Investigation of pattern division multiple access technique in wireless communication networks

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ABSTRACT

Recently, pattern division multiple access (PDMA) is a non-orthogonal multiple access system that is now being developed in next-generation telecoms to address the requirement for mass connectivity. The core premise of non-orthogonal multiple access is to simultaneously serve multiple users with varying power levels across the same spectrum resources such as time, frequency, code, as well as space with minimal inter-user interference. A simulation analysis of significant technology enhancements focusing on PDMA aims to describe the benefits of the two plans now being examined by the third-generation partnership project for 5G technologies, namely filtered orthogonal frequency division multiplexing (F-OFDM) and windowed orthogonal frequency division multiplexing (W-OFDM), and to compare them to alternative modulation processes such as 16, 32, and 128 modulations. The research results explained the PDMA is less bit error rate used in multiple access technologies compare with W-OFDM and F-OFDM.

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1. INTRODUCTION

Cellular networks are gearing up for the professionalization of 5G systems, with orthogonal multiple access (OMA) innovation likely to play a key role. To manage these patterns and satisfy the growing need for information services, cellular backhaul becomes an essential aspect in the advancement of 5G technology. OMA belongs to the category of multicarrier adjustment plans. It works by dividing the communicated bitstream into multiple sub streams and delivering them via a variety of symmetrical subcarriers, also known as subchannels.

In OFDM, the number of subcarriers is chosen so that each subcarrier has a data transfer capacity that is less than the channel's intelligence transmission capacity, allowing the subcarriers to experience general level blurring and, as a result, avoid inter-symbol impedance. As a result, large contiguous blocks aren't necessary for high-rate multicarrier communications, and a few smaller blocks can be used instead. This allows for flexibility in both the range portion and also the range of the executives. OMA's main features include resistance to multipath blurring, misuse of recurrence variety, support for cutting-edge multiple information different yield (MIMO) methods, as well as flexible subcarrier loading and fast multiple accessing. Filtered-orthogonal frequency division multiplexing (F-OFDM) and windowed orthogonal frequency division multiplexing (W-OFDM) are orthogonal multiple access (OMA) schemes proposed for future fifth-generation (5G) telecommunications to meet the demand for massive connections and modulation band on sub-band filtering. The notion of orthogonal multiple access is crucial in the design of radio access strategies for 5G wireless networks. The basic principle of orthogonal multiple access is to simultaneously serve different clients over the same spectrum resources, but at different power levels, in order to avoid inter-user interference. Universal filtered multi-carrier (UFMC), filter bank multi-carrier (FBMC), F-OFDM [1], and W-OFDM are some of the waveform contenders for 5G technology. Low-pass filters (LPF) are used in F-OFDM schemes to attenuate OOB emissions and create an effective sub-band divided system, as explained in [2]–[4], whereas low out-of-band (OOB) emissions are reduced in W-OFDM schemes by smoothing symbol transitions with a time domain window applied to each sub-band, as explained in [5], [6]. Different F-OFDM outputs can be found in [7]–[10]. While [11], [12] discussing the drop in PAPR in F-OFDM. The capacities of cellular users have increased rapidly over the growth of cellular generations, as seen in Figure 1. The paper looked at the benefits of PDMA in a downlink communication system that was fully loaded. On the other side, 4G enabled services such as the internet of things, device-to-device (D2D), and others. Therefore, the PDMA Technology is a valuable asset of 5G to achieve the high targets of data rates, as a result, 5G is expected to create opportunities for the delivery of innovative high, increasing the standard's complexity [1].

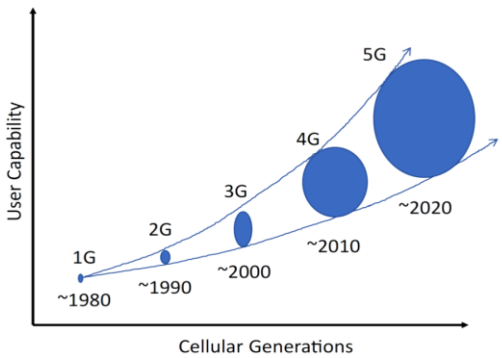

Figure 1. Mobile technology's evolution [1]

2. THEORETICAL BACKGROUND

The section describes type of waveforms that will be used in 5G. This is an important consideration for the advancement of this work. As explained in the next sections, the paper focus points of pattern division multiple access (PDMA), W-OFDM, and F-OFDM technologies.

