Design of MIMO F-OFDM System Model for PAPR Reduction in the Growth of 5G Network

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Abstract. A compact 5G technology can be defined as a system which consist of high signal data transmission, maximizing frequency diversity and can combat noise interference. By theory, it is significantly to improve system’s performance in order to obtain better voice quality, tolerance to noise interference, excellent spectral efficiency, higher network capacity, low latency and frequency selective fading in multipath environment, which is robust to the channel impairments. 5G network uses multipath environment or multiple transmissions technique, which known as multiple input multiple output, (MIMO). MIMO operates with multiple antennas technology, which includes the multiple transmitters with receivers’ circuits to minimize errors and optimize data speed. For the transmission efficiency, multiple antenna system model is commonly put together with digital data encoding method called Orthogonal Frequency Division Multiplexer (OFDM), where the carrier signals have high spectral efficiency and immunity to frequency fading. MIMO-OFDM configuration has introduced to increase the diversity gain and improve the system capacity. Currently, filtering is implemented to overcome out-of-band radiation for the spectrum efficiency and meet the diversified expectation for the growth of 5G network. The main drawback in MIMO F-OFDM system is its high peak-to-average-power-ratio (PAPR). This paper discusses the parameter specification in reducing PAPR in MIMO F-OFDM system. The proposed parameters are utilizing block coding technique that is Enhancement Asymmetric Arithmetic Coding (EAAC), together with numbers of antenna configuration to overcome the problem of high PAPR. From the simulation results, the PAPR reduced at 6.85% using block coding technique and MIMO antenna configuration and it is verified with the existing system with MIMO-OFDM. Overall, the communication system model will lead to the mutual harmonization among society with new parameters of MIMO F-OFDM and block coding technique.

Keywords: 5G, MIMO, PAPR, OFDM, EAAC
1. Introduction

Current wireless communication standard for cellular network, launched in 2020 has widely deployed smart antenna configurations with block coding techniques in the transmitter system to increase the speed of data transmission, enhanced error minimization and lower out-of-band radiation for spectral efficiency and reliability of the signal [1], [2]. This type of digital communications has been used in both wired and wireless system. Frequency signals that propagates through wireless channel is a technical challenge in combating the multipath fading and overcome the problem that arises from the conventional MIMO-OFDM system[3],[4][5]. At present, many research and development for fifth generation cellular network (5G) are focusing on mitigating the error that occur during high speed data transmission. Thus, the growth of 5G network is expected to provide reliable connectivity, supporting millions of devices at ultrafast speed, and improving the system capacity [6], [7]. The typical MIMO-OFDM are also recognized in underperforming the leakage of out-of-band radiation power which affected to the spectral efficiency of the system and limits the multipath propagation of the system[5]. Therefore, a filtered OFDM (F-OFDM) with MIMO system is introduced to overcome the limitation of the conventional method. In fact, MIMO F-OFDM has the capabilities to reduce spectrum efficiency and fix the leakage of out-of-band radiation power [5], [8]. In addition, the deployment of MIMO F-OFDM is to filter each sub-carrier so that signals are well refined before it being transmitted [9], [2]. However, the main drawback of using F-OFDM is its high PAPR values that contribute to less efficiency and high cost [5], [10]. There are various proposed techniques used to solve the high PAPR, previously [11], [12], [13]. The common issue is the type of coding technique that can detect and correct the error before it transmits. Thus, this research uses the enhancement asymmetric arithmetic code (EAAC) as a block coding technique to reduce the error probability and decrease PAPR at the transmitter. Even though many researchers had identified the technique to reduce PAPR using block coding for MIMO F-OFDM, there are still no research has been made using a combination of MIMO F-OFDM with EAAC [14], [7]. This paper analyses the performance of PAPR for MIMO F-OFDM with EAAC as block coding technique and possible increase the efficiency of data transmission in the system.

2. System Model

2.1. MIMO-OFDM

In 2016, A. Agarwal et.al [15], stated that the MIMO system has to combined with antenna arrays which can improve the link reliability and offer spectral efficiency. Thus, they successfully resulted that MIMO-OFDM gave better performance of the system with larger number of antenna configuration in their signal’s transmission[16]. The elements of the channel matrix, $H$ as $Nr \times Nt$ shows the complex coefficients with $Nr$ as receive array antenna and $Nt$ as transmit array antenna. Equation (1) representing the receiving vector, transmitting vector and $n$ is additive white Gaussian noise[15].

$$y = Hx + n (1)$$

Nevertheless, the author’s method caused them in high usage number of antennas that give no effect on the error reduction. Hence, the research of error correcting methods is compared to improve the error performance for the system.

