ISSN: 2278 – 909X
International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE)
Volume 5, Issue 4, April 2016

Refined MIMO-OFDM System in Iterative Receiver Using Message Passing Algorithm

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Abstract— Multiple Input Multiple Output Orthogonal Frequency Division Multiplexing (MIMO-OFDM) system is widely used high data rate transmission technique in the wireless system. The performance is calculated in terms of Bit Error Rate (BER) versus the Signal to Noise Ratio (SNR). The use of multiple antennas at both end of a wireless link improves the spectral efficiency of the system. The multicarrier Orthogonal Frequency Division Multiplexing (OFDM) system is well suited for the broadband communication. OFDM is a frequency-division multiplexing scheme used as a digital multicarrier modulation method. The detection of the transmitted signal is based on the Zero forcing (ZF) and Minimum Mean Square Equalization (MMSE) scheme. The equalizer is design to compensate the effect of channel. The Maximum Likelihood (ML) Detector is better than ZF and MMSE. For a high level modulation the ML detector is more complex. In this paper we discuss the BER performance of the MIMO-OFDM system with turbo equalizers for the 16-QAM modulation techniques using multipath fading channels i.e. Rayleigh channel. The MIMO-OFDM system is designed with encoder and interleaver at the transmitter side and vice versa at the receiver side. Turbo equalization is an iterative equalization and decoding technique at the receiver side to reduce the effects of the channel. The simulation results show that the BER performances of the turbo equalizer and normal MIMO-OFDM system.

Index Terms— Convolutional encoding, Equalizations, Interleaver, MIMO-OFDM System, Turbo equalization.

INTRODUCTION

Multiple Input Multiple Output Orthogonal Frequency Division Multiplexing (MIMO OFDM) is widely used in mobile communication area because it can realize more reliable and higher data-rate transmission [2]. Orthogonal Frequency Division Multiplexing is a digital multi-carrier modulation scheme. It combines modulation with multiplexing. MIMO systems divide a data stream into multiple unique streams, each of which is separately modulated and transmitted through a different radio antenna at the same time in the same frequency channel. The MIMO-OFDM system reduces the transmission time. The transmitted signal passes though the channel and it may causes distortion. These errors can be nullified by the equalizer technique used at the receiver side. The detection of the transmitted signal is based on the Zero forcing and Minimum Mean Square Equalization (MMSE) scheme [3]. The equalizer is used to compensate the effect of channel. In zero forcing equalizer the ISI component at the output of the equalizer is forced to zero [6]. It tends to amplify the noise and hence gives noisy output. The main objective of the MMSE equalizer is to minimize the errors between target signals and output. The Maximum Likelihood (ML) Detector is better than ZF and MMSE. For a high level modulation the ML detector is more complex. Turbo equalization is used in the iterative receiver [9]. A turbo equalizer is used to equalize the corrupted received signal up to number of iteration [10] and equalizes the final output signal. The difference between a turbo equalizer and a standard equalizer is the feedback loop from the decoder to the equalizer.

METHODOLOGY

MIMO-OFDM systems divide a data stream into multiple unique streams, each of which is modulated and transmitted through different radio antennas at the same time in the frequency channel. In OFDM system channel equalization play a key role in overcoming distortion. The detection of the transmitted signal in the MIMO-OFDM system is with the help of the equalizer at the receiver side. The basic system considered here is MIMO-OFDM system as shown in the Figure.1. The random binary input data is encoded and interleaved prior to OFDM transmission. Data is divided into multiple streams and same type of encoding, interleaving and modulation is applied to these streams at the transmitter. Then the multiple streams are applied to the OFDM modulation and 2x2 MIMO transmission is employed. The Turbo equalization is performed at the receiver side. It is an iterative receiver.

Manuscript received Apr, 2016.

