Performance Improvement by using a Concatenated Levels of Encoding in Wavelet based OFDM Systems

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ABSTRACT

This paper simulates a BER for OFDM system by using the wavelet transforms rather than using the Fourier transforms which reduce the BER for the same SNR. The coding algorithm using the convolutional coding and hamming coding in a series concatenated levels for wavelet based OFDM when applying the AWGN channel. This proposed coding improves the system performance. The mathematical formula for the BER in this system is deduced. The results show a decreased value of BER for the proposed coding algorithm.

Keywords

OFDM; BER; SNR; AWGN; DWT; IDWT; QAM

1. INTRODUCTION

The mobile communication systems such LTE have a high data rates in upload and download which provide the customers with new services. OFDM uses the orthogonal subcarriers to consume the bandwidth with minimized interference. OFDM based on wavelet transform enhances the system performance by reducing the bit error rate (BER). This paper apply a new channel encoder algorithm depends on using more than one encoder type to add the advantages of each one in the same system which is called the series concatenated encoder/decoder levels. The conventional FFT based OFDM uses one stage of the convolutional encoder to reduce BER [1]. This paper code the data with hamming and convolutional encoder in a series concatenated encoder/decoder levels.

There are some recent works on wavelet based OFDM system. Investigation of Using Turbo Code to Improve the Performance of DWT-OFDM System over Selective Fading Channel as in [3]. Design of Hamming Code for 64 Bit Single Error Detection and Correction using VHDL [5]. Design of Hamming Code Encoding and Decoding Circuit Using Transmission Gate Logic [7]. Implementation of Convolution Encoder and Viterbi Decoder for Constraint Length 7 and Bit Rate ½.

This paper is organized as after the introduction: OFDM based on wavelet transform systems, channel coding, simulation results, conclusion and references.

2. OFDM BASED ON WAVELET TRANSFORM SYSTEMS

OFDM is the most effective multicarrier modulations which divide the whole spectrum into equally spaced frequencies orthogonally on each other to avoid the interference. The FFT based OFDM uses a cyclic prefix which consumes 25% from the bandwidth. The OFDM based on wavelet transform don't use the cyclic prefix insertion and solve this problem to save the wasted bandwidth. This system employs Low Pass Filter (LPF) and High Pass Filter (HPF) operating as Quadrature Mirror Filters (QMF) satisfying perfect reconstruction and orthonormal bases properties. The transforms use filter coefficients as approximate and detail in LPF and HPF respectively. The approximated coefficients are sometimes referred to as scaling coefficients, whereas, the detailed is referred to wavelet coefficients [2]. Sometimes these two filters can be called sub-band coding since the signals are divided into sub-signals of low and high frequencies respectively. The general block diagram of OFDM based on wavelet transform is shown in Fig. 1. The encoder's input is binary data which modulated by M-QAM modulator. The data translated into parallel to be used as input to the IDWT block before the channel. The receiver makes the reverse process [3].

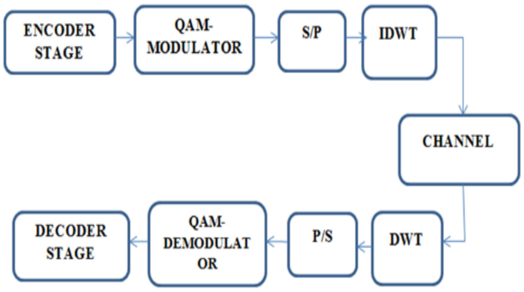

Fig. 1 OFDM Based on Wavelet Transform Block Diagram

3. CHANNEL CODING

The channel coding is a class of signal transformation which designed to improve the communication performance of the transmitted signal against the channel impairments such as noise, interference and fading. The channel coding classified into the waveform coding and the structure coding. The waveform coding transformed the waveform into better waveform to minimize the errors such as the M-ary signaling, Antipodal, Orthogonal and the trellis coding modulation (TCM) [4]. The structure sequence channel coding transforming the data sequences into better sequence with the redundancy bits. The redundant bits used for the error detections and correction such as the block coding, Convolutional coding and turbo coding. This paper discusses the bit error rate (BER) versus the signal to noise ratio (SNR) for the main block coding types and the convolutional coding to be compared with the multi levels of combination codes.

