DESIGN AND PERFORMANCE ANALYSIS OF AN INTEGRATED SENSING AND COMMUNICATION (ISAC) ANTENNA ARRAY FOR 6G WIRELESS NETWORKS

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ABSTRACT

The rapid evolution of sixth-generation (6G) wireless communication demands intelligent systems capable of providing both ultra-high-speed data transmission and accurate environmental sensing. Conventional wireless communication and radar sensing systems operate independently, requiring separate hardware, increased spectrum allocation, and higher implementation costs. Integrated Sensing and Communication (ISAC) has emerged as a promising technology that combines communication and sensing functionalities into a unified platform, enabling efficient spectrum utilization, reduced hardware complexity, and enhanced system performance. This research presents the design and performance analysis of a 28 GHz Integrated Sensing and Communication (ISAC) Antenna Array for future 6G wireless networks. The proposed system employs an 8 × 8 Uniform Rectangular Array (URA) of microstrip patch antennas integrated with digital beamforming techniques to achieve simultaneous wireless communication and radar sensing. The antenna array is modeled and analyzed using MATLAB Antenna Toolbox and Phased Array System Toolbox. The system performance is evaluated using key antenna and communication parameters, including Reflection Coefficient (S11), Voltage Standing Wave Ratio (VSWR), array gain, directivity, radiation efficiency, beam steering capability, Bit Error Rate (BER), Signal-to-Interference-plus-Noise Ratio (SINR), spectral efficiency, and radar detection probability. Simulation results demonstrate that the proposed ISAC antenna array provides high directional gain, accurate electronic beam steering, reliable communication links, and improved sensing performance while optimizing spectrum usage and reducing hardware requirements. The proposed design offers a scalable, energy-efficient, and cost-effective solution suitable for next-generation applications such as autonomous vehicles, intelligent transportation systems, smart cities, industrial automation, unmanned aerial vehicles (UAVs), and extended reality (XR). The study establishes a practical MATLAB-based framework for developing advanced ISAC antenna systems supporting future intelligent 6G wireless communication networks.

Keywords: Integrated Sensing and Communication (ISAC), 6G Wireless Networks, Uniform Rectangular Array (URA), Digital Beamforming, Millimeter-Wave (28 GHz), Antenna Array, MATLAB, Radar Sensing, Beam Steering, Spectral Efficiency.

I. INTRODUCTION

Wireless communication has evolved significantly from first-generation (1G) analog systems to fifth-generation (5G) mobile networks, enabling broadband connectivity, cloud computing, the Internet of Things (IoT), artificial intelligence (AI), autonomous transportation, and smart city applications. However, the rapid growth of connected devices, data-intensive services, and intelligent applications has exposed the limitations of current wireless infrastructures in terms of spectrum utilization, latency, sensing capability, and network intelligence. Sixth-generation (6G) wireless communication is expected to overcome these challenges by providing ultra-high data rates, extremely low latency, intelligent networking, and seamless integration of communication with environmental sensing. Unlike previous generations, 6G aims to transform wireless networks into intelligent platforms capable of simultaneously transmitting data, detecting objects, tracking targets, and understanding surrounding environments. This transformation is driven by emerging technologies such as millimeter-wave (mmWave) communication, terahertz (THz) transmission, massive Multiple-Input Multiple-Output (MIMO), digital beamforming, artificial intelligence, and Integrated Sensing and Communication (ISAC). These technologies collectively support applications including autonomous vehicles, industrial automation, healthcare monitoring, unmanned aerial vehicles (UAVs), extended reality (XR), and intelligent transportation systems. Consequently, ISAC has emerged as one of the most promising enabling technologies for future 6G wireless communication due to its capability to integrate radar sensing and wireless communication within a single hardware platform, thereby improving spectrum efficiency, reducing deployment cost, and enhancing overall network intelligence [1]–[4].

