

PAPER • OPEN ACCESS

Implementation of Particle Swarm Optimization and Genetic Algorithms to Tackle the PAPR Problem of OFDM System

To cite this article: A Abdalmonam *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **767** 012030

View the [article online](#) for updates and enhancements.

You may also like

- [Peak-To-Average Power Ratio Reduction in Polar Coded OFDM Signal in WIMAX Architecture](#)
Mr. B. Vinodh Kumar and Ms. C. Kalaiyarasi
- [PAPR and BER analysis of coded FBMC-QAM system with non-linear companding techniques](#)
Anam Mobin and Anwar Ahmad
- [Performance Improvement of OFDM System Using New Scrambling Technique with Precoded Methods](#)
Muntadher Kadhim Abdullah and Ali Jawad Ibada



The Electrochemical Society
Advancing solid state & electrochemical science & technology



249th
ECS Meeting
May 24-28, 2026
Seattle, WA, US
Washington State
Convention Center

Spotlight Your Science

**Submission deadline:
December 5, 2025**

SUBMIT YOUR ABSTRACT

Implementation of Particle Swarm Optimization and Genetic Algorithms to Tackle the PAPR Problem of OFDM System

A Abdalmunam¹, MS Anuar¹, MN Junta¹, NM Nawawi¹, A Noori¹

¹School of Computer and Communication, University Malaysia Perlis, Malaysia

Corresponding author: 1988aymen7@gmail.com

Abstract. A multi-carrier modulation technique, which represented in this paper as orthogonal-frequency-division-multiplexing (OFDM), ensured wireless high-speed data transmission. The transmission of modulated symbols uses a large number of subcarriers in the OFDM system. Consequently, the OFDM signals have an extended dynamic range, or a high output power peak envelope fluctuation or high PAPR. To mitigate the PAPR, in this paper, we implement two algorithms to reduce the output power envelope fluctuation of the OFDM system, namely PSO and GA. Also, the PTS method and PAPR in OFDM systems difficulty described briefly. We present an OFDM system through the use of conventional PTS based on PSO and GA. The simulation result shows that both evolutionary approaches outperform the conventional PTS OFDM in-terms of reducing the Peak-to-Average-Power-Ratio (PAPR). Furthermore, the performance of the PSO algorithm is found to be better than GA in-terms of its simplicity and the time execution. On the other hand, the GA algorithm outperforms the PSO and the conventional OFDM, in terms of the PAPR reduction.

1. Introduction

The digital world of today filled with wireless devices that facilitate humanity's daily life. The convenience run by wireless technology leads to a rapid increase in the number of people who are simultaneously aware of and actively using the technology. These increasing numbers of active users result in high demand for quality services and wireless broadband services[1, 2] such as High-definition television, high-speed internet, mobile video, and video conferencing. Orthogonal-frequency-division-multiplexing (OFDM) is one of the standard transmission techniques for multi-carriers, is a simple and efficient wideband communication solution, because unlike single carrier transmission systems, the channel divided into subchannels for parallel data transmission with longer symbol durations. which transforms the selective frequency fading channel into a flat fading channel and, further can encapsulate the dilemma of inter-symbol interference (ISI) estimation [3, 4]

The high dynamic range or high output power envelope fluctuation which is represented as a peak-to-average-power-ratio (PAPR) is the most common OFDM restricted problem that degrade the efficiency of OFDM system to overcome this drawback need to transmit high power amplifier (HPA) to cover non-linear signal which causes signal distorted that negatively effects on battery lifetime, to solve the above mentioned problem, several method had been proposed such as, clipping and filtering[5], iterative clipping[6], companding [7], coding[8], interleaved[9], tone-reservation[10], tone-injection [11], active-constellation-extension[12], selective-mapping(SLM)[13], partial-transmit-sequence (PTS) [14]. All these methods have



a trade-off between the PAPR, BER, and computational complexity. In the OFDM system, PTS is the most effective technique for reducing PAPR with the lowest distortion.

