International Journal of Electronics Communication and Computer Engineering
Volume 4, Issue 3, ISSN (Online): 2249–071X, ISSN (Print): 2278–4209

PAPR Reduction Techniques in Orthogonal Frequency Division Multiplexing (OFDM): A Review

Ravi Mohan
Email: ravimohan7677@yahoo.co.in

Sumit Sharma
Email: sharma.sumit3@gmail.com

Mohammad Suhel
Email: mohdsuhel41@yahoo.in

***Abstract* – High Peak-to-Average Power Ratio (PAPR) is the one of the major drawback of the Orthogonal Frequency Division Multiplexing (OFDM) transmitted signal. Many techniques have been proposed to mitigate the PAPR problem. Except for the signal distortion techniques such as clipping, peak windowing and companding and so on. The redundancy based PAPR reduction techniques include selective mapping, partial transmit sequence, tone reservation, tone injection and coding, etc information The undesired effects occurring to the distortion techniques can be alleviated with the penalty of the reduced transmission rates due to introduction of redundancy. In a turbo coded orthogonal frequency-division multiplexing (TCOFDM) system, low peak-to-average power ratio (PAPR) can be achieved by selective-mapping (SLM).**

OFDM consist of large number of independent subcarriers, as a result of which the amplitude of such a signal can have high peak values. The .Selected Mapping (SLM) and turbo coding is one of the promising PAPR reduction techniques for OFDM. In a turbo coded orthogonal frequency-division multiplexing (TCOFDM) system, low peak-to-average power ratio (PAPR) can be achieved by selective-mapping (SLM).

***Keywords* – Peak-to-Average Power Ratio, Orthogonal Frequency Division Multiplexing, Selective-Mapping, Turbo Coded Orthogonal Frequency-Division Multiplexing, Interleavers.**

I. INTRODUCTION

Much of the research focuses on the high efficient multicarrier transmission scheme based on "orthogonal frequency" carriers. In 1971 Weinstein and Ebert applied the discrete Fourier transform (DFT) to parallel data transmission systems as part of the modulation and demodulation process. The spectrum of the individual data of the sub channel.The OFDM signal, multiplexed in the individual spectra with a frequency spacing equal to the transmission speed of each subcarrier. The center frequency of each subcarrier, there is no crosstalk from other channels. Therefore, if we use DFT at the receiver and calculate correlation values with the center of frequency of each subcarrier we recover the transmitted data with no crosstalk. In addition, using the DFT-based multicarrier technique, frequency-division multiplex is achieved not by band-pass filtering but by baseband processing. Moreover, to eliminate the banks of subcarrier oscillators and coherent demodulators required by frequency-division multiplex, completely digital implementations could be built around special-purpose hardware performing the fast Fourier transform (FFT), which is an efficient implementation of the DFT. Recent advances in very-large-scale integration (VLSI) technology make high-speed, large-size FFT chips commercially affordable. Using this method, both transmitter and receiver are implemented using efficient FFT techniques that reduce the number of operations from N2 in DFT down to N log N. In the 1980s, OFDM was studied for high-speed modems, digital mobile communications, and high-density recording. One of the systems realized the OFDM techniques for multiplexed QAM using DFT and by using pilot tone, stabilizing carrier and clock frequency control and implementing trellis coding are also implemented. Moreover, various-speed modems were developed for telephone networks.

A well known problem of the orthogonal frequency division multiplexing (OFDM) system is the possible Occurrence of high peak to average power ratio (PAPR). Many techniques have been proposed to mitigate the PAPR problem. Except for the signal distortion techniques such as clipping [2], peak windowing [3] and companding, [4] redundancy is needed to control PAPR. The redundancy based PAPR reduction techniques include selective mapping [9], partial transmit sequence [10], tone reservation [11], tone injection[12] and coding[13],etc information The undesired effects occurring to the distortion techniques can be alleviated with the penalty of the reduced transmission rates due to introduction of redundancy. The basic idea of selective-mapping (SLM) technique is to generate several OFDM symbols as candidates and then select the one with the lowest PAPR for actual transmission. Conventionally, the transmission of side information is needed so that the receiver can use the side information to tell which candidate is selected in the transmission and then recover the information a selective-mapping scheme for turbo coded OFDM which does not need information was proposed, which employs the discriminating characteristic of the interleave of the turbo coded system. Several distinct interleavers are used as candidates for the selection operations in the transmitter. The receiver uses the MAP decoder for the turbo code to calculate the reliability of each candidate. Although side information is not available, the reliability of the decoded results will be high and the receiver can recover the correct codeword in case that the interleaver chosen by the receiver is correct. In case that the interleaver is not the right one, the reliability of the decoded results will be very low and the receiver needs to try another interleaver. The price to pay is the increased decoding complexity. Moreover, there is room for improving the capability of PAPR reduction. The reason is that we note that varying interleavers of turbo encoder will only vary the parity bits of the second component convolutional code of the turbo codes. With this observation, in this thesis, we present two modified side-information-free 4 selective mapping turbo coded OFDM schemes for which all the code bits of a whole turbo codeword may be varied so that the PAPR can be substantially reduced.

