MATLAB-BASED DESIGN AND PERFORMANCE OPTIMIZATION OF RECONFIGURABLE INTELLIGENT SURFACE ASSISTED ANTENNAS FOR SIXTH-GENERATION WIRELESS COMMUNICATION SYSTEMS

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ABSTRACT

The rapid evolution of sixth-generation (6G) wireless communication systems demands intelligent antenna technologies capable of supporting ultra-high data rates, ultra-low latency, massive device connectivity, improved spectrum utilization, and enhanced energy efficiency. Conventional antenna systems operating in millimeter-wave (mmWave) and terahertz (THz) frequency bands experience significant propagation losses, signal blockage, and limited communication coverage, which reduce the reliability and efficiency of wireless networks. Reconfigurable Intelligent Surface (RIS) has emerged as a promising technology that intelligently controls electromagnetic wave propagation through programmable passive reflecting elements, enabling adaptive beam steering and improved wireless communication performance. This research presents a MATLAB-based framework for the design, simulation, and performance optimization of a RIS-assisted compact microstrip antenna for sixth-generation wireless communication systems. The proposed methodology employs the MATLAB Antenna Toolbox and Phased Array System Toolbox to model the antenna structure, configure the RIS array, optimize phase-shift control, and evaluate electromagnetic performance. The antenna is assessed using key performance parameters, including reflection coefficient (S11), Voltage Standing Wave Ratio (VSWR), gain, directivity, radiation efficiency, impedance bandwidth, and radiation patterns. Simulation results demonstrate that the proposed RIS-assisted antenna significantly enhances signal coverage, beam steering capability, impedance matching, radiation efficiency, and communication reliability compared with conventional antenna designs while maintaining low computational complexity and reduced energy consumption. The programmable RIS effectively manipulates reflected electromagnetic waves, resulting in improved spectral efficiency and enhanced wireless performance. The proposed framework provides a scalable, flexible, and cost-effective solution for future 6G communication infrastructure and establishes a strong foundation for subsequent hardware implementation and experimental validation.

Keywords: Reconfigurable Intelligent Surface (RIS), Sixth-Generation (6G) Wireless Communication, MATLAB, Antenna Design, Performance Optimization, Beam Steering, Millimeter-Wave (mmWave), Terahertz (THz), Microstrip Antenna, Electromagnetic Simulation, Radiation Efficiency, Reflection Coefficient (S11).

I. INTRODUCTION

The rapid advancement of wireless communication technologies has transformed global connectivity, enabling seamless communication among people, devices, and intelligent systems. The evolution from first-generation (1G) analog communication to fifth-generation (5G) broadband networks has significantly improved data transmission speed, network capacity, spectral efficiency, and communication reliability. However, emerging applications such as the Internet of Things (IoT), autonomous vehicles, extended reality (XR), industrial automation, smart cities, holographic communication, and digital healthcare demand communication systems capable of supporting ultra-high data rates, ultra-low latency, massive machine-type communication (mMTC), and intelligent network management. These growing requirements have accelerated research toward sixth-generation (6G) wireless communication systems, which are expected to operate in the millimeter-wave (mmWave) and terahertz (THz) frequency bands to achieve transmission speeds exceeding one terabit per second. Although these higher frequency bands provide enormous bandwidth, they also suffer from severe free-space path loss, atmospheric absorption, signal blockage, and limited communication range. These propagation challenges significantly degrade network performance and necessitate the development of innovative communication technologies capable of intelligently controlling the wireless propagation environment. Consequently, researchers have identified Reconfigurable Intelligent Surface (RIS) technology as a promising solution for overcoming these limitations while improving communication coverage, spectrum efficiency, and energy efficiency in future 6G wireless networks [1]–[5].

