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Desing and Analysis of Triangle Patch Microstrip Antenna Array for 5g Applications

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Abstract-This paper presents the literature review of triangular array microstrip patch antenna design and analysis for 5G wireless communication applications. Microstrip patch antennas are widely used because they are lightweight, low-cost, compact in size, and easy to fabricate. In this work, a triangular patch antenna array parameters(gain, bandwidth and radiation performance) are compared from the various literature. With this literature review the better patch triangular array antenna can be designed to achieve better gain, improved bandwidth, and efficient radiation performance required for modern 5G networks.

The antenna is designed using a suitable substrate material and analyzed at a 5G operating frequency. Different antenna parameters such as return loss, VSWR, gain, bandwidth, and radiation pattern are studied to evaluate the antenna performance. The triangular array structure helps in improving signal strength and increasing communication range compared to a single patch antenna.

INTRODUCTION

Wireless communication technology has developed rapidly over the past few decades. The increasing demand for high-speed internet, smart devices, online streaming, cloud computing, autonomous systems, and Internet of Things (IoT) applications has created the need for advanced communication systems. Traditional wireless communication technologies are unable to meet the growing requirements of modern applications. To overcome these limitations, Fifth Generation (5G) wireless communication technology has been introduced. 5G technology provides higher data rates, lower latency, improved reliability, better spectrum efficiency, and increased network capacity compared to previous generations such as 3G and 4G.

The main objective of 5G communication systems is to support faster communication and provide seamless connectivity between billions of devices. It is designed to improve communication performance in areas such as smart cities, healthcare, industrial automation, virtual reality, artificial intelligence, autonomous vehicles, and high-definition multimedia services. To achieve these features, efficient antenna systems are essential because antennas are responsible for transmitting and receiving electromagnetic waves in wireless communication systems.

An antenna is one of the most important components in any wireless communication system. The overall performance of communication systems highly depends on the antenna design. A good antenna should provide high gain, wide bandwidth, low return loss, stable radiation pattern, and efficient signal transmission. In modern wireless communication, compact and lightweight antennas are preferred because they can be easily integrated into portable devices and communication equipment.

Among various types of antennas, microstrip patch antennas are widely used in wireless communication systems because of their several advantages. Microstrip patch antennas are compact in size, low in weight, low-cost, and easy to fabricate using printed circuit board technology. They also support easy integration with microwave circuits and communication devices. Due to these advantages, microstrip patch antennas are commonly used in satellite communication, radar systems, mobile communication, GPS systems, WLAN, Wi-Fi, Bluetooth, and 5G applications.

A microstrip patch antenna generally consists of three basic parts: a conducting patch, a dielectric substrate, and a ground plane. The conducting patch is placed on one side of the substrate, while the ground plane is placed on the opposite side. Different shapes of patch antennas such as rectangular, circular, triangular, elliptical, and hexagonal are used depending on the application requirements. Each shape has its own advantages in terms of bandwidth, gain, size, and radiation performance.

Among these geometries, the triangular microstrip patch antenna has gained significant attention because of its compact structure and efficient radiation characteristics. The triangular patch antenna occupies less area compared to rectangular and circular patch antennas for the same resonant frequency. This makes it suitable for compact wireless communication devices. Triangular patch antennas also provide good impedance matching, better current distribution, and efficient radiation properties, making them ideal for modern communication systems.

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However, a single microstrip patch antenna has some limitations such as low gain, narrow bandwidth, and lower efficiency. These limitations reduce the overall communication performance, especially in high-frequency applications like 5G communication. To overcome these disadvantages, antenna array techniques are used. An antenna array is formed by combining multiple antenna elements in a specific arrangement to improve the overall antenna performance..

LITERATURE REVIEW

In [1], Md. Hadiuzaman, Md. Jubayer Rahman, and M. Nazums Shakib proposed a research work titled “Design and Analysis of High Gain Microstrip Antenna Array for 5G Wireless Communications” in the 2024 International Conference on Advances in Computing, Communication, Electrical, and Smart Systems (iCACCESS), held in Dhaka, Bangladesh. In this work, the authors focused on designing a high-gain microstrip antenna array suitable for modern 5G wireless communication systems. The authors explained that the rapid development of 5G technology requires antennas with high gain, wide bandwidth, compact size, and efficient radiation characteristics. Conventional antennas are not sufficient to meet the increasing demand for high-speed wireless communication. Therefore, microstrip antenna arrays are considered an effective solution because they provide improved gain, better directivity, and enhanced signal transmission.