II. Reduction Techniques

1. SLM Technique -In selective mapping (SLM) technique the actual transmit signal lowest PAPR is selected from a set of sufficiently different signals which all represents the same information [8-10]. Selective Mapping (SLM) method is used for minimization of peak to average transmits power of multicarrier transmission system with selected mapping. In selective mapping (SLM) technique the signal having lowest PAPR is selected from a set of sufficiently different signals which all represents the same information [15]. Block diagram of SLM Technique is shown in figure 2.

Let the input data stream as a vector Each data block is multiplied by U different phase sequences, each of length N, , u = 1, 2,…., U, resulting in *U* modified data blocks. To include the unmodified data block in the set of modified data blocks.

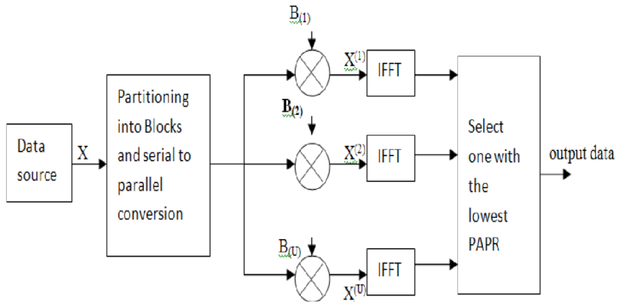

Fig.1. Block Diagram of OFDM transmitter with the SLM Technique

The SLM algorithm can be described in following steps:

- Multiply the input data signal with U different phase sequences.
- Generate the OFDM signal for each signal (U signals).
- Select the OFDM signal with lowest PAPR.

The receiver has to know which sequence was used to generate the signal, so that it can recover the original data, and the used sequence can be transmitted as side information.

2. Modified SLM Technique Using Linear Block Codes

When the error control coding and OFDM modulation process work together such system is called COFDM. In a COFDM system to add redundancy and code the bits prior to IFFT. The purpose of this step of taking adjacent bits in the source data and spreading them out across multiple subcarriers. One or more subcarriers may be lost or impaired due to a frequency null and this loss would cause a continuous stream of bit error. Such a error is a burst of errors would typically be hard to correct. The main purpose of the modified SLM techniques to reduce PAPR and IFFT block. There is only one IFFT block at transmitter if the sequence which is the lowest PAPR can be find out by a decision algorithm before IFFT.[6]

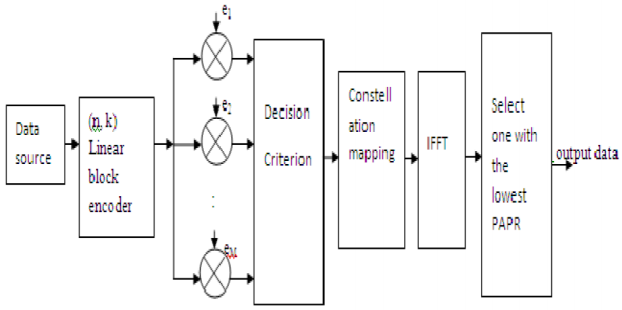

Fig.2. Block Diagram of Modified SLM Technique

2.1 Algorithm for modified SLM Technique

Step 1: A binary information source is divided into blocks of 4 bits.

Step 2: Each information block is encoded into a codeword c by a [7, 4] hamming encoder.

Step 3: A control bit added to codeword c to create an extended hamming code of 8 bits.

Step 4: Calculate the error table and coset leader, 16 in number

Step 5: Sixteen vectors are constructed as c+e1, c+e2, c+ e3...........etc

Step 6: For each scrambled codeword calculate the value of Z = U 2 + V 2 +W 2

Step 7: Scrambled codeword with the minimum Z is selected and then Transformed to OFDM signal by constellation mapping and IFFT

2.2 Linear Block Codes

Consider an [n, k] Linear code C with parity-check matrix H, where n is the length and k is the dimension of C. Since Hct=0 for any codeword c ∈ C, any vector X ∈e+c has the same syndrome as e, that is [2]*Hxt= H*(*e + c*)*t* = *Het* (5)A binary information sequence is divided into blocks of 4 bits. Each message block is encoded into a codeword C which is 7 bits by a [7, 4] hamming encoder. Hamming codes were designed for correction [11]. The parameters for the family of binary hamming codes are typically expressed as a function of a single integer m≥2 (for m=3, we have a (7, 4) Hamming code) not necessarily prime, it is any positive integer. A hamming code on GF(2)has code length n=2m-1, message length k=2m-1-m, redundancy n-k=m and error connecting capability t=1bit.

2.3 Hamming Codes

Hamming codes are only single error correcting. To improve the error detection and connection capability by adding parity check digit. The resulting code is called the extended binary hamming code. Suppose that c is a code over the alphabet {0,1}. Let c. be the code obtain by adding a single character to the end of each word in c in such a way that every word in c. has even weight.

