PERFORMANCE ANALYSIS OF INET USING FORWARD ERROR CORRECTION AND OFDM

Sileshi Boru, Diptasree Maitra
Faculty Advisors: Dr. A. Richard A. Dean and Dr. Arlene Cole Rhodes
Morgan State University.

ABSTRACT

This paper shows the improvement in performance for OFDM modulation on aeronautical channels with the addition of convolution coding. OFDM is envisioned for use on the Integrated Network Enhanced Telemetry (INET) on aeronautical channels that experience multipath fading which causes inter-symbol interference (ISI). Forward error correction coding, such as convolution coding (cc), significantly improves the bit error rate (BER) of OFDM with multipath fading. Theoretical and simulated results show a performance increase of up to 10dB with the introduction of coding gain and the cyclic prefix (cp). Such improvements can be applied to reduce errors or increase data rates for INET.

INTRODUCTION

The INET study is a project launched by both Director of the Central Test and Evaluation Investment Program (CTEIP) and Morgan State University with the primary objective of advancing networking and telemetry technology. The INET study results will lead to a CTEIP Development Project that will develop needed technology and lead to its deployment at Major Range and Test Facility Base (MRTFB) sites throughout the Department of Defense (DoD). The proposed system aims to increase and enhance data transfer and communication between aircraft and ground stations and between the aircraft themselves over an aeronautical channel. For the physical layer of the Telemetry Network system, the INET study has decided to use the 802.11 Wireless LAN Protocol which has been standardized by the IEEE society. There are several areas in the INET project such as radio link, mixed networking, network security, and network simulation. The performance of each of these areas contributes to the overall performance of INET. Essentially, this paper concentrates on the radio link. The performance of the radio link can be enhanced by enhancing the aeronautical channel performance, which is one of its major components.

An aeronautical channel is a type of radio channel which provides communication between aircraft and ground stations and between the aircraft themselves. One common problem in signal transmission through the aeronautical channel is additive noise. In addition obstacles and surfaces in the path of the transmitted signal form reflectors that cause the signal to reach the receiver through a series of paths. This phenomenon is called multipath. Multipath becomes a significant factor in degrading the quality of the signals being sent through the channels. Several techniques could minimize the effect of multipath, such as equalizers, coding and interleaving, and the use of rake receivers.

Orthogonal Frequency Division Multiplexing (OFDM) is a combination of modulation and multiplexing. It is a powerful modulation technique that increases bandwidth efficiency and reduces the multipath effect. By dividing the bandwidth into smaller channels, narrowband channels are created from a wide band environment. These narrowband subcarriers experience flat fading. In this case, fading is a distortion or attenuation that a carrier-modulated telecommunication signal experiences over the propagation media.

Forward Error Correction (FEC) is a method by which errors can be controlled during data transmission. There are several types of FEC such as block codes and convolution codes. Convolution codes were first introduced by Elias [1] in 1955. Convolution codes are error correcting codes that are used to add redundant information to the user's message, and then use this redundant information to correct errors at the receiver. In interleaving, symbols of the coded sequence are either transmitted a number of times or permutated using interleaving techniques to overcome burst error on the channel. The main objective of this project is to analyze the performance of the aeronautical Channel using a forward error correction scheme for better channel performance to satisfy the growing volume of data projected for INET. This project outlines a design of convolution coding techniques based on the IEEE802.11 standard for transceivers on aeronautical channels to improve the performance of the channel and to support high speed data required by the testing and evaluation community.

METHODOLOGY

Convolution coding has been applied to enhance performance on the aeronautical channel. However, before the introduction of convolution coding digital modulation (QPSK), researchers have employed OFDM and cyclic prefix in this work. Interleaving is applied after coding for farther error correction. Figure1 shows each of the above mentioned methods applied in this work. Each element in this figure is described below.