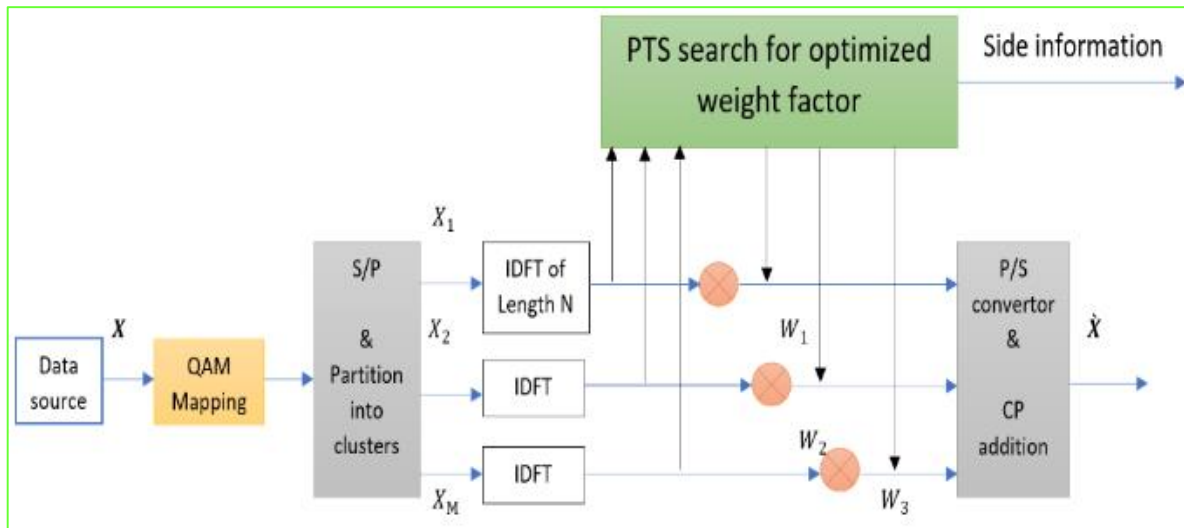


Figure1. the transmitter of PTS-OFDM

PTS is a non-distortion arrangement in which the data block inputs divided into several disjointed sub-blocks, and the IFFT performed. These IFFT sub-block outputs are weighted or scrambled by several rotation factors, which are totaled to create different candidate signals. Ultimately, the minimum PAPR signal is chosen for transmission[15], as in fig(1). As long as a PTS needs to implemented, complexity must taken into account which is a substantial parameter in the transmitter because it raises exponentially with the quantity of subsequence, for this reason, the vector's rotation should be limited to a set of finite number of element PTS is weakened by high computational complexity [16] that results from thoroughly searching for candidate signals and additionally needs data regarding rotation factors to be sent to the receiver as a side information.

In the literature PSO-PTS of OFDM system proposed in [17] by Wen, Horng et al. uses heuristics to search for the optimum integration of low-complex phase factors, got lessen of computational complexity but PAPR slightly high. The authors in [18] Presented an OFDM system that uses a sub-optimal PTS method anchor on PSO for finding optimal phase weighting factors got quite a good result in term of PAPR and complexity but a low number of iteration. Also, in [19], they worked on PTS-OFDM method, which Presented a new approach to overcoming computational complexity based on PSO, the output of approached near to be accomplished but with the trade of PAPR. According to the combination of GA-PTS with a partheno-crossover operator (PCGA), the least PAPR got, but the complexity load still a bit high[20]. Further the GA and PSO algorithms in PTS-OFDM compared and conclude that the GA is giving PAPR reduction but with the expense of computational complexity and vice versa in PSO [21, 22]. There is another algorithm called fireworks algorithm (FWA) that outperformed the above two algorithms the reader may read [23] for more information. It proposed that many evolutionary PTS-based optimization algorithms for reducing search numbers, which are particle swarm optimization (PSO) and genetic algorithm (GA)[21]. In this paper, the comparison of these two algorithms illustrated clearly especially of two notorious parameters of OFDM that are PAPR and computational complexity. Also a numerical comparison for which method resulted in better PAPR

The rest of this paper organized as follows: firstly, the introduction of OFDM and its drawback is explained, and the next described the PAPR of the OFDM-PTS signal, then implementing PSO in PTS-OFDM is discussed, also illustrate the GA. Finally, before the conclusion, we explained the simulation result of PAPR reduction.

