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Original Article

Transform-Aided Performance Enhancement in Massive MIMO-OTFS Systems over Various Fading Channels

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Abstract *- Massive Multiple Input Multiple Output or massive-MIMO systems are a cornerstone technology in modern wireless communications, especially in 5G and beyond networks. Including Orthogonal Time Frequency Space modulation (OTFS) in Massive MIMO makes the systems more robust, with further promise for robust performance in both high-mobility and multipath-rich environments. OTFS taps into the delay-Doppler domain representation of the wireless channel, ensuring greater immunity to time-frequency variations and enhanced channel estimation compared to traditional modulation methods. While going through the detailed literature available for OTFS based Massive MIMO system it was seen that a very less work has been carried out in exploring the potential and performance enhancements of the system if the system were implemented using some diverse signal transforms such as DWT, FrFT etc, moreover it has not yet been explored as to see the effect of fading onto these systems by deployment of these diverse transforms, Therefore it leaves a gap in the available literature. This paper focusses on the improvement of the Massive MIMO-based OTFS systems by implementing the systems using more advanced signal transforms such as Discrete Wavelet Transform (DWT) and Fractional Fourier Transform (FrFT) under various fading channels. The simulation results have shown significant improvement in performance when implemented using these advanced transforms.*

Keywords *- Massive-MIMO, OTFS Systems, Wavelet Transforms, Channel fading.*

1. Introduction

Wireless uses data transfer through wireless communication rather than through wiring or cables. Every new generation of wireless communications develops more sophisticated capabilities that allow users many choices on how they can get the information and services they require. As a result, content access has become possible almost from anywhere. Meanwhile, the mobile devices are getting more powerful and diverse, with the ability to execute more sophisticated operations. Its coverage is always improving along with its performance and capacity [1]. The technology of MIMO is built from the general radio-wave phenomenon known as multi-path. Multi-path transmits data multiple times, but now at slightly different angles and intervals after bouncing off objects such as walls, ceilings, or other objects. MIMO enables receivers to expand their signal-capturing capability. That is done by letting antennas combine data streams, which enter from various paths and arrive at different times [1]. Massive MIMO: The base stations make use of an exceptionally large number of antenna components to enhance spectrum and energy efficiency. This technique mainly highlights the unique opportunities and problems that are introduced by the Massive MIMO systems, with several antennas, to achieve better performance in wireless communication systems. It also explores how Massive MIMO system performance gets affected due to wireless fading channels, which is an important step while designing and optimizing the systems. This also highlights the importance of signal processing techniques, an important area of research in the field, in improving the performance of massive MIMO-based OTFS systems. Therefore, this paper thoroughly analyses the performance of Massive MIMO OTFS systems under the wireless fading channels. Further, improvement of system performance with the help of DWT and FrFT techniques is another major focus of this work.

2. Massive MIMO Model

Multiple antennas are used by MIMO systems to send and receive signals. Through the use of spatial multiplexing and antenna diversity, wireless communications may be able to satisfy the increasing need for high data rates and dependability. MIMO systems suffer from spatial correlation as a result of the fading effect and insufficient distance between the antennas [2]. The Massive MIMO model is comprised of Multiple transmit and receive antennas, which can be illustrated by the following Equation (1)

$$y = H_1x+n \quad (1)$$

In this case, (1) shows the transmission of M modulated symbols $x_{M \times 1}$ across a channel with additive noise $n_{N \times 1}$ and a gain of $H1_{N \times M}$. A received vector $y_{N \times 1}$ is created at the receiver by combining the symbols that were picked up by N antennas, as shown in the figure below.

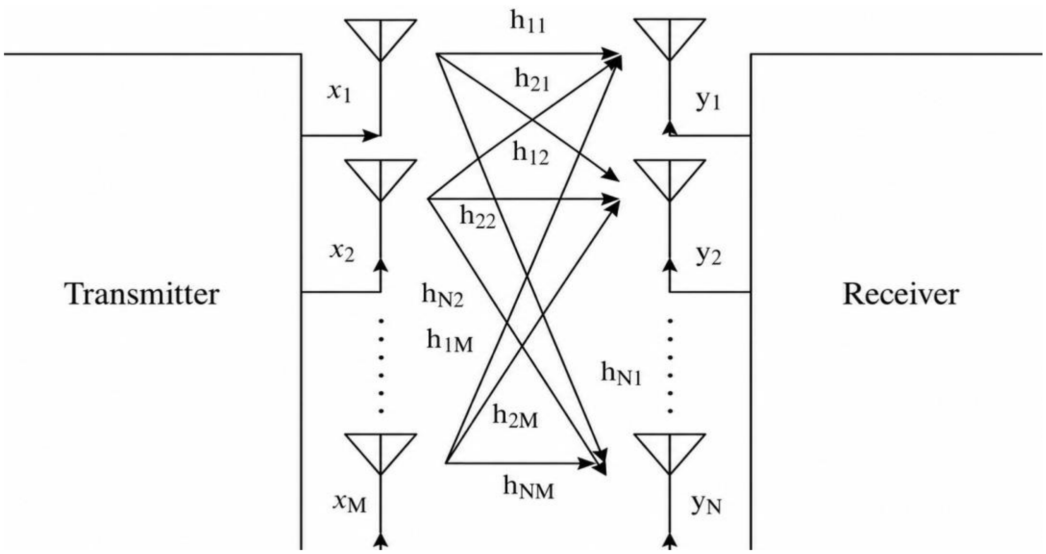


Fig. 1 Massive MIMO model [2]

