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Performance Analysis of a Turbo Coded OFDM System

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***Abstract**: Orthogonal Frequency Division Multiplexing (OFDM) has become a popular modulation method in high speed wireless communications. By partitioning a wideband fading channel into flat narrowband channels, OFDM is able to mitigate the detrimental effects of multi path fading using a simple one- tap equalizer. In this thesis, we enhance the system throughput of a working OFDM system by adding turbo coding. The smart use of coding and power allocation in OFDM will be useful to the desired performance at higher data rates. Error control codes have become a vital part of modern digital wireless systems, enabling reliable transmission to be achieved over noisy channels.*

1. Introduction

The telecommunications' industry is in the midst of a veritable explosion in Wireless technologies. Once exclusively military, satellite and cellular technologies are now commercially driven by ever more demanding consumers, who are ready for seamless communication from their home to their car, to their office, or even for outdoor activities.
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 techniques. The latter are 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. For the most part, Orthogonal Frequency Division Multiplexing (OFDM) is the standard being used throughout the world to achieve the high data rates necessary for data intensive applications that must now become routine.
Orthogonal Frequency Division Multiplexing (OFDM) is a Multi-Carrier Modulation technique in which a single high rate data-stream is divided into multiple low rate data-streams and is modulated using sub-carriers which are orthogonal to each other. Some of the main advantages of OFDM are its multi-path delay spread tolerance and efficient spectral usage by allowing overlapping in the frequency domain. Also one other significant advantage is that the modulation and demodulation can be done using IFFT and FFT operations, which are computationally efficient.

In my research, forward error correction is performed by using turbo codes. The combination of OFDM and turbo coding and recursive decoding allows these codes to achieve near Shannon's limit performance in the turbo cliff region.

2. Orthogonal Frequency Division Multiplexing

Orthogonal frequency division multiplexing, also called multi carrier modulation uses multiple carrier signals at different frequencies, sending some of bits on each channel. This is similar to FDM. However, in the case of OFDM, all sub channels are dedicated to a single data source.
OFDM has several advantages. First, frequency selective fading only affects some sub channels and not the whole signal. If the data stream is protected by a forward error correcting code, this type of fading is easily handled. More important, OFDM overcome inter symbol interference (ISI) in a multipath environment .With OFDM, the data rate is reduced by a factor of N, which increases the symbol time by a factor of N. thus if the symbol period is Ts for the source stream, the period for the OFDM signals is NTs. This dramatically reduces the effect of ISI as a design criterion, N is chosen so that NTs is significantly greater than the root mean square delay spread of the channel.

3. OFDM Generation & Reception

OFDM signals are typically generated digitally due to the difficulty in creating large banks of phase locks oscillators and receivers in the analog domain. Fig. 1 shows the block diagram of a typical OFDM transceiver. The transmitter section converts digital data to be transmitted, into a mapping of subcarrier amplitude and phase. It then transforms this spectral representation of the data into the time domain using an Inverse Discrete Fourier Transform (IDFT). The Inverse Fast Fourier Transform (IFFT) performs the same operations as an IDFT, except that it is much more computationally efficiency, and so is used in all practical systems. In order to transmit the OFDM signal the calculated time domain signal is then mixed up to the required frequency.

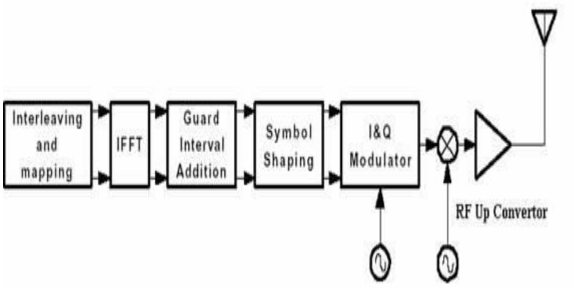

Fig. 1 – Block Diagram of a typical OFDM transceiver.

