Transmission of Data over Orthogonal Frequency Division Multiplexing (OFDM)

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Abstract: The need for efficient transmission of data is of primary concern with growth in technology. With this increased demand comes a growing need to transmit information wirelessly, quickly and accurately. To address this need, communications engineer have combined technologies suitable for high rate transmission with forward error correction (FEC) techniques. This is particularly important as wireless communications channels are far more hostile as opposed to wire alternatives, and the need for mobility proves especially challenging for reliable communications. Channel coding plays a very important role in OFDM systems performance. The structure of OFDM systems makes channel coding more effective in confronting fading channels. Different types of data such as image transmission require larger bandwidth as well as redundancy from noise. Encryption data from noise is an important aspect and this can be obtained by channel coding. This article provides an overview of OFDM basics and focuses on efficient data transmission over OFDM.

Keywords: OFDM (Orthogonal Frequency Division Multiplexing), FEC (Forward Error Correction), Channel Coding, BER (bit error rate), LDPC

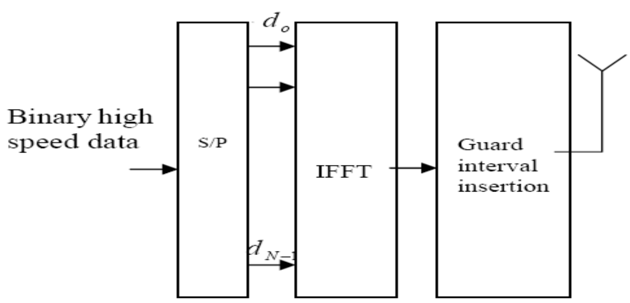
I. INTRODUCTION

With this increased demand comes a growing need to transmit information wirelessly, quickly and accurately. Channel coding plays a very important role in OFDM systems performance. The structure of OFDM systems makes channel coding more effective in confronting fading channels. The principle of multicarrier transmission is to convert a serial high rate input stream into multiple parallel streams of slow rate. The carrier signal is also divided into subcarriers and the sub-streams are then modulated over different sub- carriers. OFDM (Orthogonal Frequency Division Multiplexing) is a multicarrier technique based on frequency division multiplexing. In OFDM, the message or input stream is being divided into N parts and transmitted over N subcarriers which are orthogonal to each other. Each of these signals are individually modulated and transmitted over the channel. These signals are fed to a de-multiplexer at the receiver, where it is demodulated and recombined to obtain the original signal. OFDM reduces Inter-symbol Interference as well as Inter-channel Interference. It is a special form of multicarrier modulation which is particularly suited for transmission over a dispersive channel. The different sub-carriers are orthogonal to each other, that is, they are totally independent of one another. OFDM is also a wideband modulation scheme that is designed to cope with the problems of the multipath reception. Amongst all attractive advantages of OFDM, there are some disadvantages of OFDM such as high PAPR (Peak to Average Power Ratio) and BER (Bit Error Rate). The sensitivity of devices used in OFDM transmitter is sometimes very harsh to the signal processing loop, which may impair system performance. To overcome this problem of OFDM based systems, it is necessary to research on the BER and PAPR and their reduction techniques.

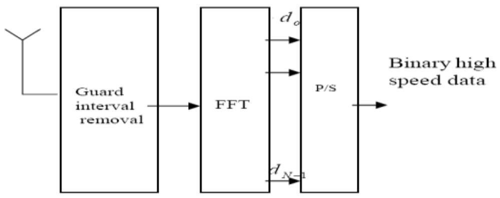
II. OVERVIEW OF OFDM

Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier system where data bits are encoded on multiple sub-carriers, while being sent simultaneously. Frequency Division Multiplexing is a form of signal multiplexing which involves assigning non-overlapping frequency ranges or channels to different signals or to each user of a medium. To ensure that the signal of one channel does not overlap with the signal from an adjacent one, a gap or guard band is left between each of these channels.

Mathematically, modulating a waveform and adding is equivalent to taking its IFFT. This is because the time domain representation of OFDM is made up of different orthogonal sinusoidal waveforms which are nothing but inverse Fourier transform. The transmitted data are the “frequency” domain coefficients and the samples at the output of the IFFT stage are “time” domain samples of the transmitted waveform.



(a)Transmitter



(b)Receiver

Fig. 1. OFDM System Model.

Let X= $\{X_0, X_1, \ldots, X_{n-i}\}$, denote the length data symbol block. The IDFT of the date block X yields the time domain sequence x=$\{x_0,x_{1,\ldots\ldots,} x_{n-1}\}$, i.e.,

x_n=$IFFT_N\{X_k\}(n)$

a guard interval comprising of either a CP or suffix is appended to the sequence X to mitigate the effects of channel delay spread. In case of a CP, the transmitted sequence with guard interval is

$X_n^g= x_{(n)N}$,n=-G,....,-1,0,1,…,N-1

where G is the guard interval length in samples, and $(n)_N$ is the residue n of modulo N.

