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2X2 MICROSTRIP PATCH ARRAY BEAM STEERING ANTENNA WITH PIN DIODES

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Abstract— **This paper introduces a novel design of a 2x2 microstrip patch array beam steering antenna integrated with pin diodes. The antenna system enables dynamic control over the beam direction, allowing for efficient wireless communication in various applications. By incorporating pin diodes, the electrical length of the patch elements can be modified, resulting in beam steering capabilities. The antenna operates in the 1.8 – 3 GHz band frequency range, utilizing cost-effective FR4 substrate material. Simulation and experimental evaluations demonstrate the antenna's performance, including return loss, radiation pattern, and beam steering range. This research contributes to the advancement of beam steering antenna technology, providing a practical and affordable solution for enhancing wireless communication systems.**

Keywords— **beam steering antenna, pin diodes, wireless communication**

I. INTRODUCTION

In recent years, wireless communication systems have witnessed remarkable advancements driven by the ever-growing demand for faster and more efficient data transmission. One critical aspect of these systems is the ability to steer the antenna beam dynamically, enabling enhanced coverage, improved signal quality, and increased capacity. In this context, the design and development of beam steering antennas have become a subject of extensive research and innovation.

This research paper presents a novel design of a 2x2 microstrip patch array beam steering antenna integrated with pin diodes, aimed at providing a practical and cost-effective solution for efficient wireless communication in various applications. By incorporating pin diodes within the antenna structure, the electrical length of the patch elements can be adjusted, thereby enabling beam steering capabilities.

The proposed antenna operates within the 1.8 – 3 GHz frequency range, making it suitable for a wide range of wireless communication systems like wireless networks. Moreover, the antenna design utilizes a cost-effective FR4 substrate material, ensuring affordability without compromising performance.

To evaluate the performance of the designed antenna, comprehensive simulations and experimental measurements were conducted on Advanced Design System. Key parameters such as return loss, radiation pattern, and beam steering range were analyzed to assess the antenna's effectiveness in practical scenarios. The results obtained from these evaluations provide valuable insights into the antenna's performance and its potential for enhancing wireless communication systems.

The rest of the paper is organized as follows. Proposed designs are presented in Section II. Experimental results are presented in section III. Concluding remarks are given in section IV.

II. PROPOSED DESIGN

A. Single Microstrip Patch Design

The patch dimensions directly influence the resonant frequency and impedance matching of the microstrip antenna. In this case, the patch has a length of 31.25 mm and a width of 2.957 mm. These dimensions are chosen based on the desired operating frequency and other design considerations. The inset feed technique involves placing the feedline on the substrate, which is typically located at a distance from the radiating patch. The location and dimensions of the feedline are critical in achieving optimal performance.

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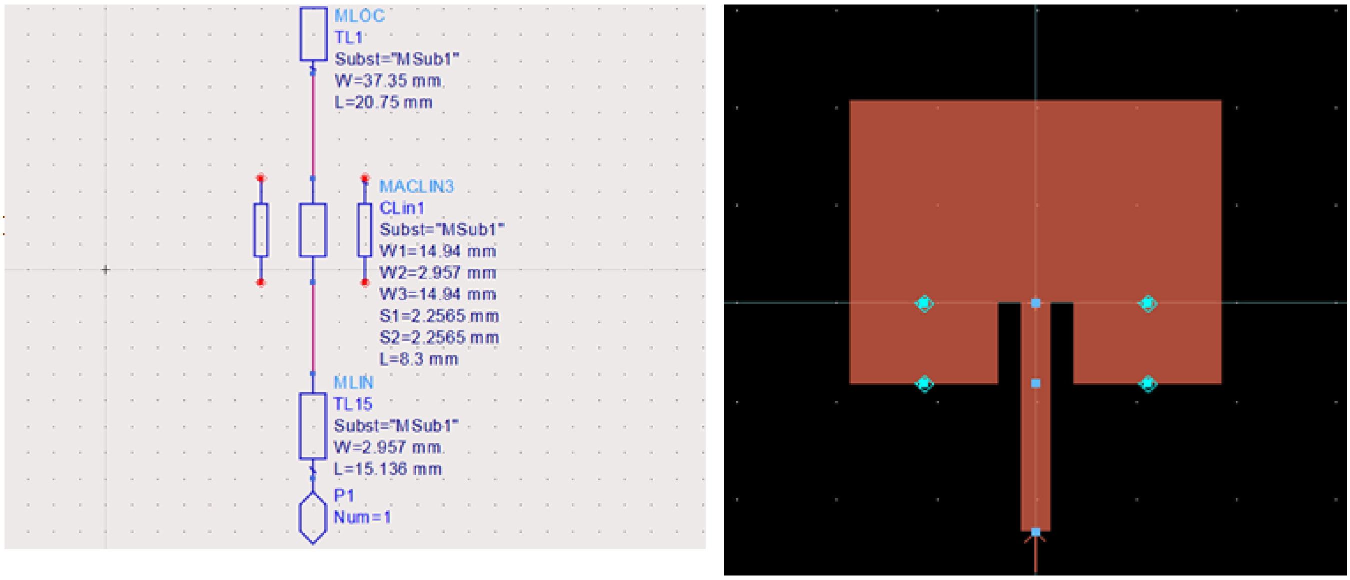