3. Massive MIMO-OTFS Model

A Massive MIMO OTFS system is a next-generation wireless communication system that integrates two key technologies: Massive MIMO (MIMO) and OTFS (OTFS) modulation. Both technologies are often used together in the next generation of wireless communication networks, including 5G and beyond, to enhance capacity, reliability, and performance, especially in challenging environments wireless environments. In the case of massive MIMO, the huge number of antennas available in the base station is used to support multiple users through spatial multiplexing and beamforming techniques. OTFS modulation, however, encodes information into the delay-Doppler domain with great performance even in a highly time-varying multi-path environment. A Massive MIMO-based OTFS system can be shown as follows.

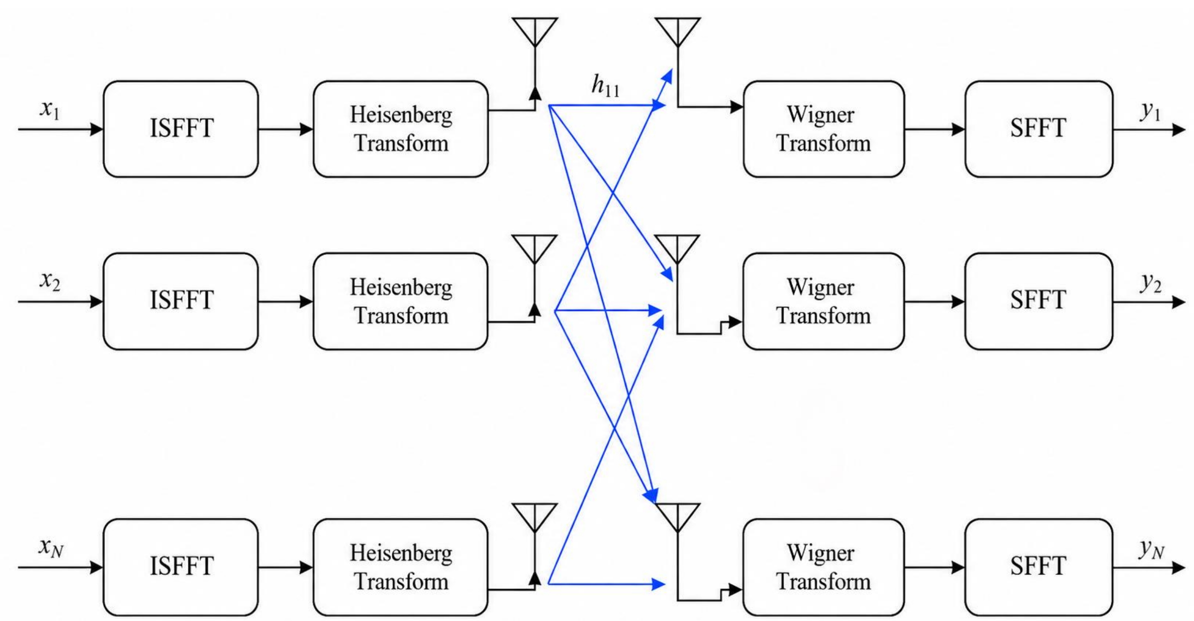


Fig. 2 Massive MIMO based OTFS system [3]

Here, the individual channels are subjected to OTFS modulation by performing ISFFT and Heisenberg's transforms on them to translate them into the DD domain. The signals are then transmitted through a very large array of antennas [3]. At the receiver, the signals are intercepted through large antenna arrays and then detected back using Wigner and SFFT transforms. At the transmitter, the signals are first converted from the Delay-Doppler domain to the TF domain using OTFS modulation by implementing the ISFFT transform as follows.

$$X_q[n,m] = \frac{1}{\sqrt{MN}} \sum_{k=0}^{N-1} . x_q[k,l] e^{j2\pi(\frac{nk}{N} - \frac{ml}{M})}$$

$$X_q[n,m] = \frac{1}{\sqrt{MN}} \sum_{k=0}^{N-1} . x_q[k,l] e^{j2\pi(\frac{nk}{N} - \frac{ml}{M})} \quad (2)$$

The signal in the TF domain is then subjected to the Heisenberg Transform as follows [4]

$$\tilde{x}_q(t) = \sum_{n=0}^{N-1} . \sum_{m=0}^{M-1} X_q[n,m] . g_{tx}(tnT) e^{j2\pi m \Delta f(t-nT)} \quad (3)$$

The Massive MIMO model can also be represented by the following equations.

