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A Low Peak To Average Power Ration Based OFDM System For IoT Applications

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Abstract—Internet of Things (IoT) is an ecosystem of connected physical objects such as sensors, vehicles, electronic equipment etc. that are accessible through the internet. Internet of Things (IoT) is an ecosystem of connected physical objects that are accessible through the internet. The definition of the Internet of things has evolved due to the convergence of multiple technologies, real-time analytics, machine learning, commodity sensors, and embedded systems.[5] Traditional fields of embedded systems, wireless sensor networks, control systems, automation (including home and building automation), and others all contribute to enabling the Internet of things. With increasing number of users, large data being generated and limited bandwidth available for systems, efficient multiplexing techniques are needed that use the available bandwidth efficiently. One of the most efficient multiplexing techniques available is the Orthogonal Frequency Division Multiplexing (OFDM). It is widely used in IoT based applications. One of the major challenges that OFDM suffers from is high value of Peak to Average Power Ratio (PAPR). Internet of Things (IoT) is an ecosystem of connected physical objects that are accessible through the internet. The definition of the Internet of things has evolved due to the convergence of multiple technologies, real-time analytics, machine learning, commodity sensors, and embedded systems.[5] Traditional fields of embedded systems, wireless sensor networks, control systems, automation (including home and building automation), and others all contribute to enabling the Internet of things. This causes high Bit Error Rates and reduced Quality of Service. The proposed work uses a modified selective mapping technique and attains lower PAPR compared to previously existing work in terms of peak to average power ratio of the system.

I. INTRODUCTION

1.1 INTRODUCTION TO INTERNET OF THINGS (IoT)

Internet of Things (IoT) is an ecosystem of connected physical objects that are accessible through the internet. The definition of the Internet of things has evolved due to the convergence of multiple technologies, real-time analytics, machine learning, commodity sensors, and embedded systems.[5] Traditional fields of embedded systems, wireless sensor networks, control systems, automation (including home and building automation), and others all contribute to enabling the Internet of things. In the consumer market, IoT technology is most synonymous with products pertaining to the concept of the "smart home", covering devices and appliances (such as lighting fixtures, thermostats, home security systems and cameras, and other home appliances) that support one or more common ecosystems, and can be controlled via devices associated with that ecosystem, such as smart phones and smart speakers. Thus, IoT can be thought of a new paradigm in technology shaping future connectivity of devices.

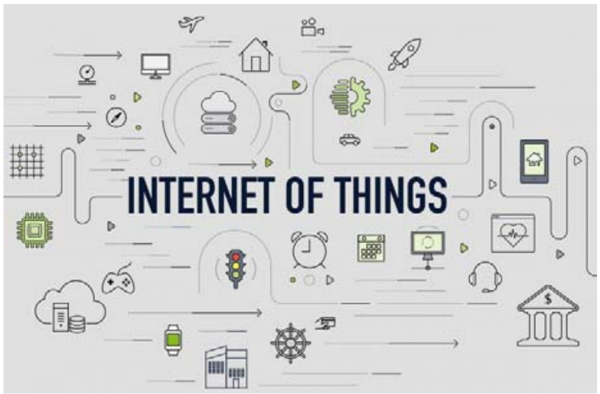

Fig.1.1 The Conceptual Model of IoT

Typical applications of IoT are:

1) Smart Cities.

2) Healthcare

3) Transportation

4) Traffic Control

5) Manufacturing

6) Large Scale Automation

7) Big Data Applications etc.

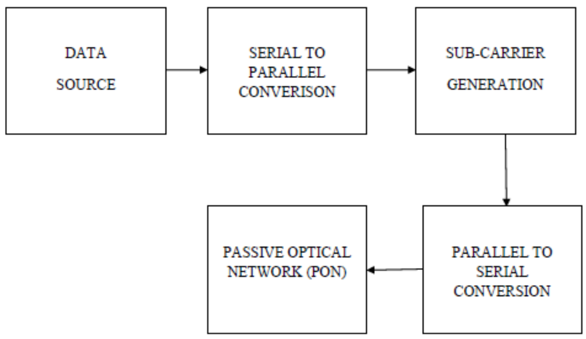

Fig. 1.2 OFDM based IoT Transmission Scheme

1.2 PHYSICAL MODEL FOR OFDM based IoT TRANSMISSION

The OFDM based IOT can be clearly understood using the transmission and reception scheme of the OFDM based IOT mechanism. The Transmission scheme is depicted below:

The transmission scheme utilizes the fact that the OFDM system can be used for passive optical networks as the optical networks support a staggering amount of bandwidth. The transmission is always implemented in the serial architecture. However, the OFDM generation needs the parallel processing IFFT structure. Hence there is a need for two-way serial to parallel and parallel to serial conversion blocks. A similar structure for the OFDM based IOT receiver structure is given below. The receiver structure is shown in the figure blow:

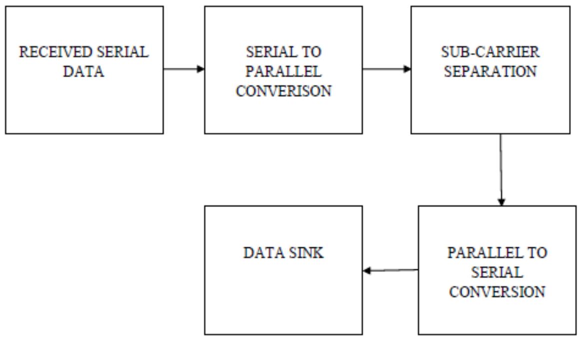

Fig. 1.3 OFDM based IoT Reception Scheme

The reception scheme is pretty much the opposite of the transmission scheme in regards to the fact that the inverse process of the transmission scheme is applied here.

1.3 THE PEAK TO AVERATE POWER RATIO (PAPR)

The PAPR of the system is defined as the ratio of the peak power to that of the average power of the system

Mathematically, it is defined as: [1]

$$PAPR = \frac{\max\{X(t)^2\}}{mean\,\{X(t)^2\}} \qquad (1.1)$$

Here,

PAPR stands for peak to average power ratio

X(t) is the transmitted signal

Max represents the peak of the signal

Mean represents the average value

The significance of this term lies in the fact that the PAPR gives the deviation of the signal from the average power there by making

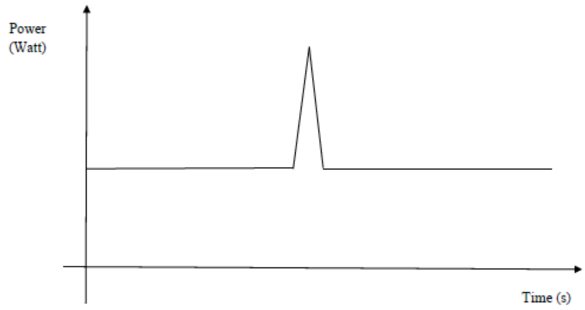

Fig. 1.4 Significance of Perceptibility due to High PAPR

1.4 OBJECTIVE

The objective of the proposed system is to design a reduction in the PAPR of the system. This would lead to lesser deviation from average power of the system in terms of the fact that the sudden surges in the power would be absent from the system. This would lead to more bit errors in at the receiving end. The basic nature of such a system would be keeping the original data intact which is possible if the PAPR of the OFDM based IoT system is kept less.

II. LITERATURE REVIEW

In 2018 Yaoqiang Xiao et al. in [1] proposed a new technique based on SLM with low complexity and reduced side information. The main focus was to reduce the complexity of SLM, but NOT on reducing PAPR further. The PAPR was 6dB.

In 2018 Amber Sultan al. in [2] proposed a technique using chaotic constellation mapping for the sake of OFDM based networks. The technique used the concept of chaos theory and chaos maps for the constellation design of the signaling points of the proposed system. The evaluation parameter used by this paper was the CCDF of the PAPR of the proposed system.

In 2017 Adnan A. E al. in [3] presented the concept of the Walsh-Hadamard Transform for OFDM based security. The chaotic Walsh Hadamard transform was shown to be an improvement over the conventional Walsh Hadamard transform. It was shown using the CCDF of the PAPR that the proposed system attains better PAPR reduction than the conventional Walsh-Hadamard Transform.

In 2017 Chongfu Zhang et al. in [4] proposed a chaotic pseudo carrier technique for the physical layer security of the OFDM systems. The technique was inspired by the fact that pseudo (false) sub-carriers can mislead the possible adversaries in thinking that data has been encoded and is being transmitted via a different set of sub carriers so as to guard the original set of sub-carriers.

