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A Peak Windowing-Selective Mapping Approach for PAPR Reduction in OFDM Systems

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ABSTRACT: One of the major concerns which the existing IoT and cellular systems face is the limited channel bandwidth needing to accommodate increasing number of users with higher spectral demands. Thus the choice of multiplexing techniques becomes extremely important as it critically decides the amount of spectrum available to each user and the total number of users which can be accommodated in the limited bandwidth space. This paper presents a selective mapping based approach along with the detection of residual peaks to get extremely low peak to average power ratio values for the OFDM transmission scheme. The CCDF of the PAPR values is chosen as the value to be considered for system performance. It has been shown that the proposed scheme attains lesser PAPR values compared to existing baseline techniques.

Keywords: Internet of Things (IoT), Orthogonal Frequency Division Multiplexing (OFDM), Peak to Average Power Ratio (PAPR), Selective Mapping, Residual Peak, Complementary Cumulative Distribution Function (CCDF).

I. INTRODUCTION

With interconnected devices, the scale of networks has grown rapidly. The number of smart devices being connected in a network has kept increasing making the demand for bandwidth grow, yet the net bandwidth available for the networks remains to the limited [1]. Moreover, as larger bandwidth is needed for the transmission of multimedia applications, the scarcity for bandwidth remains to be harrowing problem. The conceptualization of the IoT paradigm is depicted in figure 1.

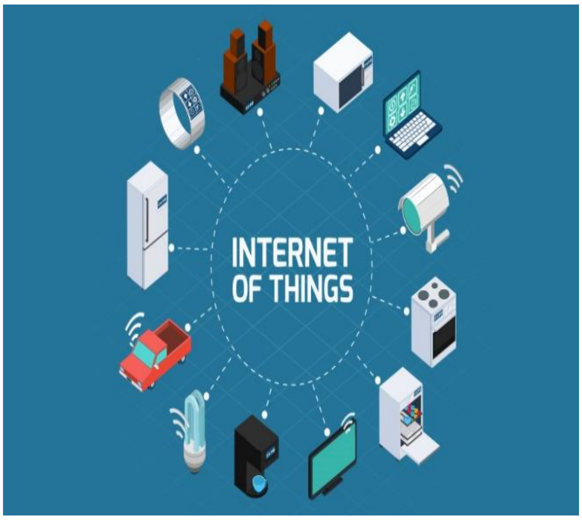

Fig.1 Conceptualization of IoT

The internet of things platform is an interconnection of a multitude of devices connected over the internet. Thus, to have a shared bandwidth among the available users, effective multiplexing techniques need to be used [2]. Out of the several multiplexing techniques at our disposal such as frequency division multiplexing (FDM), orthogonal frequency division multiplexing O(FDM), time division multiplexing (TDM), code division multiplexing (CDM), Orthogonal time frequency space (OTFS), the OFDM scheme has been one of the most efficient techniques to be used for transmission which is applicable to a large sort of networks such as local area networks (LAN), Wireless Interoperability for Microwave Access (WiMax), Long Term Evolution (LTE) etc [3]. The essence of the technique lies in the fact that the frequencies to be allocated to each user is orthogonal in nature covering the entire bandwidth space [4]. The condition for orthogonality of signals is given as [5]:

For 2 signals, the condition for orthogonality is given as:

$$\int_0^T s_1(t)s_2(t)DT = 0 \qquad (1)$$

For n number of signals in the bandwidth, the condition for orthogonality is given as:

$$\int_0^T s_1(t)s_2(t)\ldots s_nDT = 0 \qquad (2)$$

The mathematical condition of orthogonality can be translated in the graphical form as:

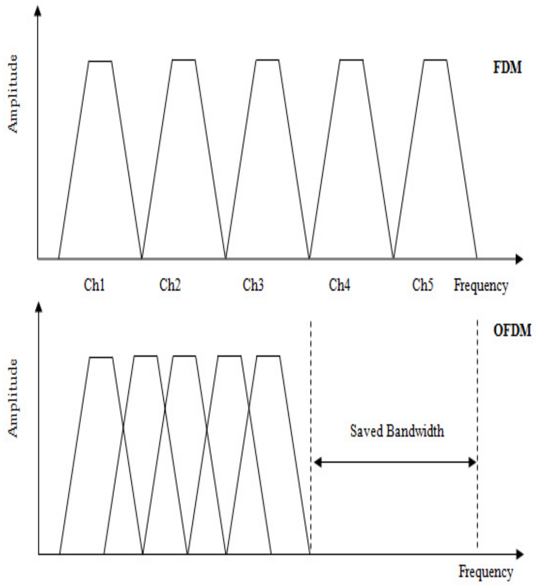

Fig.2 Graphical condition for orthogonality

Figure 2 illustrates the condition which needs to be satisfied graphically for orthogonality. In this case, when one signals maximum is reached, the other signals minimum often called the minima is to coincide. In case the maximum of one does not coincide with the minimum of the other, the condition for orthogonality is not met and inter carrier interference takes place [6].

II. PEAK TO AVERAGE POWER RATIO.

One of the basic problems of the OFDM transmission system is the fact that the signal in the time domain has extremely sporadic high peak values corresponding to high peak power as compared to the average power of the system [7]. The peak to average power ratio hinders the piece wise linear operation of the high power amplifiers (HPAs) of the system [8]. This in turn causes the increase in the error rate at the receiving end thereby degrading the quality of service of the overall communication systems [9]. This concept is illustrated in figure 3.

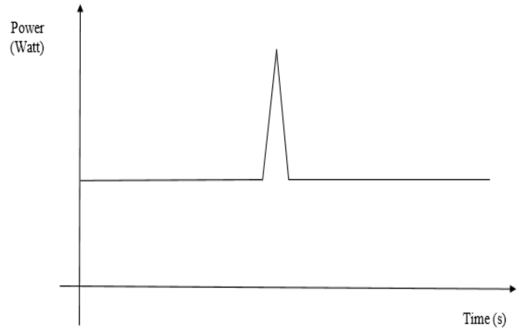

Fig.3 Sudden power spikes in the OFDM signal.

The PAPR can be expressed as [9]:

$$PAPR = \frac{\text{peak}\,\{z(t)^2\}}{avg\ zX(t)^2\}} \qquad (3)$$

Here,
PAPR denotes the peak to average power ratio.
Peak denotes the peak or maximum power value.
Avg denotes the mean or average power value
Often the impact of the PAPR value is evaluated in terms of the CCDF value or complementary cumulative distribution function [10]. It can be defined mathematically as:

$$ccfd(Z) = P\ (Z_i > Z_T) \qquad (4)$$

Here,
The variable Z denotes the CCDF of PAPR.
P denotes probability
Z_i denotes instantaneous value of PAPR
Z_T denotes a specific PAPR values.

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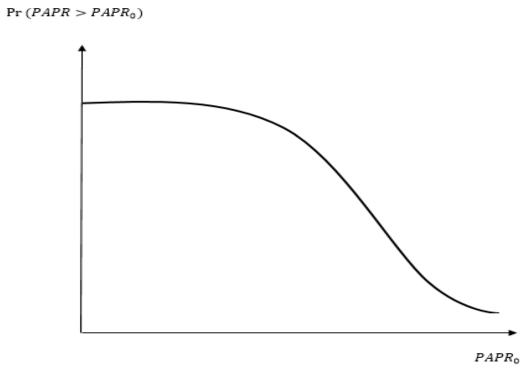

Fig.4 Typical PAPR CCDF graph for OFDM systems

The typical illustration of the CCDF function is depicted in figure 4. It can be observed that the CCDF values keep diminishing as the PAPR threshold increases. A steeper fall in the CCDF graph results in lower PAPR for a system.

III. PROPOSED METHOD

The method proposed in this paper is a modified version of the selective mapping or the SLM technique. There are several techniques to reduce the PAPR of a proposed system. One of the most effective techniques in terms of the PAPR reduction capability as well as no information loss at the same time is the SLM algorithm [11]. The selective mapping approach is based on the addition of phases to the composite OFDM signal and subsequently choosing the signal which has the least value of the PAPR. The SLM algorithm is depicted in figure 5.

