PAPR Analysis of OFDM using Partial Transmit Sequence Method

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Abstract

Orthogonal Frequency Division Multiplexing (OFDM) is one of the most widely used multicarrier transmission and effective technologies in today's communication networks. OFDM has many benefits and drawbacks. High Peak to Average Power Ratio (PAPR) is one of its main drawbacks. The spectral efficiency of the high-power amplifiers decreases with increasing PAPR. Therefore, maintaining a wireless system's efficiency is required to lower the PAPR. A possible method for lowering the high PAPR in OFDM systems is Partial Transmit Sequence (PTS). PTS generates a number of candidate signals, and the best signal with the lowest PAPR is chosen for transmission. The results shows that the PTS technique achieves greater PAPR minimization with less complexity. MATLAB simulation has been used to examine the OFDM system's PSD, spectral efficiency, BER performance, and PAPR analysis.

Keywords: PAPR, OFDM, PTS, BER, SNR, PSD

1. Introduction

The popularity of multimedia applications has grown significantly in recent years, moving people into the era of the fifth generation (5G) of Wireless Communication (WC) systems. Because of the growing demand for wireless applications and the exponential development in the number of connected users, the current WC infrastructures are saturated [1-2]. By assuring ultra-high data rates, ultra-wide radio coverage, a big number of linked devices that are extremely efficient and have low latency, researchers and network designers are encouraged to develop solutions for these basic difficulties [3].

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The development of the 5G of wireless networks will be facilitated by wireless network solutions utilizing sophisticated and effective technology. 5G needs to be ready to handle significant obstacles in order to offer a dependable, secure, and effective 5G network [3-4]. When there are many users and there is a limited amount of spectrum, it is crucial for WC systems to select such technologies that can efficiently utilize the spectrum and can serve the greatest number of users [5-6]. Along with servicing the greatest number of users, the main goal is to achieve bandwidth efficiency and resilience in multipath channel environments [7-8].

A Multi Carrier (MC) WC system has the capacity to deliver high-speed data rates at extremely cheap costs to a large number of users [3]. The main distinction between a Single Carrier (SC) system and a MC system is that in a SC system, a single carrier occupies the full available bandwidth, but in an MC system, the available bandwidth is shared among multiple subcarriers, each of which has a lesser bandwidth [9]. Because OFDM possesses MC system characteristics, studying OFDM is important. Every 4G WC framework uses OFDM frames due to its extensive subcarrier limit, high data rate of more than 100 Mbps, and excellent adaptability [10]. Along with its benefits, OFDM has one significant disadvantage i.e., a high Peak to Average Power Ratio (PAPR).

The Partial Transmit Sequence (PTS) OFDM approach for PAPR reduction has been addressed in this article. A technique for digital modulation is called OFDM. The signal is divided into several narrowband channels using OFDM at various frequencies. It is one of the key contenders for 4G connectivity. The division of the frequency spectrum into sub-bands is the fundamental principle of OFDM. Data is carried via a substantial number of closely spaced orthogonal sub carriers [11]. Then, each channel or stream of data is broken into a number of parallel sub carriers. Each sub carrier is modulated at a low symbol rate using a traditional modulation algorithm, such as QAM or PSK. With the same bandwidth, the overall data rate must be kept close to that of the traditional SC modulation system. Because having MC causes implementation issues. The main one is that OFDM systems have a high PAPR [12-13].

The output of the OFDM system, which is the superposition of many carriers, causes the instantaneous power of the signal to rise in comparison to the system's average power. The High-Power Amplifier (HPA) is used to amplify the signals in real-world OFDM systems [14-15]. However, because to HPA's constrained linear range, amplifying OFDM with high PAPR is particularly challenging. As a result, the non-linearity of HPA might substantially distort OFDM signals with high PAPR, adding more interference to the system [13].

