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OFDM PAPR Reduction by Shifting Two Null Subcarriers among Two Data Subcarriers

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Abstract: *Orthogonal frequency division multiplexing (OFDM) is an attractive modulation technique for transmitting large amount of digital data over radio waves. High PAPR of the transmit signal is major drawback of OFDM. Proposed method promises PAPR reduction by shifting and switching null subcarrier with data subcarrier. When it is compared with existing reduction techniques (Such as Shifting Null Subcarrier among Data Subcarrier, Interleaving Technique, PTS, SLM, Tone rejection etc), the proposed method is compatible with current commercial system. The MATLAB simulations show a PAPR reduction of around 1.4dB using the proposed method than the existing methods also BER performance of proposed method is much better than that of existing methods.*

Keywords: *Orthogonal frequency division multiplexing, peak-to-average power ratio, intersymbol interference, null subcarriers.*

I. Introduction

Orthogonal frequency division multiplexing (OFDM) is a special case of multi carrier transmission, where a single data stream is transmitted over a number of lower rate subcarriers [8][9]. In single carrier system, if signal gets faded or interfered, then entire link gets failed, where as in a multicarrier system, only a small percentage of the subcarriers will be affected. It is very easy and efficient in dealing with multipath fading and robust again narrow band interference [14]. It has been widely adopted in many international standards; out of these standards we used IEEE 802.11a for proposed method.

High PAPR is one of the most serious problems in OFDM system [8][9]. To transmit signals with high PAPR, it requires power amplifiers with very high power scope. These kinds of amplifiers are very expensive and have low efficiency-cost factor. This gives rise to non-linear distortion which changes the superposition of the signal spectrum [3] resulting in performance degradation.

The PAPR issue and its drawbacks are discussed in many papers. Such as PAPR reduction in OFDM by shifting null and data subcarriers is suggested as, “OFDM PAPR Reduction by Shifting Null Subcarriers Among Data Subcarriers,” by Bo Wang, Pin-Han Ho, and Chih-Hao Lin [1]. “PAPR Reduction of OFDM Signals Using Partial Transmit Sequence: An Optimal Approach Using Sphere Decoding,” by Ali Alavi and Chintha Tellambura [2]. “Peak-to-Average power ratio Reduction using OFDM Null subcarriers,” by Wang,Bo[10]. “Dynamic null-data subcarrier switching for OFDM PAPR reduction with low computational overhead,” by S. Ahmed and M. Kawai[11]. “An overview: peak-to-average power ratio reduction techniques for OFDM signals,” by T. Jiang and Y. Wu [7] et.al which explain the new PAPR reduction techniques, which reduces the PAPR of OFDM system with many other advantages.

In classical parallel data system, the total signal frequency band is divided in to non overlapping frequency subchannels. Each subchannel is modulated with separate symbol and then these subchannels are frequency multiplexed. It results it avoids spectral overlap to eliminate Interchannel Interference (ICI) [9]. However it leads inefficient use of available spectrum. Orthogonal word indicates that there is a precise mathematical relationship between frequencies of the carrier system. These orthogonal signals follows: Each subcarrier has exactly an integer number of cycles in FFT interval and number of cycles between adjacent subcarriers differs by exactly one. For integer number of cycles, all smoothing windows yields the same peak amplitude reading and have excellent amplitude accuracy side lobes do not appear because spectrum of the smoothing window approaches zero at Δf intervals (distance between subcarriers in frequency domain) on either side of the main lobe. At transmitter IFFT acts as specialized multiplexer also it takes complex numbers representing the modulated subcarriers.

PAPR reduction techniques classified on Distortion based technique in which the time domain signals are directly suppressed for which the power signal exceeds a certain threshold level. (e.g. Clipping Technique, PTS etc.) [2]. and Redundancy based technique in which number of candidate signals are generated and then selects the one candidate signal which will have lowest PAPR for transmission (e.g. Null Switching Method, SLM, etc.)[1][10]. In proposed method, null subcarrier which is used as guard band to avoid aliasing effect also it is known as unused carriers with zero transmit energy. In IEEE 802.11a, 6 null subcarriers at low frequency end and 5 null subcarriers at high frequency end [12].