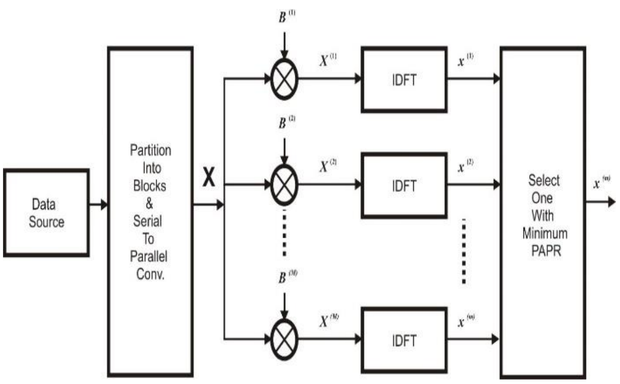

Fig.5 Block diagram for SLM

In this approach, the data source generates the serial data [12]. To feed to the IFFT/IDF block for carriers, the data needs to be converted from serial to parallel through a serial to parallel converter. Subsequently, different phases $[X^1, X^2 \ldots\ldots\ldots. X^n]$ are added to generate multiple versions of the signal. Subsequently, the parallel versions of the signal are modulated through the carrier signal generated by the IDFT/IFFT blocks. Finally, the vector resulting in the least PAPR value is selected for transmission. It is to be mentioned here that larger number of phase vectors in the phase vector X^I would results in greater chance of reduction of the PAPR value but would also result in the increase in the system complexity [13].

This approach in contrast to clipping doesn't result in information loss [14]. To further aid the PAPR reduction capability of the system, a peak windowing based approach is presented in this paper where residual peaks are found and then reduces by the product with a negatively decreasing function [15].

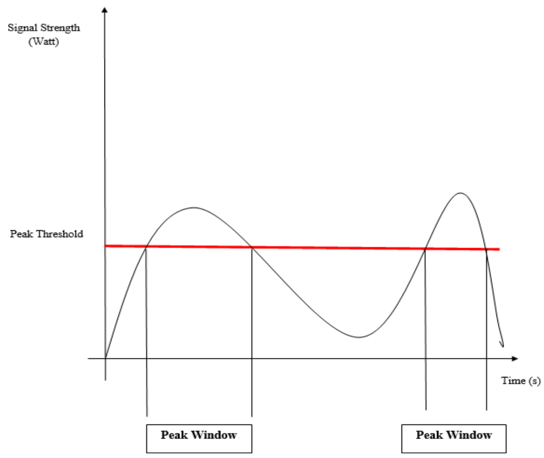

Fig.6 Peak windowing

The peak windows are selected through the condition:

$$|Z_{SLM}(t)| \geq T \qquad (5)$$

In this approach the threshold for residual peaks is chosen as T. Subsequently values greater than T in a window are selected as the peak window.

IV. EXPERIMENTAL RESULTS

The simulation platform for the proposed system has been designed on Matlab.

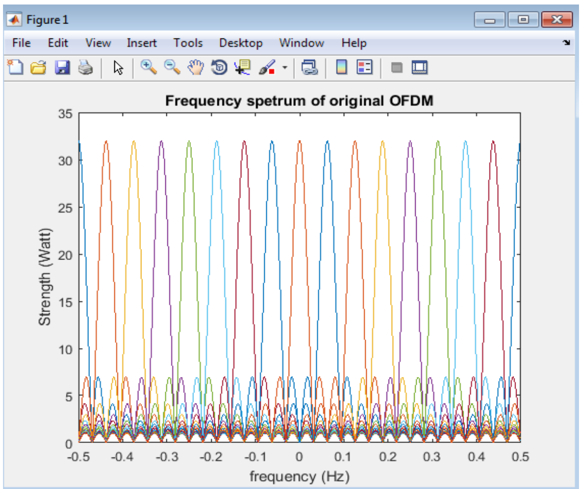

Fig.7 Spectrum of OFDM

The spectrum of OFDM depicts the mutually orthogonal subcarriers generated.

