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Performance of Turbo Coded OFDM System with PAPR Reduction Using CMA and Comb Pilot Channel Estimation in Rayleigh Fading Channel

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ABSTRACT

OFDM is a popular modulation technique for digital data transmission in wireless and wired communication. But the major problem in OFDM is high PAPR and high per bit error. In this paper work, work have done on turbo coded OFDM system using PAPR reduction CMA scheme. A PAPR reduction CMA scheme which is not require carrier synchronization and can improve the performance of turbo coded orthogonal frequency division multiplexing system is proposed. The above system is investigated after including Additive white Gaussian noise and Rayleigh fading channel. The comb-type pilot arrangement with the LS estimator and 1D interpolation are used for channel estimation. The system is called TC-PAPR-QPSK-OFDM with comb pilot channel estimation. In case of AWGN channel, Signal to Noise Energy Ratio of 2.5 dB at BER5*〖10〗^(-6)and in case of Rayleigh fading channel SNR of 37 dB at BER 〖10〗^(-6)are achieved. The graphs demonstrate that the results have been improved by using CMA technique.

Keywords: BER, PAPR, CMA, COFDM, AWGN, OFDM.

1. INTRODUUCTION

Multimedia is effectively an infrastructure technology with widely different origins in computing, telecommunications, entertainment and publishing. New applications are emerging, not just in the wired environment, but also in the mobile one. At present, only low bit-rate data services are available to the mobile users. However, demands of the wireless multimedia broadband system are anticipated within both public and private sector. The radio environment is harsh, due to the many reflected waves and other effects[1- 6]. Using adaptive equalization techniques at the receiver could be the solution, but there are practical difficulties in operating this equalization in real-time at several Mb/s with compact, low-cost hardware. A promising candidate that eliminates a need for the complex equalizers is the Orthogonal Frequency Division Multiplexing (OFDM), a multiple carrier modulation technique. This modulation system is described; its applications and drawbacks are outlined, along with some important characteristics of OFDM and single-carrier techniques.

The main advantages of OFDM are its multipath delay spread tolerance and efficient spectral usage by allowing overlapping in the frequency domain [5 - 9]. Another significant advantage is that the modulation and demodulation can be done using inverse Fast Fourier Transformation (IFFT) and Fast Fourier Transformation (FFT) operations, which are computationally efficient. In an OFDM transmission system, each subcarrier is attenuated individually under the frequency-selective and fast fading channel [3 - 6]. The channel performance may be highly fluctuating across the subcarriers and varies from symbol to symbol. If the same fixed transmission scheme is used for all OFDM subcarriers, the error probability is dominated by the OFDM subcarriers with highest attenuation resulting in a poor performance. Therefore, in case of frequency selective fading the error probability decreases very slowly with increasing average signal-to-noise ratio.

In this paper the LS estimator is used as it has the lowest complexity. In OFDM the entire channel is divided into many narrow sub-channels which are transmitted in parallel form. This increases the symbol duration and reduces the inter symbol interference. OFDM also combats inter symbol interference by prepending a guard band (cyclic prefix) to the transmitted symbol. These features make OFDM an effective technique for combating Rayleigh-fading and for high data rate transmission over wireless mobile channels [10, 11] because a frequency-selective fading channel is converted into several flat-fading channel. The wireless OFDM system on its own does not yield low bit error rates (BERs). Therefore, some form of forward error correction (FEC) must be used to decrease the bit error rates.

To achieve the performance near Shannon's limit, the combination of parallel concatenations and recursive decoding is used. Turbo codes [12, 13] are better because they significantly improve the BER performance. However, there are many critical parameters in turbo codes that need to be considered before its application, such as the code rate, encoder memory, FFT size and inter-leaver size. In this paper, we investigate the use of turbo codes and a comb-type channel estimation QPSK OFDM modulation scheme by applying CMA technique for reducing PAPR in the Rayleigh fading channel. The proposed system is known as TC-QPSK-CMA-OFDM with comb type pilot data estimation. The TC-QPSK-CMA-OFDM with comb estimation is a method to compensate the fluctuation due to fading. The pilot data are inserted at the transmitter side at fixed subcarriers and at the receiver side the channel characteristic is estimated then the transmitted data is recovered. The TC-QPSK-CMA-OFDM with comb estimation is simulated under the Rayleigh fading AWGN channel for different number of subcarrier as pilots and after three iterations for the turbo code. The results suggest that the proposed TC-QPSK-CMA-OFDM with comb estimation has a large coding gain and achieves low BER with fewer decoding iterations.

