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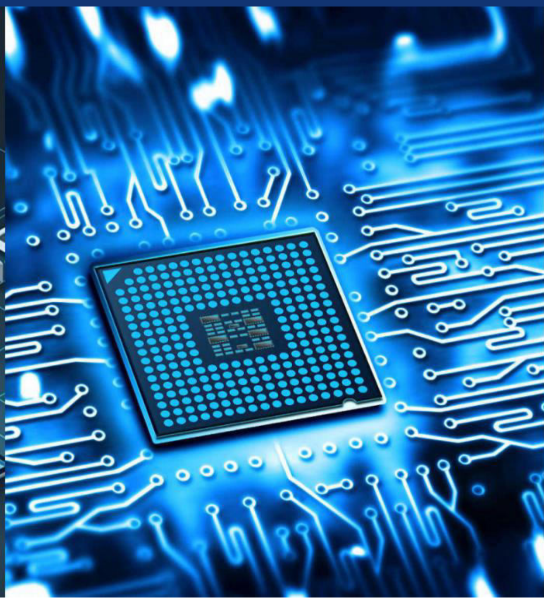
ISSN(O): 2320-9801

ISSN(P): 2320-9798



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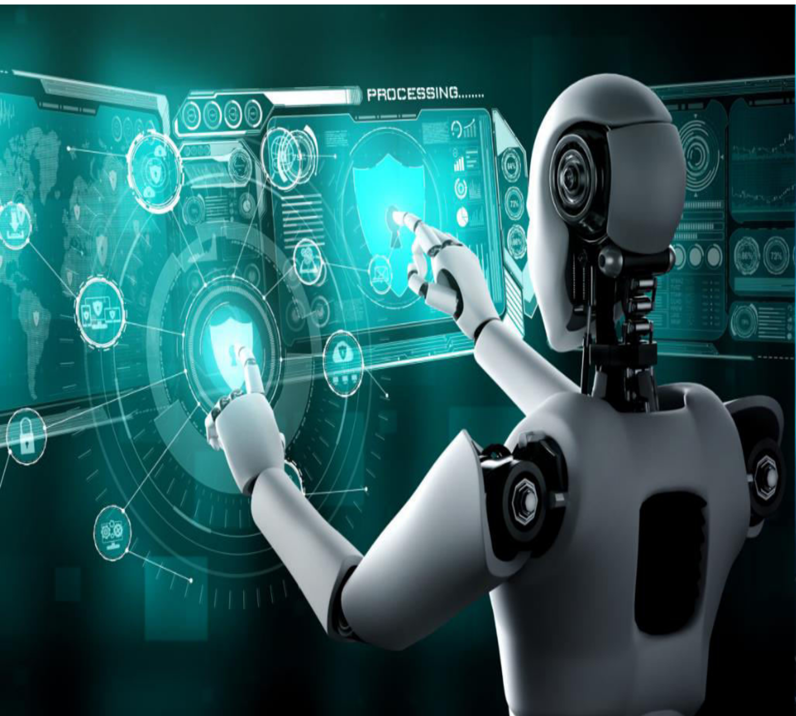

Impact Factor: 8.771

Volume 13, Issue 5, May 2025

© 2025 IJIRCCE | Volume 13, Issue 5, May 2025| DOI:10.15680/IJIRCCE.2025.1305033

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 8.771| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Estimation of Channel using FFT in Intelligent Reflecting Surfaces for 5G and Beyond

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ABSTRACT: Many independently controlled passive reflecting elements (RE) that make up intelligent reflecting surfaces (IRS) can combine coherently to enable beam forming and modify the amplitude and phase of the reflected signals. Beamforming requires an estimate of the channel coefficients for the incoming and outgoing channels. In this work, an IRS-assisted Fifth Generation (5G) orthogonal frequency division multiplexing (OFDM) waveform communication system is used to examine the efficacy of the Fast Fourier transform (FFT)-based channel estimate technique. DFT-based channel estimation can be performed while data is being given because it does not require the whole OFDM symbol for pilot broadcast. Therefore, the effects of multipath delay spread, the number of REs, and training sequence sparsity in the OFDM symbol are stated for various Signal-to-Noise Ratio (SNR) values with and without a direct channel. The results show that delay spread significantly affects performance and can cut down on training cycles.