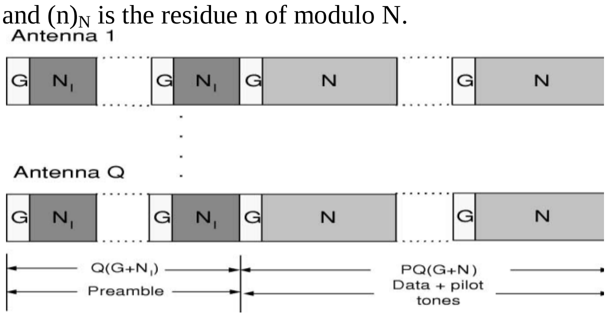


Fig. 2. Frame structure for the Q _ L OFDM system.

III. BIT ERROR RATE

Bit error rate, BER is a key parameter that is used in assessing systems that transmit digital data from one location to another. Bit error rate (BER) assesses the full end to end performance of a transmitter, receiver and the medium between them. Therefore, BER enables the actual performance of a system in operation to be tested. A bit error rate is defined as the rate at which errors occur in a transmission system or in other words it is the ratio of number of error to the total number of bits sent. BER can be affected by a number of factors.

Interference: The interference levels present in a system are generally set by external factors and cannot be changed by the system design. But the bandwidth of the system can be adjusted. By reducing the bandwidth the level of interference can be reduced. But, reducing the bandwidth limits the data throughput that can be achieved.

Increase transmitter power: It is also possible to increase the power level of a system so that the power per bit is increased. Again, this has to be balanced against factors including the interference levels to other users and the impact of increasing the power output on the size of the power amplifier and overall power consumption and battery life.

Lower order modulation: Lower order modulation schemes can be used, but this is at the expense of data throughput.

Reduce bandwidth: Another approach that can be adopted to reduce the bit error rate is to reduce the bandwidth. Thus, lower levels of noise will be received and therefore the signal to noise ratio will be improve. However, this results in a reduction of the data throughput attainable.

IV. CHANNEL CODING

Channel Coding or Forward Error Correction (FEC) is a technique used for controlling errors in data transmission over unreliable or noisy channels. Channel Coding provides provide protection from transmission errors. There are two types of Forward Error Correcting codes:

1: Block Codes

2: Convolutional Codes

Block codes work on fixed- size blocks(packets) of bits or symbols of predetermined size. Some of the commonly used block codes are Reed- Solomon codes, BCH codes, multidimensional parity codes, Hamming codes, etc. They are decoded by hard-decision algorithms as they are memoryless.

Convolutional codes work on bits or symbol streams of arbitrary length. They are most commonly decoded with the Viterbi algorithm, MAP or BJCR algorithms or other soft- decision algorithms. Convolutional codes are coding algorithms with memory.

Some of the commonly used channels coding schemes for multicarrier transmission are as follows:

A. Hamming Codes:

The binary Hamming codes are linear block codes with the property that

$$(n , k) = (2^m - 1, 2^m - 1- m),$$

where m is any positive integer. For example, for m=3 we have a (7,4) Hamming codes. The parity check matrix hamming codes has n-k rows and n columns. An (n,k) hamming code converts k- bits input symbol to n- bit code.

B. Low Density Parity Check (LDPC) Codes

An LDPC code *C(n, k)* is a special class of linear block codes whose parity check matrix H[$n - k$, n] has mainly '0's and only a small number of '1's, i.e. is sparse, where each block of k information bits is encoded to a codeword of size n. Today, LDPC codes are part of several standards (e.g. DVB-S2, WiMAX- IEEE 802.16e, and IEEE 802.11n). Consider a LDPC code of size n = 8, information bits k = 4, and parity bits $m = n - k = 4$. This code has rate 1/2 and can be specified by the following parity check matrix H:

$$H = \begin{array}{c} \begin{array}{cccccccc} n_1 & n_2 & n_3 & n_4 & .. & & .. & n_8 \end{array} \\ \left[\begin{array}{cccccccc} 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 & 1 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 & 0 & 1 & 1 & 0 \end{array}\right] \end{array} \begin{array}{c} \\ m_1 \\ m_2 \\ m_3 \\ m_4 \end{array}.$$

Parity check equations imply that for a valid codeword, the modulo-2 sum of adjacent bits of every check node has to be zero. In other words, the vector **x** is a part of the codeword **C** if it satisfies the following condition:

$$\mathrm{H}x^{T} = 0, \forall\ x \in \mathrm{C}.$$

The number of '1's in each column of this matrix **H** is only 2, which makes this matrix sparse. Due to this sparse property, the same code can be equivalently represented by a bipartite graph, called a 'Tanner' graph, which is illustrated in Figure. This graph connects each check equation (check node) to its participating bits (bit nodes). A connection between a bit node n_i and a check node m_j is established if there is a '1' in the column of the matrix **H**.

