PERFORMANCE OF TURBO CODED OFDM IN WIRELESS APP

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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. There is a growing need to quickly transmit information wirelessly and accurately. Engineers have already combine techniques such as OFDM suitable for high data rate transmission with forward error correction (FEC) methods over wireless channels. 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. Over the past decade, turbo codes have been widely considered to be the most powerful error control code of practical importance. In the same time-scale, mixed voice/data networks have advanced further and the concept of global wireless networks and terrestrial links has emerged. Such networks present the challenge of optimizing error control codes for different channel types, and for the different qualities of service demanded by voice and data.

Keywords -- *WLAN Technologies And Standards, OFDM, Intersymbol Interference, TURBO CODES, Simulation Parameters Etc*

I. 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 this thesis 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.

II. WIRELESS LAN TECHNOLOGIES

The technologies available for use in WLANs include infrared, UHF (narrowband) radios, and spread spectrum radios. Two spread spectrum techniques are currently prevalent: frequency hopping and direct sequence. In the United States, the radio bandwidth used for spread spectrum communications falls in three bands (900 MHz, 2.4 GHz, and 5.7 GHz), which the Federal Communications Commission (FCC) approved for local area commercial communications.

2.1 INFRARED (IR)

Infrared is an invisible band of radiation that exists at the lower end of the visible electromagnetic spectrum. This type of transmission is most effective when a clear line-of-sight exists between the transmitter and the receiver. Two types of infrared WLAN solutions are available: diffused-beam and direct-beam (or line-of-sight). Currently, direct-beam WLANs offer a faster data rate than diffused-beam networks, but is more directional since diffused-beam technology uses reflected rays to transmit/receive a data signal, it achieves lower data rates in the 1-2 Mbps range.

2.2 NARROWBAND TECHNOLOGY

A narrowband radio system transmits and receives user information on a specific radio frequency. Narrowband radio keeps the radio signal frequency as narrow as possible just to pass the information. Undesirable crosstalk between communications channels is avoided by carefully coordinating different users on different channel frequencies. A private telephone line is much like a radio frequency. When each home in a neighborhood has its own private telephone line, people in one home cannot listen to calls made to other homes. In a radio system, privacy and noninterference are accomplished by the use of separate radio frequencies. The radio receiver filters out all radio signals except the ones on its designated frequency.

2.3 SPREAD SPECTRUM TECHNOLOGY

Most wireless LAN systems use spread-spectrum technology, a wideband radio frequency technique developed by the military for use in reliable, secure, mission-critical communications systems. Spread-spectrum is designed to trade off bandwidth efficiency for reliability, integrity, and security. In other words, more bandwidth is consumed than in the case of narrowband transmission, but the tradeoff produces a signal that is, in effect, louder and thus easier to detect, provided that the receiver knows the parameters of the spread-spectrum signal being broadcast. If a receiver is not tuned to the right frequency, a spread-spectrum signal looks like background noise. There are two types of spread spectrum radio: frequency hopping and direct sequence.

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Standard	Release date	Op.frequency band	Max.data rate
IEEE 802.11	1997	2.4GHz	2Mbps
IEEE 802.11a	1999	5GHz	54Mbps
IEEE 802.11b	1999	2.4GHz	11Mbps
IEEE 802.11g	2003	2.4GHz	54Mbps
IEEE 802.11n	2007(projected)	2.4GHz or 5GHz	540Mbps

Table 2.1 IEEE 802.11 standards

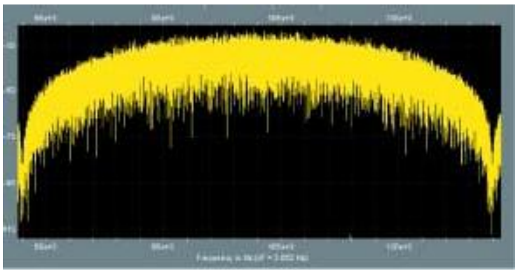
2.5 IEEE 802.11

The original version of the standard IEEE 802.11 released in 1997 specifies two raw data rates of 1 and 2 megabits per second (Mbit/s) to be transmitted via infrared (IR) signals or by either Frequency hopping or Direct-sequence spread spectrum in the Industrial Scientific Medical frequency band at 2.4 GHz. IR remains a part of the standard but has no actual implementations. The original standard also defines Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) as the medium access method. A significant percentage of the available raw channel capacity is sacrificed (via the CSMA/CA mechanisms) in order to improve the reliability of data transmissions under diverse and adverse environmental conditions. The modulation scheme used in 802.11g is orthogonal frequency-division multiplexing (OFDM) for the data rates of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s, and reverts to CCK (like the 802.11b standard) for 5.5 and 11 Mb/s and DBPSK/DQPSK+DSSS for 1 and 2 Mb/s.

