Indonesian Journal of Electrical Engineering and Computer Science
Vol. 26, No. 2, May 2022, pp. 888~894
ISSN: 2502-4752, DOI: 10.11591/ijeecs.v26.i2.pp888-894

Performance improvement on spectral efficiency and peak to avearge power reduction for 5G system

Kavitha Thandapani[1], Ganesamoorthy Raju[2], Maniganda Pujali[1]
[1]Department of Electronics and Communication Engineering, Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Chennai, India
[2]Department of Mechanical Engineering, Chennai Institute of Technology, Chennai, India

Article Info

Article history:

Received Jan 20, 2022
Revised Mar 12, 2022
Accepted Mar 23, 2022

Keywords:

5G
Discrete cosines transform precoding
Hyper multiple input multiple output
Peak to average power reduction
Spectral efficiency

ABSTRACT

Filter bank multicarrier with offset quadrature amplitude modulation (FMBC/OQAM) system which can offer higher data rate 1 Gbps and improved bandwidth efficiency because of not require of cyclic prefix (CP) to avoid interference from the adjacent channels compared to fourth generation (4G) orthogonal frequency division multiplexing (OFDM) and other wireless systems. Because of these advantages FBMC/OQAM are used in fifth generation (5G) technology. In this FBMC/OQAM system, bandwidth capacity will be further increased by using multiple input multiple output (MIMO) channel. But in our proposed scheme we can use hyper–MIMO channel, in which at base station (BS) more number of transmitting antennas are used that for the improve the spectral efficiency performance better than traditional MIMO channel. But the most important drawback of hyper MIMO FBMC/OQAM is the higher peak to average-power ratio (PAPR) that degrade overall system performance in 5G. In 4G technology, to reduce PAPR a number of techniques are used. In our proposed system we can use mu-law non-linear companding technique and precoding discrete cosine transform (DCT) to reduce PAPR value for multicarrier modulation system compare to other systems.

Corresponding Author:

Kavitha Thandapani
Department of Electronics and Communication Engineering
Vel Tech Rangarajan Dr. Sagunthala R&D institute of Science and Technology
No.42, Avadi-Vel Tech Road, Vel Nagar, Chennai, Tamil Nadu 600062, India
Email: drkavitha@veltech.edu.in

1. INTRODUCTION

The number of subcarriers in a wireless system are usually independent with each other but they are in same phase and may be aligned to produce constructive superposition that will produce the high values of envelope peaks. The huge power variation in the transmitted information signal is usually measured by PAPR parameter which is considered as severe problem in fifth generation (5G) systems. To decrease this peak to average-power ratio (PAPR) problem at 5G, many researcher are now using filter bank multicarrier with offset quadrature amplitude modulation (FBMC/OQAM) system [1], [2]. To higher the throughput value as well as increase the reliability of particular wireless system and for more coverage, multiple input multiple output (MIMO) system are used with FBMC/OQAM. At both the MIMO transmitter and receiver, a number of multiple antennas are used [3], [4]. FBMC/OQAM with MIMO is a one among the most promising technology in wireless system of 5G [5]–[7]. A new scheme discrete cosine transforms (DCT) precoding with non-linear mu-law companding which is applied to MIMO FBMC/OQAM model for improving the spectral efficiency and also the reduction in PAPR is proposed in this paper. At the end of this paper, simulation results of this MIMO FBMC/OQAM system for PAPR reduction will prove this proposed method is a one of the best method for 5G technology [8], [9].

2. PROPOSED METHOD
2.1. MIMO FBMC/OQAM system

The overall architecture of the introduced MIMO FBMC/OQAM system with DCT precoding and non-linear mu-law companding is showing in Figure 1. It consists of OQAM preprocessing, DCT precoding, IFFT, polyphase filter bank, and mu-law companding followed by multiple antennas [10]. This system transmitting OQAM symbols instead of transmitting quadrature amplitude modulation (QAM) symbol. Next the conversion from sequence of serial data to the sequence of parallel data is performed using serial-to-parallel (S/P) and then applied DCT block. Peak value of autocorrelation in the data sequence is the average power [11], [12]. So that an input sequence autocorrelation is to be reduced to decrease the PAPR value of FBMC-OQAM system before it enters into an IFFT.