Fig. 1. ADS Layout for Single Patch

B. **Design of Phase Shifters**

To incorporate a phase shifter line within the patch to achieve a 45-degree phase shift for example, a specific design approach is necessary. The phase shifter line designed with dimensions of 15.625 mm to obtain a phase shift of 45 degrees.

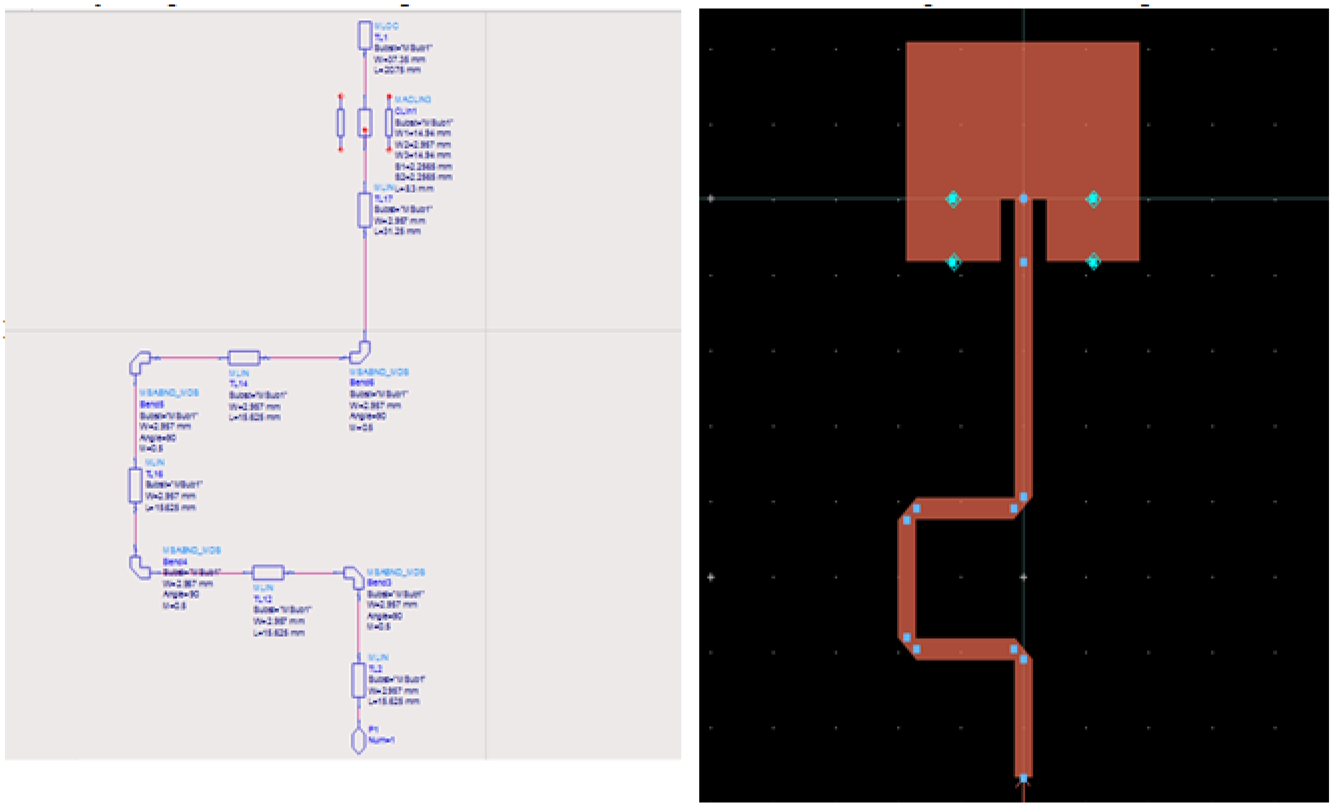

Fig. 2. 45 deg phase shifter 31.25 mm away from patch

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For this purpose the following formula is used- Length in mm = 3(θ * λ (in mm) / 360)   (1)

In similar fashion, we can design patches with phase shifters for 22.5, 45 and 180 degrees.

C. **Design of 2x2 Array with Phase Shifted Patches:**
Designing a 2x2 array with four patches, each shifted at a specific angle and utilizing a corporate feed network, offers enhanced radiation characteristics and beamforming capabilities.