Reconfigurable Intelligent Surface (RIS) is an emerging electromagnetic technology composed of a large number of programmable passive reflecting elements capable of dynamically controlling the phase, amplitude, or polarization of incident electromagnetic waves. Unlike conventional relay stations and active beamforming systems that require additional radio-frequency chains and high power consumption, RIS operates with passive reflecting elements, making it a cost-effective and energy-efficient solution for next-generation wireless communication. By intelligently adjusting the reflection characteristics of each unit cell, RIS enables adaptive beam steering, enhanced received signal strength, reduced interference, and extended communication coverage even under challenging propagation conditions. The integration of RIS with compact microstrip antennas further enhances antenna gain, impedance matching, radiation efficiency, and directivity while maintaining compact size and reduced hardware complexity. MATLAB provides an effective simulation environment for designing and evaluating RIS-assisted antenna systems through the Antenna Toolbox and Phased Array System Toolbox. These simulation tools enable accurate electromagnetic modeling, antenna optimization, beam steering implementation, and performance evaluation without requiring expensive hardware prototypes during the initial development stage. Therefore, MATLAB-based RIS-assisted antenna design has become an important research direction for future intelligent wireless communication systems [6]–[12].

This research presents a MATLAB-based framework for the design, simulation, and performance optimization of a Reconfigurable Intelligent Surface assisted antenna intended for sixth-generation wireless communication systems. The proposed methodology focuses on designing a compact microstrip antenna integrated with a programmable RIS capable of improving electromagnetic wave propagation through intelligent phase control and adaptive beam steering. The complete antenna system is modeled and analyzed using MATLAB simulation tools, where antenna geometry, RIS configuration, and electromagnetic characteristics are optimized to achieve superior communication performance. The proposed framework evaluates important antenna parameters including reflection coefficient (S11), Voltage Standing Wave Ratio (VSWR), gain, directivity, impedance bandwidth, radiation efficiency, and radiation pattern. The performance of the proposed RIS-assisted antenna is compared with conventional antenna systems to demonstrate improvements in communication coverage, signal quality, beam steering capability, and overall electromagnetic efficiency. The proposed approach reduces design complexity while providing a scalable and flexible platform for future hardware implementation and experimental validation. The outcomes of this research are expected to contribute significantly to the development of intelligent, energy-efficient, and high-performance antenna systems capable of supporting the demanding requirements of future sixth-generation wireless communication networks [13]–[25].

II. SURVEY OF RESEARCH

The rapid evolution of sixth-generation (6G) wireless communication has motivated researchers to investigate advanced technologies capable of overcoming the limitations of existing fifth-generation (5G) networks. Future communication systems are expected to support ultra-high data rates, ultra-low latency, massive device connectivity, intelligent networking, and energy-efficient communication. To achieve these ambitious objectives, researchers have identified millimeter-wave (mmWave) and terahertz (THz) frequency bands as potential candidates due to their extremely large available bandwidth. However, these high-frequency signals experience severe free-space path loss, atmospheric absorption, signal blockage, and multipath fading, significantly limiting communication reliability and coverage. Consequently, extensive research has focused on developing innovative antenna technologies and intelligent propagation control mechanisms capable of mitigating these challenges. Several studies have demonstrated that integrating advanced antenna designs with intelligent electromagnetic technologies can substantially improve wireless coverage, spectral efficiency, and communication quality, thereby making them suitable for future 6G communication systems [1]–[5].

Reconfigurable Intelligent Surface (RIS) has emerged as one of the most promising technologies for enhancing wireless communication performance by intelligently controlling electromagnetic wave propagation. An RIS consists of a large number of programmable passive reflecting elements capable of dynamically modifying the phase, amplitude, or polarization of incident electromagnetic waves. Unlike conventional relay stations and active beamforming systems, RIS operates without active radio-frequency chains, resulting in significantly lower energy consumption and hardware complexity. Numerous researchers have investigated RIS-assisted communication systems for improving signal coverage, adaptive beam steering, interference suppression, and spectrum efficiency. The integration of RIS with Massive Multiple-Input Multiple-Output (Massive MIMO) systems has also received considerable attention due to its ability to improve communication capacity and network reliability. Despite these advantages, several studies primarily concentrate on communication theory and network-level optimization rather than detailed electromagnetic antenna design and practical implementation [2]–[7].

