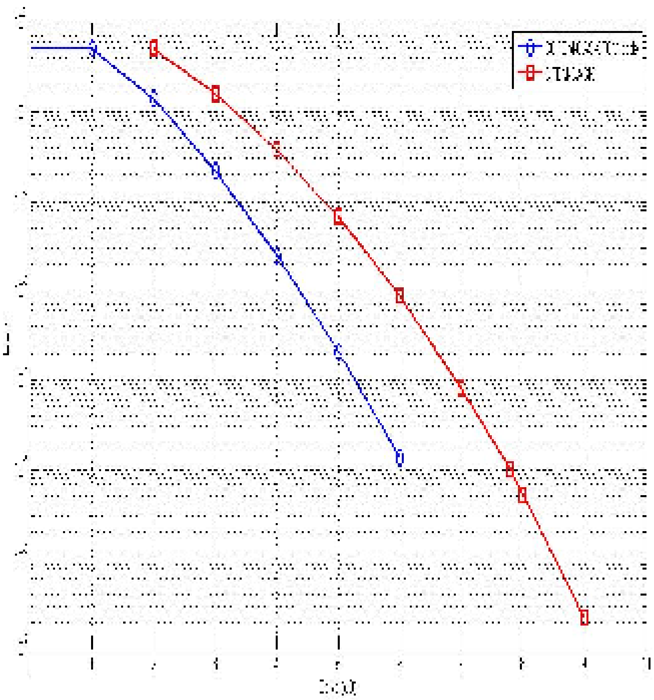

Fig. (8) the BER performance for proposed model COFDM with TCM code using QASK modulation over Rayleigh fading channel.