PAPR may decrease when IBO rises. Some in band and out band aberrations are caused by the greater IBO. The sole option, then, is to utilize certain PAPR reduction approaches to lower the PAPR. Many different strategies have recently been put out for lowering the PAPR of an OFDM system. Nevertheless, each of them has drawbacks [12]. The pilot symbols and data are subjected to extra nonlinear noise introduced by the clipping procedure, which further affects the transmission efficiency.

PTS is a potential PAPR reduction strategy that doesn't introduce distortion among the present techniques [13]. The phase factors are used to rotate the sub-blocks of the OFDM signal in PTS for providing a numerous candidate signal. Moreover, the candidate signal sections of PTS may be significantly linked; the main issue with PTS is the restricted PAPR minimization performance when the candidate signal counts are constant. The high level of computation complexity is another issue [10]. In order to increase the performance of PAPR minimization, an improved PTS scheme is suggested in this study to decrease the correlation between the candidate signals of PTS. A threshold is also included to regulate the computational complexity. As a consequence, the suggested method can lower PAPR by a greater proportion while being less difficult than traditional PTS [16].

The article is structured as follows: Section 2 provides an overview of OFDM systems, and section 3 describes the PTS method. The results are described in section 4, and finally the conclusion is mentioned in section 5.

2. Orthogonal Frequency Division Multiplexing

For 4G cellular networks in particular, OFDM is a well-liked MC technology that is frequently used in WCs [4,17]. One of the main characteristics of OFDM is the ease with which the transmitted signal is created using IFFT and the ease with which the received data is recovered using FFT. A Cyclic Prefix (CP) is added at the transmitter and deleted at the receiver for each OFDM block [18,24]. Consecutive OFDM data blocks do not overlap in the time domain if the multipath channel's duration does not exceed the CP's duration. Because of this, each block may independently conduct the OFDM transmission and receiving [12-13]. Additionally, OFDM with CP converts a parallel set of frequency flat single path channels from a frequency selective multipath channel into a scalar gain compensation for each subcarrier, permitting a straightforward equalization. One of the key reasons why OFDM is so popular for multipath channels is its reduced-complexity equalization. Additionally, MIMO systems based on multiple antennas are compatible with OFDM, resulting in a distinct MIMO channel for each subcarrier [19-20]. Zero-Padding (ZP) OFDM is a variation of OFDM that involves replacing the CP with zeros. The loss of spectral efficiency and capacity brought by the CP or the ZP is one of the disadvantages of OFDM. Additionally, each subcarrier's signal transmits with non-negligible spectral side-lobes, due to its sensitivity to frequency offsets and Doppler factors that obliterate frequency orthogonality and cause inter-carrier interference [21,25]. Another problem with OFDM is the corresponding nonlinear distortion at the transmitter side, which is driven over by HPA. The transmitting amplifier must manage a signal with a high PAPR since the signal to be sent is the IFFT combination of the signals of many subcarriers [17].

