A Review of Digital Data Encoding and Decoding Techniques for EDAC in Wireless MIMO Systems

Bhavana Kulhare[1], Dr. Poonam Sinha[2]

Ph.D Scholar, Department of Electronics and Communication Engineering University Institute of Technology, Barkatullah University Bhopal 462003, Madhya Pradesh, India

Bhawnakulhare@gmail.com

HOD, Department of Electronics and Communication Engineering University Institute of Technology, Barkatullah University Bhopal 462003, Madhya Pradesh, India

Abstract: **In the present time, the communication medium is changing to wireless from the existing wired system. 21st century certainly belongs to a new wireless world. Any information whether it is audio, video, image, text or other is communicated using wireless media. This change in the present requirements has forced the system developers and designers to consider the various technological advancements into consideration so that the best performing system can be developed. The performance parameters for an effective system are power, time, data security, noise handling, portability, etc. The advanced high speed technologies have made it possible to interface the hardware and software together to make a system high performance. But there are always some issues that are left un-optimized in any system. In this paper one of such parameter handling feature of wireless system is discussed and reviewed. This parameter is the environmental error handling decoders in wireless systems. The present work presents a review on the various works performed in recent years in the design and implementation of wireless system encoder/decoder for error detection and correction. These encoders and decoders are the hardware component of a wireless communication system that provides high data efficiency and data integrity. In a Multiple-Input-Multiple-Output (MIMO) system the channel encoding is a mandatory component of the system to reduce or eliminate the effects of the channel noise from the data.**

Indexing terms/Keywords: **Channel Encoding, Convolutional Encoder, EDAC, MIMO.**

INTRODUCTION

The need of the high performance wireless applications is the enhanced data rate for various applications of communication along with the reduction in system power requirements. These requirements are possible to achieve up to a high extent using the modern low power configurable hardware devices and sub-systems. But during communication of data, the information might get corrupted due to impairments of channels. This affects both the data-rate as well as system power. Reduction of error due to noisy channels is not a simple task as the behavior of the channel disturbances or noise is an un-predictable phenomena. So a number of techniques are proposed by the researchers in developing the data processing methods that can effectively reduce the noise effects from the data disturbed by the channel disturbances.

The field mobile communication has a requirement of a high data transmission in small networks. With the outbreak in Internet and multimedia services, wireless has become one of the most prevalent core technology that enable an efficient communication applications. The performance of these applications is limited by the multipath fading and several types of interferences. This directly affects the service performance of the application devices. This quality can be improved by making the system more better using hardware and software modification to reduce the data packet loss and more robust against the channel disturbances.

In the wireless communication system, the system modules are designed by considering the approximate behavior of the channel effects on the data in the channel. A wireless channel is characterized by a Gaussian Noise to define a limit of the maximum channel capacity and error free transmission rate (transmission speed) for a given signal-to-noise ratio (SNR) and channel bandwidth. This limit is known as Shannon's Limit. For an effective high speed data transmission with higher bit error rate, wireless systems needs implementation of data encoding technique, also referred as data-coding or channel-coding. In the channel encoding method, the data to be transmitted is added with some redundant data. The redundant data is generated using the actual data to be transmitted. This method affects the error rate of the data transmission by increasing the information bits. The method of data encoding facilitates two basic objectives, i.e., error detection and error correction at receiver end. The efficiency of error detection and correction is also dependent on the ration of the noise in the channel with respect to the transmitted data. More is the ratio of noise in the channel; less effective will be the error detecting technique. So for the channels with high noise an effective channel encoding and decoding technique is a need of the wireless system. An effective encoding has the feature of adding a minimum number of redundant data in the actual data. Thus the data overhead is small. As a supplementary requirement at the receiver, the decoder should use an effective technique to detect the presence of error in the received symbols and should be able to correct the errors so as to provide the correct data to the processing unit of the receiver.

