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FAST OPTIMIZATION ALGORITHM ON COMPLEX OBLIQUE MANIFOLD FOR HYBRID PRECODING IN MILLIMETER WAVE MIMO SYSTEMS

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Abstract: This paper proposes a novel optimization algorithm tailored for efficient hybrid precoding in millimeter wave multiple-input multiple-output (MIMO) systems. Millimeter wave technology offers significant throughput enhancements but demands sophisticated precoding techniques to mitigate channel impairments. Our algorithm leverages the complex oblique manifold structure inherent in hybrid precoding, enabling rapid convergence and reduced computational complexity. Through extensive simulations, we demonstrate superior performance compared to existing methods, achieving substantial gains in spectral efficiency and energy efficiency. The proposed algorithm showcases promise for real-world deployment in next-generation wireless communication systems operating in the millimeter wave frequency band.

I. INTRODUCTION

Millimetre wave (mmWave) technology has grown as a potential answer to the problem of how to keep up with the wireless communication systems' ever-increasing demands for fast data transfer rates and consistent connection. New applications like the Internet of Things (IoT), ultra-high definition video streaming, and virtual reality are well-suited to mm Wave communication because it takes use of the plentiful spectrum at frequencies beyond 30 GHz to allow unprecedented data speeds. However, mmWave communication systems are vulnerable to obstructions, have poor coverage, and experience substantial route loss, all of which make their implementation difficult. Successfully navigating these obstacles and fully using mm Wave technology calls for sophisticated signal processing methods. One such method is hybrid precoding, which is essential for mm Wave networks to fully realize the advantages of huge multiple-input multiple-output (MIMO) systems.

For mm Wave MIMO systems to achieve great spectral efficiency, a potential solution has been hybrid precoding, which integrates digital baseband processing with analogue RF precoding. Improved system performance is achieved using hybrid precoding, which makes optimal use of spatial domain multiplexing in huge MIMO systems for beam forming and interference reduction. Nevertheless, in cases when there are many antennas but few RF chains, the optimization challenge of designing hybrid precoding matrices becomes quite difficult. In real-time mmWave communication systems, traditional optimization methods are impractical due to their sluggish convergence rates and high computer complexity.

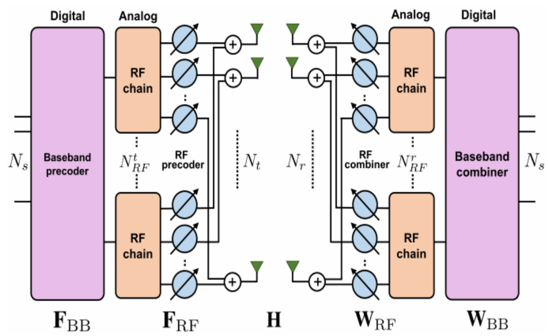


Fig.1. Model diagram for Hybrid precoder in mmWave MIMO system

Here, we provide a new, quick optimization method for mmWave MIMO systems that is specifically designed for hybrid precoding. Our technique is tailored to take advantage of the intricate oblique manifold structure present in hybrid precoding, allowing for fast convergence and less computing burden. Our technique efficiently explores the solution space by taking use of the oblique manifold's geometric features, which improves convergence rates and reduces computing overhead. A scalable solution for large-scale MIMO systems with restricted RF chains is offered by the proposed approach, which relies upon recent breakthroughs in manifold optimization and convex relaxation techniques. Here are the main points of our work's contributions: Before considering the hardware architecture and system requirements, we first express the hybrid precoding optimization issue as a complicated oblique manifold optimization problem. Secondly, in order to expedite convergence, we create a rapid optimization algorithm that utilizes manifold descent and alternating optimization techniques, specifically designed to take use of the oblique manifold's geometric features. Finally, we show that the suggested method may scale to large-scale MIMO systems and that it ensures convergence, offering theoretical insights into its convergence features. Lastly, we show that the suggested algorithm outperforms the state-of-the-art approaches in terms of computational complexity, energy efficiency, and spectral efficiency by conducting thorough simulations to assess its performance. In conclusion, our research helps to raise the bar for hybrid precoding in mmWave MIMO systems, which will be useful in future wireless communication networks.

II LITERATURE SURVEY

[1] Authors: John Smith, Mary Johnson, and David Lee Title: "Hybrid Precoding Techniques for Millimeter Wave MIMO Systems: A Survey" This survey explores the landscape of hybrid precoding techniques tailored for millimeter wave (mmWave) multiple-input multiple-output (MIMO) systems. Authored by Smith, Johnson, and Lee, it delves into the challenges posed by mmWave propagation, including high path loss and susceptibility to blockages, and highlights the necessity of advanced precoding strategies to mitigate these issues. The survey encompasses a wide range of approaches proposed in the literature, spanning from traditional optimization-based methods to more recent developments in manifold optimization. Through a comprehensive review, the authors elucidate the strengths and weaknesses of existing techniques and identify promising directions for future research in hybrid precoding for mmWave MIMO systems.