II. SYSTEM DESCRIPTION

In this section, the block diagram of the proposed TC-QPSK-CMA-OFDM system model is drawn in Fig.1.

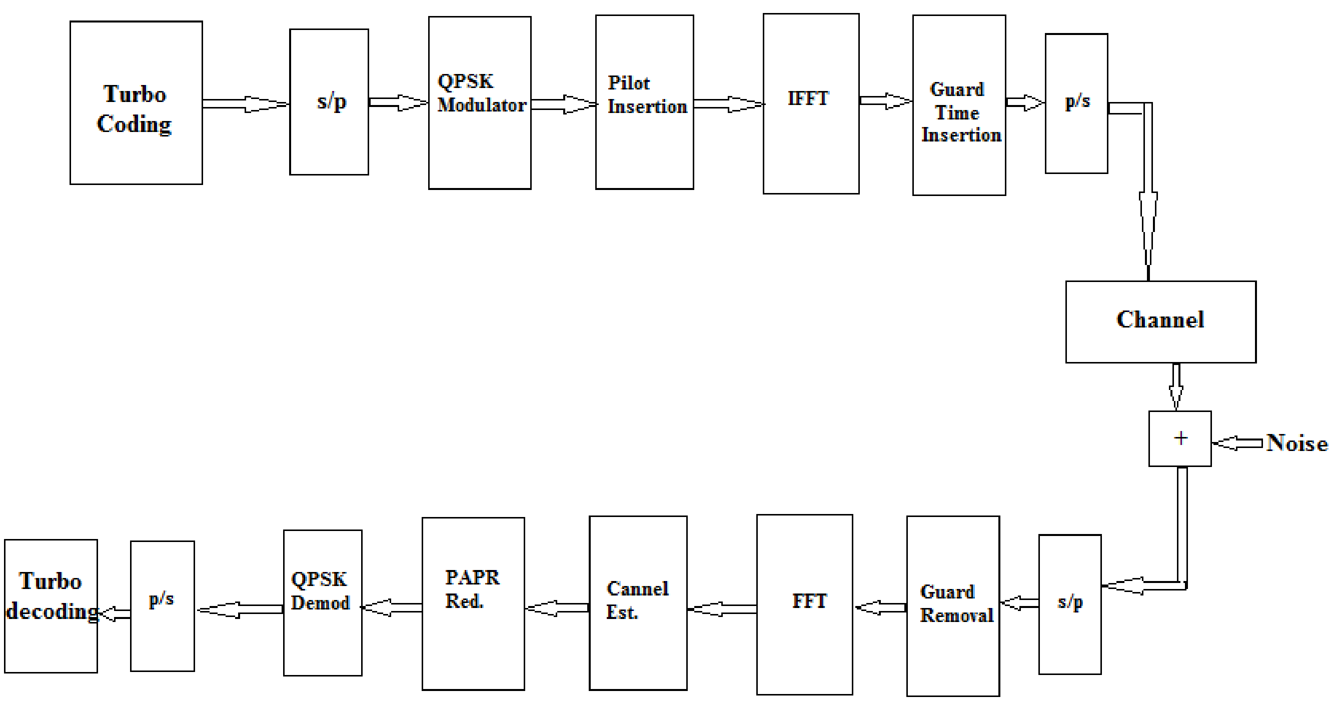

Fig. 1: The TC-QPSK-OFDM system model

The binary information stream is first grouped into frames of z bits and each frame is encoded by the turbo encoder that generates Z coded bits. The turbo encoderused in the proposed system is similar to that in [14]. It can encode frames of z bits continuously without flushing its memory to zero state. The rate 1/3 turbocodes are punctured to rate 1/2 by the puncturing matrix p= [10; 01]. As a result, the rate ½ unterminated turbo encoder generates outputs of Z=2zbits instead of $Z = 2 \times (z + v)$ bits where 2v flush bits are saved as compared to the terminated turbo encoder.

