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TURBO Coded OFDM Improves BER Performance Evaluation for Digital Video Broadcasting

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Abstract: Turbo coded Orthogonal Frequency Division Multiplexing (OFDM) is attractive technique for high data rate in wireless communication applications, mobile communications (4G) and Wireless Metropolitan Area Networks (WMAN) and Digital Video Broadcasting (DVB). The performance of TURBO Coded 16 QAM and 64 QAM schemes with OFDM for high speed data rate applications is compared which is used in digital video broadcasting. BER analysis is used to assess the system's performance. Due to the high data rate of 64 QAM, attaining BER of 10^{-4} requires Eb/No of 0.9 dB in 16QAM, whereas obtaining BER of 10^{-4} requires 0.17 dB in 64QAM. By using OFDM removes Inter Symbol Interference (ISI) and Adjacent Channel Interference (ACI).

Keywords: Wireless communication, mobile communication, OFDM, QAM, TURBO Encoding

I. INTRODUCTION

Turbo codes are a class of high-performance FEC codes, which was created between 1990 and 1991 but initially released in 1993. These were the first practical codes to approximate the maximum channel capacity or the Shannon limit closely, a theoretical maximum for the coding rate, at which reliable communication with particular noise levels is still achievable. The turbo coding is used in mobile 3G/4G communications (e.g. in UMTS and LTE), in satellite communication (deep space), as well as in other uses where designers are aiming to ensure the reliable transfer of information via bandwidth or latency restricted links in the event that data-corrupting noise occurs. Turbo codes compete with LDPC codes, which offer the same performing characteristics.

Turbo codes are error-correcting codes with performance close to the Shannon theoretical limit. These codes have been invented at ENST Bretagne, France. The encoder is formed by the parallel concatenation of two convolutional codes separated by an interleaver. An iterative process through the two corresponding decoders is used to decode the data received from the channel. Each elementary decoder passes to the other soft information about each bit of the sequence to decode. This soft information called extrinsic information is updated at each iteration. Shannon's states that data rates are limited of the received signal by using signal power content. It also related with signal bandwidth. Data rates leads to increase in signal power. By using higher modulation scheme signal power can be increased, which reduces symbols required for a given data rate and there is an increase in transmission bandwidth. Signal power can be improved by using multiple antennas at transmitter and receiver side. Turbo coder implemented with 1/3 Forward error correction (FEC) and random interleaver. Turbo coding is an iterative decoding and shannon performance.

II. OFDM SYSTEM

Orthogonal frequency –division multiplexing (OFDM) is a type of digital transmission and a method of encoding digital data on multiple carrier frequencies. OFDM used in applications such as digital television and audio broadcasting and 4G/5G mobile communications. OFDM combines the benefits of Quadrature Amplitude Modulation (QAM) and Frequency Division Multiplexing (FDM) to produce a high-data-rate communication system.

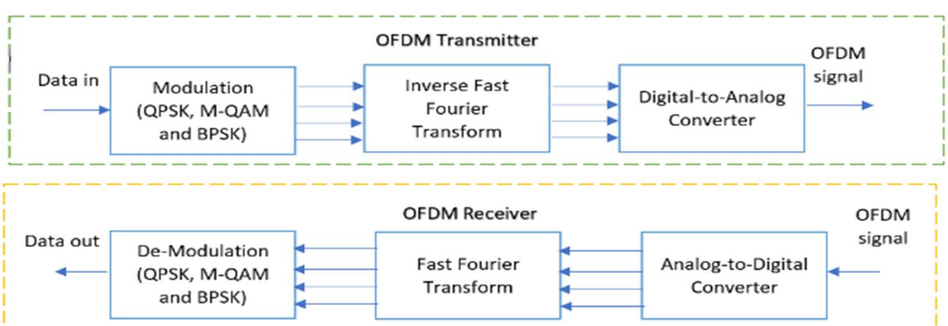

Fig 1: Block diagram of OFDM system

By using various modulation methods such as Quadrature amplitude modulation (QAM), Quadrature phase shift keying (QPSK), and binary phase shift keying (BPSK), the serial data modulates as it gives as an input to the modulator. The incoming serial data converts into parallel form in the S/P. S/P block for generating parallel information to be transmitted.

