Improvement in BER Performance of OFDM System using Interleaver

Quanitah Shaikh, Pallavi Patil, Afreenzehra Sayed

***Abstract*—The OFDM technology provides high bit rate, spectral efficiency and helps to mitigate ISI in wireless environment. In case of fading channel the BER increases, hence channel coding technique with interleaving is used to improve the performance. In this paper convolutional coding along with matrix and random interleaving is used to enhance the system performance.The modeling and simulation of OFDM system is carried out and the BER performance of matrix and random interleaving is compared.**

***Keywords*—OFDM; Convolutional codes; Matrix and Random Interleaving.**

I. INTRODUCTION

In a single carrier communication system, the data is modulated onto a single carrier frequency which results into intersymbol interference (ISI) in case of Frequency selective channel. The basic principle of orthogonal frequency division multiplexing (OFDM) is to divide the available spectrum into several orthogonal sub channels so that each narrowband sub channels experiences almost flat fading [1]. OFDM provides large data rates with sufficient robustness to radio channel impairments. In an OFDM scheme, a large number of orthogonal, overlapping, narrow band sub-carriers are transmitted in parallel resulting in compact spectral utilization. With OFDM, it is possible to have overlapping sub channels in the frequency domain, thus increasing the transmission rate. The effectiveness of OFDM lies in its way of handling the multipath interference at the receiver. Multipath phenomenon generates two effects (a) Frequency selective fading [13] and (b) Intersymbol interference (ISI). The "flatness" perceived by a narrowband channel overcomes the frequency selective fading. Modulating symbols at a very low rate makes the symbol period much longer than the delay spread of the channel and hence reduces the ISI. Use of suitable error correcting codes provides more robustness against frequency selective fading. The insertion of an extra guard interval between consecutive OFDM symbols can reduce the effects of ISI even more. The use of FFT technique to implement modulation and demodulation functions makes it computationally more efficient[6, 14, 15].

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I. OFDM SYSTEM

The basic block diagram of OFDM transmitter and receiver is shown in Fig. 1.

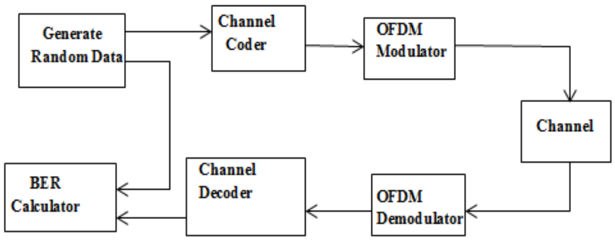

Fig. 1: Block diagram of Coded OFDM system

The main elements of coded OFDM system are channel coder, OFDM modulator and channel[9]. The channel coder consist of error correctinig codes and interleaver. In this paper convolutional encoder with random and matrix interleaver is used. These aspects make the system resistant to ISI and multipath fading. In channel coder, binary input data is encoded by a ½ rate convolutional encoder and then interleaved. In OFDM modulator the binary values are mapped into symbols usingQuadrature Amplitude Modulation (QAM). The resultant 48 data symbols are then added to 4 pilotsubcarriers, further resulting in a total of 52 symbols. The symbol is then modulated onto 52 subcarriers by applying the Inverse Fast Fourier Transform (IFFT). The output is then converted to serial and a cyclic prefix is added to make the system robust to multipath propagation. Therefore each OFDM symbol consists of 48 data subcarriers, 4 pilot subcarriers, and 12 zero padding and 16 guard periods. The OFDM symbols are then transmitted through the channel [4,12].

Basically, the OFDM demodulator performs the reverse operation. It removes the cyclic extension after which the signal is applied to a Fast Fourier Transform to recover the 52 QAM values of all subcarriers. The pilot subcarriers are used to correct the channel response as well as remaining phase drift. The QAM values are then demapped into binary values, and finally a Viterbi decoder decodes the information bits [10, 11].

