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Improvement in Performance of GFDM based 5G Wireless System with Massive MIMO and Channel Coding

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Abstract: In the realm of 5G wireless communication systems, non-orthogonal multiple access (NOMA) waveforms have emerged as highly promising candidates. Various NOMA waveforms such as FBMC, UFMC, and GFDM have gained significant attention due to their numerous advantages when compared to conventional OFDM systems. This paper delves into the examination of Bit Error Rate (BER) performance in the context of a Massive Multiple-Input, Multiple-Output (MIMO) based GFDM system for 5G technology. It explores the effects of different mapping techniques and filter roll-off factors. This approach amalgamates two advanced wireless communication technologies, Massive MIMO and GFDM, with the aim of harnessing their combined potential to elevate the performance and capacity of 5G communication systems. Massive MIMO contributes to substantial improvements in resilience against fading and interference, while GFDM offers superior frequency localization, reduced out-of-band emissions, and enhanced resource allocation flexibility when contrasted with traditional OFDM. The study demonstrates improved results, particularly when employing the optimal roll-off factor for the square cosine filter within the GFDM framework, and integrating channel coding techniques.

Keywords: NOMA, GFDM, Massive MIMO, 5G wireless communication system, Channel Coding, and more.

I. Introduction

The rapid advancement of wireless communication technologies has led to the emergence of 5G networks, promising unparalleled data rates, increased capacity, and enhanced connectivity for a wide range of applications. The application of 5G wireless system is shown in figure 1. Non-orthogonal multiple access (NOMA) waveforms, including Filter Bank Multicarrier (FBMC) and Universal Filtered Multicarrier (UFMC) and Generalized Frequency Division Multiplexing (GFDM) have emerged as highly promising alternatives [1]. These waveforms have garnered significant attention due to their numerous advantages over conventional OFDM systems.

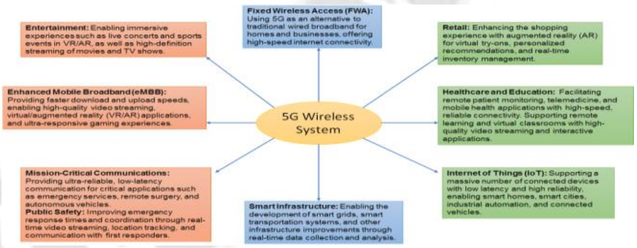

Fig 1: Applications of 5G wireless system

In this quest for superior performance, researchers and engineers have been exploring innovative solutions to meet the escalating demands of the digital era [2]. Generalized Frequency Division Multiplexing (GFDM) is a type of non-orthogonal multiple access (NOMA) waveform that has some distinct characteristics compared to other NOMA waveforms like Filter Bank Multicarrier (FBMC) and Universal Filtered Multicarrier (UFMC). GFDM is based on a filter bank structure that provides some degree of orthogonality between subcarriers, but not as strictly as in FBMC or UFMC. This means that GFDM can offer a balance between spectral

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efficiency and complexity. GFDM offers more flexibility in terms of waveform shaping and filter design compared to FBMC and UFMC, which can be advantageous in adapting to different channel conditions and requirements. GFDM can effectively mitigate interference through its filter bank structure and processing, similar to FBMC and UFMC. However, the specific interference handling capabilities may differ based on the implementation. Overall, GFDM offers a unique set of advantages and trade-offs compared to other NOMA waveforms, making it suitable for certain applications and scenarios where its characteristics align with the requirements [3].

In this paper, performance analysis and improvement of GFDM based wireless system is performed with Massive MIMO (Multiple-Input, Multiple-Output) and channel coding.

II. GFDM AND MASSIVE MIMO SYSTEM

GFDM is a novel modulation scheme that offers several advantages over the well-established OFDM (Orthogonal Frequency Division Multiplexing). GFDM allows for better frequency localization, reduced out-of-band emissions, and more flexible resource allocation, making it a compelling candidate for future communication systems. The versatility and adaptability of GFDM have sparked interest in its potential applications in 5G and beyond, especially in scenarios with stringent spectral efficiency and interference management requirements. The scheme of GFDM transmitter and receiver is shown in figure 2.

