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BCH codes in UFMC: A new contender candidate for 5G communication systems

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ABSTRACT

Nowadays, fifth generation (5G) wireless network is considered one of the most important research topics in wireless industry and it will be substituting with fourth generation (4G) in several aspects. Although the robustness of orthogonal frequency division multiplexing (OFDM) system against channel delays which is the reason behind using it in LTE/LTE Advanced however, it is suffering from high peak to average power ration (PAPR) and out of band side lobes. So, universal filtered multi-carrier (UFMC) technique is considered a new modulation scheme for 5G wireless communication system to overcome on the common OFDM demits. In contrast, to achieve reliable data transmission in digital communication systems, using error correcting codes are considered an essential over noisy channels. In this paper, BCH code has been used for UFMC system over AWGN. The results showed that using BCH codes in UFMC contributed in enhancing BER performance while could decreasing both of PAPR and OOBE values better than conventional OFDM system.

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1. INTRODUCTION

Nowadays, fifth generation (5G) wireless network is considered one of the most important research topic in wireless industry and it will be substituting with fourth generation (4G) in several aspects, owing to its potential applications in the evolution of new applications; like vehicular communications, internet of things (IoT) and low latency and ultra-reliable communications [1, 2]. Whilst, 5G wireless technologies which characterized of low power consumption and high spectral efficiency expected to introduced in 2020 and beyond [3, 4]. Comparing to present communication systems, 5G could achieve higher speed, better reliability and more security for each of machines, human users and man to machine interactions [5]. Thus, 5G cellular communications have been attracted a lots of attentions in both of industrial and academic fields [6]. The main core technique of LTE standard was orthogonal frequency division multiplexing (OFDM), nevertheless it could not be a promising solution for 5G and future wireless communications due to its disadvantages. Where, high spectrum side lobes are considered one of the drawbacks of OFDM which is happening because of the rectangular pulses of its symbols whilst, OFDM are suffering from the inability of supporting a significant feature namely flexible numerology [7].

Although the robustness of OFDM system against channel delays which is the reason behind using it in LTE/LTE Advanced however, it is suffering from high peak to average power ration (PAPR) which is caused of increasing the consumption of battery and lower efficiency of power amplifier, while low spectrum efficiency is happening due to high out of band side lobes in OFDM system. Thus, new modulation technologies have been required for 5G communication systems which are characterized of the ability of overcome of OFDM disadvantages [8]. Where, filtered-OFDM (f-OFDM) and universal filtered multi-carrier (UFMC) techniques have been proposed in [8-11] as new modulation schemes for 5G systems to overcome on the common OFDM demits.

In other hand, different waveforms candidates have been suggested for 5G in [12] such as f-OFDM, UFMC, generalized frequency division multiplexing (GFDM) and filter bank multicarrier (FBMC). They were assessing these waveforms under key performance indicators factors (PAPR, filter length, computational complexity, spectral efficiency and latency). They concluded that both of UFMC and FBMC are better coexistence with CP-OFDM that used in 4G networks. Whereas, both of UFMC and f-OFDM were more flexibility than GFDM and FBMC in reducing the complexity. While, all these waveforms candidates have lower PAPR than OFDM which is maybe results due to its utilizing filter and windowing techniques [12]. In contrast, the spectrum utilization of UFMC has been described in [13]. Where, several modulation techniques have been also reviewed and motivated the needing of UFMC in 5G wireless communication. They concluded that spectrum utilization of UFMC was much better than OFDM system and thus, UFMC is considered a right choice as candidate for 5G.

In wireless communication systems, one of the aims of next generation are introducing high data rate applications and service like, data and image in local coverage networks, video streaming, web browsing, wireless teleconferencing and multimedia. Quality digital communication systems and higher data rates are required in a bandwidth to make available all these services. However, multipath propagation phenomenon is still the major challenge factor which is causing frequency selective fading that comes from various echoes of transmitted symbols interference at the end of receiver and thus cause bit error rate (BER) degradation [14].