III. OFDM INTRODUCTION

The principle of orthogonal frequency division multiplexing (OFDM) modulation has been in existence for several decades. However, in recent years these techniques have quickly moved out of textbooks and research laboratories and into practice in modern communications systems.

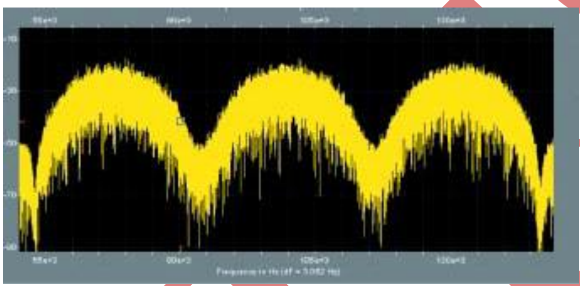
3.1THE SINGLEM CARRIER MODULATION SYSTEM



A typical single-carrier modulation spectrum is shown in Figure 3.1. A single carrier system modulates information onto one carrier using frequency, phase, or amplitude adjustment of the carrier. For digital signals, the information is in the form of bits, or collections of bits called symbols, that are modulated onto the carrier.

3.2 FREQUENCY DIVISION MULTIPLEXING MODULATION SYSTEM

A typical Frequency division multiplexing signal spectrum is shown in figure 3.2.FDM extends the concept of single carrier modulation by using multiple sub carriers within the same single channel. The total data rate to be sent in the channel is divided between the various sub carriers. The data do not have to be divided evenly nor do they have to originate from the same information source. Advantages include using separate modulation demodulation customized to a particular type of data, or sending out banks of dissimilar data that can be best sent using multiple, and possibly different, modulation schemes.



3.3 ORTHOGONALITY AND OFDM

If the FDM system above had been able to use a set of sub carriers that were orthogonal to each other, a higher level of spectral efficiency could have been achieved. The guard bands that were necessary to allow individual demodulation of sub carriers in an FDM system would no longer be necessary. The use of orthogonal sub carriers would allow the sub carriers' spectra to overlap, thus increasing the spectral efficiency. As long as orthogonality is maintained, it is still possible to recover the individual sub carriers' signals despite their overlapping spectrums. If the dot product of two deterministic signals is equal to zero, these signals are said to be orthogonal to each other. Orthogonality can also be viewed from the standpoint of stochastic processes. If two random processes are uncorrelated, then they are orthogonal. Given the random nature of signals in a communications system, this probabilistic view of orthogonality provides an intuitive understanding of the implications of orthogonality in OFDM.

3.4 MATHEMATICAL ANALYSIS

With an overview of the OFDM system, it is valuable to discuss the mathematical definition of the modulation system. It is important to understand that the carriers generated by the IFFT chip are mutually orthogonal. This is true from the very basic definition of an IFFT signal. This will allow understanding how the signal is generated and how receiver must operate. Mathematically, each carrier can be described as a complex wave:

$$S_c(t) = A_c(t)e^{j[\omega_c t + \phi_c(t)]}$$

The real signal is the real part of sc (t). Ac (t) and c (t), the amplitude and phase of the carrier, can vary on a symbol by symbol basis. The values of the parameters are constant over the symbol duration period t. OFDM consists of many carriers. Thus the complex signal Ss(t) is represented by:

$$s_s(t) = \frac{1}{N}\sum_{n=0}^{N-1} A_N(t)e^{j[\omega_n t + \phi_n(t)]}$$

Where

$$\omega_n = \omega_0 + n\Delta\omega$$

This is of course a continuous signal. If we consider the waveforms of each component of the signal over one symbol period, then the variables Ac (t) and c (t) take on fixed values, which depend on the frequency of that particular carrier, and so can be rewritten.

3.5 OFDM GENERATION AND 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 3.3 shows the block diagram of a typical OFDM transceiver [15]. 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.

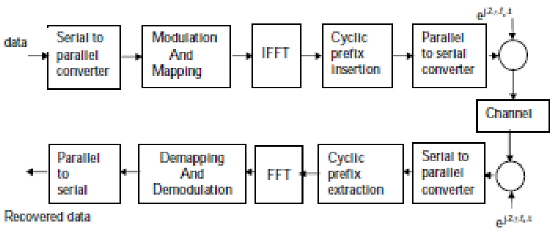


Fig 3.3 Block diagram of a basic OFDM transceiver.