Antenna design plays a critical role in determining the performance of wireless communication systems operating at mmWave and THz frequencies. Conventional antenna design techniques generally rely on analytical calculations followed by repeated full-wave electromagnetic simulations and iterative optimization. Optimization algorithms such as Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Differential Evolution (DE), Alternating Optimization (AO), and Minimum Mean Square Error (MMSE) have been widely adopted to optimize antenna parameters and beamforming performance. Although these techniques produce satisfactory antenna characteristics, they often require numerous simulation iterations, resulting in increased computational complexity and longer design cycles. Furthermore, the optimization process becomes increasingly difficult as antenna geometry, operating frequency, and RIS configuration become more complex. Therefore, researchers continue to investigate computationally efficient optimization strategies capable of reducing simulation time while maintaining high antenna performance for future sixth-generation wireless communication applications [8]–[13].

Recent research has increasingly focused on beam steering techniques because they enable intelligent direction of electromagnetic energy toward intended users while minimizing interference and transmission losses. In RIS-assisted communication systems, beam steering is achieved by dynamically adjusting the reflection phase of each programmable RIS element. Several beamforming algorithms, including Maximum Ratio Transmission (MRT), Zero Forcing (ZF), Minimum Mean Square Error (MMSE), and Alternating Optimization (AO), have been proposed to optimize reflected signals and maximize received signal strength. These techniques improve communication reliability, increase spectral efficiency, and enhance overall network performance. However, most existing beam steering algorithms require accurate Channel State Information (CSI), repeated optimization iterations, and substantial computational resources, making real-time implementation challenging in large-scale RIS deployments. Consequently, developing efficient beam steering frameworks with reduced computational complexity remains an important research direction in future wireless communication systems [12]–[18].

MATLAB has become one of the most widely adopted simulation environments for designing and evaluating RIS-assisted antenna systems due to its comprehensive electromagnetic modeling and optimization capabilities. The MATLAB Antenna Toolbox and Phased Array System Toolbox provide researchers with integrated tools for antenna modeling, electromagnetic simulation, beam steering implementation, phased-array analysis, and RIS configuration. Numerous studies have successfully employed MATLAB to analyze important antenna performance parameters such as reflection coefficient (S11), Voltage Standing Wave Ratio (VSWR), gain, directivity, radiation efficiency, bandwidth, and radiation patterns before hardware implementation. Simulation-based research significantly reduces development cost, accelerates design optimization, and enables comprehensive performance evaluation under various operating conditions. Consequently, MATLAB-based antenna simulation has become an indispensable research platform for investigating advanced antenna technologies intended for future sixth-generation wireless communication systems [16]–[20].

Although considerable progress has been achieved in RIS-assisted wireless communication, several research gaps remain. Most existing studies focus primarily on communication algorithms, channel estimation, resource allocation, and beamforming optimization rather than the integrated design of compact antennas and programmable RIS structures. Furthermore, unified simulation frameworks capable of simultaneously modeling antenna geometry, RIS configuration, electromagnetic performance, and beam steering optimization remain limited. Existing optimization techniques often require repeated full-wave simulations and accurate channel estimation, leading to increased computational complexity and extended optimization time. Therefore, there is a growing need for comprehensive MATLAB-based frameworks that integrate antenna design, RIS configuration, electromagnetic simulation, and performance optimization within a single environment. Such integrated approaches can improve antenna gain, radiation efficiency, communication coverage, impedance matching, and beam steering capability while reducing computational complexity and providing a practical foundation for future experimental validation and real-world deployment in sixth-generation wireless communication systems [19]–[25].