I. INTRODUCTION

Even though the Fifth Generation New Radio (5G NR) communication technologies are still under development, new initiatives have already started to solve any potential shortcomings in 5G NR. In order to meet the demand for greater data rates and bandwidth, it is anticipated that the number of base stations, access points, and distributed antenna systems would rise rapidly. This will raise the need for energy, processing power, and computer hardware. Intelligent Reflecting Surfaces (IRS) can be used by future communication systems to boost their data throughput and spectrum efficiency without requiring more transmission power. Although the Fifth Generation New Radio (5G NR) communication technologies are still in the early stages of development, new initiatives have already started to address any potential 5G NR vulnerabilities.

To meet the demand for higher data rates and bandwidth, a significant expansion in base stations, access points, and distributed antenna systems is expected, which will raise the cost of energy, processing power, and computing hardware. By eliminating the need for additional transmission power, Intelligent Reflecting Surfaces (IRS) can improve the data rate and spectrum efficiency of future communication systems.

Although, the Fifth Generation New Radio (5G NR) communication systems are still in the active development stage, new projects focused on the improvements of the possible shortcomings of 5G NR have already started.

In particular, to meet the demand for higher data rate and bandwidth, the number of base stations, access points, and distributed antenna systems are expected to rise significantly leading to greater need of energy, processing power and computing hardware. Intelligent Reflecting Surfaces (IRS) offer a new paradigm that can improve data rate and spectral efficiency of the future communication systems without the need for additional transmission power. Structurally, IRS is a planar surface containing multiple independently controllable passive Reflecting Elements (RE), which can alter the phase and the amplitude of the reflected signals so that the reflected signals can be combined in a coherent and constructive manner to achieve beamforming.

In other words, IRS can beamform the reflected signals without actively consuming power to generate new radio waves. For the IRS to adjust the direction of the reflection, Channel State Information (CSI) of both the incoming and outgoing

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channels are needed. However, the passive nature of the IRS means that they do not have the ability to neither detect nor predict pilot training sequences. Therefore, in IRS-assisted communication systems, the channel estimation is carried out at the Base Station (BS) and various techniques have been developed.

II. LITERATURE SURVEY

Wireless cellular networks are emerging to take a strong stand in attempts to achieve pervasive large scale obtainment, communication, and processing with the evolution of the fifth generation (5G) network[1]This survey paper offers a structured classification of channel estimation techniques relevant to 5G and future wireless communication systems. It highlights key challenges in this area, such as pilot contamination and feedback overhead[2]. In a wireless system with Intelligent Reflective Surfaces (IRS) containing many passive elements, we consider the problem of channel estimation[3].Studied about the Intelligent Reflecting Surface-Enhanced OFDM channel estimation and reflection optimization[4]. The goal is to make the system work more efficiently by intelligently adjusting how these surfaces reflect signals[5].

This paper focuses on the practical aspects of channel estimation and phase shift design for multiple-input multiple-output (MIMO) wireless communication systems that incorporate intelligent reflecting surfaces (IRS)[6]. The main focus of this review paper is to explore the application of machine learning techniques within the context of intelligent reflecting surface (IRS)-assisted wireless communications, specifically with an eye towards the requirements and potential of future 6G networks[7].

This paper's main focus is to investigate the performance of polar codes specifically within the control channels of Fifth Generation New Radio (5G NR) systems[8]. It would cover various aspects such as frequency bands, channel bandwidths, modulation schemes, power levels, receiver sensitivity, and other crucial parameters to ensure interoperability and performance across different 5G NR networks[9]. This is a direct link to the document described in item 10, hosted on the ETSI website. It confirms the source and provides access to the full technical specification[10].

