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BER Mitigation in LDPC-COFDM System with Different Modulation Schemes over Generalized Gamma Fading Channel

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Abstract—**Orthogonal Frequency Division Multiplexing (OFDM) is a very promising technique to achieve the high-data-rate transmission required for wireless communications. To minimize the error rate performance of OFDM, forward error correction coding is essential. Forward Error correction (FEC) coding like LDPC coding is generally used to Improve BER performance .Recently, low-density parity-check code (LDPC) which can achieve the near Shannon limit performance, have attracted much attention. We explore the LDPC coded OFDM (LDPC-COFDM) systems to improve the error rate performance of OFDM.LDPC provides large minimum distance and also the power efficiency of the LDPC code increases significantly with the code length. Further this system is implemented with generalized gamma fading channel. It is a versatile wireless channel model, which can generalize the commonly used models for multipath fading and shadowing. Finally using a long Irregular LDPC code, it is shown that LDPC coded OFDM provides very low bit error rate compared to OFDM without coding case with a gain in transmitter power and thus making the link power efficient.**

Index Terms— **Orthogonal Frequency Division Multiplexing (OFDM), Low Density Parity-Check (LDPC), Forward Error Correction(FEC),Bit Error Rate (BER), Signal to Noise Ratio (SNR).**

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a very effective technique to achieve the high-bit-rate data trans- mission required for the future mobile communications. OFDM is a multicarrier digital communication scheme to solve both issues ICI (inter-carrier interference) & ISI (inter-symbol interference) prevalent in earlier systems (ex. FDM) [1]. It combines a large number of low data rate carriers to construct a composite high data rate communication system. Orthogonality gives the carriers a valid reason to be closely spaced, even overlapped, without inter-carrier interference [2]. Low data rate of each carrier implies long symbol periods, which greatly diminishes inter-symbol interference [3].The OFDM system divides the wide signal bandwidth into many narrow band sub-channels that are transmitted in parallel. To improve the error rate performance of OFDM, forward error correction coding is essential. Many error-correcting codes have been applied to OFDM, convolution codes, Reed-Solomon codes, Turbo codes [3], and so on.During the past decades, channel coding has been used extensively in most digital transmission systems, from those requiring only error detection, to those needing very high coding gains. Low density parity-check (LDPC) codes have attracted much attention particularly in the field of coding theory. LDPC codes were proposed by Robert G.Gallager in 1962 [4] at MIT and the performance is very close to the Shannon limit with practical decoding complexity like Turbo codes. The success of turbo codes led to the rediscovery of LDPC codes by Mackay and Neal [5] .They were largely ignored because computational complexity was high for hardware implementation at that time. With recent advances in parallel computing power, LDPC codes have been re-discovered and studied [7]. In addition to their good performance, LDPC codes have lower complexity in the decoding process compared to other FEC codes such as Turbo codes. These codes have become so popular mainly due to the fact that the minimum distance of an LDPC code increases proportionally to the code length with high probability [6]. In addition to their excellent block error performance, highly parallel LDPC decoder architecture is realizable by directly instantiating the LDPC decoding algorithm to hardware, resulting in very high speed LDPC decoder hardware. Along with LDPC codes, many researchers have worked with different modulation schemes in multipath fading channels They are used in many high speed communication standards such as digital video broadcasting, WiMAX, 4G wireless systems, to name a few [4].In recent times, implementation of LDPC codes has lagged behind that of other codes, notably turbo codes. The fundamental patent for Turbo Codes expired on August 29, 2013.