Conventional wireless communication and radar sensing systems are typically designed as separate entities, each requiring dedicated antennas, radio-frequency resources, processing hardware, and spectrum allocation. Such independent architectures increase hardware complexity, implementation cost, power consumption, and spectrum wastage while limiting the capability of communication systems to perceive and interact with their surrounding environment. Integrated Sensing and Communication (ISAC) addresses these limitations by allowing communication signals to perform both wireless data transmission and radar sensing simultaneously using a common antenna array and shared radio-frequency resources. Among various antenna configurations, the Uniform Rectangular Array (URA) has attracted considerable attention because it offers high directional gain, narrow beamwidth, two-dimensional electronic beam steering, and excellent compatibility with digital beamforming algorithms. When combined with phased-array technology and adaptive beamforming, URA-based ISAC systems can significantly improve communication reliability, target detection accuracy, localization performance, and spectral efficiency. Operating at the 28 GHz millimeter-wave frequency band further enhances communication capacity and sensing resolution, making it an attractive candidate for future 6G deployments. Therefore, designing compact, energy-efficient, and high-performance ISAC antenna arrays has become an active research area in modern wireless communication systems [5]–[8].

This research focuses on the design and performance evaluation of a 28 GHz 8 × 8 Uniform Rectangular Array (URA) Integrated Sensing and Communication (ISAC) antenna array using the MATLAB Antenna Toolbox and Phased Array System Toolbox. The proposed antenna array integrates wireless communication and radar sensing into a unified framework through digital beamforming, enabling simultaneous high-speed communication and accurate environmental sensing. The performance of the proposed system is evaluated using several important antenna and communication parameters, including Reflection Coefficient (S11), Voltage Standing Wave Ratio (VSWR), array gain, directivity, radiation efficiency, Bit Error Rate (BER), Signal-to-Interference-plus-Noise Ratio (SINR), spectral efficiency, beam steering capability, and radar detection probability. The proposed model aims to achieve improved communication reliability, higher sensing accuracy, enhanced spectrum utilization, and reduced hardware complexity compared with conventional communication systems. The developed MATLAB-based framework provides a flexible simulation environment for analyzing advanced antenna array architectures and supports future research in intelligent wireless communication systems. The proposed ISAC antenna array is expected to play a significant role in enabling next-generation applications such as smart cities, autonomous vehicles, industrial automation, UAV communication, and intelligent 6G wireless networks [9]–[12].

II. SURVEY OF RESEARCH

Integrated Sensing and Communication (ISAC) has become one of the most significant research areas for future sixth-generation (6G) wireless communication systems. Early studies primarily focused on integrating wireless communication and radar sensing into a common hardware platform to improve spectrum utilization and reduce implementation complexity. Researchers demonstrated that sharing the same radio-frequency resources for communication and sensing enables simultaneous data transmission and environmental perception without requiring separate radar equipment. The adoption of ISAC also improves energy efficiency, reduces hardware duplication, and enhances communication reliability. Recent advancements in millimeter-wave (mmWave) communication and phased-array antenna technology have further accelerated ISAC research by enabling high-frequency operation with improved spatial resolution and beamforming capability. Several studies have shown that ISAC can significantly improve intelligent transportation, autonomous driving, smart manufacturing, and healthcare monitoring by providing real-time sensing together with high-speed wireless communication. Consequently, ISAC has emerged as one of the key enabling technologies expected to define future intelligent wireless networks.

A considerable amount of research has focused on antenna array architectures capable of supporting simultaneous communication and sensing operations. Uniform Linear Arrays (ULA), Uniform Rectangular Arrays (URA), phased-array antennas, and Massive Multiple-Input Multiple-Output (Massive MIMO) systems have been extensively investigated for ISAC applications. Among these configurations, URA-based antenna arrays have received greater attention because they provide two-dimensional beam steering, higher directional gain, reduced beamwidth, and improved target localization accuracy. Researchers have demonstrated that digital beamforming combined with URA structures enables flexible beam control without mechanical movement, thereby improving communication coverage and radar detection performance simultaneously. Several simulation-based studies operating at the 28 GHz millimeter-wave frequency band have reported higher array gain, improved spectral efficiency, and better communication reliability. However, many existing antenna designs still require complex beamforming algorithms and expensive hardware implementations, limiting their practical deployment in future 6G wireless communication systems.

