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Analysis of Bit Error Rate in Fast Optical-OFDM for Long Term Evaluation Networks

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Abstract

A communication system has a capability of transferring the data from source to destination on this planet. There will be a rapid growth in communication technology due to the day by day enhancement in the number of subscribers. Thus the need of bandwidth has increased tremendously, but most of the networks were restricting the bandwidth allocation to certain limit, which in results degradation in the performance of the system there by its quite difficult to obtain high speed data transfer over the communication channel. These reasons motivate us to implement efficient bandwidth based data transmission schemes. In this article, we proposed an analysis of bit error rate in fast optical OFDM (FO-OFDM) systems for LTE up and down links. We utilized Bi-orthogonal wavelet decomposition (BoWD) to improve the spectral efficiency of the proposed system. Additionally, we also considered different channel distribution environments to demonstrate the robustness and effectiveness of our proposed approach. Extensive simulation results show that the proposed model performed superior over the state-of-art OFDM system such as Optical-DFT-OFDM.

1. Introduction

OFDM With the quick development in innovation, the interest for flexible high data-rate administrations has likewise expanded. The execution of high data rates communication systems is restricted by frequency specific multipath blurring which brings about inter symbol interference (ISI). In the wireless channels, impedances, for example, blurring, shadowing and interferences because of multiple client get to very corrupt the system execution. . Multicarrier modulation (MCM) is an answer that conquers these issues in wireless channels. It is the method of transmitting data that partitions the serial high data rate streams into a substantial number of low data rate parallel data streams [1]. Orthogonal Frequency Division Multiplexing (OFDM) is a sort of multi-carrier modulation, which partitions the accessible range into various parallel subcarriers and each subcarrier is then balanced by a low rate data stream at various carrier frequency. The regular OFDM system makes utilization of IFFT and FFT for multiplexing the signals and lessens the multifaceted nature at both transmitter and beneficiary [2]. OFDM is included a mix of modulation and multiplexing. The first data flag is part into numerous autonomous signals, each of which is regulated at an alternate frequency and afterward these free signals are multiplexed to make an OFDM carrier. As all the subcarriers are orthogonal to each other, they can be transmitted all the while over a similar bandwidth with no interference which is an essential favorable position of OFDM [3]. OFDM makes the fast data streams powerful against the radio channel weaknesses. OFDM is an effective procedure to deal with expansive data rates in the multipath blurring condition which causes ISI. With the assistance of OFDM, an expansive number of overlapping narrowband subcarriers, which are orthogonal to each other, are transmitted parallel inside the accessible transmission bandwidth. In this way, in OFDM, the accessible range is used proficiently. With the quickly developing innovation, the requests for rapid data transmission are likewise expanding. OFDM is a multicarrier modulation procedure which has the ability to satisfy this interest for expansive capacity. OFDM is dependable and efficient to deal with the handling energy of computerized flag processors. OFDM is utilized as a part of numerous applications, for example, IEEE 802.11 wireless standard, Cellular radios, GSTN (General Switched Telephone Network), DAB (Digital Audio Broadcasting), DVB-T (Terrestrial Digital Video Broadcasting) [3], HDTV broadcasting, DSL [4] and ADSL modems and HIPERLAN write II (High Performance Local Area Network) [4]. OFDM (Orthogonal Frequency Division Multiplexing) is one sort of the methods of MCM (Multi-Carrier Modulation), which has a place with the field of wireless communication. The fundamental thought of MCM is to balance signals onto numerous carriers and afterward join these signals to transmit out (figure1). The modulation system has S/P converter, which changes over the high rate serial data into lower rate paralleled data. Because of the lower rate data has longer time length, which is ordinarily far bigger than the most extreme deferral of the flag transmitting channel, accordingly makes it conceivable to well-battle multi-way effect and simple to balance at the collector. Be that as it may, MCM additionally has a drawback. In the event that the quantity of carrier N is huge, at that point the entire system needs a wide band of frequency.