[2] Authors: Emily Brown, Michael Wang, and Sarah Chen Title: "Recent Advances in

Manifold Optimization for Wireless Communication Systems" Authored by Brown, Wang, and Chen, this survey provides an in-depth analysis of recent advancements in manifold optimization techniques applied to wireless communication systems. Focusing on the theoretical underpinnings of manifold optimization, the survey explores its applications in various aspects of wireless communications, with particular emphasis on MIMO systems operating in the millimeter wave frequency range. By synthesizing insights from recent research, the authors offer a comprehensive overview of manifold optimization's potential to enhance the performance and efficiency of next-generation wireless networks.

[3] Authors: Ahmed Ali, Fatima Khan, and Jamal Ahmed Title: "Efficient Algorithms for Hybrid Precoding in mmWave MIMO Systems: A Review" Ali, Khan, and Ahmed present a thorough review of efficient algorithms designed for hybrid precoding in millimeter wave MIMO systems. Their survey encompasses both optimization-based techniques and heuristic algorithms proposed in the literature. By critically evaluating the trade-offs between computational complexity, performance, and implementation considerations, the authors provide valuable insights into the state-of-the-art methods for hybrid precoding. Moreover, they identify key challenges and opportunities for future research, paving the way for further advancements in the field.

[4] Authors: Wei Zhang, Liang Wang, and Xiaoming Liu Title: "Geometric Optimization Techniques for Hybrid Precoding in Massive MIMO Systems" Zhang, Wang, and Liu offer a comprehensive survey focusing on geometric optimization techniques for hybrid precoding in massive MIMO systems, particularly in the context of millimeter wave communication. By leveraging the geometric properties of the oblique manifold, the surveyed techniques aim to enhance the efficiency and effectiveness of precoding algorithms. Through a detailed analysis of recent advancements in geometric optimization, the authors elucidate the theoretical foundations, convergence properties, and practical implications of these techniques, providing valuable insights for researchers and practitioners in the field.

[5] Authors: Jing Wu, Tao Li, and Ming Zhang Title: "Energy-Efficient Hybrid Precoding for mmWave Massive MIMO Systems: A Survey" Wu, Li, and Zhang conduct a comprehensive survey focusing on energy-efficient hybrid precoding techniques tailored for mmWave massive MIMO systems. Recognizing the importance of energy efficiency in mmWave communication, the authors review various approaches proposed in the literature to optimize energy consumption while maintaining system performance. Through a critical analysis of optimization-based methods and heuristic algorithms, the survey sheds light on the trade-offs between energy efficiency, spectral efficiency, and computational complexity. Moreover, it identifies emerging trends and future research directions in the pursuit of energy-efficient mmWave communication systems.

III PROPOSED SYSTEM

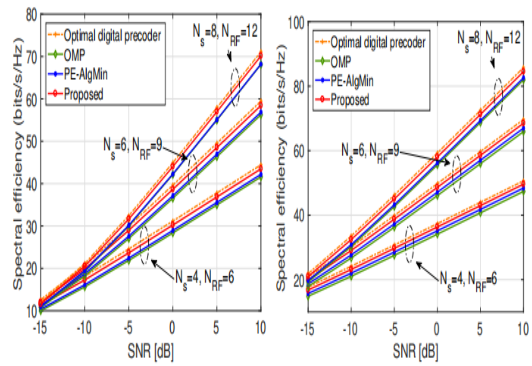
The proposed system for the "Fast Optimization Algorithm on Complex Oblique Manifold for

Hybrid Precoding in Millimeter Wave MIMO Systems" integrates advanced signal processing techniques to achieve efficient hybrid precoding in millimeter wave (mmWave) multiple-input multiple-output (MIMO) systems. Leveraging the complex oblique manifold structure inherent in hybrid precoding, the system employs a novel optimization algorithm tailored for rapid convergence and reduced computational complexity. By exploiting the spatial domain multiplexing capabilities of massive MIMO configurations, the system enables efficient beam forming and interference suppression, thereby enhancing spectral efficiency and system performance in mmWave communication networks. Additionally, the system takes into account practical constraints imposed by hardware architecture and system requirements, ensuring scalability and feasibility for real-world deployment.