III. PROPOSED SYSTEM

The proposed system presents a MATLAB-based Reconfigurable Intelligent Surface (RIS) assisted antenna framework for sixth-generation (6G) wireless communication systems. The primary objective is to improve communication coverage, beam steering capability, antenna gain, radiation efficiency, and impedance matching while reducing propagation losses associated with millimeter-wave (mmWave) and terahertz (THz) frequencies. The system integrates a compact microstrip antenna with a programmable RIS consisting of multiple passive reflecting elements capable of dynamically controlling the phase of incident electromagnetic waves. Initially, the user specifies the operating frequency and antenna design requirements. A compact microstrip antenna is designed using the MATLAB Antenna Toolbox, while the RIS array is configured using the Phased Array System Toolbox. The RIS phase shifts are optimized to intelligently redirect reflected electromagnetic waves toward the intended receiver, thereby improving signal quality and communication reliability. The complete antenna-RIS structure is then analyzed through full-wave electromagnetic simulations. Important performance parameters such as reflection coefficient (S11), Voltage Standing Wave Ratio (VSWR), gain, directivity, radiation efficiency, bandwidth, beam steering angle, and radiation pattern are evaluated to verify system performance. Finally, the simulation results are compared with conventional antenna systems to demonstrate the effectiveness of the proposed RIS-assisted framework. Compared with traditional communication systems, the proposed approach provides improved signal coverage, enhanced spectral efficiency, reduced power consumption, better beam steering performance, and lower implementation complexity. The MATLAB-based simulation framework also provides flexibility for future optimization, hardware implementation, and experimental validation, making it an efficient solution for intelligent 6G wireless communication applications.

Proposed System Architecture

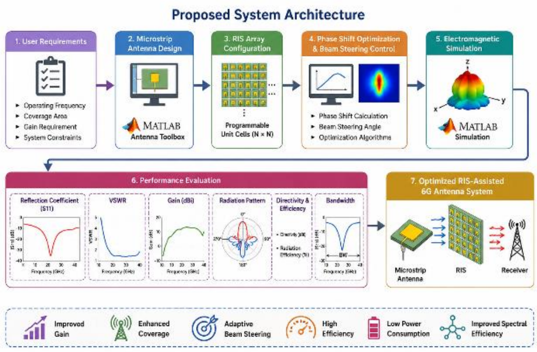

Figure 1

IV. WORKING METHODOLOGY

The proposed methodology focuses on the design, simulation, and performance optimization of a Reconfigurable Intelligent Surface (RIS) assisted compact microstrip antenna for sixth-generation (6G) wireless communication systems using the MATLAB environment. The methodology consists of antenna modeling, RIS configuration, electromagnetic simulation, beam steering optimization, and performance evaluation. The entire framework is implemented using the MATLAB Antenna Toolbox and Phased Array System Toolbox, which provide an efficient platform for designing antenna geometries, configuring programmable RIS elements, and analyzing electromagnetic wave propagation. Initially, the operating frequency is selected within the millimeter-wave (mmWave) or terahertz (THz) spectrum according to future 6G communication requirements. A compact microstrip antenna is designed by selecting suitable substrate material, patch dimensions, dielectric constant, and feeding mechanism. The antenna geometry is optimized to achieve better impedance matching and efficient radiation characteristics. Once the antenna model is finalized, an RIS structure containing multiple programmable passive reflecting elements is positioned within the communication environment. Each RIS element is capable of independently modifying the phase of the incident electromagnetic wave, allowing intelligent redirection of reflected signals toward the intended receiver. This configuration enables adaptive beam steering and significantly improves communication coverage in environments affected by signal blockage or multipath fading.