2.1. PDMA

PDMA is a non-orthogonal multiple access system that optimizes the system operation for multiple users. There are interesting manufacturing advantages to using PDMA. The signal design framework, which is based on a unified power temporal, spatial, and coding domains, has a high degree of commonality in the design model. PDMA, as a new multiple access method, significantly suppresses co-channel interference, consumes less power, and has high spectral efficiency. The 5G system, Also has versatile adaption for a variety of circumstances. Figure 2 shows a general model of the PDMA system, non-orthogonal multiple access on two resource blocks is implemented through data multiplexing for three users. The PDMA encoder generates a PDMA modulation vector by mapping the modulation symbols onto the associated resource blocks at the transmitter. To resolve multi-user data at the receiver, PDMA employs a multi-user detector.

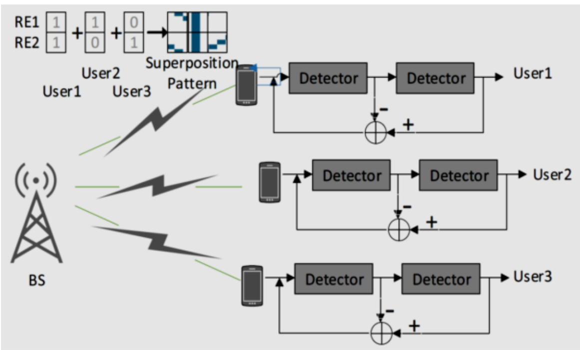

Figure 2. PDMA system model [13]

The spectrum resources of another user are not required to be orthogonal under PDMA, and they may even completely overlap. Based on the original time-frequency domain data, it presents the concept of spreading code and identifies each user from the perspective of multiple sparse spreading codes. The basic idea behind PDMA is to execute PDMA coding at the transmitter, multiplex per user's information across several resources, and then use a multi-user joint detection approach at the receiver to limit user interference and achieve proper multi-user signal analysis [13].

2.2. Filtered-OFDM

To meet time-frequency resource allocation, F-OFDM can provide distinct sub-carrier splitting and numerology for various administrations. Because sub-carrier splitting in different bandwidths is no longer symmetrical, guard bandwidth should be used. F-OFDM's is ensured by the guard band. Previously, there was always a tension between flexibility and framework usage [14], as explained in Figure 3(a) transmitter.

All of OFDM's advantages, such as spectrum efficiency and multi input multi output (MIMO) versatility, are inherent in the F-OFDM system, but it also addresses some of its weaknesses by increasing flexibility and spectral efficiency (SE). F-OFDM is a 5G proposed waveform that is dependent on sub-band filtering of a cyclic prefix-OFDM signal [15].

$$\mathrm{F-OFDM[k]} = \sum_{b=0}^{B-1}\sum_{m=0}^{M-1}\sum_{l=0}^{L_b-1}\sum_{n=0}^{N+1} d_{m.n}^{b}\, g_b[l] e^{j2nk\frac{n-l-mL_{CP}}{N}} \quad (1)$$

Where $dm,$: data of block b, subcarrier n and symbol m, CP: cyclic prefix length, and $[l]$: equivalent frequency windowing of block b.

After modulation, F-OFDM employs a transmit filter to decrease out of band emissions (OOB). It also requires a cyclic prefix; but even so, if the cyclic prefix is wider than the channel's waveform, it reduces inter-symbol interference (ISI), and inter-carrier interference (ICI), both of which are related to inter-carrier interference. In fact, as compared to cyclic prefix-OFDM systems, an F-OFDM system has a higher level of complexity [16], as explained in Figure 3(b) receiver [17]. As illustrated in Figure 4, the division in the time-frequency grid is modified based on the various channel circumstances and application scenarios. The readers can get more details in references [18]–[24] which provide further features on F-OFDM waveforms.

