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# DESIGN OF 5GHZ SLOTTED GROUND PLANE ANTENNA FOR WLAN APPLICATIONS

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**Abstract**
Antennas present an excellent interface to enhance the operation of wireless systems. A good antenna can improve this performance but also cause serious performance issues if not correctly designed. This paper presents the design of a 5GHz microstrip Patch Antenna with a metasurface superstructure placed on a 5 GHz rectangular patch antenna with a slotted ground plane. The patch antenna uses an FR-4 substrate and is designed for wireless local area network (WLAN) applications. The design implements a Defected Ground Substrate (DGS) to enhance the antenna's performance in terms of gain, directivity, etc. The antenna is designed and simulated using Computer Simulation Technology (CST) Studio Suite®, a commercially available electromagnetic software to simulate and optimise the antenna's performance. The optimised dimension of the antenna is 0.70λ x 0.81λ x 0.23λ. The antenna produces good results of gain and directivity. The proposed antenna produces a gain and directivity of 4.18 dB and 6.55 dB, respectively. The bandwidth of the proposed antenna, which stands at 450MHz from 4.83GHz to 5.27GHz, represents a good design.

**Keywords:** Antenna, DGS, metasurface, microstrip, slotted

## Introduction

The concept of the microstrip patch antenna originated in the 1950s, but it only attracted serious attention in the 1970s. Since then, thousands of papers have been on microstrip patch antennae (Lee, 2016). Microstrip antennas have the advantage of low cost, compact size, etc., Balanis, 2016; Ngobese and Kumar, 2018; Gangwar et al., 2018, which makes them suitable for various applications in mobile communication. However, the microstrip antenna has some disadvantages, which include low bandwidth, low gain, etc. (Balanis, 2016; Gangwar et al., 2018). Researchers have proposed several techniques for enhancing the properties of ordinary microstrip antennas in their native form; these techniques include stacking (Sarin et al., 2011; Dzagbletey & Jung, 2018; Feng et al., 2019), different feeding techniques (Wu et al., 2019), Frequency Selective Surfaces (FSS) (Attia et al., 2017; Asaadi et al., 2018) Electromagnetic Band Gap (EBG) (Salleh et al., 2018), Photonic Band Gap (PBG) (Zaidi et al., 2018), Defective Ground Surface (DGS) (Kumar et al., 2017), Metamaterial(Sun et al., 2018), (Yassini & Zeroual, 2019), etc. Over the past decade, metamaterial has gained popularity as an artificial material for antenna design, with performance improvement. Metamaterial properties depend, to a large extent, on the nature of the design, not the properties of the materials used in the design. Metamaterials (MTMs) are macroscopic composite structures having human-made periodic properties with lattice constants smaller than the wavelength of the incident wave (Ghanem et al., 2019).

Zhou et al. (2019) propose a multiple-microstrip dipole antenna that achieves a good gain of 8.9dBi and a

bandwidth of 1.07 GHz to improve the microstrip antenna performance for various applications. In Liu et al. (2017), a low-profile aperture-coupled antenna was proposed. The antenna exhibits an enhanced bandwidth of 15.2% while maintaining a low profile and a gain of 6.8 dBi. Park et al. (2019) proposed a low-profile, high-gain filtering antenna based on a nonuniform metasurface for fifth-generation (5G) systems. The antenna uses a Rogers RO4003C substrate (εr = 3.38, tan δ = 0.0027) and a Taconic TLX-9 substrate (εr = 2.5, tan δ = 0.0019), respectively. The proposed antenna has a 15.91% bandwidth and a maximum gain of 10.43 dBi. A circular patch antenna design with a high gain using a novel artificial planar dual-layer metamaterial superstrate was proposed (Yassini & Zeroual, 2019). The design has a 30% bandwidth and a maximum gain of 7.5dBi while maintaining a total volume of 1.01λg × 1.01λg × 0.025λg. Geetharamani and Aathmanesan (2020) presented a 2.4 GHz metamaterial microstrip patch antenna. Their design enhances the performance of conventional patch antennas. The antenna used an FR4 Epoxy substrate with excellent results such as a return loss of -46.58 dB, VSWR of 1.009, bandwidth of 574 MHz, directivity of 3.379 dBi, and gain of 3.23 dBi at a resonant frequency of 2.4 GHz. On fabrication and testing, the antenna achieved a VSWR of 1.3, return loss of -26 dB, and bandwidth of 200 MHz, making it suitable for 2.4 GHz WiFi applications (Geetharamani & Aathmanesan, 2020). In their study, Li et al. (2024) propose a textile-based microstrip antenna integrated with electromagnetic metamaterials (MA-EBG), embedding conductive copper wires in 3D spacer fabric to suppress surface wave radiation and increase antenna gain from 5.1 dB to 9.6 dB. The MA-EBG maintains structural integrity and proper electromagnetic performance even under the impact, offering a new approach to designing high-gain, mechanically robust textile-based microstrip antennas (Li et al., 2024).