II. Proposed Method

Consider OFDM transmission splits the high rate data stream into S sub streams of the lower data rate i.e. parallel system divide the available bandwidth into S non overlapping subchannels with ascending frequencies set $\{f_s, s = 1, 2,..., S\}$. the total S subcarriers are the combination of data subcarriers(D) and null subcarriers(N), where for N ascending frequency set $\{f_n, n=1,2,..., N\}$ and for D ascending frequency set $\{f_d, d = 1, 2, \ldots, S - N\}$.
Moreover, $f_n \neq f_d$, $\forall n,d$. Assigned to the data subcarriers at $\{f_d, 1 \leq d \leq S - N\}$ are, respectively, the M-ary data symbols $\{.x_d, d = 1, \cdots, L - N\}$, taken from a quadrature amplitude modulation (QAM) constellation.

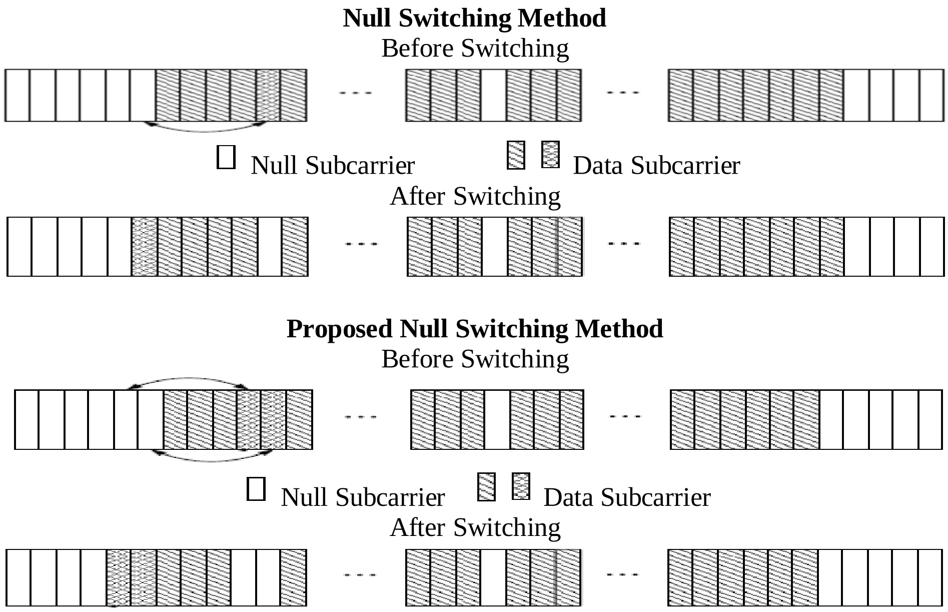

Fig. 1. Comparison between Null Switching method[1] and Proposed Null Switching method

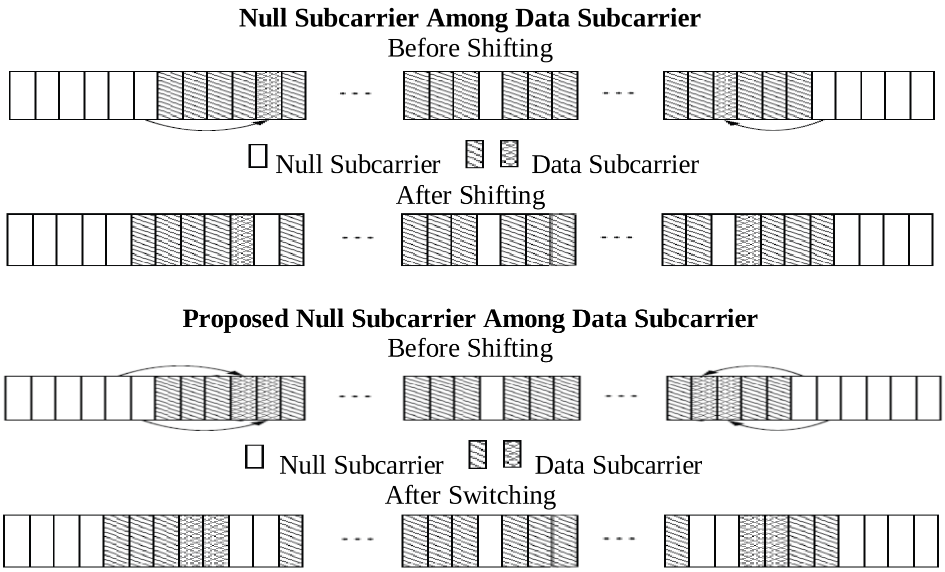

Fig. 2. Shifting Null Subcarrier Among Data Subcarrier[1] and Proposed Shifting Null Subcarrier Among Data Subcarrier

