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Performance enhancement of maximum ratio transmission in 5G system with multi-user multiple-input multiple-output

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ABSTRACT

The downlink multi-user precoding of the multiple-input multiple-output (MIMO) method includes optimal channel state information at the base station and a variety of linear precoding (LP) schemes. Maximum ratio transmission (MRT) is among the common precoding schemes but does not provide good performance with massive MIMO, such as high bit error rate (BER) and low throughput. The orthogonal frequency division multiplexing (OFDM) and precoding schemes used in 5G have a flaw in high-speed environments. Given that the Doppler effect induces frequency changes, orthogonality between OFDM subcarriers is disrupted and their throughput output is decreased and BER is decreased. This study focuses on solving this problem by improving the performance of a 5G system with MRT, specifically by using a new design that includes weighted overlap and add (WOLA) with MRT. The current research also compares the standard system MRT with OFDM with the proposed design (WOLA-MRT) to find the best performance on throughput and BER. Improved system results show outstanding performance enhancement over a standard system, and numerous improvements with massive MIMO, such as best BER and throughput. Its approximately 60% more throughput than the traditional systems. Lastly, the proposed system improves BER by approximately 2% compared with the traditional system.

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1. INTRODUCTION

Wireless network connectivity has experienced rapid technical progress in the last 20 years. Using second-generation (2G) mobile technology, subscribers' only choice was to make a phone call or send a text message (i.e., SMS). Simultaneously, 4G technology has allowed for a variety of other services [1], High-speed Internet access, web gaming, video chat and conferencing are examples of such services [2]. The new wireless communications generation called 5G network will be launched by 2021. The data rate increases to 10 Gbit/s, 1 ms latency and a hundred times higher than the previous 4G network, thereby increasing the coverage and energy consumption of connected devices by 100 percent and enhancing their service life [3]. Current cellular base stations are under pressure to handle the increasing saturation of radio frequency spectrums [4]. Massive multiple-input multiple-output (MIMO) systems have been described as essential enablers for cellular connectivity in the 5G generation [5], [6]. This plan encourages the usage of several antennas on the base station (BS) side. This method has several advantages, including the ability to utilize simple uplink and downlink transmission [7]. Massive MIMO systems, on the other hand, confront significant architectural issues as the number of BS antennas grows to dozens or even hundreds [8]. Consequently, various possible methods must be thoroughly defined before applying a huge MIMO scheme [9]. Channel measurement, channel estimates, pilot and precoding systems, and other elements of a multi-user multiple-input multiple-output method were studied. Payami and Tufvesson [10], a real massive MIMO channel model with BS deployed in a cylindrical antenna array configuration was measured. Park and Ryu [11] assessed and contrasted orthogonal frequency division multiplexing (OFDM) and orthogonal time frequency space (OTFS) output in high Doppler and time-delay contexts. It used the MP detector for OTFS as recipient. Although being the most widely employed multi-carrier modulation strategy in wireless specifications for transmission below 6 GHz, OFDM has certain intrinsic drawbacks, according to paper [12]. The rectangular pulse form causes significant frequency leakage. The cyclic prefix (CP) addition causes spectral efficiency loss. Lastly, precise time and frequency synchronization is needed to maintain subcarrier orthogonality, thereby ensuring a low degree of intra and intercell interferences. MRT precoding for MU-MIMO downlink transmission was the focus of this paper [13]. Since the transmitter precoding matrices given by singular value decomposition (SVD) are determined sequentially, block diagonalization (BD) precoding exemplifies the high complexity of multi-user multiple-input multiple-output (MU-MIMO) systems. Elabd *et al.* [14] proposed to consider the impact of increasing number of BS antenna on the bit error rate (BER) and achievable sum-rate performance of the different LP algorithms. The efficiency of the MRT algorithm based on MU-MIMO is examined in this research using various waveform types. The MRT precoding scheme is the most common for massive MIMO systems because it is a low in difficulty. The rest of this article is laid out as follows, the system model is defined in section 2, WOLA and OFDM system are covered in section 3, the feasible sum rate of the linear precoding algorithms result and the numerical outcome are in section 4. Lastly, section 5 provides a summary of this research.