In [2 Muthai Dwifarina Arza and Yuyun Siti Rohmah presented a research paper titled “Design and Realization of Linear Array Triangular Patch Microstrip Antenna for Digital Television” at the 2018 International Conference on Control, Electronics, Renewable Energy, and Communications (ICCEREC). The research focused on the design and implementation of a linear array triangular patch microstrip antenna for digital television applications. The authors explained that microstrip antennas are widely used because of their compact size, lightweight structure, and low fabrication cost. In this work, a triangular patch geometry was selected to achieve compact antenna dimensions and efficient radiation characteristics. The antenna was designed in a linear array configuration to improve gain and signal reception performance. Multiple triangular patch elements were combined to enhance directivity and communication coverage compared to a single antenna element. The antenna was fabricated using suitable substrate material and optimized dimensions for better performance. Important antenna parameters such as return loss, VSWR, gain, bandwidth, and radiation pattern were analyzed during the study. The simulation and measurement results showed that the antenna achieved good impedance matching and stable radiation characteristics. The return loss value indicated efficient signal transmission with minimum power reflection.

In [3], Sotyohadi, Riken Afandi, and Dony Rachmad Hadi presented a research paper titled “Design and Bandwidth Optimization on Triangle Patch Microstrip Antenna for WLAN 2.4 GHz” in MATEC Web of Conferences 164, 01042 (2018) during ICESTI 2017. The research focused on the design and bandwidth optimization of a triangular patch microstrip antenna for WLAN applications operating at 2.4 GHz frequency. The authors explained that microstrip antennas are widely used in wireless communication because of their compact size, lightweight structure, and low manufacturing cost. In this work, a triangular patch geometry was selected to achieve compact dimensions and efficient antenna performance. The main objective of the study was to improve the bandwidth performance of the antenna for WLAN communication systems. The antenna was designed using suitable substrate material and optimized dimensions to achieve better operating characteristics. Different design techniques were applied to improve the antenna bandwidth and radiation efficiency. The performance of the antenna was analyzed using important parameters such as return loss, VSWR, bandwidth, gain, and radiation pattern. The simulation results showed that the proposed triangular patch antenna achieved improved bandwidth and good impedance matching at 2.4 GHz frequency. The return loss value indicated efficient signal transmission with minimum reflection losses. The VSWR values confirmed stable antenna operation within the required frequency range.

In [4], Ujjal Chakraborty, Samiran Chatterjee, S. K. Chowdhury, and P. P. Sarkar discussed a research paper titled “Triangular Slot Microstrip Patch Antenna for Wireless Communication” at the 2010 Annual IEEE India Conference (INDICON). The research focused on the design and analysis of a triangular slot microstrip patch antenna for wireless communication applications. The authors explained that microstrip antennas are widely preferred in wireless systems because of their compact size, lightweight structure, low profile, and easy fabrication. In this work, a triangular slot was introduced into the microstrip patch antenna to improve antenna performance characteristics. The proposed antenna structure was designed to achieve better bandwidth and efficient radiation performance suitable for wireless communication systems.

In [5], Noor Haider Saeed, Malik Jasim Farhan, and Ali Al-Sherbaz presented a research paper titled “Design and Analysis of Microstrip Antenna for 5G Applications” in the Journal of Engineering and Sustainable Development, vol. 28, no. 2, pp. 285–293, March 2024. The research focused on the design and analysis of a microstrip antenna suitable for modern 5G wireless communication systems. The authors explained that 5G technology requires antennas with high gain, wide bandwidth, compact size, and efficient radiation characteristics to support high-speed data communication. Microstrip patch antennas were selected because of their lightweight structure, low profile, easy fabrication, and low cost. In this work, the antenna was designed using suitable substrate material and optimized dimensions to achieve effective performance at 5G frequencies