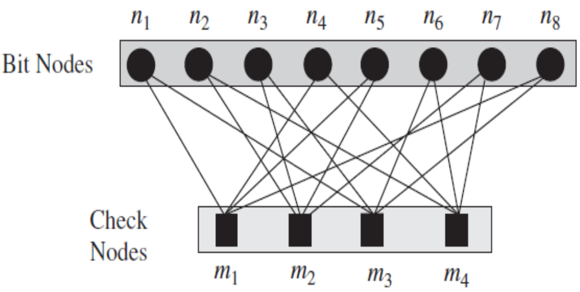


Fig. 3. The Tanner graph representation of the LDPC code

The 'Tanner graph' code representation enables the LDPC codes to have a parallelizable decoding implementation, which consists of simple operations such as addition, comparison, and table look-up. The degree of parallelism is tunable, which makes it easy to find a tradeoff between throughput, decoding delay, and the overall complexity.

C. Convolutional Codes

Convolutional codes are used for example in Universal Mobile Telecommunications System (UMTS) and Global System for Mobile communications (GSM) digital cellular systems, dial-up modems, satellite communications, 802.11 wireless Local Area Networks (LANs) and many other applications. The major reason for this popularity is the existence of efficient decoding algorithms such as Viterbi algorithms.

A convolutional encoder is a linear sequential circuit and therefore a Linear Time- Invariant (LTI) system. It is well known that an LTI system is completely characterized by its impulse response. Let us therefore investigate the two impulse responses of this particular encoder. The information sequence u results in the output **b.**

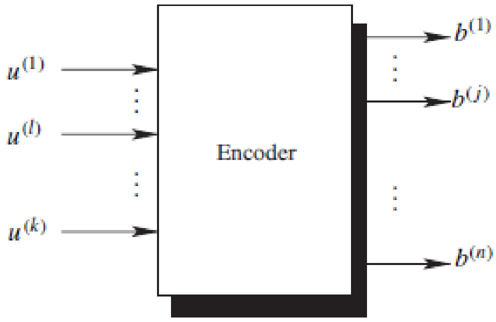


Fig. 4 Convolutional Encoder

A Convolutional encoder with k inputs and n outputs is shown in figure 4. Here, k and n denote the number of encoder inputs and outputs respectively.

Thus, the code rate is R = k/n .

The current n outputs are linear combinations of the present k input bits and the previous k × m input bits, where m is called the memory of the convolutional code. A binary convolutional code is often denoted by a three - tuple (n, k, m).

D. Turbo Codes

The first turbo code, based on convolutional encoding, was introduced in 1993. a turbo code is formed from the parallel concatenation of two codes separated by an interleaver. A generic design of a turbo code is shown in figure 5.

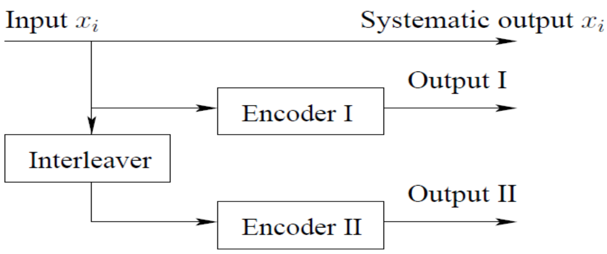


Fig. 5. The generic turbo encoder

The interleaver reads the bits in a pseudo-random order and the two encoders used are normally identical and the code is in a systematic form, i.e. the input bits also occur in the output.

E. Space Time Block Codes

The basic philosophy with STC (Space Time Coding) is to transmit independent data streams instead of transmitting the same data stream in an appropriate manner over all antennas. This could be, for instance, a downlink mobile communication, where in the base station *M* transmit antennas is used while in the terminal station only one or few antennas might be applied.