$$y_s(t) = \sum_{q=1}^{Q} \iint h_{q,s}(\tau,\nu) x_q(t\tau) e^{j2\pi\nu(t-\tau)} \, d\tau \, d\nu$$

$$\widetilde{w_s}(t) = \sum_{q=1}^{Q} \sum_{i=1}^{L_s} h_{q,s,i} \; x_q(t - \tau_{s,i}) \, e^{j2\pi\nu_{s,i}(t-\tau_{s,i})} \quad (4)$$

While the input-output relationship in the system can be represented as follows

$$\begin{aligned} y_1 &= H_{11}x_1 + H_{12}x_2 + \cdots + H_{1N_t}x_{N_t} + v_1 \\ y_2 &= H_{21}x_1 + H_{22}x_2 + \cdots + H_{2N_t}x_{N_t} + v_2 \\ &\vdots \quad \vdots \quad \vdots \quad \vdots \\ y_{N_r} &= H_{N_{r1}}x_1 + H_{N_{r2}}x_2 + \cdots + H_{N_{rt}}x_{N_t} + v_{N_r} \end{aligned} \quad (5)$$

4. Literature Survey

Both the MIMO as well as MIMO-based OTFS systems have been extensively researched over the past couple of decades due to their vast potential for deployment in future 5G/6G networks. This section briefly discusses the literature related to work being done in the said areas and future possibilities. The work in [1]discusses the vast MIMO (MIMO) system channel capacity. Important findings of this work [1] will throw light on the improvements of massive MIMO systems in wireless Communication systems. In the work conducted in [2], linear detection is employed variously with different decomposition techniques with improvements. It was noted that there is a 10 dB degradation in the Channel gain for 10% increment in correlation coefficient [2]. In order to reliably reconstruct channel information, the study[3] suggests a unique deep learning network called Doubly Selective Channel Feedback Network (DSC-FeedNet)[3], which is based on the idea of an autoencoder and an inception block[3]. According to simulation data, DSC-FeedNet performs better than CSiNet and the current Fast Iterative Shrinkage Thresholding Technique (FISTA) network [3]. In order to enable distinct demodulation of every DD domain information symbol at the User Terminals (UTs), they have suggested a unique OTFS-based multi-user precoder [4] at the Base Station (BS) and a matching Low Complexity Detector (LCD) at the UTs [4].The simulation results have validated the proposed claims[4, 5].The downlink performance of CF-mMIMO systems under probabilistic LoS/NLoS channels has been covered in this work [5].

The findings indicate that statistical beamforming methods that rely on LoS can produce performance that is comparable to or even better than complete beamforming [5]. For massive Multi-Input Multi-Output (MIMO) using OTFS (OTFS) modulation, a channel estimate technique has been put forth in [6]. The method approximates identical dominating pathways that are similar and indistinguishable [6]. It has been described[7] how Orthogonal Frequency Division Multiplexing (OFDM) modulation contributes significantly to baseband latency in huge MIMO (MIMO) systems. According to simulations[7], the architecture achieves the lowest latency for single-input pipelined FFT/IFFT to date, with a throughput of 0.6 GS/s and a delay of 1200 clock cycles structures [7].

In massive MIMO (MIMO) downlink systems based on Orthogonal Frequency-Division Multiplexing (OFDM), the issue of Peak-To-Average Power Ratio (PAPR) reduction has been investigated in [8]. According to simulation findings [8], the suggested approach significantly outperforms current techniques in terms of computational complexity and PAPR reduction. Massive MIMO orthogonal time using an uplink angle-delay-Doppler domain Non-Orthogonal Multiple Access (NOMA) method [9] in response to the issue that users' connectivity is severely constrained when they have overlapping angle signatures and limited delay-Doppler domain resources, frequency space (MIMO-OTFS) networks have been developed[9]. In multi-cell massive MIMO systems, the effectiveness of downlink transmit beamforming under Rician propagation has been taken into account [10]. The findings [10] show that the suggested ZF beamforming works better than the traditional ZF beamforming. The work presents[11] the first performance evaluation of OTFS (OTFS) modulation in cell-free massive MIMO (MIMO) systems. Assuming that each access point has many antennas coupled by low-resolution Analog-To-Digital Converters (ADCs)[12], this article examines the uplink and downlink attainable rates of cell-free massive Multi-Input Multi-Output (MIMO) systems [12] over Rician fading channels. In order to determine the circumstances in which knowing the channel statistics is advantageous while predicting a channel, this work models randomly distributed Rician fading channels and evaluates the performance difference numerically [12].

A proposed channel estimation method [13] based on the 3D Structured Orthogonal Matching Pursuit (3D-SOMP) algorithm demonstrates that the suggested 3D-SOMP[13] approach may provide precise channel state information with little pilot overhead. The work in[13] proposes a channel estimation method based on a 3D-structured orthogonal matching pursuit algorithm. Delay-Doppler Alignment Modulation (DDAM)[14], a unique approach, has been suggested[14]. The suggested DDAM technique[14] is compared numerically with several benchmarking schemes, such as beam alignment along the dominant path, MIMO-Orthogonal Frequency-Division Multiplexing (OFDM) with or without Carrier Frequency Offset (CFO) compensation, and MIMO-OTFS (OTFS). For downlink massive MIMO-OTFS in the presence of fractional Doppler, a Channel State Information (CSI) acquisition approach[15] comprising a channel estimate algorithm and deterministic pilot design has been presented [15].