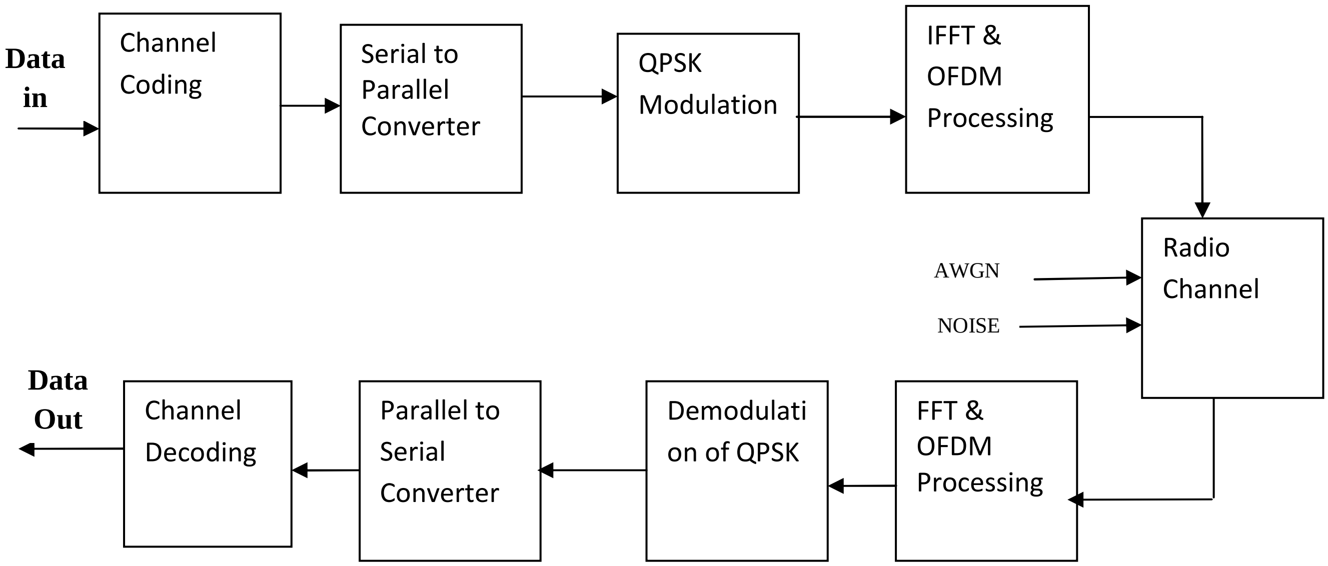


Figure 1: Block Diagram of QPSK/OFDM Scheme with Cyclic Prefix and Convolution Coding.

QPSK Modulation

Modulation is a process of encoding digital data on channels. The most common forms of modulation are amplitude, frequency and phase. Quadrature phase-shift keying (QPSK) is a modulation scheme where data is modulated onto the phase of the carrier signal.

OFDM

Orthogonal Frequency Division Multiplexing (OFDM) is a powerful modulation technique that increases bandwidth efficiency and helps to mitigate inter-symbol-interference (ISI) and inter-channel interference (ICI). OFDM is a technique to combat frequency selective fading. The basic idea of OFDM is to divide spectrum into several sub-carriers. By dividing the bandwidth into smaller channels, narrowband channels are created from a wide-band environment. These narrowband subcarriers experience flat fading, which is an important characteristic for the aeronautical multipath problem.

Cyclic Prefix

Convolution encoding causes parts of adjacent OFDM symbols to overlap causing the independently transmitted symbols to interfere with each other. This effect can be mitigated by introducing a guard-interval, referred to us as a cyclic prefix, between the symbols. OFDM system is used to increase the symbol duration and reducing ISI.

Channel

A radio channel is the communications link between a transmitter and receiver. Obstacles and surfaces in the path of the transmitted signal from reflectors cause the signal to reach the receiver through a series of paths. The line of sight (LOS) path is the direct path between the transmitter and the receiver. The other signal is referred in this case as multipath components. These multipath components are attenuated delayed versions of the LOS path that have been reflected and scattered off obstacles in the propagation path before arriving at the receiver. For our simulation purpose we used three multipath taps and added white Gaussian noise (AGWN). Figure 2 shows the multipath taps and the frequency response used [2].