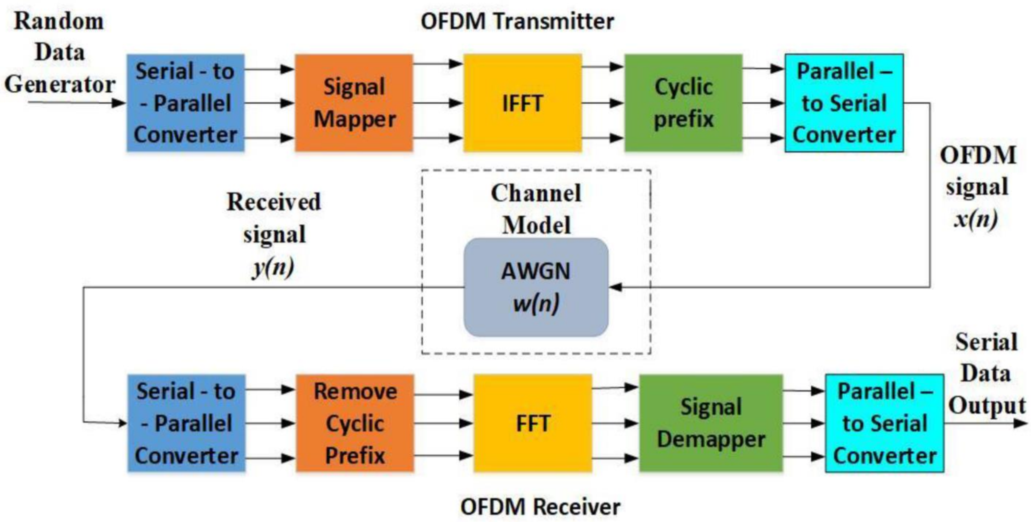

Figure 1. OFDM block diagram

3. Partial Transmit Sequence

One of the techniques for reducing PAPR that uses less distortion is the PTS algorithm. The fundamental principle of the PTS method is to multiply each subsequence of the original OFDM sequence by different weight (different phase sequences) until the best value is determined [22]. The phase sequences +1, -1, +j, and -j are frequently used. The primary phases of PTS involve dividing the data input block into smaller blocks, such that each block reflects a specific fraction of the real information. The sub-blocks are then sent to an IFFT, where they are multiplied by a corresponding phase value and combined to produce an output signal with a lower PAPR. The input is modulated using BPSK, QPSK, or QAM, and the modulated signal serves as the input for the proposed block diagram of PTS [23].

PTS algorithm is used to separate the N-symbol input data as V disjoint sub-blocks as follows:

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

Here X_i represents the sub-blocks that are equally spaced apart and sequentially arranged. In contrast to the SLM approach, which applies scrambling to all subcarriers, the PTS technique, depicted in figure 2, applies scrambling to each sub-block. Each divided sub-blocks are then multiplied with a relevant complex phase factor $b^v = e^{j\phi v}; v = 1 \ to \ V$, then using its IFFT to produce,

$$x = IFFT\left[\sum_{v=1}^{V} b^v X^v\right] \tag{2}$$

$$x = \sum_{v=1}^{V} b^v . IFFT\left[X^v\right] \tag{3}$$

$$x = \sum_{v=1}^{V} b^v x^v \tag{4}$$

Here a PTS is represented as $\mathbf{x}^V$. The phase vector is selected to minimize the PAPR.

$$\left[\tilde{b}^1, \ldots\ldots, \tilde{b}^V\right] = \underset{\left[b^1,\ldots\ldots,b^V\right]}{\arg\min}\left[\max_{n=0,\ldots,N-1}\left|\sum_{v=1}^{V} b^v x^v[n]\right|\right] \tag{5}$$

Accordingly, the time-domain signal with its matching lowest PAPR vector may be written as,

$$\tilde{X} = \sum_{v=1}^{V} \tilde{b}^v X^v \tag{6}$$

In order to simplify the search process, the phase factors are typically chosen from a limited number of elements. Where, $b = e^{\frac{j2\Pi i}{W}}$, i=0 to W-1 is the set of possible phase factors. The best set of phase vectors must be found by searching W^{V-1} sets of phase factors. As a result, the search complexity also increases with respect to the sub-blocks count. The PTS method needs $\log_2 W^V$ bits for side information and *V* IFFT operations at every data block. The PTS technique's PAPR effectiveness is affected by the sub-block partitioning in addition to the number of sub-blocks (*V*) and allowable phase factors (W). The sub-block partitioning methods are pseudo-random, interleaved, and adjacent. The one known to perform best among these is the pseudo-random. Finding the most suitable collection of phase vectors is difficult for the PTS approach, particularly as the number of sub-blocks increases.