Digital beamforming has become another major research direction within ISAC technology because it enables intelligent control of antenna radiation patterns through software-defined signal processing. Unlike analog beamforming, digital beamforming provides independent control of the phase and amplitude of each antenna element, allowing accurate electronic beam steering toward desired users or sensing targets. Numerous researchers have proposed adaptive beamforming algorithms capable of dynamically adjusting beam directions according to user mobility, environmental changes, and target movement. Machine learning and artificial intelligence techniques have also been integrated into beamforming optimization to improve beam selection, interference suppression, and communication throughput. Although these approaches significantly enhance communication quality and sensing accuracy, they often require high computational resources, large training datasets, and complex optimization procedures. Therefore, developing computationally efficient beamforming methods remains an active area of research for practical ISAC deployment.

Recent literature has also emphasized the importance of performance evaluation metrics for ISAC antenna systems. Researchers commonly analyze antenna characteristics such as Reflection Coefficient (S11), Voltage Standing Wave Ratio (VSWR), radiation efficiency, array gain, directivity, beamwidth, sidelobe level, and beam steering capability to assess antenna performance. Communication performance is typically evaluated using Bit Error Rate (BER), Signal-to-Interference-plus-Noise Ratio (SINR), throughput, spectral efficiency, and energy efficiency, while sensing capability is measured through radar detection probability, target localization accuracy, range-angle mapping, and environmental awareness. MATLAB-based simulation platforms, particularly the Antenna Toolbox and Phased Array System Toolbox, have become widely adopted for analyzing these parameters because they provide flexible environments for antenna modeling, electromagnetic simulation, digital beamforming, and communication system evaluation. These simulation tools allow researchers to validate antenna designs before hardware implementation, reducing both development cost and experimental complexity.

Several comparative studies have highlighted the limitations of conventional communication systems and existing ISAC implementations. Traditional wireless communication antennas provide reliable data transmission but lack environmental sensing capability, whereas conventional radar systems offer accurate object detection but require dedicated hardware and spectrum resources. Existing phased-array and Massive MIMO systems improve communication performance but often suffer from increased computational complexity, higher power consumption, and expensive deployment costs. Furthermore, many previously proposed ISAC antenna arrays concentrate on improving either communication performance or sensing capability independently rather than optimizing both simultaneously. The absence of comprehensive simulation frameworks capable of jointly evaluating communication, sensing, beamforming, and antenna characteristics remains another important research challenge. These limitations indicate the need for compact, energy-efficient, and computationally efficient ISAC antenna architectures capable of supporting future intelligent wireless communication networks.

Based on the comprehensive review of existing research, it is evident that Integrated Sensing and Communication continues to evolve as a foundational technology for future 6G wireless communication systems. Although significant progress has been achieved in antenna array design, phased-array technology, beamforming algorithms, and communication optimization, several research gaps still remain. Future investigations should focus on developing compact antenna arrays with lower computational complexity, higher spectral efficiency, improved beam steering accuracy, and enhanced radar sensing performance while minimizing hardware requirements. MATLAB-based modeling environments provide an effective platform for evaluating these design objectives before practical implementation. Therefore, designing a high-gain 28 GHz 8 × 8 Uniform Rectangular Array (URA) integrated with digital beamforming represents a promising research direction capable of supporting simultaneous wireless communication and radar sensing for intelligent applications such as autonomous vehicles, smart cities, industrial automation, unmanned aerial vehicles, and next-generation 6G wireless communication systems.