In 2016 Wei Zhang et al. in [5] proposed a joint PAPR reduction and Physical Layer Security paradigm for Optical PON systems that relied on OFDM. The objective of the proposed system was to design a reduction in the PAPR of the system. This would lead to lesser deviation from average power of the system in terms of the fact that the sudden surges in the power would be absent from the system. This would lead to lesser perceptibility of the transmitted data by possible adversaries.

In 2016 Chongfu Zhang et al. in [6] proposed a hybrid time-frequency domain interleaving technique for the physical layer security enhancement for OFDM signals. The interleaving technique was effective in nullifying the effect of burst errors thereby rendering higher level of reliability to the system.

In 2015 Xiaonan Hu et al. in [7] proposed the chaos Partial Transmitted Sequences (PTS) algorithm for the security of OFDM networks. The technique used sub-blocking in the OFDM – PON data followed by phase addition to implement the PTS algorithm. Moreover, the chaotic algorithm was also used in conjugation with it.

In 2015 Xuelin Yang et al. in [8] used the chaotic scrambling scheme for enhancing physical layer security of OFDM systems. The technique used the scrambler for mixing up the chaos data bits to be transmitted via the ODM-PON system. The technique was shown to have better performance compared to the conventional chaotic system.

In 2014 Bo Liu et al. in [9] used the Dimension-Transformed Chaotic Permutation for physical layer security enhancement for OFDM PON. The technique used the dimensional transform technique along with the chaos encryption for rendering security. This rendered effective reduction of peak to average power ratio (PAPR) of the system. This makes the system more secure to possible attacks.

In 2014 Wei Zhang et al. in [10] used the Chaos Coding QAM IQ-Encryption for OFDM security. The I-Q encryption technique used separate encryption for the in-phase (I) and quadrature (Q) components of the OFDM system. This made it difficult for the possible attackers in decoding the signal by brute force.

In 2013 Yong Tao et al. in [11] used spread spectrum for OFDM security. In this technique a narrow band signal was spread to transform into a wideband signal which would mislead possible attackers in thinking that the signal in noise and goes unnoticed.

In 2013 Ning Jiang et al. in [12] designed a chaos OFDM based Wavelength Division Multiplexing (WDM) system for PONs. The technique used the concept of chaos theory and chaos maps for the constellation design of the signaling points of the proposed system. The evaluation parameter used by this paper was the CCDF of the PAPR of the proposed system.

In 2012 Elaine Wong et al. in [13] proposed a survey on next generation Broadband Access Networks and Technologies wherein the concept of OFDM and PON was introduced and augmented to show the efficacy of the system for future generation wireless and broadband networks.

In 2012 Neda Cvijetic et al. in [14] proposed a DSP-OFDM optical access and OFDMA. The paper mainly focused on the processing power of digital signal processing units and DSP processors for the implementation of PFDMA-PON. The various pros and cons were addressed in the paper.

In 2011 Lijia Zhang et al. in [15] proposed a technique for OFDM that was to masquerade possible adversaries on the concept of chaos OFDM scrambling. The major constraints were however the high peak surges from the signal average level that increased the perceptibility of the system.

In 2011 Arsenia Chorti et al. in [16] focused on enhancing the security of OFDM systems on Faster than Nyquist interference assisted communications for wireless networks using OFDM as the multiple access technique. It was shown that the secrecy could be however maintained if the sudden peak fluctuations can be removed from the system. This needs the effective reduction of peak to average power ratio (PAPR) of the system.

In 2010 António Teixeira et al. in [18] put forth a survey on Standardization in PONs. It was shown that the use of PON result in extremely secure and bandwidth effective computer networks. However, the security can get compromised at routing joints where attackers can attack the signal being transmitted since there is a conversion for optical to electrical form and vice versa at routing points in case of PONs. This needs the consideration of reducing the PAPR of the OFDM.

In 2009 Navid Ghazisaidi et al. in [19] presented a survey on optical fiber assisted-wireless (FiWi) access networks. This was the nascent stages of the concept of using Optical Networks as a mainstream multiple access technique. Various parameters pertaining to the practical deployment of such systems were evaluated.