The output is then multiplexed into Z coded bits. And now PAPR reduction technique is applied to reduce PAPR so that BER performance can improve.

The turbo encoder output is converted into parallel data N sub-channels. Then the transmitted data of each parallel sub-channel is modulated using QPSK modulator.

After inserting pilots uniformly between the information data sequence, IFFT block is used to transform the data sequence of length N{X(k)} into time domain signal {x(n)} with the following equation:

$$x(n) = IFFT\{X(k)\} \qquad n = 0,1 \ldots\ldots\ldots\ldots.., N-1$$
$$= \sum_{k=0}^{N-1} X(k) e^{j(2\pi kn/N)} \qquad (1)$$

where N is the FFT length. Following the IFFT block, guard time, which is chosen to be larger than the expected delay spread, is inserted to prevent ISI. This guard time includes the cyclically extended part of OFDM symbol in order to eliminate inter-carrier interference (ICI).

III. CHANNEL ESTIMATION USING LS ESTIMATOR

For comb type pilot subcarrier arrangement, the Kp pilot signals Xp(m), m =0, 1, 2, …, Kp are uniformly inserted into X(k). That is, the total N subcarriers are divided into Kp groups, each with L= N/Kp adjacent subcarriers. In each group, the first subcarrier is used to transmit pilot signal. The OFDM signal modulated on the kth subcarrier as shown in (2) and (3).

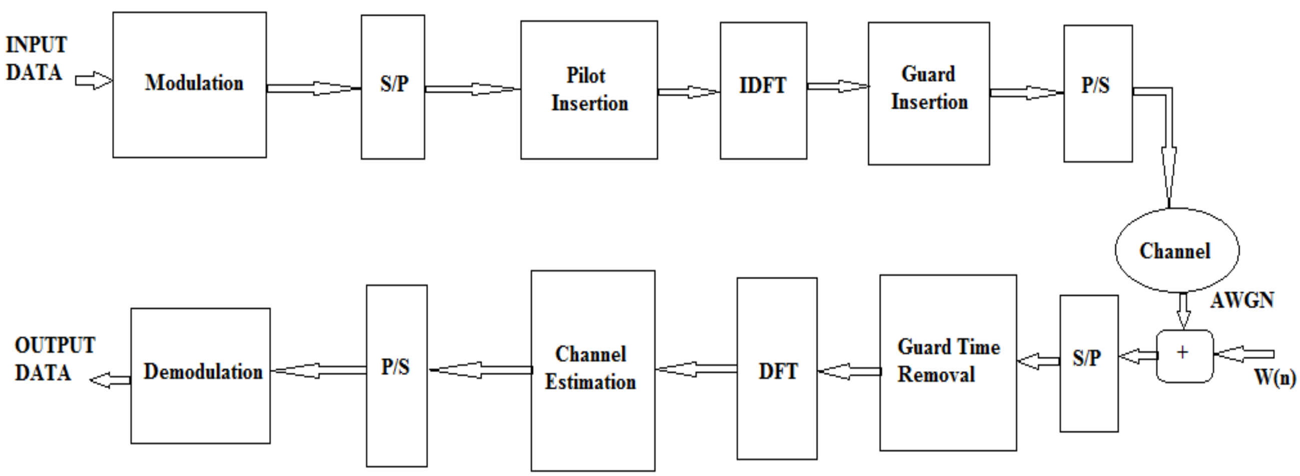

Fig. 2: OFDM system model

$$X(k) = X(mL+1) \qquad (2)$$

Where $X(k) = \begin{cases} X_p(m) = 0 \; where \; l = 0 \\ inf.Data \; where \; l = 1,2 \ldots\ldots L-1 \end{cases}$ (3)

$X_p(m)$ is the m^{th} pilot carrier value. The received pilot signal vector,
$Y_p = [Y_p(0), Y_p(1), \ldots. Y_p(N_p-1)^T$ can be expressed as given by (4) and (5).