2. MRT MODEL

A downlink MU-MIMO setup with one base station is fitted with M, N transmit and received antennas as shown in Figure 1. k users with l_k antennas are serviced by of each BS. Without sacrificing generality, we presume that the obtained antenna number l_k for each user is the same. A flat fading channel and further conclude is considered that CSI is ideally understood at the transmitter, as well as coordination between the BS and the users. The channel matrix connecting BS to the user is of the kth user group, and is modeled as a flat fading MIMO channel [15]. Equation (1) is the channel matrix for the system:

$$\mathrm{H_k} = \begin{pmatrix} h_{11} & h_{12} & \dots & h_{1M} \\ h_{21} & h_{22} & \dots & h_{2M} \\ . & . & \dots & . \\ . & . & \dots & . \\ h_{l_k 1} & h_{l_k 2} & \dots & h_{l_k M} \end{pmatrix} \tag{1}$$

$$H = [\, H_1^T \quad H_2^T \quad \dots \quad H_k^T]^T$$

the received signal is as (2):

$$y_k = \sqrt{p} H^H W_s + n \tag{2}$$

The channel for MIMO matrix represents as H of the k user, average transmit power represents by P, the precoding matrix is Ws is for symbol vector, the additive noise is n symbol. The assumption is that the ideal channel state knowledge is accessible in BS. For a large MIMO scheme, such as in the frequency-division duplexing (FDD) duplex, BS acquires its pilot open loop time division mode works well in time division duplex (TDD) before using the transmitter symbol [16], [17]. BS selects three precoding schemes. Each user is provided with a symbol at the user terminal. Thus, each user's signal is produced at the terminal:

$$y_k = \sqrt{p}\, h_k^H W_s s_k + \sqrt{p}\, H_k \sum_{i=1, i\neq k}^{K} h_k^H W_j s_j + n_k \tag{3}$$

In particular, k is ergodic and measures the ergodic rate of users for uplink, where $\in_{ki}$ is the channel estimation error.

$$R_k^* = E\{log_2(1 + \frac{p\, |h_k^H W_s|^2}{1+p\, \sum_{,i\neq k}^{K} |h_k^H W_j|^2 + p\, \sum_{i=1}^{K} E|\in_{ki}|^2 +})\} \tag{4}$$

In uplink case, the measure of the ergodic rate of user as (5), (6):

$$y_k = \sqrt{p}\ \sum_{i=1, i\neq k}^{K} h_k^H W_j s_j + n_k \quad (5)$$

$$R_k^* = E\{log_2(1 + SINR_{opt,k)}\} \quad (6)$$

where the signal to interference plus noise ratio (SINR) for optimal linear receivers is always upper bounded.