III. PROPOSED SYSTEM

The proposed system presents a 28 GHz Integrated Sensing and Communication (ISAC) Antenna Array designed to support future sixth-generation (6G) wireless communication networks. Unlike conventional systems that use separate hardware for wireless communication and radar sensing, the proposed architecture integrates both functionalities into a single platform using an 8 × 8 Uniform Rectangular Array (URA) of microstrip patch antennas. The antenna array employs digital beamforming techniques to electronically steer beams toward desired communication users while simultaneously sensing surrounding objects. The system is developed and simulated using MATLAB Antenna Toolbox, Phased Array System Toolbox, and Communications Toolbox, providing a comprehensive environment for antenna modeling, beamforming, communication analysis, and radar sensing evaluation. Performance is assessed using antenna parameters such as Reflection Coefficient (S11), Voltage Standing Wave Ratio (VSWR), array gain, directivity, radiation efficiency, and beam steering capability, together with communication metrics including Bit Error Rate (BER), Signal-to-Interference-plus-Noise Ratio (SINR), spectral efficiency, and radar detection probability. The proposed ISAC antenna array offers improved spectrum utilization, enhanced communication reliability, accurate target detection, reduced hardware complexity, and lower deployment cost compared with conventional wireless systems. The compact and energy-efficient architecture makes it suitable for intelligent applications including autonomous vehicles, smart cities, industrial automation, intelligent transportation systems, unmanned aerial vehicles (UAVs), and extended reality (XR). The proposed MATLAB-based framework also provides a flexible platform for future research involving advanced beamforming algorithms, artificial intelligence-assisted communication, and next-generation 6G wireless networks.

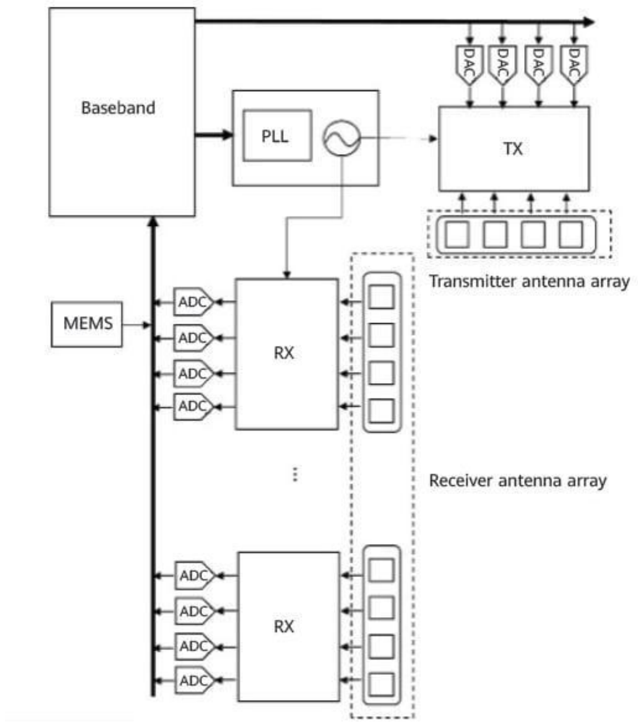

Figure 3.1: Proposed Integrated Sensing and Communication (ISAC) System Architecture for 6G Wireless Networks.

IV. WORKING METHODOLOGY

The proposed Integrated Sensing and Communication (ISAC) Antenna Array is designed to perform simultaneous wireless communication and radar sensing using a common hardware platform operating at 28 GHz for future 6G wireless networks. The system integrates an 8 × 8 Uniform Rectangular Array (URA) of microstrip patch antennas with digital beamforming to achieve high data transmission, accurate environmental sensing, and efficient spectrum utilization. The complete methodology consists of antenna array design, signal generation, digital beamforming, wireless communication, radar sensing, and performance evaluation. MATLAB Antenna Toolbox, Phased Array System Toolbox, and Communications Toolbox are used to model, simulate, and evaluate the entire system.

The first stage involves designing an 8 × 8 Uniform Rectangular Array (URA) operating at 28 GHz. The antenna consists of 64 identical rectangular microstrip patch elements placed with an inter-element spacing of 0.5λ, where λ represents the wavelength. This spacing minimizes grating lobes while maintaining high array gain and narrow beamwidth. The URA configuration enables two-dimensional electronic beam steering in both azimuth and elevation directions, making it suitable for simultaneous communication and sensing applications. Each antenna element contributes constructively toward the desired direction, producing a highly directional radiation pattern with improved directivity and reduced interference.