Through the mapping of input bits on the digital modulation scheme's components of in-phase and quadrature –phase, the OFDM symbols construct in the OFDM with the transmitter portion. IFFT block is used for convert frequency domain signal to time domain signal. In time domain , the signal should present for transmission. Based on the efficient inverse fast Fourier transform algorithm, the transmission accomplishes with determination of signal IDFT. The sum of transmitted signal's different versions with different attenuation and delays include in the received signal and ISI occurs. The equalizers of time domain uses in the traditional way of restricting the ISI. Analog to digital converter used in the OFDM receiver section to convert the incoming analog signals to digital form for further processing. ADC is used for high speed and low cost. Fast Fourier Transform (FFT) is used to transform the OFDM symbols in time domain into frequency domain. FFT algorithms namely the decimation in time and decimation in frequency (DIF) are used to find the DFT of sequence at a faster rate by reducing the number of complex additions and complex multiplications.

III. TURBO CODED OFDM SYSTEM

Figure 2 illustrates Turbo Coded OFDM. Turbo encoder with interleaver encodes the digital data bits. Turbo encoded bits are modulated by 16 QAM or 64 QAM and then transmitted via the OFDM equalization process. The process of creating orthogonal subcarriers using IFFT in transmission and FFT in reception is known as OFDM. The OFDM signal is conveyed across channels and uses N subcarriers. The signal is demodulated and sent to de-interleaved at the receiver. The means of an iterative decoder. Three streams are represented using a turbo encoder with a 1/3 channel encoding technique. The first is a systematic stream, and the other two are parity streams. Trellis structure with interleaver is used to define the TURBO encoder. Interleaver enhances BER performance by reducing code distance and avoiding low-weighted code words[4]. The interleaver is pseudorandom.

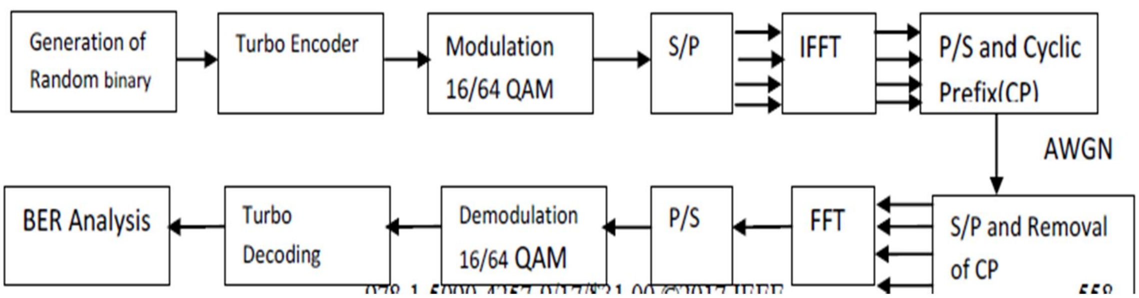

Figure 2: Block diagram of Turbo coded OFDM system by using 64QAM/16QAM modulation

There are many different instances of turbo codes, using different component encoders, input/output ratios, interleavers, and puncturing patterns. Two decoders are interconnected to each other in series. The decoder operates on lower speed and which causes delay. The functioning of a Turbo decoder is the inverse of that of a Turbo encoder. It's an iterative process. The band width utilization of 16 QAM and 64 QAM is improved by this decoding procedure. In compared to 4QAM, band width utilization is two and three times higher for 16 QAM and 64 QAM, respectively. [5]. Higher order modulations, such as 256 QAM and larger, are noisier and necessitate a higher S/N. As a result, 64 QAM is employed for cleaner channels and improves BER for greater data rates. The Turbo decoder employs the Bahl, Cocke, Jelinek, and Raviv (BCJR) algorithm, which is an iterative process that produces error-free output for high-speed applications. BER In comparison to convolution codes, Turbo Coded OFDM performs better [2]. When the amount of bits per symbol is doubled in Turbo coded OFDM, the bit energy to noise density ratio increases by 2dB [6]. To generate modulated symbols, the input bits are processed for 16 QAM or 64 QAM. 4 bits are mapped to 1 modulation symbol in 16 QAM, and the output vector is one-fourth the size of the input vector. One sixth of the input vector in the case of 64 QAM. Using 64 QAM instead of 16 QAM allows for a higher data rate of transmission. When considering message bits of size 1536, this makes sense. For the same number of message bits, 16 QAM requires 384 (1536/4) symbols, whereas 64QAM requires 256 (1536/6) symbols (1536).

