A NEW HYBRID PRE-CODING BASED INTERLEAVED ORTHOGONAL FREQUENCY DIVISION MULTIPLE ACCESS (IOFDMA) SYSTEM FOR VEHICULAR AD-HOC NETWORK

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ABSTRACT*—The OFDMA has been used by researchers as a modulation technique, for next generation networks, due to its robust against inter symbol, inter carrier interferences. Moreover, it also provides best quality of service for multiple users, efficient usage of bandwidth. However, a high peak to average power ratio and Bit Error Rate (BER) are some of its disadvantages, using the downlink of 4G networks. Therefore, a new hybrid pre-coding based interleaved OFDMA model, combined with SLM technique, has been proposed. The proposed model has shown better PAPR performance, as compared to the previous proposed pre-coding based IOFDMA, and conventional IOFDMA system models. Moreover, improved BER performance is shown, as compared to that of conventional IOFDMA systems. The derived DST matrix has shown lower complexity, as compared to previous proposed WHT matrix. The proposed model is bandwidth efficient, and minimizes the PAPR without using any error control codes, and causes extra transmission of code information. The proposed technique does not require any complex optimizations, power increase, and side information, and demonstrated efficient BER performance gain in multipath fading channels.*

IndexTerms—*PAPR, BER, SLM, WHT, DFT, DS*

I. INTRODUCTION

The Vehicular Ad-Hoc Network (VANET) gained more popularity, due to potential of road safety and traffic coordination[1]. To reduce the number of road accident, the VANET is considered an emerging technology, which provides abundant applications, such as travel information, maps, road guidance, and internet provision on the road, during traveling. The IEEE 802.11p standardized Vehicular Network (VENET), which also named Wireless Access in Vehicular Environment (WAVE)[2], gained more attention due to its advantages in transportation[3]. The WAVE Physical (PHY) layer amended IEEE 802.11a, to construct IEEE 802.11p PHY layer. To reduce the multipath fading, the VANET uses10 MHz channel bandwidth for physical layer, and Orthogonal Frequency Division Multiplexing (OFDM) is used as a modulation technique[4]. Using OFDM, the entire bandwidth is divided into N sub-channels or subcarriers. The subcarriers are transmitted parallel, to achieve high data rates, increase symbol duration and reduce Inter Symbol Interference (ISI)[5]. The OFDMA gives 18 dB gain in the upstream link budget and 12dB gain in the downstream link budget. The FFT size is much higher and it also divides the whole N subcarrier into sub channels (small group of subcarriers). Each sub channel is used for specific user. The OFDMA support different modulation techniques for different sub channel and each sub channel uses different transmitting energy. The main advantage of OFDMA is that one can allocate all available sub channels for a transmission burst. Moreover, the OFDMA based systems are pretty good for broadcast applications[6]. The OFDM and OFDMA are almost same, despite the subcarrier mapping. Three different techniques are used for subcarrier mapping in OFDMA based systems. These are Localized, Random and Random Interleaved subcarrier mapping systems. In Localized Subcarrier Mapping, the subcarriers are mapped with adjacent subcarriers and the sub channel group is used for one user. In Random Subcarrier Mapping, the subcarriers are mapped with equal distance, which forms a sub channel group for a specific user. In Random Interleaved Subcarrier mapping scheme, the subcarriers are mapped through a random process with some permutations. The permutation techniques are mathematically described at the transmitter, and the receiver is synchronized to do the same permutation on the received data block[7, 8].

The OFDMA based system is affected due to high correlation before Inverse Fast Fourier Transform (IFFT) block, in terms of degradation in PAPR and BER performance. A number of techniques have been proposed, to reduce correlation between OFDMA sub-carriers. Some of them are conventional, coding, and pre-coding techniques[8]. The SLM technique from conventional got more popularity, as this techniques does not impose additional power[9]. The Pre-coding based techniques got more popularity, as the complexity of the overall all system does not increase to the threshold value[9].