The wavelength of the operating frequency is calculated as:

$$\lambda = \frac{c}{f}$$

Where:

- (\lambda) = Wavelength (m)
- (c) = Speed of light ((3 \times 10^8) m/s)
- (f) = Operating frequency (28 GHz)

After antenna design, digital communication signals are generated and passed to the beamforming processor. Digital beamforming calculates suitable phase and amplitude weights for every antenna element so that the transmitted beam is directed toward the intended communication user while simultaneously illuminating the surrounding environment for radar sensing. Unlike conventional fixed-beam antennas, beamforming enables rapid electronic steering without mechanical movement. This significantly improves communication quality, extends coverage, reduces interference, and enhances target localization. The weighted antenna signals are combined to form a high-gain directional beam suitable for ISAC applications.

The beamformed signal can be represented as:

$$AF(\theta) = \sum_{n=1}^{N} w_n e^{j(n-1)kd\sin\theta}$$

Where:

- (AF(\theta)) = Array Factor
- (w_n) = Beamforming weight of the nth antenna
- (N) = Number of antenna elements
- (k=\frac{2\pi}{\lambda})
- (d) = Element spacing
- (\theta) = Beam steering angle

The communication subsystem transmits beamformed signals toward user equipment while the same transmitted waveform is simultaneously utilized for radar sensing. Reflected electromagnetic waves from surrounding objects are received by the antenna array and processed by the radar sensing module to estimate object location, distance, and direction. This shared use of antenna hardware and radio-frequency resources significantly improves spectrum utilization while reducing hardware complexity. Signal processing algorithms estimate communication quality and sensing accuracy simultaneously, enabling intelligent operation of future wireless networks.

Communication performance is evaluated using the Signal-to-Interference-plus-Noise Ratio (SINR), which measures signal quality under interference and noise conditions.

$$SINR = \frac{P_s}{P_i + P_n}$$

Where:

- (P_s) = Received signal power
- (P_i) = Interference power
- (P_n) = Noise power

Higher SINR values indicate improved communication reliability, increased throughput, and lower transmission errors.

The reliability of digital communication is further analyzed using the Bit Error Rate (BER). BER measures the ratio of incorrectly received bits to the total transmitted bits during communication. A lower BER indicates higher communication accuracy and better system performance.

$$\mathrm{BER} = \frac{N_e}{N_t}$$

Where:

- (N_e) = Number of erroneous bits
- (N_t) = Total transmitted bits

The proposed antenna array is also evaluated using several antenna performance parameters including Reflection Coefficient (S11), Voltage Standing Wave Ratio (VSWR), radiation efficiency, array gain, directivity, beam steering capability, and radiation pattern. These parameters determine impedance matching, antenna efficiency, directional characteristics, and overall communication performance. MATLAB provides detailed electromagnetic simulations that allow optimization of antenna geometry before practical implementation.

Radar sensing capability is evaluated by observing beam patterns, range-angle maps, target detection probability, and electronic beam steering accuracy. The integrated sensing framework enables the antenna array to identify surrounding objects while maintaining uninterrupted communication with user devices. Accurate beam steering improves target localization and reduces unwanted radiation toward non-target regions, thereby enhancing sensing resolution.

Another important parameter used to evaluate system efficiency is Spectral Efficiency, which measures the amount of information transmitted over the available bandwidth.

$$\mathrm{SE} = \frac{R}{B}$$

Where:

- (SE) = Spectral Efficiency (bits/s/Hz)
- (R) = Data Rate (bits/s)
- (B) = Bandwidth (Hz)

Higher spectral efficiency indicates better utilization of available spectrum resources, which is one of the primary objectives of ISAC technology.

