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Kite-Shaped Array Wideband Microstrip Patch Antenna With DGS For Ism Band Applications

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Abstract
The development and evaluation of a kite-shaped microstrip patch antenna array incorporated with DGS is the main goal of this study. Wideband applicability, improved gain, directivity, and effective current distribution are the goal line of the suggested design, which is well-matched for ISM band submissions. The novel layout uses Fire Resistance FR4 epoxy as the dielectric substrate. The High Frequency Structure Simulator (HFSS) software was used for simulation and parameter optimization, and fabrication to validate the design. Vector Network Analyzer (VNA) was used for experimental evaluation.
Keywords: *Microstrip Patch Antenna, Defected Ground Structure (DGS), Wireless Communication, Kite Shaped Array Antenna, ISM Band, High Frequency Structure Simulator (HFSS).*

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I. Introduction

In the sector of limited-range communication, technologies like Wi-Fi, Bluetooth, IoT devices, short-range radar systems, satellite communication, medical and industrial telemetry, operating within the S and C-Band spectrum, enable efficient and reliable exchanges [1],[2]. The growing demand for compact, efficient, and cost-effective antennas to meet the needs of ISM band applications has significantly influenced the evolution of microstrip patch antenna designs. Because the antenna type is lightweight, low-profile, and simple to build, it finds use in wearable technology, wireless communication, and Internet of Things devices [3], [4]. These antennas may be easily included into cutoff situations because to their low-profile and incredibly adaptable design [5]. Conventional microstrip antennas' limited bandwidth and poor gain are two of the main obstacles preventing their broad usage in cutting-edge communication systems [6]. The introduction of DGS is one novel way to counteract these deficiencies. By altering current flow in the ground plane, DGS enhances antenna electrical parameters such as impedance bandwidth and radiation efficiency that are very desirable for ISM band applications [7],[8].

Microstrip patch antennas (MPAs) are extensively used in modern communication systems, where array configurations serve the purpose of achieving higher gain and improved radiation patterns [9],[10]. A study indicated that good designs of DGS can be paired with optimal patch size and array geometry to greatly increase radiation efficiency and signal quality, both of which are critical features for Wi-Fi and Bluetooth applications [11],[12]. These variations of arrays increase the effective aperture area and provide considerably higher gain than the conventional patch designs, thus greatly improving performance [13]. DGSs embedded in MPAs optimize certain performance parameters such as beam steering, sidelobe suppression, and wide operating bandwidth, suitable for ISM band applications [9],[14]. Thus, DGS improves bandwidth and allows better control over radiation characteristics, both of which are vital for wireless communication systems [15]. DGS has enhanced the performance of the microstrip antennas by the controlled introduction of defects in the ground plane that optimizes its resonating properties [16][17]. Circular and slotted DGS designs have demonstrated their full capabilities toward wideband performance, hosting overlapping multiple sub-bands across the ISM range [18],[19]. While working from 2.3 GHz to 5.8 GHz, a slotted-DGS array exhibited wide coverage for its ISM applications [20],[21].

II. Antenna Design And Simulation

The kite-shaped array antenna was designed to achieve wideband performance across ISM and adjacent frequency bands. The FR4 dielectric substrate is 1.6 mm thick and having dielectric constant of $\varepsilon_r = 4.4$ and loss tangent $\tan\delta = 0.02$. Figure 1 Shows a kite-shaped radiating element for enhanced current distribution.

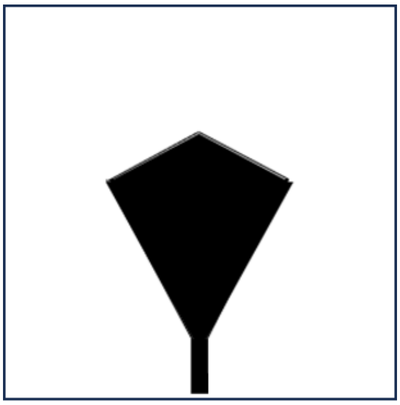

Figure 1. Patch shaped radiating element.

Figure 2 Represents two patches arranged in an array configuration to improve gain and directivity. (Where W_1 to W_8 are widths and L_1 to L_4 are lengths)

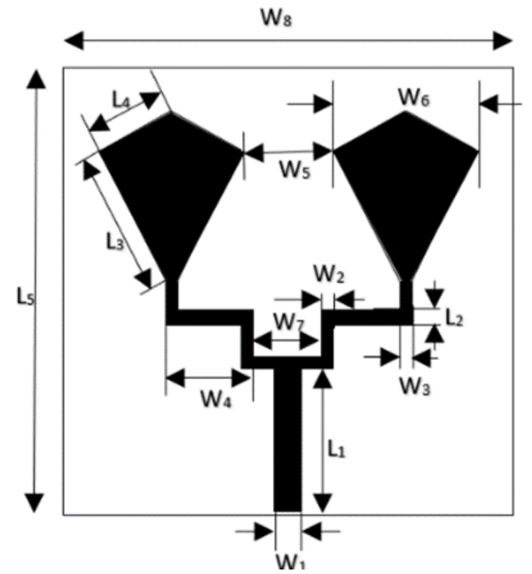

Figure 2. Kite shaped array for patch design.

