TELKOMNIKA Telecommunication, Computing, Electronics and Control
Vol. 18, No. 4, August 2020, pp. 1843~1848
ISSN: 1693-6930, accredited First Grade by Kemenristekdikti, Decree No: 21/E/KPT/2018
DOI: 10.12928/TELKOMNIKA.v18i4.15703

UFMC system performance improvement using RS codes for 5G communication system

Ghasan Ali Hussain[1], Lukman Audah[2]
[1]Department of Electrical Engineering, Faculty of Engineering.University of Kufa, Iraq
[1,2]Wireless and Radio Science Centre (WARAS), Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, Malaysia

Article Info

Article history:

Received Jan 30, 2020
Revised Mar 17, 2020
Accepted Mar 30, 2020

Keywords:

OFDM
OOBE
PAPR
RS
UFMC

ABSTRACT

Fifth generation (5G) mobile communication is expected to be deployed in several countries by 2020. Where, the data consumptions are expected to be increased to 30% thus, it cannot be supported by the present technologies 3G and 4G. In contrast, looking for new alternative modulation techniques of orthogonal frequency division modulation (OFDM) system which is suffering from high peak to average power ratio (PAPR) and out of band (OOB) side lobes are needed to use in 5G communication system. Hence, universal filtered multi-carrier (UFMC) is considered as alternative waveform to overcome of OFDM disadvantages. In communication systems, channel coding is considered vital part, where error correction codes (ECC) are used to detect and correct the errors which is occurring in channel noise. In this paper, RS codes are suggested with UFMC system to achieve the reliability of information transmission over noisy channels. The results showed that although, the values of PAPR levels for using RS codes in UFMC increased to 8.8653dB against 6.9735 dB for OFDM system. However, there are significant improvements in BER performance owing to use RS codes against uncoded-UFMC system. Furthermore, the values of OOB in UFMC system was lower than OFDM system.

Corresponding Author:

Lukman Audah,
Faculty of Electrical and Electronic Engineering,
Universiti Tun Hussein Onn Malaysia,
Parit Raja, 86400 Batu Pahat, Johor, Malaysia.
Email: hanif@uthm.edu.my

1. INTRODUCTION

With increasing the demand for Gbps data rate and combination between users and applications, a new fifth generation (5G) radio propagation technology is considered a significantly needed in future wireless network [1]. Where, it is expected that 5G communication technology could provide higher reliability, better security, faster and larger communication capacity [2]. 5G mobile communication is expected to be deployed in several countries by 2020. Where, the data consumptions are anticipated to be increased to 30% thus, it cannot be supported by the present technologies 3G and 4G. So, it is necessary to rollout 5G wireless communication system to be take a place in all around of the world [3, 4]. Compared to other generations, it could be offering higher data rate, it also dealing with increasing number of terminals and uncounted emerging applications with several requirements [5].

Nowadays, orthogonal frequency division multiplexing (OFDM) is considered a major data transmission technique in wireless communication systems, due to its immunity against inter-symbol interferences (ISI) and multipath fading thus, the modern advancements make the OFDM is highly famous technology. Hence, it is utilized in IEEE802.11 (WI-FI) networks and fourth generation (4) LTE/LTE-A [6]. Although, OFDM have all these advantages but, it is suffering from Peak to Average Power Ratio (PAPR) which caused low power amplifirer efficiency and increase the consumption of battery. In contrast, OFDM has another disadvantage namely high out-of-band (OOB) side lobes which resulted of lower spectral efficiency. So, looking for new modulation techniques which are able to overcome some of these disadvantages are needed to use in 5G communication system [7].

In the other hand, multi carrier transmission method namely universal filtered multi-carrier (UFMC) has been suggested in [8] as alternative waveform to overcome of OFDM disadvantages. Where, it can reduce OOB side lobe level through using it a filtering operation. They explained that UFMC system outperforms of the OFDM system and thus, introduced the suggested UFMC scheme as contender candidate for future 5G wireless systems. In additional to, 5G of mobile network considers UFMC for implementation in order to maintain the merits of OFDM while avoids its demerits [9, 10]. Where, UFMC outperforms OFDM in each of frequency and time synchronization errors while its performance degraded when delay spread lower than certain value [9]. Hence, UFMC is becoming one of the contender modulation technique for upcoming 5G communication system owing to combating multi-user interference and short burst support [11]. Moreover, UFMC has robustness versus each of inter-carrier interference (ICI) and inter-symbol interference (ISI) as well it is appropriate for low latency scenarios [12].