Finally, all simulation results are analyzed to compare the proposed ISAC antenna array with conventional wireless communication systems. Parameters such as array gain, directivity, BER, SINR, spectral efficiency, radar detection probability, beam steering accuracy, and communication reliability are evaluated to demonstrate system performance. The proposed architecture provides higher directional gain, improved communication quality, enhanced sensing capability, reduced hardware complexity, and efficient spectrum utilization compared with traditional communication systems. The MATLAB-based implementation offers a flexible simulation platform for future development of intelligent beamforming algorithms, artificial intelligence-assisted communication, and next-generation 6G wireless networks. This integrated approach establishes a practical and scalable solution for emerging applications including autonomous vehicles, smart cities, industrial automation, intelligent transportation systems, unmanned aerial vehicles (UAVs), healthcare monitoring, and extended reality (XR).

V. IMPLEMENTATION

The implementation of the proposed Integrated Sensing and Communication (ISAC) Antenna Array is carried out using MATLAB R2024a along with the Antenna Toolbox, Phased Array System Toolbox, and Communications Toolbox. The objective of the implementation is to develop a software-based simulation model capable of simultaneously performing wireless communication and radar sensing using a single antenna platform. Unlike conventional systems that require separate communication and sensing hardware, the proposed implementation integrates both functionalities into an 8 × 8 Uniform Rectangular Array (URA) operating at the 28 GHz millimeter-wave frequency band. MATLAB provides an efficient environment for antenna modeling, electromagnetic analysis, digital beamforming, communication simulation, and radar sensing evaluation, allowing complete verification of the proposed system before hardware deployment.

The implementation begins with the design of the 8 × 8 Uniform Rectangular Array (URA) consisting of 64 rectangular microstrip patch antenna elements. Each antenna element is positioned with an inter-element spacing of 0.5λ to reduce grating lobes and improve directional radiation characteristics. MATLAB Antenna Toolbox is used to define the antenna geometry, substrate properties, operating frequency, element dimensions, and array configuration. The antenna array is then analyzed to obtain important radiation characteristics such as Reflection Coefficient (S11), Voltage Standing Wave Ratio (VSWR), impedance matching, radiation efficiency, array gain, directivity, beamwidth, and three-dimensional radiation patterns. These parameters ensure that the antenna satisfies the performance requirements necessary for future 6G wireless communication systems.

After completing the antenna design, the communication subsystem is implemented using MATLAB Communications Toolbox. Digital information bits are generated and modulated before being transmitted through the antenna array. Various communication channel conditions, including noise and interference, are introduced to evaluate system reliability under practical operating environments. The transmitted communication signal is simultaneously utilized for radar sensing without requiring separate signal generation, thereby demonstrating the principle of Integrated Sensing and Communication. At the receiver, demodulation and signal recovery are performed, while communication performance is evaluated using Bit Error Rate (BER), Signal-to-Interference-plus-Noise Ratio (SINR), throughput, and spectral efficiency. These performance indicators help verify the reliability of the proposed communication framework under different simulation scenarios.

Digital beamforming is implemented using the MATLAB Phased Array System Toolbox. The beamforming algorithm calculates appropriate phase and amplitude weights for all sixty-four antenna elements based on the desired steering direction. These weights are applied electronically to produce a narrow, high-gain directional beam without any mechanical movement. Electronic beam steering enables the antenna array to dynamically redirect communication signals toward users while simultaneously scanning the surrounding environment for radar sensing. Multiple steering angles are evaluated during simulation to verify beam accuracy, sidelobe suppression, and communication coverage. The implementation also demonstrates rapid beam switching, which is essential for supporting mobile users and highly dynamic environments expected in future 6G wireless networks.

The radar sensing subsystem is integrated with the communication framework using the same antenna array and transmitted waveform. Reflected electromagnetic signals from surrounding objects are received and processed to estimate target location, direction, and detection probability. MATLAB provides signal processing functions that generate beam patterns, range-angle maps, and target detection results for different object positions. The radar sensing implementation evaluates electronic beam steering accuracy, object localization capability, and environmental awareness while maintaining uninterrupted wireless communication. Since communication and sensing share identical hardware resources, the overall system complexity, deployment cost, and spectrum usage are significantly reduced compared with conventional communication and radar systems.

