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Performance Analysis of DWT based Turbo Coded OFDM over Nakagami Channel

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Abstract: **Over the past decade, there is a growing need to quickly transmit information wirelessly and accurately with a considerable reduction in the error rate. For that one needs to use error correcting Codes in the design of digital transmission systems. Over the past decade, Turbo codes have been widely considered to be the most powerful error control code of practical importance. To overcome multipath fading and Inter symbol Interference (ISI), in convolutional single carrier systems, equalizers are used. But it increases the system complexity. Another approach is to use a multicarrier modulation technique such as Orthogonal Frequency Division Multiplexing (OFDM) which has become a popular modulation method in high speed wireless communications. Recently the Wavelet Transform has also been proposed as a possible transform to generate the sub channels in a multicarrier system, the major advantages of using wavelet transform is that due to the overlapping nature of wavelet properties, the wavelet based OFDM does not need cyclic prefix to deal with delay spreads of the channel. As a result, it has higher spectral containment than that of Fourier-based OFDM. The impact of Turbo codes on the performance of system under Quadrature Phase Shift Keying (QPSK) and Orthogonal Frequency Division multiplexing (OFDM) over Nakagami channel will be investigated in this work. Obtained results will show that Turbo codes can improve transceiver system over nakagami channel.**

Keywords: **QPSK; OFDM; AWGN; DWT; Nakagami**

1. INTRODUCTION

Wireless technologies are the veritable explosions in telecommunication industries. 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 (FEC) techniques. 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. A particularly attractive feature of OFDM systems is that they are capable of operating without a classic equalizer, when communicating over depressive transmission media, such as wireless channels, while conveniently accommodating the time- and frequency-domain channel quality fluctuations of the wireless channel. The principle of the OFDM is employed in a large number of transmission standards, over wired and wireless channels.

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. To improve the error rate performance, various types of forward error correction codes such as Convoluional code, Reed-Solomon, etc are reported to have been applied to OFDM. In recent years, Turbo codes have attracted much attention particularly in the field of coding theory. 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.

Wavelets represent a successful story of the last decade in signal processing applications. Thus, these signals, with some highly desirable properties, are widely used in domains as compression, denoising, segmentation, inpainting or classification. On the other hand, in data communications, the same successful story can be assigned to multi-carrier modulation techniques such as OFDM.

The wavelet based OFDM (WOFDM), sometimes referred to as wavelet modulation is the point where the above concepts meet with each-other. Although they are widely used in signal processing, few wavelets applications are known in data transmission. The idea that gathers the two concepts is to use wavelet signals as carriers in a multicarrier data transmission.

Recent research has shown that, by associating the multicarrier concept and the wavelet signals, some of the OFDM's classical drawbacks can be counteracted. There are different forms of multi-carrier wavelet-based transmission and most of them use the Inverse Discrete Wavelet Transform (IDWT) for the implementation of the multicarrier transmitter. Goal of this work is to associate the WOFDM transmission with a very powerful channel coding technique, namely the turbo-codes.

Turbo codes were first presented at the International Conference on Communications in 1993 by C. Berrou. 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.

Turbo codes can be achieved by serial or parallel concatenation of two (or more) codes called the constituent codes. Parallel concatenated codes, 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.

Encoders and decoders working on permuted versions of the same information. This is achieved by using an interleaver.

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.

Turbo codes are a class of high-performance error correction codes, which are finding use in deep space satellite communications and other applications where designers seek to achieve maximal information transfer over a limited-bandwidth communication link in the presence of data-corrupting noise. They are particularly attractive for cellular communication systems and have been included in the specifications for both the WCDMA (Wideband Code Division Multiple Access)/UMTS (Universal Mobile Telecommunications System) and cdma2000 third generation cellular standards.

The combination of turbo codes with the wavelet based OFDM transmission is so called Turbo Coded OFDM (TCOFDM) can yield significant improvements in terms of lower energy needed to transmit data, a very improvement issue is in personnel communication devices.

