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Design and Simulation of 1x4 Patch Array for Enhanced Gain

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Abstract: *In contemporary wireless communication systems, antenna design plays a crucial role in achieving better performance metrics like gain, directivity, radiation efficiency, and appropriate impedance matching. In this work, a 1x4 array antenna operating at 2.4 GHz is designed and simulated. With an emphasis on single patch antennas and linear arrays with 1x2 and 1x4 components, beam steering in antenna array investigates the design, simulation, and analysis of antenna arrays at 2.4 GHz using CST Microwave Studio. In order to maximize performance, the project starts with the design of a single patch antenna. Important factors such as substrate material, patch dimensions, and feed mechanisms are examined. To improve gain, directivity, and bandwidth, 1x2 and 1x4 linear arrays are designed as an extension of the single patch design. The antennas are simulated using CST Microwave Studio, which offers comprehensive insights into their radiation patterns, impedance matching, and overall performance. Based on the simulations, it can be observed that a 1x4 array has substantially better gain and directivity when compared to a single patch. As a result, these arrays are more appropriate for applications that need more concentrated beams and greater coverage. Performance comparisons between the single patch, 1x2, and 1x4 arrays are included in the project's thorough study, along with a discussion of the trade-offs between design complexity, physical size, and performance advantages. The findings demonstrate the advantages of antenna arrays in improving 2.4 GHz wireless communication systems and provide insightful guidance for the creation of effective and high-performing antennas in this frequency range. The suggested antenna array exhibits encouraging performance in terms of parameters like gain, directivity, and efficiency, which qualifies it for use in particular applications including Internet of Things (IoT), wireless communication systems, and radar systems.*

Keywords: Patch Antenna, CST, gain, directivity, return loss

I. INTRODUCTION

In order to improve output transmission, an antenna is a specialized device that can emit certain energy in a specific direction. Antenna arrays are created by adding a few additional antenna elements to an existing antenna for more efficient output. An array of antennas is utilized because a single antenna has strong directivity but struggles to transmit signals to the receiver due to losses. We require antennas with exceptionally high directional properties for a wide range of applications, and these characteristics can be further improved by enlarging the antenna's electrical dimension. The requirements of contemporary wireless communication systems, such as 5G and the soon-to-be 6G networks, are driving current advancements in antenna array technology.Antennas are essential for efficient transmission and reception of signals in the field of current wireless communication and sensor technologies. The capacity of array antennas to improve performance measures including gain, directivity, and efficiency has drawn a lot of interest among different antenna configurations. In particular, the 1x4 patch array antenna is an adaptable design with uses in a variety of industries where directional and high-performance antennas are critical. Array antennas are known for their ability to synthesize a desired radiation pattern by combining signals from multiple elements, thereby offering improved signal reception, transmission range, and interference rejection capabilities.

The 1x4 configuration, consisting of four patch elements arranged in a specific pattern, further enhances these capabilities while maintaining a compact form factor and cost-effectiveness. The 1x4 patch array antenna consists of four patch elements arranged in a specific geometric configuration, each element contributing to the overall antenna's radiation pattern and gain. Designing such an antenna involves careful selection of patch dimensions, substrate material properties, feeding techniques, and element spacing. These design parameters are critical in achieving optimal performance in terms of radiation efficiency, directivity, and impedance matching across the desired operating frequency range.An antenna array is a collection of antennas configured to create the same radiation patterns as a single antenna but without the radiation patterns produced by individual antennas. Consequently, radio signals can be sent or received using a group of antennas working together. In this study, the substrate material is FR4, with a dielectric constant of ε = 3.6, and the resonant frequency is set at 2.4 GHz. The MSA employs the Microstrip 50 ũ feedline feeding method.

II. LITERATURE SURVEY

Antenna Array Design System for Directional Networking,[1], G.C. Huang Developed a novel LSA antenna with a simplified feeding structure, operating effectively over a 4-6 GHz bandwidth with a beamwidth smaller than 12 degrees.The antenna achieved a return loss of less than -7 dB and an average gain of 16 dBi, indicating good impedance matching and high gain. The study focused on fixed beam patterns and did not extensively cover dynamic beam steering, necessitating future work on advanced algorithms and hardware.