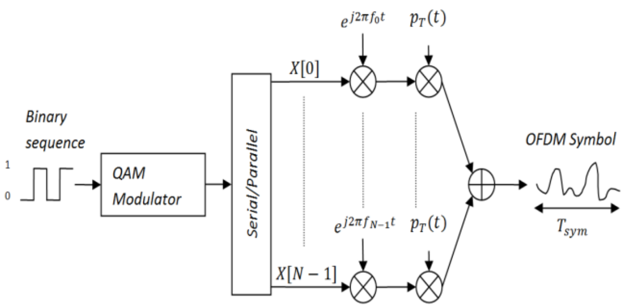

Fig.1 Multi-Carrier Modulation

OFDM contributes on the frequency sparing. It picks a gathering of sub-carriers which are orthogonal to each other at the time space, however they are covered in the frequency area, which is deferent from MCM expressed above (ensure no covered in frequency space by monitor). Along these lines, in spite of the fact that they are covered, they are orthogonal to each other and in this manner can be isolated at the beneficiary. We first write out the modulated signal as:

$$S = \sum_{i=0}^{N-1} d(i) e^{j w_i t}$$

wherew_i is the frequency of sub-carrier *i*. Suppose the time duration after S/P is T, before S/P is t0.

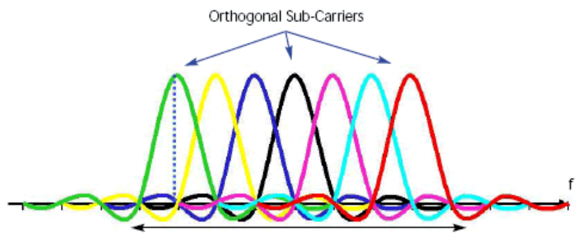

Fig. 2 Overlapped frequency in OFDM

So we have T = Nt0. We choose the sub-carrier frequency by

$$w(i) = w(0) + \frac{1}{T} = w(0) + {2\pi i}/{N t_0}$$

So that we can represent modulated signal as:

$$S = \sum_{i=0}^{N-1} d(i) e^{j \frac{2\pi i}{N t_0}} e^{j w(0)}$$

2. Problem Definition

Wavelet based OFDM is observed to be an effective strategy to supplant FFT based OFDM systems as wavelets have many favorable circumstances when contrasted with FFT-OFDM [9-13]. DWT based OFDM can possibly diminish the equipment unpredictability on the grounds that Cyclic Prefix isn't required for this situation and proposed system gives almost consummate remaking. wavelet is a viable instrument to think about the signals in time frequency joint space as it can give concurrent data about time and frequency, along these lines gives the time frequency portrayal of the flag. It has been discovered that wavelets have minimal restriction in both time space and frequency area and have better orthogonality. Wavelet based OFDM can battle the narrowband interference as the wavelets have high phantom control properties; making the system more vigorous against inter-carrier interference when contrasted with FFT acknowledgment. As cyclic prefix isn't utilized as a part of wavelet OFDM, the data rates are superior to that of FFT OFDM systems [5]. Wavelet based OFDM is utilized keeping in mind the end goal to expel the utilization of cyclic prefix which diminishes the bandwidth wastage and the transmission control is likewise lessened by the utilization of wavelet transform. The unearthly regulation of the channels in Wavelet-OFDM is additionally superior to the FFT-OFDM. Discrete wavelet transform is a kind of wavelet transform which is observed to be an elective way to deal with supplants IFFT and FFT in OFDM systems.