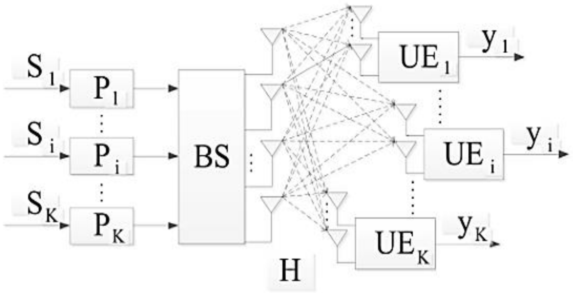

Figure 1. Block diagram of MU-MIMO model

3. WOLA AND OFDM SYSTEM MODELS

Consider 4G and 5G cellular networks, in which the digital modulation strategy used in the standards is called orthogonal frequency-division multiplexing [18], [19], as presented in Figure 2. OFDM is a common multi-carrier waveform format for RF systems. With high spectral efficiency and efficient MIMO integration, it can significantly increase data rate in bandwidth-constrained networks [20], [21]. Furthermore, the robustness of OFDM to phase noise and time-selective channels is determined by subcarrier spacing [22]. Consequently, OFDM can withstand nearly any channel condition enforced by the scenario and other criteria by employing scalable numerology and subcarrier spacing [23]. The addition of a CP and large side lobes, which necessitate certain null guard tones at the spectrum edges, reduces the spectral efficiency of OFDM [24]. Furthermore, high peak-to-average-power-ratio (PAPR) values can be present in OFDM signals. Subcarriers would no longer be orthogonal owing to frequency deviations, resulting in inter-carrier interference (ICI) [25]. WOLA-OFDM is the window strategy [26], which weighs overlap with and adds bases OFDM. Without considerable difficulty, this approach lowers out of band (OOB) emissions significantly. Interference from OOB is a significant restriction of an OFDM system. It is produced by the roll off of one subcarrier's side lobes onto neighboring subcarriers, resulting in inter-carrier interference and lower system performance. Given that this length determines the window length, the WOLA-OFDM OOB emission level decreases with the duration of CP. An asymmetrical window should be used to reduce the cyclical prefix by 30% instead of well-known symmetrical windows. This technique reduces OOB emissions but makes the device considerably sensitive to ISI and ICI caused by the channel.

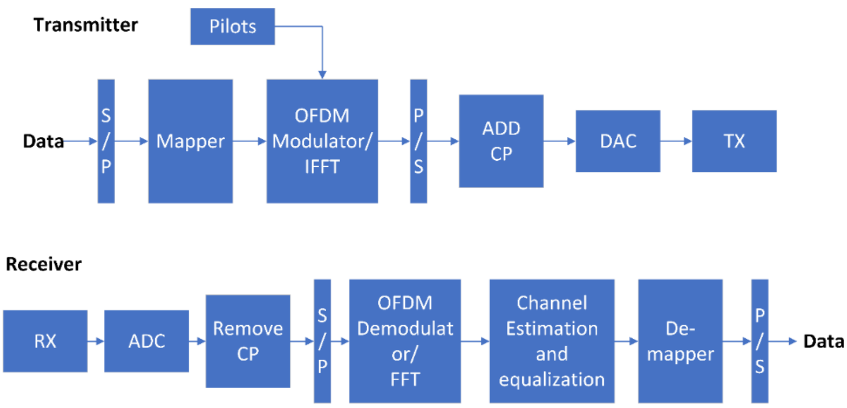

Figure 2. Block diagram of OFDM

To comply with the cyclic prefix in a conventional OFDM scheme of N subcarriers, the final CP samples from Inverse Fast Fourier Transform (IFFT) are added to the beginning of the N samples. In the WOLA method, three related sections are applied to the IFFT output samples (N). N samples are extended to both ends of the OFDM symbol, with $\alpha + \beta + GI$ samples at the start and samples at the end. At the transmitter, the first and last samples are formed by multiplying a non-rectangular window. The α samples at the start and end of the symbol are omitted. GI samples are used to absorb the interference from ISI and ICI. Figure 3 shows that the corresponding $\beta + N$ samples are windowed, Figure 4 shows the component of WOLA is used, where T_0 is symbol time, Tw time windowed for TX and RX. Steps of the simulation as shown in Figure 5.