3.6 RF MODULATION

The output of the OFDM modulator generates a base band signal, which must be mixed up to the required transmission frequency. This can be implemented using analog techniques as shown in Fig 3.8 or using a Digital up Converter as shown in Fig 3.9.

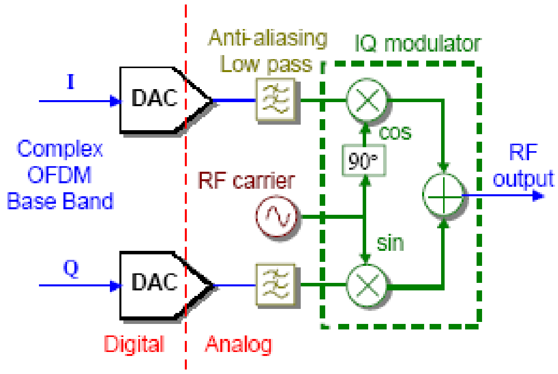


Fig 3.8 RF modulation of complex base band OFDM signal, using analog techniques

IV. ENCODERS FOR TURBO CODES

The encoder for a turbo code is a parallel concatenated convolutional code. Figure 3.1 shows a block diagram of the encoder first presented by Berrou et al [10]. The binary input data sequence is represented by $d_k = (d_{1,} \ldots d_{N)})$ the input sequence is passed into the input of a convolutional encoder [8], ENC 1 and a coded bit stream, $x_{k_1}^p$ is generated. The data sequence is then interleaved. That is, the bits are loaded into a matrix and read out in a way so as to spread the positions of the input bits. The bits are often read out in a pseudo-random manner. The interleaved data sequence is passed to a second convolutional encoder, ENC 2 and a second coded bit stream, 2 *ENC* $x_{k_2}^p$ is generated. The code sequence that is passed to the modulator for transmission is a multiplexed (and possibly punctured) stream consisting of systematic code bits and parity bits from both the first encoder $x_{k_2}^p$ and the second encoder $x_{k_2}^p$

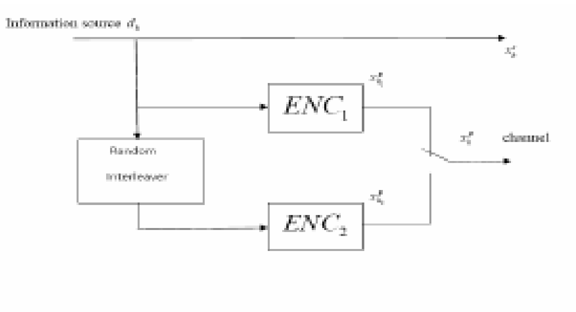


Figure 4.1Structure of a turbo encoder

4.1 TURBO DECODING

A block diagram of a turbo decoder is shown in Figure 3.5. The input to the turbo decoder is a sequence of received code values { *s* , *p*}

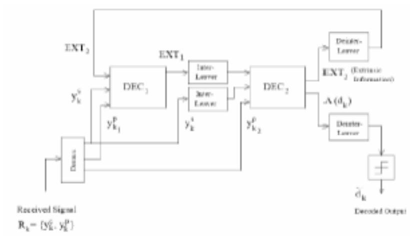


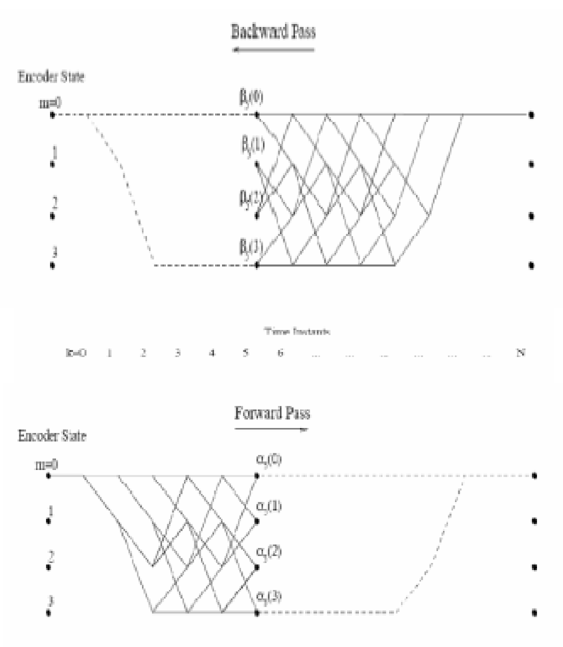
Figure 4.5 Turbo Decoder Structure.