2. ANALYSIS OF TURBO CODED WAVELET BASED OFDM SYSTEM

The system model used is shown in Fig. 1. The data to be transmitted over the channel was randomly generated by the binary source. The binary source is assumed to be memory-less, which is often the result of source coding, and therefore all information sequences are equally probable. This data is coded by using Turbo encoder. After the coded bit sequence has been obtained, it is applied to a modulator. This modulated waveform is transmitted over the channel in the presence of AWGN. The received signal is passed through demodulator and decoder where the errors are detected and corrected. The various blocks used in the model have been described in detail below.

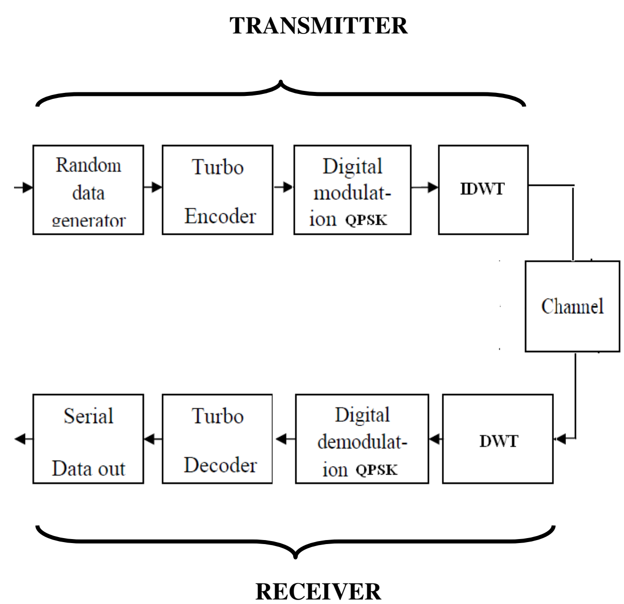

Figure 1. Turbo coded wavelet based OFDM model.

2.1 Data Source:

The data to be transmitted over the channel will be randomly generated by the binary source. The binary source is assumed to be memory-less, which is often the result of source coding (data compression), and therefore all information sequences are equally probable.

2.2 Turbo Encoding:

The encoder for a turbo code is parallel concatenated convolutional code. The block diagram of the encoder was first presented by Berrou et al is as shown in Figure 2. The binary input data sequence is represented by $dk = (d1, …….. dN)$. The input sequence is passed into the input of a convolutional encoder $ENC1$, and a coded bit stream, x^{p}_{k1} 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 out in a pseudo-random manner. The interleaved data sequence is then passed to a second convolutional encoder $ENC2$, and a second coded bit stream, X^{p}_{k2} 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 x^s_k and parity bits from both the first encoder and the second encoder.

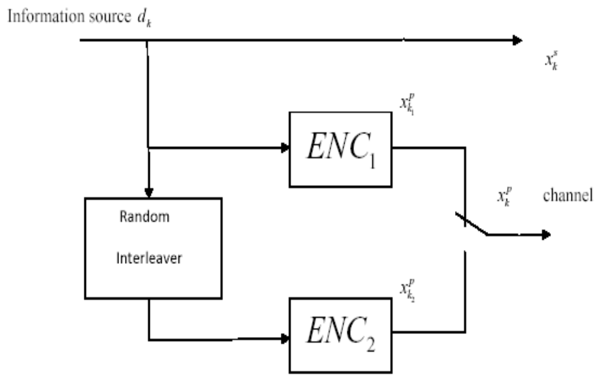

Figure 2. Structure of a Turbo Encoder.

2.3 Wavelet Based Modulation:

A wavelet is a waveform of effectively limited duration that has an average value of zero [11]. The comparative difference between wavelets and sine waves, which are the basis of Fourier analysis is that sinusoids do not have limited duration, they extend from minus to plus infinity and where sinusoids are smooth and predictable, wavelets tend to be irregular and asymmetric. Wavelet analysis consists of breaking up of a signal into shifted and scaled versions of the original wavelet. The Discrete Wavelet Transform (DWT) is used in a variety of signal processing applications, such as video compression, Internet communications compression, object recognition and numerical analysis. The advantage of wavelet transform over other transforms such as Fourier transform is that it is discrete both in time as well as scale. The transform is implemented using filters [11]. One filter of the analysis (wavelet transform) pair is a low-pass filter (LPF), while the other is a high-pass filter (HPF). Each filter has a down-sampler after it, to make the transform efficient. Any iteration of IDWT up samples two signals and filters one with a High Pass (HP) Finite Impulse Response (FIR) filter and the other one with a Low Pass (LP) FIR filter. The outputs of the HP and LP filters are then subsequently added. Consequently, DWT-OFDM does not require P/S in the transmitter and S/P in the receiver.

