Design of higher gain linearly polarized 2×2 microstrip patch array antenna for wireless communication

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ABSTRACT

The fifth-generation technology is popular and best as far as data rates are concerned for wireless applications. To meet the increased demand of the modern world for faithful communication, this research work is carried out. In this approach, a single patch, 1×2 array, and 2×2 array are designed using a low-cost FR4 dielectric substrate (ϵr=4.4) covering the 3.3–3.8 GHz frequency band. Due to the lack of gain from arrays in the present research, an attempt is made to achieve excellent gain from arrays with a minimum number of patches. First, the gain of a single inset-fed antenna is compared with another normal single patch of the same thickness but with an additional air dielectric medium. Next, the second single patch is extended to obtain a rectangular 1×2 array and a 2×2 array antenna. A second single patch measuring 50×32.5×0.8 mm is designed assuming an infinite ground plane. It has 3 mm air gap between the patch strip and the ground. Air acts as a second dielectric layer that reduces power loss. This allows a maximum gain of 15.2 dB with a return loss of -22 dB. Also, antenna efficiency and bandwidth are 91% and 267.69 MHz, respectively.

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1. INTRODUCTION

Microstrip array antenna is flexible in terms of radiation direction, enhanced multipath propagation, and weather penetration. hence, it is often used in radar and geostationary satellite orbits (GSO) satellite applications. A specific form of an antenna made up of several microstrip patch coils stacked in an array pattern is known as a microstrip patch array antenna. A power line that powers the entire array is connected to the patch. Compared to other antenna designs, rectangular microstrip patch arrays have a number of benefits, making it a preferred option for communication systems. A low profile, low cost, high gain, directionality, and frequency agility are some of the benefits. The antenna is designed using suitable appropriate equations [1]. A complete analysis of a 2×2 micro-strip patch array is undertaken, the results shows a return loss -23.27 dB and bandwidth (BW) of 150 MHz with gain 7.3 dB [2]. The designed antenna has a frequency range that ranges from 3.8–4.4 GHz and the gain of 12.1 dB at 4.148 GHz [3]. With gain of 3.83 and 0.576 dB, antenna described in [4] has a broader BW of 160 MHz at 3.45 GHz and 220 MHz at 5.9 GHz. A sixteen element Ku/Ka-band multi-polarized antenna patch is built, and experimental results shows that impedance bandwidth of 19.4% (14.4–17.5 GHz) for dual linearly polarized (LP) and 7.4%

(32.5–35 GHz) for dual circularly polarized (CP) may be achieved. Peak gain for the dual LP are 18.4 and 18 dB, respectively. While, those for the dual CP are 23.4 and 22.9 dB [5]. A wideband array with an FSS reflector achieved BW of 2.3 GHz with a fractional bandwidth of 51.12% over an operational frequency range 3.5–5.8 GHz. An ideal gain of 12.4 dB was measured at 4.1 GHz, representing a 4.4 dB improvement over the antenna alone [6]. An antenna prototype with a 2×4 radiation array and a simulated bandwidth of 23% is being built for testing at 20 GHz. The prototype is assembled from various PCB boards; the measured antenna gain is 12.7–13.5 dB. The proposed design provides a low-loss, wideband solution for future higher-frequency mm-wave antennas [7]. The antenna is made from a FR4 substrate with a relative permittivity of 4.7, a loss of tangent 0.0197, and a thickness of 0.5 mm. Based on simulation results, new proposed array achieves appropriate impedance matching at the desired frequency with a voltage standing wave ratio of < 2. Furthermore, given a high bandwidth of f=2.8 GHz, the resulting gain and directivity are significant [8]. The proposed hexagonal patch antenna targets long-distance point-to-point connectivity. At 3.5 GHz, antenna resulted in a higher gain of 6.938 dB and return loss of -10 dB [9]. A wideband high-gain circularly polarized microstrip antenna (CP MSA) array is constructed at 3.5 and 5.8 GHz, and it has a peak gain of 17.77 dBic and a 3-dB gain bandwidth of 53.9% [10]. For extensive wireless communication applications, a Rectangular-shaped RT Duroid 5880 substrate microstrip antenna capable of resonating at 3.30 GHz is built to have a gain of 7.59 dB [11]. A high-band 4×4 array designed for 3.4 and 3.8 GHz, and a low-band (LB) antenna that operates between 0.69 and 0.96 GHz [12]. Beyond this, a low-cost trapezoidal patch antenna array on FR4 substrate for low frequency medical application is developed, with this 2×2 array yielding BW enhancement 80 MHz and gain 4.48 dBi [13]. Many lightweight, cost-effective antenna designs with diverse frequency ranges have been presented, although there are still significant backlogs.