Wireless systems suffer from detrimental effects introduced by short term fading and long term shadowing. Considerable efforts have been devoted to statistically model these effects. Various multipath fading models have been used in the literature considering different radio propagation environments and underlying communication scenarios [8]. Fading has long been modeled using Rayleigh and Rician models, but they lack flexibility to fit in these new increasingly diverse fading scenarios. Another versatile wireless channel model, which can generalize the commonly used models for multipath fading and shadowing, is the two-parameter generalized gamma model [9]. It includes multipath fading models such as Rayleigh,

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Nakagami-m,andWeibull as special cases and lognormal shadowing model as the limiting case. We proposed the LDPC coded OFDM (LDPC-COFDM) systems to improve the error rate performance of OFDM over generalized gamma fading channel. In this paper, we evaluate the bit error rate (BER) of the LDPC-COFDM systems with both MQAM & M-PSK using the Gray mapping.We showed that the LDPC-COFDM systems achieve the good error rate performance with a small number of iterations on both AWGN and generalized gamma fading channels.

The rest of paper is organized as follows: The following part of the paper discusses theoretically the complete block diagram of OFDM in baseband. In the third part we have discussed the advantages of using error control coding followed by the discussion on LDPC code and its types [6].The fourth part explains the channel model and then the proposed system model. In the fifth part, the performance of LDPC coded OFDM over AWGN channel & generalized gamma fading channel is analyzed through soft decision decoding so as to prove it as a suitable candidate for high speed optical applications. The fifth part lists the conclusion.

II. OFDM MODEL

A much more efficient use of bandwidth can be obtained with a parallel system if the spectra of the individual sub channels are permitted to overlap. Consider the system shown in fig.1.The transmitted spectral shape is such that the inter-channel interference does not occur; that is, the spectra of the individual sub channels are zero at the other subcarrier frequencies[10]. In addition the subcarrier frequencies are separated by multiples of 1/T so that with no signal distortion in transmission, coherent detection of one symbol gives no output at any other received symbol [11]. Using a two dimensional digital modulation format, data symbols d(n) can be represented as d(n)=a(n) + jb(n) (where a(n) and b(n) are real sequences representing the in-phase and quadrature component respectively) and the transmitted waveform can be represented as [10]:

$$\sum_{n=0}^{n=N-1} a(n)\, cos\omega t + b(n)\, sin\omega t \tag{1}$$

A Complex base band OFDM signal with N subcarriers is expressed as [16]:

$$s(t) = \sum_{k=0}^{N-1} D_i e^{j2\pi k f_0 t} \qquad 0 \le t \le T \tag{2}$$

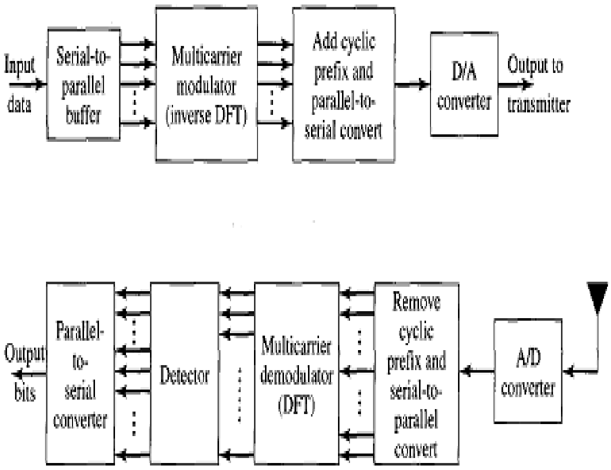


Fig.1 Basic OFDM system model

For each OFDM symbol, the modulated data sequences are denoted by D(0),D(1),D(2)…..D(n) here, f_o denote the sub-carriers spacing and is set to the condition of orthogonality. After IFFT, the time-domain OFDM signal can be expressed as [16]:

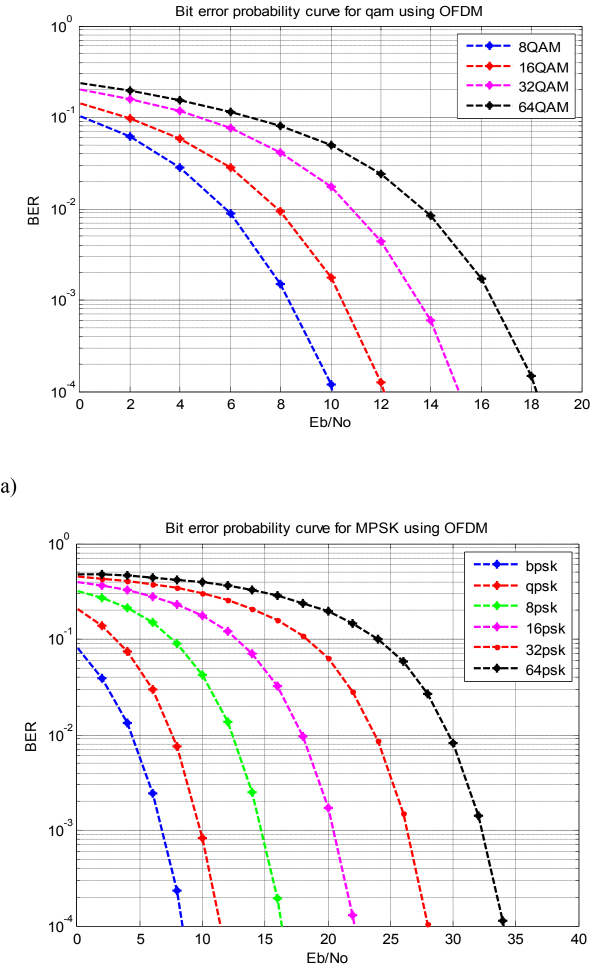
$$\begin{aligned} s(t) &= \tfrac{1}{N}\textstyle\sum_{k=0}^{N-1} D_i e^{\frac{j2\pi k f_0 n}{N}} \\ &= IFFT(D_0, D_1, \dots, D_{N-1}) \end{aligned} \tag{3}$$

After IFFT, the modulated signal is up-converted to carrier frequency and then the following signal is produced and transmitted through channel [16]:

$$x(t) = Re\left\{\sum_{k=0}^{N-1} D_i e^{j2\pi k(f_0+f_c)t}\right\} \quad 0 \le t \le T \tag{4}$$

Here, x(t) represents the final OFDM signal in which sub-carriers shall undergo a flat fading channel.

An OFDM system is successfully simulated using MATLAB .All major components of an OFDM system are covered. In fig.2 (a), 2(b) we have shown the BER versus SNR plots for MQAM & MPSK modulated OFDM system using gray mapping over AWGN channel. It is clear from figure 2 that BER performance of OFDM system is good and is better with MQAM modulations than MPSK. It is also clear that with higher levels of modulation, SNR has to be increased to achieve the same BER.



(a)

(b)

Fig. 2 (a) Simulation results (a) BER V/S SNR for MQAM OFDM (b) BER V/S SNR for MPSK OFDM

III LDPC AND ITS TYPES

LDPC codes are linear block codes specified by a sparse parity-check matrix with the number of 1's per column (column weight) and the number of 1's per row (row weight), both of which are very small compared to the block length [12]. LDPC codes are classified into two groups, regular LDPC codes and irregular LDPC codes [13]. Regular LDPC codes have a uniform column weight and row weight, and irregular LDPC codes have a non-uniform column weight. Irregular LDPC codes have better performance than regular LDPC codes. Furthermore, when the block length is relatively large (more than 1000), irregular LDPC codes outperform Turbo codes [15]. We describe an LDPC code defined by M x N parity- check matrix has (N,K) LDPC, where K=N-M and the code rate is R = K/N. When the H doesn't have full rank, K > N-M and the error rate performance of an LDPC code becomes worse. Also, each column contains a small fixed number, Wc>= 3, of l's and each row contains a small fixednumber, Wr>=Wc of 1' s. Low-density implies that Wc<<M and Wr<<N. Number of ones in the parity check matrix H = Wc. N = Wr, M. where M>= (N - K) =) R = K/N>= 1- (Wc/Wr), and thus Wc<Wr. Thus, when we construct the parity-check matrix H, we ensure that all the rows of the matrix are linearly independent.