2.4 Channel:

The received signal vector is affected by the noise vector. The noise is assumed to be additive white Gaussian noise (AWGN) with zero mean and variance σ^2, in addition to multipath fading channel for such system, in this work Nakagami fading model is employed.

2.5 Receiver:

The receiver basically does the reverse operation to that of the transmitter. The DFT of each symbol is then taken to find the original transmitted spectrum. The phase angle of each transmission carrier is then evaluated and converted back to the data word by demodulating the received phase. The data words are then combined back to the same word size as the original data.

2.6 Turbo Decoding:

Two component decoders are linked by inter-leavers in a structure similar to that of the encoder as shown in fig 3. Each decoder takes three inputs i.e. the systematically encoded channel output bits, the parity bits transmitted from the associated component encoder, and the information from the other component decoder about the likely values of the bits concerned. The decoder operates iteratively, and in the first iteration the first component decoder produces a soft output as its estimate of the data bits. The soft output from the first encoder is then used as additional information for the second decoder, which uses this information along with the channel outputs to calculate its estimate of the data bits. The second iteration can begin, and the first decoder decodes the channel outputs again, but now with additional information about the value of the input bits provided by the output of the second decoder in the first iteration. This cycle is repeated and with every iteration, the Bit Error Rate (BER) of the decoded bits tends to fall. Both decoders provide estimates of the same set of data bits, albeit in a different order. If all intermediate values in the decoding process are soft values, the decoders can gain greatly from exchanging information, after appropriate reordering of values. Information exchange can be iterated a number of times to enhance performance. Such decoders, although more difficult to implement, are essential in the design of turbo codes.

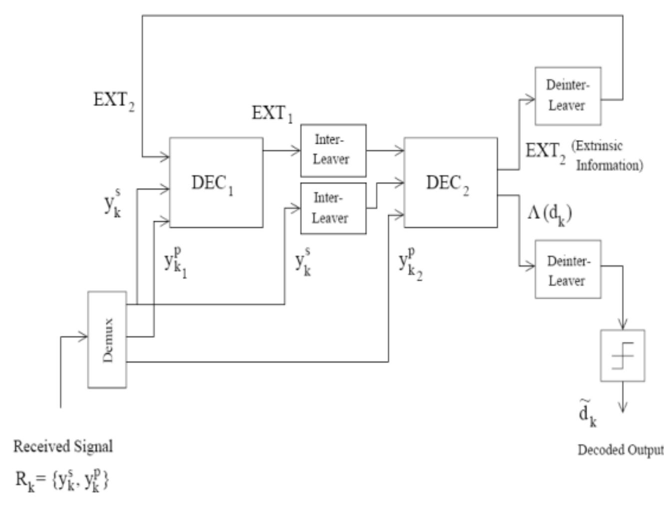

Figure 3. Structure of a Turbo Decoder.

3. RESULTS AND DISCUSSION

In this paper, the performance of Turbo codes is evaluated over Nakagami channel. Jakes Doppler filter impulse response of fading channels is employed for all simulations. The simulations are applied on system model shown in Figure (1), using the MATLAB software package. The results are displayed as graphs in which the (BER) is plotted versus (SNR), measured in decibel (dB).

From the results of simulation it will be clear that this code achieved significant improvement for SNR at low BER. For wireless communication (Nakagami channel) 6.5 to 9 dB code gain can be achieved with low range of SNR at BER of 10^{-4}.