A rectangular microstrip patch with a gain value of roughly 7.7 dB is intended for 2.45 and 5.2 GHz [14]. A unique microstrip patch antenna for both C and X-band is proposed, which employs an annealed copper patch placed over a lossy Rogers RT5880 dielectric. This antenna has rectangular patch size of 22.94×16.84 mm^2. At 5.564 GHz, it has a return loss of -21 dB, a gain of 5.09 dB, a Voltage standing wave ratio (VSWR) of 1.19, and a directivity of 5.39 dB [15]. A broadband series-fed CP microstrip antenna array is envisaged. The series-fed array is composed of four consecutively rotating circular microstrip antennas with an impedance bandwidth of 3.77–6.30 GHz (50.2%) of $|S_{11}|$–10 dB. The antenna has a bandwidth of 3.77–5.85 GHz (43.2%) and an axial ratio of 3 dB. The highest gain of the series-fed CP antenna array is 12.1 dB [16]. The 1×2 antenna array achieved gains 6.06 and 7.56 dB at 2.4 and 5.2 GHz, respectively, on the other hand 2×2 array achieved gain of 9.25 and 8.66 dB at 2.4 and 5.2 GHz, respectively [17]. A 4-element circularly polarized dual-frequency reconfigurable microstrip patch antenna array with dual-frequency reconfigurability at 27 and 35 GHz is suggested for mm-wave usage. In terms of their reconfigurable behavior with related return loss, radiation pattern features, and 3 dB axial ratio polarization bandwidth, patch antenna arrays behave better than individual elements [18]. Antennas for X-band frequency applications are developed, with rectangular and E-shaped patch arrays constructed from 2×2 mm^2 Roger RT5880 sheet with a thin coating of copper applied over it, and the feed line is implemented using microstrip lines [19]. With a center frequency of 5.8 GHz and 22 patches measuring 14.38×18.42 mm each, a low-cost C-band microstrip array with a substantial gain attained a return loss -32.02 dB, a voltage standing wave ratio of 0.4 dB, and a maximum gain of 13.34 dB [20]. A Ka-band inset-fed microstrip patches linear antenna array for 5G applications in various nations is proposed. The array in study [21] has sixteen elements in a new H-plane configuration. With an in-line amplitude distribution, a maximum broadside gain of 19.88 dB obtained.

A microstrip antenna array with 2×4 ultra-wide patch elements has been devised to improve antenna gain by up to 20 dB for a point-to-point wireless local area network (WLAN) and wireless personal area network (WPAN) application, operating at 60 GHz [22]. For use in airborne synthetic aperture radars (AIR-SARs) with center frequencies of 9.3 and 13.265 GHz, respectively, and achieving maximum gain values of 12.8 dBi for the X-band and 12 dBi for the Ku-band, a new dual-band single-polarized (DBSP) high-gain shared aperture antenna (SAA) with enhanced separation is proposed [23]. A microstrip patch antenna array with 8×2 components that is compact, high-gain, and efficient has been implemented and tested. The proposed array structure, designed to operate at 60 GHz, has exceptional gains (16.8 dB), directivity (17.9 dB), and radiation efficiency (77.43%) [24], [25] focuses on optimizing patch size for Wi-MAX systems with a resonant frequency of 3.55 GHz. This method yields a good impedance bandwidth of 3.94%, gain 7.49 dB, reflection coefficient -47.23 dB, and SWR of 1. A 3.3 GHz WiMAX microstrip antenna array is made up of 16 rectangular patches in 4×4 and microstrip-line feeding network built with quarter-wavelength transformer impedance matching technology. Patches have a total gain of 16.02 dB and return loss of 29.85 dB, resulting in SWR of 1.07 at 3.35 GHz [26]. Using the IE3D simulator, array of (4×2) rectangular microstrip antennas (RMSA) is developed and compared with a single patch RMSA, and augmented for noticing an improvement in directivity as well as reaching predicted radiating features such as $|S_{11}|$ of -10 dB and side lobe level (SLL) of -20 dB. The highest directivity of 13.058 dBi is attained by implementing (4×2) array of 8-patches, in contrast to 6.74 dBi for a single patch for WLAN at 2.4 GHz center frequency [27]. Multiple microstrip array antennas, such as 1×1, 1×2, and 2×2, are developed, simulated, studied, and compared in terms of antenna performance. The simulation was carried out using the HFSS simulator. An established antennas have a frequency range of 5.3143 to 5.6291 GHz and are made of a FR4 substrate platform with a permittivity (ϵ_r= 4.4) and height of 1.588 mm. This type antennas can be used in Wi-Fi applications [28]. Using both-sided microwave integrated circuit (MIC) technology, a circularly polarized microstrip patch array antenna with a triple feed network has been developed. At the working frequency, $|S_{11}|< -35$ dB, 12 dBi gain with omniscient pattern, and the axial ratio is 0.7 dB, Antenna's BW is 430 MHz [29]. For 3.5 GHz wireless communication application, concurrent use of geometric alteration on patch components and electromagnetic band gap (EBG) structures (hybrid method) has been proposed to minimize mutual coupling between radiating elements [30]. Thus, in almost all of the references achievement of improvement in gain is either by going to higher frequency or by using higher dielectric, or by increasing the number of patches. But in this proposed methodology, the basic single patch, 1×2, and 2×2 microstrip antenna (MSA) designs are made for the band range 3.3–3.8 GHz, which is also one of the 5G band in wireless communication. In the notion of dual dielectric, an additional layer of air is added beneath FR4 to act as a dielectric. 15.2 dB is the maximum gain that was attained.

To accommodate the tremendous data rates of the current world, high gain array antennas are developed on an endless ground plane. First, single patch antenna is developed with 3mm gap between the antenna patch and ground plane. The suitable SMA connectors are used to feed the patch through the transformer, which has a dimension of 15.5×7.5 mm. In order to create a 2×2 array antenna, 1×2 is doubled and all are feeded with a common corporate feeding. The development of high gain antenna is done on infinite ground plane to meet requirements of a data rate in the modern world. In this design, the focus is mainly on the improvement of the gain which is enhanced to 15.2 dB. Antenna is simulated in IE3D which is famous for its simplicity. The single patch resonates between 3.3–3.8 GHz with RL -30 dB, and a gain of 9.55 dB. Also, the bandwidth obtained is 15%. The impedance is matched appropriately to lower the power loss due to impedance mismatch; this can be seen in the figure of smith chart given in below section. The standing wave ratio must be less than 2 for a better impedance matching which is 1.1 in our case. Next, the single patch is extended to double to achieve further improvement of gain of the double patch array. Using the corporate feeding this antenna resonates at 3.55 GHz, with $|S_{11}|\leq$ -32 dB and achieving the gain enhancement up to 12.5 dB, VSWR is 1.1, and impedance matching of approximately 50 Ω. Compared with gain of single patch, in the double patch exact 3 dB increment of gain is achieved. Also, the bandwidth achievement is doubled to 34%. The double patch array is then expanded to a 2×2-array antenna, which has a matching impedance of 51 Ω, a return loss -26 dB, gain of 14.557 dB, an SWR of 1.1, and a bandwidth of 26%. Only the gain increase of the arrays is the focus of this concept. In wireless applications like radar, GSO satellites, and data transmission, a higher gain can extend the reach or coverage area of an antenna. The prototypes of the designed simulated array antennas are made, and the outcomes of these tests are analyzed.