The corporate feed network is employed to efficiently distribute power to the individual patches in the array. It comprises a network of transmission lines, phase shifters, and power dividers that ensure proper phasing and amplitude distribution among the patches.

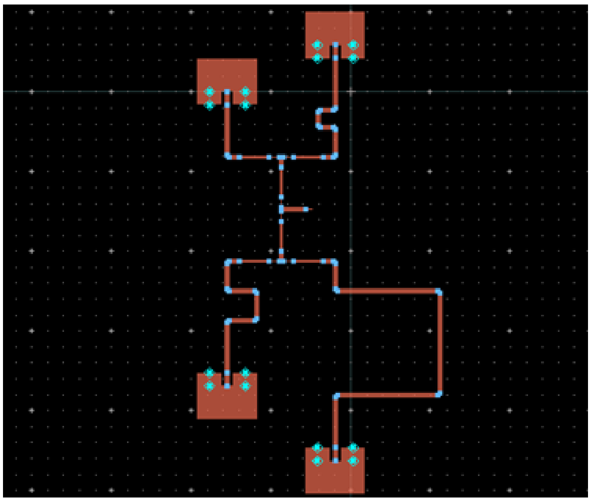

Fig. 3. 2x2 Array Antenna Design

D. **Using TFRs as Equivalent for Pin Diodes**
In ADS, we can simulate varactor diodes with a biasing network to enable and disable any patch we want on the go. This requires support for ADS Co-Simulation. Another simplified approach would be to use thin film resistors, that are supported by EM Simulation.
When studied, the RLC equivalent of varactor diode shows its heavy reliance on its resistive component when it comes to blocking a signal or letting it propagate through the feed line. For our simulation's sake, we used 1 ohm resistance to simulate forward biasing condition and 30k ohms for reverse biasing condition.
The patch we want to radiate is set to forward bias while the rest are reverse biased.