A number of pre-coding techniques have been proposed in the literature, to reduce the auto-correlation between sub-carriers. Some of these techniques are Walsh Hadamard Transform (WHT), Discrete Hartley Transform, Zadoff-Cho Transform, Discrete Cosine Transform, and Discrete Fourier Transform[10, 11]. The proposed techniques have their own advantages and disadvantages, in different environment. For a technique to be acceptable, it must reduce the PAPR as well as BER. Moreover, some performance factors i.e. average power, complexity of the overall system, bandwidth expansion, spectral efficiency, and additional power, must be measured in a valid region. The pre-coding based techniques have less complexity, required no extra power, and no need of extra bandwidth.

The pre-coding techniques have been categorized into two sections. One of them is used to improve the BER performance. For example, the COFDM systems have been used, to improve the diversity gain of the OFDM signal[12].

Moreover, the COFM systems also reduce the system complexity, at the expense of large decoding delay. However, these types of systems need Channel state Information (CSI) at the transmitter, which cause the loss in performance[13]. The second types of techniques have been used, to improve PAPR performance. These techniques use WHT, DHT, DCT, ZCT and DST, to reduce high PAPR[14]. This results in improved BER performance, in terms of BER reduction. In addition, these techniques use the pre-coding of the constellation symbols, with a linear channel independent pre-coder, which results in reduction of autocorrelation between OFDM symbols before IFFT operation, and spreads the information to all subcarriers. In case of multipath fading channel, these techniques take the advantage of the frequency variation in the channel, and reduce the BER. Due to the fix size of pre-coder, these techniques do not impose any complex optimization or power increase. A hybrid technique used for PAPR reduction has been also proposed in[10].

If there is some similarity in the input data of IFFT block of the OFDMA based system, then the autocorrelation issue arises, which causes the PAPR and BER performance degradations. The correlated data subcarriers are arranged in in-phase form, and passed through the IFFT block[15]. In the IFFT operation, the high correlated data blocks are multiplied, summed it up, and sampled. Since the high correlated input sequences (arranged in-phase) are added in-phase during IFFT[15]. This in-phase addition of input sequences causes high PAPR[16].

For discrete IFFT input sequence, the autocorrelation X_k can be given as[9]:

$$P_k = \sum_{n=1}^{N-K} X_{n+k} X_n^* \quad k=0,\ldots,N-1 \tag{1}$$

The maximum α of PAPR is shown as:

$$\alpha \le 1 + \frac{2}{N} \sum_{k=0}^{N-1} |P_k| \tag{2}$$

If the sub carriers are added in phase, this causes N times high peak power than average power. The PAPR is calculated through the following formula:

$$PAPR = \frac{\max(x^2(t))}{\text{mean}(x^2(t))} \tag{3}$$

Where $x(t)$ denotes the amplitude of the signal. The high peak signals are transmitted through High power Amplifier (HPA). The high peak of OFDM signal causes HPA to operate in the saturation region, which distort the linearity of HPA. The non-linearity of HPA also distorts the orthogonality of sub carriers, causes out of band distortion, in band radiation, and high BER probability. Due to high PAPR, the peaks saturate the HPA, and operate it on the nonlinear region. The HPA clips the high peaks above the saturation region. The high peaks consist of some data information which lost, and causes BER performance degradation. Moreover, this also causes the orthogonality issue, at the receiver side.

In this research work, a hybrid Discrete Sine Transform (DST) pre-coding based interleaved OFDMA system combined with SLM technique is proposed, to improve the PAPR & BER performance. The proposed system results are compared with WHT-IOFDMA, and Conventional SLM-IOFDMA systems. It is demonstrated from results that the proposed DST-SLM-IOFDMA technique showed good performance, as compared to the previous proposed techniques.

II. THE PRPOPOSED HYBRID IOFMA MODEL

The proposed hybrid DST-SLM-IOFDMA model is shown in the figure 1. The SLM are modified for OFDMA, to reduce the high PAPR with less complexity. Some of the subcarriers are dedicated for side information transmission, at the transmitting side.