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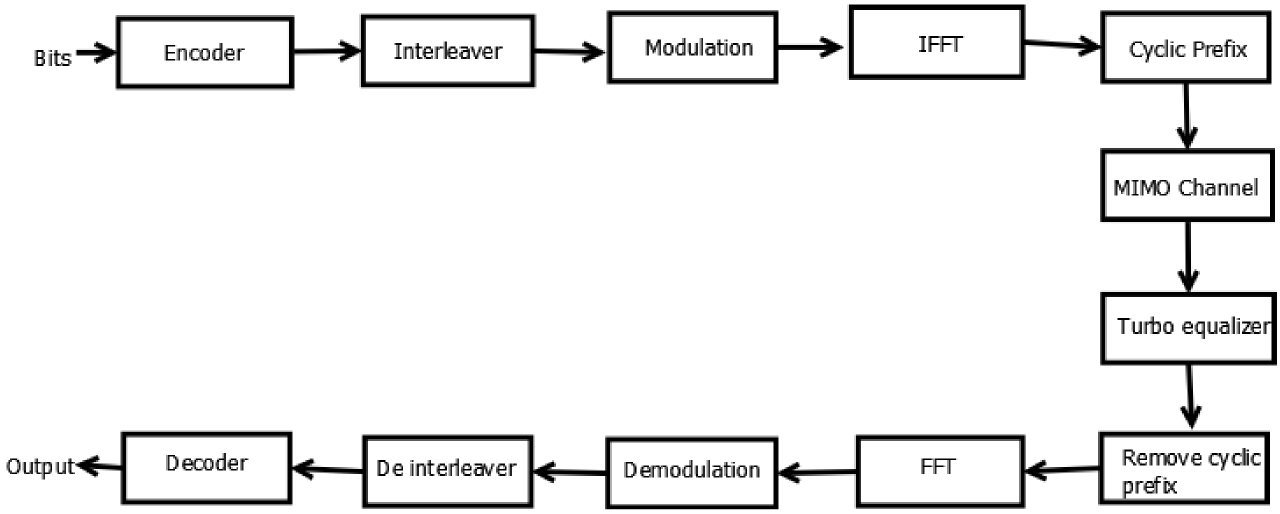

Fig. 1: Block diagram of MIMO-OFDM with iterative receiver

A. Transmitted section

Encoder: The role of the encoder, which is the first block in Figure 4.1. Encoders encode signal in one form into another. It takes 100 bits binary data sequence to be transmitted as input and produce 200 bits output. The encoder is used to protect the signal from the errors. They accept one or more inputs and generate a multiple bit output and also that contain the additional redundant information along with the transmitted data. The purpose of encoder is standardization, speed and security. In order to decrease the error rate of the system, a simple convolution encoder of rate ½ is used as channel coding. For the MIMO system divide the encoded signal and then take the further processes.

Interleaver: The transmitted data may causes distortion while passing through the channel. Mainly the burst errors may occur. An inter-leaver is used to shuffle the order of the code bits prior to transmission and it can reduce the errors. The example of interleaved data is shown below Figure 2, three sets of data are randomized and the given to the channel. Therefore it can avoid the burst errors. The use of interleaving greatly increases the ability of error protection codes to correct for burst errors.

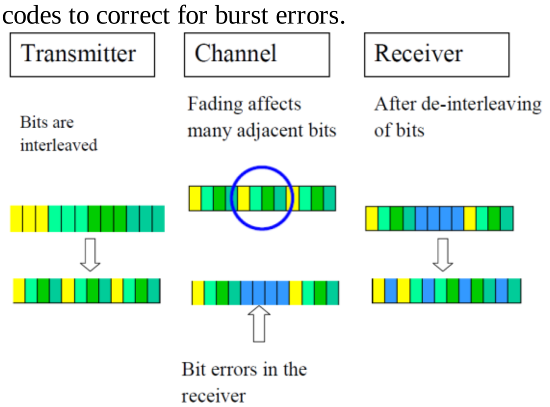

Fig. 2. Interleaving and deinterleaving of bits

The inter-leaver shuffles the bits contained in the data blocks that are coming from the encoder, and distributes them over a number of bursts.

The interleaved data bits are then mapped using the 16 QAM modulation techniques. QAM is a type of modulation in which two carriers are shifted by 90degrees and output consists of both amplitude and phase variations.

IFFT: Data are transformed into time-domain using IFFT. The total number of sub-carriers translates into the number of points of the IFFT/FFT. The key components of an OFDM system are the inverse FFT at the transmitter and FFT at the receiver. The discrete-time representation of the signal after IFFT is:

$$x(n) = {}^{1}/_{\sqrt{N}} \sum_{k=0}^{N-1} X(K) e^{j2\pi kt/N} \quad (1)$$

The cyclic prefix is added to the end of each OFDM block to avoid the intermission of the each OFDM symbols.

B. Channel Model

Multiple Input Multiple Output (MIMO) techniques based on using multiple antennas at both transmitter and receiver can provide spatial diversity, multiplexing gain, interference suppression, and make various trade-offs between them. Each antenna at the receiver receives all the signals transmitted from the two transmitter antennas. The transmitted signal takes multiple paths to reach the receiver. Even if some radio paths are completely lost due to fading another strong path may have a strong signal. A two antenna at transmitter and receiver system is shown in Figure 3. Each antenna at the receiver receives copies of all the transmitted signals. The received signal at the receiver can be expressed as