Metasurface-Enabled Cavity Antenna: Beam Steering With Dramatically Reduced Fed Elements,[2],Kayode Adedotun Oyesina This paper introduce a new type of antenna that use a metasurface. A specially designed surface with tiny structures that can control electromagnetic wave in many ways. Bandwidth Limitations Complexity in Design and Fabrication

Design And Simulation Of Edge Fed Microstrip Patch Antenna Array,[3],K. Mydhili, P. Parvathi and K. Prasanthi The microstrip patch antenna has three layers Top layerradiating patch, Middle layer-substrate (FR4),Bottom layer ground plane. In single antenna element directivity is less as the array elements increases directivity increases.In edge fed array antenna, quarter wave transformer is used for impedance matching. The 1x4,2x2,4x4 antenna is designed and compared based on various parameters such as return loss, gain etc

High-Gain Compact Circularly Polarized X-Band Superstrate Antenna for CubeSat Applications,[4],Leszkowska, L. This paper entails a critical assessment and summary of the previous studies and advancements in the field of circularly polarized antennas, with a focus on those created for CubeSat applications. It might entail talking about various antenna designs, their advantages and disadvantages, and their performance metrics. Determines what needs to be improved upon or where there are gaps in the current body of study. The review frequently identifies particular difficulties or restrictions in the current designs and makes recommendations for possible areas of innovation or additional research.

Towards a full design of a super-wide band slotted antenna array using graphene material for future 6G applications,[5],O. E. Hassani and A. Saadi This research involves designing various configurations of slotted antenna arrays and evaluating their performance in terms of key metrics such as return loss, Voltage Standing Wave Ratio (VSWR), gain, and directivity.

Bandwidth and Gain Enhancement of Rectangular Microstrip Patch Antenna (RMPA) Using Slotted Array Technique,[6],Srivastava, H., Singh, A., Rajeev, A In this paper both the bandwidth and the gain of the antenna is improved by introducing rectangular slots in the patch.This method is known as slotted array technique.The gain has been improved by 12.96 dB by using this technique.

Low RCS Automotive Radar Antenna with Beam Steering Capability,[7], Avinash Singh The paper presents an effective design for a low RCS automotive radar antenna with passive beam steering capabilities.Passive beam steering is achieved by introducing delay lines into the antenna array structure, allowing the beam to steer at specific angles. Passive beam steering, achieved through delay lines, allows for discrete beam scanning at specific angles but lacks the flexibility and precision of active beam steering systems.

Combined Single-Layer K-Band Transmitarray and Beamforming S-Band Antenna Array for Satcom,[8],Serup, D.E., Pedersen, G.F. and Zhang, S. A shared-surface dual-band antenna for 5G applications, demonstrating significant gains in efficiency and performance. However, scaling these designs to handle larger frequency ratios remains a challenge.A dual-polarized high-gain antenna designed for synthetic aperture radars. This design emphasized low-cost and high-efficiency but did not fully address the dualband operation with high frequency ratios.

Direction of arrival estimation for BLE: Antenna array design and evaluation,[9],A. Simončič, T. Javornik, A. Sešek, and A. Hrovat The study presents the design and evaluation of a uniform circular antenna array equipped with 12 monopole antennas. This array is used in conjunction with RF switches to select the active antenna for DoA estimation, leveraging the BLE Angle of Arrival feature.

Beam steering in antenna,[10],A. Singh, A. Kumar, A. Ranjan, A. Kumar and A. Kumar In this paper the beam steering is done by changing the direction of the radiation pattern of the antenna. The main reason behind changing the direction of the radiation pattern is to get the antenna output in the desired direction. In this paper they have performed the above said beam steering technique by using the MATLAB 2014 Ra version. The main purpose of performing beam steering in antenna is to increase the output gain of the antenna. In this paper it is observed that the gain of the antenna before was 1.25 but this gain increased up to 1.76 after beam steering was performed. It is also observed that, the return loss of the micro strip antenna which was -42 earlier has reduced to -53 once we performed beam steering in the antenna.