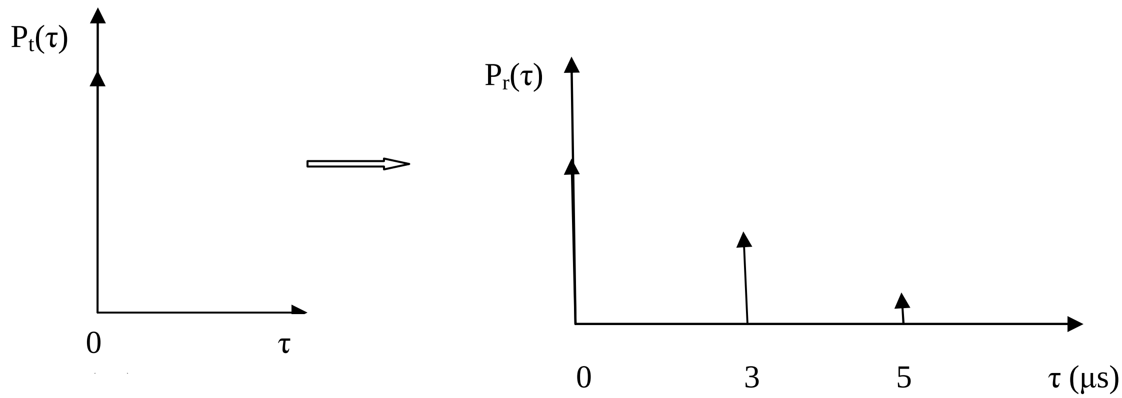


Figure 2 Multipath Components of 5 Taps

Convolution Coding

The schematic of the Convolution coding applied in this work is shown in Figure 3. The Number of inputs bits, (k), is 1 and the number of outputs bits (n) is 2. These blocks are called the shift registers. Number of registers (K) is 7. This is also called the constraint length. U is the information sequence U= (u_1 u_2 u_3 ….) entering the encoder. Then the input is an impulse, the response to the system are generator polynomials (g1 g2). Only one bit from the input can go to the first register at a time and output corresponding to it is obtained in the output terminal. When the next bit comes, the previous bit shifts by one and another set of outputs are obtained in output terminal. This process continues until all the bits are ended in output. The generator polynomial is [g1=171, g2= 133] here [3]. After combining g1 and g2, the generator matrix called the G-matrix is produced. Encoded data (V) is achieved by convolving U and G matrix. This briefly explains how the Convolution code works. After encoding, the data is sent to the channel. As mentioned earlier, code rate is the ratio of input and output. Thus, a code rate of R=k/n = ½ will mean that only half of the input bits are transmitted through channel.