From Fig. 1 and 2, without changing the values of total subcarrier, data subcarrier and null subcarrier, we need to shifts P elements to generate number of candidates and then selects one candidate which will have lowest PAPR for transmission. For finding shifting possibilities we can derive using

$$ {}^{S-N}{}_{P} = \frac{(S-N)!}{P!(S-N-P)!} \qquad (1) $$

The designing of null subcarrier in standard is at low frequency end is one more than that at high frequency end when shifting element is even and vice versa. Proposed method requires low CSI, for maintaining the synchronization between transmitter and receiver which helps to recover data subcarrier as in its original form i.e. sequencing back to original format which were changed due to various shifting to get one of the candidate which having lowest PAPR. Here two proposed methods are derived from existing reduction techniques which shown in figure.

III. Simulations

The standard IEEE 802.11a ensures appropriate candidate which has minimum PAPR after shifting of null subcarrier. An 802.11a OFDM carrier signal (burst type) is the sum of one or more OFDM symbols each comprised of 52 orthogonal subcarriers with baseband data on each subcarrier being independently modulated using Quadrature amplitude modulation (QAM). This composite baseband signal is used to modulate a main RF carrier.

To begin the OFDM signal creation process, the input bit stream is encoded with convolution coding and interleaving. Each data stream is divided into group of 4 bits because here we are using 16-QAM and then converts into complex numbers $(I + JQ)$ representing the mapped constellation point. 52 bins of the IFFT block are loaded. Out of these 48 bins contains constellation points which are mapped into frequency offset indexes ranging from -26 to +26, skipping the 4 pilot and zero bins. There are 4 pilot subcarrier inserted into frequency offset index location -21,-7, +7 and +21. The zero bin is the Null or DC subcarrier (contains 0 value i.e. 0+0j) and is not used. When the IFFT block is completely loaded, the IFFT computed, giving a set of complex time domain samples representing the combined OFDM subcarrier waveform. In between each OFDM symbols preamble is used for synchronization and concatenated together, in this way OFDM burst is transmitted.

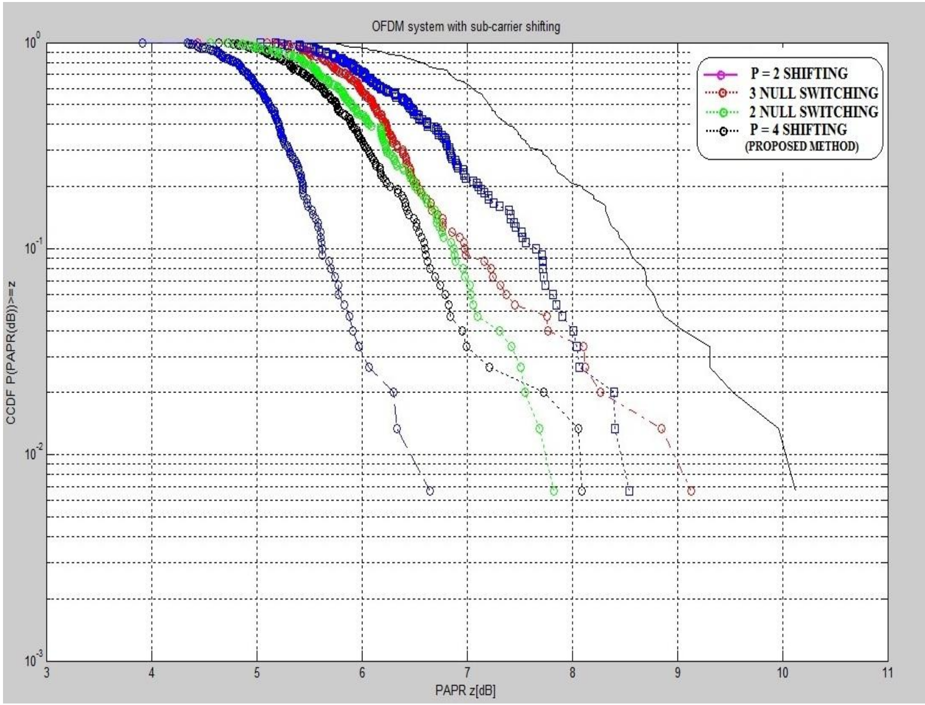

Fig. 3. The PAPR's CCDF @ $p = 2$[1], Switching by 3 & 2 Null subcarrier, Null switching and $p = 4$.