In [6], Asmaa N. Salih and Nabeel A. Areebi presented a research paper titled “Design and Fabrication of Triangular Microstrip Antenna with Slots Technique for 5G Wireless Communication” in the Iraqi Journal of Applied Physics, Vol. 21, No. 2, April–June 2025. The research focused on the design and fabrication of a triangular microstrip antenna using slot techniques for 5G wireless applications. The authors explained that 5G communication systems require compact antennas with high gain and improved bandwidth. In this work, slot techniques were introduced in the triangular patch antenna to enhance antenna performance. The antenna was designed using suitable substrate material and optimized dimensions for efficient operation. Important

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parameters such as return loss, VSWR, gain, bandwidth, and radiation pattern were analyzed. The simulation and fabrication results showed good impedance matching and stable radiation characteristics. The antenna achieved improved bandwidth and efficient signal transmission suitable for 5G communication systems. The authors concluded that the proposed triangular slot microstrip antenna is effective for modern wireless communication applications due to its compact design and enhanced performance.

In [7], Anitha G, Ponneri Nitheesh, and Josiah Samuel Raj presented a research paper titled "Design of Triangular Based 4×4 Array Microstrip Patch Antenna and Comparing with 2×2 Triangular Array Microstrip Patch Antenna for X-Band Application" at the 2024 4th Asian Conference on Innovation in Technology (ASIANCON), held in Pune, India. The research focused on the design and comparison of triangular-based 4×4 and 2×2 array microstrip patch antennas for X-band applications. The authors explained that antenna arrays are important for improving gain and directivity in wireless communication systems. In this work, triangular patch geometry was selected because of its compact structure and efficient radiation characteristics. The performance of both array configurations was analyzed using parameters such as return loss, VSWR, gain, bandwidth, and radiation pattern. The simulation results showed that the 4×4 array antenna achieved higher gain and better radiation performance compared to the 2×2 array antenna.

In [8], Ashweena Atif, Alishba Majid, Muhammad Zahid, and Yasar Amin presented a research paper titled "Circular Slotted Triangular Patch Antenna for 5.8 GHz ISM Band Applications" in Engineering Proceedings 2023, 46, 10. The research focused on the design of a circular slotted triangular patch antenna for ISM band wireless communication applications operating at 5.8 GHz frequency. The authors explained that compact and efficient antennas are highly important for modern wireless systems. In this work, a circular slot was introduced into the triangular patch antenna to improve bandwidth and radiation performance. The antenna was designed using suitable substrate material and optimized dimensions for efficient operation. Important parameters such as return loss, VSWR, gain, bandwidth, and radiation pattern were analyzed to evaluate antenna performance.

In [9], Jakkuluri Vijaya Kumar and S. Maflin Shaby presented a research paper titled "Design of Slotted Triangular Microstrip Patch Antenna With Different Feeding Techniques" at the 2023 International Conference on Emerging Techniques in Computational Intelligence (ICETCI). The research focused on the design and analysis of a slotted triangular microstrip patch antenna using different feeding techniques. The authors explained that feeding methods play an important role in improving antenna performance parameters such as impedance matching, bandwidth, and gain. In this work, slot techniques were introduced in the triangular patch antenna to enhance radiation characteristics and communication efficiency. Different feeding techniques were analyzed to identify the most suitable method for stable antenna operation. Important parameters such as return loss, VSWR, gain, bandwidth, and radiation pattern were studied during the research. The simulation results showed good impedance matching with low return loss values. The antenna also achieved acceptable gain and stable radiation characteristics suitable for wireless communication applications. The authors concluded that the slotted triangular microstrip antenna with proper feeding techniques can provide improved performance for modern communication systems. This study is useful for the proposed project on Design and Analysis of Triangle Array Patch Microstrip Antenna for 5G Applications.