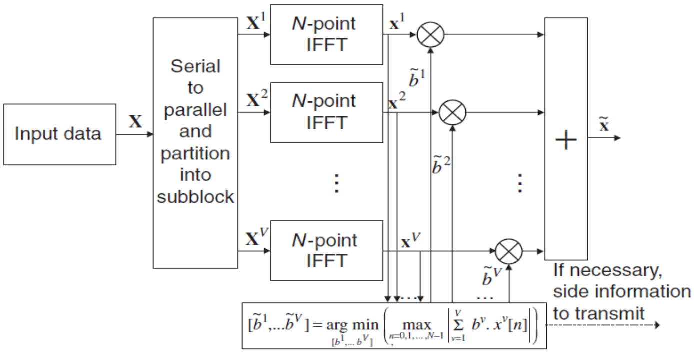

Figure 2. PTS method PAPR minimization

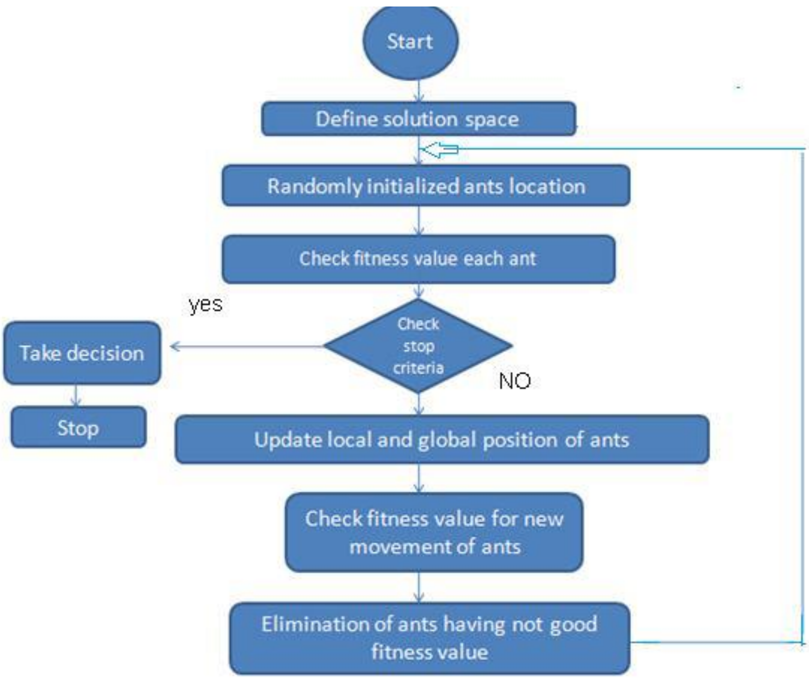

Figure 3. Flowchart of PTS method using ant colony optimization

4. Simulation Results

Using MATLAB simulation, the PTS technique's performance for various sub-block is evaluated and compared. Performance of PAPR minimization is dependent on the size of sub-blocks and the amount of possible phase values. In Figure 4, the PSD for OFDM is displayed. The spectrum is normally flat up to a normalized frequency of 0.2. However, the sideband of OFDM is relatively broad.

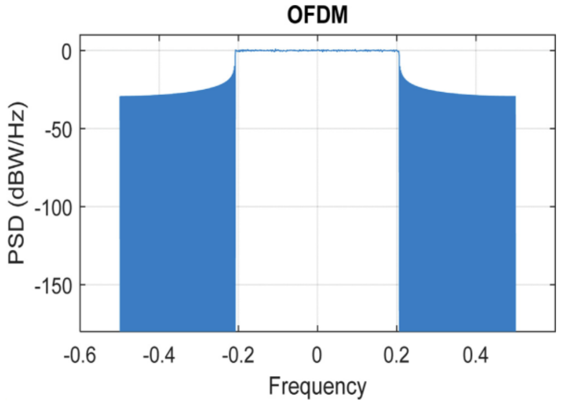

Figure 4. PSD

Figure 5 depicts the Spectral Efficiency of OFDM. The burst's duration is varied between 0 and 50 ms to generate it. The SNR vs BER of OFDM is shown in Figure 6.