The purpose of this paper is to study the architecture of a MIMO system and review the various works that are performed by the previous scholars for data encoding-decoding in MIMO systems. It has been that the selection of code is dependent on the application. So a number of codes are suggested in previous work for MIMO implementation. The commonly implemented coding techniques include Single-Parity bit code, Multiple Parity Bit Code, Multi-dimensional Parity Coding, Turbo Code, Reed-Solomon (RS) coding, Low Density Parity Check (LDPC) coding, Space Time Block Coding (STBC), space-time trellis codes (STTC) and Convolution Coding. The paper is organized as follows: Section II gives an overview of MIMO system architecture along with the various attributes of the system. Section III describes the various channel coding techniques and the concepts of data decoding using these techniques. Section IV focus on the problem formulation and future scope in the development in the coding technique using convolution encoding-decoding. Section V presents a short conclusion that is based on the reviews in this paper. Finally the references are mentioned in the last of the paper.

MIMO OFDM SYSTEM

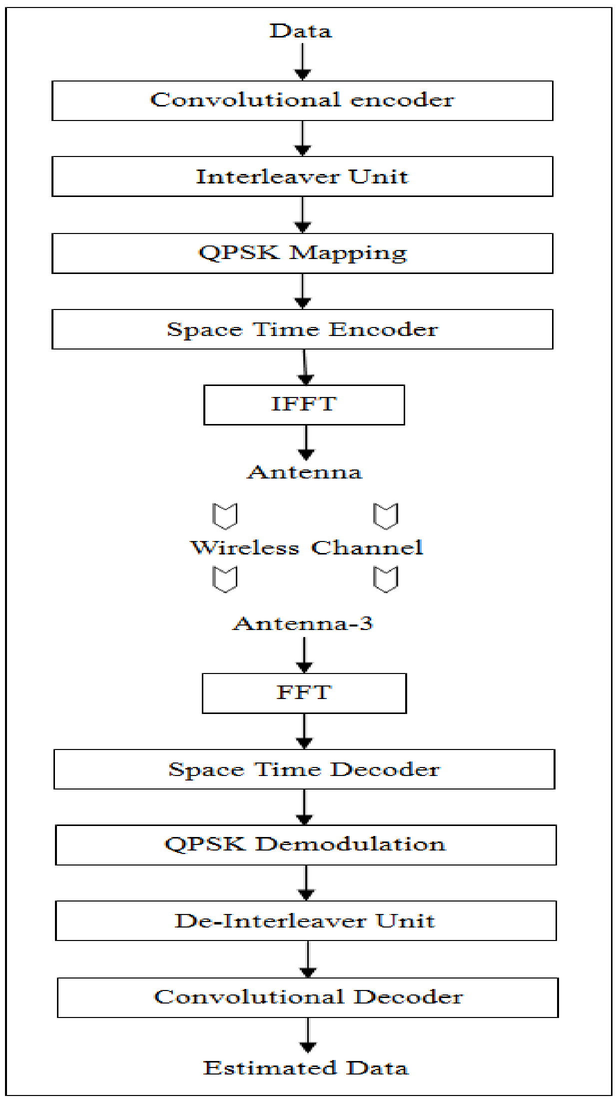

Fig 1: General Block Diagram of OFDM Single Channel Communication System

High data rate applications can be promisingly implemented using the Orthogonal Frequency Division Multiplexing (OFDM). OFDM can be effectively used in multipath frequency selective channel communication. In the Multiple Input Multiple Output (MIMO) based wireless system the transceivers uses multiple antennas that increases the throughput and the capacity of the communication network. In OFDM, the radio frequency carrier signals are used for wireless signal communication. Fig 1 shows a simple block diagram of OFDM based system. In this system, as shown in Fig 1, the information data is encoded using a convolutional coding technique, preferably error detection and correction (EDAC) coding technique.