2. PAPR of the OFDM-PTS signal

The high-rate binary input data sequence on the transmitter of the OFDM technique is mapped to complex symbols using a modulation structure such as QAM, which simulated in this paper. To produce a block vector with complex symbols valued, $X = \{X_k\}_{k=0}^{N-1} = [X_0, X_1, \dots, X_{N-1}]^T$. The symbols are divided and simultaneously transmitted to low-rate with N subcarriers, where each symbol modulates one set of the subcarriers. Then each length N grouped then fed into the IFFT module, the signal of an OFDM gotten by adding all the autonomously modulated sub-carriers at the IFFT block output. The signal of OFDM transmitted using a discrete-time complex envelope defined as in (1).

$$x[n] = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} x_k e^{\frac{j2\pi nk}{LN}}, 0 \leq N \leq LN - 1 \quad (1)$$

Where N represents a subcarrier number (IFFT size), x_k is the n^{th} complex symbol carried and conveyed by the k^{th} subcarrier, the factor of oversampling represents as L that equal four ($L=4$) in OFDM signals to get an efficient, accurate value of estimating PAPR in discrete-time compared to the continuous-time. The large subcarrier in the time-domain causes significant output power envelope fluctuation, which know as the peak-to-average-power-ratio (PAPR) parameter. PAPR described as the ratio between the supreme power of the transmitter and its average that happened after the IFFT block executed. It can define as

$$P_{X(N)}(dB) = PAPR = \frac{P_{peak}}{P_{average}} = 10 \log_{10} \frac{\max[(x_n)^2]}{E[(x_n)^2]} \quad (2)$$

The PAPR reduction efficiency is calculated through Complementary Cumulative Distribution Function (CCDF) [24]:

$$p_r(PAPR > z) = 1 - p_r(PAPR \leq z) = 1 - (1 - e^{-z})^k \quad (3)$$

3. PSO Based PTS-OFDM

Kennedy and Eberhart established an evolutionary computing technique in [25] that is a PSO algorithm by simulated a random movement of a bird's bunch. We implement the PSO algorithm to mitigate high peak power fluctuation with lower computational-complexity in the PTS technique of an OFDM system. The phase factor of large space represents every value in a dimension as a factor. A factor's set can be a point or place in space [19]. A sequence of the least PAPR represented by the best place. PSO algorithm initializes a particle, which is an incipient population of solutions. Every particle is a point in the space of M dimensions (M is the sub-block number of PTS). Any particle has phase vector M , which is a vector element chosen from phase vectors. Particles fly in space to search on the best place, and the position of the particle modified depends on the relationship between each other [26]. Moreover, the points occur meanwhile searching on the local and global optimization. Eventually, all particles coverage to optimal location, which is the ability to discover causes particles to find the sequence of phase vectors. Briefly, The PTS technique can be applied by altering the optimization for block W appropriately. The first goal of PTS that comes by a weighted combination of N sub-block written as

$$X' = \sum_{i=1}^M W_i X_i, W_i = e^{j\theta_i} \quad (4)$$

The factor of phase weighted limited within $[0, 2\pi]$ where $W_i, i=1, 2, \dots, M$. Generally, the selection of phase weighting factors (W) is limited to a finite set of elements to reduce the complexity search. The second important goal is to reduce the PAPR of X' by chose $W = W_1, W_2 \dots, W_i$ and the optimum of OFDM symbol parameter

$$\hat{W} = \arg W_{\min} \left\{ \max \left| \sum_{i=1}^M W_i X_i \right| \right\} \quad (5)$$