The study examines a multi-cell Downlink (DL) massive MIMO system[16] that uses Rician fading channels where each user has a single antenna, and each Base Station (BS) has a vast array of antennas [16]. The tightness and correctness of these closed-form formulations are supported by numerical findings [16], which also demonstrate that EGT and LOS-EGT are more resilient to intercell interference and pilot contamination than the MRT when the number of antennas and intercell interference level are high. The study in [17] examines, while accounting for channel estimate errors, the Downlink (DL) rate of multi-cell huge multi-user multiple-input and multiple-output systems using Rician fading channels [17]. The findings [17] indicate that situations with limited mobility, small Rician K-factors, and a high signal-to-noise ratio are the only ones where using BT with MRT processing is recommended [17].

A two-way full-duplex decode and forward relaying system [18] with poor channel state information under Rician fading channels has been studied[18]. Investigations are conducted on the performance of mixed-ADC Massive MIMO systems [19] over Rician fading channels. It was determined that by using the mixed-ADC architecture for 5G, realistic massive MIMO may achieve a significant performance with low power consumption [19]. The work in [20]examines, analyses, and evaluates the performance of a TDD Massive MIMO with Non-OPs running[20] in Rician fading when HWIs are present.

The LSFD enhances the UL SE performance, and coherent transmission mode outperforms non-coherent transmission in the DL[21], according to numerical results that examine the Uplink (UL) and Downlink (DL) Spectral Efficiency (SE) of a cell-free massive Multiple-Input-Multiple-Output (MIMO) system over Rician fading channels[21]. The study[22] examines a grant-free random access system's combined channel estimation and device activity detection. Simulation results[22] show that the suggested algorithms perform better than traditional techniques.

The study [23] presents a PAPR-aware precoding scheme that takes advantage of the large-scale MIMO antenna systems' excessive spatial degrees of freedom. The numerical results[23] demonstrate that several orders of magnitude improvements can be made in comparison to state-of-the-art methods, including multi-user interference cancellation and instantaneous power consumption reduction. New issues have been addressed in the proposed work[24], and thorough modelling, performance analysis, and algorithm design for simultaneous localisation and communications based on huge MIMO-OTFS have been thoroughly studied [24].

The detailed rate analysis[25] for cell-free massive MIMO (MIMO) systems over spatially correlated Rayleigh fading channels is presented in this paper. The effectiveness of the suggested max-min fairness algorithms and our analytical results are validated by the numerical results [25]. This study proposes a tensor-based Orthogonal Matching Pursuit (OMP) channel estimation method [26] that takes use of the delay-Doppler-angle domain's channel sparsity. The suggested tensor-based OMP algorithm's superiority and resilience are confirmed by numerical simulations [26]. This investigation[27] looked at the massive MIMO OTFS network's UL-assisted high mobility DL channel estimation technique.

5. Research Gap

Although OTFS is a very new concept, which started gaining popularity after 2018, but with the implementation of OTFS in the OFDM system and observing its large-scale implementation and advantages and ability to cater to high data rates and upcoming next-generation wireless networks, a lot of research work has started being done in this area. While going through the detailed literature available for OTFS based Massive MIMO system it was seen that a very less work has been carried out in exploring the potential and performance enhancements of the system if the system were implemented using some diverse signal transforms such as DWT, FrFT etc, moreover it has not yet been explored as to see the effect of fading onto these systems by deployment of these diverse transforms, Therefore it leaves a gap in the available literature to be filled to see the promising and possible performance enhancements in the Massive MIMO based system if implemented using these transforms. This research Gap is explored in the proposed research work.

6. Introduction to Diverse Signal Transforms

The proposed OTFS system performance was implemented using various diverse Transforms which include the Fast Fourier Transform, the FrFT Transform and the Discrete Wavelet Transform, which are explained in this section.

6.1. Discrete Wavelet Transform (DWT)

Discrete Wavelet Transform (DWT) is a mathematical technique used in image reduction and signal processing. Wavelets, which are localized in both the frequency and temporal domains, are the units that make up a signal. This decomposition provides a multi-resolution analysis of the signal, including both the high- and low-frequency components, with different levels of detail. The DWT separates the signal into detail and approximation coefficients in turn. The approximation coefficients capture the signal's broad patterns at its coarsest scale, while the detail coefficients show finer details at other scales. A multi-level signal representation can be obtained by an iterative hierarchical decomposition. The two main types of wavelet transformations are the Continuous Wavelet Transform (CWT) and the DWT. The DWT is highly useful in digital signal processing because it provides a discrete and computationally efficient approach to signal analysis. Because it can represent signals in both domains simultaneously, the DWT is helpful incase of non-stationary signals with changing frequency values. To create the wavelet transform, the signal is passed through a number of digital filters of different sizes. This scaling procedure is accomplished by subsampling, which modifies the resolution of the signal [28]. The following diagram can be used to show how such wavelets are generated.