This paper proposes a simple metasurface design using the modified split E-slot surface design in which a split ring is inserted into an antenna to improve its properties. The design includes an upper metasurface placed 5mm above a rectangular I-slotted ground plate patch antenna designed for a 5GHz frequency for WLAN applications. The antenna has an improved bandwidth response, a good gain, and a compact design. This improves the antenna's performance, resulting in a compact antenna performance and good gain and directivity.

**Design of the Proposed Antenna**

The proposed design uses a rectangular microstrip patch antenna with an inset feeding method. This feeding method ensures good performance coupled with the ease of design and matching. The antenna is matched at the input to the conventional input impedance of 50Ω to ensure a balanced system. The antenna has a rectangular patch, and a metasurface material structure suspended 5mm above it to enhance the properties of the antenna. The metasurface material was adjusted between 1mm to 6mm. During optimisation, the antenna had the best performance at 5 mm, enhancing the gain of the proposed antenna from 3.6 dB to slightly above 4 mm. The antenna is designed to radiate at a frequency of 5GHz. This is so that the antenna can be used for WLAN applications. The antenna properties were calculated using the transmission line model. As stated, the rectangular patch microstrip antenna design equations are given below.

$$W = \frac{c}{2 f_r} \sqrt{\frac{2}{\epsilon_r + 1}} \qquad (1)$$


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W, c, fr, and εr are the patch width, speed of light, resonant frequency, and dielectric constant of the substrate, respectively. Equations (2) and (3) produce the effective dielectric constant $\varepsilon_{reff}$ due to the fringing effect and the effective length of the patch L.

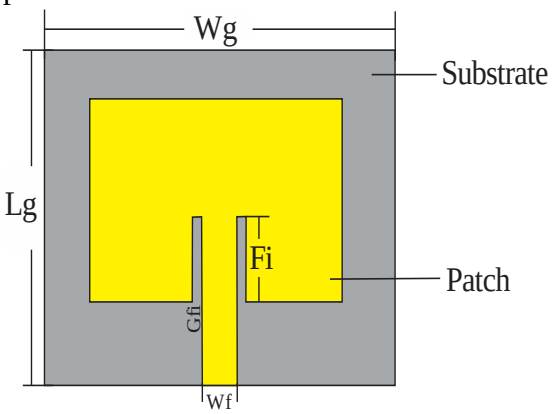
$$\in_{reff} = \frac{\in_r +1}{2} + \frac{\in_r -1}{2\sqrt{1+\frac{12h}{W}}} \qquad (2)$$

$$L = L_{eff} - 2\Delta L = \frac{c}{2 f_r \sqrt{\in_{reff}}} - 2\Delta L \qquad (3)$$