In communication systems, channel coding is considered vital part, where error correction codes (ECC) are using to detect and correct the errors which is occurring in channel noise [13]. Hence, in practical applications, bit error rate (BER) will be high without using forward error correction (FEC) techniques and doesn't meet its requirements. So, applying powerful FEC techniques are considered one of the key method to improve the BER performance and receiver sensitivity [14]. So, to achieve the reliability of information transmission in digital communication systems over noisy channels, ECC is considered an essential issue [15]. Where, several ECC have been suggested in 4G such as turbo, LDPC, convolutional, BCH and RS codes [16-20] and in 5G such as LDPC, turbo, polar and convolutional [21] and BCH [22]. In contrast, reed solomon (RS) codes are commonly used in wireless and optical systems owing to its strong capability in correcting both of random and burst errors [14]. Where, using RS codes (hard-decision decoding (HDD)) which characterized by low decoding complexity in downlink LTE system contributed by improving system performance. Furthermore, RS codes could decrease BER more than both turbo and convolutional codes [20]. In this paper, RS codes have been suggested in UFMC system to achieve the reliability in data transmission by decreasing BER and thus introduced it as contender waveform for 5G wireless communication system owing to its advantages. The rest of the paper is arranged as following; the description of system model of proposed RS codes in UFMC system are explained in section 2. While, section 3 is presenting the simulation results and discussion. The conclusion has been lastly presented in section 4.

2. RESEARCH METHOD

The description of proposed RS codes with UFMC system diagram has been discussed and shown in Figure 1 whereas, Table 1 is depicted the simulation parameters that used in this paper. Where, 5 MHz transmission bandwidth, 64-QAM modulation scheme and RS (7.1) error correction code are used for all of OFDM, f-OFDM and UFMC systems in order to comparing all of these systems under the same parameters. In contrast, the remaining parameters for each system are presented in the table. UFMC system is divid the whole band to sub-bands, and these sub-bands will be processed individually and each of them have a fixed number of sub-carriers [23]. In contrast, the N-point inverse fast fourier transform (IFFT) converts the frequency domain (Xi) of each sub-band to time domain (xi) as following:

$$Y_l = IFFT\{x_i\}$$

After performing IFFT which are used to prevent the sub-band carriers from the interference. All of the sub-band output will be filtered by band filter. While, a Chebyshev filter has been used as Band filter in UFMC. The purpose of using filtering approach in order to reduce OOB emission for suitable design of filter. The output data that comes from the channel will be performing on 2N point FFT in the receiver and insert interval guard of zeros among successive IFFT symbols to combat ISI owing to transmitter filter delay [23].

In other hand, RS codes are commonly used in storage and digital communication systems which have the capability of correcting burst errors. It is a type of linear block codes. Where, (n-k+1) is the distance between any codeword RS (n,k) code and HDD algorithms have a capable of correcting [(n-k)/2] errors [24]. In other word, RS code is a non-binary cyclic code with symbols consists of m-bit sequences, where [25]:

$$0 < k < n < 2^m + 2$$

where, m is any positive integer number more than 2, n is representing the code symbols of encoded block and k is data symbols that will be encoded. Hence, *RS(n,k)* as following [25]:

$$(n,k) = (2^m\text{-}1, 2^m\text{-}1\text{-}2t)$$

where, the capability of correcting symbol errors for the code represented by t, and 2t=(n-k) which is called the number of parity symbols [25]. In this paper, RS (7,1) codes have been used in this paper. The purpose of using RS codes with UFMC system to enhance the BER performance whilst, the UFMC system have the capability of reducing OOBE levels.