2. THE PROPOSED METHOD OF ANTENNA DESIGN

In the first trial of the design, a single microstrip patch antenna is designed with an inset feeding for the band of 3.3–3.8 GHz using FR4 as a substrate. The inset feeding patch is resonated at 3.55 GHz with a return loss of -26 dB and gain of approximately 6 dB. But this much of gain is not appreciable for the single patch. This design patch, return loss and its gain are as shown in Figures 1 to 3. Thus, knowing that the gain is very less for this single inset patch shown in Figure 1, in order to obtain a higher gain another patch with same specifications for the same band is designed after a thought process.

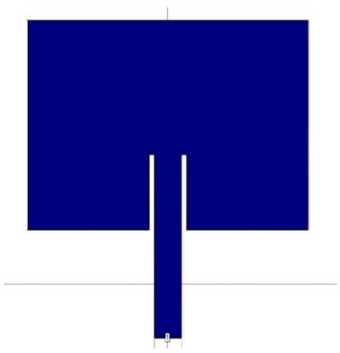

Figure 1. Simulation structure of inset feed single patch

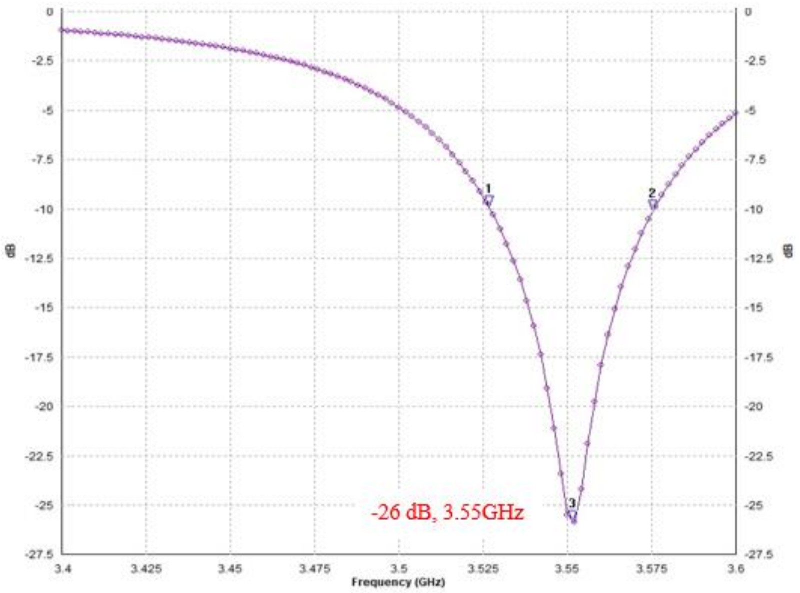

Figure 2. |S11| Return loss of inset feed single patch

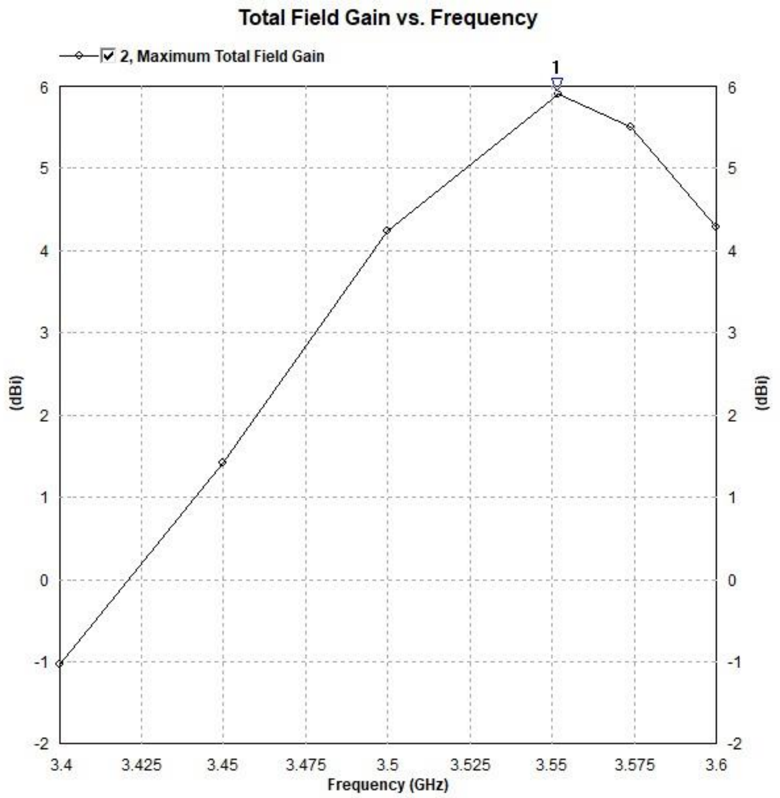

Figure 3. Frequency vs gain curve of inset feed single patch

Now, in the first iteration of the new design introduced, it is a straight forward single rectangular microstrip antenna with a patch dimension of 50×32.5×0.8 mm. A microstrip transformer with dimensions of 15.5×7.5 mm is used to provide feeding. Air gap of 3 mm is introduced between the patch and the ground layer, then the top layer and the ground layer are connected together by tiny nut-bolts as shown in Figure 4. The single patch, 1×2-pattern, and 2×2-pattern design simulations are depicted in Figures 4 to 6.

