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A New Approach to Enhance Performance of OFDM using BCH and Newly Designed Filter

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ABSTRACT
Orthogonal frequency division multiplexing (OFDM) is a multicarrier communication technique and it has capability to rise above the frequency-selective fading problem, which is common in wireless broadband communications. This has made it popular since last few years. The OFDM system suffers from a number of drawbacks such as the high peak-to-average power ratio (PAPR). Many PAPR reduction techniques used either destroy the system performance, which is the clipping technique or increases the overall complexity of the system, such as the selective mapping (SLM). In this paper a unique approach has been proposed to obtain a new code from the existing codes in order to reduce the bit error rate (BER), to mitigate the gap between the performance and Shannon limit while the bounded peak average power ratio (PAPR) of OFDM symbol is guaranteed. A new code based on the BCH with a Barthannwin Wave Filter has been proposed to achieve the desired results.

General Terms
BCH with Barthannwin Wave Filter

Keywords
OFDM, BCH, Barthannwin Filter, PAPR, BER, PTS, SLM

1. INTRODUCTION
Wireless communication has become a household name in this fast growing tech savvy world. Directly or indirectly we all use wireless communication devices. Innovation has always been an integral part of human development from pigeon carriers to wireless communication there has been a constant development in communication field. Increased usage has increased the demand for high speed in many recent wireless multimedia applications. Traditional single carrier modulation techniques can achieve only limited data rates due to the restrictions imposed by the multipath effect of wireless channel and the receiver complexity. In single carriers systems, as the data-rate in communication system increases, the symbol duration gets reduced. Therefore, the communication systems using single carrier modulation suffer from severe inter-symbol interference (ISI) caused by dispersive-channel impulse response, and thereby need a complex equalization scheme. Orthogonal Frequency Division Multiplexing (OFDM) has been proved to be an effective multicarrier modulation scheme that improves the bandwidth efficiency even for present 3G or 4G wireless system.

OFDM is a special form of multicarrier modulation scheme, which divides the entire frequency selective fading channel into many orthogonal narrowband flat-fading sub channels, in which high-bit-rate data stream is transmitted in parallel over a number of lower data rate subcarriers thereby substantially reducing the ISI due to larger symbol duration [2].

1.1 Barrier
A major barrier to the widespread acceptance of OFDM is the high peak-to-average power ratio (PAPR). OFDM signal consists of number of independently modulated subcarriers which can give a large peak to average power ratio (PAPR) when they are coherently added [2]. There is possibility of PAPR exceeding certain threshold value leading Power amplifiers to saturate. This causes signal distortion such as in-band distortion and out-of band radiation due to the nonlinearity of the high power amplifier (HPA) and leads to bad bit error rate (BER) performance.

1.2 Solution
PAPR reduction schemes can be categorized as multiplicative and additive schemes with respect to the computational operation in the frequency domain. Selected mapping (SLM) and partial transmit sequences (PTS) are the multiplicative schemes as the phase sequences are multiplied by the input symbol vector in the frequency domain.

Even though one of the subcarriers is lost due to burst errors, use of error control code helps to maintain BER performance and to reduce PAPR. [3-7]

$$PAPR = 10\log_{10}\frac{\max_{0\le t\le T} I_x.I^2}{P_{av}} \cdots\cdots(1)$$

There P_{av} is the average power of the signals in time domain, and x $(t)^2$ is the maximum peak of the signal.

$$x(t) = \frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} X.k.e^{(j2\pi ft)}, 0 \le t \le T......(2)$$

In an OFDM system, the data block of N symbols, denoted by $X=[X_0, X_1, X_3, XN_{-1}]^T$, is modulated by a set of orthogonal sub-carrier, f_k, {k=0, 1, 2, N-1}, where T denotes the transpose. In OFDM system to maintain the orthogonality of the signals, the spacing Δf between neighboring subcarriers is set to be a multiple of 1/T. i.e., Δf=1/T, where T is the duration of an OFDM symbol and m is a positive integer we set m to be the least positive integer, in order to make full use of the bandwidth; then the transmitted OFDM symbol is given by [2].

1.3 Proposed
In this paper Error control (EC) codes like BCH with interleaving and Barthannwin Wave Filter is proposed to reduce PAPR in OFDM system.

2. OFDM SYSTEM

The principle of Orthogonal Frequency Division Multiplexing (OFDM) is to split a high-rate data stream into a number of lower rate streams that are transmitted simultaneously over a number of orthogonal subcarriers. In a classical parallel data system, the total single frequency band is divided into N non-overlapping frequency subchannels and data are multiplexed using Frequency Division Multiplexing (FDM) as shown in Figure 1 (a). FDM method is good to eliminate interchannel interference, but this leads to inefficient use of frequency resources. To improve the efficiency of parallel data and FDM with overlapping subchannels as shown in Figure 1 (b) is used.