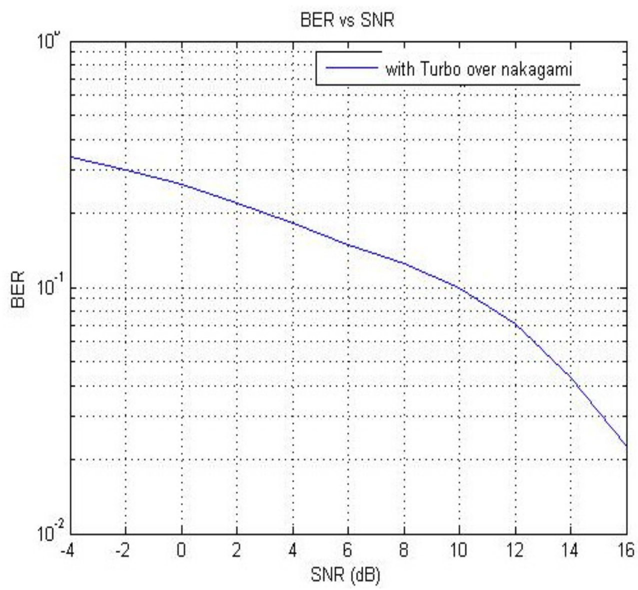

Figure 4: OFDM over Nakagami channel with Turbo coding.

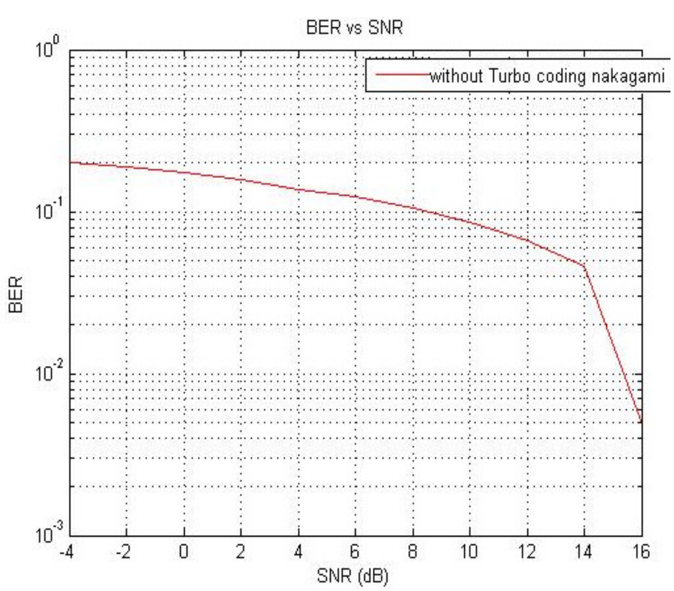

Figure 5: OFDM over Nakagami channel without Turbo coding.

Fig. 4-5 shows that turbo coded OFDM modulated signal gives a higher coding gain over the use of un-coded OFDM. As a result the performance of coded OFDM is much better than the performance of uncoded OFDM.

From the results of simulation it is clear that this code achieved significant improvement for SNR at low BER. For wireless communication (Nakagami channel) 6.5 to 9 dB code gain can be achieved with low range of SNR at BER of 10-4.

4. CONCLUSION

This work investigates the orthogonal frequency division multiplexing used for high data rate transmission and reviews the latest development on OFDM and Parallel concatenation turbo codes. A wide investigation showed that the OFDM inherently suffers from high Inter symbol interference (ISI) (caused by a dispersive channel), Inter channel interference (ICI) (caused by frequency offset) In order to combat ISI and ICI, This work has proposed the use of Discrete Wavelet transform, the major advantages of using this transform is that due to the overlapping nature of wavelet properties, the wavelet based OFDM does not need cyclic prefix to deal with delay spreads of the channel. It has also been investigated that in OFDM bit errors occur in burst form rather than independent, and burst errors extensively degrade the performance of the system. A solution to address this issue is to make use of a stronger FEC technique as proposed in this work. Most of the attention is focused on to improve the performance of OFDM by eliminating its shortcomings. From the study, it can be concluded that better performance of wavelet based OFDM can be achieved by using turbo codes. To conclude, this work deals with the knowledge of the current key issues of Orthogonal Frequency Division like ISI, ICI and adding FEC like turbo codes.

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