LDPC codes are often represented in graphical form by a Tanner graph. The Tanner graph consists of two sets of vertices: n vertices for the codeword bits (c_i) (called bit nodes), and m vertices for the parity-check equations called check nodes (v_i). An edge joins a bit node to a check node if that bit is included in the corresponding parity-check equation and so the number of edges in the Tanner graph is equal to the number of ones in the parity-check matrix.

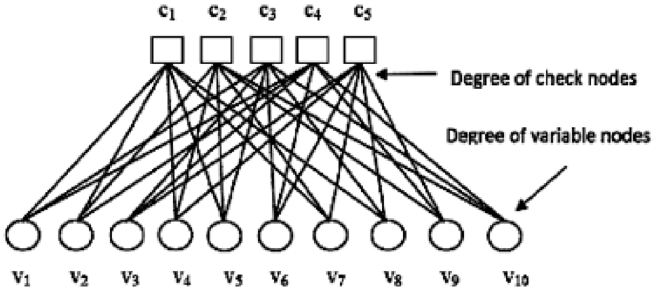


Fig.3 Tanner graph representation of parity check

IV SUM PRODUCT ALGORITHM

The sum-product algorithm is a soft decision message-passing algorithm. The messages representing each decision (check met, or bit value equal to 1) in probabilities, the sum-product algorithm is a soft decision algorithm which accepts the probability of each received bit as input. For a binary variable x it is easy to find p(x = 1) given p(x = 0), since p(x = 1) = 1−p(x = 0) and so we only need to store one probability value for x. Log likelihood ratios are used to represent the metrics for a binary variable by a single value. The input to the LDPC decoder is log-likelihood ratio (LLR), L (c_i), which is defined by the following equation:

$$L(c_i)=\log\left(\frac{\Pr(c_i=0\mid\text{channel output for } c_i)}{\Pr(c_i=1\mid\text{channel output for } c_i)}\right) \tag{5}$$

Here c_i is the i^{th} bit of the transmitted codeword,c_i. There are three key variables in the algorithm $L(r_{ij})$,$L(q_{ij})$ and $L(Q_i)$. $L(q_{ij})$ is initialized as $L(q_{ij})= L(c_i)$.For each iteration, update $L(r_{ii})$,$L(q_{ii})$ and $L(Q_i)$ using the following equations:

$$L(r_{ji}) = 2\,\text{atanh}\left(\prod_{i'\in V_j\setminus i}\tanh\left(\frac{1}{2}L(q_{i'j})\right)\right) \tag{6}$$

$$L(q_{ij}) = L(c_i)+\sum_{j'\in C_i\setminus j} L(r_{j'i}) \tag{7}$$

$$L(Q_i) = L(c_i)+\sum_{j'\in C_i} L(r_{j'i}) \tag{8}$$

at the end of each iteration, $L(Q_i)$ provides an updated estimate of the a posterior log-likelihood ratio for the transmitted bit c_i. The soft-decision output for c_i is $L(Q_i)$, then at the end of each iteration the algorithm verifies the parity check equation ($Hc^T=0$) and stops if it is satisfied.

V SYSTEM MODEL

A. Channel Model

We have chosen Generalized Gamma flat fading channel with additive white Gaussian noise. In flat fading environment, the base-band signal at the input of receiver y(t) is as described as follows:

$$y(t) = x(t) * r(t) + n(t) \tag{9}$$

where x(t) denotes the base-band transmitted signal, r(t) is the Generalized Gamma distributed channel envelope and is the additive white Gaussian noise with zero mean. Generalized Gamma fading distribution function is given as:

$$r(t) = \frac{2vr^{2vm-1}}{\Gamma(\mathrm{m})(\Omega/\mathrm{m})} \exp\left(-\frac{mr^{2v}}{\Omega}\right) \qquad r \geq 0 \tag{10}$$