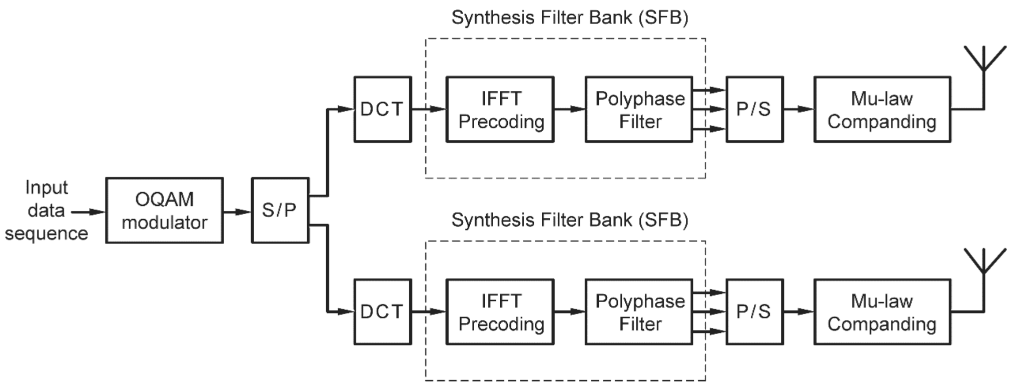

Figure 1. Proposed MIMO FBMC/OQAM system

In inverse fast Fourier transform (FFT), the baseband information stream I_n in the transform domain is converted into domain of time when Inverse FFT matrix M_k^H multiply with I_n. Then to get FBMC-OQAM signal finally it will be multiplied with polyphase filter coefficients P_n [13]. The FBMC-OQAM signal is now expressed as,

$$S[n] = \sum_{n=0}^{2N-1} I_n M_k^H P_n \quad (1)$$

before transmitting FBMC-OQAM signal s_n through the MIMO antennas, it fed through the nonlinear mu-law companding block for compression of the signal to improve spectral efficiency of the channel.

$$Y[n] = NC\{S[n]\} \quad (2)$$

In (2), $NC\{\quad\}$ represents the non-linear mu-law companding function of FBMC/OQAM signal. At the last stage of the transmitter, the signal y_n is transmitted by the multiple antennas through the additive white gaussian noise (AWGN) channel. In the AWGN channel, the signal y_n is corrupted by AWGN noise η_n.The receiver will receive the distorted signal r_n as,

$$r_n = y_n * h[n] + \eta_n \quad (3)$$

in (3) $h[n]$ represents AWGN channel impulse response [14]. At receiver, first for the expansion of FBMC/OQAM distorted signal, r_n the inverse mu-law companding function is applied as,

$$y_n^* = NC^{-1}[r_n] \quad (4)$$

the remaining processes are inverse operation of the transmitter.

3. RESEARCH METHOD

3.1. Spectral efficiency (SE) analysis of MIMO FMBC/OQAM

For FBMC/OQAM system which use SISO antennas, as per the Shannon capacity theorem its spectral efficiency is expressed [15], [16] as,

$$SE_{SISO} = W\, log_2\left(1 + \frac{S}{N}\right) \tag{5}$$

in (5), W is the bandwidth of system and $S/N$is a SNR of the received signal. When forward error coding (FEC) and M-QAM modulators are not present at that time only in (5) is valid. This spectral efficiency is better for FBMC/OQAM system when SNR increases, which equal to low SNR values of 4G-OFDM system [17]. Spectral efficiency of flat-fading MIMO FBMC/OQAM based on Shannon Capacity theorem is expressed as,

$$SE_{MIMO} = W \sum_{n=1}^{N} \quad log_2(1 + MT_{UE}\psi_n) \tag{6}$$

where, variable M denotes the total antenna numbers used in base station, N is number of user equipment (UE) in service at BS, T_{UE} is the UE transmitting power which may be considered as equal for all user of the system and ψ_n define the fading of large-scale for the n^{th} user. In (6) signal to noise ratio of MIMO is expressed by,

$$\left(\frac{S}{N}\right)_{MIMO} = MT_{UE}\psi_n \tag{7}$$

in (6) gives the relation between spectral efficiency and signal to noise ratio of MIMO system (M>>N).