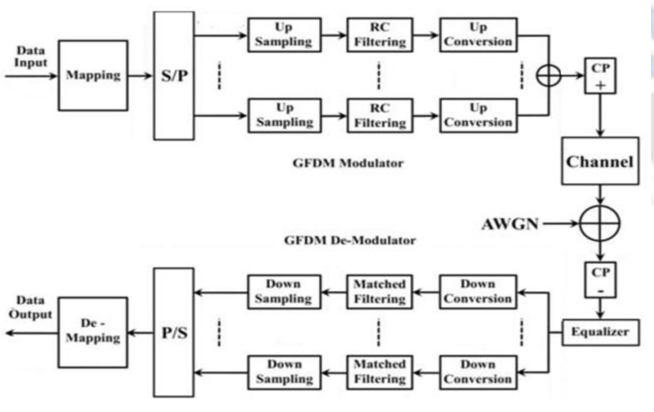

Figure 2: Scheme of GFDM based data transmission

Researchers have done a great work in respect for GFDM based wireless system for 5G. Kaiming Liu et al. developed a theoretical analysis of the Peak-to-Average Power Ratio (PAPR) and optimal pulse shaping filter design for GFDM systems. They derived closed-form expressions for the PAPR distribution and proposed an optimization criterion for pulse shaping filter design. Their analysis aids in understanding PAPR properties and designing PAPR reduction schemes for GFDM signals [4]. Amirhossein et al. focused on self-interference cancellation in GFDM full-duplex transceivers under various impairments. They studied analog and digital self-interference cancellation and proposed a complementary suppression method, showing significant improvements in SIR and uplink rate compared to OFDM [5].Siva et al. investigated blind CFO estimation for GFDM systems using universal software radio peripheral synchronization. They derived the maximum likelihood estimate of CFO and evaluated it in various channel environments, demonstrating the effectiveness of blind methods for CFO estimation in GFDM [6].Jessica et al. designed a non-orthogonal multicarrier waveform using GFDM for radar with communications systems, showing its benefits over OFDM in mitigating inter-system interference and achieving superior radar performance [7]. Peng Wei et al. studied N-continuous signaling for GFDM to balance BER and side lobe suppression performance. They proposed a signal recovery algorithm and demonstrated that N-continuous GFDM outperforms N-continuous OFDM in sidelobe suppression [8]. Fei Li et al. proposed a novel interference-free GFDM transceiver with dual filter, guaranteeing orthogonality of subcarriers to eliminate intrinsic self-interference. Their GFDM-dual filter scheme showed better performance than conventional GFDM systems [9]. Zhenu developed a pseudo-noise sequence-based synchronization approach for GFDM in 5G communication systems, showing lower mean square error and symbol error rate compared to conventional CP-based synchronization [10].

The different advantageous techniques are embedded with the GFDM based wireless technique to overcome the issues and improvement of performance. Massive MIMO, a key technology in 5G, brings a significant change to wireless communication by deploying a large number of antennas at the base station. Unlike traditional MIMO systems, which are limited to 8 antenna elements, massive MIMO in 5G can support up to 256 antennas at the base station and 32 antennas at user equipment. This increase in antenna elements leads to notable improvements in throughput and coverage in cellular networks [11,12].

Using multiple antennas helps mitigate the higher path loss at higher frequencies. By combining energy from these antennas in specific directions, the system can overcome the challenges of high frequencies. This incorporation of beamforming techniques into MIMO allows for radio energy to be concentrated within smaller angular sectors, greatly improving spectral efficiency [13].

Massive MIMO systems are a groundbreaking technology in wireless communication, significantly increasing system capacity. The adoption of MIMO systems has been invaluable in overcoming various challenges such as fading and multipath issues, substantially enhancing wireless communication capabilities [14]. The advantage of Massive MIMO system for 5G is shown in figure 3.

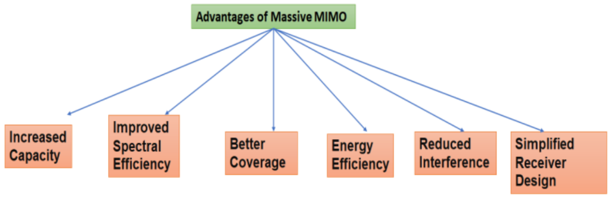

Figure 3: Advantages of Massive MIMO system for 5G

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The seamless integration of Massive MIMO and GFDM presents an exciting opportunity to harness the benefits of both technologies and address some of the key challenges faced by 5G networks. The combination of Massive MIMO's spatial multiplexing capabilities with GFDM's spectral efficiency and improved frequency localization promises to deliver a communication system with unmatched performance and reliability.

The primary objective of this paper is to conduct a comprehensive parametric analysis of a Massive MIMO based GFDM system for 5G. We aim to investigate the impact of various system parameters, including the number of antennas, subcarrier spacing, symbol duration, and modulation order, on the overall system performance by evaluating the spectral efficiency, bit error rate (BER). Furthermore, in recognition of the importance of robust communication in real-world scenarios, we explore the potential benefits of incorporating channel coding techniques into the system.

III. SYSTEM DESCRIPTION

The simulation of the GFDM based wireless system along with massive MIMO and has been done based on the simulation of the scheme shown in the figure 4.

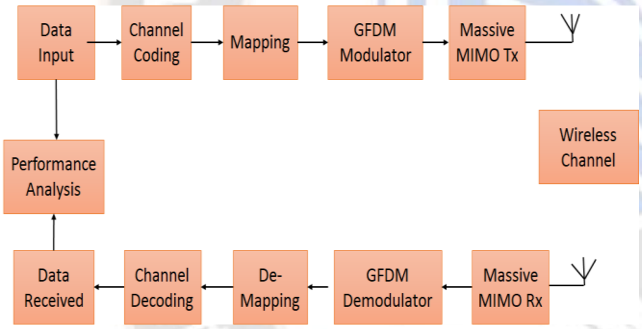


Figure 4: Scheme of simulation for GFDM wireless system

let's consider a simplified model. In GFDM, the transmitted signal can be represented as:

$$x(t) = \sum_{k=0}^{N-1}\sum_{n=-\infty}^{\infty} S_k\, g(t-nT)\, e^{j2\pi kf(nT)} \qquad (1)$$

Where:

- x(t) is the transmitted signal.
- N is the number of subcarriers.
- $S_k[n]$ is the symbol transmitted on the k^{th} subcarrier at time index n.
- g(t) is the prototype pulse shaping filter.
- f(nT) is the carrier frequency offset at time index n with symbol duration T.