where v > 0 and m > 0 are fading parameters, Ω is the scaling parameter and is the Gamma function. The fact that generalized gamma distribution has one more parameter than the well known distributions renders it more flexible to better adjust with measurement data. Moreover, this model is based on more realistic heterogeneous scattering environment. For wireless systems, generalized gamma model provides a simple way to model all forms of channel fading conditions including shadowing [14]. By varying the two parameters v and m, different fading and shadowing conditions can be described. For instance, v = 1, in above represent Nakagami-m fading; m = 1, represent Weibull fading; m = v = 1, represent Rayleigh fading.The received envelope at any point is assumed to consist of m number of multipath components and the non-linearity of this heterogeneous environment represented in the form of an exponent 1/v, so that the resultant generalized gamma distributed envelope of can be generated using the following equation:

$$r(t) = \left(\sqrt{\sum_{\mathrm{i}=1}^{\mathrm{m}} \mathrm{p}_\mathrm{i}^2 + \sum_{\mathrm{i}=1}^{\mathrm{m}} \mathrm{q}_\mathrm{i}^2}\right)^{1/v} \tag{11}$$

where p_i& q_i are independently distributed Gaussian variables with zero mean and unit variance. Equation 8 is valid for only discrete value of m [13]. Equation (11) clearly indicates the generalized gamma distributed envelope, which can also be obtain by using PDF equations of both the fading distributions[14].

B.LDPC coded OFDM

In a multipath fading channel, some subcarriers of OFDM may be completely lost because of the deep fades. Hence, in this case, it is expected that lots of errors prevail on continuous some subcarriers and the two dimensional errors in time and frequency domains occur. That is why we apply LDPC codes, which can compensate for the two dimensional errors[7], to OFDM system. Fig. 4 shows the model of the LDPC-COFDM system over generalized gamma fading channel. At the transmitter, information bits are encoded at the LDPC encoder and modulated at the modulator. After the serial-to-parallel conversion, the OFDM sub-channel modulation is implemented by using an inverse fast Fourier transform (IFFT) and the outputs of the IFFT are assigned to some OFDM symbols for the purpose of compensating two dimensional error in the OFDM system. On a frequency selective fading channel, the guard interval is inserted for the purpose of eliminating ISI. After the serial to parallel conversion, the OFDM sub-channel demodulation is implemented by using a fast Fourier transform (FFT) [7]. The received OFDM symbols generated by the FFT are demodulated at the demodulator. The demodulated bits are decoded with each LDPC encoded block and data bits are restored.The generalized gamma fading channel have been modeled by simulating the fading envelope.The adaptive fading channel has been used to generate various fading conditions for testing the BER performance of LDPC coded OFDM system.