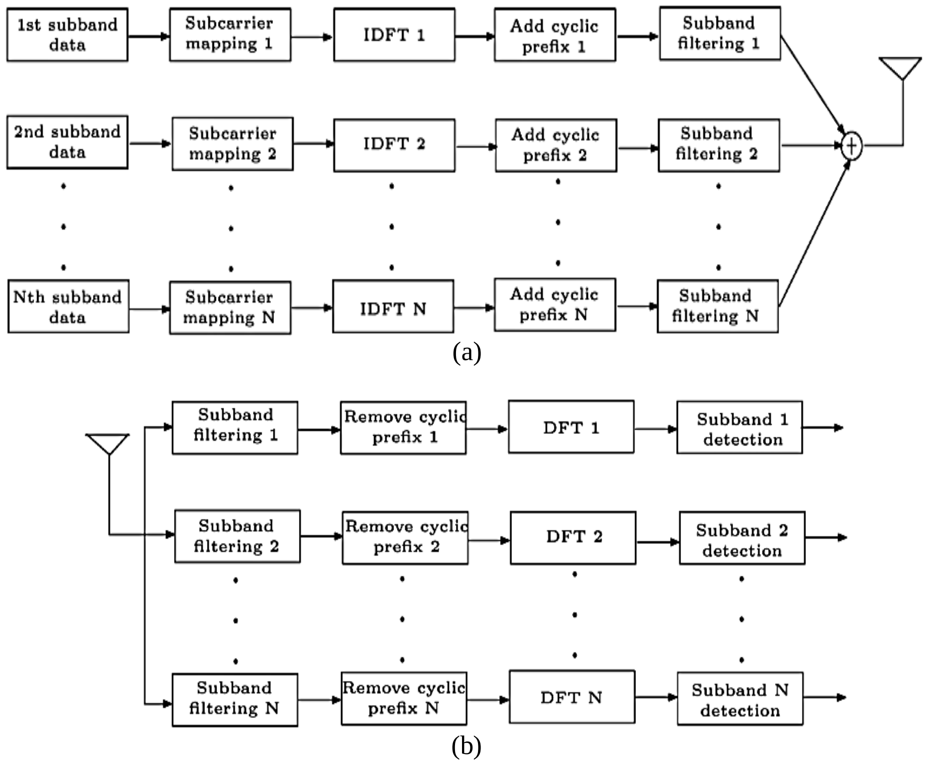

Figure 3. Design of F-OFDM of (a) Transmitter and (b) Receiver [17]

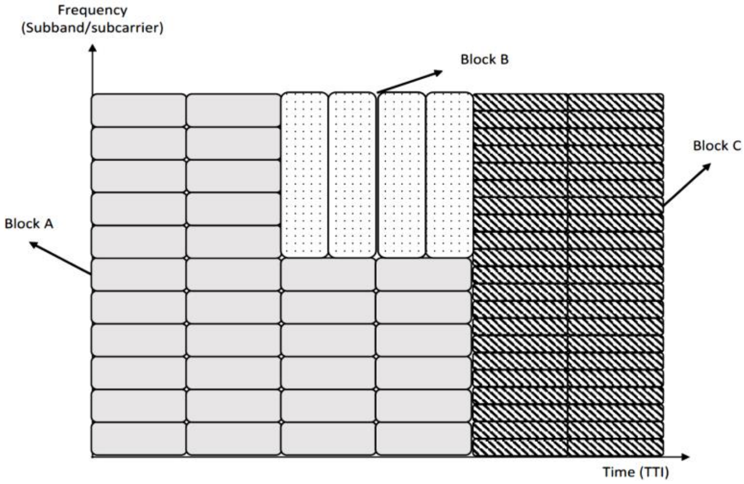

Figure 4. F-OFDM allows for flexible resource allocation [15]

2.3. Windowed-OFDM

Several situations were investigated during this research in order to determine which is the W-OFDM signal on baseband. It can be written like (2):

$$\mathrm{W-OFDM[k]} = \sum_{m=-\infty}^{+\infty} \sum_{n=0}^{N+1} d_{m.n} g[k - n(N + L_{CP} + L_{Ext})] e^{j\pi k \frac{n}{N}} \quad (2)$$

where: n: subcarrier, m: symbol, dm,: data symbol, $LExt$: windowing extension, LCP: cyclic prefix size, and $[n]$: windowing function.