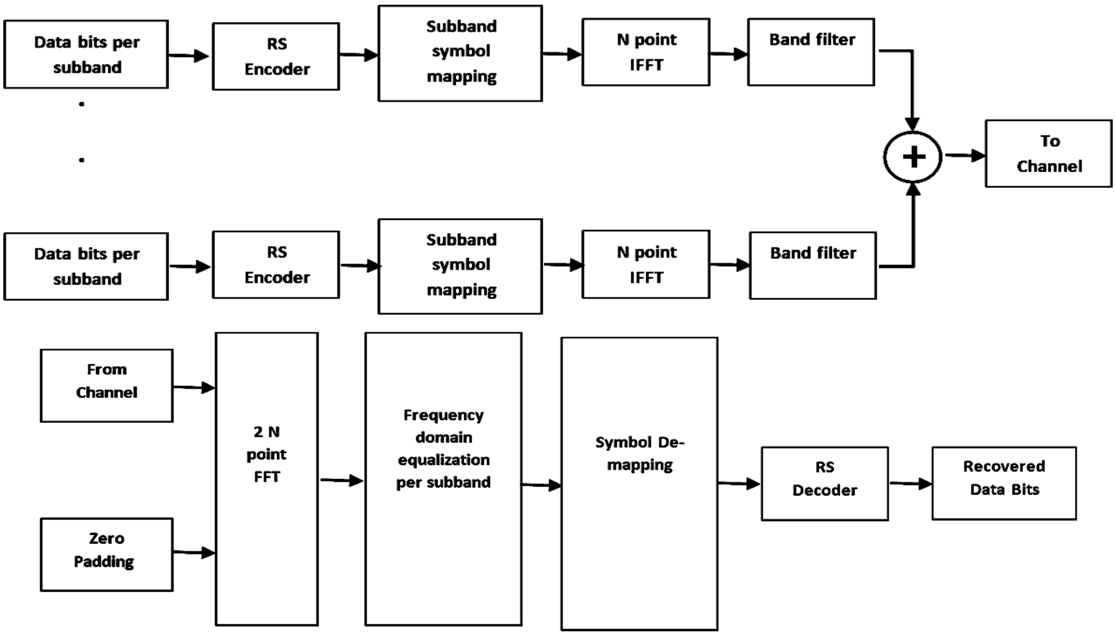

Figure 1. Proposed RS codes with UFMC system diagram

Table 1. Simulation parameters

Parameter		Value
	Transmission Bandwidth (MHz)	5
	Number of FFT points	512
	Modulation	64-QAM
	Error Correcting Techniques	RS (7,1) Codes
	No. of Occupied Sub-carrier	300
OFDM	Cyclic Prefix Length	36
	Type	RRC Windowed- Sinc
f-OFDM	Roll-off factor (α)	0.6
	Length	513
	Sub band offset	156
UFMC	Filter length	43
	Side lobe attention	40

3. RESULTS AND DISCUSSION

The results in this section will be simulated by MATLAB software and it will be divided into 3 parts, first part is discussing the BER performance of uncoded-UFMC against RS codes with UFMC system and compared its performance with OFDM system which is considered as a core waveform of 4G. Moreover, comparing the performance of UFMC system with f-OFDM which is a candidate waveform for 5G. While, the comparison of OOBE levels between UFMC and OFDM systems have been discussed in second part. Lastly, the PAPR levels of both OFDM and UFMC systems have been discussed in third part.

Figure 2, shows the performance of uncoded system for each of OFDM, f-OFDM and UFMC. The results showed that, the performance of un-coded UFMC and OFDM systems are somehow close to one another whilst, uncoded f-OFDM system was better than both of uncoded UFMC and OFDM systems. So, uncoded f-OFDM system performance outperformance both uncoded of OFDM and UFMC systems. In contrast, the comparison of the system performance between uncoded UFMC and proposed RS codes with UFMC has been depicted in Figure 3. The results showed there are a significant improvement have been noted when using proposed RS codes with UFMC system against uncoded-UFMC system. Where, it is clear to see that the red curve which are representing the proposed system went to zero at around 8dB while the blue curve of uncoded system went to zero at around 24 dB. Thus, the proposed RS codes with UFMC system achieved around 10 dB coding gain at $3x10^{-2}$ against uncoded system. So, proposing RS codes is contributing in enhancing the BER performance of UFMC system against uncoded system.