The symbol mapping for 16 QAM and 64 QAM as [11 10 14 15 9 8 12 13 1 0 4 5 3 2 6 7] and [47 46 42 43 59 62 45 44 40 41 57 56 60 61 37 36 32 33 49 48 52 53 39 38 34 35 51 50 54 55 7 6 2 3 19 18 22 23 5 4 0 1 17 16 20 21 13 12 8 9 25 24 28 29 15 14 10 11 27 26 30 31]

Message bits size	1536
64QAM	256 symbols
16 QAM	384 symbols

Table 1: number of symbols used for different modulation

IV. MATHEMATICAL OPERATION OF TURBO CODED OFDM SYSTEM

In OFDM System, number of subcarriers overlapped for bandwidth efficiency and by eliminating inter symbol interference, Adjacent channel interference. Orthogonal signals are generated by discrete Fourier transform and inverse discrete Fourier transform process.

These process are implemented efficiently by FFT and IFFT for reception and transmission respectively. It is an efficient and robust process to deal multi path fading.

In OFDM System ,N-point IFFT is implemented for transmission symbols by using OFDM transmission system. N-point IFFT is an $Y_1[K]_{k=0}^{N-1}$ which generates for N orthogonal sub carrier signals is $Y_1[n]_{n=0}^{N-1}$ and x[n] is the received sample corresponding to y[n]. With addition of white Gaussian Noise is x[n]=y[n]+w[n]. N-point FFT is implemented at receiver side is $X_1[K]_{k=0}^{N-1}$ which is a noise version of received symbol. Number of sub-carriers in OFDM occupy finite duration for each symbol indicated by T. The modulated symbols are converted into serial to parallel by using QAM. The transmission of N symbols is $Y_l[K]$ and transmitted symbol at k^{th} sub carrier where l=0,…..∞, K=0,1…..N-1 and time duration of the symbol is NTs seconds. The single OFDM symbol with length indicate T_{symbol}=NTs. $\psi_{l,k}(t)$ denotes the l^{th} OFDM signal at the K^{th}subcarrier, which is given by

$$\psi_{l,k}(t)=\begin{cases} e^{j2\pi f_k}\left(t-lT_{sym}\right) where..0<t\leq T_{sym} \\ 0\ldots\ldots elsewhere \end{cases}\ldots\ldots(1)$$

t=lT_{sym} +nT_s … (2) where T_s is the overlapped sinc function spacing with T_{sym} / N=T_s and FDM signal sampled at t.

f_k=k/T_{sym} where f_k is center frequency of k.

$X_l[n]=\sum_{k=0}^{N-1}X_l[k]\,e^{j2\pi kn/N}$ for n=0,1,2,…..N-1….(3)

This expression is N-point IFFT of 64-QAM or 16-QAM

$$Y_l\,[k]=\frac{1}{T_{sym}}\int_{-\infty}^{\infty}\left\{\sum_{i=0}^{N-1}X_l[i]e^{j2\pi f_{1(t-lT_{sym})}}dt\right\}\ldots\ldots(4)$$

$$Y_l[k]=\frac{1}{T_{sym}}\int_{-\infty}^{\infty}X_l[i]e^{j2\pi f_{k(t-lT_{sym})}}\ldots.\text{where } lT_{sym}<t\leq lT_{sym}+nT_{s\ldots\ldots}(5)$$

Y_l[k] is the received symbol, FFT effectively calculates output. The effect of fading is corrected in the frequency domain technique by implementing equalization. For optimum results, Data is aligned with subcarriers in the implementation signals in the frequency domain and OFDM are generated. This Resource element mapping is the name of the procedure. In the next paragraphs, the step data is represented as a vector of resource elements.