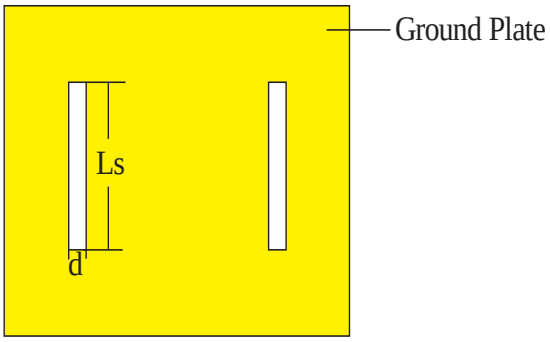
Where $\Delta L$ is given by:

$$\Delta L = \frac{h(0.412)\left(\left(\in_{reff} +0.3\right)\left(\frac{W}{h}+0.264\right)\right)}{\left(\in_{reff} -0.258\right)\left(\frac{W}{h}+0.8\right)} \qquad (4)$$

Where h is the substrate height or thickness, for this design, the substrate height is 1.6mm, the dielectric constant is 4.3, and the radiating frequency is 5GHz, respectively. Figure 1 (a) shows the front of the patch. Figure 1 (b) shows the back end of the patch. The figure shows that the ground plane of the design has some I-slotted twin slots to enhance the design's performance.



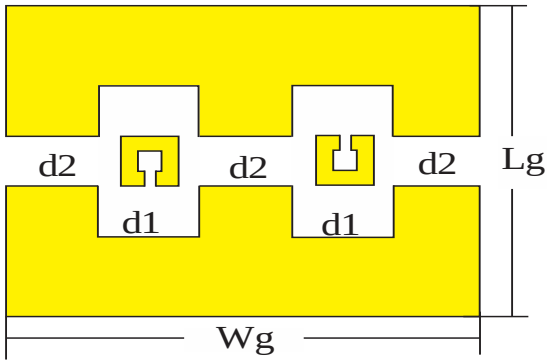

(a)



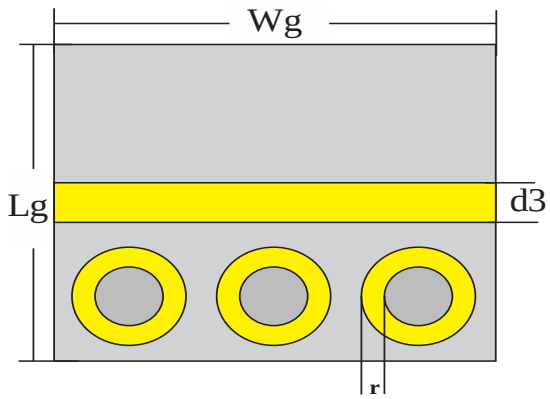

(b)

Figure 1: (a) Top view (b) Back view of the proposed patch antenna

Figures 2 (a) and (b) show the top and bottom views of the metasurface. The metasurface is to enhance the performance of the structure. Figure 2 (c) shows the side view of the antenna. As seen, the top and bottom layers of the antenna are separated by an air gap of 5mm. The air gap is significant because it helps to focus the antenna radiation as designed.



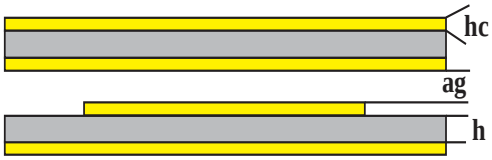

(a)




(b)


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(c)

Figure 2: (a) Top view (b) Back view (c) Side view of the proposed patch antenna superimposed metamaterial

Figure 3 shows the simulated metasurface I-Slotted microstrip antenna. The port is shown in red with the port number labelled on the figure.

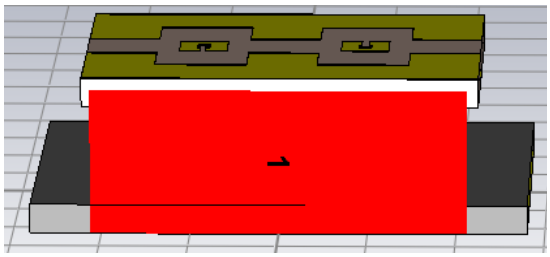


Figure 3: Optimised antenna design

Table 1 shows the optimised antenna parameters. The design equations of equations 1 to 4 are used to calculate the value of the antenna parameters. The antenna's width, length, patch width, and height are calculated using the equations. During the antenna simulation in the CST Studio suite, it was observed that some tuning was necessary to get the optimal parameter value, as stated in Table 1. After necessary optimisation, the table shows the details of the dimensions specified in Figures 1 and 2.