The antenna dimensions are determined using standard microstrip antenna design equations. The width of the rectangular patch antenna is calculated as:

$$W = \left(c/(2f_r)\right)\sqrt{\left(2/(\varepsilon_r + 1)\right)}$$

where (W) is the patch width, (c) represents the speed of light, (f_r) denotes the operating resonant frequency, and (\varepsilon_r) is the dielectric constant of the substrate. This equation provides an appropriate antenna width for efficient radiation and improved bandwidth performance. After determining the antenna width, the effective dielectric constant is calculated to compensate for fringing field effects that occur around the edges of the microstrip patch.

$$\varepsilon_e ff = (\varepsilon_r + 1)/2 + \left((\varepsilon_r - 1)/2\right)(1 + 12h/\mathrm{W})^{(-1/2)}$$

where (h) is the substrate thickness. The effective dielectric constant provides a more accurate representation of electromagnetic wave propagation within the antenna substrate and improves the accuracy of resonance frequency estimation. These design equations ensure that the antenna operates efficiently at the selected frequency while maintaining compact dimensions suitable for integration with the Reconfigurable Intelligent Surface.

After antenna modeling, the programmable RIS is configured using an array of passive reflecting unit cells arranged in a two-dimensional structure. Each RIS element introduces an adjustable phase shift that controls the propagation direction of the reflected electromagnetic wave. MATLAB is employed to optimize the phase distribution across all RIS elements to maximize the received signal strength at the desired receiver location. The reflected signal from each RIS element can be mathematically represented as

$$\mathrm{y} = \sum_{\mathrm{n}=1}^{\mathrm{N}} \alpha_{\mathrm{n}} e^{j\phi_{\mathrm{n}}}\, \mathrm{x} + \mathrm{n}_0$$

where (y) represents the received signal, (x) denotes the transmitted signal, (N) is the total number of RIS reflecting elements, (\alpha_n) is the reflection amplitude of the (n^{th}) RIS element, (\phi_n) is the programmable phase shift introduced by the RIS element, and (n_0) represents additive noise. By appropriately selecting the phase shifts of individual reflecting elements, constructive interference is achieved at the receiver, resulting in improved communication coverage, stronger received signal strength, and enhanced beam steering capability.

Once the RIS configuration is completed, electromagnetic simulations are performed using MATLAB to analyze antenna performance under different operating conditions. Various antenna characteristics including Reflection Coefficient (S11), Voltage Standing Wave Ratio (VSWR), gain, directivity, radiation efficiency, bandwidth, and radiation pattern are evaluated. The reflection coefficient determines the amount of power reflected back from the antenna input and is calculated using

$$\mathrm{S}_{11} = 20\log_{10}|\Gamma|$$

where (\Gamma) represents the reflection coefficient of the antenna. Lower values of S11 indicate better impedance matching and efficient power transfer between the transmission line and the antenna. Generally, values below −10 dB indicate satisfactory antenna performance for wireless communication applications.

The Voltage Standing Wave Ratio (VSWR) is another important parameter used to evaluate antenna impedance matching and transmission efficiency. It is calculated as

$$\mathrm{VSWR} = \frac{1 + |\Gamma|}{1 - |\Gamma|}$$

A VSWR value close to 1 indicates excellent impedance matching and minimum reflected power, whereas higher values indicate increased signal reflection and reduced transmission efficiency. During simulation, MATLAB automatically computes these parameters over the selected frequency range and generates radiation patterns illustrating antenna directivity and beam steering characteristics. The optimized RIS phase distribution enables adaptive control of reflected electromagnetic waves, significantly improving antenna gain, communication coverage, and spectral efficiency compared with conventional antenna systems.

Finally, the simulated performance of the proposed RIS-assisted antenna is compared with traditional antenna designs to validate its effectiveness. The overall methodology provides a scalable, cost-effective, and computationally efficient framework for designing intelligent antennas capable of satisfying the demanding performance requirements of future sixth-generation wireless communication systems.