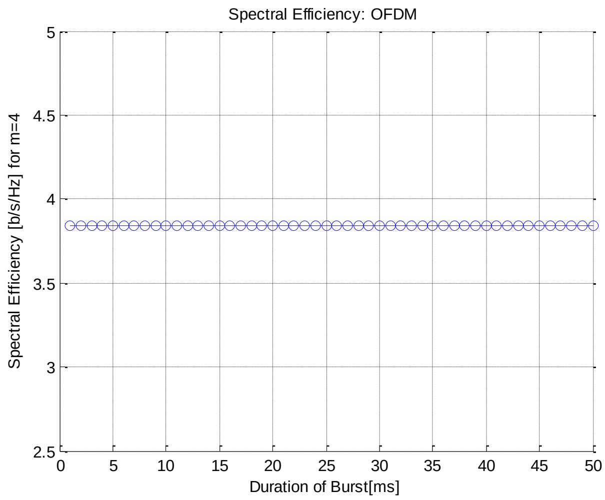

Figure 5. Spectral Efficiency

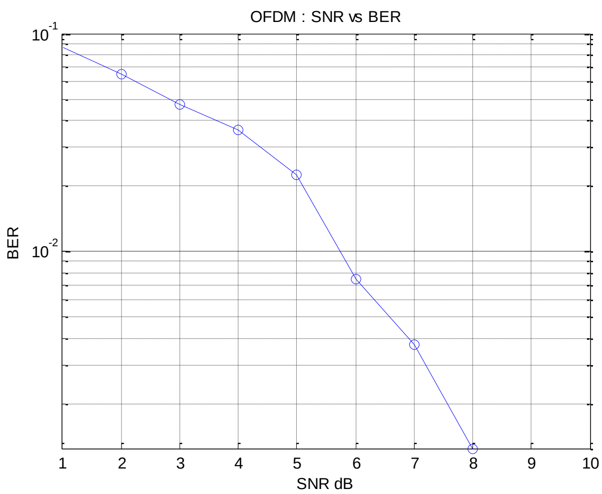

Figure 6. SNR vs BER

Figure 7 depicts the frequency spectrum of the original OFDM signal, with the number of subcarriers to be 8, the number of transmitted symbols equal to 128, and the overall frequency being 100 MHz.

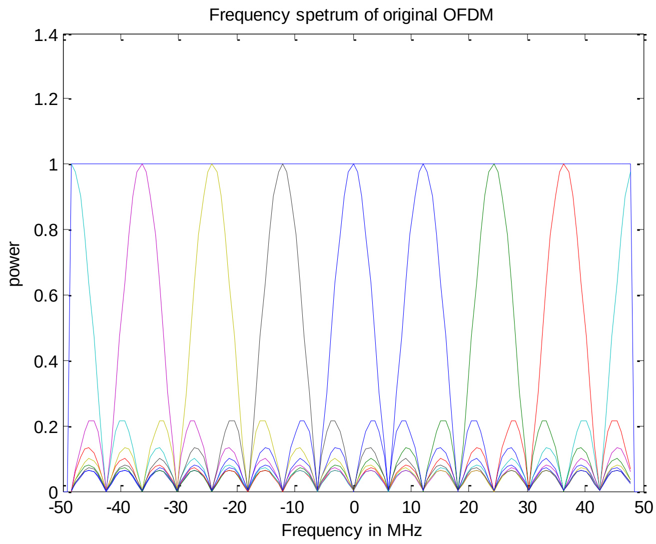

Figure 7. Frequency spectrum

Figure 8 shows the CCDFs for OFDM signals with N = 64, 128, 256, 512, and 1024. The simulation findings differ from the theoretical ones as N decreases.