V. RESULTS AND SIMULATION ANALYSIS

MATLAB is used for simulation of BER performance of Turbo coded OFDM. Figure 3 shows the MATLAB simulation result, which shows BER of 10-5,Eb/N0 of 1.9dB for 16QAM and 4.5 dB for 64 QAM. The 64 QAM. The 64 QAM data rate is high because 256 symbols are required to represent 1536 input bits. As a result, 64 QAM modulation can be used in high-data-rate applications.

PARAMETER	VALUE
Modulation Technique	16-QAM or 64-QAM
Channel model	AWGN channel
Used number of subcarriers	64
FFT size	256
Code rate	1/3

Table 2: Simulation Parameter values

A. BER Performance 0f Turbo Coded OFDM For 16 & 64 QAM

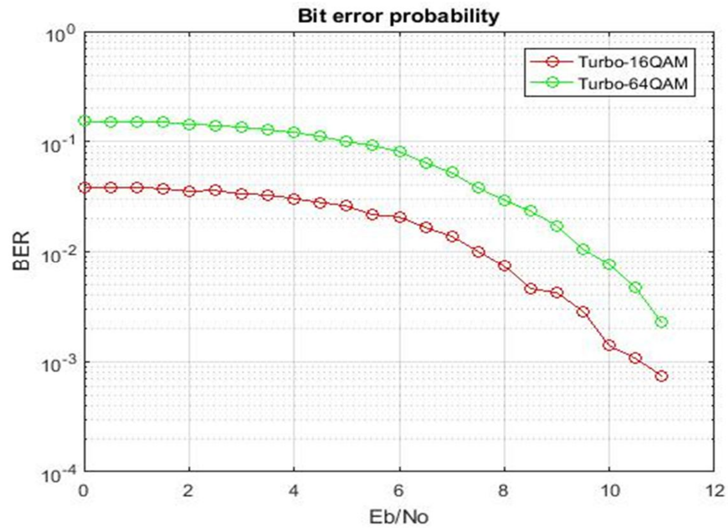

Fig 3: Simulation outcome of BER vs. SNR by the measurements of various techniques Turbo coded OFDM For 16 & 64 QAM

B. BER Performance of Turbo Coded OFDM 16 –QAM And 64 –QAM Comparison

Modulation techniques	BER values at 2dB	BER values at 4dB	BER values at 8dB	BER values at 10dB
Turbo 64-QAM	0.1466	0.1227	0.02581	0.0017
Turbo 16 -QAM	0.0365	0.0313	0.007	0.0009

Table 3: Comparison of the BER values for OFDM using Turbo coded OFDM 16-QAM and 64 –QAM.

C. OFDM With LBC And Turbo Coding Comparisons

1) 16 –QAM Comparison

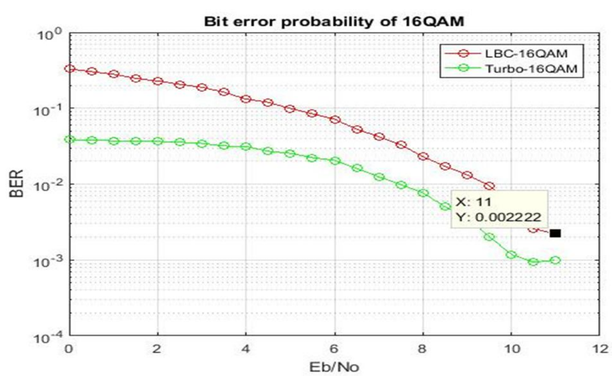

Fig 4: Simulation outcome of BER vs. SNR by the measurements of various techniques LBC and Turbo coded OFDM For 16 QAM

2) 16 –QAM Comparison Values

Modulation Techniques	BER values at 2 dB	BER values at 4 dB	BER values at 8 dB	BER values at 10 dB
LBC 16	0.2287	0.1321	0.02299	0.0022
Turbo 16	0.0365	0.0313	0.007	0.0009

Table 4: Comparison of the BER values for OFDM using LBC and Turbo coded OFDM 16-QAM modulation