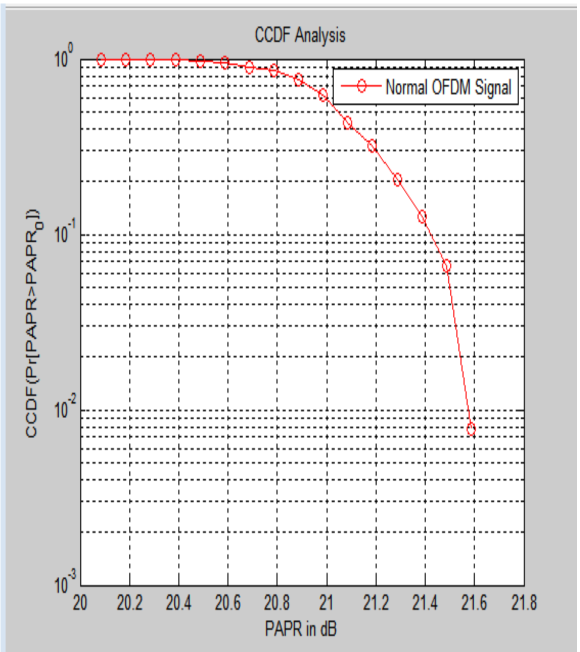

Fig.8 CCDF of original OFDM

Figure 8 depicts the CCDF for PAPR for the original OFDM case.

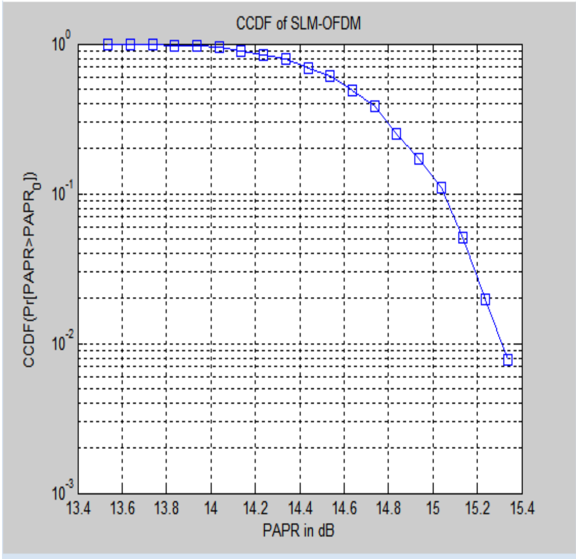

Fig.9 CCDF with SLM

Figure 9 depicts the CCDF for PAPR for the SLM case.

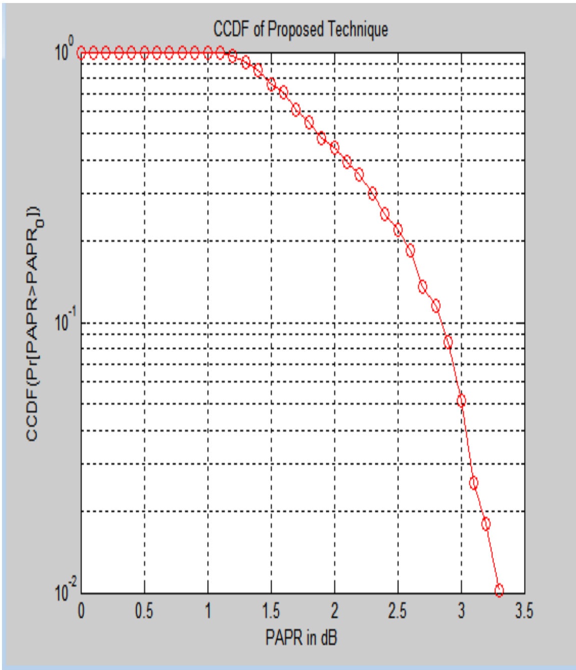

Fig.10 CCDF of proposed scheme

Figure 10 depicts the CCDF for PAPR for the proposed scheme.

It can be observed that the CCDF (PAPR) graph falls the fastest in case of the proposed technique with

SML and residual peak windowing. The windowing function using this case is the negative sync given by:

$$w(t) = 1 - \frac{\sin(\pi t)}{(\pi t)} \quad (6)$$

The inverted sync normalizes the residual peak in the signal.

V. CONCLUSION

This paper presents a residual windowing function for the reduction of peak to average power ration in conjugation with the SLM based approach. The necessity for the reduction of peak to average power ratio has also been cited so as to minimize the non linear distortion in the signal received at the receiving end of the transmission system. The analysis of the proposed system has been laid out by means of the complementary cumulative distribution function or the CCDF of the PAPR values. The cases considered in this approach are the normal or conventional OFDM, SLM and proposed scheme. It has bene showed through the results that the proposed scheme clearly outperforms the exiting systems in terms of the PAPR values.

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