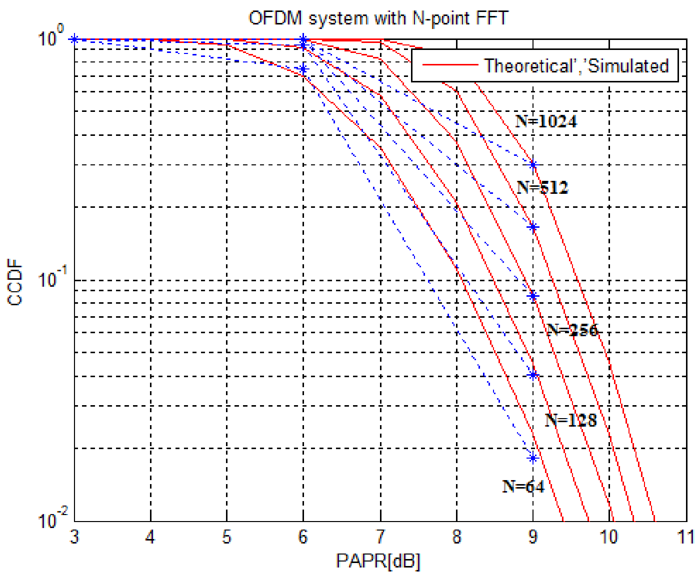

Figure 8. CCDFs of OFDM with different values of N

The PAPR for traditional OFDM data is greater than 11dB. After utilizing PTS, PAPR is lowered below 6dB. The PAPR is reduced by around 5dB. Therefore, PTS is particularly effective in lowering PAPR.

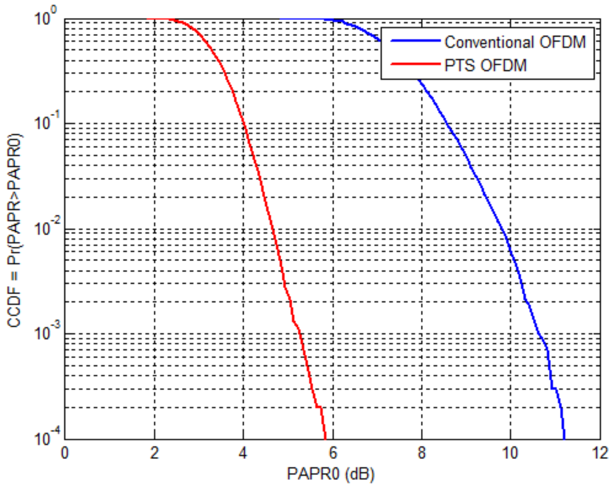

Figure 9. PAPR of OFDM using PTS

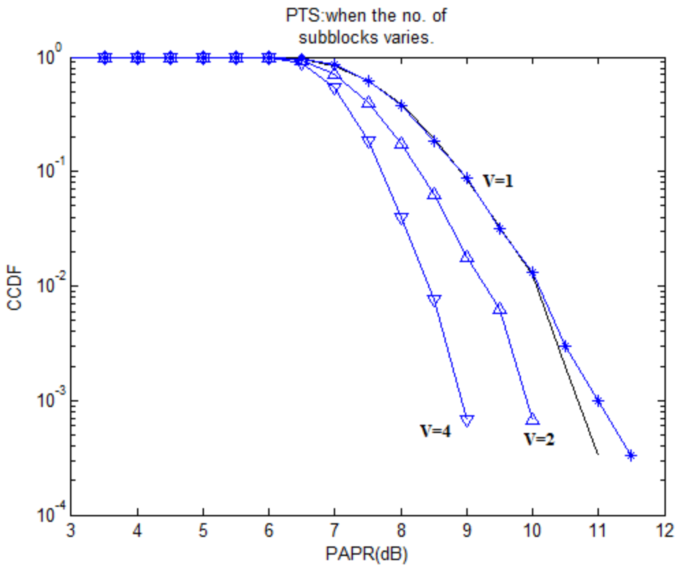

Figure 10. PAPR of a 16-QAM OFDM with PTS

The CCDF of PAPR for a 16-QAM OFDM system utilizing PTS is depicted in Figure 10. As the number of sub-blocks increases, the PAPR performance increases.