3.2. MIMO PAPR measure in FBMC/OQAM system

By considering MIMO at FBMC/OQAM system, huge PAPR is a main drawback and it is defined as the high (or) maximum power of a FBMC/OQAM transmitting symbol and its average power [18], [19]:

$$PAPR = 10\, log_{10}\left[\frac{P_{t,peak}}{P_{t,avg}}\right] \tag{8}$$

then FBMC/OQAM signal PAPR is expressed by,

$$PAPRof\{S[n]\} = 10\, log_{10} \quad \frac{Max\{|S[n]|^2\}}{E\{|S[n]|^2\}} indB \tag{9}$$

in (9), $E\{.\}$ is an expectation operation. Consider a MIMO FBMC/OQAM system that use *'i'* transmitting antennas and *'j'* sub-carriers [20]. Then PAPR is expressed [12], [13] as,

$$[PAPR]_j = max[PAPR_1, PAPR_2 \ldots\ldots\ldots\ldots PAPR_M] \tag{10}$$

$[PAPR]_i$ defines the peak to average ratio of i^{th} transmitting antenna and it is as (11).

$$[PAPR]_i = PAPR\{S_i[n]\} = \frac{Max\{|S_i[n]|^2\}}{E\{|S_i[n]|^2\}} \tag{11}$$

3.3. DCT precoding

First FBMC/OQAM signal PAPR value is reduced by using DCT that is, autocorrelation value of the input data sequence is reduced [21], [22]. Mathematically, DCT applied to input data sequence I_n with the length of N is given as,

$$y_n = x(k) \sum_{n=0}^{N-1} I_m\, cos\left[\frac{\pi(2n+1)k}{2N}\right] k = 0,1,2 \ldots\ldots . N - 1 \tag{12}$$

in (12) N defines as total subcarriers used. $x(k)$ is the window function and as:

$$x(k) = \sqrt{\frac{1}{N}} ifk = 0 \tag{13a}$$

$$x(k) = \sqrt{\frac{2}{N}} ifk \neq 0 \tag{13b}$$

3.4. Non-linear mu-law companding

Finally, the FBMC-OQAM signal is converted into an analog signal that is to be transmitted through the AWGN channel, but before that it will be compressed by using nonlinear mu-law companding block to improve spectral efficiency and it is expressed [23], [24] as,

$$C(S[n]) = sgn(S[n])\frac{ln(1+Mu|S[n]|)}{ln(1+Mu)} \tag{14}$$

at receiver, compressed FBMC/OQAM signal is expanded by using function of inverse companding [25] that is, an opposite operation of the transmitter and it is as (15).

$$NC^{-1}[r_k] = sgn(r_k)\left(\frac{1}{M_u}\right)\left((1+M_u)^{|r_k|} - 1\right) \tag{15}$$

4. RESULTS AND DISCUSSION

The simulation results of our proposed system, shows that MIMO FBMC/OQAM system performance improvement. Figure 2 show that when antennas number increases in base station (BS), then the SNR of the FBMC/OQAM signal also increases. Because of this, the system spectral efficiency of MIMO FBMC/OQAM also improved compare SISO system.

Figure 3 shows that PAPR reduction using non–linear mu-law companding with various mu-law ratios. Here mu-law ratio value 500 gives the better PAPR reduction than others. Table 1 shows that the PAPR reduction in different schemes.