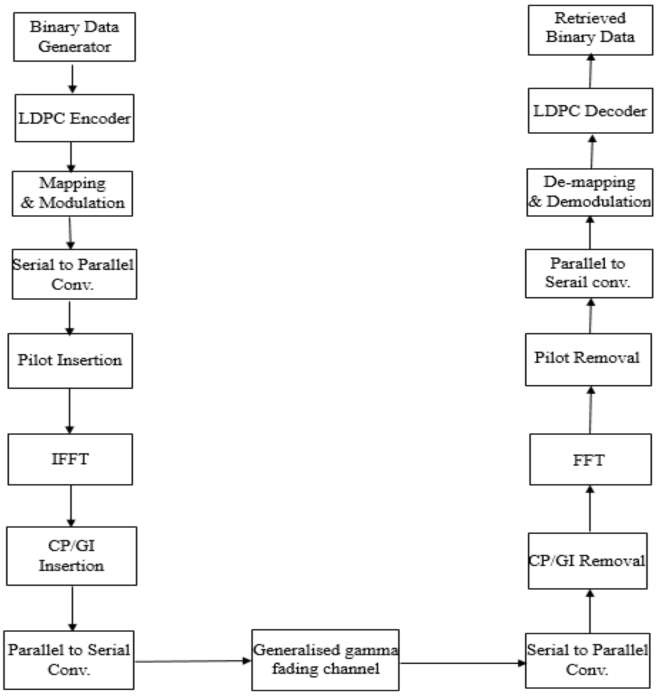


Fig.4 Complete Block Diagram of System

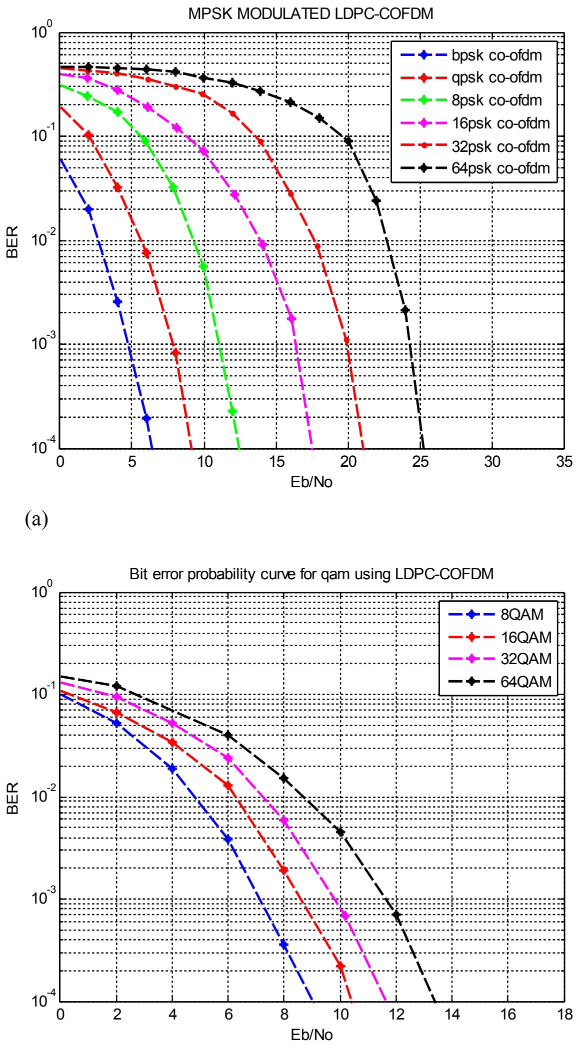
V PERFORMANCE ANALYSIS

TABLE 1
INPUT PARAETERS FOR SIMULATION

PARAMETERS	VALUE
FFT size(nFFT)	64
No. of used sub-carriers(nDSC)	52
Used sub-carrier index	-26 to -1 & +1 to +26
No. of pilots used	12
modulations used	MQAM & MPSK
SNR range	0 db to 18db for MQAM modulated OFDM 0 db to 34 db for MPSK modulated OFDM
Encoding technique	LDPC
LDPC matrix size	(32400,64800)

We present the results of our computer simulation. TABLE 1 shows the simulation parameters. We use the (32400,64800) LDPC code with column weight of 3 and setting the maximum number of iterations in decoding to 50.Fig. 6.a shows the BER v/s SNR plot for 8QAM,16QAM,32QAM,64QAM for