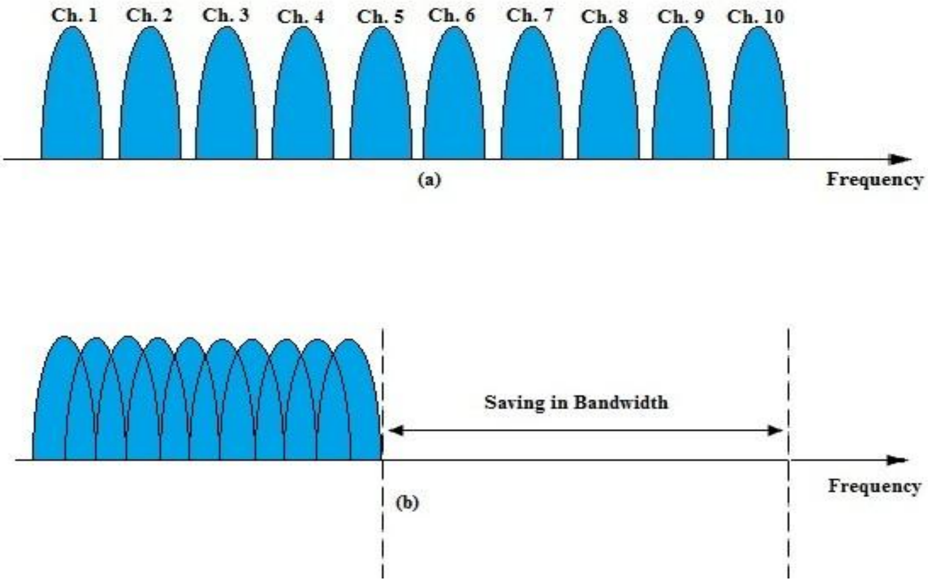

Fig. 1: Concept of OFDM signal: (a) Conventional multicarrier technique (FDM), (b) Orthogonal multicarrier modulation technique (OFDM)

3. TECHNIQUES

Various techniques have been proposed to solve this PAPR problem. An interesting method for the PAPR-alleviating approach is to use the channel coding method to generate codewords of reduced PAPR. This approach was first proposed in [8]. Although the method of [8] provides a worst case guarantee for PAPR, it entails an exhaustive search which increases the computational complexity especially for large number of subcarriers. Furthermore since in this solution the encoding and decoding are also performed by the use of look-up tables, which is also requires large memory when the OFDM block length increases. In [9], the selection of the appropriate codeword has been developed based on specific sequences such as Shapiro-Rudin and Golay sequences. However, neither in [8] nor in [9] the error correcting issue has been addressed. The study in [10] discusses the error correction problem where firrst a powerful block code is selected and then by using a weight vector the PAPR of the codeword is decreased. The theoretical aspects of the relation between the code rate, minimum Euclidean distance of the code and its block length is provided in [11] as two fundamental theorems. The first theorem proves a lower bound for PAPR based on the three aforementioned parameters. The second theorem provides a lower bound for the code rate as a function of maximum acceptable PAPR, code block length and code minimum distance. Despite all the research on this subject, the error correction capability of coding-based PAPR reduction methods is not been paid the attention which it deserves. Through the effort of seeking a relationship between PAPR and error correction probability, [13] showed that finding the PAPR of a code is associated with minimum distance decoding of the code. Moreover, a sophisticated algorithm is presented in [13] to find the weight vector discussed in [12]. In [14], a new class of Reed-Muller (RM) code with reduced PAPR is proposed. Although the error correction properties of RM code has been well-studied, the performance of this code is quite far from the Shannon limit and cannot compete with that of the capacity achieving codes, e.g. turbo codes [15] or LDPC codes [16]. Therefore the problem of designing codes that performs close to the Shannon limit while having good PAPR properties has remained unsolved.