**Table 1**
Antenna Parameters

| **Parameter** | **Wp** | **Lp** | **H** | **Gfi** |
|---|---|---|---|---|
| Value (mm) | 18.42 | 13.84 | 1.6 | 0.101 |
| Parameter | Wg | Lg | Fi | Wf |
| Value (mm) | 28.03 | 23.45 | 5.20 | 3.04 |
| Parameter | Ls | D | d1 | d2 |
| Value (mm) | 17.45 | 2 | 7.01 | 7.01 |
| Parameter | r | Hc | h | $\varepsilon$ |
| Value (mm) | 1.5 | 0.035 | 1.6 | 4.3 |

## Results and Discussions

### S-Parameter

The S-parameter or return loss of the proposed 5GHz I-slotted metasurface antenna is presented in Figure 4. The figure shows that the S-Parameter has a maximum value of -23 dB, which shows a suitable value. An S-parameter of -10dB is the minimum required for an antenna to radiate power at the required frequency. From the S-parameter plot, we can determine the bandwidth of the proposed antenna, which stands at 450MHz from 4.83GHz to 5.27GHz.

### VSWR of the Proposed Antenna

The Voltage Standing Wave Ratio (VSWR) of the proposed antenna is shown in Figure 5. The figure shows that the


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VSWR at 5.03GHz is 1.18. This shows a good value for this design. A VSWR of less than 2.0 is recommended for patch antennas for a good antenna parameter. Our proposed antenna has a value much less than 2.0 throughout the bandwidth of the antenna.

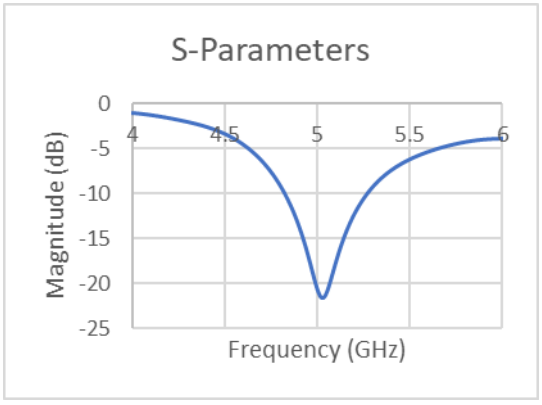



Figure 4: S-Parameter

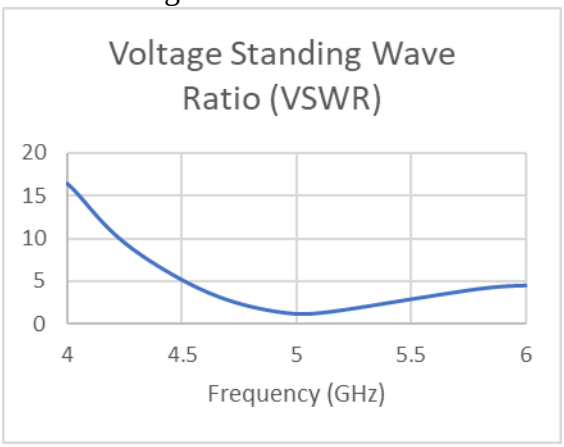



Figure 5: Voltage Standing Wave Ratio (VSWR)

The simulation of the proposed antenna was done using CST Studio suite, a commercially available Electromagnetic Simulation software. The far-field radiation of the antenna as obtained from CST Suite is shown in Figures 6 and 7, which show the antenna 3d gain and directivity of the antenna. The gain and directivity stand at 4.18 dB and 6.55 dB, respectively. Patch antenna can perform beautifully at a gain and directivity much less than that of the proposed antenna. This shows that this design has good gains and directivity values, as proposed.