Edge windowing is used to avoid unnecessary windowing and low spectral efficiency since the outer sub-carriers have a greater impact on out of band emissions than the inner sub-carriers. In order to construct windows with spectral effectivity (SE), the system relies on the cyclic prefix period [18]. Figures 5 and 6 demonstrate the architecture of the W-OFDM transmitter and receiver, respectively [25]. The research provide more current articles that offer a W-OFDM simulation technique [26]–[29].

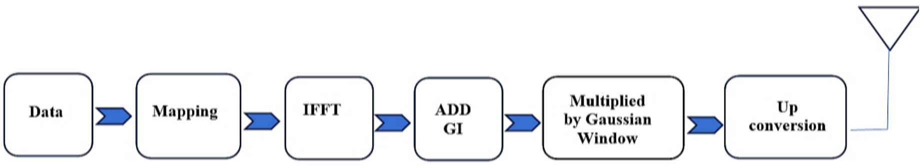

Figure 5. Transmitter system design of W-OFDM [30]

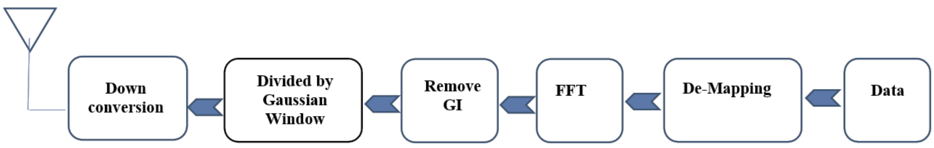

Figure 6. W-OFDM transceiver system architecture [30]

3. RESULTS AND DISCUSSION

In this part, simulations are carried out to verify the results of the system model. Performance analysis of F-OFDM, W-OFDM, and PDMA models are proposed based on different modulations (16, 32, and 128 QAM). Each subframe has a varied size measured in bits, as shown in Figure 7. Every waveform of the 3 distinct modulations uses the transport unit.

This research combines these three technologies F-OFDM, W-OFDM, and PDMA to provide an efficient system model with enhanced rates. In F-OFDM, where we can see the no of bits/subframe in 16

QAM is 22243, while the number of bits/subframe in 32 QAM is 32645, and the number of bits/subframe in 128 QAM is 50671. In Figures 8-10, bit error rates (BER) and energy per bit to noise power spectral density ratio (Eb/No) dB of F-OFDM are represented.