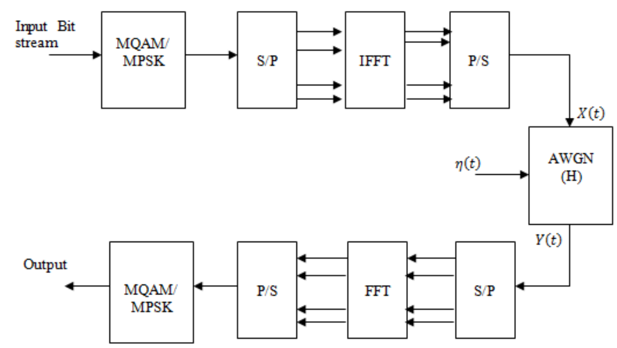

Fig. 3 DFT based O-OFDM system

In Wavelet transform, the coveted flag is disintegrated into set of premise waveforms, known as wavelets, which give the best approach to dissecting the signals by examining the coefficients of wavelets. Wavelet is utilized as a part of a few applications and has turned out to be extremely famous among specialists, technologists and mathematicians. The premise elements of wavelet transform are restricted both in time and frequency and have diverse resolutions in the two areas which makes the wavelet transforms an intense instrument in different applications. Diverse resolutions compare to investigate the conduct of the procedure and the energy of the transform. Because of these properties, the wavelets and wavelet transform discover their applications in different fields, for example, data pressure, picture pressure, radar, PC designs and activity, cosmology, human vision, atomic building, acoustics, biomedical designing, music, seismology, turbulence, attractive reverberation imaging, fractals and unadulterated science. Since wavelet transform has many focal points, for example, adaptability, lesser affectability against channel bending and interference and in addition better use of range, it has been proposed to outline the modern wireless communication systems [5]. Wavelets are helpful in different angles, for example, channel displaying, data portrayal, handset plan, and source and channel coding, data pressure, interference minimization, vitality proficient systems administration and flag de-noising in wireless communication systems. A low pass filter and high pass filter is utilized to work as QMF and fulfills idealize remaking and ortho-ordinary properties. In wavelet based OFDM, the tweaked flag is transmitted utilizing zero cushioning and vector transposing. Wavelet decomposition is known as a flexible

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and very proficient strategy for disintegration of signals. Be that as it may, it has been experienced the destruction consider which comes about the loss of data at the season of recreation of the data at the transmitter or beneficiary end, therefore the bi-orthogonal wavelet decomposition (BoWD) is utilized as a substitution for the DWT based OFDM. Above all, we considered the proposed approach in fast optical-OFDM (FO-OFDM) systems which are being used in LTE systems [6] and [7].

3. Wavelets

Wavelets are especially useful for compressing image data, since a wavelet transform has properties which are in some ways superior to a conventional Fourier transform [8].

$$W(\tau,s)=\int_0^T x(t).\psi\left(\frac{t-\tau}{s}\right).e^{-j\omega t}dt$$

x(t)=actual time series, ***ψ****(t)*=wavelet function

The channel model can be AWGN, Rayleigh or any other channel. To generate an OFDM symbol, the channel encoding of serial data stream is done followed by modulating the symbol using any modulation scheme .To successfully generate OFDM, the relationship among all the carriers must be controlled carefully to sustain the orthogonality of the carriers. Due to this, OFDM symbol is generated choosing the spectrum required firstly, based on the input data, and modulation scheme used. Some data is assigned to each carrier to be produced to transmit. The required amplitude and phase of the carrier is then calculated based on the modulation scheme which is typically differential BPSK, QPSK, or QAM. DWT based OFDM is an efficient approach to replace FFT in conventional OFDM systems. DWT is employed in order to remove the use of cyclic prefix which decreases the bandwidth wastage and the transmission power is also reduced by the use of wavelet transform. The spectral containment of the channels in DWT-OFDM is better than FFT-OFDM. In Wavelet transform, the signal of interest is decomposed into set of basis waveforms, known as wavelets, which provide the way for analyzing the signals by investigating the coefficients of wavelets.

4. BoWD-OFDM System

BoWD based OFDM is an efficient approach to replace FFT in conventional OFDM systems. DWT is employed in order to remove the use of cyclic prefix which decreases the bandwidth wastage and the transmission power is also reduced by the use of wavelet transform. The spectral containment of the channels in BoWD-OFDM is better than FFT-OFDM as well as DWT-OFDM. In Wavelet transform, the signal of interest is decomposed into set of basis waveforms, known as wavelets, which provide the way for analyzing the signals by investigating the coefficients of wavelets. BoWD is used in several applications and has become very popular among engineers, technologists and mathematicians. The basis functions of wavelet transform are localized both in time and frequency and possess different resolutions in both domains which makes the wavelet transforms a powerful tool in various applications. Different resolutions correspond to analyze the behavior of the process and the power of the transform. Due to these properties, the wavelets and wavelet transform find their applications in various fields such as data compression, image compression, radar, computer graphics and animation, astronomy, human vision, nuclear engineering, acoustics, biomedical engineering, music, seismology, turbulence, magnetic resonance imaging, fractals and pure mathematics. Since wavelet transform has many advantages such as flexibility, lesser sensitivity against channel distortion and interference as well as better utilization of spectrum, it has been proposed to design the sophisticated wireless communication systems. Wavelets are beneficial in various aspects such as channel modelling, data representation, transceiver design, and source and channel coding, data compression, interference minimization, energy efficient networking and signal de-noising in wireless communication systems. BoWD is known as a flexible and highly efficient method for decomposition of signals. Since wavelet transform has many advantages such as flexibility, lesser sensitivity against channel distortion and interference as well as better utilization of spectrum, it has been proposed to design the sophisticated wireless communication systems. BoWD is known as a flexible and highly efficient method for decomposition of signals.