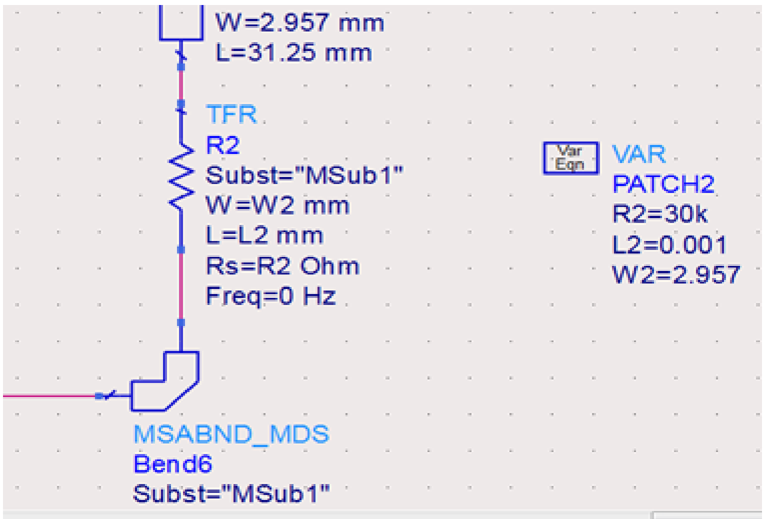

Fig. 4. Reverse Biasing Condition Simulated for a Line

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In practical application, a biasing network for diodes can be designed.

III. EXPERIMENT AND RESULT

The proposed designs were tested for solution frequency of 2.4 GHz through EM Simulator in ADS.

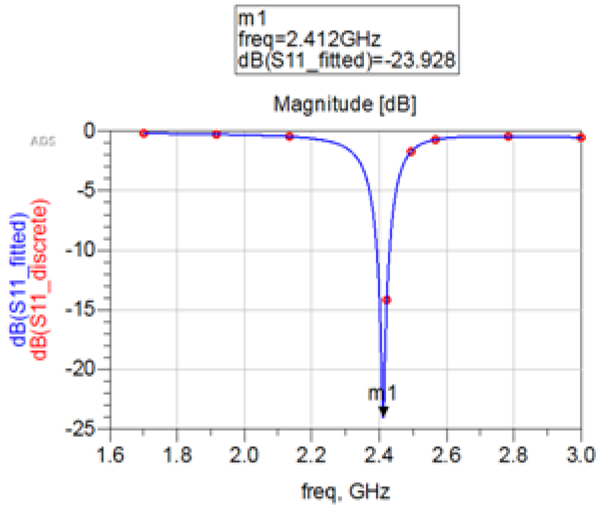

Fig. 5. Single Patch Return Loss

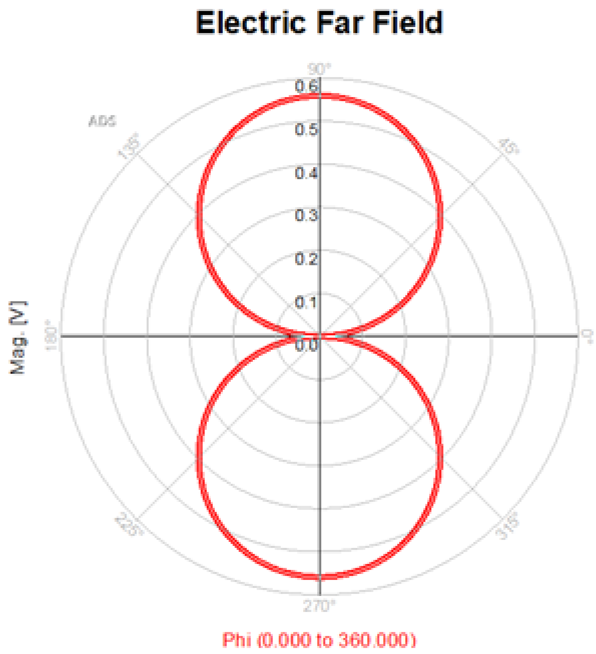

Fig. 6. Single Patch Beam (Broadsides)