$$y1 = h11 * x1 + h21 * x2 \quad (2)$$
$$y2 = h12 * x1 + h22 * x2 \quad (3)$$

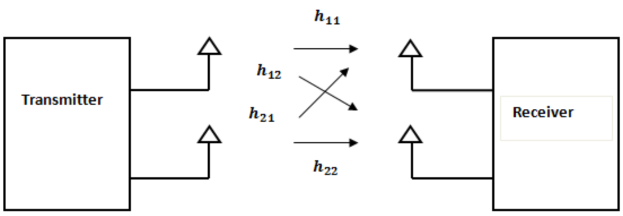

Fig. 3. 2x2 MIMO channel

C. Receiver section

FFT: Data are transformed back to frequency-domain using FFT. At the receiver side, the data is recovered by performing FFT on the received signal,

$$Y(k) = {}^{1}/_{\sqrt{N}} \sum_{k=0}^{N-1} x(n)e^{-j2\pi kt/N} \quad (4)$$

De-modulation: Symbols are transformed back to bits. The inverse of the estimated channel response is used to compensate the channel gain.

De-interleaver (Interleaving inverse operation): The stream of bits fills the matrix column by column. Then, the bits leave the matrix row by row.

Convolution decoder: The decoder performs the Viterbi decoding algorithm to generate transmitted bits from the coded bits.

D. Turbo equalization

The Turbo equalization is an iterative equalization technique. The iterative equalization is used at the receiver side for the better performance of the system. The transmitter section is same as the general MIMO-OFDM system. The difference between a turbo equalizer and a normal equalizer is the feedback loop from the decoder to the equalizer at the receiver side. Turbo equalization is an iterative equalization and decoding technique. To improves the receiver performance by giving the feedback loop between the decoder and the equalizer. It removes the ISI effects in the channel. The decoder not only gives the final information bits, but it also find new information about the coded bits . The number of iteration is performed in the Turbo equalization. At the first stage of iteration the decoder does not get any value form the detector. Therefore the first stage of turbo equalization is similar to the standard equalizer. In the next iteration the soft information is givens as a priori information in the present iteration. Therefore it can reduce the number of errors occurring during transmission. The turbo equalizer repeats this iterative process until a stopping criterion is reached. Figure 4 shows the performance of Turbo equalization.

Algorithm of Turbo equalization:

1. After receiving the transmitted data. We have to send it to the Turbo Equalizer.
2. In TE, Applying de-mapping and convert the signal to the parallel signal.
3. Then it applied to the de-interleaving and converts to the serial.
4. Mapping and interleaving applied and produce equalized signal

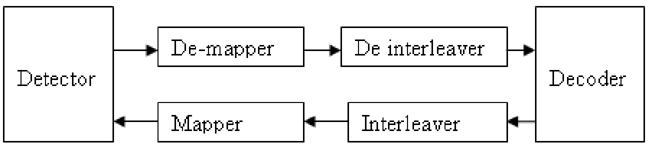

Fig. 4. Turbo Equalization

EXPERIMENTAL RESULTS AND DISCUSSION

Objective of the work is to create MIMO-OFDM systems with iterative receiver. A 2x2 MIMO-OFDM with iterative receiver is designed and analysis it with simulation. The Turbo equalization is used at the receiver side for the better reception of the system. At the transmitter, the random bits are generated, encoded, interleaved, modulated and results are shown below. At the receiver, equalization technique is used the Turbo equalization. Simulation is performed using the MATLAB R2015b. The random bits are used for the work and the simulation results are as follows. The data with 64 bits to be encoded is given as the input. Figure 5 shows the input command.

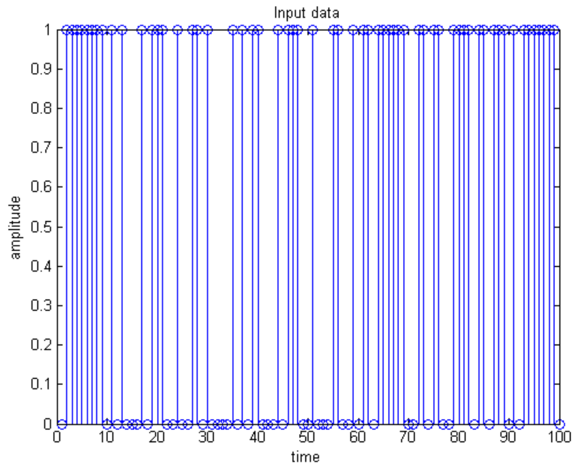

Fig. 5. Input bits

Parameter	Value
Modulation	Modulation
Channel Model	Rayleigh
Noise mode	AWGN
FFT or IFFT point	64
CP length	16

A. Transmitted Data

The random data is encoded using the convolution encoder and produce an output with 128 bits that contains not only this data but also additional redundant information that can be used to protect the data of interest in the event of errors during transmission. The 1/2 code rate is used in this encoder. For every 1 input bit, the convolution encoder outputs is 2 bits. The encoded data is as shown in Figure 6.