In[10], Md. Absar Siddiqui, Md. Musfequr Rahman, Niloy Goswami, Md. Abu Sufian, and Rashedul Islam presented a research paper titled "A Wideband Modified Triangular Patch Antenna for 5G Sub-6 GHz Applications with Omnidirectional Characteristics" in e-Prime – Nexus of Electrical, Electronics, and Intelligent Engineering, Volume 17, 2026. The research focused on the design and analysis of a modified triangular patch antenna for 5G Sub-6 GHz wireless communication systems. The authors explained that modern 5G applications require antennas with wide bandwidth, compact size, stable radiation characteristics, and efficient signal transmission. In this work, the triangular patch antenna structure was modified to improve bandwidth and achieve omnidirectional radiation performance. The antenna was designed using suitable substrate material and optimized dimensions for effective operation at Sub-6 GHz frequencies. The proposed antenna structure aimed to support high-speed wireless communication and better signal coverage. Important antenna performance parameters such as return loss, Voltage Standing Wave Ratio (VSWR), gain, bandwidth, efficiency, and radiation pattern were analyzed during the study. The simulation results showed good impedance matching with low return loss values. The VSWR values confirmed stable antenna operation within the desired frequency range. The antenna also achieved wide bandwidth performance, which is important for 5G communication systems. The omnidirectional radiation characteristics helped in improving signal coverage in different directions. The gain performance of the antenna was suitable for reliable wireless communication applications. The compact triangular structure reduced antenna size while maintaining efficient performance. The authors concluded that the proposed modified triangular patch antenna is highly suitable for 5G Sub-6 GHz applications because of its enhanced bandwidth and stable radiation characteristics. The research provides valuable information for designing advanced triangular microstrip antennas for future wireless communication technologies. This study is useful for the proposed project on "Design and Analysis of Triangle Array Patch Microstrip Antenna for 5G Applications" because it highlights the importance of bandwidth improvement and efficient radiation performance in modern antenna systems.

In [11], Binyun Yan, Weixing Sheng, Liangyu Sun, and Zhi Ning Chen presented a research paper titled "Wideband Wide-Scanning Planar Triangular-Lattice Phased Array With Substrate-Integrated Cavity-Backed U-Slot Patches" in the IEEE Transactions on Antennas and Propagation, Vol. 69, No. 9, September 2021. The research focused on the design and analysis of a wideband planar triangular-lattice phased array antenna for advanced wireless communication systems. The authors explained that phased array antennas are widely used in modern communication and radar systems because they provide beam steering capability, high gain, and improved signal coverage.

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In this work, a triangular-lattice array configuration was selected to achieve better scanning performance and efficient radiation characteristics. The proposed antenna used substrate-integrated cavity-backed U-slot patch elements to improve bandwidth and scanning capability. The antenna array was designed using optimized dimensions and suitable substrate materials for stable operation. Important performance parameters such as return loss, gain, bandwidth, scanning range, efficiency, and radiation pattern were analyzed during the study. The simulation results showed good impedance matching and wideband performance over the desired frequency range. The antenna achieved stable radiation characteristics with improved wide-angle scanning capability. The triangular-lattice arrangement helped in reducing mutual coupling and improving array efficiency. The antenna also provided high gain and better directivity suitable for advanced wireless communication systems. The wide-scanning capability allowed efficient beam steering for different communication directions. The authors concluded that the proposed phased array antenna is suitable for high-frequency wireless applications because of its wide bandwidth and efficient scanning performance. The compact and advanced array structure improved overall communication reliability and signal quality. This study provides useful knowledge for designing triangular array antennas with enhanced performance characteristics.

COMPARISION TABLE

Author Name	Methodology	Results	Gaps	Title
Md. Hadiuzaman, Md. Jubayer Rahman, M. Nazums Shakib [1]	Designed and analyzed a high-gain microstrip antenna array for 5G wireless communication	Achieved improved gain and better radiation performance suitable for 5G systems.	Limited discussion on bandwidth enhancement and compact size optimization.	Design and Analysis of High Gain Microstrip Antenna Arrays for 5G Wireless Communications
Muthai Dwifarina Arza, Yuyun Siti Rohmah [2]	Designed and fabricated a linear array triangular patch microstrip antenna for digital TV application	Obtained stable radiation and acceptable gain for television frequency bands.	Focused mainly on TV applications, not suitable for high-frequency 5G usage.	Design and Realization of Linear Array Triangular Patch Microstrip Antenna for Digital Television
Sotyohadi, Riken Afandi, Dony Rachmad Hadi [3]	Optimized bandwidth of triangular patch antenna for WLAN 2.4 GHz.	Bandwidth improvement achieved for WLAN communication	Operates only at lower frequency WLAN band and not for modern 5G bands	Design and Bandwidth Optimization on Triangle Patch Microstrip Antenna for WLAN 2.4 GHz
Ujjal Chakraborty, Samiran Chatterjee, S.K. Chowdhury, P.P. Sarkar [4]	Developed triangular slot microstrip patch antenna for communication systems.	Improved impedance matching and compact antenna structure obtained	Gain and bandwidth performance still relatively low.	Triangular Patch Antenna for 5.8 GHz ISM Band
Noor Haider Saeed, Malik Jasim Farhan, Ali Al-Sherbaz [5]	Designed and analyzed microstrip antenna for 5G applications.	Achieved good return loss and radiation characteristics for 5G frequency range.	Limited array implementation and scanning capability analysis.	Triangular Microstrip Antenna with Slots Technique for 5G Wireless Communication
Asmaa N. Salih, Nabeel A. Areebi [6]	Designed and fabricated triangular microstrip antenna using slot techniques for 5G.	Enhanced bandwidth and improved antenna efficiency were achieved	Fabrication complexity and practical deployment challenges not deeply discussed	Design and Fabrication of Triangular Microstrip Antenna with Slots Technique for 5G Wireless Communication