In Massive MIMO, let's assume we have M transmit antennas. The signal at the antennas can be represented as:

$$x(t) = \begin{bmatrix} x_1(t) \\ x_2(t) \\ \cdot \\ \cdot \\ \cdot \\ x_m(t) \end{bmatrix} \qquad (2)$$

The signal at the m^{th} transmit antenna, $x_m(t)$, can be obtained by applying the appropriate beamforming weights w_m to the transmitted signal:

$$x_m(t) = w_m^H x(t) \qquad (3)$$

Where w_m is the beamforming weight vector for the m^{th} antenna. In Massive MIMO, the received signal at the k^{th} subcarrier and the m^{th} receive antenna can be represented as:

$$y_{km}(t) = h_{km}^H x(t) + n_{km} \qquad (4)$$

Where:

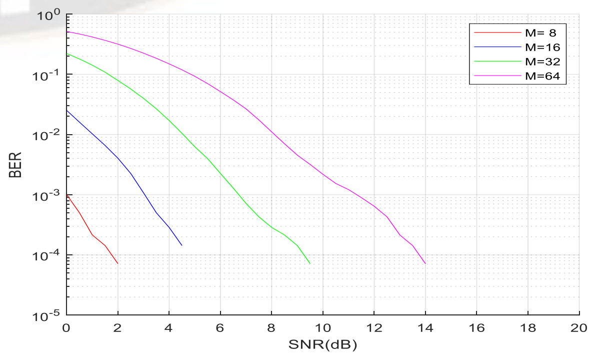
- y_{km} is the received signal.
- h_{km} is the channel response between the k^{th} subcarrier and the m^{th} receive antenna.
- n_{km} is the additive white Gaussian noise (AWGN) at the k^{th} subcarrier and the m^{th} receive antenna. The received signal is then being processed to recover the transmitted symbols using zero forcing equalization.

IV. SIMULATION AND RESULT

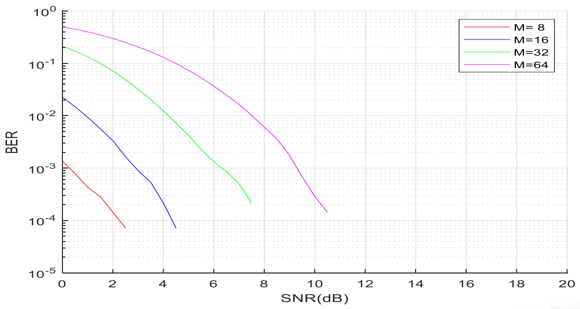
The system is simulated for different parameters and technique. The list of the important parameters are shown in the table : 1

S. No.	Parameters	Value
1	Channel Coding Technique	Convolution Coding
2	Mapping Technique	QAM-8, QAM-16, QAM-32, QAM-64
3	Filter Type	Root Raised Cosine Filter
4	Roll Off Factor	0.1, 0.25
5	No. of Transmitter Antenna	16
6	No. of Receiver Antenna	10 to 50
7	Channel Type	Rayleigh fading channel
8	Receiver Equalizer	Zero forcing
9	Decoding Technique	Viterbi

The BER performance for different antenna and different roll off factors for different mapping scheme are illustrated in the figure 5.



(a)



(b)

Figure 5: BER Result for different roll off factor (a) 0.1, (b) 0.25

There is a improvement has been observed at roll of factor 0f 0.25. Particularly at higher QAM mapping scheme, BER is significant improved with optimized roll of factor.

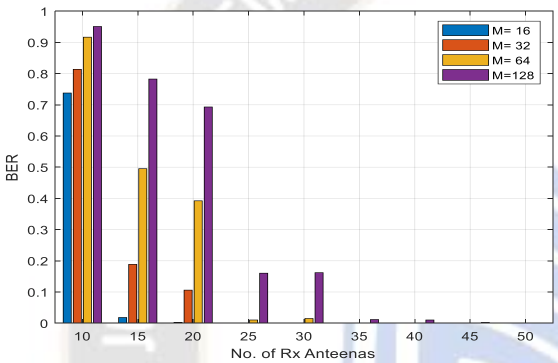


Figure 6: BER Result for different number of receiving antennas

With increase in number of receiver antenna, there is a significant gain are observed for QAM-64 in required SNR to maintain the BER of 0.0001.

V. CONCLUSION

This paper aims to contribute to the growing body of research in the area of advanced 5G communication systems, paving the way for more efficient, reliable, and future-proof wireless networks. The combined strength of Massive MIMO and GFDM, augmented by channel coding, holds the promise of transforming the 5G landscape and shaping the future of wireless communication. The improvement has been noticed with channel coding as well as by increasing the transmitting antenna.

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