III. PROBLEM FORMULATION

The problem with OFDM based IOT systems lies in the fact that the high swing in the strength of the OFDM based IOT signal is responsible for increased perceptibility of the data transmission. In this section we evaluate the reasons for the increased PAPR of the OFDM PON systems:

Let the time domain signal for the OFDM based IOT system be given by;

$$Xi(f)=\Sigma x(n)vn(i)\exp \quad (-j2\pi fn)$$

Where,

i=0, 1, 2,……………,(n-1)

n are the number of sub carriers

X(f) is the frequency spaced signal

Let the number of users be N

Let the bandwidth requirement of each user be W

Then the overall bandwidth available to the OFDM based IOT system can be given by:

$$C_0=NW \quad (3.2)$$

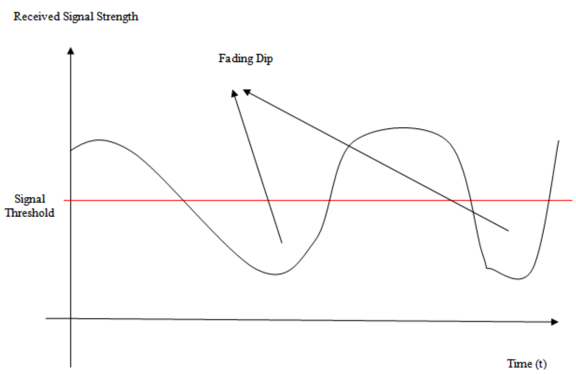

Fig.3.1 Chances of Fading Dips

The fading dips result in the increased chances of bit errors in the reception. Thus is to be ensured that the fading dips are avoided. This clearly indicates the fact that clipping the signal to reduce the PAPR of the system is not an effective measure to ensure security for the OFDM PON system. This paves the path for the need of different PAPR reduction techniques that would not adversely affect the BER of the system. However, the chances for the system to attain a PAPR greater than a particular value of threshold PAPR is given by the complementary cumulative distribution function (CCDF) of the system.

IV. PROPOSED METHODOLOGY

4.1 Different PAPR reduction techniques for OFDM

Among the various techniques which are commonplace for PAPR reduction, the most effective ones are being cited here.

4.1.1 Clipping

This is relatively a simple technique in which the signal above a particular threshold is directly clipped. This results in substantial information loss and bit errors. It is illustrated below:

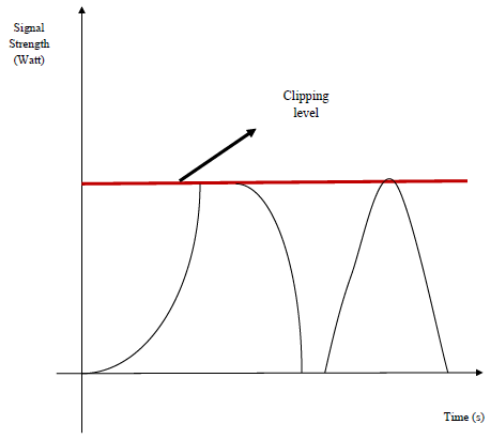

Fig. 4.1 Concept of Clipping in OFDM

4.1.2 Tone Rejection

In this process, the tones exhibiting a high spectral peak are first detected and then rejected. Hence this technique is called tone rejection. It is illustrated below. It suffers from the additional overhead of channel estimation

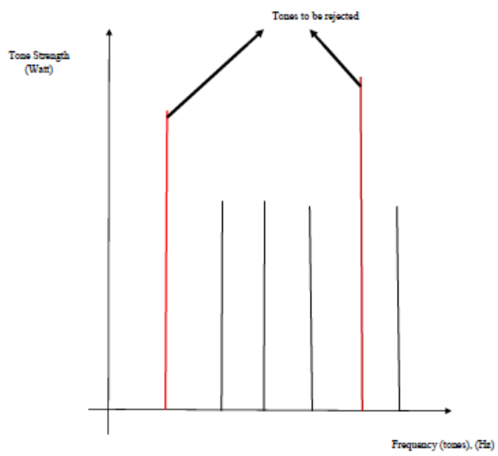

Fig. 4.2 Concept of Tone-Rejection in OFDM

4.1.3 Selective Mapping (SLM)

Selective Mapping or SLM is OFDM based IoT on an exhaustive search algorithm where different phase addition vectors are added to the original bit stream to generate multiple copies of the same signal. Subsequently an exhaustive search algorithm is used to search for the phase addition corresponding to the least PAPR. This is illustrated below:

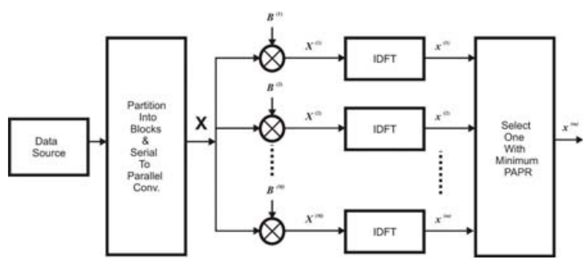

Fig.4.3 Concept of Selective Mapping in PFDM-PON

It is worth mentioning here that although SLM does not increase the BER of the system, but it can substantially increase the system complexity by increasing the number of searches as the number of sub-carriers increase in the OFDM based IOT system. This however compensates for the low PAPR of the system.

4.2 MODIFIED SELECTIVE MAPPING

The selective mapping can be modified to remove residual peaks existent from the application of the SLM technique. This needs the concept of peak windowing. Peak windowing is a technique of detecting and removing residual peaks. This can be done using weighted functions. The function used in this case is the inverse sync function.

The sync function is mathematically defined as:

$$sinc(x) = \frac{\sin(\pi x)}{(\pi x)}$$

A typical sync function resembles peaks in spectrum of the signal. Thus, if inverted sync functions are used, then it is possible to reduce the peaks in the windowed sections of the signal spectrum.

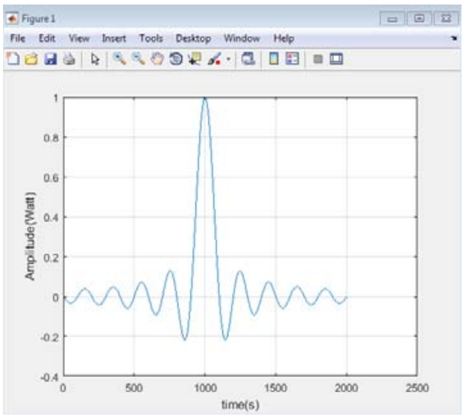

Fig.4.4 A typical sync function

The sync function's inverse can be applied to the peak windowed signal. The concept of peak windowing is clarified below.

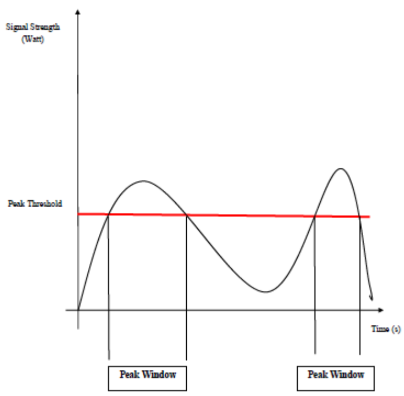

Fig. 4.5 Concept of Peak Windowing

The modified peak windowing can be done using an inverted sync function given by:

$$w(t) = \frac{1}{sync(t)} \; ; -T < t < T \qquad (4.19)$$

Here,

T represents the time frame of the Peak Window.

t is time variable

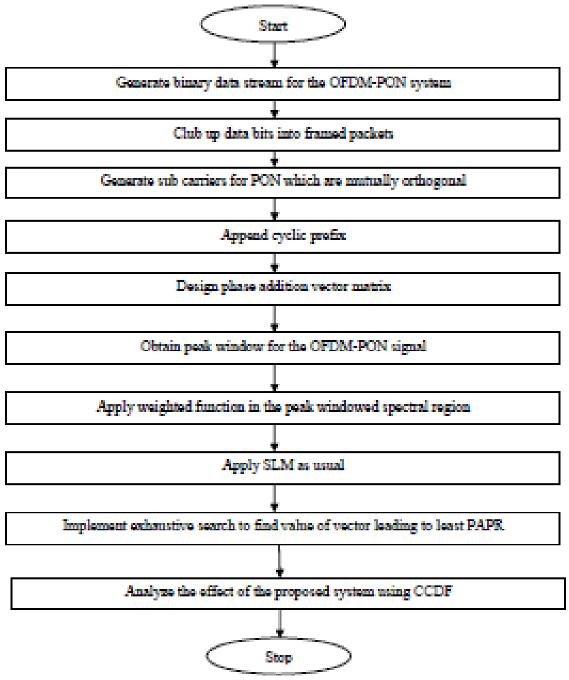

Fig.4.6 Flowchart of Proposed System

V. RESULTS AND DISCUSSIONS

The results obtained using the proposed system is given below. The simulations are on MATLAB 2010 a