III. EXISTING SYSTEM

The articles describe antenna arrays for a range of uses, including beam steering, directional networking, communication for CubeSats, and upcoming 6G technologies. A number of approaches are investigated, including slotted antenna arrays, superstrate designs, microstrip patch arrays, and beam control methods. One of the limitations is that it can be difficult to build and simulate complicated antenna arrays, especially for wideband applications. Compact designs are necessary for applications like CubeSats, where size limits play a critical role. Optimizing for aspects like gain, bandwidth, and compactness is still important. To make sure the suggested designs fulfill the required specifications, the approaches primarily rely on theoretical analysis, simulation, and experimental validation. HFSS and MATLAB are the programs used.

IV. RESEARCH METHODOLOGY

Determining the needs, such as the operational frequency range, bandwidth, gain, radiation pattern, polarization, and physical limits, is the first step in the antenna design process. After that, a preliminary design is made using mathematical formulas and theoretical models, including those for dipoles, monopoles, and patch antennas. By examining its performance, simulation tools such as HFSS, CST, or FEKO are then used to improve the design. A single microstrip patch antenna array is suggested in this paper.

The suggested antenna features a low-profile structure with measurements of 83.64 mm × 202 mm × 1.6 mm and is intended to resonate at 2.4 GHz. The process flow chart is provided below.

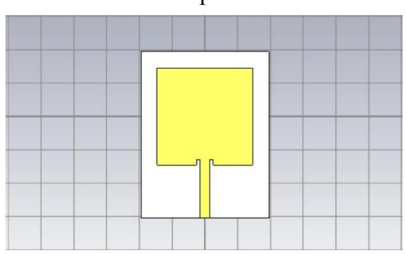

Figure 1:Structure of single patch antenna

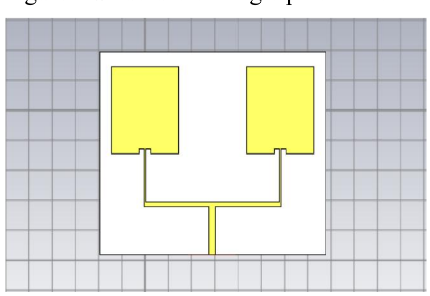

Figure 2:Structure of 1x2 patch antenna

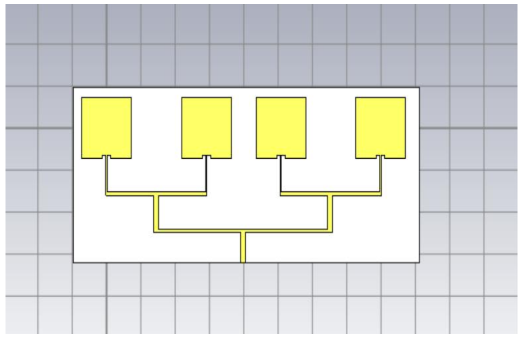

Figure 3:Structure of 1x4 patch antenna

After choosing the microstrip patch, antenna was designed using the approximation equation rating frequency (2.4 GHz) and dielectric constant of the substrate (FR4), the main parameters are the Length L, the width W, and the thickness h, of the substrate. The dimensions of the microstrip patch antenna were designed using the approximation equation. Where e is velocity of electromagnetic wave in free space, fo is operating frequency, εr is dielectric constant of the substrate, h is thickness of the substrate in mm, w is width of the patch in mm.

V. RESULTS AND DISCUSSION

A single patch was designed first as shown in fig 1. Fig 4shows the S11 of single patch antenna. Value of S11 at 2.4GHz is -9dB. Fig 5 shows the obtained radiation pattern with again of2.014dBianddirectivityof5.755dBi.