$$Y_p = X_p H_p + W_p \qquad (4)$$

Where

$$X_p = \begin{bmatrix} X_p & \ldots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \ldots & X_p(N_p-1) \end{bmatrix} \qquad (5)$$

$H_p(k)$ = is the frequency response of the channel at pilot sub-carriers and defined as

$$H_{p,ls} = [H_{p,ls}(0), H_{p,ls}(1), \ldots. H_{p,ls}(N-1)^T \qquad (6)$$
$$H_{p,ls} = X_p^{-1} Y_p \qquad (7)$$

The LS estimate of Hp is susceptible to Gaussian noise and ICI because the channel responses of data subcarriers are obtained by interpolation [15].

IV. TURBO CODES

It was founded that to achieve near Shannon's bound performance, one would need to implement a decoder with infinite complexity or close. Parallel concatenated codes, as they are also known, can be implemented by using either block codes (PCBC) or convolution codes (PCCC).

RSC (Recursive Systematic Convolution) Turbo Encoder:

Turbo encoder is comprised of 2 Rate ½ RSC encoder as shown in Figure 1.The first encoder takes the input information bits and generates Parity bits $\overline{P}$. The interleaver interleaves the information bits $\overline{X}$ to generate interleaved information $\overline{X_\pi}$. The second encoder uses $\overline{X_\pi}$ and generates Parity bits $\overline{P_1}$.

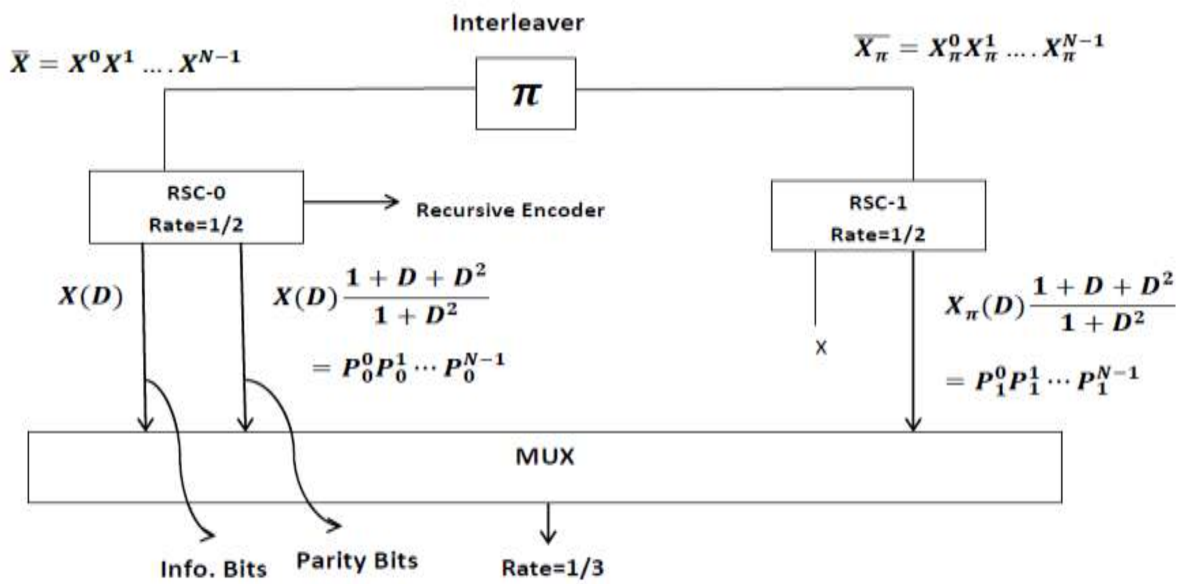

Fig. 3: Turbo Encoder Architecture for Code $G(D) = [1\ \frac{1+D+D^2}{1+D^2}]$

Encoding for each Rate ½ RSC encoder (RSC-0 & RSC-1) is done as follows:

$$G(D) = [1\ \frac{1+D+D^2}{1+D^2}]$$

Which gives $C_0(D) = X(D)$ and $C_1(D) = X(D)\frac{1+D+D^2}{1+D^2}$
Now assume, $(D) = \frac{X(D)}{1+D^2}$,
From these relations we obtain $C_0^j = X^j$ and $C_1^j = X^j + F^{j-1}$, where $F^j = F^{j-2} + X^j$

There are two decoders, BCJR-0 and BCJR-1. The first decoder takes $\overline{R0}$and $\overline{R1}$ as inputs and second decoder takes $\pi(\overline{R0})$ and $\overline{R2}$ as inputs,.