5. Conclusion

The PAPR reduction utilizing the PTS approach has been explored in this article. Several methods exist to minimize the PAPR in an OFDM. Each PAPR reduction method has benefits and drawbacks. The PAPR problem may be reduced substantially more effectively using PTS approach, which are demonstrated using graphs. The number of sub-blocks and the range of potential phase values determine the effectiveness of the PTS approach. As the number of sub-blocks increases, the PAPR of the OFDM signal can be greatly reduced. Theoretical analysis and results demonstrate that the PTS method may minimize PAPR more effectively and reduce the complexity.

References

[1] Karthik Kumar Vaigandla and Dr.N.Venu, "A Survey on Future Generation Wireless Communications - 5G : Multiple Access Techniques, Physical Layer Security, Beamforming Approach", Journal of Information and Computational Science, Volume 11 Issue 9,2021, pp. 449-474.

[2] Kommabatla Mahender, Tipparti Anil Kumar and K S Ramesh, "An Efficient FBMC Based Modulation For Future Wireless Communications," ARPN Journal of Engineering and Applied Sciences, VOL. 13, NO. 24, DECEMBER 2018, pp. 9526-9531

[3] Karthik Kumar Vaigandla, SandyaRani Bolla , RadhaKrishna Karne, "A Survey on Future Generation Wireless Communications-6G: Requirements, Technologies, Challenges and Applications", International Journal of Advanced Trends in Computer Science and Engineering, Volume 10, No.5, September - October 2021, pp.3067-3076, https://doi.org/10.30534/ijatcse/2021/211052021

[4] Karthik Kumar Vaigandla, Nilofar Azmi, Podila Ramya, Radhakrishna Karne, "A Survey On Wireless Communications : 6g And 7g," International Journal Of Science, Technology & Management, Vol. 2 No. 6 (2021): November 2021, pp. 2018-2025. https://doi.org/10.46729/ijstm.v2i6.379

[5] Sharanjit Kaur, Inderdeep Kaur Aulakh, "Analysis of PAPR Reduction Techniques in OFDM," International Journal of Computational Intelligence Research, Volume 13, Number 5 (2017), pp. 1097-1105

[6] Mahender, K., Kumar, T.A., Ramesh, K.S. (2019). Simple Transmit Diversity Techniques for Wireless Communications. In: Panigrahi, B., Trivedi, M., Mishra, K., Tiwari, S., Singh, P. (eds) Smart Innovations in Communication and Computational Sciences. Advances in Intelligent Systems and Computing, vol 669. Springer, Singapore. https://doi.org/10.1007/978-981-10-8968-8_28

[7] Karthik Kumar Vaigandla, Allanki Sanyasi Rao and Kallepelli Srikanth. Study of Modulation Schemes over a Multipath Fading Channels. International Journal for Modern Trends in Science and Technology 2021, 7 pp. 34-39. https://doi.org/10.46501/IJMTST0710005

[8] Kommabatla Mahender , Tipparti Anil Kumar , K.S Ramesh, "SER and BER Performance Analysis of Digital Modulation Scheme over Multipath Fading Channel," International Journal of Control Theory and Applications, Volume 10, Number 22, 2017, pp.81-91.

[9] Usha S.M, Mahesh H.B, "A new approach to improve the performance of OFDM signal for 6G communication," IJCNC 14(3):121-134 (2022) , https://doi.org/10.5121/ijcnc.2022.14308-121.

[10] K. K. Vaigandla, "Communication Technologies and Challenges on 6G Networks for the Internet: Internet of Things (IoT) Based Analysis," *2022 2nd International Conference on Innovative Practices in Technology and Management (ICIPTM)*, 2022, pp. 27-31, doi: 10.1109/ICIPTM54933.2022.9753990.

[11] C. Chen et al., "OFDM-Based Generalized Optical MIMO," in Journal of Lightwave Technology, vol. 39, no. 19, pp. 6063-6075, Oct.1, 2021, doi: 10.1109/JLT.2021.3095359.