II. CONVOLUTIONAL CODING

A ½ rate convolutional encoder is shown in Fig. 2.

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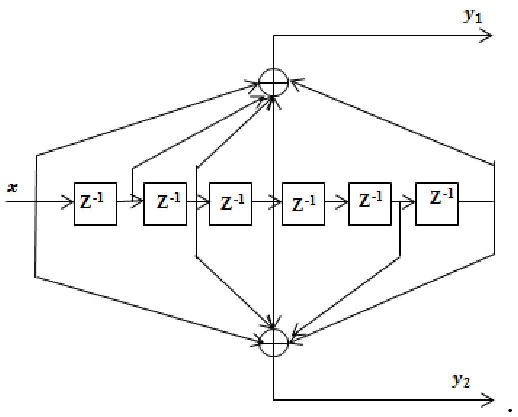

Fig.2:Convolutional encoder

Convolutional encoder consists of a shift register and exclusive-OR logic circuits. Shift register provides temporary storage and a shifting operation for the input bits and exclusive-OR logic circuits generates the coded output from the bits currently held in the shift register. Usually, k data bits may be shifted into the register at once, and n code bits are generated [5, 7].

A convolutional code introduces redundant bits into the data stream through the use of linear shift registers. Connection of the shift register taps to the modulo-2 adders is represented by generator polynomials $g_0 = (133)_8 = [01011011]_2$ and $g_1 = (171)_8 = [01111001]_2$. A “1” in binary vector indicates connection to modulo-2 adder and a “0” represents no connection, asshown inFig.2 .Computations of convolutional encoder depend not only on the current input bit, but also on bits stored in each shift register [8].

III. INTERLEAVER

Interleaving is used to cope with the channel noise such as burst errors which results due to fading channel. The interleaver rearranges input data such that consecutive data are split among different blocks. At the receiver end, the interleaved data is arranged back into the original sequence by the de-interleaver. Interleaving can be employed in digital data transmission technologies to mitigate the effect of burst errors. When too many errors exist in one code word, due to a burst error, the decoding of a code word cannot be done correctly. To reduce the effect of burst error, the bits in one code word are interleaved before being transmitted. When interleaving occurs, the place of bits will change, which means that a burst error cannot disturb a huge part of one code word [2, 3].

The given example explains that only a small part of each code word is distorted with interleaving, so the decoding of code word can be done correctly.

Transmission without Interleaving:
Error-free message: aaabbbcccdddeeefff
Transmission with a burst error:aaabbbc_____deeefff

In the above case, the code-word ccdd is altered, so either it cannot be decoded at all or it might be decoded incorrectly.

Transmission with Interleaving:
Error-freecodeword: aaabbbcccdddeeefff
Interleaved:abcdefabcdefabcdefabcdef
Transmission with a burst error: abcdefab___fabcdef
Received code words after de-interleaving:
aaabbbcc_dd_ee_fff

There exist two types of interleaver, namely block and convolutional interleaver. In a block interleaver, the input data is written along the rows of a matrix, and then read out along the columns. Another kind of a block interleaver is pseudorandom block interleaver, in which data is written in memory in sequential order and read in a pseudorandom order. In a convolutional interleaver, the data is multiplexed into and out of a fixed number of shift registers

A. Matrix Interleaving

In Matrix interleaving bits are fed in a matrix row by row and read out column by column. *Fig. 3.* illustrates an example of the matrix interleaver block. The input vector is a column vector. The input column vectoris converted into a 2 by 3 matrix by matrix interleaver. The first three elements of input vector are the first row of matrix and the second three elements of input vector are the second row of matrix. Finally the matrix interleaver block rewrites the elements column by column. Therefore the first two elements of output are the first column of matrix, the second two elements of output are the second column and the third two elements of output are the third column.

$$\begin{bmatrix} 1 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \end{bmatrix} \rightarrow \begin{bmatrix} 1 & 4 & 5 \\ 6 & 7 & 8 \end{bmatrix} \rightarrow \begin{bmatrix} 1 \\ 6 \\ 4 \\ 7 \\ 5 \\ 8 \end{bmatrix}$$