According to the formula S= eH. T, the syndromes which are corresponding to the non-error and one error patterns could be obtained. And other seven two errors patterns could be obtained from the other syndromes. So the standard array of c. is constructed. The standard array an [n, k] binary linear code C is a M×N array and for extended array an [8, 4] for binary linear code c. is also M×N array where M=2m-K, N=2K.

At last sixteen vectors are constructed as c. +e1 , c. +e2 ,.... c.+ e16 , where e1 =0 and e1, e2 ,----- e16 are properly selected as the coset leaders of the standard array in terms of their PAPR. Then the Decision criterion is used to calculate the value of Z. Finally, the scrambled codeword with the minimum Z is selected and then transformed to an OFDM signal by constellation mapping and IFFT.

Table 1: Standard array of an [n, k] linear block code

Zero Codeword	$e_1 = c_1$	c_2	……	c_N	
	e_2	c_2+e_2	……	c_N+e_2	
coset leader	e_3	c_2+e_3	……	c_N+e_3	coset
	.	.	.	.	
	.	.	.	.	
	.	.	.	.	
	e_M	c_2+e_M	……	c_N+e_M	

In this array there are M rows and each row is a coset c denotes the codeword and e denotes the error in transmission. This criterion is used for each codeword to calculate the value. Finally the codeword with the minimum value is selected and then transformed to an OFDM signal by constellation mapping and IFFT. At the receiver, the received signal is converted into r by FFT and constellation de-mapping. The syndrome calculated from r is used for estimating the coset leader e chosen at the transmitter. The codeword c is obtained by calculating c= e+r and then is converted into a message sequence of k bits.

3. PTS Technique

The PTS technique is a powerful PAPR reduction technique. The block diagram of the PTS scheme is shown in figure 1. In the PTS scheme, the input data X is partitioned into M disjoint sub-blocks. The sub-carriers in each sub-block are weighted by a phase factor for that sub-block. The phase factors are selected such that the PAPR of the combined signal is minimized. The input data X divided into M disjoint sub-blocks. All the sub-carriers position which are presented in other sub-blocks must be zero so that the sum of all the sub-blocks constitutes the original signal.

There are three sub-block partition techniques, namely adjacent partition, interleaved partition, and random partition. The random partition technique is the best choice for PAPR reduction, whereas the interleaved partition has the worst PAPR reduction performance.

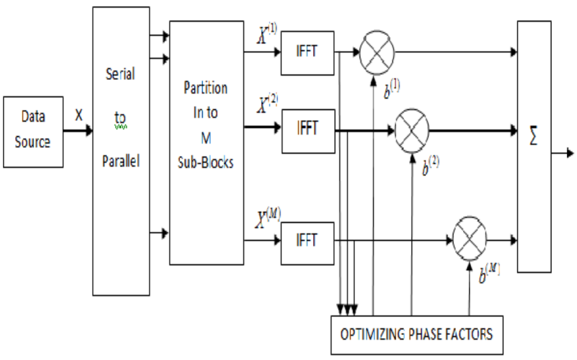

Fig.3. The block diagram of PTS scheme

The PTS algorithm can be described in following steps:

- Divide the OFDM sub-carriers into M disjoint sub-blocks.
- Generate the OFDM signal for each sub-block by taking IFFT of each sub-block.
- Combine the M output OFDM signals with weighting factors bi.
- The weighting factors are generated with some optimization algorithm.

The phase factors must then be transmitted as side information, resulting in some loss of efficiency. The receiver has to know the generation scheme in order to recover the data.

III. Conclusion

OFDM is a very attractive technique for multicarrier transmission and has become one of the standard choices for high speed data transmission over a communication channel. It has various advantages; but also has one major drawback: it has a very high PAPR. In this project, the different properties of an OFDM System are analyzed and the advantages and disadvantages of this system are understood. Results of simulation of modified SLM technique show that the PAPR reduction of OFDM system, which further results in high performance of wireless communication. With the rising demand for efficient frequency spectrum utilization, OFDM proves invaluable to next generation communication system.

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International Journal of Electronics Communication and Computer Engineering
Volume 4, Issue 3, ISSN (Online): 2249–071X, ISSN (Print): 2278–4209

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AUTHOR'S PROFILE

Ravimohan
has completed his B.E. in Electronics & Telecommunication Engineering form GEC Jabalpur and received his Master's degree in Communication System from GEC Jabalpur. Currently he is pursuing PHD and working as H.O.D. in PG courses at Shri Ram Institute of Technology Jabalpur M.P.

Sumit Sharma
has received B.E. in Electronics & Telecommunication Engineering and M.Tech in image processing and is currently working as H.O.D. in EC dept. at Shri Ram Institute of Technology, Jabalpur M.P.

Mohammad Suhel
has completed B.E. in 2010 from Guru Ramdas khalsa Institute of Sciencee and Technology, Jabalpur and at present he is pursuing M.E. in Digital Communication from Shri Ram Institute of Technology , Jabalpur M.P.