3.1 BCH

RM codes, despite their appropriate PAPR properties, are not that efficient performance-wise. To select the time domain component code, the following issues should be taken into account; efficiency in terms of bit error rate (BER) performance, low PAPR, moderate decoding complexity and feasibility of generating soft output. Considering these requirements, Bose-Ray-Chaudhuri (BCH) codes seem as good option for time domain component code. This is owing to the fact that turbo block codes using BCH codes as the component codes in both dimensions are reported to perform close to the Shannon limit in [18]. The simplicity of BCH decoder is also appealing although it only generates hard output. To implement a soft-input soft-output (approximated MAP) decoder for the BCH, the Chase algorithm is used as proposed by [18]. The detailed encoding and decoding of the time-frequency turbo block code with RM and BCH code can be described as follows. Assume that we have the information bit matrix M such that

$$M = \begin{bmatrix} m_1 \\ m_2 \\ \vdots \\ m_{k1} \end{bmatrix} = \begin{bmatrix} m_{11} & m_{12} \cdots & m_{1k_2} \\ m_{21} & m_{22} \cdots & m_{2k_2} \\ \vdots & \vdots & \ddots \vdots \\ m_{k_1 1} & m_{k_1 2} \cdots & m_{k_1 k_2} \end{bmatrix} \quad \cdots\cdots(3)$$

Supposed that RM2 (1: m) is used for frequency component code and BCH (n1; k1) is used for frequency component code and BCH (n1; k1) is used for time component code, k_2 is equal to m + 1. Using RM2(1;m), we encode the message bit sequence ($m_{i1};m_{i2};\ldots\ldots;m_{i(m+1)}$) to have RM codewords ci = (c_{i1}; c_{i2};…. ; c_{i2m}) for i = 1; 2;…; k_1. And using BCH(n_1; k_1), we encode the message bit sequence (c_{1j} ; c_{2j} ;…. ; ck_{1j}) to make BCH parity bits ($c_{(k1+1)j}$; $c_{(k1+2)j}$;…..; c_{n1j}) for j = 1; 2; _ _ _ ; 2^m. Now we have the matrix C = [d1 d2….d_{n1}] T, comprising bits of size n_1X 2^m, where A^T is the transpose of the matrix A. We choose a pre-defined coset representative s = (s_1; s_2;…. ; s_2^{m}) of the form

$$\sum_{k=1}^{m-1} X_{\pi k} . X_{\pi(k+1)}$$

Using s we obtain the final sequence di in the frequency domain such that $d_i = c_i + s$ for i = 1; 2;…. ; n1 and form the matrix D = [d1 d2 ….. d_{n1} $]^T$. Finally, we map each bit of the matrix D to Binary Phase Shift Keying (BPSK) constellation symbols (`0' to `+1' and `1' to `-1') and then map the matrix D consisting of BPSK symbols to the corresponding 2-dimensional block.

Decoding is basically performed iteratively as soft extrinsic information is exchanged between RM and BCH. The decoder receives the real-valued BPSK symbol matrix R of size n1X 2^m, such that.

$$R = \begin{bmatrix} r_1 \\ r_2 \\ \vdots \\ r_{n1} \end{bmatrix} = \begin{bmatrix} r_{11} & r_{12} \cdots & r_{12^m} \\ r_{21} & r_{22} \cdots & r_{22^m} \\ \vdots & \vdots \ddots & \vdots \\ r_{n_1 1} & r_{n_1 2} \cdots & r_{n_1 2^m} \end{bmatrix} \cdots\cdots(4)$$

4. TECHNIQUE USED

A unique method has been proposed in this paper where BCH is used along with a new filter designed in MATLAB and named Barthannwin Wave Filter (BWF) to get low PAPR and BER. BCH has already been discussed in detail in 3.1. Let us talk about now the filter and the algo used.

4.1 Barthannwin Wave Filter

Barthannwin Wave Filter is a high pass FIR filter which is designed by using Barthannwin window. We have designed a FIR filter because of its following basic characteristics:

- linear phase characteristic
- high filter order (more complex circuits)
- Stability

Barthannwin window is a combination of two windows Bartlett Window and Hann(also known as Hann) Window.

4.1.1 Bartlett Window

The Bartlett window is very similar to a triangular window. The Bartlett window always ends with zeros at samples 1 and n, however, while the triangular window is nonzero at those points. For L odd, the center L-2 points of bartlett(L) are equivalent to triang(L-2). If you specify a one-point window (set L=1), the value 1 is returned.

w = Bartlett (L) returns an L-point Bartlett window in the column vector w, where L must be a positive integer. The coefficients of a Bartlett window are computed as follows:

$$w(n) = \begin{cases} 2n/N, o \le n \le N/2 \\ 2 - 2n/N,\ N/2 \le n \le N \end{cases} \cdots(5)$$

The window length L=N+1.