Fig. 3. Matrix Interleaving

At the de-interleaver the reverse operation takes place as illustrated by the example given in Fig. 4.

$$\begin{bmatrix} 1 \\ 6 \\ 4 \\ 7 \\ 5 \\ 8 \end{bmatrix} \rightarrow \begin{bmatrix} 1 & 4 & 5 \\ 6 & 7 & 8 \end{bmatrix} \rightarrow \begin{bmatrix} 1 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \end{bmatrix}$$

Fig. 4. Matrix De-interleaving

B. Random Interleaving

Random interleaver merely permutes all lines of the input bit stream randomly. The effect of this random shuffling makes almost all symbols correlated with each other. It rearranges the elements of its vector using a random permutation. The Random Deinterleaver block rearranges the elements of its input vector using a random permutation. The Initial seed parameter initializes the random number generator that the block uses to determine the permutation. If this block and the Random Interleaver block have the same value for Initial seed, then the two blocks are inverses of each other [8].

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IV. SIMULATION RESULTS

The simulation results are plotted in terms of performance of the OFDM system that is Bit Error Rat (BER). Mainly the modulation techniques of 16-QAM, 32-QAM and 64-QAM are used. Analysis is done by observing the simulation results.

Various graphs are plotted using data provided in the Table I.

TABLE I.SIMULATION PARAMETERS

Bit rate R = 1/T	2 Mbps
Coding	½rate Convolutional codes
Interleaver	Matrix and Random
IFFT, FFT size	64
Channel used	AWGN
Guard Interval size IFFT size/4	16 samples
OFDM transmitted frame size	64+16 = 80

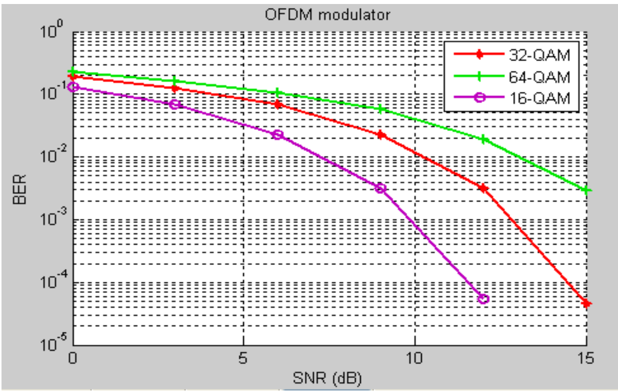

Fig. 5. OFDM system without channel coding and interleaving

To improve the performance of this system FEC code can be used. Convolutional code is used as a FEC code. Convolutional coding in OFDM can give performance improvement of 3dB on AWGN channel over the uncoded OFDM system for required BER.