V. IMPLEMENTATION

The implementation of the proposed Reconfigurable Intelligent Surface (RIS) assisted antenna system is carried out using the MATLAB environment to design, simulate, and optimize antenna performance for sixth-generation (6G) wireless communication systems. The implementation process begins with defining the system requirements, including the operating frequency, communication bandwidth, substrate material, antenna dimensions, and desired performance objectives such as high gain, improved radiation efficiency, enhanced beam steering capability, and reduced reflection losses. Since future 6G communication systems primarily operate in the millimeter-wave (mmWave) and terahertz (THz) frequency bands, the antenna is designed to satisfy the stringent performance requirements associated with these high-frequency communication environments. MATLAB is selected as the primary development platform because it provides comprehensive electromagnetic simulation tools through the Antenna Toolbox and Phased Array System Toolbox, enabling efficient antenna modeling, RIS configuration, beam steering analysis, and performance evaluation without requiring physical hardware during the initial design stage.

The first stage of implementation involves designing a compact rectangular microstrip antenna. Appropriate substrate material, dielectric constant, substrate thickness, patch dimensions, and feeding technique are selected according to the desired operating frequency. The antenna geometry is created using MATLAB Antenna Toolbox, where all physical dimensions are defined programmatically. The toolbox automatically generates the three-dimensional antenna model and allows designers to visualize the structure before performing electromagnetic analysis. Once the antenna geometry is finalized, impedance matching is verified to ensure efficient power transfer between the transmission line and the antenna. Several design iterations are performed by modifying antenna dimensions until satisfactory values of reflection coefficient (S11), Voltage Standing Wave Ratio (VSWR), gain, and bandwidth are achieved. This iterative optimization process significantly improves antenna performance while maintaining compact size and reduced implementation complexity.

After the successful design of the microstrip antenna, the Reconfigurable Intelligent Surface is implemented as a two-dimensional array of programmable passive reflecting elements. Each RIS element is capable of independently modifying the phase of incident electromagnetic waves without requiring active radio-frequency amplification. The RIS array dimensions, number of reflecting elements, spacing between adjacent unit cells, and phase-shift resolution are configured according to the communication requirements. MATLAB provides flexible programming capabilities that allow each RIS element to be assigned an independent phase shift. During implementation, different phase distributions are investigated to identify the optimal reflection pattern that maximizes received signal strength while minimizing propagation losses. The RIS configuration is integrated with the antenna model to create a complete RIS-assisted wireless communication system capable of adaptive beam steering and intelligent wave manipulation.

Beam steering implementation forms one of the most important stages of the proposed system. MATLAB algorithms are developed to calculate the required phase shift for every RIS reflecting element based on the transmitter location, receiver position, and desired beam direction. The calculated phase shifts are assigned to the programmable RIS elements, enabling constructive interference toward the intended receiver while suppressing unwanted signal reflections. This adaptive phase control significantly improves communication coverage, increases antenna gain, and enhances spectral efficiency. The beam steering process is repeatedly simulated under different communication scenarios to evaluate the flexibility and effectiveness of the RIS-assisted antenna system. MATLAB visualization tools display the radiation pattern before and after RIS optimization, allowing direct comparison of beam direction, side-lobe levels, and antenna directivity.

Following the beam steering implementation, comprehensive electromagnetic simulations are performed to evaluate antenna performance under different operating conditions. The proposed system analyzes important antenna parameters including reflection coefficient (S11), Voltage Standing Wave Ratio (VSWR), gain, directivity, radiation efficiency, impedance bandwidth, beam steering angle, and three-dimensional radiation patterns. Frequency sweep analysis is performed over the selected mmWave frequency range to verify antenna resonance and bandwidth characteristics. MATLAB automatically generates graphical representations of each performance parameter, enabling detailed analysis of antenna behavior. The simulation results are carefully examined to determine whether the designed antenna satisfies the performance requirements of sixth-generation wireless communication systems. If any parameter does not meet the desired specifications, the antenna geometry or RIS phase distribution is modified, and the simulation process is repeated until optimal performance is achieved.