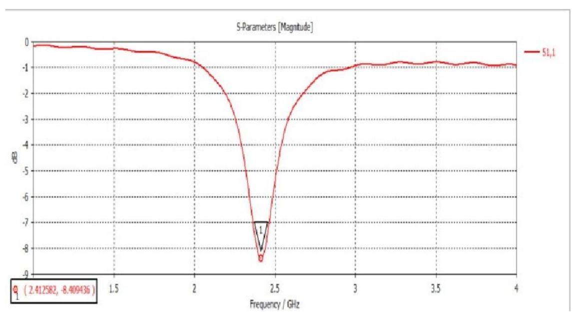

Fig 4: S parameter of Single Patch antenna

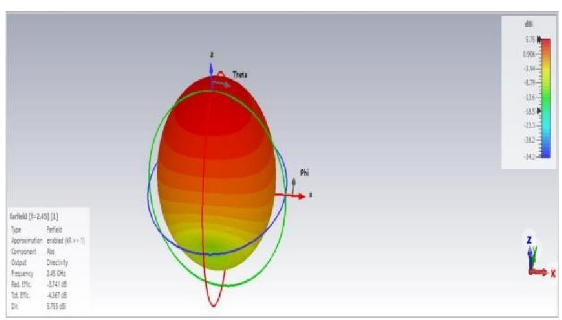

Fig 5: 3D Farfield radiation pattern of Single Patch antenna

Then we designed a 1x2 array antenna as shown in fig.2. Fig 6 shows the S11 of 1x2 patch antenna. Value of S11 at 2.4GHz is-25dB. Fig 7 shows radiation pattern with increased gain and directivity to 3.762 dBi and 8.263 dBi respectively.

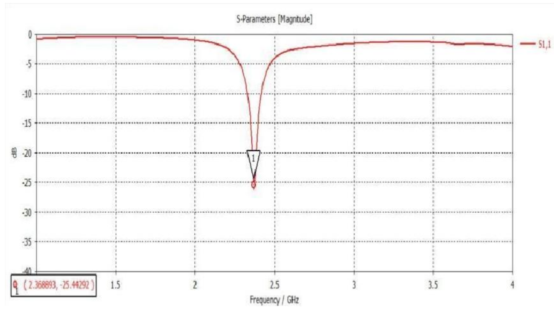

Fig 6: S parameter of 1x2 Patch antenna

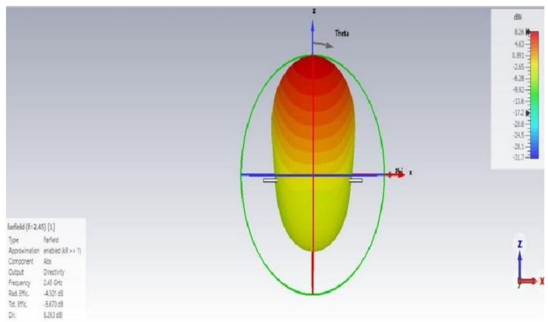

Fig 7: 3D Farfield radiation pattern of 1x2 Patch antenna

Finally designed 1x4 array antenna as shown in fig 3. Fig 8 shows the S11 of 1x4 patch antenna. Value of S11 at 2.4GHz is-17dB. Fig 9 shows the radiation pattern with increased gain and directivity further to 5.752 dBi and 11.09 dBi respectively.