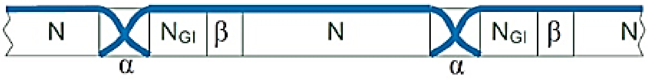

Figure 3. Block diagram of the WOLA symbols

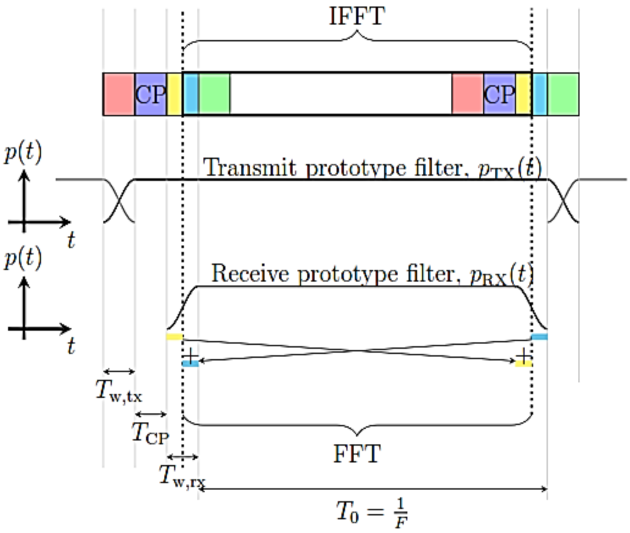

Figure 4. Component of WOLA parameters

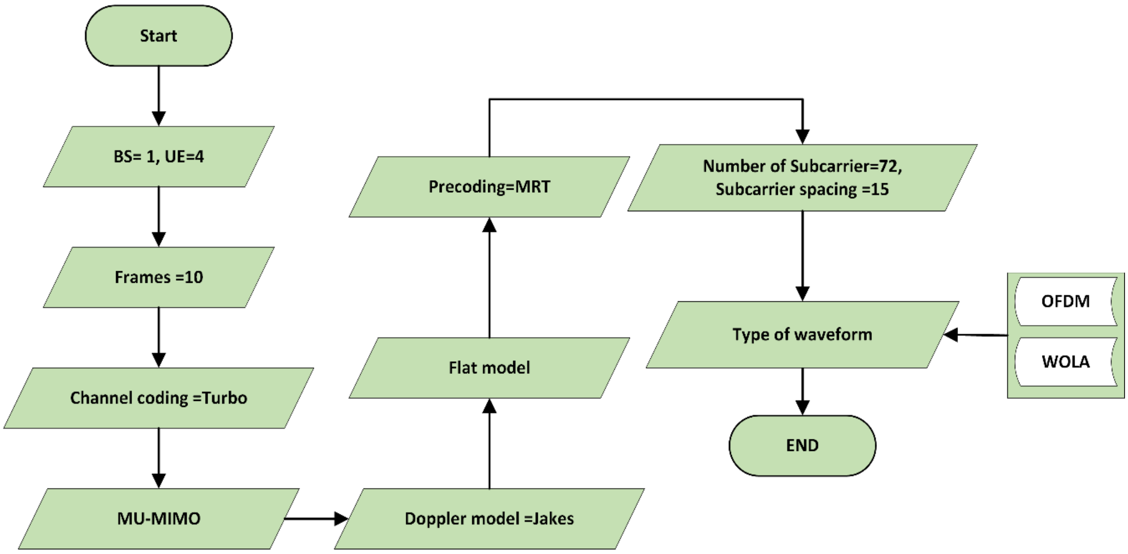

Figure 5. Phases of the simulation system model

4. RESULTS AND DISCUSSION

This section presents the numerical results obtained via the MATLAB simulation to validate the derived results. For fairness, the same setup for massive MIMO system was used under different WOLA and OFDM with MRT precoding scheme. The block diagram of system model simulation steps is illustrated in Figure 4. 5G NR techniques have been used in simulation, such as modulation up to 1024, as well as the massive MIMO up to 64 antennas. MATLAB is used to implement the model, it shows the number of Bs and user nodes, type of channel coding, Doppler model. The simulation parameters are presented in Table 1.

Table 1. Simulation parameters

Parameters	Values
No. of frames	10
Frame structure	FDD
User velocity (km/h)	15, 30, 50
Center frequency (GHz)	2.5
Path loss (dB)	100
Subcarrier spacing (kHz)	30
Feedback average type	MIESM
No. of subcarriers	72
N in WOLA	72
WOLA Window Length (α+β)	1/(14*2*30)
Channel modulation	QPSK to QAM 1024
Massive MIMO	4, 8, 12, 16, 24, 32, 64
Channel coding	Turbo
Waveform	OFDM, WOLA

Figure 6 shows the sum of the uplink throughput result of the proposed system and traditional systems (i.e., (MRT-WOLA and MRT-OFDM, respectively) at 15 km/h. The proposed system has the highest throughput, which is approximately 2.9 Mbps, compared with the traditional system, which has a throughput of approximately 1.9 Mbps. Figure 7 describes the sum of the downlink throughput result of the proposed and traditional systems. Accordingly, some improvements in the throughput are noted compared with the proposed system in terms of the different number of antennas, in which the proposed throughput has a higher bit rate than the traditional (approximately 8.4 Mbps and 5.5 Mbps, respectively).