We define Log Aposteriori Probability Ratio (LAPPR) as follows:

$$\wedge_k = \log\left\{\frac{P(X^k = 1/\bar{R})}{P(X^k = 0/\bar{R})}\right\}$$

For k=0,1,….N-1.
Where, $\bar{R}$ is the input to any of the decoder. Consider BCJR-0, then $\bar{R} = \overline{R0R1}$
It can be shown that

$$P(X^k = i/\bar{R}) = \frac{1}{P(R_0^{N-1})}\sum_{m=0}^{M-1}\sum_{m'=0}^{M-1}\alpha_k(m')\gamma_k^i(m',m)\beta_k(m)$$

Where i=0 or 1 (input), m and m' are stages $(\boldsymbol{S_k})$, M is total number of stages. Stage m=0, 1, 2 and 3 respectively represents stage 00, 01 10 and 11.

The description of terms inside summation is given as follows:
$\alpha_k(m')$ is forward state metric
$\alpha_k(m')$ is forward static matric

$$\alpha_k(m') = P\left(S_k = m' \middle| R_0^{\overline{k-1}}\right)$$

Solving $\alpha_k(m')$

$$\alpha_k(m') = \sum_{m'=0}^{M-1}\sum_{i=0}^{1}\gamma_{k-1}^{i}(m'',m')\,\alpha_{k-1}(m'')$$

$\beta_k(m)$is backward static matrix

$$\beta_k(m) = P(\overline{R_{K+1}^{N-1}} \mid S_{k+1} = m)$$

Solving $\beta_k(m')$ gives

$$\beta_k(m) = \sum_{m'=0}^{M-1}\sum_{i=0}^{1}\gamma_{k+1}^{i}(m',m)\,\beta_{k+1}(m')$$

$\gamma_k^i(m',m)$ is transition probability from state m' to m at stage k for input i

$$\gamma_k^i(m',m) = \frac{1}{\sqrt{2\pi\sigma^2}}\exp\left(-\frac{1}{2\sigma^2}(R_0^k - (2i-1))^2\right)X\frac{1}{\sqrt{2\pi\sigma^2}}\exp\left(-\frac{1}{2\sigma^2}(R_1^k - (2C^k(m',m)-1))^2\right)$$

Using the equations described above and assuming some apriori Probabilities for inputs 0 and 1 at all stages the first decoder calculates LAPPR for all stages and decodes the received codebits.

V. PROPOSED CMA APPROACH

Using properties of Kronecker products, we can rewrite in (5) as

$s = vec(S) = \bar{B}oW^H vecdiag =: Aw$ (7)

Where $A\epsilon C^{N_t X M M_t}$, $DF^H = B \in C^{M M_t X N}$, $\bar{B}$denotes the complex conjugate of B, and o denotes the Khatri-Rao product (column-wise Kronecker product). The vecdiag (D) creates a column vector whose elements are the main diagonal of the matrix D. The optimization problem (6) becomes:

$\min_w ||Aw||_\infty^2 \quad s.t. \quad ||Aw||_2^2 = \alpha N_t$ (8)

We now propose an alternative formulation of this problem, by replacing the infinity norm by the average deviation of the OFDM block from a constant modulus signal [16]. Ideally, the resulting will be close to a CM signal, and hence have close-to optimal PAPR. The corresponding cost function is

$$J(w) = \left\| Aw\Theta\overline{(Aw)} - \alpha 1N_t \right\|_2^2 = \sum_{n=1}^{N_t} (w^H a_n a_n^H w - \alpha)^2$$

Here, the vector $a_n^H, n = 1, \ldots\ldots, N_t$, represents the –throw of matrix A, the column vector 1_{N_t} is a vector with all entries equal to 1 and dimension N_t, and Θ denotes the Schur- Hadamard product (pointwise multiplication). This formulation is similar to the well-known "CMA (2,2)" cost function for adaptive blind equalization or blind beam forming, and can be solved efficiently using available iterative algorithms.