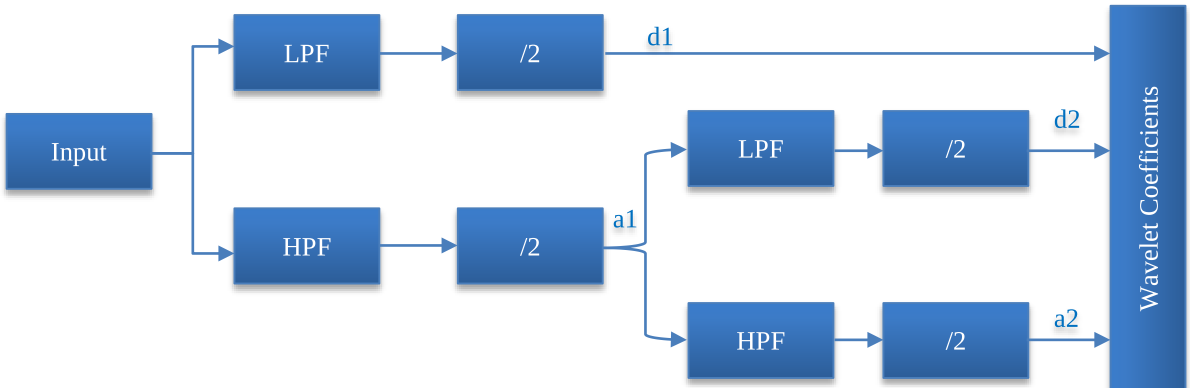


Fig. 3 Signal decomposition into Wavelets [28]

The Low-Pass and High-Pass sub-components of the input strings are separated here during breakdown, and each contains half of the prime string [28]. The following is a representation of the signal's DWT.

$$X(m,k) = \sum_n x(n) 2^{\frac{m}{2}} \; \Psi(2^m \text{n-k}) \qquad (6)$$

The inverse wavelet transform is used to create the transmitted symbol [28]. Synthesising into wavelet coefficients, also known as "analyzing from wave-let coefficients," is used to refer to the opposite process of processing a signal using an in-verse wavelet transform. The following diagram may be used to show how the signal is reconstructed from its coefficients.

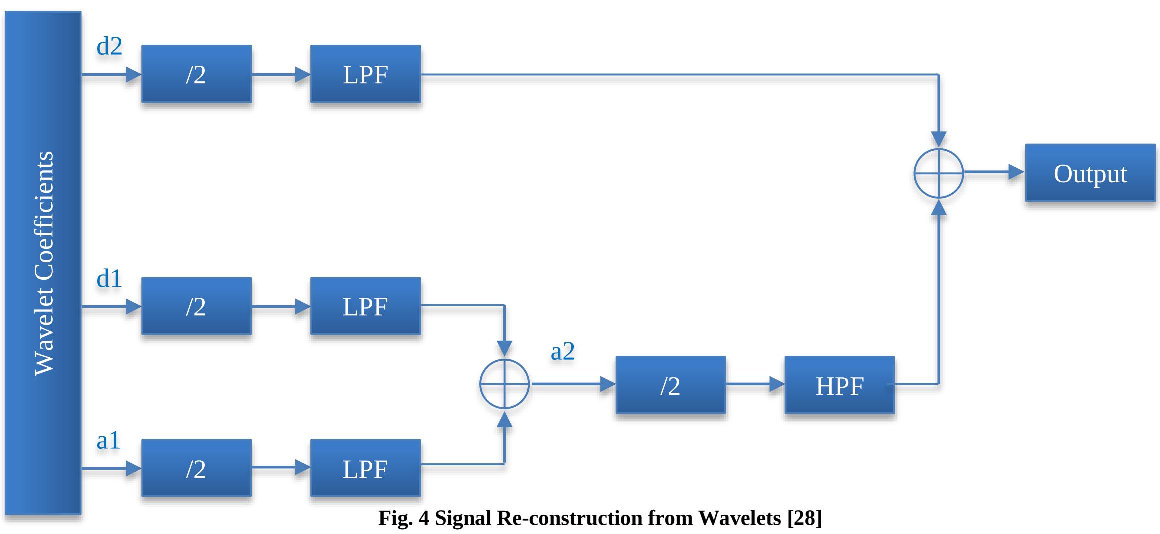


Fig. 4 Signal Re-construction from Wavelets [28]

The reconstructed signal can be estimated using the following equation.

$$X(n) = \sum_{m=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} X(m,k) 2^{m/2} \Psi(2^m \text{n} - \text{k}) \qquad (7)$$

6.2. Fractional Fourier Transform (FrFT)

The chirp basis expansion [29] that determines the alternation in the frequency plane of time is known as the unified time frequency transformation [29], or FrFT. The FrFT adds a parameter that allows the conversion to be performed at a fractional angle. The FrFT is defined by the parameter α, which represents the order or angle of rotation. When α = 1, the Fourier Transform (FrFT) is equivalent to the traditional Fourier Transform. However, for different values of α, the FrFT provides a flexible way to analyze signal content in the time-frequency domain at different angles [29]. Mathematically, for a signal x(t), the FrFT is defined as follows

$$X(\alpha, f) = \int_{-\infty}^{\infty} x(t).\, e^{-j\pi\alpha t^2}\ .\, e^{-j2\pi f t}\, dt \qquad (8)$$

Equation (6) represents the FrFT of x(t) at an angle of α and at frequency f.