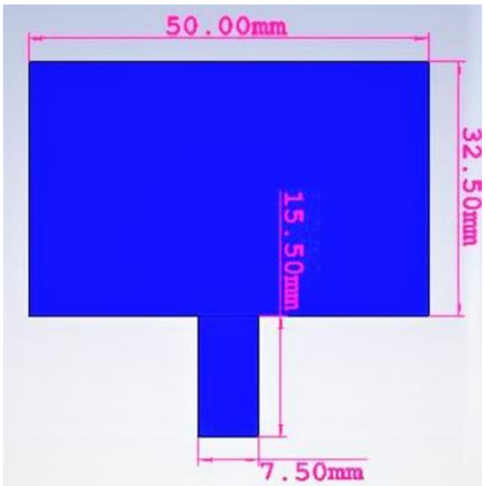

Figure 4. Simulation structure of basic single patch

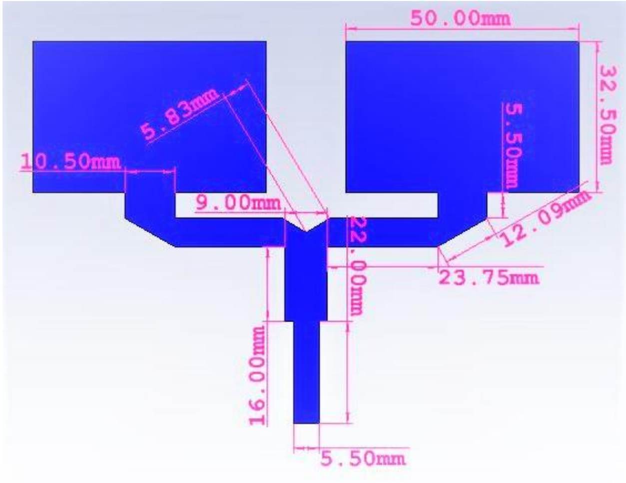

Figure 5. Simulation layout of 1×2 array antenna

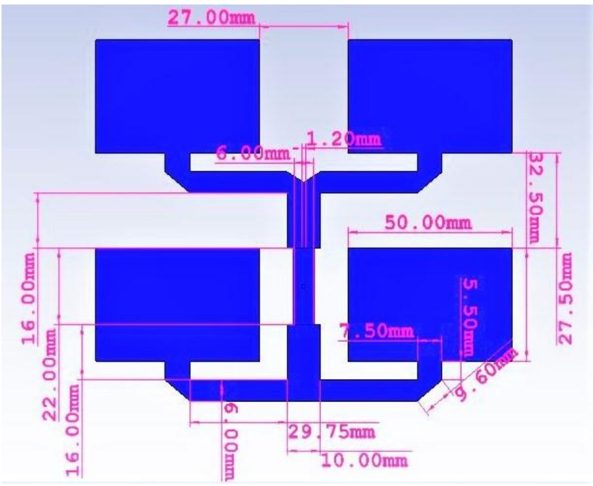

Figure 6. Simulation layout of 2×2 Array antenna

The layout of a simple single patch is depicted in Figure 4. The patch is designed for infinite ground plane, resonates at frequency 3.55 GHz. The thin microstrip patch is made up of copper, and its typical thickness is 5 microns. The thickness of the dielectric is 0.8 mm, an additional layer of air dielectric is introduced to achieve the gain enhancement for this antenna. The design equations used to find patch length and width calculation are as follows [1],

$$\text{Width of an element } W = \frac{C}{2fr}\left[\frac{\epsilon r+1}{2}\right]^{1/2}$$

$$\text{Length of an element } L = \frac{C}{2fr\sqrt{\epsilon r}} - 2\Delta L$$

where $\Delta L = \frac{h}{\sqrt{\epsilon e}}$, '$h$' is the thickness of patch, ϵ_e is effective dielectric value defined by,

$$\epsilon\, e = \frac{\epsilon r+1}{2} + \frac{\epsilon r-1}{2}\left(\left(1+\frac{12h}{W}\right)^{-\frac{1}{2}}\right)$$

Second, a single patch is extended to create 1×2 array that is excited with a common or corporate feed. The corporate feeding is one of the simple methods of feeding and exciting the antenna. Third, 1×2 array is again extended to obtain 2×2 Array antenna. The $|S_{11}|$ reflection coefficient, is the metric most often stated in relation to antennas represents power reflected from antenna. The fabricated models are as shown in Figure 7. In this study, the radiation pattern is also discussed, a directional radiation pattern is a characteristic of microstrip antennas which enables the array to focus the power in a particular direction. The size, shape, and thickness of the radiating patch, the substrate's height and thickness, the feed position, and the type of feed all these plays a very important role in antenna's directivity. Increasing the radiating patch size, reducing the substrate thickness, and using high dielectric material with high permittivity are all the ways to improve the direction of propagation for microstrip element. Directivity of the patch element is directly proportional to gain which is also enhanced by using extra components like reflectors, directors, or parasitic elements. In this instance, the single patch's directivity is 9.57, and the highest antenna efficiency was attained at 98.6%. An antenna's capacity to efficiently transform the electricity it receives into a radiation is referred to as its efficiency. Thus, a number of variables, including an antenna's design, operating frequency, material used in construction, and surroundings, may have an impact on how effective an antenna is. At the resonant frequency, the impedance is matched to 51 Ω, indicating that the antenna can radiate more broadly with less power loss. The process of altering an antenna's electrical impedance to match the transmission link and the system connected is known as impedance matching. The reason why this so essential is, if the antenna impedance and transmission line impedance are out of phase, some of the energy transmitted to the antenna may be reflected back to the source, resulting in signal loss, poor efficiency, and possibly even damage to the transmitter or antenna. It is the basic requirement for any array to have directional feature.