The population, in this context, pointing to swarm and the individuals pointing to particle, resembling the swarm social behavior, which clearly explained in [27, 28]. The PSO procedures optimization based on a populace of particles flying with dynamic velocity in the solution space according to their own experience of flying and the best experience of flying among the swarm. Each possible solution pointed as swarm with a position vector x , during the process of PSO, which is referred respectively as a phase weighting factor (W) and velocity (V). Therefore, the K -dimensional optimization and the i^{th} a particle of position and velocity respectively represented as $W_i = (W_{i,1}, W_{i,2}, \dots, W_{i,K})$ and $V_i = (V_{i,1}, V_{i,2}, \dots, V_{i,K})$. Every particle has its best position $W_i^P = (W_{i,1}, W_{i,2}, \dots, W_{i,K})$. Corresponds to the best individual objective value obtained in time t , referred to as $pbest$ and $W^G = (W_{g,1}, W_{g,2}, \dots, W_{g,K})$ denoted as a global best particle ($gbest$), which represents the optimal particle detected at a time t in entire swarm. The equation below had been structured to update the velocity for particle i .

$$V_i(t+1) = wv_i + c_1r_1V_i(t+1) = (W_i^P(t) - W_i(t)) + c_2r_2(W^G(t) - W_i(t)) \quad (6)$$

Further, the new position of a particle calculated according to the subsequent equation based on the updated velocities

$$W_i(t+1) = W_i(t) + V_i(t+1) \quad (7)$$

Where the initial velocity of particle i at time t represented in (6) as $v_i(t)$. The new velocity is associated with the weight w of the old velocity and also with the particle's position and that of the global best velocity by acceleration factors of c_1 and c_2 . Therefore those acceleration factors are denoted as cognitive and social relates respectively; these weighting factors are pulling individual particle toward the $pbest$ and $gbest$ positions. The inertial weight w is used to manipulate the impact of the previous velocity history on the current velocity. Generally, the suitable value of $w(t)$ provides the desired balance between the globe and the swarm's ability of local exploration. The particle populations then moved by the new velocity and locations calculated by (6,7) Tend from different directions to cluster together. Thus, the assessment of each associated fitness of the new particle population begins again. Further, in this paper, we set the particle swarm size is 30 with 1000 iterations, and the acceleration coefficient (c_1, c_2) is (1,3), respectively. The flow chart of PSO portrayed below.