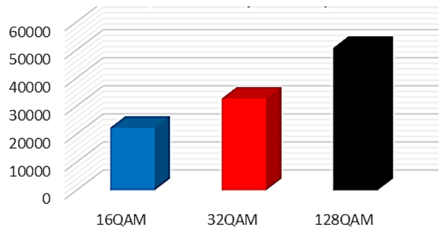

Figure 7. Filtered-OFDM number of bits of each subframe with 16, 32, and 128 QAM

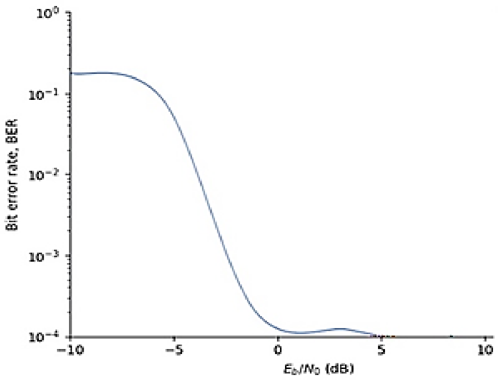

Figure 8. Bit error rates of filtered-OFDM system with 16 QAM modulation

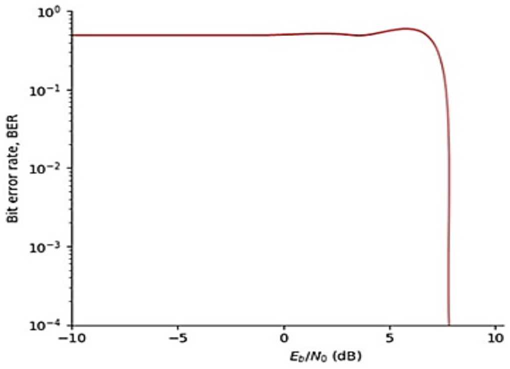

Figure 9. Bit error rates of filtered-OFDM system with 32 QAM modulation

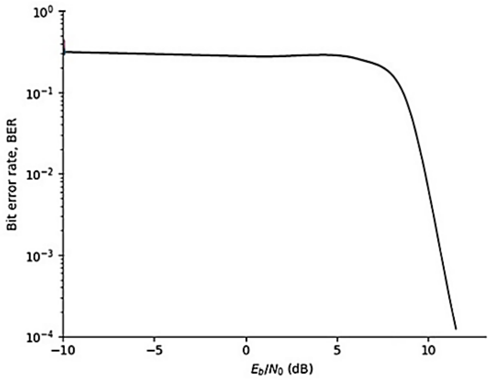

Figure 10. Bit error rates of F-OFDM system with 128 QAM modulation

It is clear that using modulation scheme 128 QAM met to increase the S/N of the signal, or it must have a value more than 11 dB, while this value can be about 0 dB for 16 QAM at the same value of BER. Figure 11 shows the size of a subframe for various modulation indexes, especially for 16 QAM, 32 QAM, and 128 QAM for the WIN-OFDM system.

In W-OFDM, where we can show the no. of bits/subframe in 16 QAM is 22243, while the number of bits/subframe in 32 QAM is 32645, and the value is about 50671 for 128 QAM which is the largest value of bits/subframe. In such a simulated model, segments of different signals for different modulation will be processed. Figures 12-14, bit error rates & energy per bit to noise power spectral density ratio (Eb/No) dB of W-OFDM are represented.

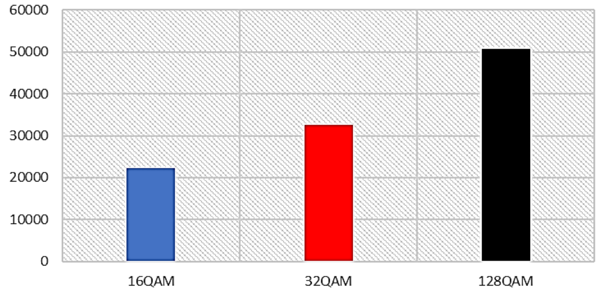

Figure 11. W-OFDM number of bits of each subframe with 16, 32, and 128 QAM

In W-OFDM, where we can show the no. of bits/subframe in 16 QAM is 22243, while the number of bits/subframe in 32 QAM is 32645, and the value is about 50671 for 128 QAM which is the largest value of bits/subframe. In such a simulated model, segments of different signals for different modulation will be processed. Figures 12-14, bit error rates & energy per bit to noise power spectral density ratio (Eb/No) dB of W-OFDM are represented.