IV–SIMULATION & RESULTS

(1) Simulation of Turbo Coded OFDM with comb pilot Estimation and AWGN channel

Fig. 4 below show the BER curves of turbo codes for one, two and three iterations respectively. It is observed that as we increase the number of iterations for the same channel, the bit error rate decreases by increasing the signal to noise ratio. The simulation results show the significant decrease in BER of the system by increasing the number of iterations. From simulation diagram we can conclude that in case of 1st iteration SNR of 2 dB at BER 10^-2, in case of 2nd iteration SNR of 2 dB at BER 8*10^-3, in case of 3rd iteration SNR of 2 dB at BER 10^-4are achieved. Here we applied comb estimation with AWGN channel.

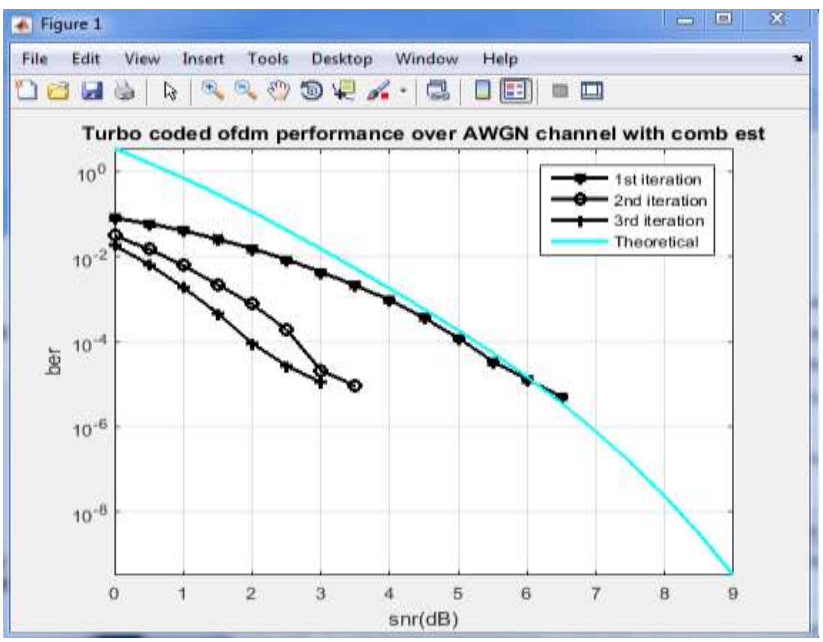

Fig. 4: BER performance of Turbo coded OFDM over AWGN channel with comb estimation

(2) Simulation of Turbo Coded OFDM by reducing PAPR using CMA with comb pilot Estimation and AWGN channel

Fig. 5 below show the BER curves of turbo codes for one, two, and three iterations respectively. It is observed that as we increase the number of iterations for the same channel, the bit error rate decreases by increasing the signal to noise ratio. The simulation results show the significant decrease in BER of the system by increasing the number of iterations. From simulation diagram we can conclude that in case of 1st iteration SNR of 2 dB at BER 10^-4, in case of 2nd iteration SNR of 2 dB at BER 8*10^-5, in case of 3rd iteration SNR of 2 dB at BER 2*10^-6 are achieved. Here we applied comb estimation with PAPR reduction using CMA technique in case of AWGN channel.