6.3. Fast Fourier Transform

The Fast Fourier Transform (FFT) algorithm is a useful method for figuring out the discrete Fourier transform and its inverse. A cyclic prefix has to be inserted at the transmitter side in order to increase spectral efficiency and reduce Inter-Symbol Interference (ISI) [30]. Both the Fast Fourier Transform (FFT) and the Inverse Fast Fourier Transform (IFFT) originate from the fundamental function, which is called the Discrete Fourier Transform (DFT). The following equations of the Discrete Fourier Transform [30] can be used to construct the implementation equation for FFT/IFFT.

$$X(k) = \sum_{n=0}^{N-1} X(n) e^{-j2\pi k/N} \qquad (9)$$

Here, X(k)represents the DFT frequency output at the k-th spectral point, where k ranges from 0 to (N-1), where N is the total number of samples taken.

7. Proposed Methodology

Here, we first create an OTFS system based on Massive MIMO that incorporates the Discrete Wavelet Transform. As shown in Table 1, the System's BER and SNR were assessed using PSK-modulation levels set at 64, 128, 256, 512, and 1024 levels. Every system was run separately under several fading channels, such as RAYLEIGH and AWGN. Following a redesign of the system employing FrFT and FFT at the previously specified modulation levels, the System's BER and SNR were once more achieved under the previously mentioned fading situations. In order to compare performance across these various transformations, modulation levels, and fading settings, the collected findings were examined and analyzed. The following operating settings govern how the suggested system operates.

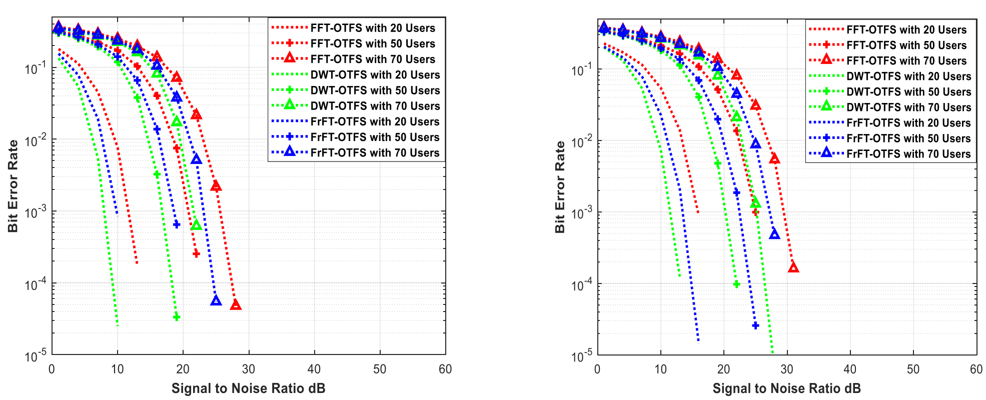
Table 1. System Parameters

Modulation Type	64,128,256,512 and 1024 levels PSK
Fading Channels used	AWGN, RAYLEIGH
Parameters evaluated	BER, SNR
Transforms used	DWT, FrFT, FFT
MIMO Channels Used	20,50 & 70
BER Reference Value	10^-2

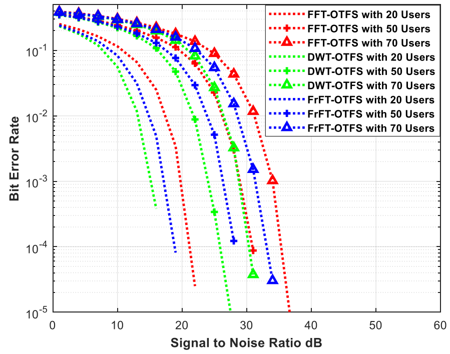
8. Results and Discussions

8.1. Results for AWGN Channel

The massive MIMO-based OTFS system was designed using Various transforms such as DWT, FrFT and FFT and was operated under an AWGN fading channel. The results were obtained for SNR values required to maintain a healthy BER for various levels of PSK modulation. The obtained results are presented here.



(a) (b)



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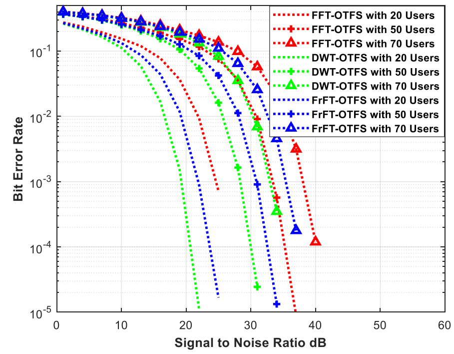
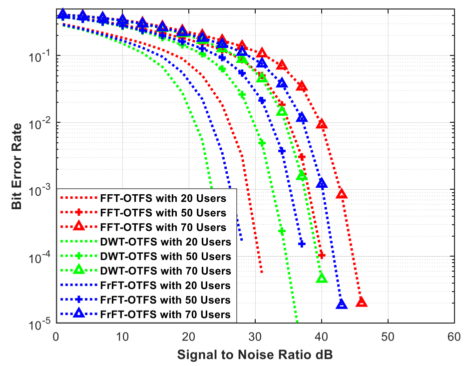