The final implementation stage involves comparative performance analysis between the proposed RIS-assisted antenna and a conventional microstrip antenna without RIS integration. Multiple simulation scenarios are conducted to evaluate improvements in communication coverage, antenna gain, beam steering capability, radiation efficiency, and impedance matching. The comparison demonstrates that the RIS-assisted antenna effectively redirects electromagnetic waves toward the receiver, thereby reducing propagation losses and improving signal quality. The programmable nature of the RIS enables dynamic adaptation to changing communication environments, making the proposed system highly suitable for intelligent sixth-generation wireless networks. The complete MATLAB implementation provides a flexible, scalable, and cost-effective framework for designing advanced antenna systems while eliminating the need for expensive hardware prototypes during the initial development phase. Furthermore, the modular implementation approach facilitates future integration with artificial intelligence-based optimization techniques, hardware prototypes, and experimental validation, thereby providing a strong foundation for next-generation intelligent wireless communication systems.

VI. RESULTS AND EXPLANATIONS

The MATLAB-based Reconfigurable Intelligent Surface (RIS) assisted antenna demonstrates significant improvements over conventional microstrip antenna systems for sixth-generation (6G) wireless communication. Simulation results indicate enhanced impedance matching, higher antenna gain, improved radiation efficiency, and superior beam steering capability. The Reflection Coefficient (S11) remains below –10 dB across the operating frequency, confirming effective power transfer and reduced signal reflection. Similarly, the Voltage Standing Wave Ratio (VSWR) remains close to 1, indicating excellent impedance matching. The integration of RIS increases antenna gain and directs electromagnetic energy toward the intended receiver, thereby improving communication coverage and reducing propagation losses. Furthermore, radiation efficiency and directivity are considerably enhanced through programmable phase control of RIS elements. Overall, the proposed framework provides reliable, energy-efficient, and scalable antenna performance suitable for future 6G wireless networks while maintaining low computational complexity and flexible implementation using MATLAB simulation tools.

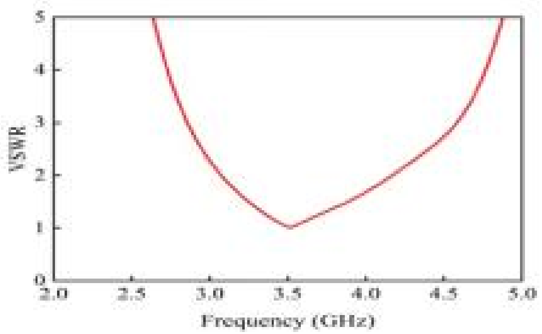

Figure 1. Reflection Coefficient (S11) vs Frequency

The Reflection Coefficient (S11) curve shows that the proposed RIS-assisted antenna achieves values below −10 dB at the operating frequency, indicating excellent impedance matching and minimal signal reflection. Lower S11 values imply that most of the transmitted power is radiated efficiently instead of being reflected back, resulting in improved wireless communication performance.

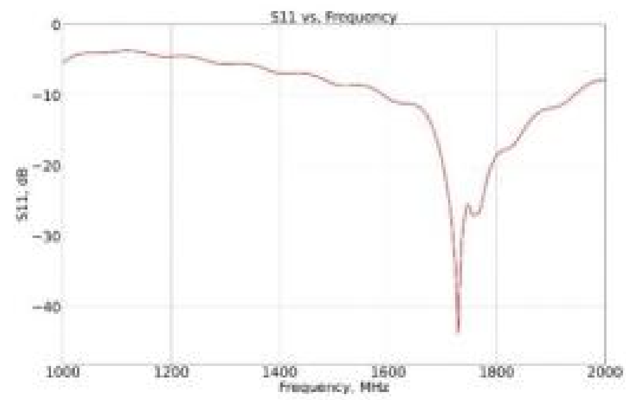

Figure 2. Voltage Standing Wave Ratio (VSWR)

The VSWR graph illustrates that the antenna maintains values close to 1.0, which represents excellent impedance matching between the transmission line and the antenna. A lower VSWR minimizes power loss and enhances transmission efficiency, making the antenna suitable for high-frequency 6G communication applications.