Reconfigurable intelligent surfaces (RISs) are capable of enhancing the capacity of wireless networks at a low cost. In practical RIS-assisted communication systems, the acquisition of channel state information (CSI) and RIS reflection optimization constitute a pair of challenges[11]. This work by A. Elbir and K. Mishra, available as a preprint from 2020, presents a survey of various deep learning architectures that are relevant to intelligent reflecting surfaces[12]. The paper's findings would contribute to the practical implementation and performance enhancement of IRS-aided wireless communication systems[13]. This study serves as a crucial reference for researchers, developers, and network planners in the 5G ecosystem, providing standardized models to simulate and evaluate the performance of 5G systems across diverse frequency ranges[14]. The main focus of this work is to propose a structure-aware sparse Bayesian learning approach for the problem of channel estimation in intelligent reflecting surface (IRS)-aided multiple-input multiple-output (MIMO) systems[15].

III. EXISTING METHOD

Intelligent reflecting surfaces (IRS), which may alter the phase and amplitude of the reflected signals and combine them coherently to enable beamforming, are composed of numerous independently controlled passive reflecting elements (RE). Estimating the incoming and outgoing channels' channel coefficients is necessary for beamforming. This study uses a Fifth Generation (5G) orthogonal frequency division multiplexing (OFDM) waveform communication system to test the effectiveness of the discrete Fourier transform (DFT)-based channel estimate approach. Because it doesn't take the entire OFDM symbol for pilot transmission, DFT-based channel estimate can be done while data is being transmitted. As a result, for various Signal-to-Noise Ratio (SNR) values with and without a direct channel, the impacts of multipath delay spread, the quantity of REs, and training sequence sparsity in the OFDM symbol are observed.

The findings demonstrate that delay spread can shorten training sequences and significantly affect performance.

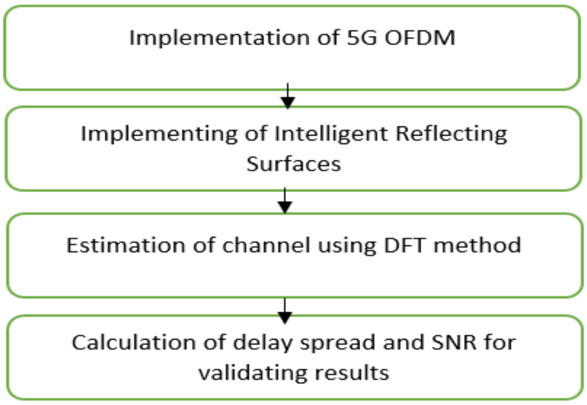

Figure1: Flow diagram of Existing Method

the flow chart describes a method to investigate the integration of Intelligent Reflecting Surfaces with a 5G OFDM system. It involves setting up the system, incorporating the IRS, estimating the channel using DFT, and then evaluating the impact by calculating the delay spread and SNR. This suggests the study aims to understand how IRS can affect the channel quality and potentially improve the performance of 5G OFDM communication.

The limitations of the existing methods are: (i)DFT method is complex: The DFT-based channel estimation method used in this existing approach is identified as complex. This likely refers to the computational complexity associated with performing DFT operations, especially as the number of subcarriers in the OFDM system increases. (ii) DFT method will calculate values for even redundant data: The method calculates channel estimates across the entire OFDM symbol, including parts that might contain redundant data. This implies an inefficiency in the estimation process as computational resources are spent on estimating channels for data that might not be essential for the core communication.

IV. PROPOSED METHOD

This work investigates the effectiveness of a Fast Fourier Transform (FFT)-based channel estimation method for Intelligent Reflecting Surface (IRS)-assisted 5G Orthogonal Frequency Division Multiplexing (OFDM) communication systems. The study examines how factors like multipath delay spread, the number of reflecting elements (REs) on the IRS, and the sparsity of pilot signals within the OFDM symbol impact the accuracy of channel estimation (measured by Normalized Mean Square Error, NMSE) under varying Signal-to-Noise Ratio (SNR) conditions, both with and without a direct communication path. Simulations using the 3GPP TDL channel model demonstrate that delay spread significantly affects performance and can necessitate longer training sequences (pilots).

While the number of REs influences received power, its impact on estimation performance is less pronounced when SNR is sufficient. The findings suggest a correlation between pilot occupancy rate and delay spread, where larger delay spreads require a higher proportion of the OFDM symbol dedicated to pilot signals for effective channel estimation.