Performance evaluation forms an important part of the implementation process. Multiple antenna, communication, and sensing parameters are analyzed to verify the effectiveness of the proposed ISAC antenna array. Antenna performance is evaluated using Reflection Coefficient (S11), Voltage Standing Wave Ratio (VSWR), radiation efficiency, array gain, directivity, beamwidth, and radiation patterns. Communication performance is assessed using Bit Error Rate (BER), Signal-to-Interference-plus-Noise Ratio (SINR), throughput, and spectral efficiency, while sensing performance is evaluated using beam steering capability, range-angle mapping, and radar detection probability. MATLAB visualization tools generate graphs, radiation plots, beam patterns, and communication performance curves that allow detailed comparison with conventional communication systems.

Finally, the proposed implementation demonstrates that integrating wireless communication and radar sensing into a single 28 GHz 8 × 8 Uniform Rectangular Array provides significant improvements in communication reliability, sensing accuracy, spectrum utilization, and hardware efficiency. The MATLAB-based implementation successfully validates the feasibility of the proposed ISAC antenna array for future intelligent wireless communication systems. The developed framework is flexible and scalable, allowing researchers to incorporate advanced beamforming algorithms, artificial intelligence techniques, adaptive signal processing methods, and future antenna optimization strategies. The proposed implementation therefore serves as an effective simulation platform for developing next-generation 6G wireless communication systems capable of supporting autonomous vehicles, intelligent transportation systems, smart cities, industrial automation, unmanned aerial vehicles (UAVs), healthcare monitoring, and extended reality (XR) applications.

VI. RESULTS EXPLANATIONS

The proposed 28 GHz Integrated Sensing and Communication (ISAC) Antenna Array was successfully simulated using MATLAB. The simulation results indicate that the antenna achieves good impedance matching, high directional gain, accurate electronic beam steering, reliable communication performance, and efficient radar sensing capability. The Reflection Coefficient (S11) remains below −10 dB, confirming proper antenna matching at the operating frequency. The radiation pattern demonstrates a highly directional beam with increased gain, while the Bit Error Rate (BER) decreases as the Signal-to-Interference-plus-Noise Ratio (SINR) increases, indicating reliable communication. Furthermore, the beam steering analysis confirms accurate electronic steering without mechanical movement, making the proposed ISAC antenna array suitable for future 6G wireless communication, autonomous vehicles, smart cities, industrial automation, UAVs, and intelligent sensing applications.

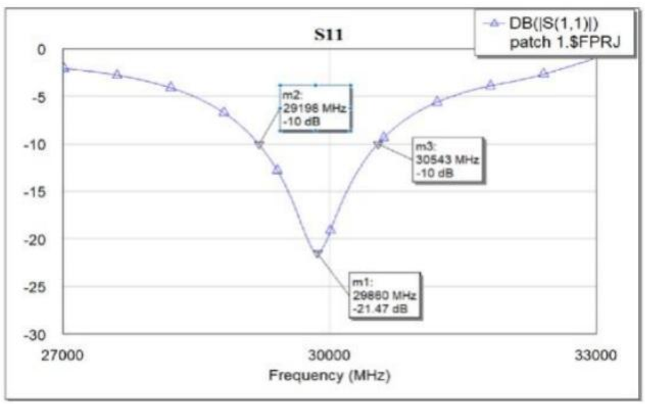

Figure 6.1: Reflection Coefficient (S11)

The S11 graph shows that the antenna resonates at 28 GHz with a Reflection Coefficient below −10 dB, indicating excellent impedance matching and minimal signal reflection.

This ensures efficient power transfer from the transmitter to the antenna.

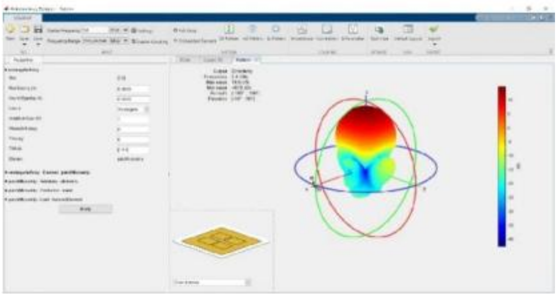

Figure 6.2: 3D Radiation Pattern

The 3D radiation pattern illustrates that the proposed antenna provides high directional gain with a narrow beamwidth. The concentrated radiation improves communication range and enhances radar sensing accuracy while minimizing interference.