Authors in [2], stated that the increment of symbol duration has affect the channel delay and decreased the ISI of the system. Thus, it impaired the performance of the system. In [6], the authors proposed new sub-carrier mapping scheme to achieve the optimal frequency diversity and repeated sub-carriers that can reduce the interference during the signal transmission. The outcome of the research stated that by using diversity scheme STFBC-MIMO OFDM, the system’s performance slightly improved the error rate and increase signal-to-noise ratio.
2.2. MIMO F-OFDM

Figure 1 shows the block diagram that contain F-OFDM to overcome the issues of MIMO-OFDM which is the high PAPR as well as having high side lobes in the frequency [17],[18]. Besides, F-OFDM has the characteristics needed for 5G networks which has the ability to provide massive connectivity for the wireless access. F-OFDM offers an increment in the number of multiple users that the system can accommodate [19], [10]. Hence, the proposed F-OFDM technique should be able to accommodate massive users with better PAPR reduction and maximize the BER degradation as compared to OFDM and existing F-OFDM system.

![Figure 1. Block diagram of MIMO F-OFDM system (*work contributions)](image)

2.3. Enhancement Asymmetric Arithmetic Coding (EAAC)

Referring to Figure 1, EAAC scheme is developed as a block coding technique applied in MIMO F-OFDM system and compare with the existing system for an accuracy entropy coding where the information in the most significant position is added in the least significant position [5]. EAAC meets equation (2.1) and (2.2) as follows, with asymmetrical increase by changing the range propositions.

\[ x' = x + s2^m \; ; s \text{ chooses between range } - \text{most significant position} \]  \hspace{1cm} (2.1)

\[ x' = 2x + s \; - \text{least significant position} \]  \hspace{1cm} (2.2)

2.4. Space Time Frequency Block Coding (STFBC)

For the system implementing multiple access scheme, there are limited researchers that provide solution for PAPR reduction by using a combination of block coding and error correcting techniques. In 2011, authors in [20] compared error correcting codes for STFBC MIMO OFDM to provide low complexity and maximum diversity. They obtained an enhancement of error correcting codes with frequency offset being evaluated[21]. For this work, STFBC used as an approach to gain maximum diversity order during data transmission[22].
3. Methodology

3.1. System Flow Chart

The common operational of the system development is shown in Figure 2. All simulations were done by using MATLAB software.

![Software Development Flowchart](image)

Figure 2. Software Development Flowchart

The simulation shows the process flow, starting with the input data symbol as random sequence of codeword transmitted by the system\[8\]. Next, apply the EAAC coding technique in the encoder for the encoding process. Then, implement F-OFDM scheme at the transmitter. Digital modulator was used to modulate the data and maintain the strength of the data. In order to measure the system’s performance, PAPR were plotted. The simulation results obtained is then being compared with the theoretical framework as the result verifications \[23\]. The effectiveness from the simulations has been measured and identified, to meet the research objective.
4. Results and Discussion

The simulation results of PAPR and BER for MIMO F-OFDM system are presented in this section. Table 1 shows the system parameter used for the design simulation of MIMO F-OFDM. CCDF will be used to observe the PAPR measurements for the system.

| Parameter                  | Specification   |
|----------------------------|-----------------|
| Channel Model              | Rayleigh        |
| Bandwidth                  | 10MHz           |
| Modulation Scheme          | 64 QAM          |
| FFT Size                   | 4096            |
| Cyclic Prefix Mode         | (1/4) *4096     |
| Filter Order               | 256             |
| Antenna Configurations     | MIMO (Nt x Nr)  |

4.1. Initial PAPR for OFDM vs F-OFDM

Figure 3 illustrates the distribution plots of CCDF for MIMO F-OFDM system without a modulator to compare the values of PAPR in decibels(dB). The tabulated readings showed in Table 3. It is analyzed that the MIMO-OFDM was initially 9.79% less PAPR as compared to MIMO F-OFDM system has the effect of high PAPR values as compared to OFDM system that is shown in Figure 4 [16]. Thus, an approach of the work is introducing EAAC encoder technique to improve to the PAPR at the transmitter part in STFBC MIMO F-OFDM system.

Figure 3. Initial PAPR for both MIMO OFDM and F-OFDM.

| Parameter | By Simulation |
|-----------|---------------|
| Type of Coding | Original      |
| OFDM      | 9.45dB        |
| F-OFDM    | 10.21dB       |
4.2. PAPR Performance with F-OFDM using Coding Technique

Figure 4 demonstrate the plot of distribution (CCDF) for PAPR F-OFDM system with different type of modulation techniques that are conventional Arithmetic Coding and compared with Huffman Coding. PAPR values were taken at CCDF at $10^{-2}$. The tabulated result shown in Table 3.

![PAPR Plot for F-OFDM with Coding Techniques](image)

Table 3. PAPR plot at CCDF $10^{-2}$

| Type of Coding      | OFDM (dB) | F-OFDM (dB) |
|---------------------|-----------|-------------|
| Arithmetic Coding   | 10.29     | 9.62        |
| Huffman Coding      | 10.20     | 9.64        |

5. Conclusion

In this research the performance of F-OFDM system has been compared with the OFDM system. The current STFBC MIMO F-OFDM system model has introduced EAAC as a block coding method to spread its capabilities in contributing to the compact 5G technology by reducing the PAPR at the transmitter part.

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Acknowledgments
Authors wishing to acknowledge gratitude to the research team and colleagues, and this work was partly supported by IPSIS UiTM on financial support.