BER in wireless communications can be caused surely via all types of disturbances. Thus, using channel coding technologies are best choice to minimize the impact of actual channel. Where, Bose-Chaudhuri-Hocquenghem (BCH) coding considered a good type of linear error correction codes owing to its powerful correction capability as well it is so close to theory value. Furthermore, BCH code is commonly using in data transmission because of it has some effective coding and decoding algorithms because of the strict algebraic architecture. In additional to, the structure of BCH coding with interleaving contribute in correcting both of burst and random errors and thus greatly reducing BER of the system [15].

Generally, to achieve reliable transmission in digital communication systems, using error correcting codes are considered an essential over noisy channels [16]. Hence, to reduce BER in LTE system via MIMO channel, BCH codes have been suggested in [17]. They showed that using BCH codes that have low decoding complexity is contributed in controlling of errors in LTE system via LTE-MIMO channel. Whilst, simulation results indicated that BCH codes outperform than both convolutional and turbo codes in reducing BER.

BCH codes are also proposed in [18] to achieve reliable data transmission of filtered-OFDM system via multi-path fading channel. The results showed that using BCH code with f-OFDM system achieved significant improving in terms of BER performance and OOBE better than conventional OFDM system. Although, PAPR in their system was high due to the tradeoff among OOBE, PAPR and SNR performance. Nevertheless, they indicated that their proposed system is considered a competitor candidate for 5G communication systems to meet its requirements owing to the ability of decreasing both OOBE and BER. So, in this paper, BCH codes have been proposed to achieve reliable data transmission for UFMC system that have low OOBE and PAPR levels.

2. SYSTEM MODEL

Block diagram of using BCH codes with UFMC system over AWGN channel has been described and depicted in Figure 1. The suggested system will be introduced as promising candidate waveform for 5G wireless mobile system because of its ability of solving the OFDM disadvantages. Compared to OFDM, UFMC is dividing the whole band into sub-bands then in each subband, the data will be processing by IDFT and sub-band filter respectively. Lastly, the signals which is filtered in all subbands will be added with each other to create UFMC signal to be ready for transmission [1]. The purpose of using IFFT in UFMC is to protect the subbsand carriers from the interferences. While, by suitable design of filter, using filtering method in UFMC is minimizing the OOBE. Where, filtering the parameterized side lobe attenuation utilized in order to filter the output of IFFT per subband.

The band filter is used in UFMC to execute the Chebyshev filter operation. In the UFMC receiver the data that comes from the channel will be performed by 3N point FFT then adding guard interval of zeros between successive IFFT symbols. Thus, that will protect from inter symbol interference (ISI) that may accrue owing to transmitter filter delay [8]. The same parameters that shown in Table 1, will be used for both OFDM, f-OFDM systems and proposed UFMC system to achieve fairly comparison among them and explain the advantages/disadvantages of each of them.

Table 1. System parameters [8]

Variable	Power (kW)
Number of FFT points	512
Sub band size	20
No. of Subbands	10
Sub band offset	156
Modulation	64-QAM
Filter length	43
Side lobe attention	40
Error Correcting Techniques	BCH (15,5) Codes