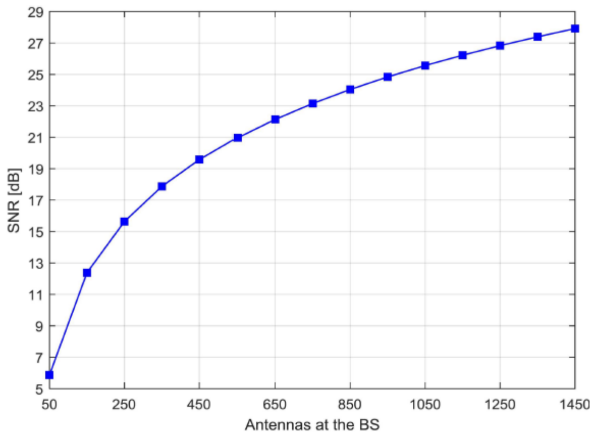

Figure 2. Average SNR in a MIMO system with multiple antennas at the BS

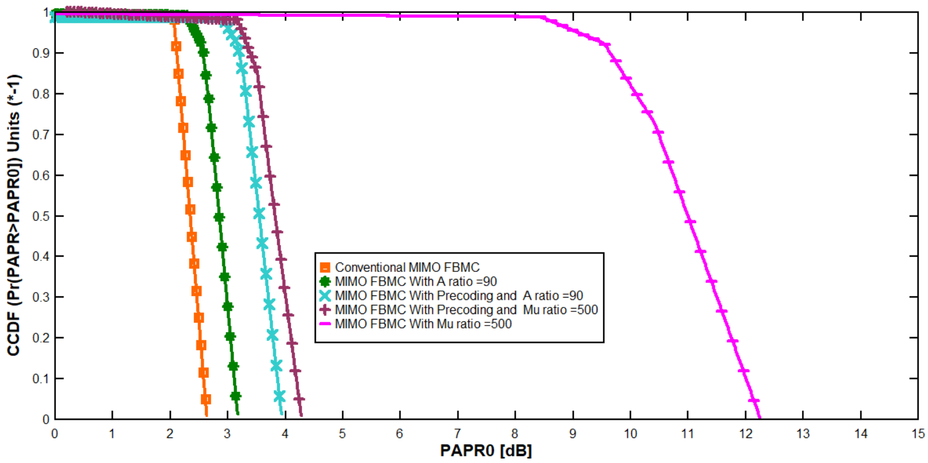

Figure 3. PAPR reduction in MIMO FBMC-OQAM with different mu-law ratio

Table 1. Reduction in PAPR of various existing models

Techniques	PAPR in dB
traditional MIMO and FBMC	12.7
MIMO–FBMC+a-law	4
MIMO–FBMC+mu-law	3.8
MIMO–FBMC+Precoding DCT+a-law	3.3
MIMO–FBMC+Precoding DCT+mu-law	2.8

Figure 4 shows the reduction in PAPR performance of MIMO FBMC/OQAM system using different schemes. Our proposed scheme MIMO FBMC/OQAM and precoding of DCT along mu-law companding gives low PAPR value that will be 2.8 dB, compare to other schemes. Figure 5 shows that bit error rate performance of MIMO FBMC-OQAM against SNR which is based on precoding of DCT along with mu-law scheme of companding and precoding of DCT with linear companding of a-law. It is mostly observed that the better bit error rate (BER) performance occurs with the use of precoding of DCT and mu-law companding.