3.1 The Block Codes

The source data of length m bits is segmented into a blocks of data of length k bits of message bits. The encoder transfers the message bits into coded bits of length n. the redundant is the

$n-k$ bits which carry no new information. The code formula is (n,k) for a code rate of k/n. for any block code (n,k) for small values of n,k there is a simple look-up table of length $2k$ which stores the code words. For large values of n,k the generator matrix used to generate a code word instead of storing it because the look-up table needs a large memory [4]. The most likely types of the block codes are the hamming codes, Extended Golay Codes and BCH codes [5] [6] [7].

3.2 the Hamming Codes

The hamming codes are a simple class of the block codes which can be detect and correct single bit error in a block of data and take the form [8] [9]:

$$(n,k) = (2m-1, 2m-1-m) \tag{1}$$

where $m > 1$ and d_{min} =3

3.2.1 The Hamming Codes Advantages

1. Correcting all single error so have good performance
2. Detecting all the combination of two or more errors within the block
3. Suited for random bit errors for the transmitted signal
4. Not suited for the channel of burst errors
5. Easy to implement
6. Low cost and low power applications
7. Low simulation time as studied in this paper

3.2.2 Deducing BER for Hamming Encoder at M-QAM Modulator

The bit error rate probability represented as [4]:

$$P_B = \frac{1}{n}\sum_{j=2}^{n} j \binom{n}{j} p^j (1-p)^{n-j} \tag{2}$$

Where, P is the channel symbol error. The above equation takes a simplified form as shown [4]:

$$P_B = p - p(1-p)^{n-1} \tag{3}$$

The modulation technique used in this paper is the M-QAM modulator, the channel symbol error in M-QAM modulation is [10]:

$$P_{mqam} = 4\left(\frac{\sqrt{M}-1}{\sqrt{M}}\right) Q\left(\sqrt{\frac{3kE_b}{N_o(M-1)}}\right) - 4\left(\frac{\sqrt{M}-1}{\sqrt{M}}\right)^2 Q^2\left(\sqrt{\frac{3kE_b}{N_o(M-1)}}\right) \tag{4}$$

Substitute in (3) to obtain the bit error rate probability for hamming encoder at M-QAM:

$$p_{bhamming\_mqam} = \{[4\left(\frac{\sqrt{M}-1}{\sqrt{M}}\right) Q(\sqrt{\frac{3kE_b}{N_o(M-1)}}) - 4\left(\frac{\sqrt{M}-1}{\sqrt{M}}\right)^2 Q^2(\sqrt{\frac{3kE_b}{N_o(M-1)}})\ ] - [4\left(\frac{\sqrt{M}-1}{\sqrt{M}}\right) Q(\sqrt{\frac{3kE_b}{N_o(M-1)}}) - 4\left(\frac{\sqrt{M}-1}{\sqrt{M}}\right)^2 Q^2(\sqrt{\frac{3kE_b}{N_o(M-1)}})][(1-[(4\left(\frac{\sqrt{M}-1}{\sqrt{M}}\right) Q(\sqrt{\frac{3kE_b}{N_o(M-1)}}) - 4\left(\frac{\sqrt{M}-1}{\sqrt{M}}\right)^2 Q^2(\sqrt{\frac{3kE_b}{N_o(M-1)}})]]^{n-1}\} \tag{5}$$

Let $S=\frac{\sqrt{M}-1}{\sqrt{M}}$, $R=\sqrt{\frac{3kE_b}{N_o(M-1)}}$ for simplification and substitute in Eq. 5:

$$P_{bhq} = \{[4SQ(R) - 4S^2Q^2(R)\ ] - [4SQ(R) - 4S^2Q^2(R)][(1-[(4SQ(R)-4S^2Q^2(R)]]^{n-1}\} \tag{6}$$

The bit error rate for M-QAM modulation at hamming encoder depends on the M levels of the input symbols which equal 2^k for k binary bits which selected for the system. The hamming encoder circuit consists of six XOR, one multiplexer. The hamming decoder circuit consists of nine XOR gates and seven OR gates and multiplexer and one 3 x 8 decoder.