Figure 3 Shows a half ground plane structure i.e., DGS introduced to further enhance bandwidth and impedance matching. Parametric studies were conducted in HFSS Simulator to optimize the slot dimensions and position.

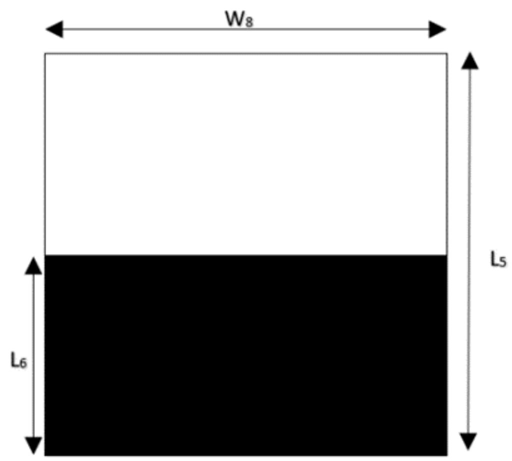

Figure 3. Defected Ground Structure of ground plane.

The proposed kite shaped array microstrip patch antenna is simulated by HFSS simulation software shown in Figure 4 and simulated DGS structure as shown in Figure 5.

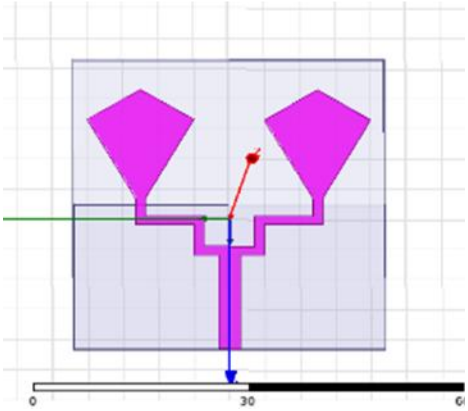

Figure 4. Simulated kite shape array for patch design

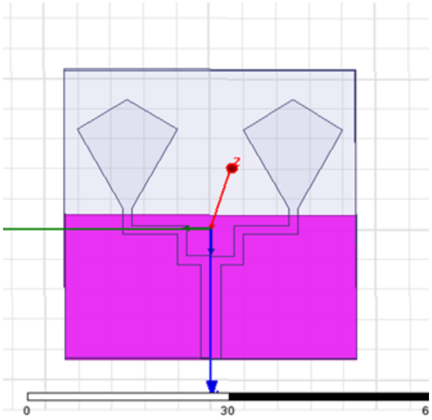

Figure 5. Simulated DGS Structure.

The parameters of our proposed kite shaped array patch design are shown as Table 1.

Parameters	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8
Values (mm)	3	1.4	1.4	9.6	10	15	7.2	48
Parameters	L_1	L_2	L_3	L_4	L_5	L_6		
Values (mm)	15.6	1.4	14.3	4.3	48	24		

Table 1: Proposed antenna parameters.

The antenna was refined through precision PCB manufacturing. Testing was performed using Vector Network Analyzer (VNA) to check the input return losses (S_{11}) and VSWR, as illustrated in Figure 6.

Figure 6. Experimental setup using VNA (Agilent Technologies, FieldFox, Model No. N9925A up to 9GHz) for optimized antenna.

III. Result And Discussion

RETURN LOSS (S_{11})

In this configuration, the kite shape allows for an exceptionally broad S_{11} bandwidth for the antenna from 2.66 to 5.57 GHz and from 7.55 to 8.51 GHz, where the return loss test reveals -34 dB, as seen in Figure 7. Furthermore, it demonstrates dual Voltage Standing Wave Ratio (VSWR) regions corresponding to the specified resonating frequencies.