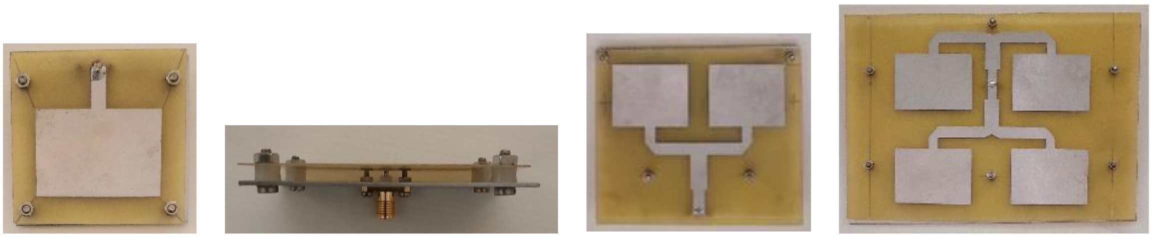

Figure 7. Fabricated antennas of basic patch, side view of basic patch, 1×2 array, 2×2 array

3. RESULTS AND DISCUSSION

In this section, results of various configurations are explained. Figure 8, illustrates return losses of single patch for both simulation and practical cases. The simple single patch yields return loss of -30 dB. Further, it can be seen that the reflection losses are equal in both cases. The gain of basic patch is as shown in Figure 9, it is observed that, simulated gain (9.5 dB) and practical gain (11.7 dB) readings are almost matching. It is quite difficult to make antenna to work for the 5G band 3.3 to 3.8 GHz as it is the lower frequency range. Normally, to achieve higher gain, either the number of patches must be increased or higher frequency band is chosen. But in this research, higher gain of 11.7 dB is made possible with just a single patch for the same 5G band. This is possible mainly because of an introduction of free-space gap of 3 mm in the middle of the patch plate and ground plane. Next, the same extended for 1×2 array and 2×2 array. Doubling the number of patches in antenna can have more benefits including better signal-to-noise ratio, more directivity, improved gain, and increased capacity. Overall, increasing an array antenna's patch count by two will result in noticeable performance and functional improvements, making it a desirable alternative for wireless communications.

Next, Figure 10, shows the S_{11} parameter of 1×2 MSA Array in case of both simulation and practical, -32 and -29.7 dB respectively. Even though there are slight variations in the resonance frequencies of this array, it is having an incredible return loss for the resonating frequency. The simulation and practical gain of 1×2 array antenna is as shown in Figure 11, it depicts that the gain is 12.5 dB for simulation and 13.57 dB for practical at the resonant frequency 3.55 GHz. In general, the gain increases by 3 dB when patches are doubled in array. Compared to the gain of single patch, gain in this dual patch array is approximately increased by 3 dB. Furthermore, in the third iteration patches are doubled, to get 2×2 patch array structure. The graphs of simulation and practical return losses are displayed in Figure 12. Even in 2×2 microstrip array antenna configuration, the resonating frequency is within the range 3.3-3.8 GHz. From Figure 12, reflection losses are -26 and -22 dB in simulation and practical correspondingly. Practical and simulation gain curves are shown in Figure 13. The practical gain obtained for this array combination is 15.2 dB, which far greater for such a simple array 2×2, which is developed using FR4 dielectric that too for lower frequency range. Thus, three antennas, a Basic patch, 1×2 MSA array, and 2×2 MSA array, are built and results are measured. The air medium plays a critical role in boosting antenna's effective gain. In this paper, it was focused on improvement of S_{11} parameter and gain of 2×2 microstrip array antenna. This work is resulted in more advanced and improved results than obtained in recent papers with same configuration and operating band of frequencies.