3.3 The Convolutional Codes

The convolutional encoder takes the form of (n,k,L) where n is the code word, k is the input sequence and equal $m_1, m_2, m_3 \ldots.mk$. The km values take 0 or 1 only for binary input and L is the constrain length of the encoder. The encoder converts each sequence k to code word $U = G\ (m)$ for the generator polynomial G. The general convolutional encoder with L shift registers and n modulo-2 adder [11]. The encoder rate is k/n and the constrain length K represent the number of k bit shifts which the information sequence influence the encoder output. The shift register consists of number of k flip flops [8] [12].

Deducing the Bit Error Probability of a Convolutional Encoder for M-QAM

The bit error rate probability for a convolutional encoder at hard decision is represented as [4]:

$$P_B \leq \frac{dT(D,N)}{dN} \text{ at } N = 1 \text{ and } D=2\sqrt{p(1-p)} \tag{7}$$

Where, p is the probability of channel symbol error, D is the hamming distance from the branch word of that branch to all zero branch and $T\ (D,N)$ is the transfer function of the system which can be represented as [13]:

$$T\ (D,N) = \frac{D^5N}{1-2DN} \tag{8}$$

Differentiate and substitute in (7) to find the bit error rate probability in terms of the channel symbol error [4]:

$$P_B = \frac{\{2[p(1-p)]\wedge 0.5\}^5}{\{1-4[p(1-p)\wedge 0.5]\}\wedge 2} \tag{9}$$

Substitute in (4) to find the final form of bit error rate probability in M-QAM modulation:

$$P\_B = \frac{\{2[[4\,S\,Q(R) - 4\,S^2Q^2(R)\ ](1-[4\,S\,Q(R) - 4\,S^2Q^2(R)\ ])]\wedge 0.5\}^5}{\{1-4[[4\,S\,Q(R) - 4\,S^2Q^2(R)\ ](1-[4\,S\,Q(R) - 4\,S^2Q^2(R)\ ])\wedge 0.5]\}\wedge 2}$$

(10)

Eq.10 shows the deducing of bit error probability at convolutional encoder for M-QAM as a function in M,k and N_o (signal to noise ratio).

3.4 The Series Concatenated Encoder/Decoder Levels

The new coding algorithm is the series concatenated encoder/decoder levels uses two or more levels of encoders in the transmitter stage and decoders in the receiver stages. The series concatenated encoder/decoder levels achieve high error correcting capability of the code and long block length. This paper using the coding algorithm of concatenated levels for cascaded hamming encoder and the convolutional encoder as shown in Fig. 2

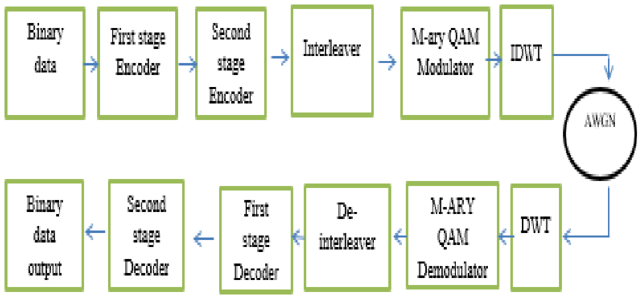

Fig. 2 The Block Diagram of OFDM for Series Concatenated Encoder/Decoder Levels

4. SIMULATION RESULTS

All the simulations are performed using MATLAB R2015b to draw the BER versus the SNR for OFDM based on Wavelet transform system at different cases of channel coding. The simulation compares the new coding concatenated level with the conventional coding method. The simulation parameters are listed in table 1.

Table.1 The Simulation Parameters

The simulation parameters	specification
modulation	16-QAM
Wavelet function	Haar
(n,k), constrain length	(6,3,7)
BW, Carrier spacing	10MhZ, 15 kHz
Binary data	9600 bits
Encoder/decoder	Convolutional/Viterbi/hamming

The simulation of OFDM system using the multi levels of the encoding studied in different cases for this paper. The results studied for series concatenated encoder/decoder levels at two or more convolutional or hamming encoder/decoder and a combination of hamming and convolutional encoder [14].

4.1 One Stage Hamming Encoder Decoder in OFDM system

Simulation the BER versus SNR for OFDM system using one stage hamming encoder / decoder shown in Fig. 3 with MATLAB 2015 for the simulation parameters listed in table1.