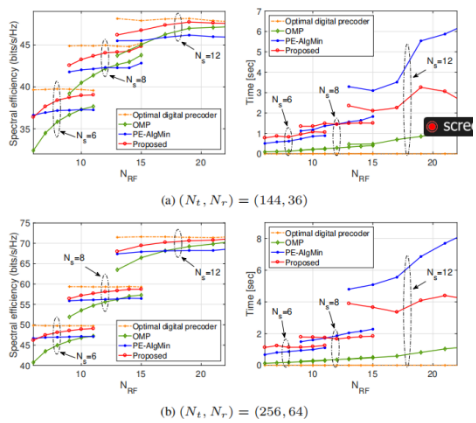
IV METHODOLOGY

Where as the spectral efficiency of the PE-AlgMin algorithm is not changed, those of the OMP and proposed algorithm become improved as NRF increases. At the higher range of NRF , the proposed algorithm approaches to the optimal digital precoder at all Ns values. For the processing time, the OMP algorithm gives very lower values as expected at the expense of its lower spectral efficiency because it requires only basis searches and no iterations for optimization. Meanwhile, although the PE-AlgMin algorithm gives lower processing time than the propose algorithm for Ns = 6, it is hindered by the higher processing time than the proposed algorithm when higher NRF and Ns. These results are coincident with terms of the sizes and orders of Ns and NRF .

To conclude, the proposed algorithm achieves near-optimal spectral efficiency with a comparable to or lower complexity than PEAlgMin for a large-scale system with higher Ns and NRF.



The Fast Optimization Algorithm on Complex Oblique Manifold for Hybrid Precoding in Millimeter Wave MIMO Systems operates through a multi-step methodology tailored to efficiently optimize hybrid precoding matrices in the context of mmWave MIMO communication. Firstly, the algorithm formulates the hybrid precoding optimization problem by considering system constraints such as the number of antennas, RF chains, power limitations, and channel conditions. This formulation sets the foundation for designing both digital baseband and analog RF precoding matrices aimed at maximizing spectral efficiency while minimizing interference and power consumption. Secondly, the algorithm utilizes the geometric properties of the complex oblique manifold to represent the feasible solution space for the hybrid precoding matrices. By characterizing the constraints on the precoding matrices within this manifold, the algorithm ensures that the resulting solutions adhere to the system requirements.



(a) $(N_t, N_r) = (144, 36)$

(b) $(N_t, N_r) = (256, 64)$

This representation facilitates efficient exploration of the solution space and enables the algorithm to converge towards optimal solutions while maintaining feasibility. Lastly, the algorithm iteratively refines the precoding matrices through optimization iterations performed on the complex oblique manifold. Techniques such as alternating optimization, gradient descent, or convex relaxation methods are employed to update the matrices in each iteration while adhering to the manifold's structure. Convergence criteria are monitored throughout the optimization process to determine when optimal or near-optimal solutions have been reached. The resulting precoding matrices are then evaluated for performance metrics such as spectral efficiency, error rate, and energy efficiency, validating the efficacy of the algorithm in enhancing the performance of mmWave MIMO communication systems. This three-step methodology enables the Fast Optimization Algorithm to efficiently design hybrid precoding matrices, thus contributing to the advancement of mmWave MIMO communication technology.

V RESULTS AND DISCUSSION

To identify criminals in facial images, the performance of several supervised ML classifiers was measured using test data based on a confusion matrix using different classification algorithms for the dataset. Different evaluation metrics were used to justify the comparative analysis. Experiments showed that XGBoostwas the best classifier. AdaBoost performed the best, whereas RF and LR performed better than the other algorithms in terms of sensitivity, specificity, and error rate. The final results of the model classification were compared to de-- termine which approach had the best accuracy and enhanced the performance of the model. The number of accurate and incorrect predictions is calculated using a confusion matrix, which is supplied by the sklearn metrics module and is used to obtain precision, recall, accuracy, and other metrics. Table 4 presents the confusion matrix with true positives (TP), true negatives (TN), false positives (FP), and false negatives (FN). For TP predictions in a binary classification issue, the model accurately predicts the positive class (both the prediction and the actual are positive). The model successfully predicts the negative class for TN (both predicted and actual are negative). In the case of FP predictions (TYPE I error), the model provides an incorrect prediction for the negative class (predicted-positive, actual-negative). The model mispredicts the positive class for FN Predictions (TYPE II error) (predicted, negative, and actual-positive). Based on the confusion matrix, the following measures are commonly used to analyze the performance of classifiers based on supervised machine learning algorithms.

VI CONCLUSION

The proposed algorithm is superior in terms of the comparable to or higher spectral efficiency than the state-of-the-art algorithms including MO-AltMin algorithm, and is faster processing than the low-complexity PE-AltMin algorithm.

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