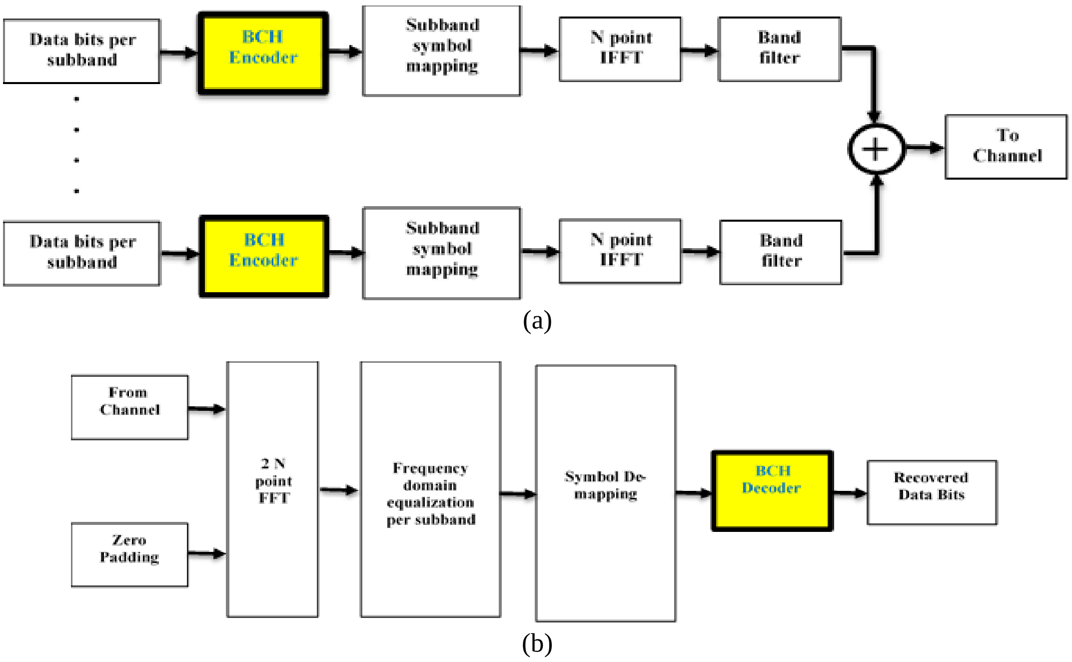

Figure 1. UFMC block diagram, (a) Transmitter, (b) Reciever [8]

In general, BCH codes are special type of cyclic code and considered one of the best cyclic codes which have wide applications in storage and communication systems [19, 20]. Where BCH codes have been intensively studies because of its strict algebraic structure. The codeword of BCH code is generated by divide the polynomial m(x) by a generated polynomial g(x), then take the rest as parity check bits r(x) [21]. Hence, by using source encoding, the message will be converted into coded form which are transmitting via channel which is adding extra bits in order using it in detection and correcting errors [22]. So, the encoded data c(x) has been explained in (1) [21]:

$$C(x) = m(x) + r(x) \quad (1)$$

By selected g(x), the characteristics of the code will be determined. Where, BCH code could be correct ≤ t independent errors (for integer t and m) [21]:

$$n = 2^m - 1$$
$$(n - k) \leq mt$$
$$d \geq (2t + 1)$$

where, n is the block length, k is code dimension, (n-k) is parity check bits, d is minimum hamming distance and t is the capability of error correction [17, 21]. In this paper, BCH (15, 5) has been used.

3. RESULTS AND DISCUSSION

The results in this paper are divided into two stages; BER performance of UFMC system using BCH code over AWGN has been discussed and compared with un-coded system and both OFDM and f-OFDM systems in first stage. In second stage, OOBE and PAPR levels of UFMC have been discussed and compared with conventional OFDM system. Where, the aim of comparing the proposed system with conventional OFDM system which is a core waveform of 4G [23, 24] and f-OFDM system which is a competitor candidate of 5G [25] to show the merits/demerits of proposed system against both of them.

First, Figure 2 shows the comparison of uncoded systems performance for OFDM, f-OFDM and UFMC systems over AWGN channel. It reveals that the performance of both UFMC and OFDM systems are somehow close to one another. While, f-OFDM system outperforms both UFMC and OFDM systems. Thus, the uncoded f-OFDM system performance was the best among of uncoded OFDM and UFMC systems in terms of BER.

In the other hand, the performance of UFMC system using BCH codes through AWGN channel has been showed in Figure 3. It reveals that the performance of proposed system using BCH code is considerably enhanced better than uncoded system. Thus, using BCH code in UFMC system contributes in enhancing BER performance through decreasing BER, where the errors goes to zero at 12 dB SNR for proposed system against 20 dB SNR for uncoded system.