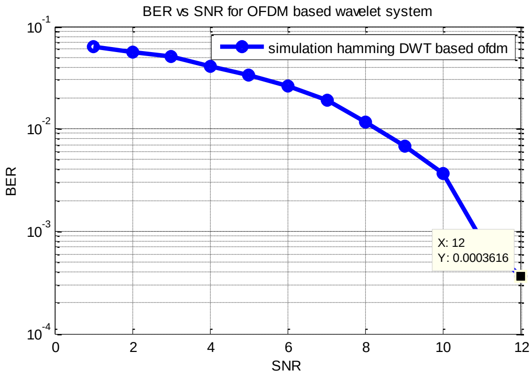

Fig. 3 BER for One Stage of Hamming Encoder/Decoder

The value of BER in one hamming encoder/decoder gives 3.616*10^-04 at SNR of 12dB with a simulation time of 12.1 sec.

4.2 One stage Convolutional Encoder /Viterbi Decoder in OFDM system

Applying the convolutional encoder at the transmitter and Viterbi decoder at the receiver in OFDM systems as shown in Fig. 4 The value of BER in one stage convolutional encoder is 7.813*10^-05 at SNR of 12dB with a simulation time of 14.24 sec. the performance of convolutional encoder is better than the hamming encoder because of the reduced value of BER. The simulation time in hamming is less than the simulation time of convolutional encoder but more complex. The convolutional encoder is simpler.

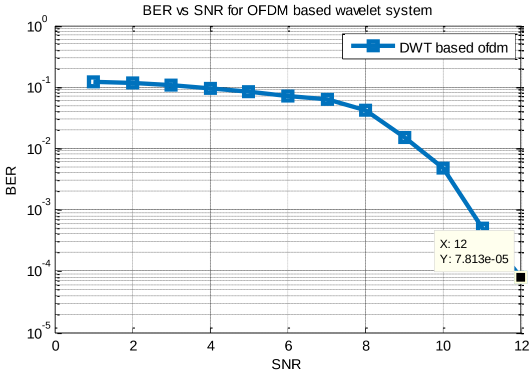

Fig. 4 BER for One Stage of Convolutional Encoder/ Viterbi Decoder

Applying the convolutional encoder at the transmitter and Viterbi decoder at the receiver in OFDM systems as shown in Figure 4 The value of BER in one stage convolutional encoder is 7.813*10^-05 at SNR of 12dB with a simulation time of 14.24 sec. the performance of convolutional encoder is better than the hamming encoder because of the reduced value of BER. The simulation time in hamming is less than the simulation time of convolutional encoder but more complex. The convolutional encoder is simpler.

4.3 The series Concatenated Encoder/Decoder Levels

The series concatenated encoder/decoder levels using more than one stage in the encoder and decoder circuit diagram.

4.3.1 Two Series Concatenated Levels of Convolutional Encoder/ Viterbi Decoder

The conventional OFDM uses a one stage of convolutional encoder and gives a good results compared with FFT based OFDM and no coding system [14]. The two stages convolutional encoder uses series concatenated encoder/decoder levels of convolutional encoder in the transmitter and also series concatenated encoder/decoder levels of Viterbi decoder at the receiver. The relation of BER versus SNR is shown in Fig. 5.

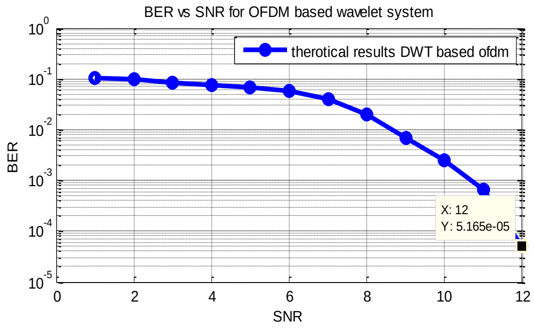

Fig. 5 BER for Two Stages of Convolutional Encoder/ Viterbi Decoder

The value of BER in two stages convolutional encoder Viterbi/decoder equal 5.205*10^-05 at SNR of 12dB.The simulation time required for this system is nearly 24.79 sec. the convolutional encoder is simple and gives low values of BER than the hamming encoder but with high simulation time. The two stages convolutional encoder/Viterbi decoder gives good results with respect to the one stage convolutional encoder, one stages of hamming encoder decoder.

4.3.2 Two series Concatenated Levels of Hamming Encoder/Decoder

The two stages hamming encoder uses two series concatenated hamming encoders in the transmitter and also two series concatenated hamming decoders at the receiver. BER versus SNR for two stage hamming encoder/decoder is shown in Fig. 6.