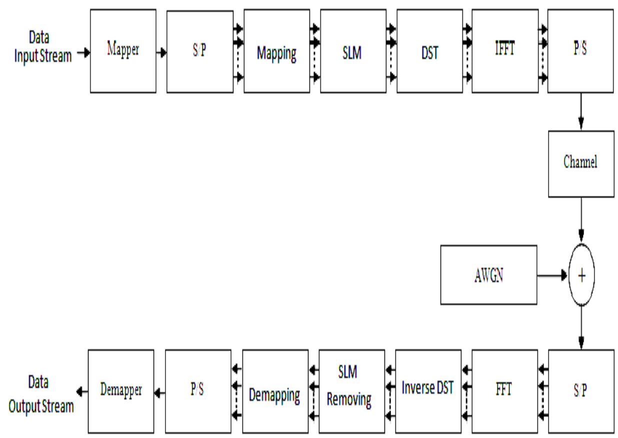

Fig. 1. The Proposed hybrid IOFDMA Model

These subcarriers transmit all user information including phase sequence of each user, to the receiver. The receiver takes knowledge of subcarriers usage, for each user and assigns specific subcarriers to specific user, according to the information. In the proposed hybrid IOFDMA model, the SLM technique is applied on X data blocks with phase factors V. Moreover, the DST pre-coder is applied on the produced sequences.

For the SLM based DST pre-coding system, if we have X subcarriers data after serial to parallel conversion, then X can be shown as:

$$X = [X_0, X_1, X_{2\ldots} X_{L-1}]^T \tag{4}$$

Each data block is multiplied with V dissimilar phase factors, each of length equal to L, and then we have,

$$B^{(v)} = [b_{v,0}, b_{v,1}, \ldots, b_{v,L-1}]^T (v= 1,\ 2\ldots V), \tag{5}$$

The eq. (5) results in V altered data blocks. Therefore, the v^{th} phase sequence is shown by eq. (6) as:

$$X^{(v)} = [\, X_0 b_{v,0}, X_1 b_{v,1}, \ldots, X_{L-1} b_{v,L-1}]^T,\ v=1,\ 2,\ 3\ldots\ V. \tag{6}$$

Each X_l^v can be defined as:-

$$X_l^v = X_l b_{v,l} \tag{7}$$

Where l=0,1,…..L-1, and v=1,2,3,….,V

After the SLM phase rotation multiplication process, the signal is passed from a DST-pre-coder block. If the DST pre-coded matrix A of size $N = L \times L$ is multiplied with complex input signal vector X of size N, then it results a new matrix Y of size S, as shown by eq. (8):

$$Y = A.X = [y_0, y_1, \dots, y_{S-1}]^{T} \quad (8)$$

And,

$$Y_i = \sum_{n=0}^{N-1} A_{i,n} X_n;\ wher\ i = 1,2,\dots,S-1 \quad (9)$$

Where $m = 0,1, \dots N-1$, and $A_{i,n}$ denotes the i^{th} row and n^{th} column of the Pre-coding matrix. The PAPR of signals for this system can be calculated as:

$$PAPR=\frac{\max[|x_n^{(v)}|^2]}{E[|x_n^{(v)}|^2]} \quad (10)$$

The *E* [.] denotes expectation.

III. SIMULATION RESULTS AND DISCUSSION

The simulations have been performed, using 10^5 random data blocks. The 10^5 random blocks are affectively used, as the lowermost probability measured is 10^{-3}. The MATLAB simulator has been used for performance evaluation of the proposed system. The PAPR is evaluated statistically by using Complementary Cumulative Distribution Function (CCDF). The CCDF of PAPR for DST Pre-Coded I-OFDMA signal, measures the probability that the signal exceeds a given threshold $\mathrm{PAPR}_0 (\mathrm{CCDF} = \mathrm{Prob}\,(\mathrm{PAPR} > \mathrm{PAPR}_0))$. For the PAPR analysis, the simulation parameters are based on IEEE 802.11p VANET, and are described in table 1.