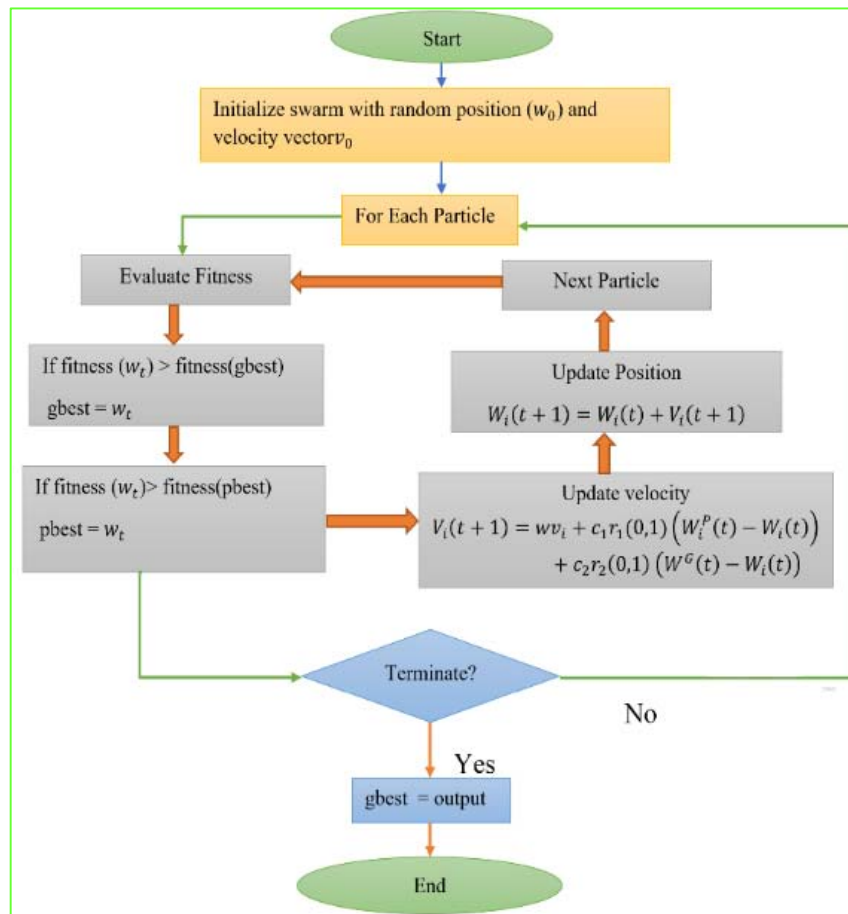


Figure2. Block diagram of the PSO algorithm

4. GA Based PTS-OFDM

John Holland introduced the Genetic Algorithm in the United States in the 1970s. The fundamental ideas of the algorithm are natural selection and genetic inheritance[29]. GA is Focusing on finding a suitable phase factor to diminish PAPR. Hence, the evaluation function defined in order to increase the value of the evaluation function as the PAPR decreases. This algorithm initially picks the random population defined as a chromosome, which is then the chosen value multiplied by a set of phase factors leading to the calculation of PAPR. Each chromosome's fitness value can be calculated by

$$F(ya(t)) = \frac{1}{10 \log_{10} PAPR(ya(t))} \quad (8)$$

Candidates are chosen for the generation of additional chromosomes for the subsequent population according to the calculated fitness value of each chromosome[30]. The crossover procedure is carried out by selecting a crossover point for the chromosomes of the parent. For both chromosomes, the whole process is repetitive and adding new offspring to the population. Some of their genes mutated in some new offspring formed, i.e., Some of the bits inverted in the bitstream. The best fit the chromosome selected as the desired object among the current survivors. Further we set the simulation of GA by giving the population size is 30, and consequently, the mutation and cross over are 0.001, single point, respectively. The process step of GA portrayed below.

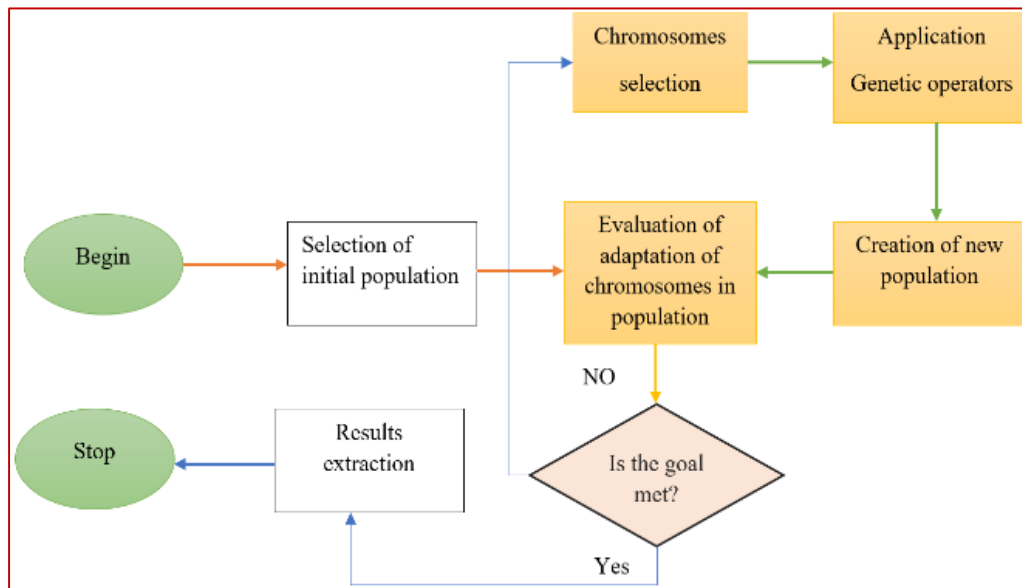


Figure3. Flowchart of genetic algorithm steps

Table 1. Previous studies

Ref.	OFDM technique	Brief description	Advantage	Drawback
[17]	PTS	Heuristics search of optimum combination used as a proposed PSO scheme to get low complex phase factors	Got lower complexity than the optimum method	PAPR slightly high
[21]	Comparison of GA and PSO OFDM	Adaptive subcarrier and bit allocations were applied to GA and PSO to minimize the overall transmit power of an OFDM multi-user system.	PSO better than GA in term of coding capability, execution time, simplicity and computational resource	PSO takes higher power while GA got better PAPR reduction
[18]	PTS-OFDM	Presented an OFDM system that uses a sub-optimal PTS method based on particle swarm optimization (PSO) to find optimal phase weighting factors	Got power reduction same as the optimal PTS with low complexity	Computation complexity is direct proportionally with iterations
[19]	PTS-OFDM	Presents a new approach to overcoming computational complexity based on PSO	Got lower complexity	The PAPR of the proposed method is higher than compared exhaustive search