The receiver performs the reverse operation of the transmitter, mixing the RF signal to base band for processing, then using a Fast Fourier Transform (FFT) to analyze the signal in the frequency domain. The amplitude and phase of the sub carriers is then picked out and converted back to digital data. The IFFT and the FFT are complementary function and the most appropriate term depends on whether the signal is being received or generated. In cases where the signal is independent of this distinction then the term FFT and IFFT is used interchangeably.

4. Turbo Codes

Turbo codes were first presented at the International Conference on Communications in 1993. Until then, it was widely believed that to achieve near Shannon's bound performance, one would need to implement a decoder with infinite complexity or close.

Parallel concatenated codes, as they are also known, can be implemented by using either block codes (PCBC) or convolutional codes (PCCC). PCCC resulted from the combination of three ideas that were known to all in the coding community: The transforming of commonly used non-systematic convolutional codes into systematic convolutional codes. The utilization of soft input soft output decoding. Instead of using hard decisions, the decoder uses the probabilities of the received data to generate soft output which also contain information about the degree of certainty of the output bits.

This is achieved by using an interleaver. Encoders and decoders working on permuted versions of the same information. An iterative decoding algorithm centered around the last two concept would refine its output with each pass, thus resembling the turbo engine used in airplanes. Hence, the name Turbo was used to refer to the process.

5. Scope of Work

An OFDM system was modeled using MATLAB to allow various parameters of the system to be varied and tested. The aim of doing the simulations was to measure the performance of OFDM under AWGN channel and RAYLEIGH channel conditions, for different modulation schemes like BPSK, QPSK used in IEEE 802.11a wireless LAN standard simulation model. Since the main goal of the research work was to simulate the COFDM system by utilizing turbo code.

The block diagram of the entire system is shown in Figure 2

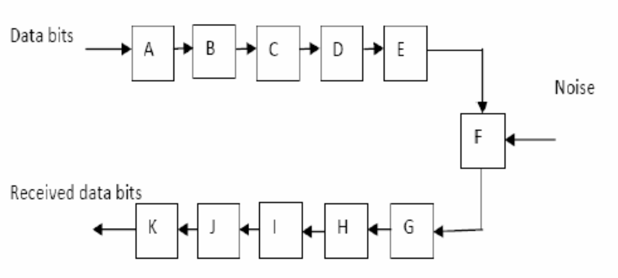

Fig 2 – Simulation Model of Turbo Coded OFDM

Here A = turbo encoder, B = BPSK / QPSK modulation, C = serial to parallel converter, D = IFFT, E = parallel to serial convertor, F = channel with noise, G = serial to parallel Converter, H = FFT, I = parallel to serial converter, J = BPSK/QPSK demodulation and K = turbo decoder.

6. Conclusion:

To conclude, this major project gives the detail knowledge of a current key issue in the field of communications named Orthogonal Frequency Division Multiplexing (OFDM). We focused our attention on turbo codes and their implementation. We described the encoder architecture. In our case, the code is the result of the parallel concatenation of two identical RSCs. The code can be punctured in order to fulfill bit rate requirements. The decoder succeeded in its duty thanks to the decoding algorithms that it is built around. We focused mainly on the study of the MAP. We discovered that the power of the scheme came from the two individual decoders performing the MAP on interleaved versions of the input. Each decoder used information produced by the other as a priori information and outputted a posteriori information. We elaborated on the performance theory of the codes. Then we tied concepts of OFDM and turbo coding with a target-based, modulation scheme. First I developed an OFDM system model then try to improve the performance by applying forward error correcting codes to our uncoded system. From the study of the system, it can be concluded that we are able to improve the performance of uncoded OFDM by convolutional coding scheme. Further improvement on the performance has been achieved by applying turbo coding to uncoded OFDM system. Turbo codes with low order decoding iterations have been evaluated. The SNR performance for BER 10 2 and 10 4, that are suitable for speed and data applications, are analyzed. As a result, the TCOFDM system with least number of decoding iterations, 3 to 5 iterations are shown to be sufficient to provide good BER performance.

7. Scope of future work:

- VLSI implementation of turbo codes.
- Multi path channel can also be investigated.

8. Acknowledgements

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