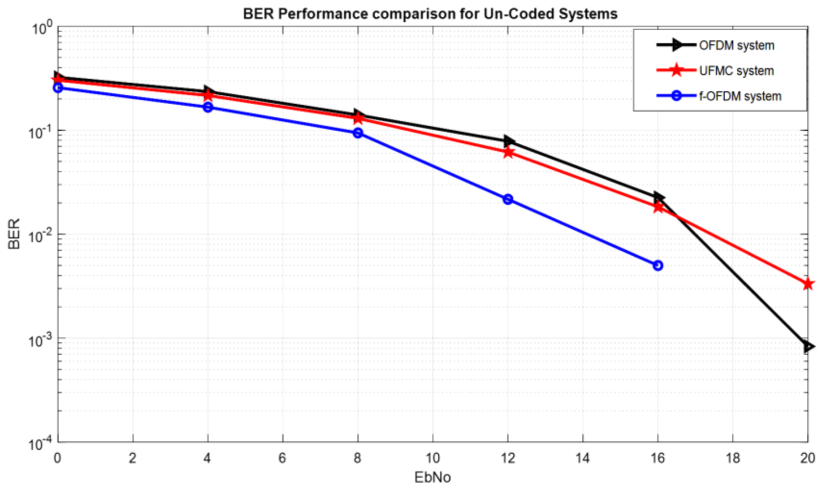

Figure 2. The comparison of uncoded systems performance

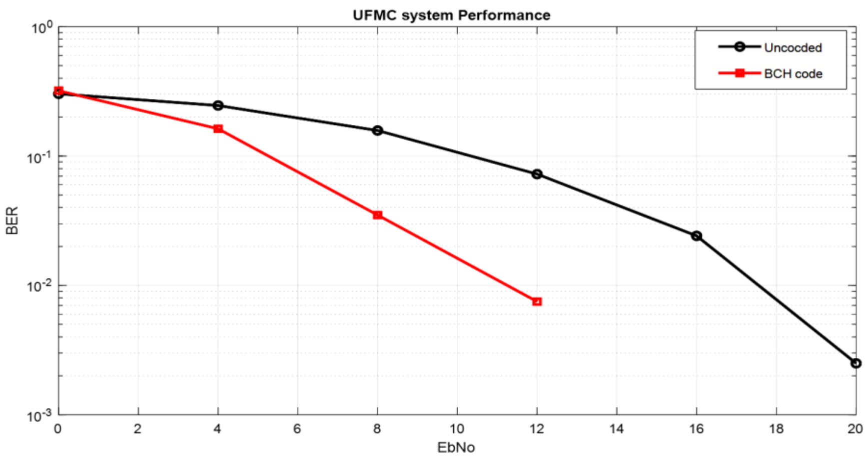

Figure 3. The performance of UFMC system

Whereas, the comparison of system performance between UFMC and f-OFDM systems using BCH codes is depicted in Figure 4. The result reveals that the performance of f-OFDM system using BCH code still outperforms UFMC system. However, using BCH code in the proposed UFMC system contributed in improving BER performance to be better than uncoded UFMC system as shown in Figure 3.

Second, the comparison of OOBE between OFDM and UFMC systems has been depicted in Figure 5 [8]. It shows that 200 subcarriers for OFDM system while 10 subbands which is divided in whole band for UFMC system. The result shows that the side lobes of UFMC was less than OFDM and thus, OOBE was lower for UFMC system and better than familiar OFDM system. Where, OOBE of UFMC system was around 40 dB lower than OFDM system. Whereas, the values of PAPR of OFDM versus UFMC systems have been explained in Table 2.