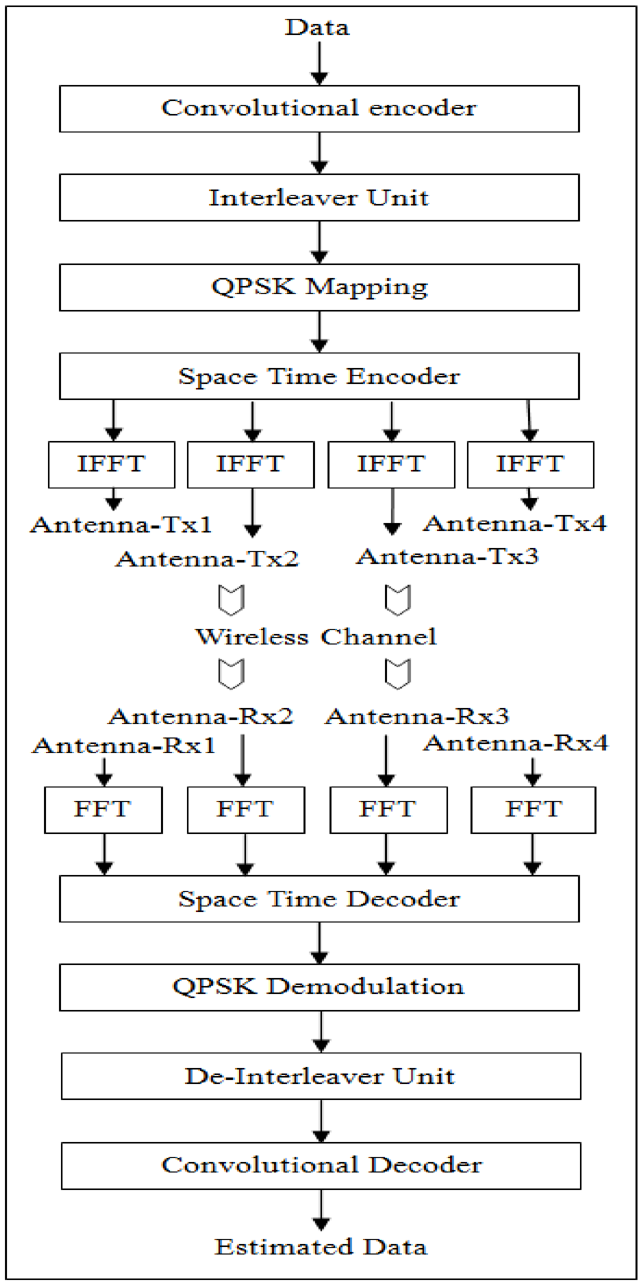

Fig 2: General Block Diagram of MIMO based OFDM Communication System

The accuracy of the received data to the actual transmitted information, improves directly in proportion to the error detection and correction efficiency of the convolutional decoder. In the communication system, data interleaving is performed on the encoded data where the encoded data is first arranged in matrix and then the rows and columns are interchanged. The interleaving/de-interleaving helps the recovery of data affected by multiple-bit error by performing uniform error-distribution in the received data stream. In transmitter the data bits from the interleaved data stream are further grouped to map with the complex numbers representing the OFDM modulation type. Each mapped group of bits (symbol) is then represented by a number that represents a particular sub-carrier phase and frequency according to the type of the Quadrature Phase Shift Keying (QPSK) modulation. This modulated data is ready to be transmitted through the communication channel after space-time encoding. At receiver, the received data is space-time decoded then QPSK demodulation is performed to get the estimated interleaved data stream. This data stream is operated by De-interleaver and convolutional decoder to obtain the estimated data.

In multiple channel based OFDM communication system, as shown in Fig 2, the transmitter section uses multiple antennas to transmit the data at different frequencies in the wireless channel. At receiver the signals from each receiver-antenna are processed parallel to get the transmitted data. The QPSK demodulation output is related to the received signal corresponding to a particular phase and frequency. When a complete set of bit stream corresponding to data-packet size is received then it is de-interleaved and de-coded using convolutional decoder. A serial decoding is thus performed on received symbol bits.

The super-orthogonal space time trellis (SOSTT) code provides a significant coding with respect to conventional space time trellis (STT) codes without increasing the complexity of decoding alt the receiver side. We use an important technique as transmit antenna selection (TAS) to solve the complexity problem of multiple antenna that arise from employing a separate RF chain for each antenna. It combines SOSTT coding with TAS in order to exploits the performance for improvement which is provided by SOSTT codes while realising the promises made by the TAS technique. The transmit antennas maximize the SNR at the receiver for chosen and activated out of the all available transmit antennas for the transmission of the baseline SOSTT codes, while all other transmit antennas are silent. The performance of error in the structure is investigated by deriving the moment generating the function (MGF)-based upper bound expression on the pairwise error probability in quasi-static flat Rayleigh fading channel for both the perfect and imperfect antenna subset selection.