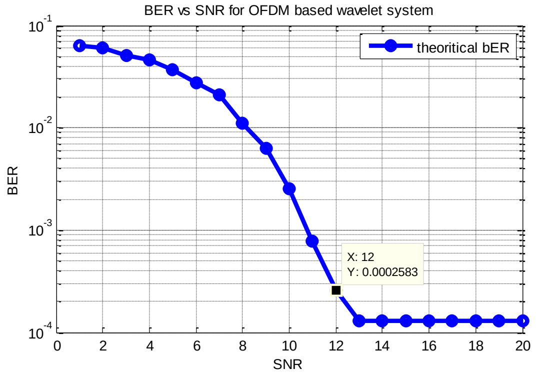

Fig. 6 BER for Two Stage Hamming Encoder/Decoder

The value of BER in two stages hamming encoder/decoder equal 0.0002583 at SNR of 12dB.The simulation time required for two stage hamming encoder/decoder is 18.6 sec only. The BER value in two stages hamming encoder/decoder is less than the BER in one stage hamming encoder/decoder but with high simulation time. The BER value for two stages convolutional encoder/Viterbi decoder is less than BER value for two stages hamming encoder/decoder at the same SNR. The systems which wants to save time must work with the hamming encoder but the systems which wants a good performance must choose the convolutional encoder.

4.3.3 Two Series Concatenated Levels of Hamming-Convolutional Encoder/Decoder

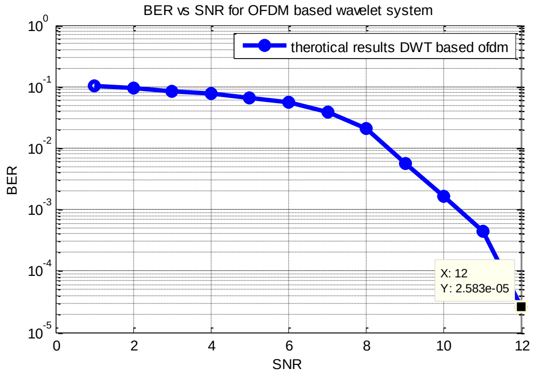

Fig. 7 BER in Two Stages Hamming/Convolutional Encoder Decoder

The two stages hamming/convolutional encoder/decoder uses a hamming encoder as a first stage in the transmitter followed by a convolutional encoder as a second stage. At the receiver the convolutional decoder is the first stage and then the hamming decoder. BER versus SNR in two stages hamming/convolutional encoder/decoder is shown in Fig. 7. The value of BER in two stages hamming/convolutional encoder/decoder gives 2.583*10^-05 at SNR of 12dB. Cascading a convolutional encoder with hamming gives a low value of BER than the above mentioned systems at the same SNR. The simulation time required is about 20.1 sec. The two stages hamming/convolutional encoder gives less simulation time than the two stages convolutional encoder/Viterbi decoder. Working with a series concatenated levels of hamming and convolutional encoder saves the time and improves the performance by reducing BER in addition to less complexity. The summarized results listed in table. 2.

Table.2 The Summarized Results

Coding algorithm	BER at 12dB	Simulation time (sec)
One hamming	3.616*10^-4	12.1
One convolutional	7.813*10^-5	14.24
Two hamming	0.0002583	18.6
Two convolutional	5.205*10^-5	24.79
Series hamming/convolutional	2.58*10^-5	20.1

5. CONCLUSION

The OFDM based on wavelet transform system saves the bandwidth by cancelling the cyclic prefix and improve the performance by reducing the BER than the FFT based OFDM.

Channel encoder used in the communication system to detect and correct the bit errors due to the channel impairments at the receiver. Choosing the encoder/decoder types that detect and correct large numbers of bits enhance the performance of the communication system. The coding algorithm used in this paper is series concatenated hamming /convolutional encoder/decoder levels. This algorithm enhances the system performance by reducing BER at a suitable SNR and low simulation time. The simulation time for the hamming/convolutional algorithm is less than the simulation time for two convolutional cascaded encoders. Increasing the encoder/decoder stages increase the complexity and consume much time in simulation without any effective decreasing in BER. The future scope for this work is applying the proposed channel codding algorithm on the image, voice and video as an input signal.

6. REFERENCES

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