[12] Karthik Kumar Vaigandla and B. J, Study and analysis of multi carrier modulation techniques – FBMC and OFDM, Materials Today: Proceedings, Volume 58, Part 1, 2022, Pages 52-56, https://doi.org/10.1016/j.matpr.2021.12.584

[13] Karthik Kumar Vaigandla , Dr.J.Benita, "Study and Analysis of Various PAPR Minimization Methods," International Journal of Early Childhood Special Education (INT-JECS), Vol 14, Issue 03 2022, pp.1731-1740.

[14] Niji Kuriakose,"PAPR ANALYSIS IN OFDM SYSTEMS USING PTS REDUCTION TECHNIQUE," International Journal of Engineering Trends and Technology (IJETT) – Volume 22 Number 2- April 2015, pp.61-65

[15] Kommabatla Mahender , Tipparti Anil Kumar , K.S Ramesh, "Performance Study of OFDM over Multipath Fading Channels for Next Wireless Communications," International Journal of Applied Engineering Research , Volume 12, Number 20 (2017) pp. 10205-10210

[16] Y. Xiao, Q. -s. Wen, X. Lei and S. -q. Li, "Improved PTS for PAPR Reduction in OFDM Systems," *The Third Advanced International Conference on Telecommunications (AICT'07)*, 2007, pp. 37-37, doi: 10.1109/AICT.2007.26.

[17] Karthik Kumar Vaigandla, J.Benita, "PRNGN - PAPR Reduction using Noise Validation and Genetic System on 5G Wireless Network," *International Journal of Engineering Trends and Technology*, vol. 70, no. 8, pp. 224-232, 2022. Crossref, https://doi.org/10.14445/22315381/IJETT-V70I8P223

[18] Nikhade, Vinayak P. and Kokate, Dr. Mahadev and Kharate, Dr. Gajanan, A review on analysis of PAPR and BER reductions in OFDM (February 25, 2022). Proceedings of the 3rd International Conference on Contents, Computing & Communication (ICCCC-2022)

[19] Karthik Kumar Vaigandla, Radhakrishna Karne, Allanki Sanyasi Rao, "Analysis of MIMO-OFDM: Effect of Mutual Coupling, Frequency Response, SNR and Channel Capacity", YMER Digital - ISSN:0044-0477, vol.20, no.10 - 2021, pp.118-126, 2021.

[20] Karthik Kumar Vaigandla, Dr.N.Venu, "Survey on Massive MIMO: Technology, Challenges, Opportunities and Benefits," vol. 20, no. 11 (Nov) - 2021, pp.271-282, 2021.

[21] H. F. Arrano and C. A. Azurdia-Meza, "OFDM: today and in the future of next generation wireless communications," *2016 IEEE Central America and Panama Student Conference (CONESCAPAN)*, 2016, pp. 1-6, doi: 10.1109/CONESCAPAN.2016.8075209.

[22] H. Chu and T. Shimamura, "A new PTS method for OFDM signals without side information based on constellation reshaping," *2016 Annual Conference on Information Science and Systems (CISS)*, 2016, pp. 216-221, doi: 10.1109/CISS.2016.7460504.

[23] Sohangjot Kaur Randhawa, Daljeet Singh Bajwa," PAPR Reduction in OFDM using PTS Technique," International Journal of Engineering Research & Technology, Vol. 6 Issue 07, July - 2017, pp.466-468

[24] Karthik Kumar Vaigandla and J.Benita (2022), Novel Algorithm for Nonlinear Distortion Reduction Based on Clipping and Compressive Sensing in OFDM/OQAM System. IJEER 10(3), 620-626. DOI: 10.37391/IJEER.100334.

[25] Karthik Kumar Vaigandla, Dr.N.Venu, "BER, SNR and PAPR Analysis of OFDMA and SC-FDMA," GIS Science Journal, Volume 8, Issue 9, 2021, pp.970-977