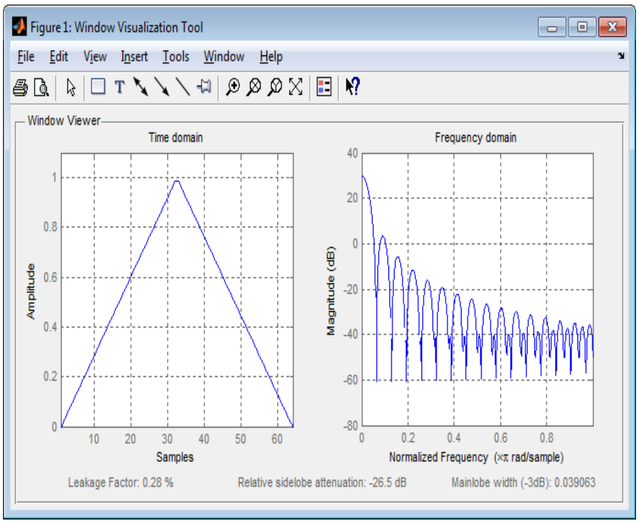

Fig. 2: Designed Filter-Bartlett Windows

4.1.2 Hann Window

The Hann window has the shape of one cycle of a cosine wave with 1 added to it so it is always positive. The sampled signal values are multiplied by the Hann function. The ends of the time record are forced to zero regardless of what the input signal is doing.While the Hann window does a good job of forcing the ends to zero, it also adds distortion to the wave form being analyzed in the form of amplitude modulation; i.e., the variation in amplitude of the signal over the time record. Amplitude Modulation in a wave form results in sidebands in its spectrum, and in the case of the Hann window, these sidebands, or side lobes as they are called, effectively reduce the frequency resolution of the analyzer by 50%. The Hann window should always be used with continuous signals, but must never be used with transients. The reason is that the window shape will distort the shape of the transient, and the frequency and phase content of a transient is intimately connected with its shape. w = hann(L) returns an L-point symmetric Hann window in the column vector w. L must be a positive integer. The coefficients of Hann windows are computed from the following equation.

$$W(n) = \begin{cases} 0.5[1 - \cos] \\ 0.5[1 - \cos(2\pi n / N)] \end{cases}, 0 \le n \le N ....(6)$$

The window length is L=N+1.

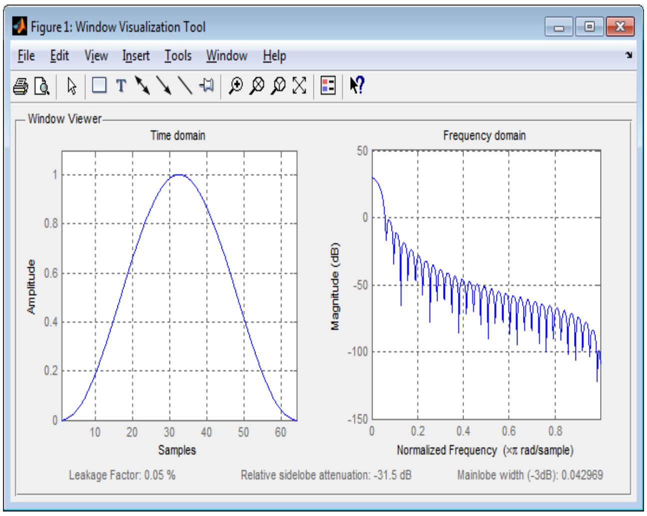

Fig. 3: Filter - HanningWindow

4.2 Barthannwin Window

This window has a mainlobe at the origin and asymptotically decaying sidelobes on both sides. It is a linear combination of weighted Bartlett and Hann windows with near sidelobes lower than both Bartlett and Hann and with far sidelobes lower than both Bartlett and Hamming windows. The mainlobe width of the modified Bartlett-Hann window is not increased relative to either Bartlett or Hann window mainlobes.

w = barthannwin(L) returns an L-point modified Bartlett-Hann window in the column vector w. The equation for computing the coefficients of a Modified Bartlett-Hann window is

$$W(n) = 0.62 - 0.48\{(n/N - 0.5)\} + 0.38\{2\pi(n/N - 0.5)\}$$

Where 0 ≤ n ≤ N and the window length is L= N+1.

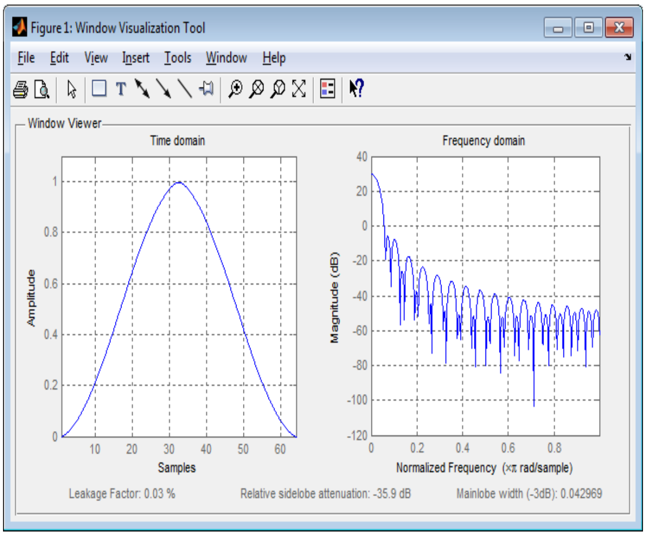

Fig. 4: Designed Filter – Hanning Window

5. STEPS

A Graphical User Interface (GUI) has been designed to test PAPR values for different parameters. Table 1 shows different Parameters.