Table 1: Simulation parameter for PAPR

Channel Bandwidth	10 MHz
Oversampling Factor	4
Modulation	16-QAM and 64-QAM
Pre-Coder Type	DST
Sub-carrier Mapping	Interleaved
Pre-Coder Size	512
SLM Phase Factors	4 and 8
System Sub-Carriers (IFFT Size)	512
CCDF Clip-Rate	10^{-3}

The simulation parameters, to find BER of the proposed model are shown in table 2. Moreover, to evaluate the BER performance for DST-Pre-Coded-IOFDMA based system, the computer simulation has been carried in MATLAB, using ITU vehicular A channel. The ITU vehicular A channel, corresponds to multipath fading channel with 6 taps, severe frequency selectivity in frequency domain, and longer delay as well.

Table 2: Simulation Parameters for BER

Channel Bandwidth	10 MHz
Modulation	QPSK
Sub-carrier Mapping	Interleaved
Pre-Coder Type	DST
Pre-Coder Size	512
Sub-Carriers	512
SLM Phase Factors	4 and 8
Equalization	MMSE
Channel	ITU Vehicular A Channel
Number of Iteration	$> 10^4$

The behavior of the autocorrelation function on the randomly generated QAM-16 sequence, normalized by length, is shown in figure 2. It is shown from the figure 2 that both autocorrelation functions have different side lobe levels. The side lobe value of the DST-pre-coded-IOFDMA output is uniformly much smaller, as compared to the conventional IOFDMA sequence. The data with better autocorrelation function approximates to an impulse and produce a constant output signal after IFFT. The figure 2 indicates that pre-coding is superior, to improve the autocorrelation shape of the data, and demonstrates that column-wise DST pre-coding recovers the autocorrelation of the data. Hence, this results to improve the PAPR performance over the previous proposed models.

The figures 3, 4, 5 and 6 showed the CCDF comparison of PAPR, for the proposed IOFDMA model with WHT-pre-coding-SLM-IOFDMA[10], WHT-pre-coding-IOFDMA [9], SLM-IOFDMA[17], and the conventional IOFDMA model, respectively. The figures 3 and 4 indicated PAPR comparison for modulation QAM-16 as well as 4 tap V and QAM-16 as well as 8 tap V, respectively. The horizontal axis demonstrated the threshold for the PAPR in decibel and the vertical axis showed probability of the PAPR. It is demonstrated from figures 3 and 4 that the proposed hybrid model showed significant improvement in PAPR, as compared to the previous proposed models.