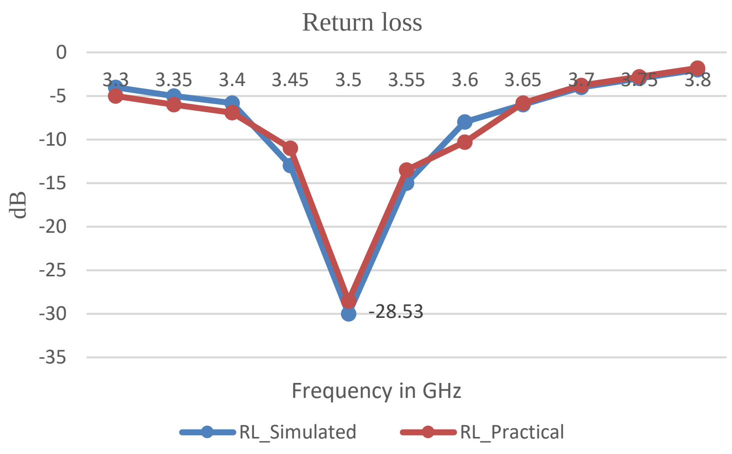

Figure 8. $|S_{11}|$ return loss of basic single patch

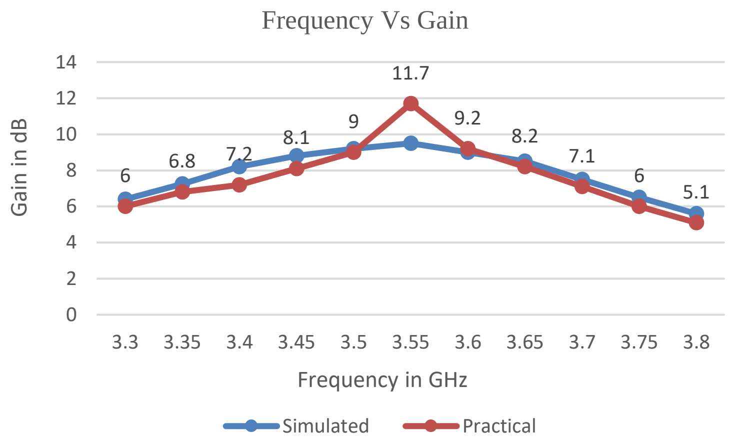

Figure 9. Frequency vs gain curve of basic single patch

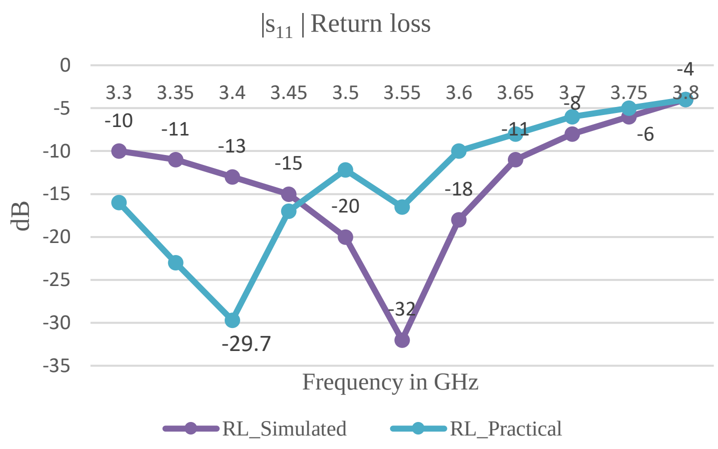

Figure 10. $|S_{11}|$ parameter of 1×2 array antenna

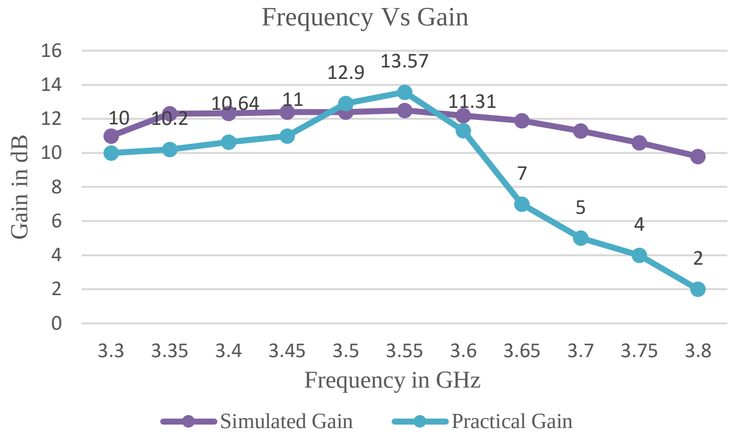

Figure 11. Gain of 1×2 array antenna

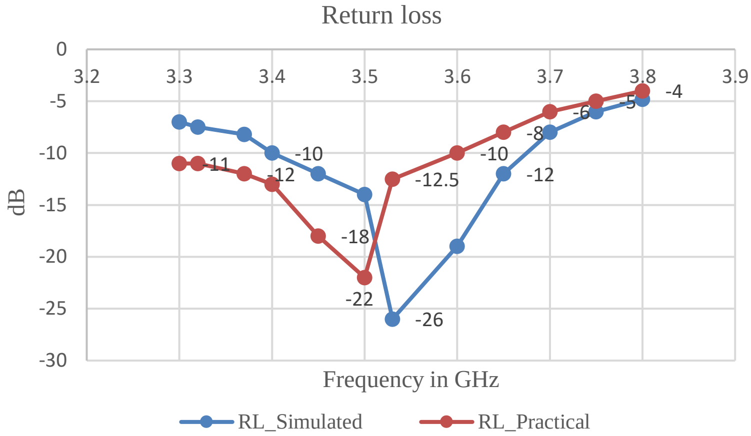

Figure 12. Return losses of 2×2 microstrip array antenna configuration

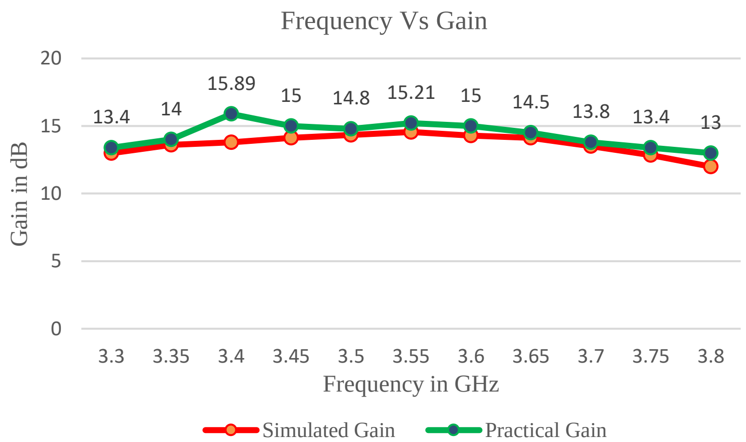

Figure 13. Gain of 2×2 array configuration

The patches in each configuration is/are excited simultaneously and the practical results are measured in vector network analyzer (VNA) and anechoic chamber. Further, for 2×2 array combination, analysis of the 2-D and 3-D radiation pattern is also done. In the practical analysis, it is noticed that return loss for combination 2×2 array is -22 dB due to the path loss and cable losses occurred during the experimental process. In the 2×2, practical gain obtained is 15.2 dB, means it is still higher than that measured while simulation (-14.5 dB). Thus, it is noticed that the improvement of the gain is good for 2×2 RMS antenna array configuration.