[23]	FWA-PTS in OFDM	Suggested a reduced computational complexity in fireworks algorithm (FWA) PTS-OFDM bases to mitigate PAPR	Got minimum complexity	PAPR Does not reduce
[22]	GA-PTS, PSO, PTS, ABC-PTS A, and BBO-PTS	Described the PAPR reduction technique for reducing various computational, time, and space complexity factors, thereby making the system more optimized.	GA outperformed PSO, and another optimization in lessening PAPR and PSO is easier to implement and has fewer components	Got higher complexity compared to another mentioned optimization
[20]	GA-PTS using PCGA	uses a two-stage crossover operator and a mutation operator to generate the offspring and selects the appropriate offspring candidates for the new population	Got least PAPR than conventional GA-PTS	Still complexity load slightly high

5. Simulation Result

In this section, partial swarm optimization and the genetic algorithm have been studied extensively along with conventional PTS-OFDM features. The channel has assumed here is an additive white Gaussian noise (AWGN). Computer simulations conducted for 2048 as a number of a subchannel to run a 32-QAM PTS-OFDM system with $N = 64$ and Number of Monte-Carlo Iterations=100 iterations. The simulations have done with different numbers of initial population and swarms. Further, every algorithm iterated 100 times. Performance metrics for conducting a comparative evaluation between GA-PTS and PSO-PTS are considered PAPR and computational complexity as metrics; the simulation shows that GA needs more time to converge here than PSO in all cases. Also, the computational complexity GA more than PSO but it is outperformed PSO in terms of PAPR reduction as shown in fig 4. the complementary cumulative distribution function (CCDF) at 0.1 dB almost got the same PAPR but at 0.001dB GA got more power to lessen. Moreover, those two algorithms are remarkably outperforming the original PTS-OFDM.

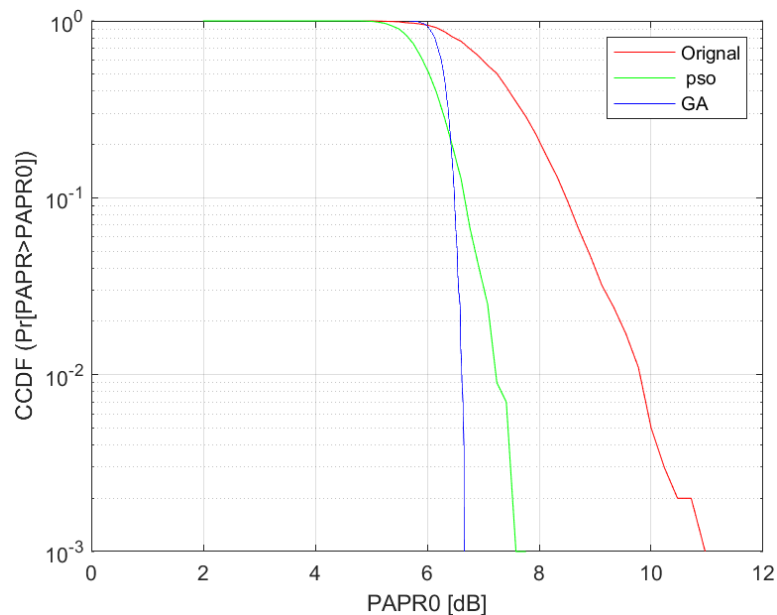


Figure4. comparison of PAPR using two optimizations and the original PTS-OFDM

6. Conclusion

The PAPR reduction performance of the PTS technique has been analyzed in this paper. The PTS search for phase rotation factors was simulated by a comprehensive search to obtain the optimal combination of phase factors, we have seen, whenever the number of sub-blocks increased the searching for complexity exponential increased as well. To overcome this challenge, we used GA and PSO algorithms to get optimum phase rotation factor with low complexity. The simulation result of implemented algorithms gives a practical approach to the trade-off between PAPR reduction and computational complexity. Further, GA remarkably gives higher performance in-term of PAPR lessen than PSO and conventional PTS, but the computational complexity of PSO notably lower than GA and the execution time as well.