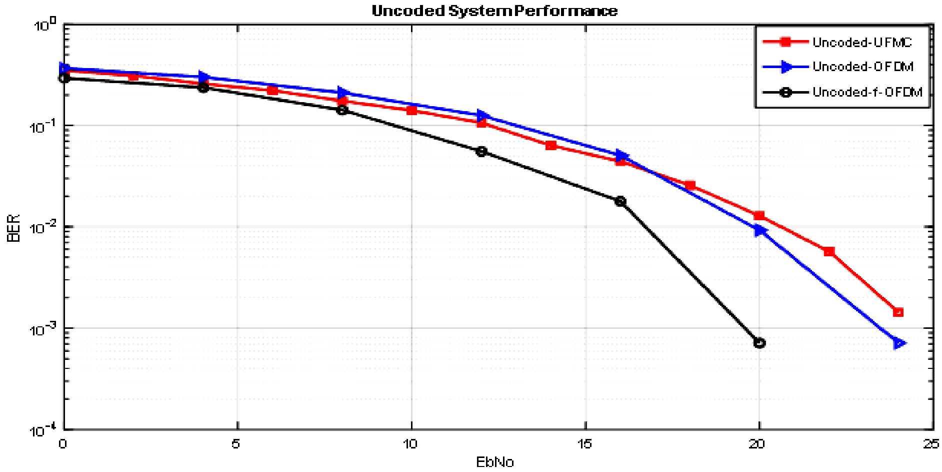

Figure 2. The performance of OFDM, f-OFDM and UFMC systems

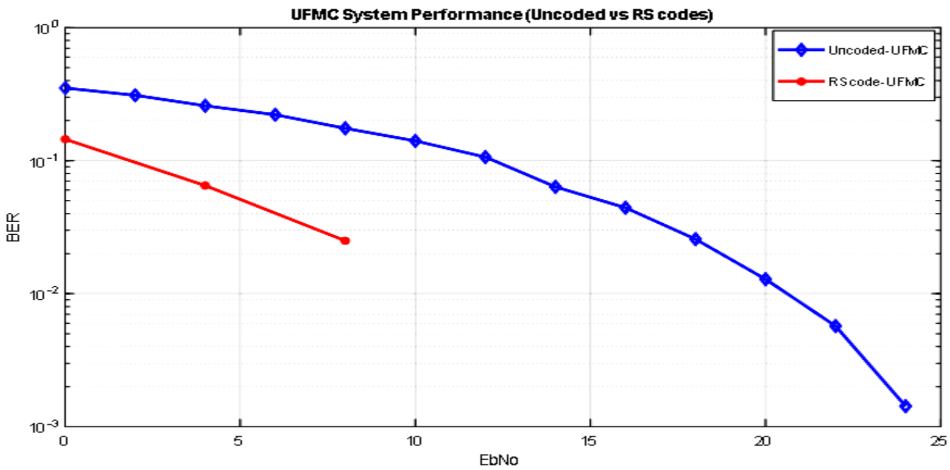

Figure 3. The proposed systems performance

Whereas, power spectral density (PSD) of OFDM system versus UFMC system has been shown in Figure 4. Where, 200 sub-carriers have been shown in OFDM system while, the whole band in UFMC system will be divided into 10 sub-bands, each sub-band consists of 20 sub-carriers which have less side lobes [7]. So, the UFMC system as shown in Figure 4, could solve problem of OFDM systems where it minimizes the OOBE levels. Where, it minimizes around 40dB of PSD compared to OFDM.

Table 2 shows the comparison of PAPR levels among OFDM, UFMC and proposed RS-UFMC systems. The table showed that both of uncoded OFDM and UFMC systems are somehow close to one another whilst, by using RS codes in UFMC the values of PAPR levels increased to 8.8653 dB against 6.9735 dB for

OFDM system. So, although using RS codes in UFMC system contributed in enhancing BER performance. However, the PAPR levels are still high and couldn't be solved in the proposed RS-UFMC system.

Based in the previous results, despite of the proposed system could not reduce PAPR levels compared to OFDM system. Nevertheless, it can be introduced as a new contender waveform candidate for 5G wireless communication system as alternative waveform of OFDM system, due to its capability of reducing OOBE levels because of using filtering approach in contents of UFMC system furthermore, it is enhancing the BER performance of the proposed system owing to use RS codes with UFMC system.