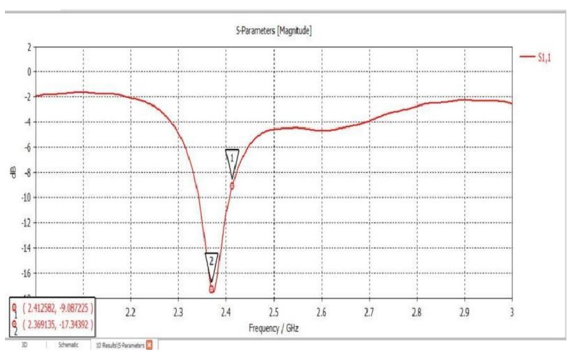

Fig 8: S parameter of 1x4 Patch antenna

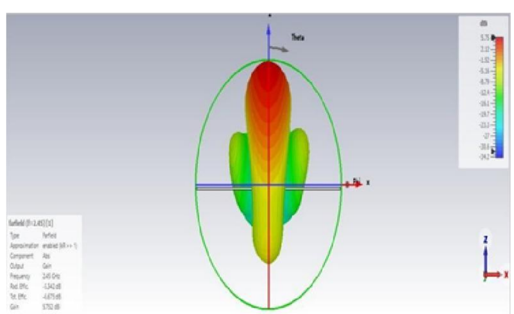

Fig 9: 3D Farfield radiation pattern of 1x4 Patch antenna

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VI. CONCLUSION

A 1x4 patch antenna array is designed which operates at afrequencyof2.4GHz.Thisconfigurationoutperformsasingle-patchantennaintermsoftotalperformance.Theantenna'sDirectivityof11.09dBishowshowwellitconcentratesradiationinacertaindirection.Increaseddirectivity translates into more concentrated energy, which is advantageous for focused communication. The antenna's gain of 5.752 dBi indicates its capacity to transform input power into radio waves directed in a particular direction. It showshoweffectivetheantennaisatemittingorreceivingenergybytaking into consideration both the directivity and efficiency of the antenna. This array configuration improves the signal strength and coverage area, making it suitable for applications requiring reliable and efficient wireless communication, such as Wi-Fi and other 2.4GHz wireless systems.

REFERENCES

[1]. Huang, G.C. et al. (2015a) 'Antenna Array Design andsystem for Directional Networking', IEEE Antennas andWirelessPropagationLetters,14,pp.1141–1144.doi:10.1109/lawp.2015.2391199.

[2]. Oyesina,K.A.and Wong, A.M.(2020)'Metasurface-enabled cavity antenna: Beam steering with dramaticallyreducedfedelements',IEEEAntennasandWirelessPropagationLetters,19(4),pp.616–620.doi:10.1109/lawp.2020.2973507.

[3]. K. Mydhili, P. Parvathi and K. Prasanthi, "DESIGN ANDSIMULATION OF EDGE FED MICROSTRIP PATCHANTENNA ARRAY," 2018 2nd International Conferenceon ISMAC (IoT in Social, Mobile, Analytics and Cloud)(I-SMAC)I-SMAC (IoT in Social, Mobile, Analytics andCloud)(I-SMAC),20182ndInternational Conferenceon,Palladam,India,2018,pp.356-360,doi:10.1109/I-SMAC.2018.8653698.

[4]. Leszkowska,L.etal.(2021)'High-gaincompactcircularlypolarizedX-bandsuperstrateantennaforCubeSatApplications',IEEEAntennasandWirelessPropagationLetters,20(11),pp.2090–2094.doi:10.1109/lawp.2021.3076673.

[5]. O. E. Hassani and A. Saadi, "Towards a full design of asuper-wide bandslottedantennaarrayusinggraphenematerial for future 6G applications," Results in Optics,vol.11,p.100427,May2023,doi:10.1016/j.rio.2023.100427.

[6]. Srivastava, H., Singh, A., Rajeev, A. et al. Bandwidth and Gain Enhancement of Rectangular Microstrip Patch Antenna (RMPA) Using Slotted Array Technique. Wireless Pers Commun 114, 699–709 (2020). https://doi.org/10.1007/s11277-020-07388-x

[7]. Singh, A. et al. (2020) 'Low RCS automotive radar antenna with Beam Steering Capability', 2020 IEEE International Conference on Electronics, Computing and Communication Technologies (CONECCT),doi:10.1109/conecct50063.2020.9198572.

[8]. Serup, D., Pedersen, G. and Zhang, S. (2022) 'Combined single-layer K-Band Transmitarray and beamforming S- band Antenna Array for Satcom', *IEEE Open Journal of Antennas and Propagation*, 3, pp. 1134–1140. doi:10.1109/ojap.2022.3203253.

[9]. Simončič, T. Javornik, A. Sešek, and A. Hrovat, "Direction of arrival estimation for BLE: Antenna array design and evaluation," AEÜ. International Journal of Electronics and Communications, vol. 168, p. 154722, Aug. 2023, doi: 10.1016/j.aeue.2023.154722

[10]. A. Singh, A. Kumar, A. Ranjan, A. Kumar and A. Kumar, "Beam steering in antenna," 2017 International Conference on Innovations in Information, Embedded and Communication Systems (ICIIECS), Coimbatore, India, 2017, pp. 1-4, doi: 10.1109/ICIIECS.2017.8275895