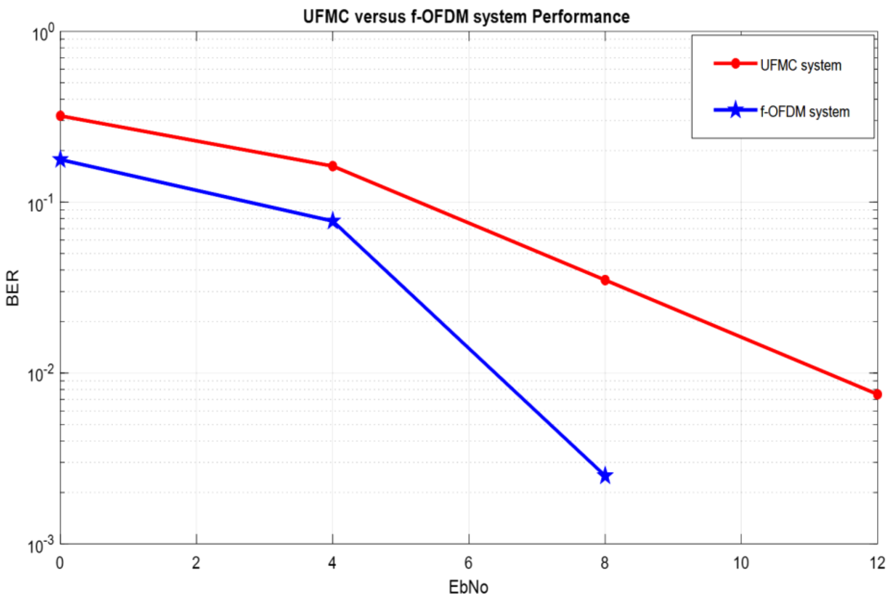

Figure 4. The comparison between UFMC and f-OFDM system performance

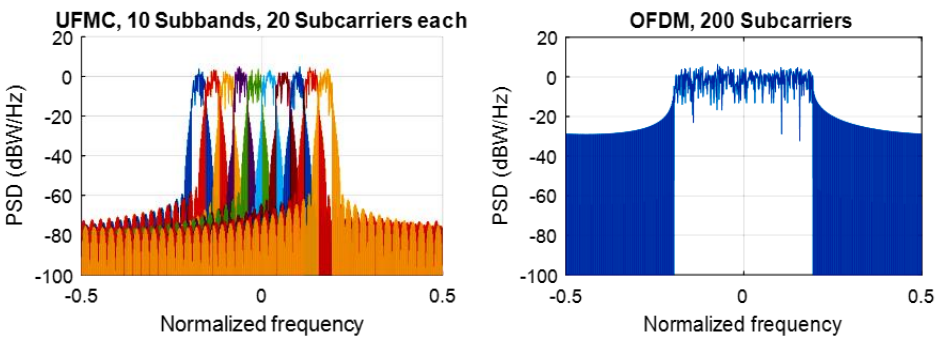

Figure 5. Power spectral density of OFDM vs UFMC

Table 2. (PAPR values)

	OFDM	Uncoded UFMC	BCH-UFMC
PAPR (dB)	9.9269	8.6229	8.6899

The comparison in Table 2 explained that PAPR values of uncoded-UFMC system is lower than conventional OFDM system. Moreover, the suggested UFMC system using BCH codes is also lower than OFDM system. Where, PAPR for OFDM system was 9.9269 dB while it was 8.6229 dB and 8.6899 dB for Uncoded and BCH codes with UFMC system respectively.

Although, BER performance of f-OFDM system is better than UFMC system in both uncoded and with BCH codes. While, both uncoded-UFMC and OFDM systems were somehow close to one another and UFMC system performance is enhancing more using BCH codes. However, the suggested UFMC could be considered a competitor candidate of 5G wireless communication systems owing to the ability of decreasing both OOBE and PAPR while enhancing BER performance better than conventional OFDM system.

4. CONCLUSION

In this paper, UFMC system has been proposed as a solution for disadvantages of OFDM system to be used as a competitor waveform of 5G wireless communication systems. Where, high both PAPR and OOBE values are considered a common demerits of OFDM systems which are prevent using it for next generation. BCH codes have been proposed in this paper for UFMC system to improve the BER performance. Whereas, the proposed system has been compared with both OFDM and f-OFDM system. The outcomes showed that the performance of both uncoded OFDM and UFMC systems are somehow close to one another. While, uncoded f-OFDM system outperforms all of uncoded OFDM and UFMC systems. Although, f-OFDM system performance using BCH codes outperforms of UFMC system. However, using BCH code in UFMC system contributes in enhancing BER performance through decreasing BER, where the errors go to zero at 12 dB SNR for proposed system against 20 dB SNR for uncoded UFMC system. In other hand, the values of PAPR and OOBE for proposed UFMC were lower than conventional OFDM system. Where, PAPR for OFDM system was 9.9269 dB while it was 8.6229 dB and 8.6899 dB for Uncoded and BCH codes with UFMC system respectively. Furthermore, the OOBE level of UFMC system was around 40dB lower than OFDM system. Hence, the proposed UFMC can considered a contender candidate for 5G wireless communication system because of its ability of decreasing each of OOBE and PAPR while enhancing BER performance better than conventional OFDM system.

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