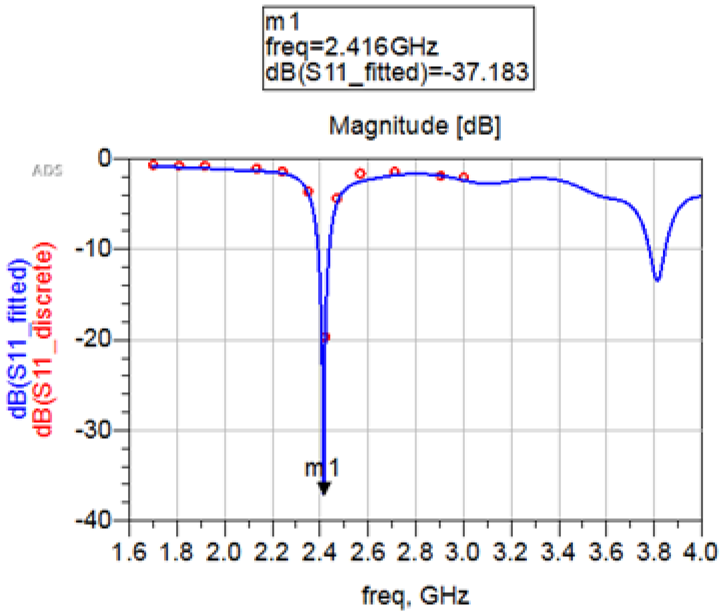

Fig. 7. 45 degrees phase shifter return loss

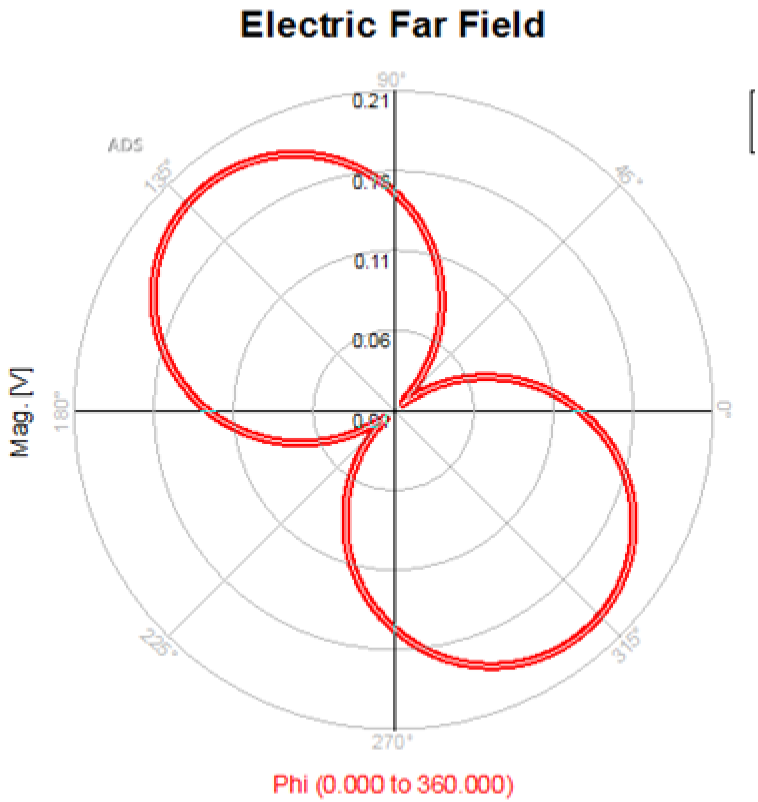

Fig. 8. 45 degrees phase shifter beam

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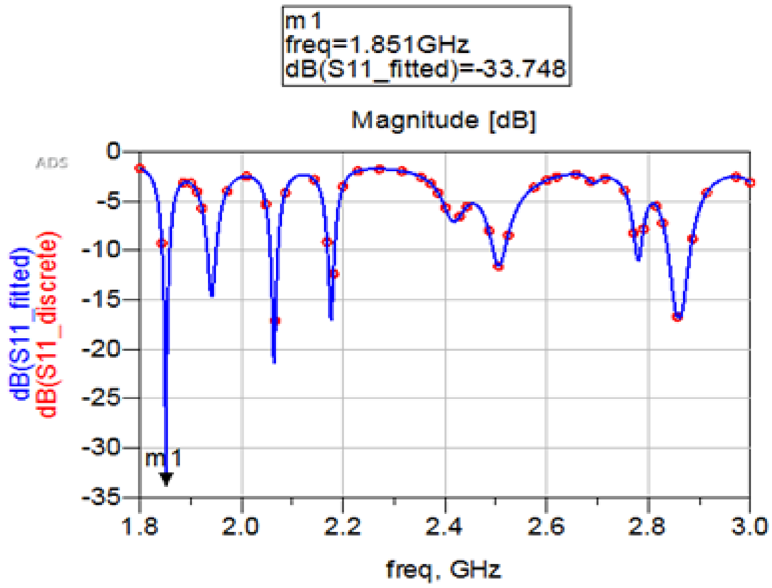