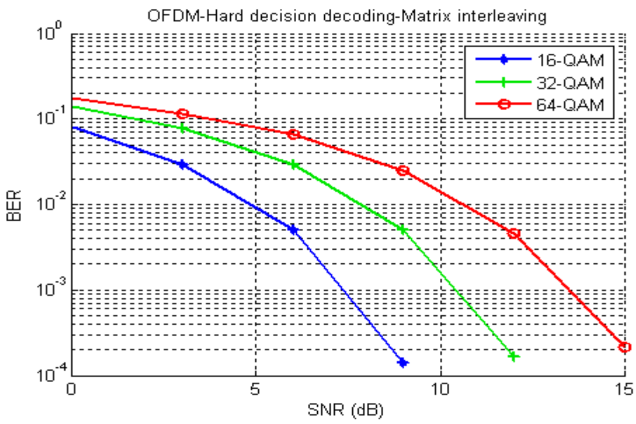

Fig. 6. OFDM system with matrix interleaver and hard decision decoding

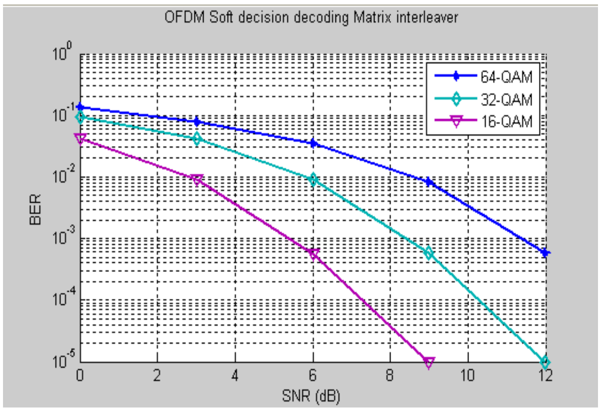

Fig.7. BER vs. SNR for OFDM system with matrix interleaver and soft decision decoding

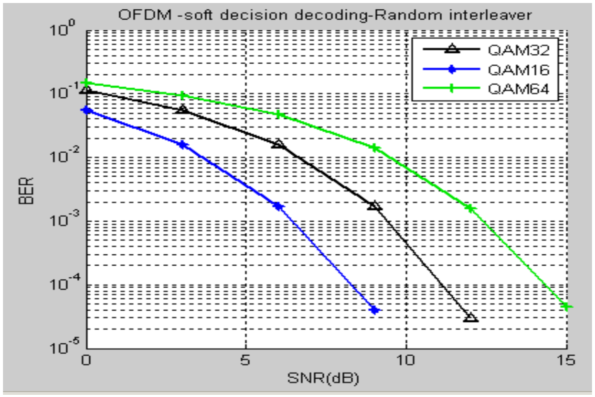

Fig. 8. BER vs. SNR for OFDM system with random interleaver and soft decision decoding

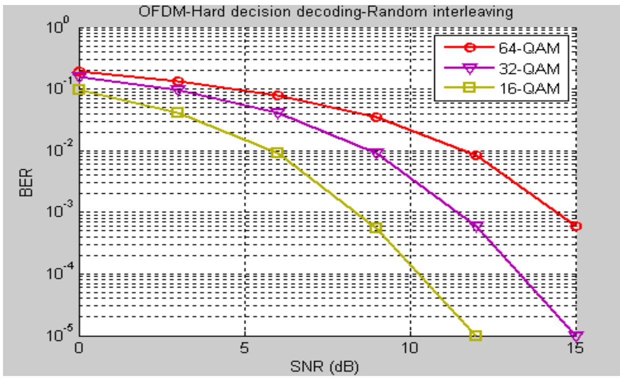

Fig. 9. BER vs. SNR for OFDM system with random interleaver and hard decision decoding

From the above graphs, it is clear that of the three options 16, 32 and 64 -QAM, 16-QAM gives better BER results.For 16 QAM with SNR equal to 9 dB the effect of interleaver and hard/soft decision decoding is summarized in Table II.

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TABLE II. BER VALUES FOR 16-QAM AND SNR=9 dB

16-QAM	BER values
Matrix interleaver and Hard decision decoding	$1.3*10^{-4}$
Matrix interleaver and Soft decision decoding	$9.9*10^{-6}$
Random interleaver and Hard decision decoding	$5.5*10^{-4}$
Random interleaver and Soft decision decoding	$3.99*10^{-5}$

V. CONCLUSION

The work presented here gives design, implementation and analysis of OFDM transmitter-receiver using Matlab/Simulink under AWGN channel. The performance of OFDM is tested for digitalmodulation technique M-QAM using MATLAB/SIMULINK toolbox.It is observed from BER plot that BER is less in case of 16-QAM for low SNR as compared to 32-QAM and 64-QAM. In this paper an effort is made to enhance the performance of the system by reducing BER using convolution code along with interleaving techniques. It is evident from the BER plots that matrix interleaverand soft decision decoding gives better BER results.

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