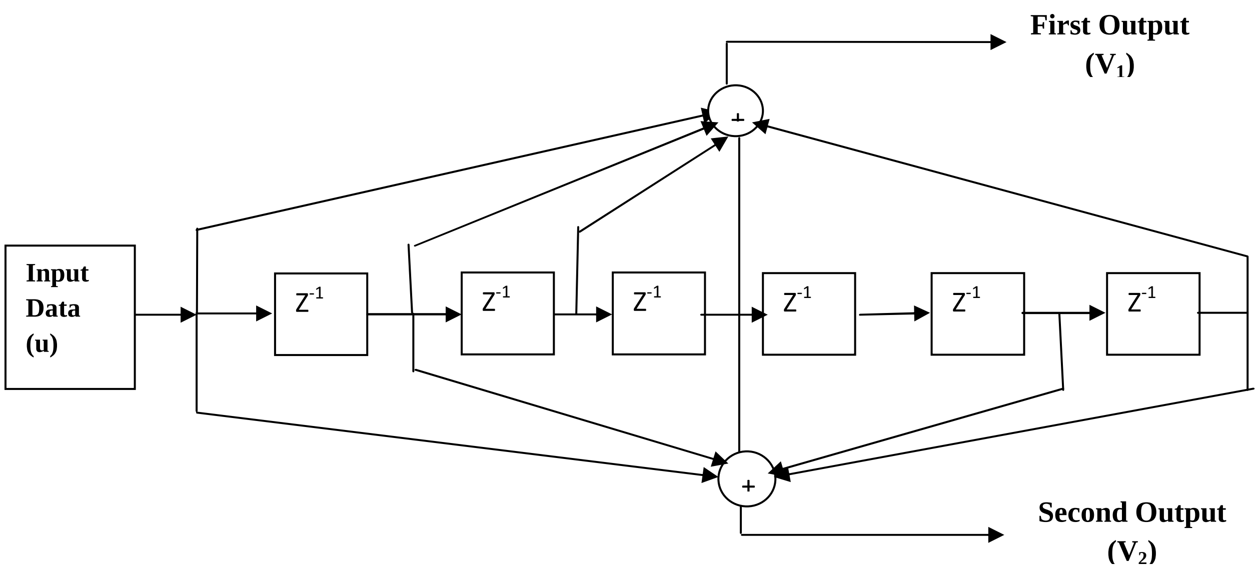
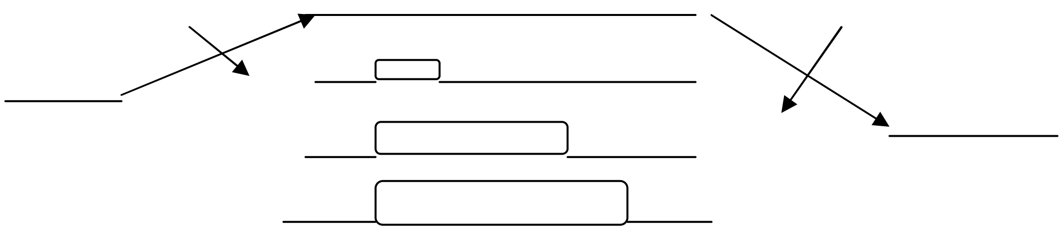


Figure 3: Schematic of Convolution coding for K=7

Convolution Interleaver

The aeronautical channel experiences random and burst errors. Burst errors are caused by natural events and electronic devices that cause an instantaneous burst in energy. The burst errors present themselves as impulses that can affect multiple data bits. Channel performance in the presence of burst errors can be improved by the process of interleaving. Rather than operating on bits that are adjacent in time and/or frequency, the code is made to operate on symbols with sufficient spacing such that the errors are more independent. In interleaving, symbols of the coded sequence are either transmitted a number of times or scrambled (permutation) using interleaving techniques. It does not add or subtract from the total number of bits being transmitted [4].



Input sequence: 1 2 3 4 5 6 7 8 9 10 11 12 13 ……
Output sequence: 1 * * * 5* *9 6 3* 13 …….

Figure 4 Convolution Interleaver

The above Figure 4 shows how the process is achieved when adjacent symbols of the transmitted sequence are separated by more than the average duration of error burst. The inverse operation is done at the receiver using de-interleaving to restore the transmitted sequence.

RESULTS AND DISCUSSION

Error Performance analysis is performed by plotting the bit error-rate versus signal to noise ratio (SNR) for AWGN. Simulations were run for different test conditions. Figure 5 shows the simulation result for a rate ½ Convolutional code with constrain length, K=7. Here we have compared the theoretical performance of QPSK in noise to OFDM with multipath, OFDM with multipath and the cyclic prefix, and OFDM with multipath, cyclic prefix and the rate ½ convolutional coding. In the literature [3] it is believed that the coding gain that can be achieved is 7dB, for this code**.** Our simulation result for BER 10^ (-4), the coding gain obtained, is approximately 11dB. OFDM system with n=64 carriers have been assumed at a sampling rate of 20 MHz with a guard interval equal to 16 samples. QPSK mapping for all sub channels has been employed. Figure 5 shows the simulation results plotted as BER vs. SNR. The performance gain for n=64 is reduced by 11db at BER 10^-4. This project also analyzes an OFDM system and the effect of channel coding in reducing the BER.