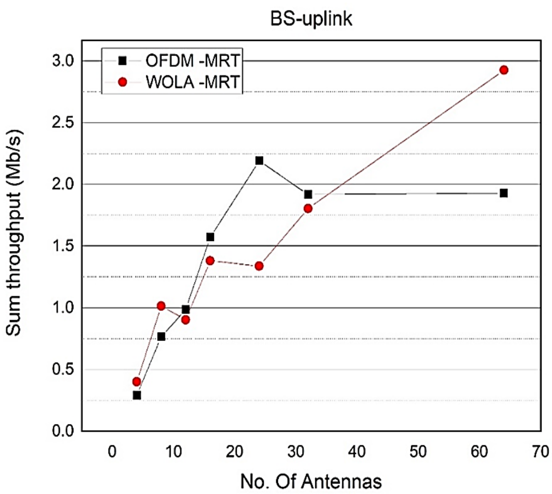

Figure 6. Sum of throughput in the uplink BS at 15 km/h

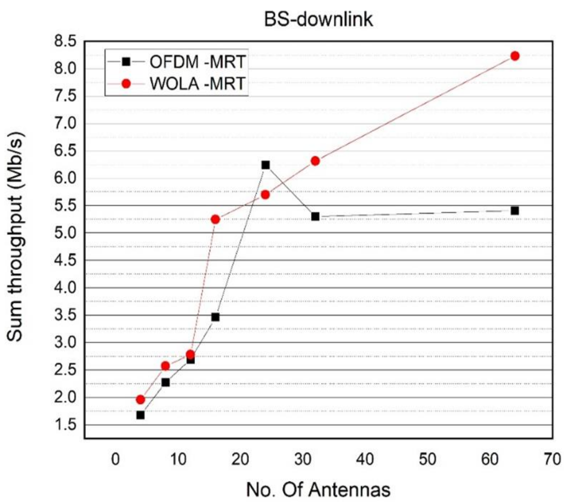

Figure 7. Sum of throughput in the downlink BS at 15 km/h

Figure 8 illustrates the uplink throughput result of UE with two systems (i.e., proposed and traditional systems). The proposed system has a higher throughput than the traditional system (i.e., approximately 1.5 Mbps and 1 Mbps, respectively). Figure 9 describes the sum of the downlink throughput results of the proposed and traditional systems, which show some improvements in the throughput with the proposed system for a different number of antennas. In particular, the proposed throughput has a higher bit rate than the traditional one (i.e., approximately 4 Mbps and 2.8 Mbps, respectively). Figure 10 shows that using two model schemes, the proposed and standard systems would decide which method offers the better BER, particularly when the number of antennas is 64. The proposed system achieves a lower BER of approximately 0.01 compared with the traditional system, which is approximately 0.03. Figure 11 shows that using two model schemes over SNR, MRT-WOLA offers the better BER when the SNR value about -3 db. The proposed system achieves a lower BER of approximately 0.06 compared with the traditional system, which is approximately 0.12.

