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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 multipath fading using a simple one - tap equalizer.

Engineers have already combined techniques such as OFDM suitable for high data rates transmission with forward error correction (FEC) methods over wireless channels. Now, we enhance the system throughput of a working OFDM system by adding turbo coding. 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.

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, communication engineers 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 a 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 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 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. Now, forward error correction is performed by using turbo codes. The combination of turbo codes and OFDM and recursive decoding allows these codes to achieve near shannon's limit performance in the turbo cliff region.

The single carrier modulation system:

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 collection of bits called symbols, that are modulated onto one carrier.

As higher bandwidths are used, the duration of one bit or symbol of information becomes smaller. The system becomes more susceptible to loss of information from impulse noise, signal reflections and other impairments. These impairments can impede the ability to recover the information sent. In addition, as the bandwidth used by single carrier system increases, the susceptibility to interference from other continuous signal sources becomes greater. This type of interference is commonly labeled as carrier wave (CW) or frequency interference.

Orthogonality and OFDM :

If the OFDM system 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 sub carriers spectra to overlap thus increasing the spectral efficiency. As long as the 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. If two random processes are uncorrelated, then they are orthogonal.

OFDM is implemented in practice using the discrete Fourier transform (DFT).

Recall from signals and systems theory that the sinusoids of the DFT form an orthogonal basis set, and a signal in the vector space of DFT can be represented as a linear combination of the orthogonal sinusoids. One view of the DFT is that the transform easily correlates its input signal with each of the sinusoidal basic functions. If the input signal has some energy at a certain frequency, there will be a peak in the correlation of the input signal and basic sinusoids that is at the corresponding frequency. This transform is used at the OFDM transmitter to map an input signal onto a set of orthogonal sub carriers i.e. the orthogonal basis functions of the DFT. Similarly, the transform is used again at the OFDM receiver to process the received sub carriers. The signals from the sub carriers are then combined to form an estimate of the source signal from the transmitter. The orthogonal and uncorrelated nature of sub carriers is exploited in OFDM with powerful results. Since the basic functions of the DFT are uncorrelated, the correlation performed in the DFT for a given sub carrier only sees energy for that corresponding sub carrier. The energy from other sub carriers does not contribute because it is because it is uncorrelated. This separation of signal energy is the reason that OFDM sub carriers spectrums can overlap without causing interference.

OFDM generation and reception:

OFDM signals are typically generated digitally in creating large banks of phase locks oscillators and receivers in the analog domain. 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 in the time domain using an Inverse Discrete Fourier transform (IDFT). The Inverse Fast Fourier transform performs the same operations an IDFT, except that it is much more computationally efficient 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.

The receiver performs the reverse operation of the transmitter, mixing the RF signal to baseband 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 FFT are complementary functions and the most appropriate term depends on whether the signal is being received or generated. In case where the signal is independent of this distinction then the term FFT and IFFT is used interchangeably.

Guard Period:

For a given system bandwidth the symbol rate for an OFDM signal is much lower than a single carrier transmission scheme. For example for a single carrier BPSK modulation, the symbol rate corresponds to the bit rate of the transmission. However for OFDM the system bandwidth is broken up into NC sub carriers, resulting in a symbol rate that is NC times lower than the single carrier transmission. This low symbol rate makes OFDM naturally resistant to effects of Inter-Symbol Interference (ISI) caused by multipath propagation. Multipath propagation is caused by the radio transmission signal reflecting off objects in the propagation environment, such as walls, buildings, mountains, etc.