(d)



(e)

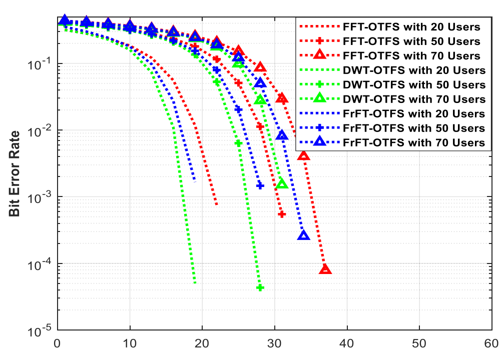
Fig. 5 (a)-(e) BER vs SNR for Massive MIMO OTFS system using AWGN Fading at, a) 64-PSK, b) 128-PSK, c) 256-PSK, d) 512-PSK, e) 1024-PSK.

Table 2. BER vs SNR for AWGN Fading

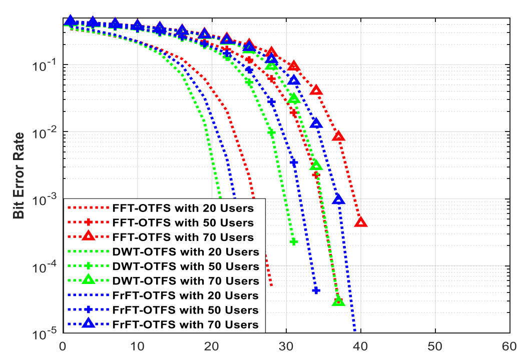
Modulation	**MIMO Channels using FFT**			**MIMO channels Using DWT**			**MIMO channels Using FrFT**		
	20	**50**	**70**	**20**	**50**	**70**	**20**	**50**	**70**
64-PSK	12 dB	22 dB	27dB	8 dB	17dB	22dB	10 dB	19dB	24 dB
128-PSK	16 dB	26dB	29dB	12dB	20dB	27dB	14dB	23dB	29dB
256-PSK	20 dB	29dB	35dB	16dB	24dB	29dB	17dB	26dB	32 dB
512-PSK	26 dB	35dB	37dB	19dB	27dB	34dB	23dB	32dB	36dB
1024-PSK	29dB	37dB	44dB	24dB	33dB	37dB	26dB	36dB	40dB

8.2. Results for RAYLEIGH Channel

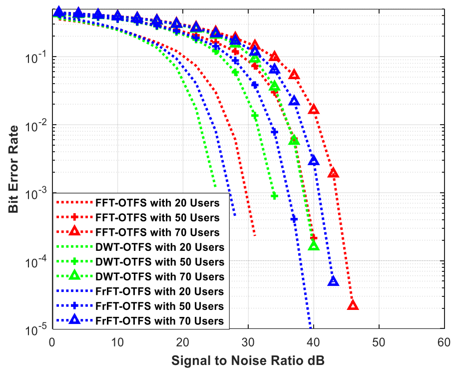
The massive MIMO based OTFS system was designed using Various transforms such as DWT, FrFT and FFT and was operated under a RAYLEIGH fading channel. The results were obtained for SNR values required to maintain a healthy BER for various levels of PSK modulation. The obtained results are presented here.



(a)



(b)



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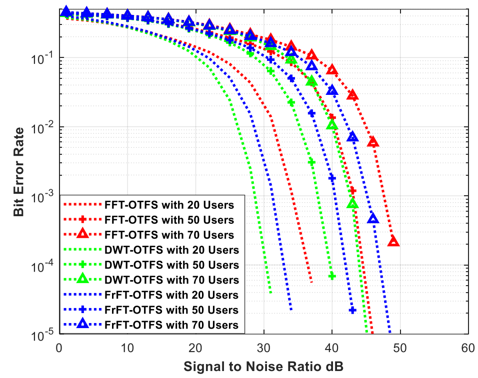

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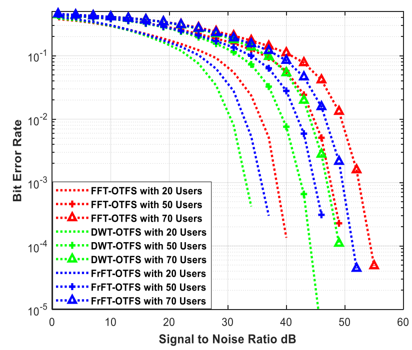

(e)

Fig. 6 (a)-(e) BER vs SNR for Massive MIMO OTFS system using RAYLEIGH Fading at, a) 64-PSK, b) 128-PSK, c) 256-PSK, d) 512-PSK, e) 1024-PSK