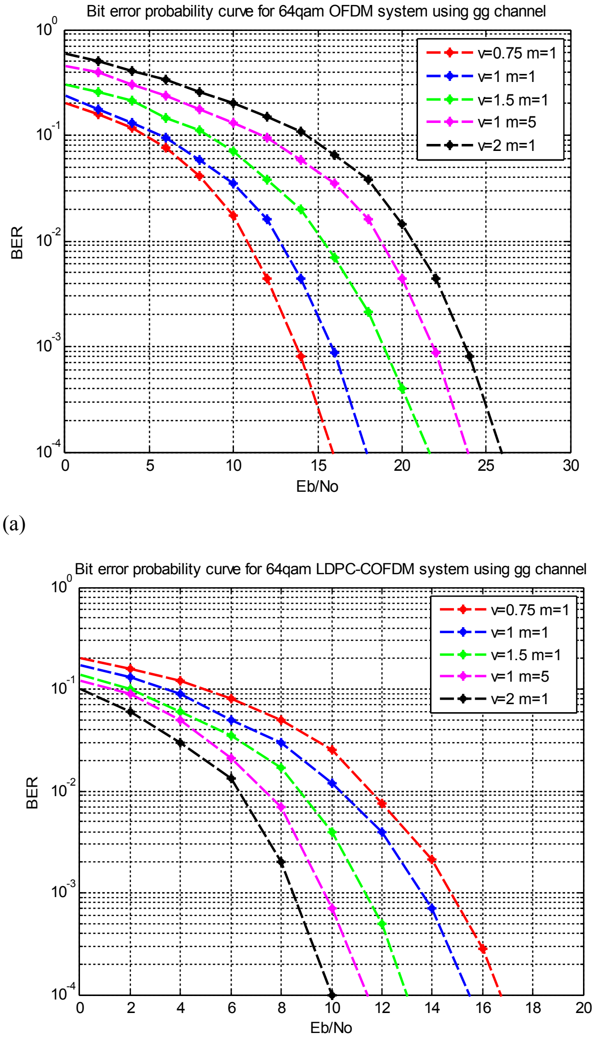
LDPC-COFDMsystem over AWGN channel .We observed that 64QAM is 2.1 db worse than 32QAM and 32QAM is 1.4 db worse than 16QAM and this difference is even less for 16QAM & 8QAM which is 1.2 db.Thus with increase of modulation levels ,we need more and more power. From the comparison of fig. 2.a & fig 6.a, the 64 QAM system has the coding gain of 4.9 db ,for 32 QAM coding gain is 3.4db, for 16QAM coding gain is 1.8db, for 8QAM system coding gain is 1db. Fig 6.b shows the BER v/s SNR plot for BPSK ,QPSK ,8PSK ,16PSK ,32PSK & 64PSK.For LDPC-COFDM system over AWGN channel, 64PSK system is 4.1 db worse than 32PSK , 32PSK is worse with 3.9db than 16PSK, 16PSK is worse with 2.7db than 8PSK, 8PSK is worse with 3.4db than QPSK and QPSK is worse with 2.5db than BPSK From comparison of fig2.b & 6.b the 64PSK system has the coding gain of 8.9 db ,for 32PSK coding gain is 5.4db, for 16PSK coding gain is 4.9db, for 8PSK system coding gain is 3.6db,for QPSK coding gain is 2.1db & for BPSK coding gain is 1.8db.we see that there is larger coding gain in higher modulations in both MQAM & MPSK system as compared to low level modulations.



(b)

Fig.6 Simulation results (a) BER V/S SNR plot for MQAM modulated LDPC-COFDM
(b)BER V/S SNR plot for MPSK modulated LDPC-COFDM

Further this system is implemented with generalized gamma fading channel. We have choosen MQAM our best modulation technique and thus performed the simulations for the same with generalized gamma fading channel.For range of fading scenarios, i.e. m=1, v=0.75 (severe fading); m = 1, v = 1 (Rayleigh fading); m = 1, v = 1.5 (Weibull fading); m = 1, v = 2 (Weibull fading); m = 5, v = 1(Nakagami-m fading. It can be seen from nearly linear BER curves contrary to that of exponential decay found in non-fading channels, severe penalty in terms SNR has to be paid due to small scale fading. Thus increase in SNR is needed to combat these losses. Comparison of uncoded OFDM & LDPC-COOFDM has been shown in Fig. 7.a & 7.b.



(b)

Fig.7 Simulation results (a) BER v/s SNR for uncoded 64 QAM OFDM system over GG channel
(b)BER v/s SNR for 64 QAM LDPC-COFDM system over GG channel

VIII CONCLUSION

In this paper, we evaluated the error rate performance of the (32400,64800) LDPC-COFDM systems with both MQAM & MPSK modulations. We showed that the LDPC-COFDM systems with M-PSK/MQAM using gray mapping have the better error rate performance than the systems with M-PSK/MQAM using natural mapping on an AWGN channel.