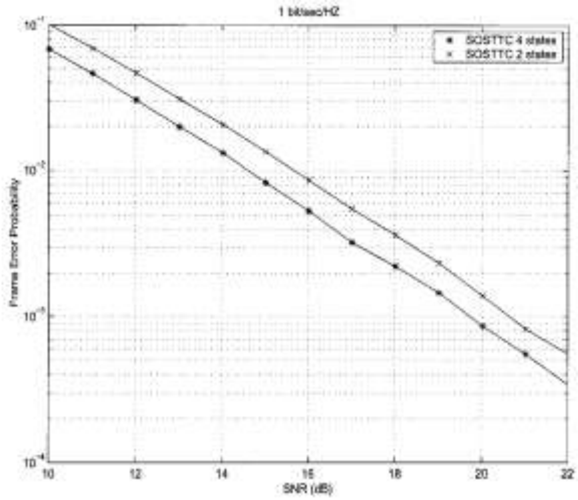

Fig 3: super-orthogonal space time trellis

A new class of space-time codes called super-orthogonal space time trellis code. To provide full diversity and improved coding gain over earlier space-time trellis code constructions it combine the set of partitioning and set of super orthogonal space time block code in a systematic way. Codes operates at different rates, up to the highest theoretically possible rate, for different number of states can be designed by using our optimal set partitioning. Super-orthogonal space-time trellis code can provides a tradeoff between the rate and the coding gain. Simulation results show more than 2-dB improvements over the codes.

LITERATURE REVIEW

In reference [1], the channel coder, its decoder, interleaver and de-interleaver of a MIMO-OFDM are discussed and implemented using trellis encoding method with rate=1/2. This paper describes the various steps in which a MIMO-OFDM executes the task of data transmission and reception. The simulation results from this paper shows error handling ability of the proposed design in a MIMO-OFDM system. This paper is concluded with the summary of resource utilization by the encoder and decoder hardware in reference to a field programmable gate array device. A single channel based communication process is simulated in [2]. This work proposed for orthogonal frequency-division multiplexing (OFDM) system in a channel which has low-complexity block turbo equalizers. The concept in this paper is based on a soft minimum mean square error (MMSE) block linear equalizer (BLE). This concept exploits the structure of the frequency domain channel matrix. This paper shows that the proposed iterative MMSE BLE achieves a better bit error rate (BER) performance. In reference [3], the design and simulate of wireless communication system which is based on the IEEE 802.11n draft. This paper describes a system which is to be built and simulated in MATLAB. The functionality of each block in the design verifies a bit error rate (BER) plots to obtain numerical result. So that whole system is rebuild in VHDL for simulation and implement on a FPGA. This work is to evaluate the maximum data rate by creating the feasible wireless system on FPGA.

The recently emerged "4G" technology is called as "Long Term Evolution" because it represents the advanced step technology in wireless communication. A communication decoding process in 4G is presented in [4]. It provides significantly increased peak data rates. This paper describes the bit error rates performance. In the modulation scheme used the BER performance of BPSK, which has better than QPSK. Mixed data, voice, video and messaging traffic are supported by LTE. In this work the used UMTS Technology provides reduced latency, scalable bandwidth capacity and backwards compatibility with existing GSM. The pre-computation technique is used in reference [5]. It is used to speed up the process of searching for the optimal path metric from the ACSU loop. Add-Compare-Select Loop architecture is modified by using pre-computation architecture. This issue is focused and appropriate solution for Register Exchange Algorithm which has a pre-defined end state. So the optimized T-algorithm is used. The proposed paper requires less logic resources and power sufficient as compared with conventional decoder.Trellis coded modulation (TCM) Systems which has High-speed, low power design of Viterbi decoders. This paper [6] proposed a pre-computation architecture incorporated with T-algorithms for Viterbi decoder (VD) which is the dominant module determining the overall power consumption of TCM Decoders. VD could reduce the power consumption by 70% with only 11% reduction of the maximum decoding speed T-algorithm efficiently reduces the power consumption of VDs without reducing the decoding speed appreciably.