These multiple signals arrive at the receiver at different times due to the transmission distances being different. This spreads the symbol boundaries causing energy leakage between them. The effect of ISI on an OFDM signal can be further improved by the addition of a guard period to the start of each symbol. This guard period is a cyclic copy that extends the length of the symbol waveform. Each sub carrier, in the data section of the symbol,(i.e. the OFDM symbol with no guard added, which is equal to the length of the IFFT size used to generate the signal) has an integer number of cycles. Because of this, placing copies of the symbol end-to-end results in a continuous signal, with no discontinuities at the joins. Thus by copying the end of a symbol and appending this to the start results in a longer symbol time. The total length of the symbol is TS=TG+TFFT, where TS is the total length of the symbol in samples, TG is the length of the guard period in samples, and TFFT is the size of the IFFT used to generate the OFDM signal. In addition to protecting the OFDM from ISI, the guard period also provides protection against time-offset errors in the receiver. The effects of multiplath propagation and how cyclic prefix reduces the inter symbol interference in detail.

PROTECTION AGAINST TIME OFFSET:

To decode the OFDM signal the receiver has to take the FFT of each received symbol, to work out the phase and amplitude of the sub carriers. For an OFDM system that has the same sample rate for the both the transmitter and receiver, it must use the same FFT size at the both receiver and transmitted signal in order to maintain sub carrier orthogonality. Each received symbol has TG + TFFT samples due to the added guard period. The receiver only needs TFFT samples of the received symbol to decode the signal. The remaining TG samples are redundant and are not needed. For an ideal channel with no delay spread the receiver can pick any time offset, up to the length of the guard period, and still get the correct number of samples, without crossing a symbol boundary. Because of the cyclic nature of the guard period changing time offset simply results in a phase rotation of all the sub carriers in the signal. The amount of this phase rotation is proportional to the sub carrier frequency, with a sub carrier at the nyquist frequency changing by 180˚ for each sample time offset. Provided the time offset is held constant from symbol to symbol, the phase rotation due to a time offset can be removed out as part of channel equalization. In multipath environments ISI reduces the effective length of the guard period leading to a corresponding reduction in the allowable time offset error. The addition of guard period removes most of the effects of ISI. However in practice, multipath components tend to decay slowly with time, resulting in some ISI even when a relatively long guard period is used.

TURBO CODES:

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 codes.

The utilization of soft input soft output decoding. Instead of the 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 decoder working on permuted.

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.

Termination:

In contrast to block codes, Convolutional codes do not have fixed block length. Convolutional coding is a continuous process, and could span an entire message, rather than a small group of bits. Turbo codes, however, do have a fixed block length, determined by the length of the interleaver. Tail bits are usually appended to each block of data bits entering one or other of the component encoders, to return it to all-zeroes state at the end of the trellis. This process is called termination, all allows the MAP algorithm to make assumptions about the start and end trellis states. This yields better BER performance. Termination of both component encoders is more difficult, because the terminating sequence for the first encoder is interleaved and may well not,by itself, terminate the second encoders. Interleaver designs have been been devised [9] which interleaver a terminating sequence in the first encoders into terminating sequence in the second encoders. This tends to yield better BER performance than a single code terminating process and is another promising area for investigation.

Results and Conclusions:

Introduction

An OFDM system was modeled using matlab to allow various parameters of the system to be varied and tested. The aim of doing simulations was to measure the performance of OFDM under AWGN channel and RAYLEIGH channel conditions, for different modulation schemes like BPSK,QSPK used in IEEE 802.11a wireless LAN Standard.

Following this introduction, sections 5.2 discusses model used in simulation, steps in OFDM simulation, modulation schemes and their constellation diagram. Section 5.3 presents the parameters used in simulation. Section 5.4 provides the simulations results of OFDM Systems for different modulation schemes. It also shows the results to compare the performance of OFDM using coded and uncoded OFDM.

SIMULATION MODEL:

Since the main goal of this was to formulate the COFDM system by utilizing turbo code.

A= turbo encoder

B= BPSK/QPSK modulation

C= serial to parallel converter

D= IFFT

E= parallel to serial converter

F= channel with noise

G= serial to parallel converter

H= FFT

I= parallel to serial converter

J= BPSK/QPSK demodulation

K= turbo decoder

CONCLUSION:

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 achieved by applying turbo coding to uncoded OFDM system.