Table 1: Parameter Used

Parameter	Value/type
Transmitted Data	70400
PAPR Reduction Technique	BCH with Wave Filter
Modulator Used	QAM
Modulation Order 'M'	2,8,16,32,64
Sub-band 'SB'	64,128,256,512
Over Sampling Factor 'L'	4

Following step were used –

1. Generate random signal optionally generated OFDM signal may also be used.

```
t_data=randint(9600,1);
```

2. Apply wave filter on the generated signal

3. Perform Convolutional encoding of data

```
constlen=7;
codegen = [171 133];    % Polynomial
Trellis = poly2trellis (constlen, codegen);
codedata = convenc(data, trellis);
```

4. Perform BCH encoding of data
5. Interleave coded data
6. Convert binary to decimal
7. Modulate data using QAM
8. Perform Pilot insertion
9. Apply IFFT
10. Add Cyclic Extgension
9. Add AWGN (white Gaussian noise)
10. Remove Cyclic Extension
11. Apply FFT
12. Remove Pilot insertion
13. Demodulate
14. Convert data from decimal to binary
15. De-Interleave data
16. Decode data
17. Decode of BCH data
18. Calculate BER and PAPR

6. RESULTS

Simulation was carried out using different parameters. Some of the better results obtained are shown in Table 2 and A comparison between PAPR of original signal without any scheme and PAPR using proposed scheme was observed.

Table 2:

PAPR Performance using BCH + Wave Filter technique				
Experiment	**M**	**L**	**SB**	**PAPR in db**
1	16	4	64	5.12
2	16	4	128	4.67
3	16	4	256	5.61
4	16	4	512	5.73

In table 3 representations of results shown.

Table 3:

PAPR Performance using BCH + Wave Filter technique				
Technique	**M**	**L**	**SB**	**PAPR in db**
Proposed	16	4	128	4.67
Original Signal	16	4	128	7.41

Table 4 shows a comparison between various techniques used in [19] with the proposed scheme.

Table 4:

PAPR Performance using BCH + Wave Filter technique				
Technique	**M**	**L**	**SB**	**PAPR in db**
Proposed	16	4	128	4.67
SLM	16	4	128	7.31
PTS	16	4	128	5.82

7. CONCLUSION

The results obtained in [19] for QAM were compared with the results obtained using the proposed scheme; it was observed that the proposed scheme works better than the conventional PTS and SLM techniques in [19]. Simulation for QAM was carried out as in [19] other modulators were used and it was observed that QAM gives better results. BER obtained is also better using the proposed scheme. Figure 5 Shows a plot between Original and improvised signal using Proposed scheme.

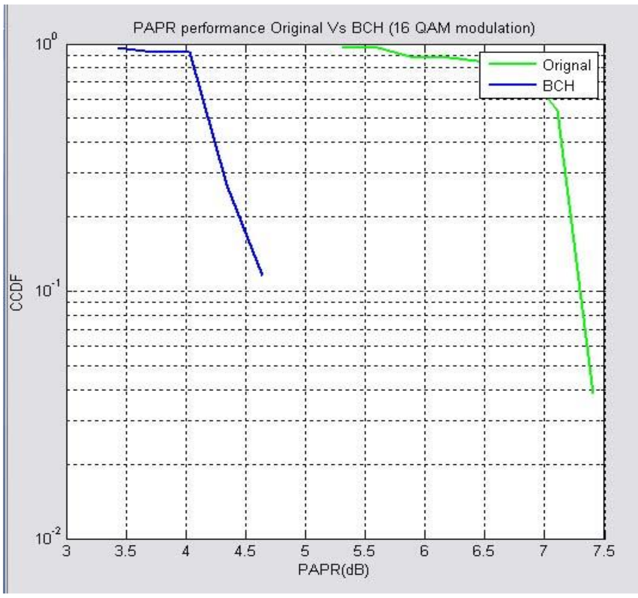

Fig. 5: Plot between original and proposed scheme at 16 QAM sub-band 128

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