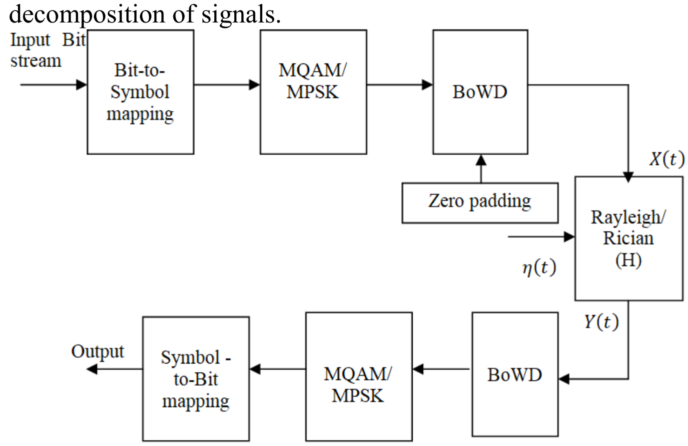


Fig. 4 BoWD based FO-OFDM system with Rayleigh and Rician channel

A. Bi-orthogonal Wavelet Decomposition (BoWD)

Bi-orthogonal wavelet decomposition is very much utilized for multi resolution analysis because of its multi scaling functionality i.e., two scaling functions to generate wavelet channel banks for disintegration and remaking separately. It will give more viable disintegration coefficients because of its multi scaling property.

In the case of orthogonal, we have one hierarchy of approximation spaces $V_{j-1} \subset V_j \subset V_{j+1}$ and an orthogonal decomposition

$$V_{j+1} = V_j \oplus W_j \qquad (1)$$

which leads us to use two filter sequences h_n and g_n for decomposition and reconstruction. Hence, we need to construct two different wavelet functions and two different scaling functions.

Let $f_k, g_k \in H$. if $\langle f_j, g_k \rangle = \delta_{jk}$ Then we will say that the two sequences are biorthogonal.

Now, our aim is to build two sets of wavelets

$$\psi_{j,k} = 2^{\frac{j}{2}}\psi(2^j x - k) \quad (2)$$

$$\widetilde{\psi}_{j,k} = 2^{\frac{j}{2}}\psi 2^j x - k \quad (3)$$

To do so, we need four filters $g, h, \tilde{g}, \tilde{h}$ i.e., two sequences to be act as decomposition sequences and two sequences as reconstruction sequences. For example, if c_n^1 is a data set, it will be decomposed as follows:

$$c_n^0 = \sum_k h_{2n-k} c_k^1 \quad (4)$$

$$d_n^0 = \sum_k g_{2n-k} c_k^1 \quad (5)$$

And the reconstruction is given by

$$c_l^1 = \sum_n \tilde{h}_{2n-l} c_n^0 + \tilde{g}_{2n-l} d_n^0 \quad (6)$$

We can achieve perfect reconstruction by following some conditions given below:

$$g_n = (-1)^{n+1}\tilde{h}_{-n}, \ \tilde{g}_n = (-1)^{n+1} h_n$$

$$\sum_n h_m \tilde{h}_{n+2k} = \delta_{k0}$$

Now consider that $\phi(x)$ and $\widetilde{\phi}(x)$ are two scaling function with their own hierarchy of approximation spaces, then we will generate function of wavelet in a method of analogous to the orthogonal case. We now define the scaling function as follows:

$$\phi(x) = \sum_n \sqrt{2} \sum_n h_n \phi(2x - n) \quad (7)$$

$$\widetilde{\phi}(x) = \sqrt{2} \sum_n \tilde{h}_n \phi(2x - n) \quad (8)$$

So, finally the bi-orthogonal wavelet functions can be defined as follows:

$$\psi(x) = \sqrt{2} \sum_n g_n \phi(2x - n) \quad (9)$$

$$\widetilde{\psi}(x) = \sqrt{2} \sum_n \tilde{g}_{n+1} \widetilde{\phi}(2x - n) \quad (10)$$