Fig. 9. 22.5 deg phase shifter enabled in 2x2 array – rest disabled

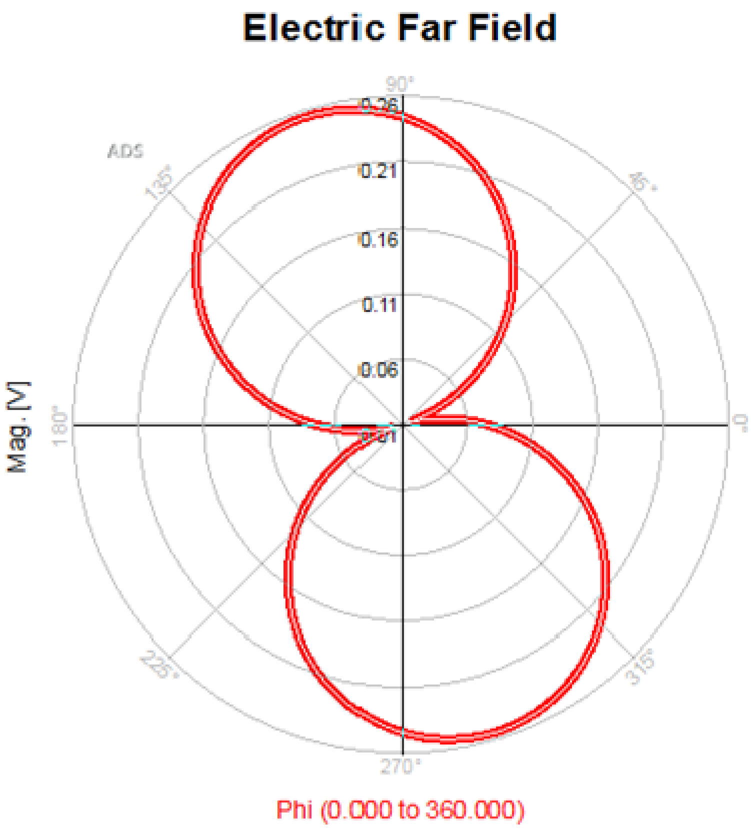

Fig. 10. 22.5 deg phase shifter patch beam

Table -1 Experiment Result

Patches	Expected Beam Angle	Actual Beam Angle
Single Patch	**90**	**90**
45 Phase Shifter Patch	**45**	**44**
2x2 Array with 22.5 deg phase patch enabled	**22.5**	**23**

IV.CONCLUSION

In conclusion, this research has successfully introduced and demonstrated the design of a 2x2 microstrip patch array antenna with beam steering capabilities. By incorporating a corporate feed network and shifting the patches at specific angles, the antenna enables dynamic control over the beam direction, enhancing wireless communication efficiency in various applications.

The research focused on designing the microstrip patch array for operation in 1.8 to 3 GHz band with focus on WLAN frequency, utilizing cost-effective FR4 substrate material with a thickness of 1.6 mm. Extensive simulations and experimental evaluations were conducted to assess the antenna's performance, including return loss, radiation pattern, and beam steering range.

The results of the research highlight the practicality and affordability of the designed antenna system. The beam steering capabilities provided by the integrated pin diodes allow for efficient adaptation to different communication scenarios, enabling enhanced signal reception and transmission. The antenna design demonstrates good impedance matching, radiation pattern control, and beam steering range, indicating its effectiveness in real-world applications.

V. REFERENCES

[1] H. Kaschel and C. Ahumada, 2018, "Design of Rectangular Microstrip Patch Antenna for 2.4 GHz applied a WBAN," 2018 IEEE International Conference on Automation/XXIII Congress of the Chilean Association of Automatic Control (ICA-ACCA), Concepcion, Chile, pp. 1-6, doi: 10.1109/ICA-ACCA.2018.8609703.