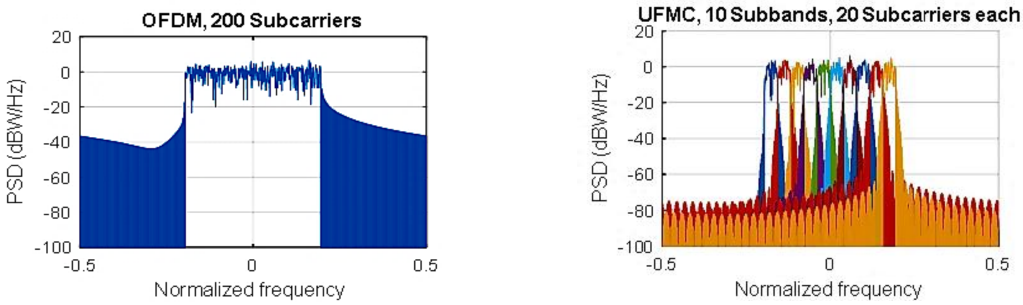

Figure 4. Power spectral density of OFDM system versus UFMC system

Table 2. Comparison of PAPR levels

	OFDM	Uncoded-UFMC	RS-UFMC
PAPR (dB)	6.9735	7.0836	8.8653

4. CONCLUSION

In this paper, RS codes have been suggested in UFMC system to achieve the reliability of information transmission over noisy channels. Three issues have been discussed namely: BER performance, OOBE and PAPR levels and compared its results with UFMC and OFDM systems. The results showed the BER performance of the proposed system using RS codes is significantly improved against uncoded UFMC system. Where, , the proposed RS codes with UFMC system achieved around 10dB coding gain at $3x10^{-2}$ against uncoded system. Moreover, the UFMC system can solve the problem of OFDM systems, where it could minimize around 40dB of PSD compared to OFDM system. Although, UFMC system can solve two issues however, using RS codes in UFMC system is increased the values of PAPR to 8.8653dB against 6.9735dB for OFDM system. Lastely, the proposed UFMC system using RS codes can be introduced as a new contender waveform candidate for 5G wireless communication system as alternative waveform of OFDM system owing to its advantages against OFDM system.

ACKNOWLEDGEMENTS

The authors would like to thank the Research Management Centre (RMC), Universiti Tun Hussein Onn Malaysia for the generous financial support under the RMC Research Fun (E15501).

REFERENCES

[1] A. K. M. Baki, et al., "Novel Methods of Filtering for FBMC/UFMC Based 5G Communication Systems," *2019 7th International Conference on Smart Computing & Communications (ICSCC),* 2019.

[2] Y. Zhang, et al., "A Novel PAPR Reduction Algorithm Based on SLM Technique in UFMC Systems," *2018 IEEE/CIC International Conference on Communications in China (ICCC Workshops),* 2018.

[3] A. Kumar and M. Gupta, "A review on activities of fifth generation mobile communication system," *Alexandria Engineering Journal,* vol. 57, no. 2, pp. 1125-1135, 2018.

[4] R. N. Mitra and D. P. Agrawal, "5G mobile technology: A survey," *ICT Express,* vol. 1, no.3, pp.132-137, 2015.

[5] K. Zerhouni, et al., "On the cyclostationarity of Universal Filtered Multi-Carrier UFMC," *AEU- International Journal of Electronics and Communications*, vol. 89, pp. 174-180, 2018.

[6] R. T. Kamurthi and S. R. chopra, "Review of UFMC Technique in 5G," *2018 International Conference on Intelligent Circuits and Systems (ICICS),* 2018.

[7] P. N. Rani and Ch. S. Rani, "UFMC: The 5G modulation technique," *2016 IEEE International Conference on Computational Intelligence and Computing Research (ICCIC*), 2016.