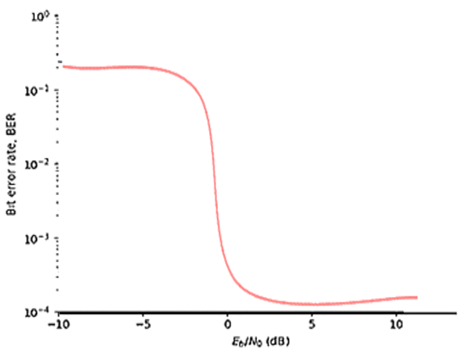

Figure 12. Bit error rates of W-OFDM system with 16 QAM modulation

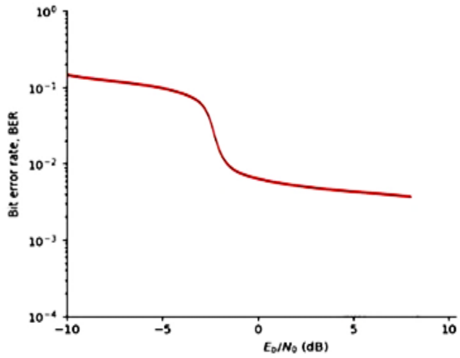

Figure 13. Bit error rates of W-OFDM system with 32 QAM modulation

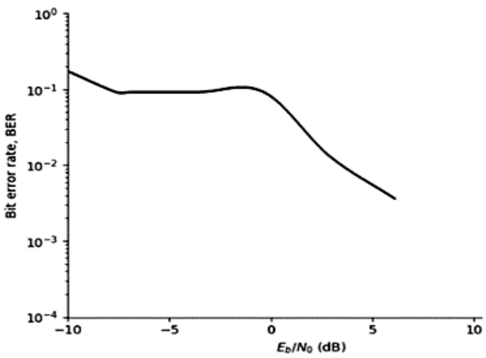

Figure 14. Bit error rates of a W-OFDM system modulated with 128 QAM

In this part, results are obtained to show how different forms of channel coding as well as power allocation, improve the output of a 5G compatible downlink multiple users F-OFDM data transmission in terms of bit error rate. Figures 9-11 demonstrate that the designed F-OFDM achieves greater spectral efficiency than W-OFDM after BER calculations 12, 13, and 14. When comparing Figures 10 and 14, it is clear that F-OFDM has a BER of 10^{-4} at 11 E_b/N_o (dB), whereas the value W-OFDM (E_b/N_o) is equal to 19 dB. The results show that the flexibility of the F-OFDM system in terms of filtering resolution is better than the W-OFDM system and that the spectrum localization of F-OFDM is higher than W-OFDM. But on the other hand, if the filter length is shorter than that of subcarrier-wise actions, massive MIMO spectral efficiency and band emissions are also compatible. We can observe from Figure 15 that PDMA has the best BER performance with QPSk modulation, when comparing F-OFDM and W-OFDM as mentions in Figures 8 and 14, it is clear that PDMA has a BER of 10^{-5}, whereas value (E_b/N_o) is equal to 20 dB.

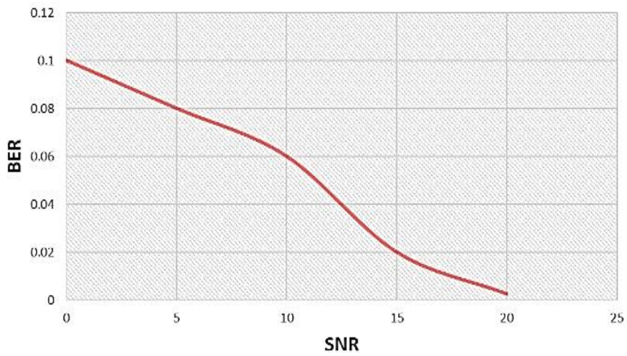

Figure 15. Bit error rates of PDMA system with QPSK modulation

4. CONCLUSIONS

The findings of this study will be crucial in forthcoming PDMA work for mobile communications. When PDMA technology is employed for non-orthogonal multi-access access, a better design strategy may be established, allowing 5G communication technology to better satisfy its needs. The frequency bands in the F-OFDM system have divided the radio spectrum, and each frequency band is divided into sub-bands. This goal is accomplished while being filtered by several filters at the same time. Currently, the band uses different spacing and cyclic prefix lengths according to the application. With an indefinite length of the filter, the amount of energy utilized by the guard band is limited. W-OFDM, on the other hand, reduces the change in the middle of connected symbols. Despite long delay spreading, the W-OFDM structure improves as the window length increases. The channel's resilience is reduced as a result of these situations. Moreover, the simulation for the PDMA system better results compares to W-OFDM and F-OFDM for 16, 32, and 128 QAM modulation techniques. Furthermore, the study concludes that the suggested PDMA modulation technique performs better for QPSK modulation techniques.

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