7. Recommendation

Both of the evolutionary approaches outperform the conventional PTS. We can develop these algorithms to get better results by integrating or hybrid upcoming algorithms with these approaches. Further, the improvement of the PAPR lessen of GA and PSO-PTS in OFDM is still active research.

8. References

- [1] D. Tse and P. Viswanath, *Fundamentals of wireless communication*: Cambridge university press, 2005.
- [2] R. Prasad, *OFDM for wireless communications systems*: Artech House, 2004.
- [3] I. G. Muhammad, K. E. Tepe, and E. Abdel-Raheem, "QAM equalization and symbol detection in OFDM systems using extreme learning machine," *Neural Computing and Applications*, vol. 22, pp. 491-500, 2013.
- [4] N. Taşpınar and Ş. Şimşir, "Pilot tones design using particle swarm optimization for OFDM-IDMA system," *Neural Computing and Applications*, pp. 1-10, 2018.
- [5] V.-N. Tran, "Hybrid scheme using modified tone reservation and clipping-and-filtering methods for peak-to-average power ratio reduction of OFDM signals," *Signal Processing*, vol. 158, pp. 166-175, 2019.
- [6] X. Zhu, W. Pan, H. Li, and Y. Tang, "Simplified approach to optimized iterative clipping and filtering for PAPR reduction of OFDM signals," *IEEE Transactions on Communications*, vol. 61, pp. 1891-1901, 2013.