An orthodox Viterbi decoder is designed and simulated in [7]. The Gate Diffused Input Logic (GDIL) based Viterbi decoder is designed using Xilinx ISE, for faster process applications which are simulated and synthesized successfully. This new proposed technique GDIL Viterbi is again compared with proposed techniques, which comprises a Survivor Path Unit (SPU) implements a trace back method with DRAM. The three type of decoder(s) Add-Compare-Select (ACS) and Trace Back (TB) units and its sub circuits which have been operated in deep pipelined manner to achieve high transmission rate. The approach of modified Viterbi is used in fast decoding, which shows significant result in high applications. Reference [8] presented the study of orthogonal frequency-division multiplexing and multiple–input multiple-output (MIMO) area units the key experience for today's world. This shows that the most effective doable signal technique is bit-error-rate (BER) presentation which is higher to alternative signal strategies. A RLS based versatile channel estimation strategy is proposed for MIMO-OFDM frameworks. The work performed in [9] led to various studies of wireless communication by using different techniques. The study presented in this paper shows that most of the results by the researchers is based on theoretical analysis that is based on software based simulation. A review of performance improvement techniques used in wireless communication is presented in this work. The areas that are covered in this study include diversity combiners, MIMO antenna structures, equalization methods and OFDM.

A design of full-rate Space-Time-Frequency Trellis Code (STFTC) based on MIMO-OFDM Quasi-Orthogonal design systems is presented in [10]. The presented Quasi-Orthogonal Space-Time-Frequency Trellis code combines set partitioning and the structure of quasi-orthogonal space-frequency designs to provide receive diversity, array gain and achieve high-coding gain over a frequency selective fading channel. The code in this work outperforms the existing Quasi-Orthogonal Space-Time-Frequency Trellis codes in terms of frame error rate performance. The reference [11] presents the design of a MIMO system which takes advantage of both space time block coding and space time trellis coding schemes. Between these coding schemes, space time block codes provide full diversity with no code gain and space time trellis code provides full diversity and coding gain with complex receivers. In this work a new technique called orthogonal space time block coding combined with trellis code modulation has been proposed to achieve full diversity of orthogonal space time block code and large coding gain of trellis code modulation. Multiple Input Multiple Output Orthogonal Frequency Division Multiplexing (MIMO OFDM) based system design is shown in [12]. This work shows increase capacity of link to a great extent. This paper proposed the performance of Vertical Bell Labs Layered Space Time (VBLAST) architecture for different single antenna and multiple antenna Orthogonal Frequency Division Multiplexing systems. System performance in terms of Bit error Rate (BER) is increased by Vertical Bell Labs Layered Space Time (VBLAST) associated with MIMO OFDM. Reference [13] presents study and analysis of the performance and efficiency of different Forward Error Correcting (FEC) codes. In this work performance is improved and compared with tradeoffs in complexity and decoding of the design. Convolution Codes, RS codes, LDPC, STBC and turbo codes, in the areas of both implementation and performance are investigated by this paper. This paper presents the conclusion in terms of effectiveness of hardware implementation of FEC codes.

M-PSK and QAM is the modulation technique which is used for OFDM-LTE (4G) [14] systems. So, in this proposed paper the Bit error rate (BER) of M-PSK and QAM digital modulation schemes are compared under AWGN, and Rayleigh fading channels to identify a suitable digital modulation scheme for OFDM application. To measure Bit Error rate with different modulation schemes is the main objective of our work. The work in this work focus on getting the best configuration to achieve better utilization of bandwidth. A special case of Protograph-based LDPC convolutional Codes is Trellis-based Quasi-Cyclic (TQC)-LDPC convolutional [15]. This is a new type of code. The proposed TQC-LDPC convolutional code can be derived from any QC-LDPC block code by introducing Trellis-based convolutional dependency to the code and associated Trellis-based decoders to be efficiently implemented in high data rate. To increase the code rate related power efficient methods are used. Low decoding complexity, low BER, and fine granularity makes it feasible for the proposed TQC-LDPC Convolutional codes. In reference [16], a cost-efficient high level soft decision (up to 8 bits) Viterbi decoder with a multi stage pipelined ACS for IEEE802.11ac systems. It reduce the hardware complexity by about 70% and 90% compared with conventional single-stage pipelined ACS. The appropriate adopted a method for the multi-stage ACS structure the bit-level pipelining. In order to increase the working speed considerably without requiring huge hardware costs. The Proposed architecture was very useful for IEEE802.11ac WLAN systems, in which the low power design architecture is required.