Cyclic prefix is used to reduce ISI and maintain orthogonality between sub carriers, eliminating ISI as shown in Figure 5. The channel performance improvement and the gain obtained by including a cyclic prefix is 5db. The performance improvement due to the convolution encoder is 7 decibels providing an overall improvement of 12 decibels.

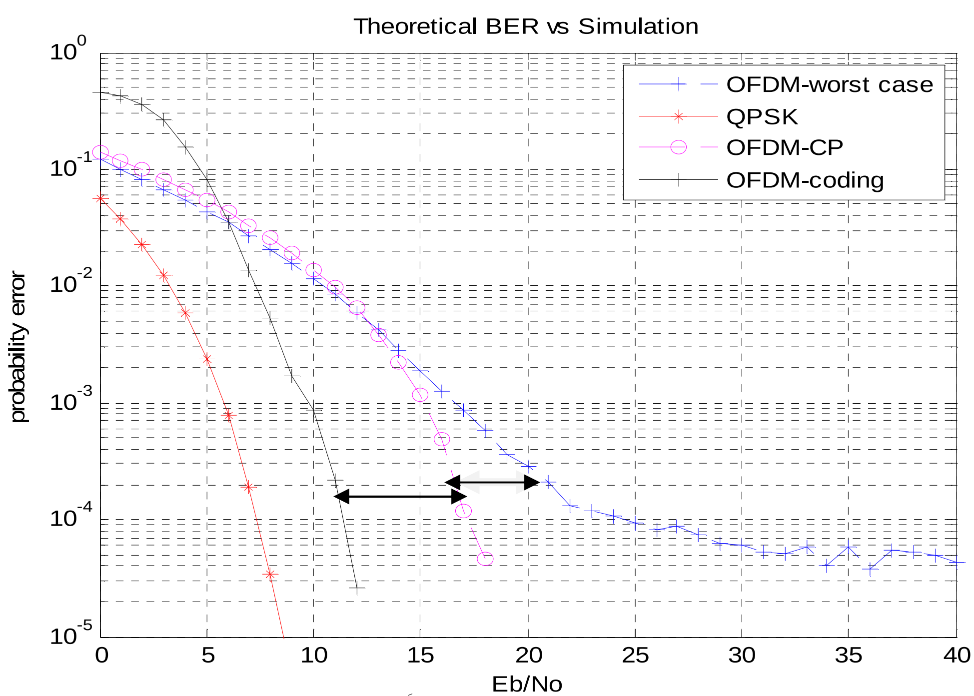


Figure 5: Theoretical BER Vs Simulation with Coding

CONCLUSIONS

The work presented in this project can be classified into two parts: the first part presents the degradation in the performance of an OFDM system in AWGN channels with multipath channels and second part shows the improvement in performance with the introduction of the Cyclic Prefix and Convolutional Coding.

Introducing the cyclic prefix was shown to reduce ISI and maintain orthogonality between sub carriers, reducing ISI. The channel performance improvement and the gain obtained by including a cyclic prefix is 5decibels. The channel performance improvement due to the R=1/2 convolution encoder is 7 decibels, for a net improvement of 12 decibels. This improvement can be applied to more robust error performance, higher data rates, less power or some combination of these.

ACKNOWLEDGMENT

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REFERENCES

[1]Christopher Lamont Taylor "Punctured Convolutional Coding Scheme for Multi-Carrier Multi-Antenna Wireless Systems". Masters Thesis, University of California, Berkeley, 2001.

[2]Rappaport T, Wireless Communications-Principles and practices prentice hall 2002

[3] Proakis John G.; Digital Communication New York: McGraw—Hill 2001
Chapter (5,6,8)

[4]Victor W.Cheng and China-Hui Lin the Design of the Soft Decoder of the Interleaved Convolution code used in IEEE 802.11a