B. Rayleigh Distribution

Rayleigh fading is a rational model, when an environment that consists of many objects can scatter the transmitted signal before the arrival of signal at receiver. The central limit theorem holds that, the channel impulse response can be modelled well as a Gaussian process irrespective of individual components distribution when there are enough much scatter. When we apply Central Limit Theorem (CLT) to the large number of paths, then each path can be modelled with time as the variable as circularly symmetric complex Gaussian random variable (GRV), which is known as Rayleigh channel model. When there is no prevalent component to the scatter such model will have the mean of zero and the phase between 0 and 2π radians. Therefore the channel response envelope is Rayleigh distributed. A circularly symmetric complex GRV is of the form,

$$Z = X + iJ$$

where the real and imaginary parts are zero mean i.i.d. GRV's. For circularly symmetric complex random variable,

$$E[Z] = E\left[e^{j\theta} Z\right] = e^{j\theta}[Z]$$

A circularly symmetric complex GRV is completely specified by the variance

$$\sigma^2 = E[Z^2]$$

The magnitude $|Z|$, which has the PDF of $\wp(z)$, is called as Rayleigh random variable

$$\wp(z) = \frac{z}{\sigma^2} e^{-\frac{z}{2\sigma^2}}, z > 0$$

C. Rician Channel Distribution

It occurs when a transmitted signal will deviate from its normal path and cancels itself automatically. It is a non-deterministic model. The transmitted signal can arrive at the receiver end by several different paths, and at least there is change in one path. When the path is much stronger than the others, typically a line of sight (LoS) signal is known as Rician fading (RF). In this, a Rician distribution is used to characterize the gain of the amplitude. When there is no LoS path between the transmitter and the receiver of OFDM then the Rayleigh fading can categorize the RF. RF can be defined by two parameters known as K and Ω. Parameter K is called a Rise factor and it is defined as the ratio between the direct paths power to the other scattered paths power. And the Ω is the total power of both paths, which can acts as a scaling factor for the Rician distribution. The resulting PDF is then given by,

$$f(x) = \frac{2(K+1)x}{\Omega} exp\left(-K - \frac{(K+1)x^2}{\Omega}\right) I_0\left(2\sqrt{\frac{K(K+1)}{\Omega}}x\right)$$

Where the I_0 is the 0_{th} order modified Bessel function of first kind. If the value of K is zero then the RF envelope will produced down to the Rayleigh faded envelope.

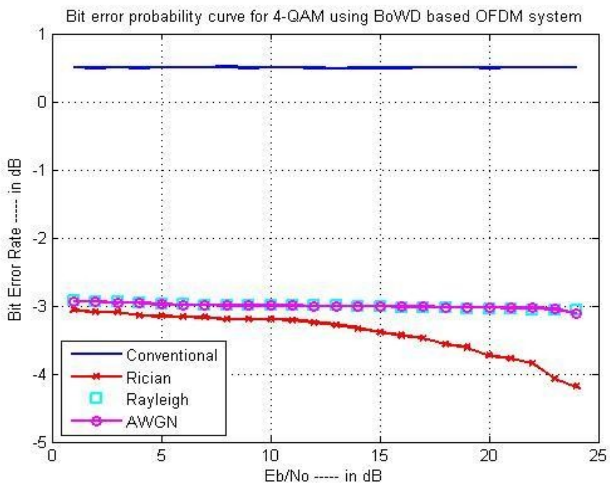
5. Performance Evaluation

Simulations have been done in MATLAB 2014a version with 4 GB RAM. We tested the conventional and proposed OFDM systems with various QAM modulation levels that are used for the LTE. Modulations that could be used for LTE are 4 QAM, 16 QAM and 32 QAM (Uplink and downlink). For the purpose of simulation, signal to noise ratio (SNR) of different values are introduced through AWGN, RAYLEIGH, RICIAN channel. Data of 10,000 bits is sent in the form of 100 symbols, so one symbol is of 100 bits.