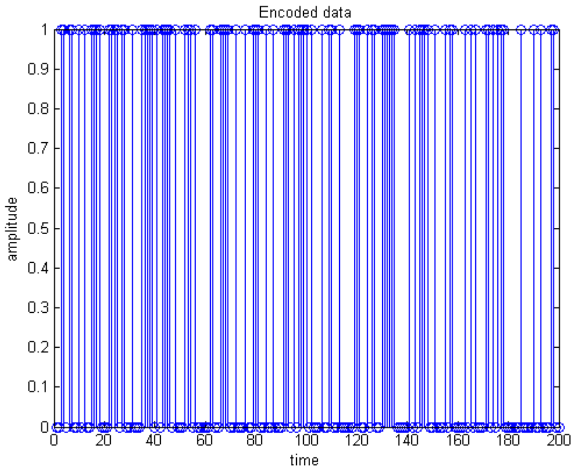

Fig. 6. Encoded bits

The encoded data is given to the interleaver for reducing the errors due to the transmission. An interleaver is used to rearrange the transmitted code bits. After the 16 QAM modulation of the interleaved data then given to the OFDM modulator. The 64 subcarrier is used to produce an OFDM signal. The OFDM signal is obtained by using inverse fast Fourier transform (IFFT) and can be detected by fast Fourier transform (FFT).

B. Received Data

The transmitted signal travels to the receiver through several paths that may have different lengths and hence different associated time delays. There are so many scatters present in the transmitted signal. The received signal is then given to the OFDM demodulator. The equalizer and de-interleaver are performed on the demodulated signal and this signal is given to the decoder.

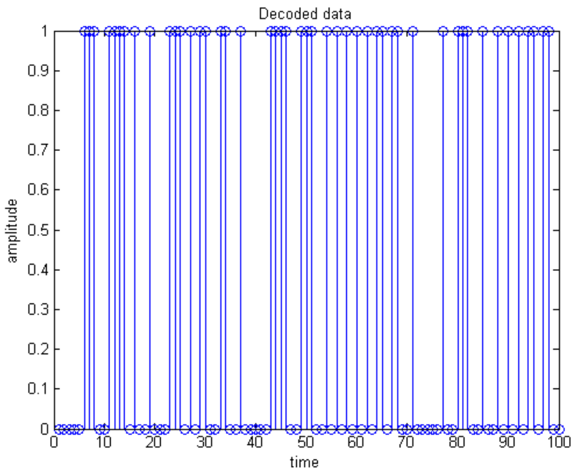

Fig. 7. Decoded bits

The number of iterations is followed at the receiver side. The performance of turbo codes makes it clear that the information is not only travel in one direction. In the turbo equalization the decoding stage perform the error control processes for the each iteration. This decoder information is then interleaved properly and is used in the equalization process, it form a feedback loop from decoder to the equalization stage. This process is also called message passing Figure 7 shows the decoded bits. The bit error rate performance of the proposed system is given below figure 8. The BER graph compares the normal MIMO OFDM system and MIMO-OFDM with turbo equalization. It is clearly seen that that BER of the turbo equalizer is less than the normal MIMO-OFDM system.

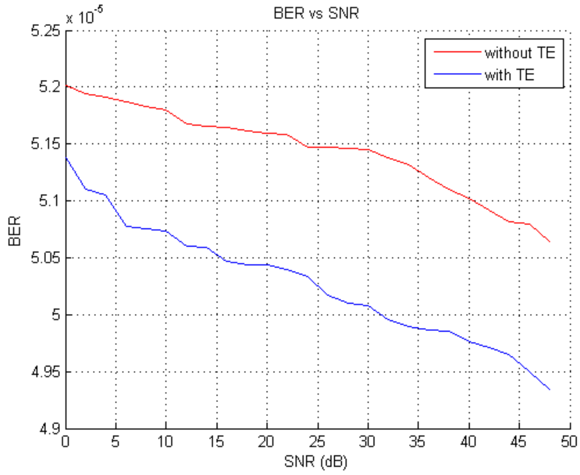

Fig. 8. Comparing BER graph normal MIMO OFDM and MIMO OFDM with turbo equalizer

CONCLUSION

According to the simulation parameters, we can get the better BER graph. The transmitted signal is passed through the Rayleigh channel. It may effects the Inter Symbol Interference (ISI). Many equalizers are introduced in the receiver side to mitigating the ISI effects. These equalizer are Zero forcing equalizer (ZF), Minimum Mean Square Equalizer (MMSE) and MMSE Successive Interference cancellation (MMSE-SIC). These equalizers are not suited for the large scale MIMOOFDM equalizer. Therefore an iterative receiver is used for this system. Turbo equalization is an iterative equalization and decoding technique. To improve the receiver performance by giving the feedback loop between the decoder and the equalizer up to number of iterations. Further work can be extended to add the channel estimation technique before the equalization technique.

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