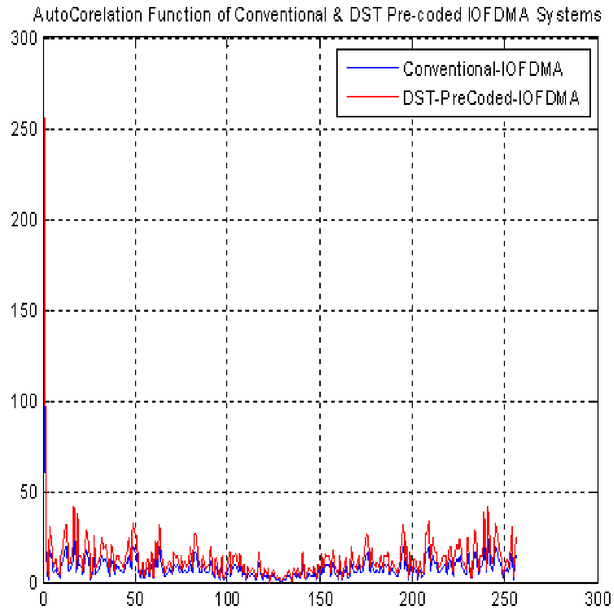

Fig. 2 Normalized Autocorrelation Function

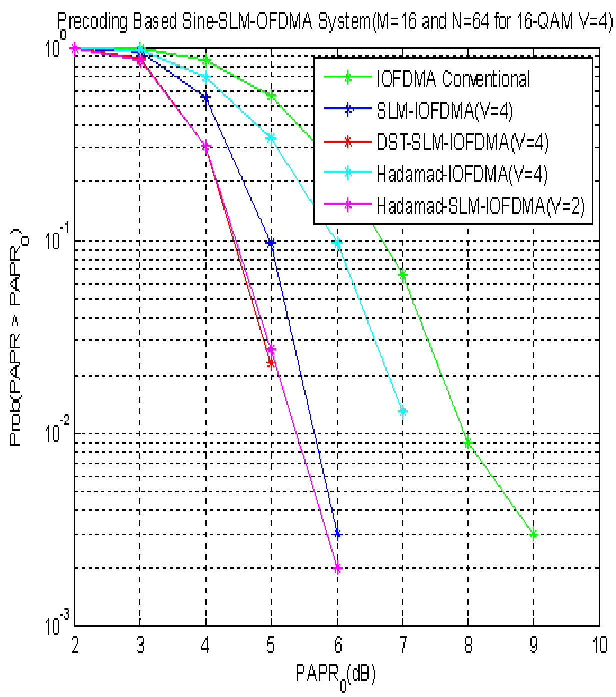

Fig. 3. CCDF of PAPR for QAM-16, V=4

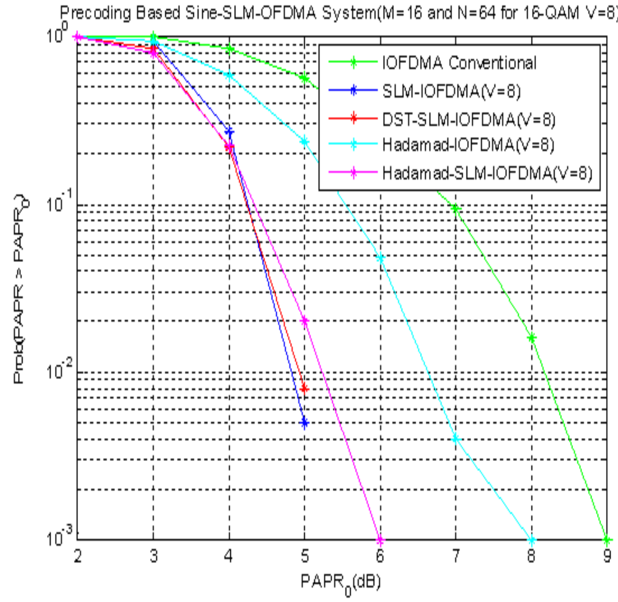

Fig. 4. CCDF of PAPR for QAM-16, V=8

The figures 5 and 6 indicated PAPR comparison for modulation QAM-64 as well as 4 tap V and QAM-64 as well as 8 tap V, respectively. The proposed model indicated improvement, in terms of low PAPR, over the previous proposed models.