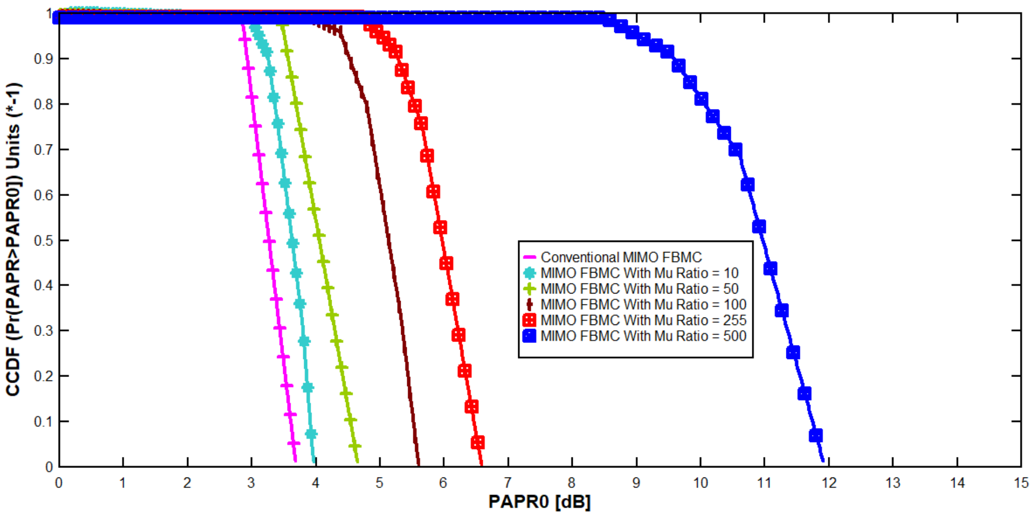

Figure 4. MIMO FBMC/OQAM PAPR reduction of different techniques

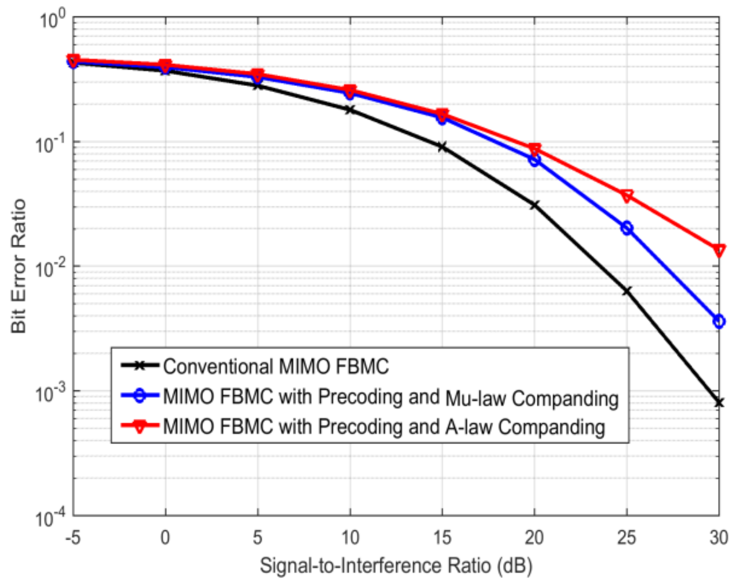

Figure 5. BER vs SNR of MIMO with FBMC/OQAM for different techniques

5. CONCLUSION

This research proposal, dealt with performance analysis of the proposed FBMC with OQAM based MIMO system concentrate mainly on the reduction of PAPR, Bit Error Rate performance and spectral efficiency by using DCT with non-linear mu-law companding. From our simulation results, we observe that our proposed system produces the low PAPR compared to other reduction PAPR techniques. In addition to this, performance of BER also analyzed in terms SNR that increasing the number antennas which is good compare to other techniques but our proposed system has acceptable complexity. This proposed system will be extended by using FEC concepts.

REFERENCES

[1] R. Nissel, S. Schwarz, and M. Rupp, "Filter bank multicarrier modulation schemes for future mobile communications," *IEEE Journal on Selected Areas in Communications*, vol. 35, no. 8, pp. 1768–1782, 2017, doi: 10.1109/JSAC.2017.2710022.

[2] I. A. Shaheen, A. Zekry, and F. Newagy, "Combined DHT precoding and a-law companding for PAPR reduction in FBMC/OQAM signals," *International Journal of Computing Academic Research (IJCAR)*, vol. 6, no. 2, 2017.

[3] S. J. Ku, "A low-complexity PTS scheme for PAPR reduction in SFBC MIMO-OFDM systems," *IEEE Vehicular Technology Conference*, 2014, doi: 10.1109/VTCFall.2014.6965817.

[4] Q. Duong and H. H. Nguyen, "Walsh-hadamard precoded circular filterbank multicarrier communications," *Proceedings - 2017 International Conference on Recent Advances in Signal Processing, Telecommunications and Computing, SigTelCom 2016*, 2017, pp. 193–198, doi: 10.1109/SIGTELCOM.2017.7849821.

[5] D. Zhang, M. Matthe, L. L. Mendes, and G. Fettweis, "A study on the link level performance of advanced multicarrier waveforms under MIMO wireless communication channels," *IEEE Transactions on Wireless Communications*, vol. 16, no. 4, pp. 2350–2365, 2017, doi: 10.1109/TWC.2017.2664820.