[8] V, Vakilian, Th, et al., "Universal-filtered multi-carrier technique for wireless systems beyond LTE," *2013 IEEE Globecom Workshops (GC Wkshps)*, 2013.
[9] Ch. D. M. Ambatali and J. J. S. Marciano, "Performance evaluation of the UFMC scheme under various transmission impairments," *2016 IEEE International Conference on Communication, Networks and Satellite (COMNETSAT)*, 2016.
[10] F. Schaich and Th. Wild, "Waveform contenders for 5G-OFDM vs. FBMC vs. UFMC," *2014 6th International Symposium on Communications, Control and Signal Processing (ISCCSP)*, 2014.
[11] I. Baig, et al., "A Low PAPR DHT Precoding Based UFMC Scheme for 5G Communication Systems," *2019 6th International Conference on Control, Decision and Information Technologies (CoDIT)*, 2019.
[12] R. S. Yarrabothu and U. R. Nelakuditi, "Optimization of out-of-band emission using kaiser-bessel filter for UFMC in 5G cellular communications," *China Communications*, voi. 16, no. 8, pp. 15-23, 2019.
[13] Dh. Shah, et al., "RS-LDPC product code for high SNR applications," *2015 2nd International Conference on Signal Processing and Integrated Networks (SPIN)*, 2015.
[14] M. Chen, et al., "Improved BER Performance of Real-Time DDO-OFDM Systems Using Interleaved Reed–Solomon Codes," *IEEE Photonics Technology Letters*, vol. 28, no. 9, pp. 1014 – 1017, 2016.
[15] D. Jo, et al., "Blind Reconstruction of BCH Codes Based on Consecutive Roots of Generator Polynomials," *IEEE Communications Letters*, vol. 22, no. 5, pp. 894-897, 2018.
[16] L. Yang, et al., "Partially Information-Coupled Turbo Codes for LTE Systems," *IEEE Transactions on Communications*, vol. 66, no. 10, pp. 4381–4392, 2018.
[17] I. Bhurtah, et al., "Enhancing the error-correcting performance of LDPC codes for LTE and WiFi," *International Conference on Computing, Communication & Automation*, 2015.
[18] L. L. fu, et al., "Research and implementation of Viterbi decoding in TD-LTE system," *2017 IEEE 2nd Advanced Information Technology, Electronic and Automation Control Conference (IAEAC)*, 2017.
[19] Gh. A. Hussain and L. Audah, "Downlink LTE System Performance Improvement by Using BCH Codes over LTE-MIMO Channel," *International Journal of Integrated Engineering*, vol. 10, no. 4, pp. 95-101, 2018.
[20] Gh. A. Hussain and L. Audah, "RS Codes for Downlink LTE System over LTE-MIMO Channel," *TELKOMNIKA Telecommunication, Computing, Electronics and Control*, vol. 16, no. 6, pp. 2563-2569, 2018.
[21] Z. R. M. Hajiyat, et al., "Channel Coding Scheme for 5G Mobile Communication System for Short Length Message Transmission," *Wireless Personal Communications*, vol. 106, no. 2, pp. 377–400, 2019.
[22] Gh. A. Hussain and L. Audah, "BCH codes for 5G wireless communication systems over multipath fading channel" *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 17, no. 1, pp. 310-316, 2020.
[23] P. N. Rani and Ch. S. Rani, "UFMC: The 5G modulation technique," *2016 IEEE International Conference on Computational Intelligence and Computing Research (ICCIC)*, 2016.
[24] Z. Yan, et al., "A Low-Complexity RS Decoder for Triple-Error-Correcting RS Codes," *2019 IEEE Computer Society Annual Symposium on VLSI (ISVLSI)*, 2019.
[25] A. S. Sanghvi, et al., "Performance of Reed-Solomon Codes in AWGN Channel," *International Journal of Electronics and Communication Engineering*, vol. 4, no. 3, pp. 259-266, 2011.

BIOGRAPHIES OF AUTHORS

Ghasan A. Hussain is currently a PhD student in Universiti Tun Hussein Onn Malaysia since 2017. He received Bachelor degree in Communication Engineering from Alfatah University Tripoli/Libya in 2003. Hussian received the Master degree in communication Engineering from University Putra Malaysia in 2013. Since 2006, he has been with Electrical Engineering, University of Kufa, Iraq, where he is now a lecturer. His research interests include wireless communication systems, Mobile systems, LTE and Error Correction Techniques. He has a number of publications in different journals in his field.

Lukman Audah received his BS degree in electrical engineering from the University Technology Malaysia, Johor, Malaysia, in 2005, and his MS and PhD degrees in communication networks and software from the University of Surrey, United Kingdom, in 2007 and 2013, respectively. Since 2014, he has been with the Faculty of Electrical and Electronic Engineering, University Tun Hussein Onn Malaysia, Johor, Malaysia, where he is now a Senior lecturer. His main research interests are wireless and mobile communications, Internet traffic engineering, network system management, data security, and satellite communications.