3) 64 –QAM Comparison

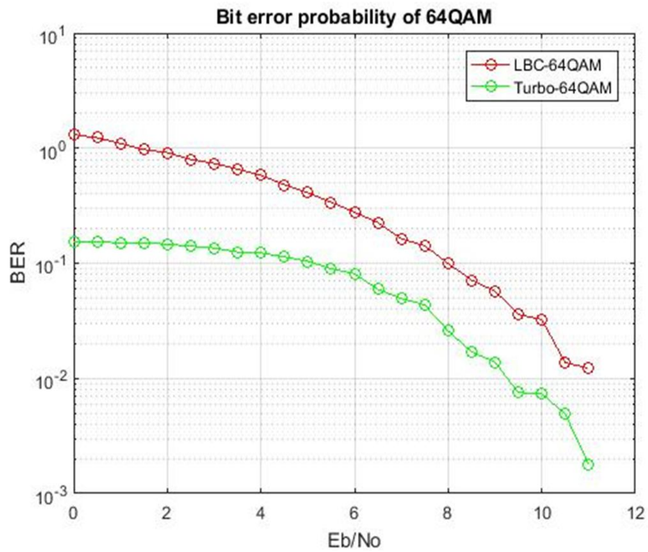

Fig 5: Simulation outcome of BER vs. SNR by the measurements of various techniques LBC and Turbo coded OFDM For 64 QAM

4) 64 –QAM Comparison Values

Modulation Techniques	BER values at 2dB	BER values at 4dB	BER values at 8dB	BER values at 10dB
LBC 64	0.9138	0.5819	0.09949	0.0324
Turbo 64	0.1466	0.1227	0.02581	0.0017

Table 5 :Comparison of the BER values for OFDM using LBC and Turbo coded OFDM 64-QAM modulation

5) 16 –QAM AND 64 –QAM Comparison

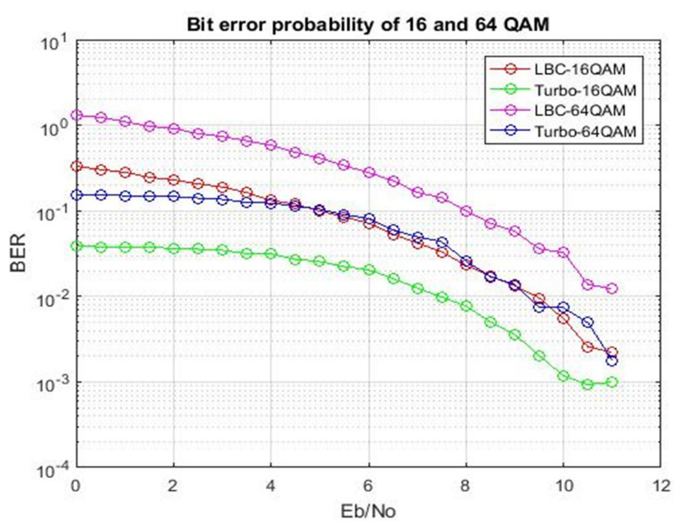

Fig 6: Simulation outcome of BER vs. SNR by the measurements of various techniques LBC and Turbo coded OFDM For 16 & 64 QAM

6) 16 –QAM AND 64 –QAM Comparison Values

Different Modulation Techniques	BER values at 2 dB	BER values at 4 dB	BER values at 8 dB	BER values at 10 dB
LBC 64 QAM	0.9138	0.5819	0.09949	0.0324
LBC 16 QAM	0.2287	0.1321	0.02299	0.0022
Turbo 64 QAM	0.1466	0.1227	0.02581	0.0017
Turbo 16 QAM	0.0365	0.0313	0.007	0.0009

Table 6 :Comparison of the BER values for OFDM using LBC and Turbo coded OFDM16 QAM and 64-QAM modulation

VI. CONCLUSION

TURBO Coded OFDM is implemented on 16QAM and 64QAM modulations and the BER performance is compared. 64 QAM performs better at greater data rates, but it causes more mistakes in the AWGN and fading channels. Data transmission in a particular time (data rate) is high for 64QAM. It denotes an increase in bandwidth. For 64QAM, the Eb/No is 2dB. The Iterative turbo decoding approach can reduce errors, but it adds time delay, and Eb/No demands more, roughly 10 dB [10]. Due to the high data rate of 64 QAM, BER of 10^{-4} ,16 QAM requires Eb/No of 0.9 dB, whereas 64 QAM only 0.17 dB. Iterative Turbo decoding and video signal processing can both control data mistakes created by the channel.

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