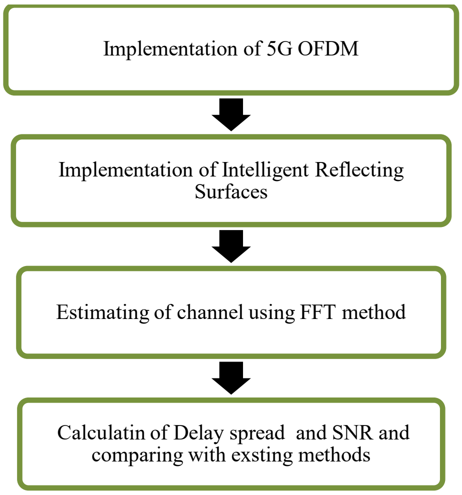

Figure2: Flow diagram of Existing Method

Figure 2 outlines a proposed method to investigate the use of IRS in a 5G OFDM system. It involves setting up the system, incorporating the IRS, estimating the channel using an FFT-based approach, and then evaluating its performance in terms of delay spread and SNR, with a direct comparison to existing techniques. This implies the research aims to demonstrate the benefits or differences of this proposed channel estimation or overall system design compared to what is currently used.

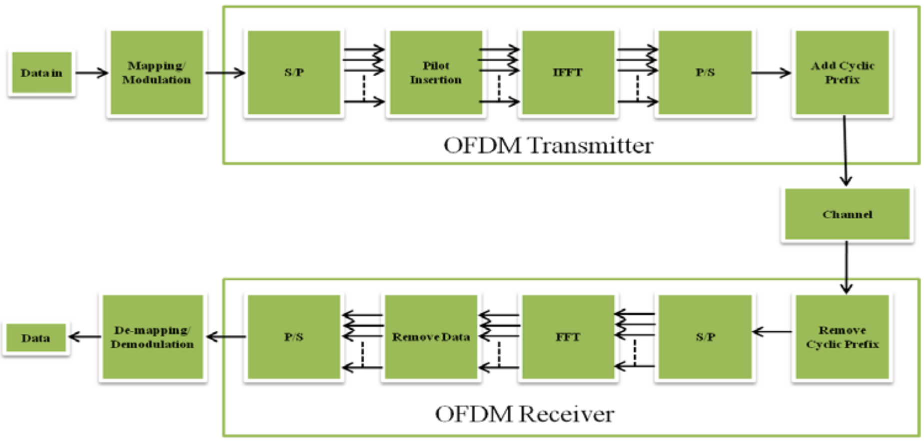

Figure3: Block diagram of OFDM

At the OFDM transmitter, the journey begins with the data input, which represents the information to be transmitted. This data undergoes mapping and modulation, where groups of bits are converted into complex symbols based on a chosen modulation scheme like QPSK or QAM. To prepare these symbols for parallel transmission, a serial-to-parallel (S/P) converter arranges them into multiple parallel streams. For robust channel estimation at the receiver, pilot symbols, known reference signals, are strategically inserted into these parallel data streams. The heart of OFDM lies in the Inverse Fast Fourier Transform (IFFT), which takes these frequency-domain symbols and transforms them into time-domain signals. This process generates orthogonal subcarriers, ensuring they don't interfere with each other. These parallel time-domain signals are then converted back into a single serial stream by a parallel-to-serial (P/S) converter. Finally, to mitigate the effects of multipath propagation in the wireless channel, a cyclic prefix (CP), a copy of the end of the OFDM symbol, is added to the beginning. The resulting signal is then ready for transmission through the channel.

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On the receiving end, the OFDM receiver mirrors the transmitter's operations in reverse. First, the cyclic prefix is removed, as it has served its purpose of absorbing multipath delays. The serial received signal is then converted into multiple parallel streams using a serial-to-parallel (S/P) converter. The Fast Fourier Transform (FFT) is applied to these parallel time-domain signals, transforming them back into the frequency domain and separating the signals carried by each subcarrier. The pilot symbols are extracted, and based on the difference between the transmitted and received pilots, the channel characteristics are estimated.

This channel estimate is then used for equalization, a process that compensates for the distortions introduced by the channel. After equalization, the parallel streams of recovered data symbols are converted back into a single serial stream by a parallel-to-serial (P/S) converter. Finally, the de-mapping and demodulation stage converts the received complex symbols back into the original data bits, resulting in the data output. This intricate process of parallel subcarrier modulation and demodulation makes OFDM highly resilient to frequency-selective fading and a cornerstone of modern wireless communication.