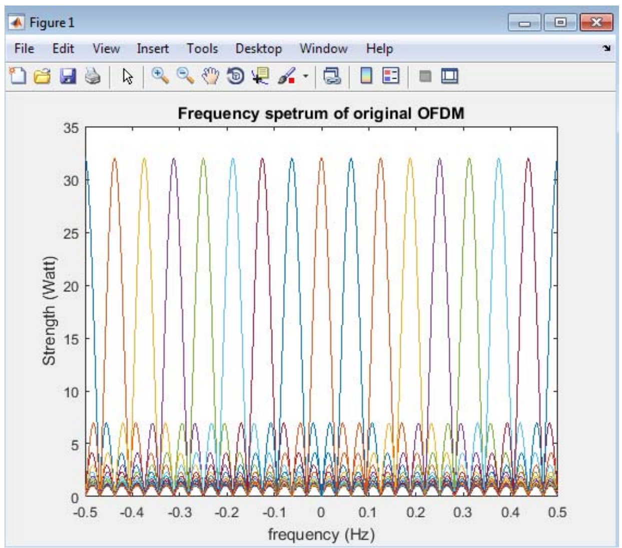

Fig.5.1 Spectrum of OFDM

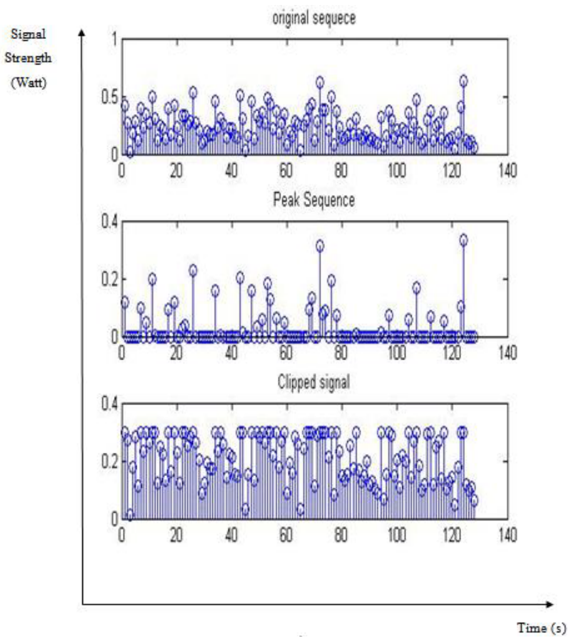

Fig.5.2 Concept of Clipping

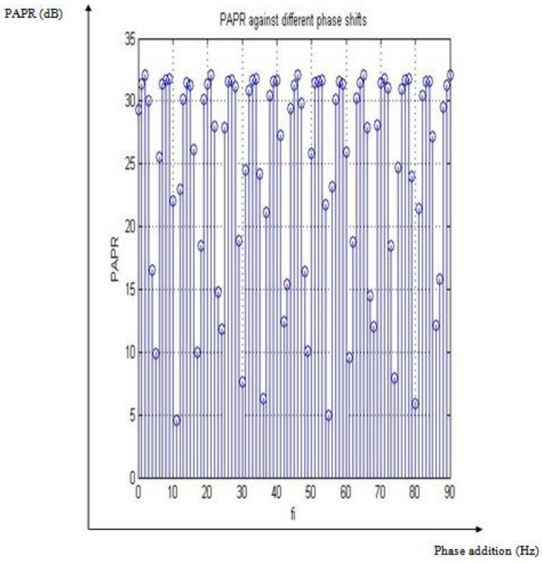

Fig.5.3 Concept of SLM in OFDM

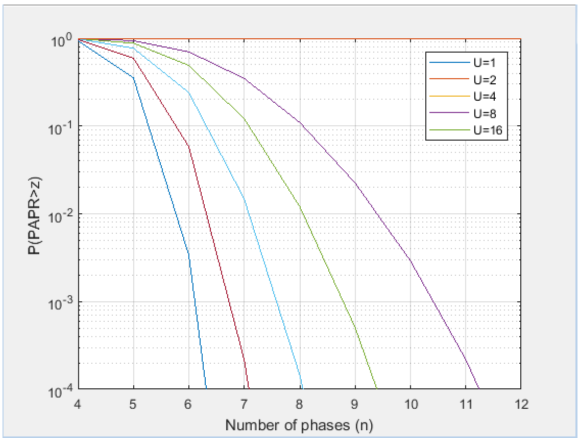

Fig.5.4 Effect of Increasing phase addition in SLM for OFDM

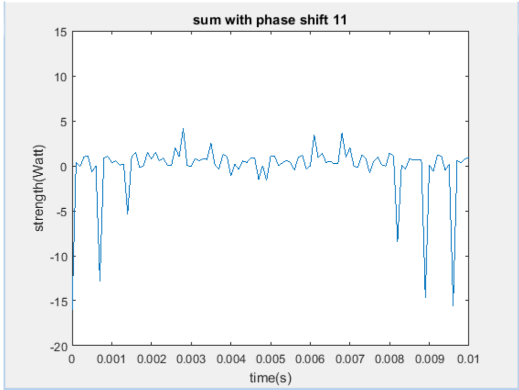

Fig.5.5 Visible residual peaks even after application of SLM

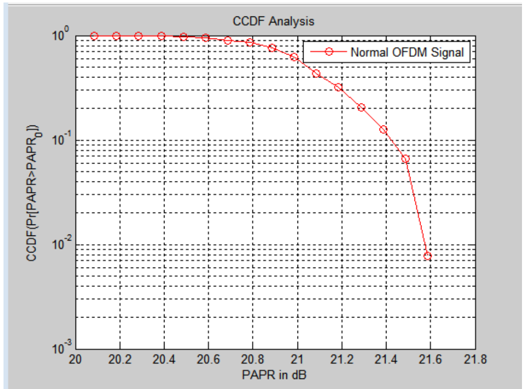

Fig.5.6 CCDF analysis of Conventional OFDM

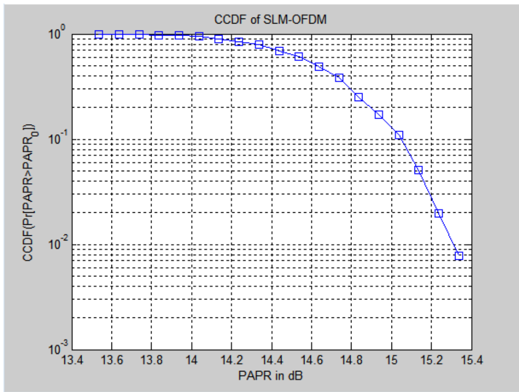

Fig.5.7 CCDF analysis of SLM

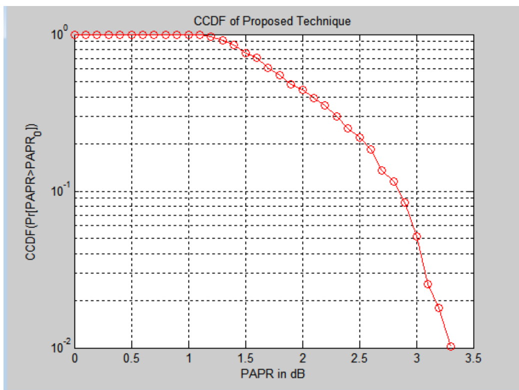

Fig.5.8 CCDF analysis of Proposed Technique

Table 5.1 Comparative PAPR Analysis at CCDF of PAPR=10^{-1}

S.No	Method	Pr(PAPR>$PAPR_0$)	PAPR
1	Conventional OFDM	10^{-1}	21.4 dB
2	Clipping	10^{-1}	17.5 dB
3	SLM	10^{-1}	15.2 dB
4	Previous Work (Base Paper)	10^{-1}	5 dB
5	Proposed Work	10^{-1}	2.8 dB

Table 5.2 Comparative PAPR Analysis at CCDF of PAPR=10^{-2}

S.No	Method	Pr(PAPR>$PAPR_0$)	PAPR
1	Conventional OFDM	10^{-2}	21.6 dB
2	Clipping	10^{-2}	17.8 dB
3	SLM	10^{-2}	15.3 dB
4	Previous Work (Base Paper)	10^{-2}	5.4 dB
4	Proposed Work	10^{-2}	3.3 dB

The comparative analysis clearly shows that the proposed system outperforms the previous work .