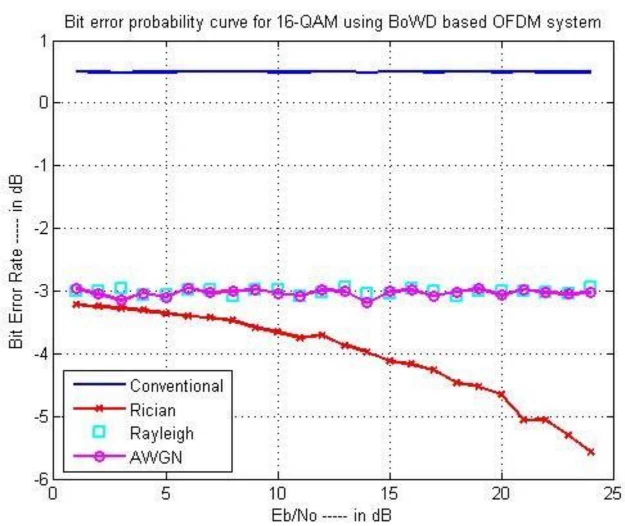
Table I Simulation Parameters

Parameters	Specifications
FFT & IFFT size	64
No. of bits	10000

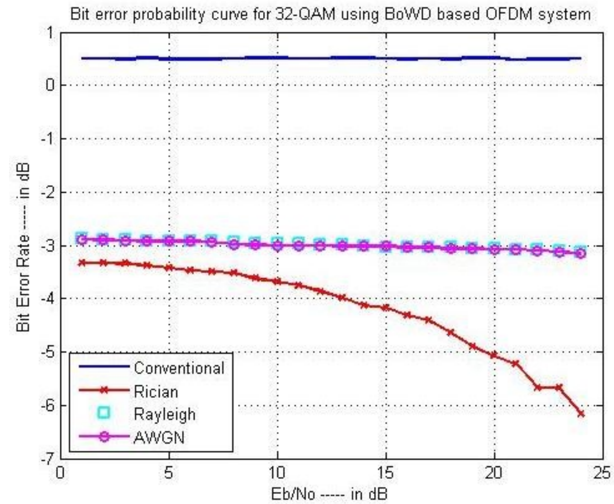
No. of Data subcarriers	32
Channel model	AWGN, Rayleigh and Rician
Modulation scheme	QAM/QPSK
Constellation points	4, 8, 16, and so on



(a)



(b)



(c)

Fig. 5 BER performance of proposed and conventional system with (a) 4-QAM (b) 16-QAM and (c) 32-QAM under AWGN, Rayleigh and Rician channels

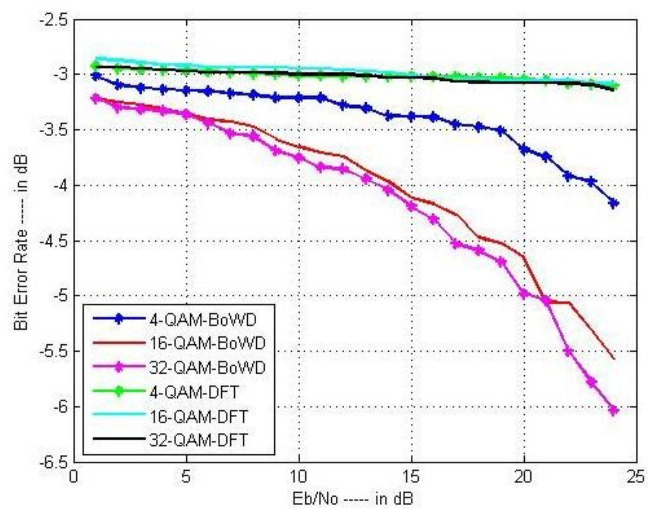


Fig. 6 Analysis of BER for DFT-OFDM and BoWD-OFDM with various modulation schemes

Averaging for a particular value of SNR for all the symbols is done and BER is obtained and same process is repeated for all the values of SNR and final BERs are obtained. Figure 5 demonstrated that the comparative analysis of BER with respect to signal to noise ratio (SNR) for the conventional OFDM and proposed system under AWGN, Rayleigh and Rician channel distributions. Fig 5(a), (b) and (c) show that the 4-QAM, 16-QAM and 32-QAM respectively. In all the three figures we can observe that the BER value of proposed BoWD-OFDM system with Rician channel obtained lesser values compared to the conventional schemes. This figure shows the relationship between BER and SNR. The values of SNR are from 0 db to 25 db and the scale of SNR is linear. Figure 6 show that the analysis of BER with various modulation schemes for conventional and proposed systems. We can see that while increasing the modulation constellation point the BER get reduced further.

6. Conclusions

In this article, we had given an analysis of bit error rate in FO-OFDM for LTE networks. We utilized BoWD for spectral efficiency enhancement, which offers excellent bandwidth utilization over large number of users. Thus, the performance of the system has been improved in terms of bit error rate. We also compared our proposed system with conventional OFDM systems such as optical-DFT-OFDM under AWGN, Rayleigh and Rician channel distributions with different modulation techniques like M-QAM by varying M=4, 16, 32 and so on. Further, our system can be improved by implementing hybrid wavelet approaches which will extensively enhance the system spectral efficiency.

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