V. RESULTS

Figure 5 explains "NMSE vs SNR for Different IRS Elements of Both Methods," from a study on channel estimation in reflecting surfaces for 5G and beyond, illustrates the relationship between the Normalized Mean Squared Error (NMSE) and the Signal-to-Noise Ratio (SNR) for two different channel estimation methods: an "Existing" method and a "Proposed" method. The performance of these methods is evaluated for Intelligent Reflecting Surfaces (IRS) with varying numbers of reflecting elements (N = 80, 100, and 120).

Comparison of Methods: By comparing the red and black lines, we can assess the performance difference between the "Existing" and "Proposed" methods. Generally, if the black lines are consistently lower than the corresponding red lines for the same number of IRS elements across different SNR values, it suggests that the "Proposed" method offers better channel estimation accuracy (lower NMSE) compared to the "Existing" method.

Impact of Number of IRS Elements (N): The graph also allows us to observe how the number of reflecting elements in the IRS affects the channel estimation performance for both methods. Typically, increasing the number of reflecting elements can improve the performance of IRS-assisted

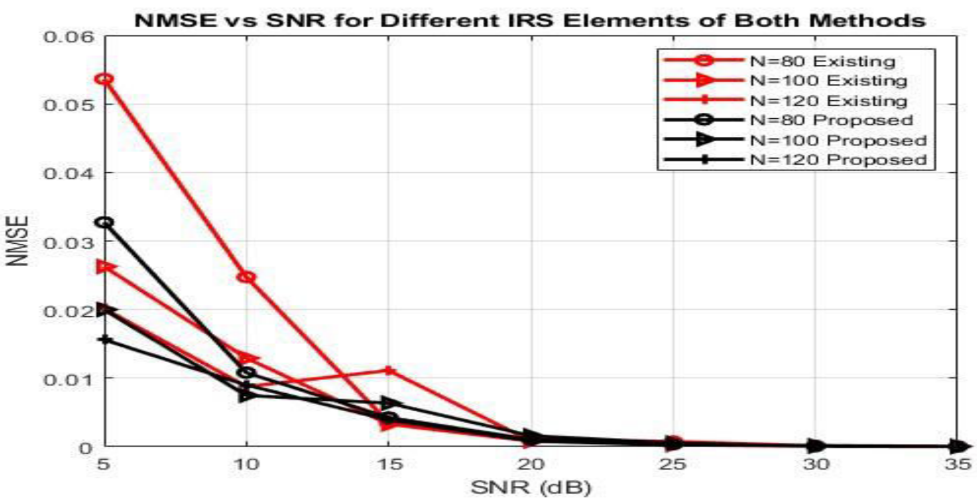

Figure 5: NMSE VS SNR For Different IRS Elements of Both Methods

Figure 5 provides a visual comparison of the channel estimation accuracy (in terms of NMSE) of two different methods under varying SNR conditions and for different sizes of the Intelligent Reflecting Surface. By analyzing the trends and the relative positions of the lines, one can draw conclusions about the effectiveness of the proposed method compared to the existing one and the impact of the number of IRS elements on the estimation performance.

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Figure 6 Explains "NMSE vs SNR for Various Delay Spreads and SCS for 10ns of Both Methods," from the same study on channel estimation in reflecting surfaces for 5G and beyond, builds upon the previous analysis by investigating the impact of different subcarrier spacings (SCS) and delay spreads on the performance of the "Existing" (using DFT) and "Proposed" (using FFT for IRS) channel estimation methods. The delay spread is fixed at 10 nanoseconds (ns) in this specific plot.