The convolutional encoder and Viterbi decoder are implemented on FPGA for constraint length of 9 and bit rate ½ in reference [17] using VHDL and simulated on XILINX ISE Tool. The efficiency of error detection and correction increases with constraint length. The Powerful methods of forward error detection (FEC) are convolutional encoding with Viterbi decoding. This comprises of minimum path and value calculation and retracing the path. Reference [18] presents performance of rate adjustment for TCM by means of puncturing the convolutional code (CC) on which a TCM-Scheme is based. The proposed approach has some modifications in the convolutional Viterbi-decoder and has several decisive advantages with respect to flexibility and complexity over multidimensional TCM. For this, good generator polynomials for the CC as well as corresponding puncturing schemes are given. Optimization for the channel encoder increased the transmission rate by appending encoded information bits. The basic concepts of error correction method are Convolutional encoding and Viterbi algorithm [19]. A low complexity and configurable design of hard-decision Viterbi decoder design using VLSI hardware is presented in this paper. The presented design can be configured for any number of traceback by increasing or decreasing the size of traceback parameters. It needs N+2 clock cycles latency to complete the process. This design gives good synthesis results in area consumption and operational speed.

The main objective of the design proposed in [20] is to describe comparative analysis between simulation and synthesized result of various FPGA Devices for proposed design resource optimized implementation of Viterbi Decoder. By using Trace back architecture resource optimized Viterbi decoder has been designed. The proposed Viterbi decoder has been designed by using VHDL with rate ½ and constraint Length 3 has simulated using Xilinx ISE Simulator and synthesized with Xilinx Synthesis Tool (XST). In communication channels, error correcting techniques plays a vital role. This paper proposed Error correcting techniques in communication network. In this two types of techniques are considered is Viterbi decoder and Convolutional encoder. Proposed design can work at Max. Frequency 113.104 MHz [21] for targeted FPGA Device VIRTEX 5 among all FPGA Devices. Convolutional encoder Length k and code rate of k/n can be simulated by using Xilinx and Modelsim 10.1b. The work in [22] proposed a formula for the exact bit error probability for Viterbi decoding of the rate $R = 1/2$, Memory $m = 1$ convolutional encoder with generator matrix $G(D) = (1\ 1{+}D)$ when used to communicate over the binary Symmetric channel. This work presents various approaches to derive and solve a general matrix recurrent equation connecting the average information weight. In [23] Multiple Trellis Coded Modulation (MTCM) is extended from Phase Shift Keying (PSK) signals to non-PSK signals in some special cases. The simulation results are presented at rates 2.5, 3, 3.5, 4 bits/s/Hz in this paper and its outperformance is shown with respect to the existing ones to show the performance of the proposed codes. The curves of frame error rate (FER) are obtained by averaging over 50,000 frames with the length of each frame be 130 symbols. The simulated systems used two transmit antennas and one receive antenna.

CONCLUSION AND FUTURE SCOPE

Space diversity can be implemented in transmitter and receiver of a wireless system creating Multiple-Input Multiple-Output (MIMO) channels. In the cases where the fading channels are frequency selective, Orthogonal Frequency Division Multiplexing (OFDM) modulation can be used to transform the frequency-selective channel into set of parallel frequency non-selective channels. MIMO-OFDM systems have been proposed in [24] to take advantage of both MIMO systems and OFDM modulation to guarantee reliability and high spectral efficiency for next-generation wireless communication systems. In many of the schemes, good performance and the frequency and spatial diversities are guaranteed by concatenating space-time-frequency code with Trellis Coded Modulation (TCM). However, these proposals have several drawbacks such as not being optimized for MIMO-OFDM systems, having a low coding rate, a large number of trellis states and a low coding gain among others. This paper presents an overview of MIMO based OFDM system and a review on the various works related to the MIMO-OFDM systems is presented. In the review of various papers it is found that the Bit-Error-Rate (BER) performance obtained by implementing BPSK is better than 16QAM, 16PSK or QPSK schemes. Still there is a scope for further improvement in BER performance with lower SNR. In wireless communication systems a higher signal to noise ratio (SNR) at the receiver enabled by MIMO-OFDM provides improved coverage and throughput. Furthermore, there is a great scope to work on the MIMO-OFDM system design to improve the performance of the system in terms of improved SNR and a reduced BER. Also there is need to work a lot to reduce the decoding complexity of such systems, increase the code rate, reduced numbers of trellis state, high code gain, etc.

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