Table 3. BER vs SNR for Rayleigh Fading

Modulation	MIMO Channels using FFT			MIMO channels Using DWT			MIMO channels Using FrFT		
	20	50	70	20	50	70	20	50	70
64-PSK	22dB	31dB	35dB	17dB	26dB	32dB	20dB	28dB	33dB
128-PSK	26dB	35dB	39dB	22dB	30dB	36dB	23dB	32dB	37dB
256-PSK	30dB	38dB	44dB	26dB	34dB	38dB	27dB	36dB	41dB
512-PSK	34dB	43dB	47dB	28dB	37dB	43dB	31dB	40dB	46dB
1024-PSK	38dB	47dB	53dB	34dB	43dB	47dB	36dB	46dB	50dB

8.3. Discussions from Graphs

The results obtained and presented above have been analysed and the inferences that can be drawn from these results are summarised as in this section. While implementing the Massive MIMO-based OTFS system using various Transforms under AWGN fading, it was seen that the SNR values showed significant Improvements when the conventional FFT-based system was replaced by DWT and FrFT-based systems. With DWT based OTFS system proving to be the most efficient oneIn case of Conventional massive MIMO OTFS system using FFT, the Minimum SNR required for healthy transmission was found to be as 12 Decibels which has been improved in case of DWT based Massive MIMO OTFS system as 08 decibels. The Maximum SNR required was found to be equal to 44decibels in the case of FFT based system at a modulation level equal to 1024 and for MIMO channels equal to 70, while as the it was found to be equal to just 37decibels in the case of DWT based system. The Required SNR values increased as the number of MIMO channels increased, and the required SNR values increased with an increase in levels of modulation.

While implementing the Massive MIMO based OTFS system using various Transforms under AWGN fading, it was seen that the SNR values showed significant Improvements when the conventional FFT-based system was replaced by DWT and FrFT-based systems, With DWT based OTFS system proving to be the most efficient one. In case of a conventional massive MIMO OTFS system using FFT, the Minimum SNR required for healthy transmission was found to be 22 Decibels which has been improved in case of DWT based Massive MIMO OTFS system to 17 decibels. The Maximum SNR required was found to be equal to 53 decibels in the case of FFT based system at a modulation level equal to 1024 and for MIMO channels equal to 70, while as the it was found to be equal to just 47 decibels in the case of DWT based system. The Required SNR values increased as the number of MIMO channels increased, and the required SNR values increased with an increase in levels of modulation.

9. Comparative Analysis

The results obtained can be analysed for comparison within and among the proposed and existing techniques, as shown below.

Table 4. Comparative for AWGN Fading

Transform Used	Min. SNR obtained in dBs	Maximum SNR obtained in dBs	Fading Channel Used
Conventional OTFS using FFT	12	44	AWGN
OTFS using DWT	8	37	AWGN
OTFS using FrFT	10	40	AWGN

It can be clearly seen from the comparative results from Table 4 that the OTFS system incorporating DWT as its signal transform outperforms the other transform-based OTFS system with significant improvement in its performance evaluating parameters. The minimum SNR requirement in DWT-based system was found out to be 8dBs which was around 12dBs incase of conventional OTFS systems. It was also observed that the DWT-based OTFS system performs better than FrFT based OTFS system under AWGN fading.

Table 5. Comparative for RAYLEIGH Fading

Transform Used	Min. SNR obtained in dBs	Maximum SNR obtained in dBs	Fading Channel Used
Conventional OTFS using FFT	22	53	RAYLEIGH
OTFS using DWT	17	47	RAYLEIGH
OTFS using FrFT	20	50	RAYLEIGH

From the comparative results from Table 5 it is observed that with the system being now implemented under a Rayleigh fading channel, the DWT-based OTFS system again outperforms all other transforms—moreover, the Min. SNR requirement was found to be around 17dBs incase of DWT-based system as compared to 22 dBs in case of conventional OTFS system, thus showing a clear enhancement in system performance. Moreover, by comparing the results with those obtained under AWGN fading, as mentioned in Table 4 it is also observed that the system performance under AWGN fading is better as compared to its performance under Rayleigh fading.

10. Comparison with Existing Results

The existing results have been explored by implementing OFDM with various transforms and with OTFS using the conventional ISFFT transform. The results obtained in them are at a BER of 10^{-2} an SNR of 15db was Required incase of DWT-based OFDM system [28], which improved to just 8db incase of our proposed system using DWT and AWGN fading. Moreover a SNR of 10 db was required to achieve a BER of 10^{-2} in case of an MIMO OTFS system [31], our proposed results have shown significant improvements over already existing related work.

11. Conclusion

The research work explored the improvement of the Massive MIMO based OTFS systems by implementing the systems using more advanced signal transforms such as Discrete Wavelet Transform (DWT) and Fractional Fourier Transform (FrFT). The system performance is also evaluated under AWGN and RAYLEIGH fading scenarios to establish the effect of fading channels on the system performance. Based on the simulation results, it was observed that the DWT-based Massive MIMO OTFS system outperforms FrFT-based and conventional FFT-based Massive MIMO OTFS systems with significant improvement in its performance evaluating Parameters. Moreover, The System Performance was found to be better when operated under AWGN fading compared to RAYLEIGH fading. Also, all the systems showed performance degradation with higher levels of modulation.

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