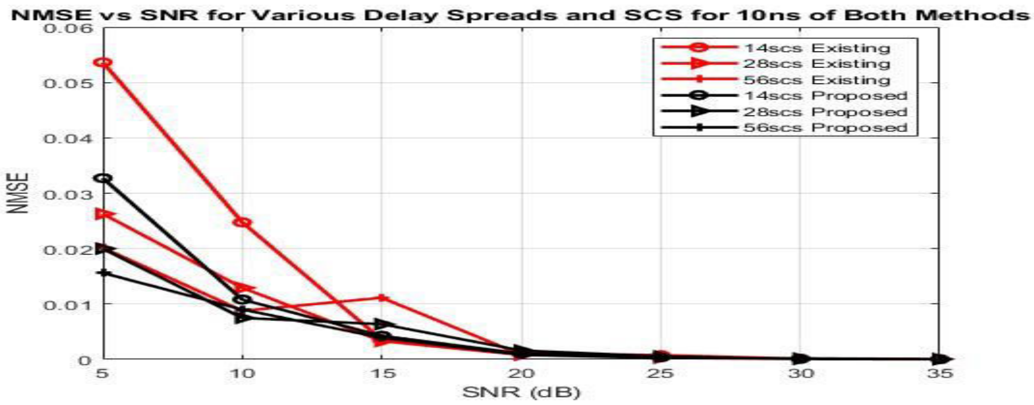

Figure 6: NMSE VS SNR For Various Delay Spreads and SCS for 10ns of Both Methods

Comparison of Methods (DFT vs. FFT for IRS): By comparing the red and black lines for the same SCS value, we can assess the performance difference between the DFT-based "Existing" method and the FFT-based "Proposed" method (utilizing the IRS). If the black lines are consistently below the corresponding red lines, it suggests that the "Proposed" method offers improved channel estimation accuracy under these conditions.Impact of Subcarrier Spacing (SCS): The graph allows us to observe how different subcarrier spacings affect the channel estimation performance for both methods. We can compare the lines of the same color (same method) but with different markers (different SCS values). In essence, this graph delves deeper into the performance evaluation by considering the influence of subcarrier spacing on the channel estimation accuracy of both the DFT-based "Existing" method and the FFT-based "Proposed" method (leveraging the IRS), while keeping the delay spread constant at 10 ns. Analyzing the relative positions and trends of the different lines helps to understand the interplay between the channel estimation technique, the subcarrier spacing used in the communication system, and the resulting estimation error under varying signal-to-noise conditions.

Figure 7 Explains "NMSE vs Pilot Occupancy Rate for Different Delay Spreads of Both Methods," continues the investigation into channel estimation performance in IRS-assisted systems. Here, the focus shifts to the impact of the pilot occupancy rate for different delay spread values, comparing the "Existing" (DFT-based) and "Proposed" (FFT for IRS) methods.

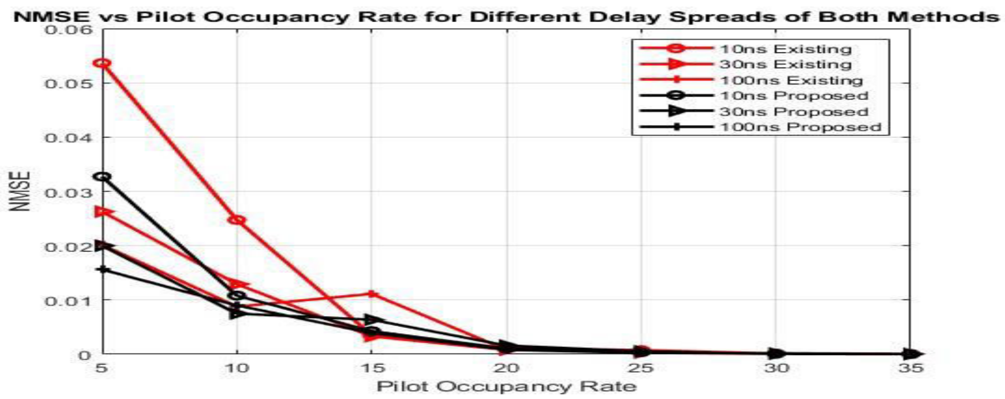

Figure 7: NMSE VS pilot Occupancy Rate for Different Delay Spreads of Both Methods

This graph explores the trade-off between the resources allocated for pilot signals (pilot occupancy rate) and the resulting channel estimation accuracy (NMSE) for both the DFT-based "Existing" method and the FFT-based "Proposed" method (with IRS), under different channel delay spread conditions. Analyzing the trends and relative performance of the different lines helps to understand how the pilot design and the channel characteristics influence the effectiveness of each estimation technique.