- [7] S. Jiang, H. Deng, W. Xiao, and J. Du, "New nonlinear companding technique to decrease peak to average power ratio of the optical orthogonal frequency division multiplexing system based on Hartley transform," *Optical Engineering*, vol. 54, p. 106112, 2015.
- [8] M. Peng, M. Chen, H. Zhou, Q. Wan, L. Jiang, L. Yang, et al., "Hybrid PAPR reduction scheme with Huffman coding and DFT-spread technique for direct-detection optical OFDM systems," *Optical Fiber Technology*, vol. 40, pp. 1-7, 2018.
- [9] S.-y. Zhang and B. Shahrava, "A Selected Mapping Technique Using Interleavers for PAPR Reduction in OFDM Systems," *Wireless Personal Communications*, vol. 99, pp. 329-338, 2018.
- [10] T. Jiang, C. Ni, C. Ye, Y. Wu, and K. Luo, "A novel multi-block tone reservation scheme for PAPR reduction in OQAM-OFDM systems," *IEEE Transactions on Broadcasting*, vol. 61, pp. 717-722, 2015.
- [11] W. Wang, M. Hu, Y. Li, and H. Zhang, "A low-complexity tone injection scheme based on distortion signals for PAPR reduction in OFDM systems," *IEEE Transactions on Broadcasting*, vol. 62, pp. 948-956, 2016.
- [12] S.-H. Wang, W.-L. Lin, B.-R. Huang, and C.-P. Li, "PAPR reduction in OFDM systems using active constellation extension and subcarrier grouping techniques," *IEEE Communications Letters*, vol. 20, pp. 2378-2381, 2016.
- [13] D. Mestdagh, J. G. Monsalve, and J.-M. Brossier, "GreenOFDM: a new selected mapping method for OFDM PAPR reduction," *Electronics Letters*, vol. 54, pp. 449-450, 2018.
- [14] M.-J. Hao and P.-H. Huang, "Pilot assignment for PTS-OFDM with channel estimation for PAPR reduction," in *Intelligent Signal Processing and Communication Systems (ISPACS), 2016 International Symposium on*, 2016, pp. 1-6.
- [15] Y. Rahmatallah and S. Mohan, "Peak-to-average power ratio reduction in OFDM systems: A survey and taxonomy," *IEEE communications surveys & tutorials*, vol. 15, pp. 1567-1592, 2013.
- [16] Y. Polyanskiy and Y. Wu, "Peak-to-average power ratio of good codes for Gaussian channel," *IEEE Transactions on Information Theory*, vol. 60, pp. 7655-7660, 2014.
- [17] J.-H. Wen, S.-H. Lee, Y.-F. Huang, and H.-L. Hung, "A suboptimal PTS algorithm based on particle swarm optimization technique for PAPR reduction in OFDM systems," *EURASIP Journal on wireless communications and networking*, vol. 2008, p. 14, 2008.
- [18] H.-L. Hung, Y.-F. Huang, C.-M. Yeh, and T.-H. Tan, "Performance of particle swarm optimization techniques on PAPR reduction for OFDM systems," in *2008 IEEE International Conference on Systems, Man and Cybernetics*, 2008, pp. 2390-2395.
- [19] M. H. Aghdam and A. A. Sharifi, "PAPR reduction in OFDM systems: An efficient PTS approach based on particle swarm optimization," *ICT Express*, 2018.
- [20] H. Liang, Y.-R. Chen, Y.-F. Huang, and C.-H. Cheng, "A modified genetic algorithm PTS technique for PAPR reduction in OFDM systems," in *2009 15th Asia-Pacific Conference on Communications*, 2009, pp. 182-185.
- [21] I. Ahmed and S. P. Majumder, "Adaptive resource allocation based on modified genetic algorithm and particle swarm optimization for multiuser OFDM systems," in *2008 International Conference on Electrical and Computer Engineering*, 2008, pp. 211-216.
- [22] A. Joshi, A. Garg, E. Garg, and N. Garg, "PAPR Reduction Analysis of OFDM Systems Using GA-, PSO-, and ABC-Based PTS Techniques," in *Advances in Signal Processing and Communication*, ed: Springer, 2019, pp. 145-155.
- [23] A. Lahcen, H. Mustapha, E. Ali, A. Saida, and A. Adel, "Peak-to-Average Power Ratio Reduction Using New Swarm Intelligence Algorithm in OFDM Systems," *Procedia Manufacturing*, vol. 32, pp. 831-839, 2019.
- [24] F. Sandoval, G. Poitau, and F. Gagnon, "Hybrid peak-to-average power ratio reduction techniques: Review and performance comparison," *IEEE Access*, vol. 5, pp. 27145-27161, 2017.
- [25] R. Eberhart and J. Kennedy, "A new optimizer using particle swarm theory," in *MHS'95. Proceedings of the Sixth International Symposium on Micro Machine and Human Science*, 1995, pp. 39-43.
- [26] M. Miyatake, M. Veerachary, F. Toriumi, N. Fujii, and H. Ko, "Maximum power point tracking of

- multiple photovoltaic arrays: A PSO approach," IEEE Transactions on Aerospace and Electronic Systems, vol. 47, pp. 367-380, 2011.
- [27] P. A. Abdulla, S. Aronis, M. F. Atig, B. Jonsson, C. Leonardsson, and K. Sagonas, "Stateless model checking for TSO and PSO," Acta Informatica, vol. 54, pp. 789-818, 2017.
- [28] F. Marini and B. Walczak, "Particle swarm optimization (PSO). A tutorial," Chemometrics and Intelligent Laboratory Systems, vol. 149, pp. 153-165, 2015.
- [29] Y. Kohama, T. Takada, N. Kozawa, and A. Miyamura, "Collapse analysis of rigid frame by genetic algorithm," WIT Transactions on The Built Environment, vol. 31, 1970.
- [30] S.-S. Kim, M.-J. Kim, and T. A. Gulliver, "A new PTS for PAPR reduction by local search in GA," in The 2006 IEEE International Joint Conference on Neural Network Proceedings, 2006, pp. 2370-2373.

Acknowledgments

The author would like to acknowledge the support from the Fundamental Research Grant Scheme (FRGS) under a grant number of *FRGS/1/2017/ICT03/UNIMAP/02/3* from the Ministry of Higher Education Malaysia.