[6] K. N. R. S. V. Prasad, E. Hossain, and V. K. Bhargava, "Energy efficiency in massive MIMO-based 5G networks: opportunities and challenges," *IEEE Wireless Communications*, vol. 24, no. 3, pp. 86–94, 2017, doi: 10.1109/MWC.2016.1500374WC.

[7] F. K. Jose, L. H. Lolis, S. B. Mafra, and E. P. Ribeiro, "Spectral efficiency analysis in massive MIMO using FBMC-OQAM modulation," *Journal of Microwaves, Optoelectronics and Electromagnetic Applications*, vol. 17, no. 4, pp. 604–618, 2018, doi: 10.1590/2179-10742018v17i41544.

[8] F. Rottenberg, X. Mestre, F. Horlin, and J. Louveaux, "Single-tap precoders anddecoders for multiuser MIMO FBMC-OQAM under strong channel frequency selectivity," *IEEE Transactions on Signal Processing*, vol. 65, no. 3, pp. 587–600, 2017, doi: 10.1109/TSP.2016.2621722.

[9] S. A. Talele, A. G. Ambekar, and D. Hinger, "Improved PAPR reduction for STBC-MIMO-OFDM by using new phase factor with four transmitting," in *International Conference on Communication Technology (ICCT 2015)*, 2015, pp. 17–22.

[10] M. Mounir, M. B. El-Mashade, S. Berra, G. S. Gaba, and M. Masud, "A novel hybrid precoding-companding technique for peak-to-average power ratio reduction in 5g and beyond," *Sensors*, vol. 21, no. 4, pp. 1–22, 2021, doi: 10.3390/s21041410.

[11] I. Dey, D. Ciuonzo, and P. S. Rossi, "Wideband collaborative spectrum sensing using massive MIMO decision fusion," *IEEE Transactions on Wireless Communications*, vol. 19, no. 8, pp. 5246–5260, 2020, doi: 10.1109/TWC.2020.2991113.

[12] Y. Liu, Y. Wang, and B. Ai, "An efficient ACE scheme for PAPR reduction of OFDM signals with high-order constellation," *IEEE Access*, vol. 7, pp. 118322–118332, 2019, doi: 10.1109/ACCESS.2019.2936917.

[13] A. Singh, A. Jain, and P. Vyavahare, "A study of peak to average power ratio for different companding techniques in VLC-OFDM system," *2016 International Conference on Advances in Computing, Communications and Informatics, ICACCI 2016*, 2016, pp. 2390–2393, doi: 10.1109/ICACCI.2016.7732413.

[14] D. Agarwal, N. Sharan, M. P. Raja, and A. Agarwal, "PAPR reduction using precoding and companding techniques for OFDM systems," *Conference Proceeding - 2015 International Conference on Advances in Computer Engineering and Applications, ICACEA 2015*, 2015, pp. 18–23, doi: 10.1109/ICACEA.2015.7164696.

[15] X. Gao, W. Wang, X. G. Xia, E. K. S. Au, and X. You, "Cyclic prefixed OQAM-OFDM and its application to single-carrier FDMA," *IEEE Transactions on Communications*, vol. 59, no. 5, pp. 1467–1480, 2011, doi: 10.1109/TCOMM.2011.031611.100045.

[16] N. A. Mohammed, M. M. Elnabawy, and A. A. M. Khalaf, "PAPR reduction using a combination between precoding and non-linear companding techniques for ACO-OFDM-based VLC systems," *Opto-Electronics Review*, pp. 59–70, 2021, doi: https://doi.org/10.24425/opelre.2021.135829.

[17] A. Kumar and H. Rathore, "Reduction of PAPR in FBMC system using different reduction techniques," *Journal of Optical Communications*, vol. 42, no. 2, pp. 303–309, 2021, doi: 10.1515/joc-2018-0071.

[18] I. A. Shaheen, A. Zekry, F. Newagy, and R. Ibrahim, "Performance evaluation of PAPR reduction in FBMC system using nonlinear companding transform," *ICT Express*, vol. 5, no. 1, pp. 41–46, 2019, doi: 10.1016/j.icte.2018.01.017.