[2] M. S. Rana and M. M. Rahman, 2022, "Study of Microstrip Patch Antenna for Wireless Communication System," 2022 International Conference for Advancement in Technology (ICONAT), Goa, India, pp. 1-4, doi: 10.1109/ICONAT53423.2022.9726110.

[3] G. Casu, C. Moraru and A. Kovacs, 2014, "Design and implementation of microstrip patch antenna array," 2014 10th International Conference on Communications (COMM), Bucharest, Romania, pp. 1-4, doi: 10.1109/ICComm.2014.6866738.

[4] N. Ab Wahab, Z. Bin Maslan, W. N. W. Muhamad and N. Hamzah, 2010, "Microstrip Rectangular 4x1 Patch Array Antenna at 2.5GHz for WiMax Application," 2010 2nd International Conference on Computational Intelligence, Communication Systems and Networks, Liverpool, UK, pp. 164-168, doi: 10.1109/CICSyN.2010.73.

[5] Z. Muludi and B. Aswoyo, 2017, "Truncated microstrip square patch array antenna 2 × 2 elements with circular polarization for S-band microwave frequency," 2017 International Electronics Symposium on Engineering Technology and Applications (IES-ETA), Surabaya, Indonesia, pp. 87-92, doi: 10.1109/ELECSYM.2017.8240384.

[6] N. A. Wahab, S. A. Nordin, W. N. W. Muhamad and S. S. Sarnin, 2020, "Microstrip Rectangular Inset-Fed Patch Array Antenna for WiMax Application," 2020 IEEE International RF and Microwave Conference (RFM), Kuala Lumpur, Malaysia, pp. 1-4, doi: 10.1109/RFM50841.2020.9344799.

[7] J. Park, S. Kong, S. Jang, H. D. Lee, K. -S. Kim and K. C. Lee, 2018, "Design of 6-Bit 28GHz Phase Shifter in 65NM CMOS," 2018 Asia-Pacific Microwave Conference (APMC), Kyoto, Japan, pp. 1513-1515, doi: 10.23919/APMC.2018.8617563.

[8] S. Voisin, V. Knopik and E. Kerhervé, 2022, "A 25-50 GHz Digitally Controlled Phase-Shifter," 2021 16th European Microwave Integrated Circuits Conference (EuMIC), London, United Kingdom, pp. 305-308, doi: 10.23919/EuMIC50153.2022.9783836.

[9] K. Watanabe, M. Arima and T. Yamamoto, 1981, "Graph Design of P-I-N Diode Phase Shifters(Short Paper)," in IEEE Transactions on Microwave Theory and Techniques, vol. 29, no. 8, pp. 829-831, doi: 10.1109/TMTT.1981.1130455.

[10] K. M. Tran, H. V. N. Anh, N. D. Van Le, T. M. Nguyen, L. H. Trinh and F. Ferrero, 2021, "Design of Varactor-Loaded Transmission-Line Phase Shifter with Integrated Single-Stage LNA in 0.18 um RF CMOS Technology," 2021 International Conference on Advanced Technologies for Communications (ATC),

Ho Chi Minh City, Vietnam, pp. 244-248, doi: 10.1109/ATC52653.2021.9598246.

[11] L. Bos, 1994, "Performance of thin-film chip resistors," IEEE Transactions on Components, Packaging, and Manufacturing Technology: Part A, vol. 17, no. 3, pp. 359-365, doi: 10.1109/95.311744.

[12] D. Lamey, Lei Zhang, H. Rueda, H. Kabir, R. Sweeney and K. Kim, 2017, "Device physics and EM simulation based modeling methodology for LDMOS RF power transistors," 2017 IEEE MTT-S International Conference on Numerical Electromagnetic and Multiphysics Modeling and Optimization for RF, Microwave, and Terahertz Applications (NEMO), Seville , pp. 79-81, doi: 10.1109/NEMO.2017.7964193.