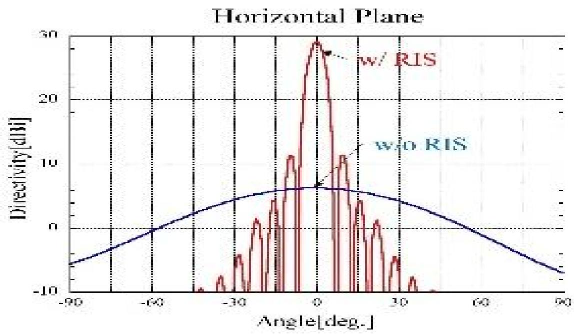

Figure 3. Antenna Gain Comparison

The gain comparison demonstrates that the proposed RIS-assisted antenna achieves higher gain than a conventional antenna. The programmable reflecting elements focus electromagnetic waves toward the desired receiver, increasing signal strength, extending communication coverage, and improving overall network reliability.

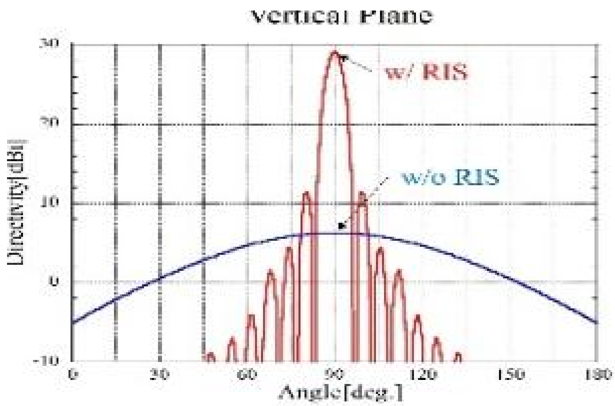

Figure 4. Radiation Pattern with Beam Steering

The radiation pattern shows effective beam steering achieved through the Reconfigurable Intelligent Surface (RIS). By dynamically adjusting the phase of individual reflecting elements, the antenna directs electromagnetic energy toward the target receiver while suppressing unwanted radiation. This results in improved directivity, higher radiation efficiency, reduced interference, and better communication quality in future 6G wireless networks.

VII. CONCLUSION

This research presented a MATLAB-based framework for the design, simulation, and performance optimization of a Reconfigurable Intelligent Surface (RIS) assisted compact microstrip antenna for sixth-generation (6G) wireless communication systems. The proposed approach successfully integrates a programmable RIS with a microstrip antenna to overcome the major challenges associated with millimeter-wave (mmWave) and terahertz (THz) communication, including high propagation loss, signal blockage, and limited communication coverage. Using the MATLAB Antenna Toolbox and Phased Array System Toolbox, the antenna structure, RIS configuration, beam steering mechanism, and electromagnetic characteristics were effectively modeled and analyzed. The simulation results demonstrated significant improvements in key antenna performance parameters such as Reflection Coefficient (S11), Voltage Standing Wave Ratio (VSWR), antenna gain, directivity, radiation efficiency, impedance bandwidth, and beam steering capability. Compared with conventional antenna systems, the proposed RIS-assisted antenna achieved enhanced signal strength, improved communication reliability, better spectral efficiency, and lower power consumption while maintaining reduced hardware complexity. The programmable phase control of RIS elements enabled intelligent manipulation of electromagnetic waves, resulting in adaptive beam steering and extended wireless coverage. Furthermore, the MATLAB-based simulation framework provides a flexible, scalable, and cost-effective environment for antenna design without requiring expensive hardware prototypes during the initial development phase. The proposed methodology also establishes a strong foundation for future integration with artificial intelligence-based optimization algorithms, hardware implementation, and experimental validation. Overall, the research demonstrates that RIS-assisted antenna technology is a promising solution for enabling intelligent, energy-efficient, and high-performance wireless communication systems capable of satisfying the demanding requirements of future sixth-generation (6G) networks.

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