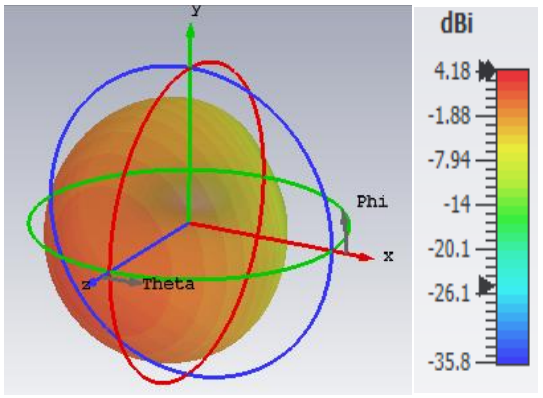



Figure 5: Gain of the antenna

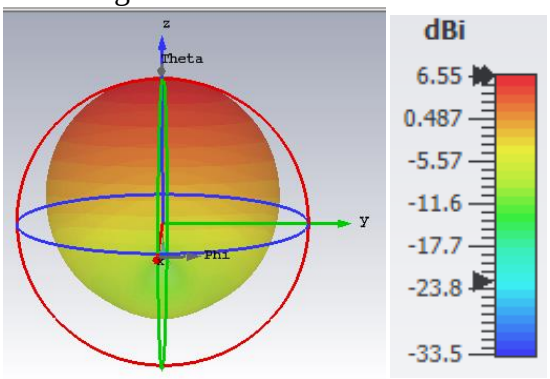



Figure 6: Directivity of the antenna

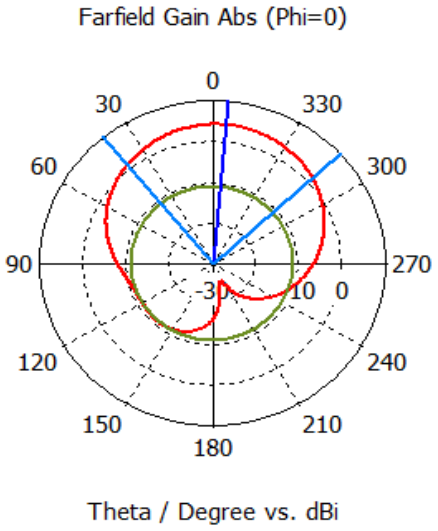



Figure 7: Fairfield gain (phi = 0)


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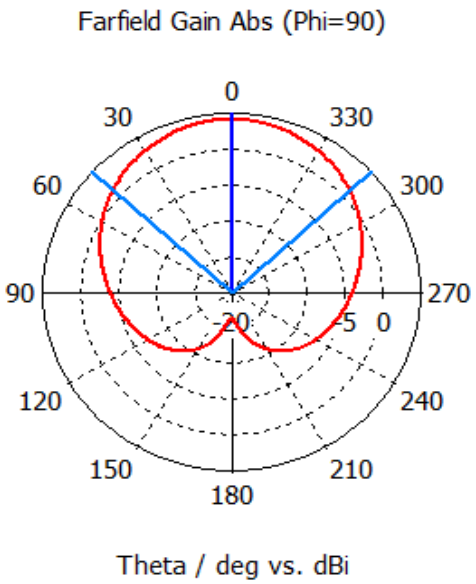



Figure 8: far-field gain (phi = 90)

Figures 7 and 8 show the maximised far-field properties of the antenna at Phi = $0^0$ and Phi = $90^0$. The figure shows that the antenna is a directional antenna that can meet the task it is intended for as required. It is clear from Figures 7 and 8 that the antenna has a tiny back lobe, which is a requirement for directional antennas.

## Conclusion

A slotted ground plane microstrip antenna with metasurface placed 5mm on top of the patch antenna with a double I-slotted ground plane patch has been designed in this paper. The antenna is designed for a radiation frequency of 5GHz. After optimising the design, the radiation frequency obtained is 5.03 GHz at a compact dimension of 0.70λ x 0.81λ x 0.23λ. The antenna produces good results of gain and directivity. The proposed antenna produces a gain and directivity of 4.18 dB and 6.55 dB, respectively. The bandwidth of the proposed antenna, which stands at 450MHz from 4.83GHz to 5.27GHz, represents a good design for WLAN applications.

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