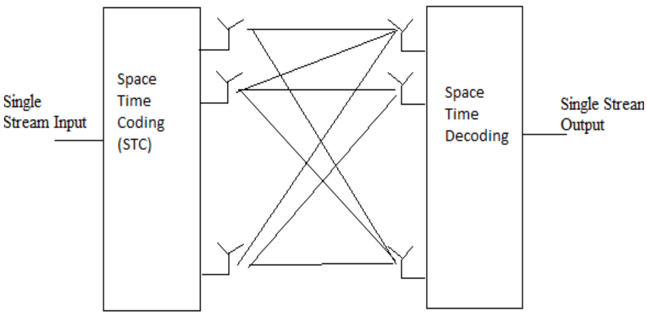


Fig.6. Space Time Coding Block Diagram

The basic idea is to provide through coding constructive superposition of the signals transmitted from different antennas. Constructive combining can be achieved, for instance, by modulation diversity, where orthogonal pulses are used in different transmit antennas. The receiver uses the respective matched filters, where the contributions of all transmit antennas can be separated and combined with MRC.

Space–time block coding is a technique used in wireless communications to transmit multiple copies of a data stream across a number of antennas and to exploit the various received versions of the data to improve the reliability of data-transfer. A simple transmit diversity scheme for two transmit antennas using STBCs was introduced by Alamouti. In the simplest Alamouti scheme with M = 2 antennas, the transmitted symbols xi are mapped to the transmit antenna with the mapping where the row corresponds to the time index and the column to the transmit antenna index.

$$B = \begin{bmatrix} x_0 & x_1 \\ -x_1^* & x_0^* \end{bmatrix}$$

In the first symbol time interval x_0 is transmitted from antenna 0 and x_1 is transmitted from antenna 1 simultaneously, while in the second symbol time interval antenna 0 transmits $-x_1^*$ and simultaneously antenna 1 transmits x_0^*. The coding rate of this STBC is one, meaning that no bandwidth expansion takes place. Due to the orthogonality of the space–time block codes, the symbols can be separated at the receiver by a simple linear combining.

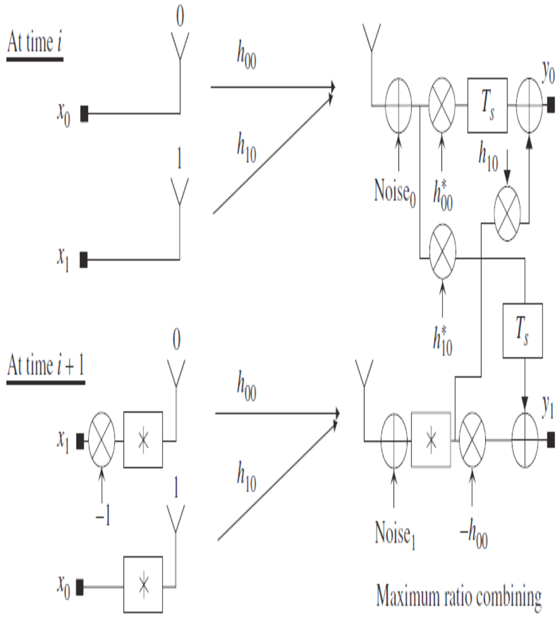


Fig.7. Principle of space time- block coding

V. SIMULATION

An n- bit data stream was transmitted through an AWGN channel with BPSK modulation scheme with and without channel coding using bit error rate analysis tool of Matlab communication toolbox. It was observed in figure 8 that the bit error rate verses signal to noise ratio is lower in data received with channel coding

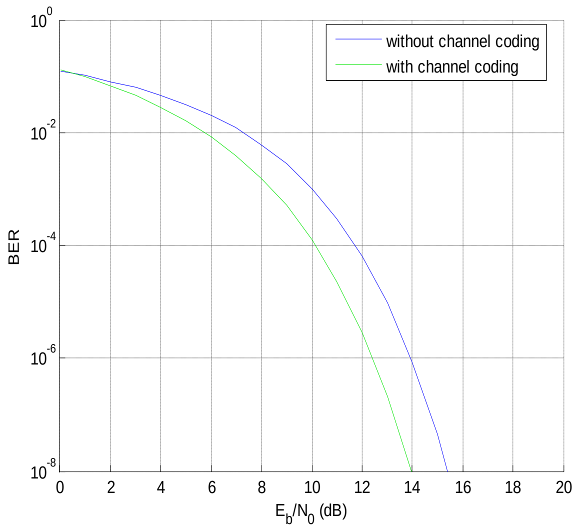


Fig. 8. BER vs SNR

VI. CONCLUSION

In this paper, survey on bit error rate reduction has been discussed using various forward error correction schemes on data stream before transmitting them using OFDM modulation scheme. It is concluded that there is a reduction in bit error rate when transmitted with channel coding.

FUTURE WORK

A survey paper on different error correction schemes in OFDM based system is presented in this paper. In future different channel coding algorithms will be used on OFDM system before transmitting the data on different subcarriers for more efficient transmission and bit error rate reduction.

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