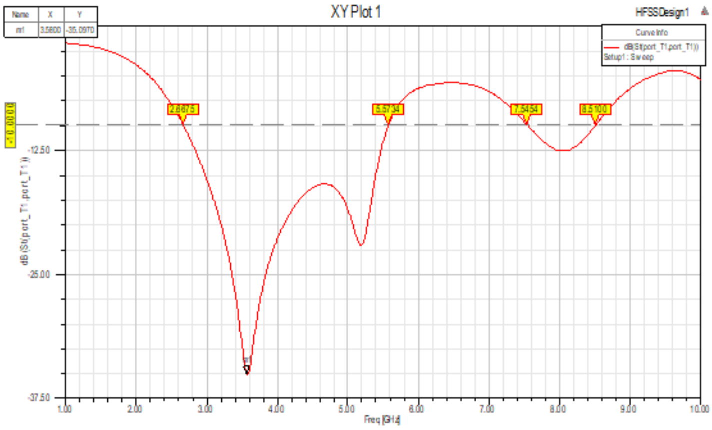

Figure 7. Simulated S_{11} parameter of kite shaped array configuration.

Fabricated kite shaped array configuration was experimentally tested through VNA as shown in Figure 8 and confirmed these results, demonstrating good agreement with simulated data, ranging from 2.4 GHz to 5.5 GHz.

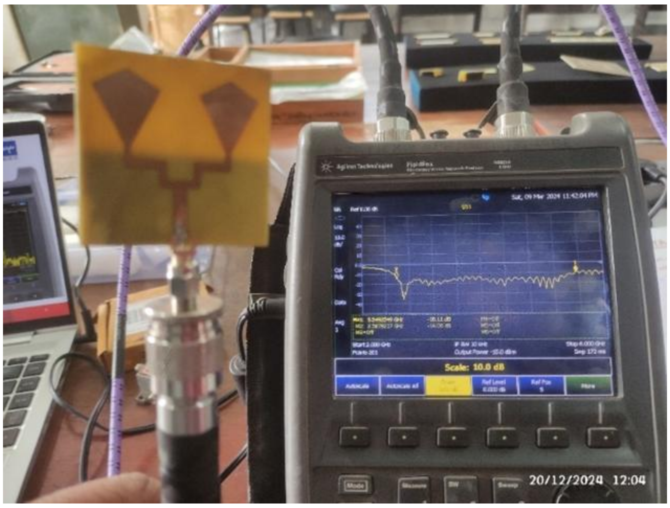

Figure 8. Experimentally measured S_{11} parameter through VNA

Simulated and Measured VSWR are as shown in Figure 9 and Figure 10. The antenna exhibited dual VSWR regions from 2.63 GHz to 5.59 GHz, achieving VSWR < 2 and at higher-frequency range from 7.48 GHz to 8.56 GHz, which clearly indicates multi-band functionality.

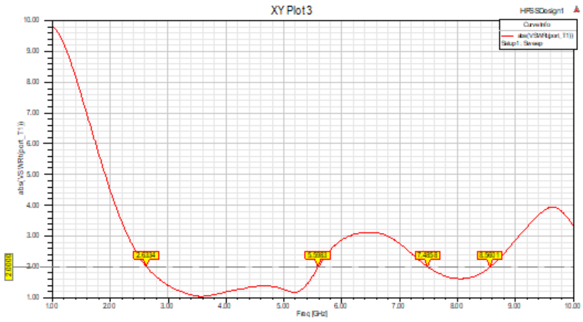

Figure 9. VSWR of simulated design.

Figure 10. Measured VSWR of fabricated array antenna.

The wideband characteristics, validated experimentally, make the antenna suitable for applications requiring broad frequency coverage for ISM band applications.

Directional radiation with an improved front-to-back ratio, suitable for wideband communication are shown in Figure 11.

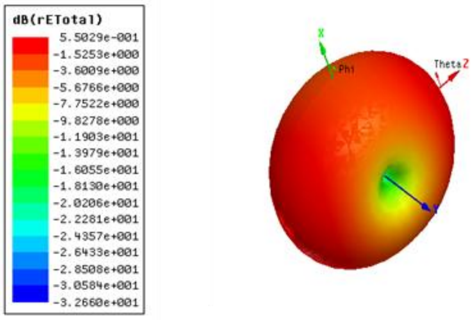

Figure 11. Simulated radiation pattern using HFSS

Comparison of simulated and measured values have been shown in Table 2 Which shows good agreement between simulated and measured values.

Table 2. Comparison between simulated and measured values.

Parameter	Simulated Value	Measured Value
S11 Bandwidth	2.66–5.57 GHz	2.4–5.5 GHz
Maximum Return Loss	-34 dB	-37 dB
VSWR (Wideband)< 2	2.63–5.59 GHz	2.4–5.5 GHz

IV. Conclusion

In this research work, a kite-shaped array microstrip antenna for wideband applications has been designed, simulated, fabricated, and verified successfully. The unique kite-shaped patch and DGS integration resulted in improved multi-band capability, return loss, and bandwidth. The simulations and experiments were in close agreement, substantiating the antennas' performance and applicability for real-life applications. The future work to extend the working range of the antenna will include complex array designs and different DGS variants.

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