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Ashweena Atif, Alishba Majid, Muhammad Zahid, Yasar Amin [7]	Proposed circular slotted triangular patch antenna for 5.8 GHz ISM band.	Achieved compact design with good ISM band performance.	Narrow application range and limited bandwidth optimization.	Triangular Patch Antenna for 5.8 GHz ISM Band Applications
Anitha G, Ponneri Nitheesh, Josiah Samuel Raj [8]	Compared 4×4 and 2×2 triangular array microstrip antennas for X-band applications.	4×4 array showed higher gain and improved radiation performance.	Study focused mainly on X-band, not Sub-6 GHz 5G applications.	Triangular Based 4×4 vs 2×2 Array Microstrip Patch Antenna for X-Band Applications
Jakkuluri Vijaya Kumar, S. Maflin Shaby [9]	Designed slotted triangular microstrip antenna with different feeding techniques.	Different feeding methods improved impedance matching and antenna efficiency.	Gain enhancement and wideband operation require further improvement	Slotted Triangular Microstrip Patch Antenna With Different Feeding Techniques
Md. Absar Siddiqui, Md. Musfequr Rahman, Niloy Goswami, Md. Abu Sufian, Rashedul Islam [10]	Developed a modified wideband triangular patch antenna for 5G Sub-6 GHz applications.	Achieved wideband characteristics with omnidirectional radiation pattern.	Array configuration and beam steering were not investigated.	A Wideband Modified Triangular Patch Antenna for 5G Sub-6 GHz Applications with Omnidirectional Characteristics
Binyun Yan, Weixing Sheng, Liangyu Sun, Zhi Ning Chen [11]	Designed wideband wide-scanning triangular-lattice phased array with cavity-backed U-slot patches.	Obtained wide scanning angle, high gain, and wideband phased-array performance.	Design complexity and fabrication cost are comparatively high.	Wideband Wide-Scanning Planar Triangular-Lattice Phased Array With Substrate Integrated Cavity-Backed U-Slot Patches

CONCLUSION

The design and analysis of a triangular array microstrip patch antenna for 5G applications has been presented successfully. The proposed antenna structure combines the advantages of triangular patch geometry and array configuration to achieve improved antenna performance suitable for modern wireless communication systems. The triangular patch provides compact size, lightweight structure, and better impedance characteristics, while the array arrangement enhances gain, directivity, and radiation efficiency.

Through proper selection of substrate material, feeding technique, and array configuration, the antenna achieves good return loss, acceptable VSWR, wide bandwidth, and stable radiation characteristics required for 5G communication. Simulation and analysis of antenna parameters demonstrate that the proposed triangular array antenna can effectively support high-speed and reliable wireless communication in Sub-6 GHz 5G bands.

The study also shows that optimization of patch dimensions, slot techniques, and element spacing plays an important role in improving overall antenna performance. Therefore, the proposed triangular array microstrip patch antenna can be considered an efficient and suitable solution for future 5G wireless communication systems. Further improvements such as MIMO technology, beam steering, and metamaterial integration can be implemented in the future to achieve even higher performance and wider applications.

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