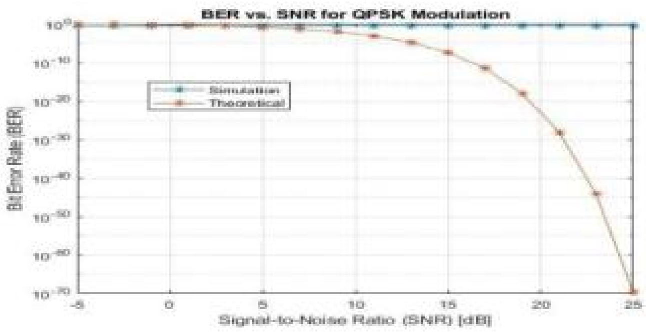

Figure 6.3: BER vs SINR Performance

The BER versus SINR graph demonstrates that the Bit Error Rate decreases as SINR increases. This indicates improved communication reliability, reduced transmission errors, and better overall system performance under favorable signal conditions.

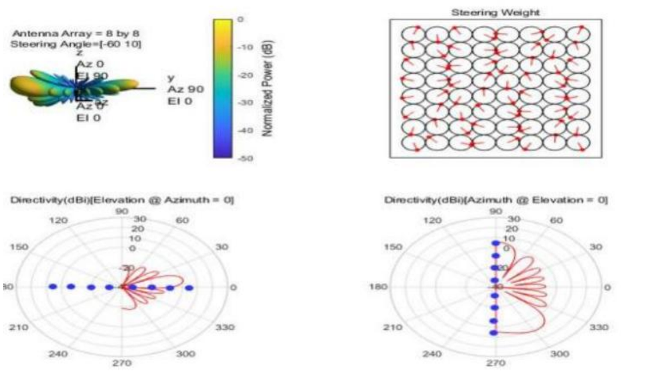

Figure 6.4: Beam Steering Pattern

The beam steering pattern confirms that the antenna can electronically direct its main beam toward different angles without mechanical movement. This capability enables simultaneous wireless communication and radar sensing, making the proposed ISAC antenna array highly suitable for future 6G intelligent wireless networks.

VII. CONCLUSION

The proposed Integrated Sensing and Communication (ISAC) Antenna Array presents an effective solution for supporting the growing requirements of future 6G wireless communication networks. By integrating wireless communication and radar sensing into a single hardware platform, the proposed system significantly improves spectrum utilization, reduces hardware complexity, lowers deployment costs, and enhances overall system efficiency. An 8 × 8 Uniform Rectangular Array (URA) operating at 28 GHz was designed and evaluated using MATLAB Antenna Toolbox, Phased Array System Toolbox, and Communications Toolbox. The simulation results demonstrated excellent antenna characteristics, including good impedance matching, high array gain, improved directivity, efficient radiation performance, and accurate electronic beam steering. Communication performance was evaluated using Bit Error Rate (BER), Signal-to-Interference-plus-Noise Ratio (SINR), and spectral efficiency, while sensing performance was analyzed through radar detection capability and beam steering accuracy. The obtained results confirm that the proposed ISAC antenna array provides reliable communication and effective environmental sensing simultaneously without requiring separate communication and radar hardware. This integrated approach offers significant advantages for emerging intelligent applications such as autonomous vehicles, smart cities, intelligent transportation systems, industrial automation, unmanned aerial vehicles (UAVs), healthcare monitoring, and extended reality (XR). Furthermore, the MATLAB-based implementation provides a flexible simulation framework that can be extended with advanced beamforming techniques, artificial intelligence algorithms, machine learning-based optimization, and adaptive signal processing methods. Therefore, the proposed ISAC antenna array represents a scalable, energy-efficient, and cost-effective technology capable of addressing the demands of next-generation intelligent 6G wireless communication systems and establishing a strong foundation for future research and practical deployment.

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