Fig. 3 shows the PAPR values of various reduction techniques, here proposed null switching method i.e. 2-null switching (≈ 7.8dB) is better than Null switching method i.e. 1-null switching (≈ 8.5dB) based on same computational complexity also graph shows proposed shifting null subcarrier among data subcarrier method i.e. $p = 4$ (≈ 6.7dB) is better than shifting null subcarrier among data subcarrier method i.e. $p = 2$ (≈ 9.2dB) [1]. Comparing all methods, Shifting Null Subcarrier among Data Subcarrier Method is better than other methods. Figure 4 shows that the BER performance of proposed null subcarrier among data subcarrier method (≈ 14.8dB) is close to that of Shifting at $p = 2$ (≈15.3dB) [1]. But when comparing both with proposed null switching i.e. 2-null switching (>15.3dB) is not better one. As we have seen in Fig. 3 PAPR performance of proposed Null switching method i.e. 2-null switching is better than Null switching method i.e. 1-null switching and shifting null subcarrier among data subcarrier method i.e. $p = 2$ [1]. But in case of BER performance is not good as shown in Fig. 4.

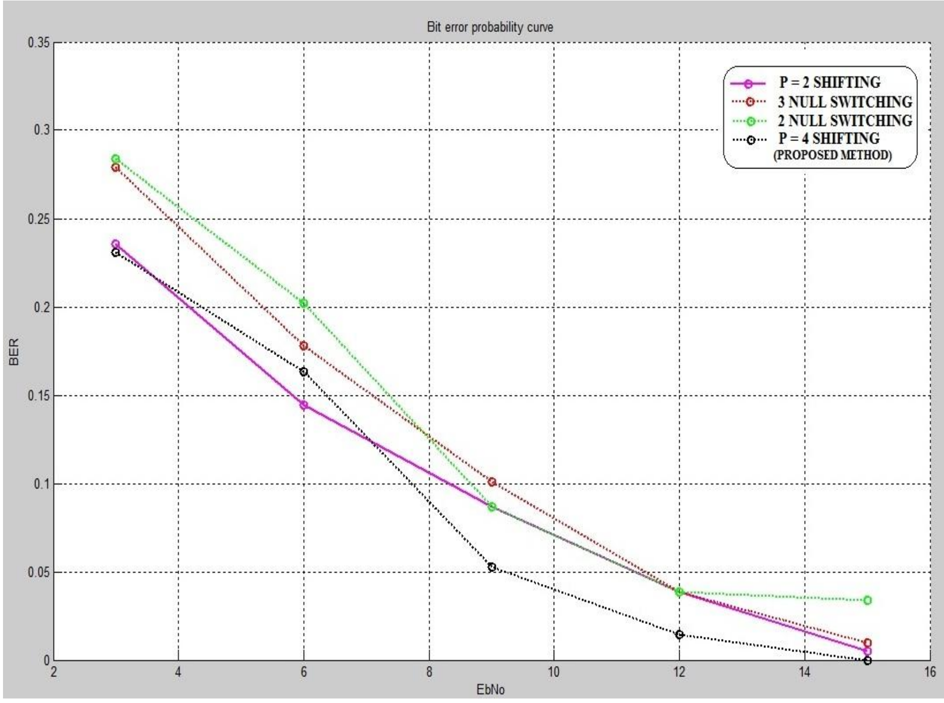

Fig. 4. BER against SNR at $\gamma = 3dB$ with $p = 2$[1], Switching by 3 & 2 Null subcarrier and $p = 4$.

IV. Conclusion

The simulation results have demonstrated the effectiveness of the approach for a 16 QAM modulation scheme and had been evaluated in terms of BER versus SNR. The results clearly show the effectiveness of our proposed algorithm, as well as ability to achieve large reduction in PAPR by keeping constant performance of BER.

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