4.2 THE MAP ALGORITHM

We review now the decoding algorithms used within 1 *DEC* and 2 *DEC* to implement the soft-input, soft-output processing needed for iterative decoding. We begin with the modified Bahl, or Maximum A Posteriori (MAP), algorithm presented in Berrou et al.'s original paper [10].

4.3 THE NEED FOR A SOFT INPUT/SOFT OUTPUT ALGORITH

Decoding of convolutional codes is most frequently achieved using the Viterbi algorithm [11], which makes use of a decoding trellis to record the estimated states of the encoder at a set of time instants. The Viterbi algorithm works by rejecting the least likely path through the trellis at each node, and keeping the most likely one. The removal of unlikely paths leaves us, usually, with a single source path further back in the trellis. This path selection represents a ‘hard’ decision; on the transmitted sequence.



4.4 DERIVATION OF THE MAP ALGORITHM

The MAP algorithm has been described in [13] and is repeated here: Forward Pass - Calculation of State Probabilities Figure 3.7 illustrates the calculations made at each time interval k , for the simple four states RSC code with trellis connectivity defined by the generator polynomial G={7,5} First, the trellis is traversed in the forward direction. At each node, the current state probability, is calculated by multiplying the state probability at the previous node 1(') k m by the branch transition probability, (Equation 3.3), given the ' received code pair This is expressed as follows:

$$\alpha_k(m) = \frac{\sum_{m'} \sum_{i=0}^{1} \gamma_i((y_k^s, y_k^p)m', m)\alpha_{k-1}(m')}{\sum_{m'} \sum_{i=0}^{1} \gamma_i((y_k^s, y_k^p)m', m)\alpha_{k-1}(m')} \quad (4.1)$$

4.5 THE MAX LOG-MAP ALGORITHM

As stated above, working in the logarithmic domain compacts the dynamic range of all the values we are working with. It also converts the multiplication operations in Equations 3.1 through 3.4 to additions. Let us take the logarithm of derived in Equation 3.3 and, for the AWGN channel, insert:

$$p(y_k^p | d_k = i, m', m) = \frac{1}{\sqrt{\pi N_0}} . \exp(-\frac{1}{N_0}[y_k^p - x_k^p(i, m', m)]^2)$$

$$p(y_k^p | d_k = i) = \frac{1}{\sqrt{\pi N_0}} . \exp(-\frac{1}{N_0}[y_k^s - x_k^s(i)]^2)$$

The simplification provides us with the so-called Max Log-MAP algorithm. If we use this approximation in Equation 3.7, we can write ( ) *k m* the log version of ( ) *k m* , as:

$$\overline{\alpha}_k(m) \approx \max_{(m',i)}\left\{\overline{\gamma}_i\left[(y_k^s, y_k^p), m', m\right] + \overline{\alpha}_{k-1}(m')\right\} - \max_{(m,m',i)}\left\{\overline{\gamma}_i\left[(y_k^s, y_k^p), m', m\right] + \overline{\alpha}_{k-1}(m')\right\} \quad (4.9)$$

Similarly

$$\overline{\beta}_k(m) \approx \max_{(m',i)}\left\{\overline{\gamma}_i\left[(y_{k+1}^s, y_{k+1}^p), m, m'\right] + \overline{\beta}_{k+1}(m')\right\} - \max_{(m,m',i)}\left\{\overline{\gamma}_i\left[(y_{k+1}^s, y_{k+1}^p), m, m'\right] + \overline{\alpha}_k(m)\right\} \quad (4.10)$$

The log-likelihood probability of each bit $\Lambda(d_k)$ is then given approximately by:

$$\Lambda(d_k) \approx \max_{(m,m')}\left\{\overline{\gamma}_1\left[(y_k^s, y_k^p), m', m\right] + \overline{\alpha}_{k-1}(m') + \overline{\beta}_k(m)\right\} - \max_{(m,m')}\left\{\overline{\gamma}_0\left[(y_k^s, y_k^p), m', m\right] + \overline{\alpha}_{k-1}(m') + \overline{\beta}_k(m)\right\} \quad (4.11)$$

4.6 THE LOG-MAP ALGORITHM

Equation 3.8 estimated in 1 ln(exp( ) ... exp( )) *n* by considering only the maximum exponential term. Robertson et al. used the Jacobian algorithm [16] to improve the approximation It was found in that good performance can be achieved with as few as eight correction values.

V. 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 bepunctured 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.

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