Figure 8 Explains "NMSE vs SNR for Various Delay Spreads and SCS for 30ns of Both Methods," is another plot from the same study on channel estimation in reflecting surfaces. Similar to the second graph we analyzed, it investigates the relationship between NMSE and SNR for different subcarrier spacings (SCS) and compares the "Existing" (DFT-based) and "Proposed" (FFT for IRS) methods. However, the key difference here is that the delay spread is now fixed at 30 nanoseconds (ns).

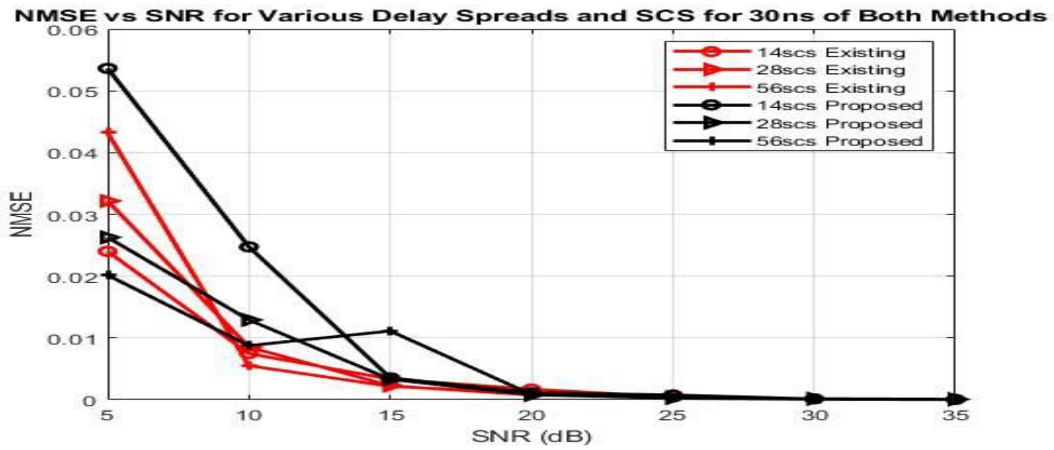

Figure 8: NMSE VS SNR for Various Delay Spreads and SCS for 30ns of Both Methods

Impact of Subcarrier Spacing (SCS) at 30ns Delay Spread: The graph allows us to examine how different subcarrier spacings affect the channel estimation performance for both methods when the delay spread is 30 ns. By comparing lines of the same color (same method) but with different markers (different SCS values), we can see if there's an optimal SCS for each method under these channel conditions.

this graph provides insights into the performance of the DFT-based "Existing" method and the FFT-based "Proposed" method (with IRS) in terms of channel estimation accuracy (NMSE) under varying SNR and subcarrier spacing conditions, specifically when the channel has a delay spread of 30 ns. By comparing the trends and the relative positions of the lines, we can understand how these system parameters influence the effectiveness of the two channel estimation techniques in a more dispersive channel environment compared to the 10 ns delay spread scenario.

VI. CONCLUSION AND FUTURE SCOPE

The study concludes that the proposed FFT-based channel estimation for IRS-assisted systems significantly outperforms the existing DFT-based method, achieving lower NMSE across various conditions like varying IRS elements, SNR levels, pilot occupancy, and delay spreads. This improvement is attributed to the FFT's ability to eliminate redundant data, leading to more efficient OFDM symbol utilization and reduced computational resources. The inherent lower complexity of FFT compared to DFT makes the proposed method more suitable for real-time 5G MISO and MIMO applications, with potential benefits extending to future 6G MIMO systems.

The study highlights the impact of parameters like SNR, IRS element count, subcarrier spacing, and pilot occupancy on performance, suggesting that optimal configurations are scenario-dependent. The superior results advocate for the adoption of FFT-based channel estimation in IRS-enhanced 5G and beyond deployments. Future research directions include reducing training overhead, dynamic IRS configuration, experimental validation, and exploring security

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(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

implications, further solidifying the contribution of FFT-based estimation to the evolution of advanced wireless communication.

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