Using the LDPC coding, the BER has reduced significantlycompared to without coding case of OFDM simulation using higher order QAMs.The LDPC coded

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OFDM has low BER at low SNR's and at high SNR's it is also very low.There is a reduction in BER with coding with less transmitted power, making the link power efficient.The fall in SNR is more significant as modulation level is increased.

A comparative study of LDPC-COFDM and uncoded OFDM using MQAM & MPSK has been done. It is seen that behaviour of MQAM LDPC-COFDM system is better than MPSK LDPC-COFDM. Further behaviour of generalized gamma fading channel for different values of m & v has been analysed for 64-QAM modulated system (coded &uncoded). The existence of two fading parameters m and v make it possible to describe different levels of fading individually or collectively. Thus, the Generalized Gamma model analyses presented here provide a significant enhancement in the ability to evaluate the multi-channel wireless system performance over all existing models, including the Rayleigh, Nakagami-m, Weibull.So, here the versatility of Generalized Gamma model of using the two fading parameters has been proved.

REFERENCES

1. Lei Wan, V. K. Dubey,"Bit error probability of OFDM system over frequency nonselective fast Rayleigh fading channels", IEEE Electronics letters, Vo. 36, No. 15, pp1306- 1307, July 2000.
2. Jun Lu, ThiangTjhung,Fumiyuki Adachi and Cheng Li Huang,,"BER performance of OFDM-MDPSK system in Frequency Selective Rician Fading with Diversity Reception,"IEEE Trans. On Vehicular Technology, vol. 49, no. 4, pp. 1216-1225, July 2000.
3. Lui, Hui and Li. Guoqing,"OFDM-Based Broadband Wireless Networks Design and Optimization Wiley-Interscience" 2005.
4. R G. Gallager, "Low density parity check codes:' IRE Trans. Infonn.Theory,vol.IT-8,pp.21-28,jan.1962.
5. S.jjohnson,"introduction to LOW DENSITY PARITY CHECK CODING",ACoRN Spring School version 1.1,2006.
6. M. Franceschini ,G. Ferrari ,R. Rahel"LDPC coded modulations",SPRINGER,2009.
7. Hisashifutaki ,tomoakiohtsuki,"Low density Parity check coded OFDM systems with MPSK""IEEE VTC2002 fall,vol. 1,pp.82-86,mar. 2002.
8. J. D. Parsons, The Mobile Radio Channel, 2nd ed., Wiley: New York, 2000.
9. Aalo VA, Piboongungon T and C D Iskander ,"Bit-error rate of binary digital modulation schemes in generalized gamma fading channels",, IEEE Communication Letters, Vol. 09, No. 2, pp 139–141, Feb. 2005.
10. Eldomabiala, Mathias coin chon, KarimMaouche, "Study of OFDM Modulation," lerucom Institute, December, 1999.
11. Acosta, Guillermo. "OFDM Simulation Using MATLAB" 2000.
12. Shu Lin and Daniel I.Costello ,"Error Control Coding",Ir.second. edition, Prentice Hall, 2004.
13. Aalo VA, Piboongungon T and C D Iskander , ‗ Bit-error rate of binary digital modulation schemes in generalized gamma fading channels,‖ IEEE Communication Letters, Vol. 09, No. 2, pp 139–141, Feb. 2005.
14. P.Mohana Shankar" Fading and Shadowing in wireless systems",SPRINGER , 2012.
15. T.Richardson,A.shokroillahi and Rurbanke,"design of probably good low-density parity check codes" submitted to IEEE trans. Inform.theory,2006.
16. Ruhallah Ali Hemmati, PaeizAzmi,"Clipping distortion mitigation in OFDM systems over fading channels by using DFT-based method"Elsevier Computers and Electrical Engineering, vol.31, issue 7, pp 431-443, Oct. 2005