This can be seen from the CCDF curve of the PAPR of the system that clearly indicates that the proposed system outperforms the previous work at a PAPR of 10-1 and 10-2. A tabular analysis is supports and augments the results that have been furnished in the tabular form.

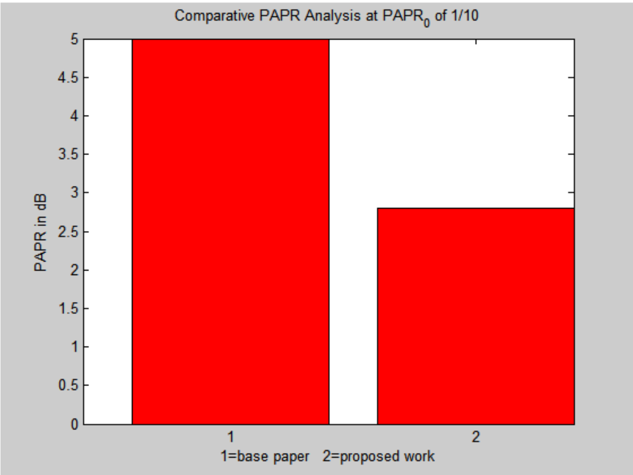

Fig.5.9 Comparative PAPR Analysis at PAPR_0 of 1/10

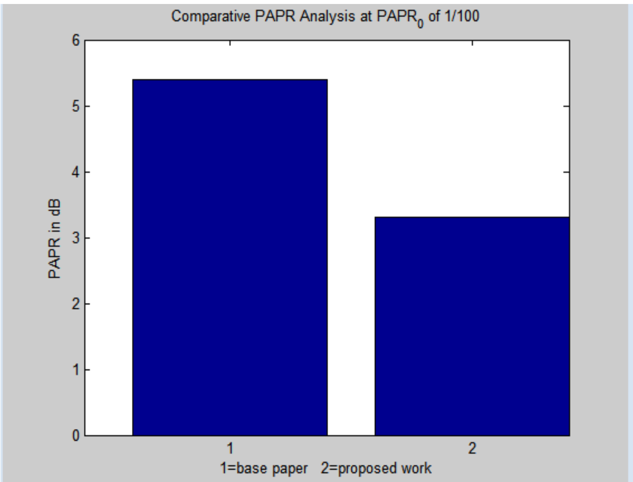

Fig.5.9 Comparative PAPR Analysis at PAPR_0 of 1/100

VI. CONCLUSION & FUTURE WORK

6.1 CONCLUSION

It can be concluded form the previous discussion that Internet of Things (IoT) is an ecosystem of connected physical objects such as sensors, vehicles, electronic equipments etc that are accessible through the internet. With increasing number of users, large data being generated and limited bandwidth available for systems, efficient multiplexing techniques are needed that use the available bandwidth efficiently. One of the most efficient multiplexing techniques available is the Orthogonal Frequency Division Multiplexing (OFDM). It is widely used in IoT based applications. One of the major challenges that OFDM suffers from is high value of Peak to Average Power Ratio (PAPR). This causes high Bit Error Rates and reduced Quality of Service. The proposed work uses a modified selective mapping technique and attains lower PAPR compared to previously existing work.

A comparative analysis of different PAPR reduction techniques have been analyses and simulated. The techniques simulated are:

1) Conventional OFDM

2) Clipping

3) Conventional SLM

4) Modified SLM

The comparative analysis in tabular and graphical form clearly shows that the proposed system outperforms the previous work. This can be seen from the CCDF curve of the PAPR of the system that clearly indicates that the proposed system outperforms the previous work at a PAPR of 10-1 and 10-2. The reduction in the PAPR value clearly indicates the fact that the level of perceptibility of the proposed system is lesser compared to the previous system. Thus, enhancement in security of OFDM PON can be enhanced by employing the proposed system.

6.2 FUTURE SCOPE

There are different avenues wherein the future research work can be directed. The most prominent ones are:

Trying to reduce the complexity of the OFDM system using hybrid techniques as a cascade of different algorithms.

Enhancing the proposed system for MIMO OFDM based IOT networks.

Implementing chaos theory for bit level encryption in conjugation to the proposed technique

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