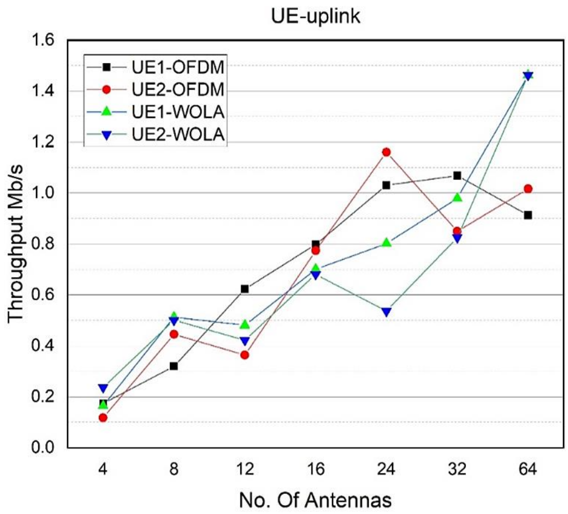

Figure 8. Throughput in the uplink UE at 15 km/h

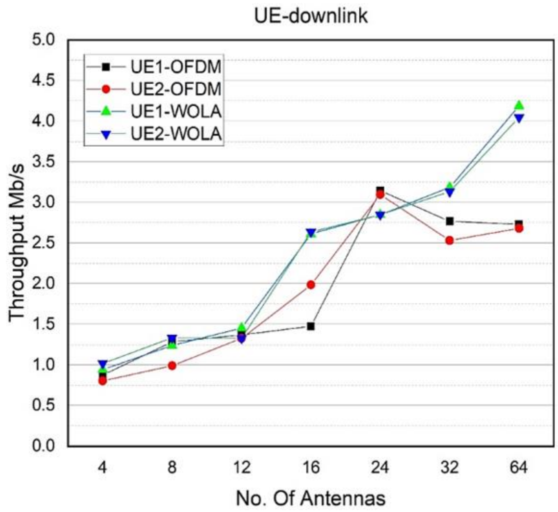

Figure 9. Throughput in the downlink UE at 15 km/h

Figures 12 and 13 show the effect of velocity on performance, three speeds of UEs are used to show the performance of throughput on two system MRT-WOLA and MRT-OFDM. MRT-OFDM provides the best performance with different velocity cases. Figure 14 describes the sum of the downlink throughput results of the proposed and traditional systems for 4 UEs, which show some improvements in the throughput with the proposed system for a different number of antennas. In UE3 and UE4, the proposed throughput has a higher bit rate than the traditional one (i.e., approximately 4.2 Mbps and 2.68 Mbps, respectively). The system model provides throughput highest at large MIMO, our system is not affected by the number of antennas due to the lack of interference.