[19] F. Schaich, T. Wild, and R. Ahmed, "Subcarrier spacing - how to make use of this degree of freedom," in *2016 IEEE 83rd Vehicular Technology Conference (VTC Spring)*, 2016, pp. 1–6, doi: 10.1109/VTCSpring.2016.7504496.

[20] D. Madhavi and M. R. Patnaik, "Implementation of non linear companding technique for reducing PAPR of OFDM," *Materials Today: Proceedings*, vol. 5, no. 1, pp. 870–877, 2018, doi: 10.1016/j.matpr.2017.11.159.

[21] R. Nissel and M. Rupp, "Enabling low-complexity MIMO in FBMC-OQAM," in *2016 IEEE Globecom Workshops (GC Wkshps)*, 2016, pp. 1–6, doi: 10.1109/GLOCOMW.2016.7848888.

[22] M. Mounir, I. F. Tarrad, and M. I. Youssef, "Performance evaluation of different precoding matrices for PAPR reduction in OFDM systems," *Internet Technology Letters*, vol. 1, no. 6, p. e70, Nov. 2018, doi: 10.1002/itl2.70.

[23] M. Mounir, M. B. El_Mashade, and G. S. Gaba, "On the selection of the best MSR PAPR reduction technique for OFDM based systems," 2020, doi: http://dx.doi.org/10.1007/978-981-15-3075-3_11.

[24] K. Anoh, B. Adebisi, K. M. Rabie, and C. Tanriover, "Root-based nonlinear companding technique for reducing PAPR of precoded OFDM signals," *IEEE Access*, 2018, doi: 10.1109/ACCESS.2017.2779448.

[25] D. Romero and G. Leus, "Wideband spectrum sensing from compressed measurements using spectral prior information," *IEEE Transactions on Signal Processing*, vol. 61, no. 24, pp. 6232–6246, 2013, doi: 10.1109/TSP.2013.2283473.

BIOGRAPHIES OF AUTHORS

Dr. Kavitha Thandapani received her Bachelor of Engineering degree in ECE from Madurai Kamaraj University, Madurai, Tamilnadu, India in 1999. She obtained her Master Degree in Applied Electronics from Anna University, Chennai, Tamilnadu, India in 2004 and completed, Ph. D in Information Technology from Anna University, Chennai in 2014. Currently She is working as Professor in Veltech Rangarajan Dr. Sagunthala R & D Institute of Science and Technology, Chennai, Tamilnadu, India. Her research interests are Modeling of Multigate MOSFETs, Optical Networking, Wireless communication, VLSI. She can be contacted at email: drkavitha@veltech.edu.in.

Ganesamoorthy Raju received his Bachelor of Engineering degree in Mechanical from Madurai Kamaraj University, Madurai, Tamilnadu, India in 1995. He obtained Master Degree in Engineering Design from Bharathiar University, Coimbatore, Tamilnadu, India in 2000 and completed PhD in Mechanical Engineering from Anna University, Chennai in 2017. Currently, he is working as Professor at Chennai Institute of Technology, Chennai, Tamilnadu, India. His research interests are Mechanical Engineering, Composite Materials, Optimization Techniques, Robotics Engineering, Vibration Analysis and Machine Design. He can be contacted at email: ganesamoorthy72@gmail.com.

Mr. Maniganda Pujali received his Bachelor of Technology degree in ECE from Sri Venkatesa Perumal College of Engineering and Technology Puttur, Chittoor District Andhrapradesh India in 2008. He obtained his Master of Engineering in Sree Sastha Institute of Engineering and Technology in Chembarapakkam Chennai Tamilnadu India in 2010 he Persuing Ph.D in 5G Technology in Veltech Rangarajan. Dr. Sagunthala R&D Institute of Science and Technology Chennai Tamilnadu India Under the Esteemed guidence of Dr.Kavitha Thandapani. His research interest are Wireless communication, Network on chip, VLSI, System on Chip. He can be contacted at email: maniganda.1986@gmail.com.