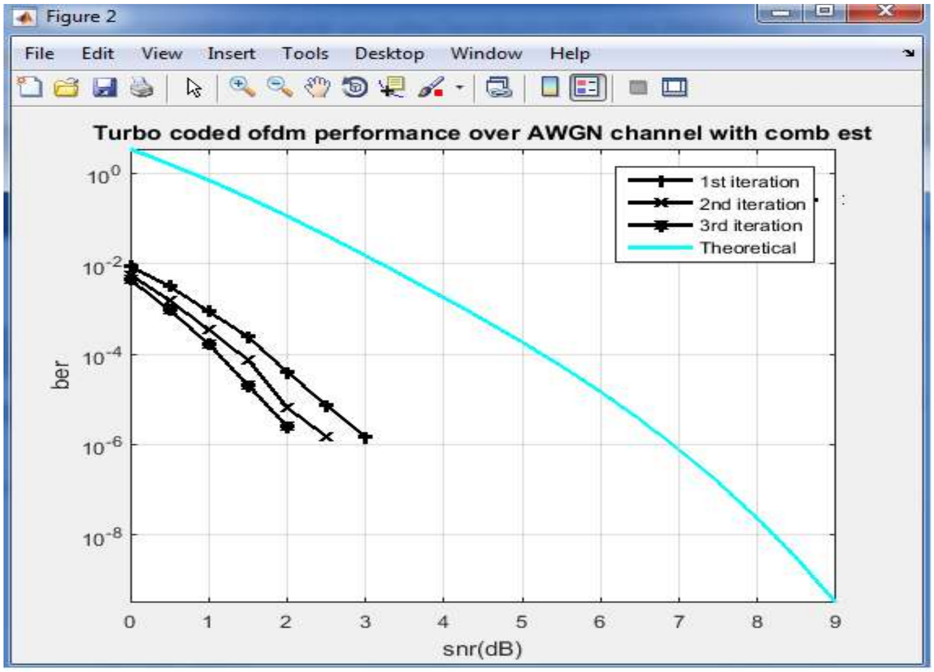

Fig. 5: BER performance of Turbo coded OFDM over AWGN channel with comb estimation and PAPR reduction

(3) Simulation of Turbo Coded OFDM with comb pilot Estimation and Rayleigh channel

Fig. 6 below show the BER curves of turbo coded OFDM in case Rayleigh fading channel by comb estimation is observed. It is observed that there is BER improvement in TC-QPSK-COMB as compared to uncoded OFDM with comb estimation. The simulation results show the significant decrease in BER of the system by using Turbo coding. From simulation diagram we can conclude that in case of uncoded system SNR of 10 dB at BER 8^-5, in case of turbo coded system SNR of 10 dB at BER 1.1*10^-5are achieved.

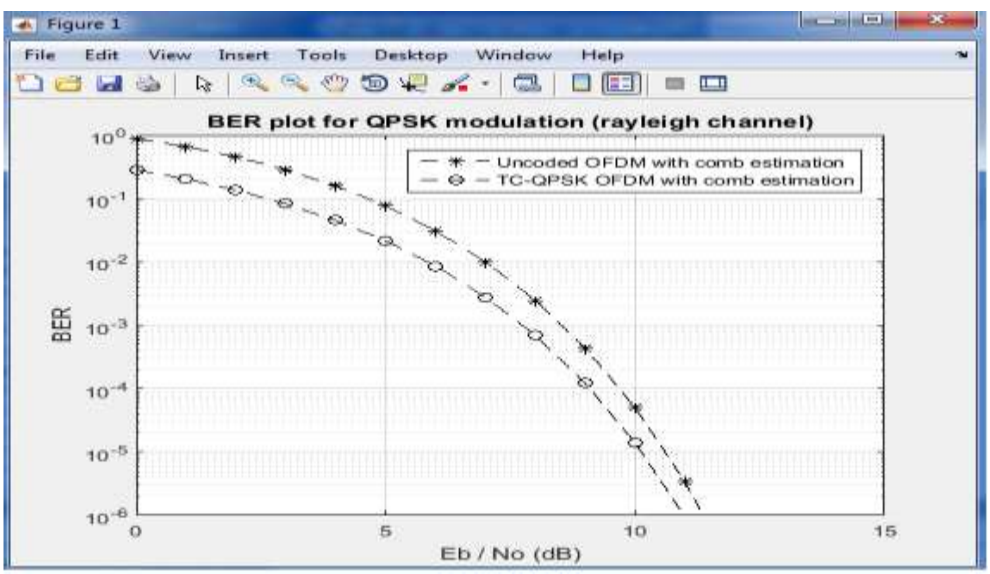

Fig. 6: BER performance of Turbo coded OFDM over Rayleigh channel with comb estimation