Figure 14 shows the side view of practically obtained radiation patterns for E-plane and H-plane, Figures 15 and 16 shows 3D and 2D simulation radiation patterns respectively. The simulation and practical radiation patterns are exactly matching in their shape and pattern of propagation. The radiation pattern is normally very directive, from Figures 14 to 16, it is seen that the major lobe is wider than the minor lobes, at ±30° the major lobe is wider than at 0° from the origin. At ±30° the bandwidth is approximately 267.69 MHz, this indicates that there is an improvement of impedance bandwidth. As the major lobe is sharp tapered and unidirectional, it provides good directivity for the antenna array. However, there are minor lobes which are due to the mutual coupling between the patches. By maintaining the distance between the adjacent patches suitably, these minor lobes can be minimized and further improvement of the directivity can be achieved.

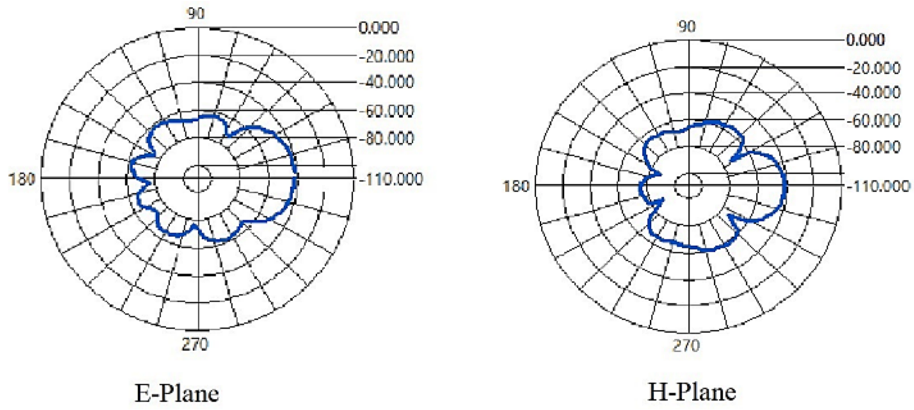

Figure 14. Practical radiation pattern of E-plane and H-Plane for 2×2 array

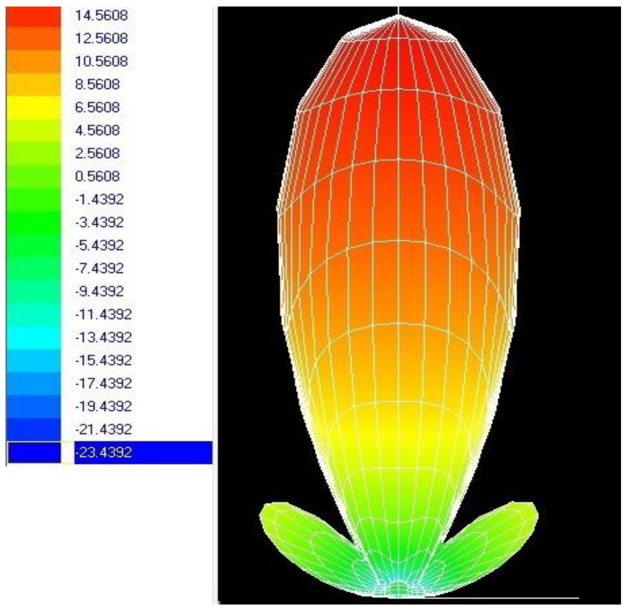

Figure 15. 3D radiation pattern for 2×2 array

Figure 17 shows the current distribution pattern, maximum power transmission takes place at -24 dB which is nearly equal to the -23 dB return loss. All these results can be improved further by maintaining a uniform fabrication and uniform fixing of the plates and uniform 3mm gap between upper and lower plates. It is well-known that, all the array antennas are highly directional antennas. Those antennas will have higher directivity and good gain. In this research, the gain obtained practically is still higher than the gain obtained in simulation. This is due to the air gap introduced, air gap acts as another dielectric material during antenna excitation and propagation of radiation. Hence, this design is also called as dual dielectric 2×2 microstrip array antenna. The practical radiation pattern in Figure 14, shows that the major lobe is wider and fully open along the 0° axis in both E-plane and H-plane. This is one of the features of the directional antenna with higher gain. However, there are backlobes also in the form of undesirable back radiation, these backlobes occur due to the interaction between the patches in an array. Microstrip arrays are made up of a grid of radiating patches. Each element adds to the array's overall radiation pattern. When the gap between the elements in an array is large (more than half a wavelength), extra lobes in the radiation pattern, are known as grating lobes. Grating lobes direct energy in unexpected directions, resulting in inferior antenna performance. Various strategies are used to overcome minor lobes and increase performance of microstrip array antennas. These include adopting suitable feeding strategies and carefully adjusting the element spacing. Likewise, the adoption of improved materials and manufacturing processes may help reduce mutual coupling and other parasitic effects that generate side lobes. The primary direction in which the antenna radiates electromagnetic energy is represented by the major lobe.