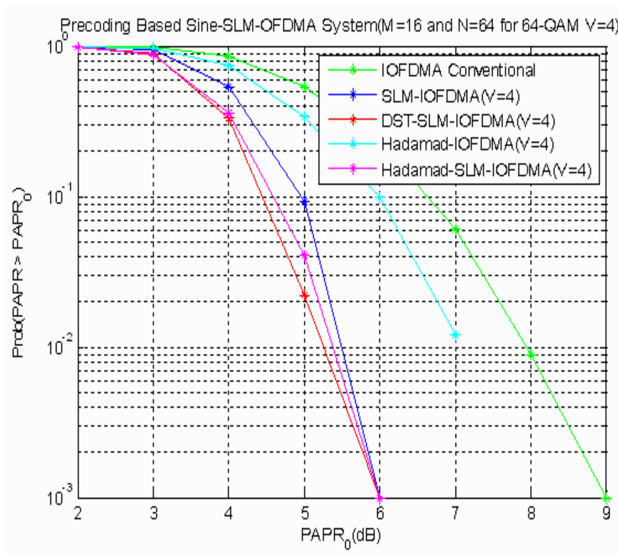

Fig. 5. CCDF of PAPR for QAM-64, V=4

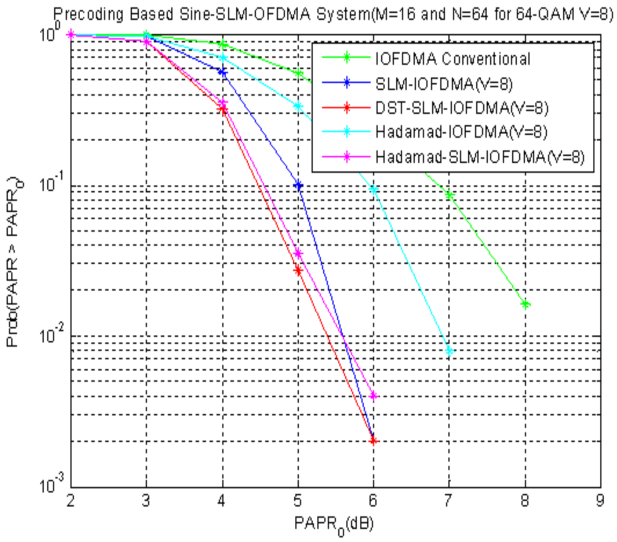

Fig. 6. The PAPR for QAM-64, V=8

The BER performance comparison of DST-pre-coded-IOFDMA system, with the WHT-pre-coded-IOFDMA system, and the conventional IOFDMA system, is shown in figure 7. The QAM-16 modulation scheme is used. In order to obtain BER, the SNR of 14dB, 14.5dB and 22.8dB are taken for DST pre-coded based IOFDMA, WHT pre-coded IOFDMA and conventional IOFDMA systems, respectively. It is expressed from results shown in figure 7, that DST pre-coding based IOFDMA system demonstrated improved BER gain, as compare to WHT pre-coded IOFDMA and conventional IOFDMA systems.

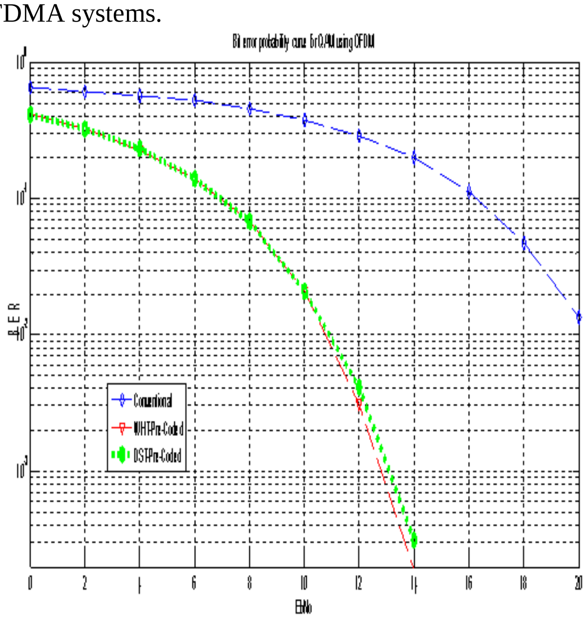

Fig. 7. BER Performance curve

IV. CONCLUSIONS AND FUTURE WORK

In this paper, a new Pre-Coding based IOFDMA system has been proposed for VANET. It has been shown from results that the proposed DST pre-coding IOFDMA system has better PAPR performance, as compared to the previous proposed WHT pre-coding based IOFDMA, and conventional IOFDMA systems. Moreover, improved BER performance is shown, as compared to conventional IOFDMA systems. It was also shown that the proposed DST matrix has lower complexity, as compared to WHT matrix, and results in reduced cost and complexity of the transmitter. Moreover, the proposed model does not need any side information between the transmitter and the receiver. The proposed model is bandwidth efficient as well, because it minimizes the PAPR without using any error control codes and causes extra transmission of code information. The proposed technique does not require any complex optimizations, power increase, and side information, and offer substantial BER performance gain in multipath fading channels.

This proposed work can be implemented, using the hardware, in future. The DST matrix derived could be more efficient as FFT. The proposed work can easily be applied to LTE, LTE advance, MIMO, and different wireless sensor networks for uplink communication.

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