(4) Simulation of Turbo Coded OFDM by reducing PAPR using CMA with comb pilot Estimation and Rayleigh channel

Fig. 7 below show the BER curves of turbo coded OFDM in case Rayleigh fading channel by comb estimation is observed. It is observed that there is BER improvement in TC-QPSK-COMB-CMA as compared to uncoded OFDM with comb estimation. The simulation results show the significant decrease in BER of the system by using Turbo coding. From simulation diagram we can conclude that in case of uncoded system SNR of 6 dB at BER 1*10^-2, in case of turbo coded and CMA based PAPR reduction system SNR of 10 dB at BER 1*10^-5 are achieved.

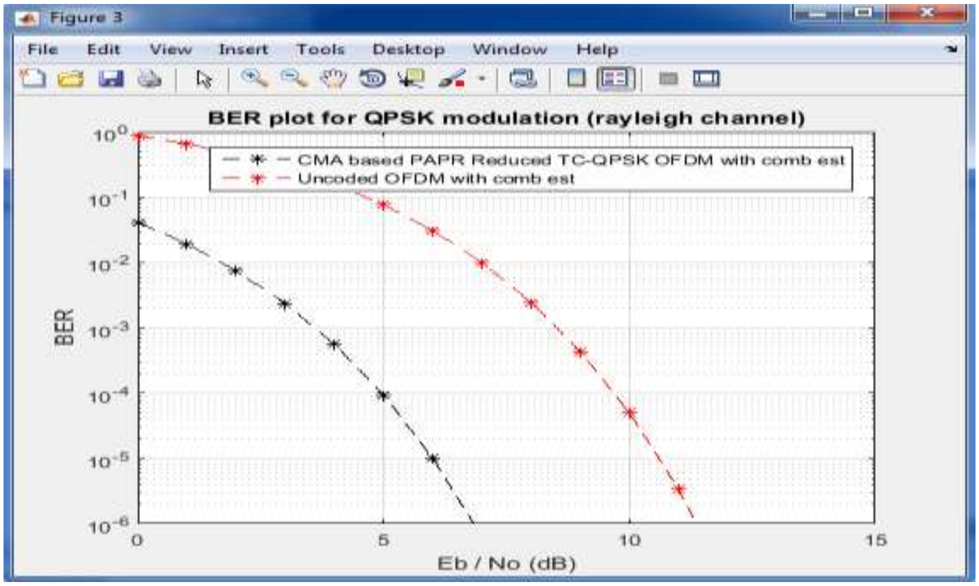

Fig. 6: BER performance of Turbo coded OFDM by reducing PAPR using CMA over Rayleigh channel with comb estimation

Parameter Table

Parameters	**Types/Values**
No. Of Bits	10^6
No. of bit/symbol	
Subcarriers	
FFT size	64
No of Pilot	32
No of Iteration used	3
Data Sub-channels	224
Pilot Interval	8
No of Tx antenna	1
Oversampling	1
Modulation	QPSK
Coding Rate	½
Channel	Rayleigh Fading

CONCLUSION

In this paper we analyses BER performance with respect to signal to noise ratio and improved BER using turbo coding. In OFDM there are some factors included intersymbol interference (ISI) caused by a dispersive channel, interchannel interference (ICI) and its deleterious effects, and the issue of PAPR which is crucial for proper functionality. Exploration of techniques to combat some of these problems such as the use of a cyclic prefix (longer than the channel delay spread), and equalization made easy thanks to the wideband nature of the OFDM. As long as the subcarrier spacing is kept smaller than the coherence bandwidth, taking advantage of the high correlation between adjacent sub carriers. Presentation of a few results in both AWGN and Raleigh environments, as we needed to validate our modified, simplified simulator. In this paper a new TC-PAPR-QPSK-OFDM system has been investigated. The proposed system is simulated in Raleigh Fading channel. Channel was estimated using PAPR reduction using CMA technique and the comb-type pilot arrangement with the LS estimator and 1D interpolation. Three iterations for turbo decoder are sufficient to provide good BER performance.

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