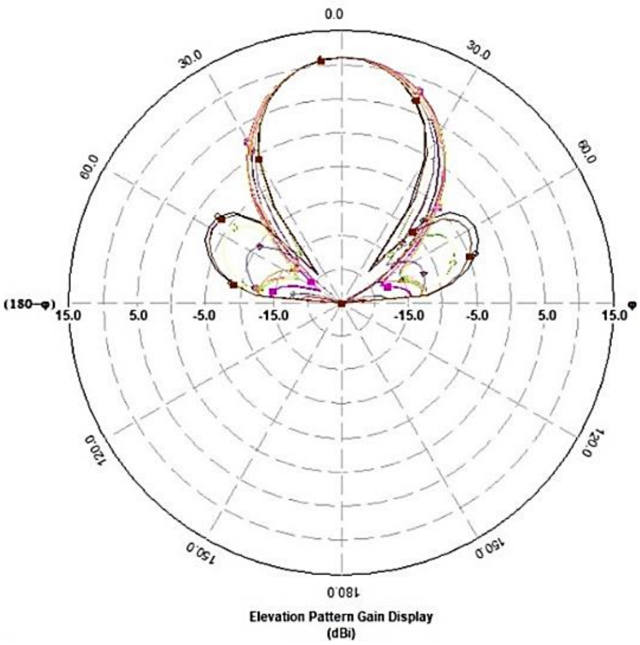

Figure 16. 2D radiation pattern for 2×2 array

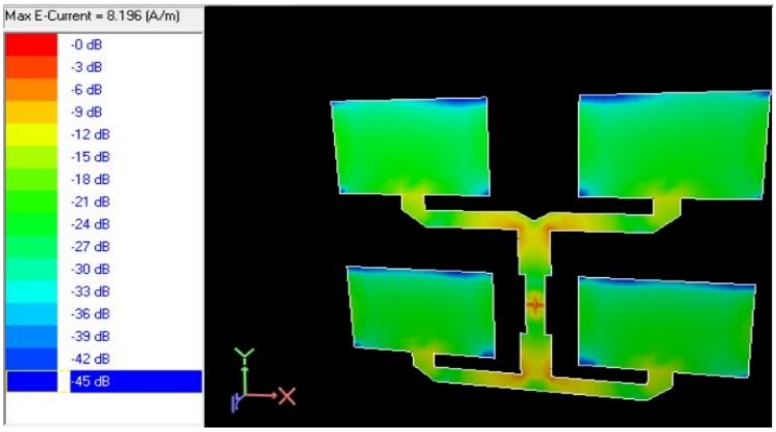

Figure 17. Maximum current distribution at resonating frequency 3.55 GHz (at return loss -24 dB)

Figure 18 shows the anechoic chamber setup where, 2×2 RMS array antenna parameters are being measured. In 2×2 array, multiple radiating elements are arranged in a specified form on a dielectric substrate to build arrays, each radiating patch adds to the array's overall radiation pattern. When the signals from all of the elements combine constructively in one direction, a strong beam, known as the major lobe, is formed. Further, the main lobe can also be steered or molded to meet specific communication or radar requirements by modifying the geometry and excitation of the array parts. The results obtained in this research are compared with the previous work done and are displayed in Table 1.

Figure 18. Laboratory set up of anechoic chamber during measurement of practical readings for 2×2 array

Table 1. Analysis of results

References	Substrate	Dimensions (mm)	Frequency	Gain
[2], Year 2023	FR4 substrate (ϵ_r=4.4)	-	4-8 GHz	7.3 dB
[3], Year 2023	Rogers RT 5880	120×85×3.255	4.148 GHz	12.1dB without reflection
[4], Year 2023	FR4 substrate (ϵ_r=4.4)	50×80	3.45 GHz	3.83 dBi
[6], Year 2022	FR4 substrate (ϵ_r=4.4)	30×35×1.6	3.5–5.8 GHz	12.4 dB
[13], Year 2022	FR4 substrate (ϵ_r=4.4)	70×30	1.8 GHz	4.48 dB
[29], Year 2023	Teflon glass fiber substrate (ϵ_r=2.15)	9.46×9.46×0.8	10 GHz	12 dBi
Proposed results	FR4 substrate	50×32.5×0.8	3.55 GHz	15.2 dB (Gain), -22 dB (RL)

4. CONCLUSION

In this study, a basic single patch, 1×2 array, and 2×2 MSA arrays are designed and simulated for wireless communication in the 5G band. The simulation and practical results are measured and outcomes are correlated with the previous research results already done by the different authors as shown in Table 1. In the comparative analysis, according to the first reference, FR4 substrate and obtained 7.3 dB gain for C-band applications. According to the second comparison, the author used Rogers RT 5880 dielectric and achieved 12.1 dB gain without reflection at 4.148 GHz. As per the third reference, the author used FR4 dielectric and obtained 3.83 dB gain at an excitation frequency 3.45 GHz. According to the fourth reference, the author used FR4 substrate and achieved 12.4 dB gain at 3.5–5.8 GHz. As per the fifth reference, author used FR4 substrate and obtained 4.48 dB gain at 1.8 GHz. In the last reference, author used a different dielectric Teflon glass fiber substrate (ϵ_r=2.15) and obtained gain 12 dB at 10 GHz. But in the present work, using FR4 substrate (ϵ_r=4.4) achieved gain of 15.2 dB for 3.3–3.8 GHz band. Thus, in this study for 2×2 microstrip array antenna designed using FR4 dielectric with additional layer of air medium, achieved gain improvement of 15.2 dB with return loss -22 dB.

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