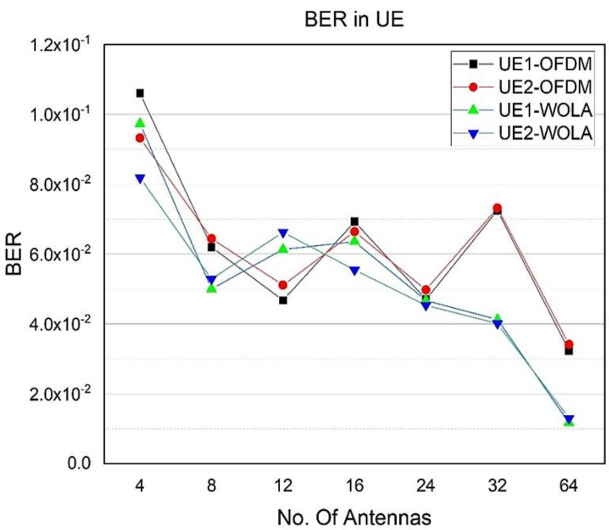

Figure 10. Results of BER vs. number of the antenna in UE at 15 km/h

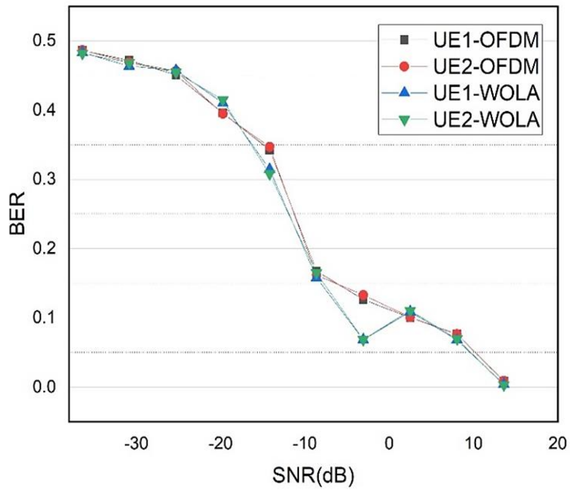

Figure 11. Results of BER vs SNR in UE at 15 km/h

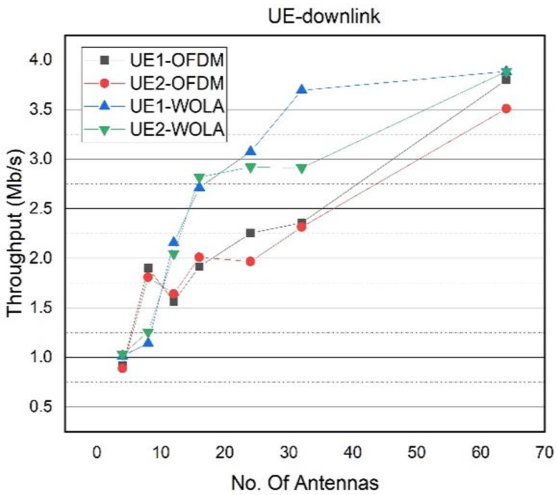

Figure 12. Throughput in the downlink UE at 30 km/h

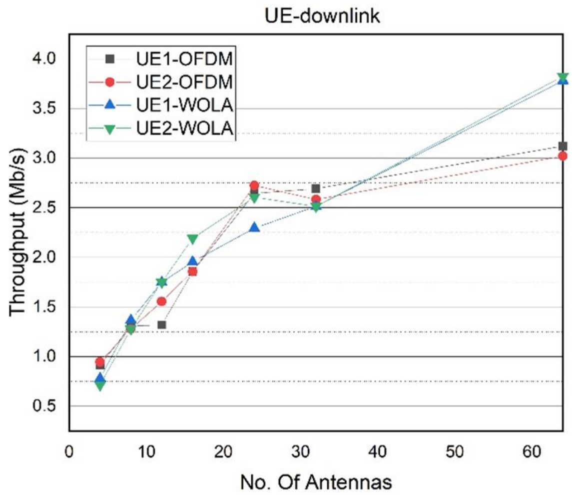

Figure 13. Throughput in the downlink UE at 50 km/h

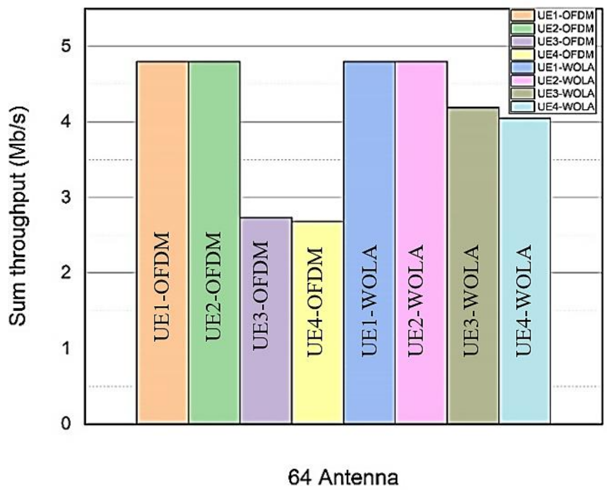

Figure 14. Results of throughput downlink over four UEs at 15 km/h

5. CONCLUSION

This research proposes a technique to improve the MRT precoding algorithm with MU-MIMO in 5G. The WOLA waveform is used in the proposed system as a replacement for OFDM, which enhances the overall communication system. Based on the throughput and bit error rate, the overall result shows that the proposed MRT-WOLA provides higher throughput than MRT-OFDM at approximately 45%. Meanwhile, the BER result provided the best performance in the proposed system, which is approximately 2% lower than MRT-OFDM. Therefore, the proposed system provides better performance when the number of antennas is large compared with the previous traditional method, which fails when increasing the number of antennas. This result will be used in the current and future generations of communications.

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