

Flexible Printed Dual-Band MIMO Antenna

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Abstract— The proposed 2x1 dual-band flexible MIMO antenna is fabricated using conductive ink printed on a 0.19 mm-thick polyimide substrate. It operates in dual bands at 2.4 GHz and 5.8 GHz, covering impedance bandwidths of 2.07–2.93 GHz for ISM and 5.33–6.12 GHz for WLAN applications. The antenna ensures good isolation and gain, along with strong diversity performance metrics, including Envelope Correlation Coefficient (ECC), Diversity Gain, and radiation pattern. Its compact design has an overall size of $50 \times 70 \text{ mm}^2$.

I. INTRODUCTION

Flexible and printable dual-band multiple-input-multiple-output (MIMO) antennas are pivotal in next-generation wireless and sensing technologies due to their adaptability and cost-effective fabrication. These antennas, made using conductive inks on flexible substrates, enable lightweight, conformable, and durable designs suitable for integration into various surfaces. They find applications in wearable devices, where they support health monitoring and IoT connectivity, as well as in flexible electronics for smart textiles and bendable displays. Furthermore, their dual-band functionality enhances wireless communication in 5G, V2X, and satellite systems, while their ability to interpret changes in parameters like S_{11} makes them effective as sensors in environmental monitoring and industrial automation.

This paper presents a 2x1 MIMO antenna system implemented on a Polyimide substrate. The proposed antenna design is studied and analyzed using the CST Studio Suite 3D full Electromagnetic Simulator (2023) tool, and a hardware prototype is fabricated by using NOVA, a modular, benchtop precision dispensing system, specifically designed for prototyping and development of additive electronics, to verify the simulated results.

II. ANTENNA DESIGN AND MANUFACTURING

The proposed 2x1 MIMO antenna builds upon a dual-band single antenna that was successfully designed, tested, and exhibited excellent performance. The detailed layouts of the designed single and MIMO antennas are shown in Figure 1 and Figure 2, respectively. The size of the proposed MIMO antenna is as following; length of the antenna is 50 mm and width of the antenna is 70 mm. The dielectric properties of the polyimide substrate were accurately measured using a Split Post-Dielectric Resonator, yielding a dielectric constant of $\epsilon_r = 3.5$ and a loss tangent of $\tan \delta = 2.70 \times 10^{-3}$.

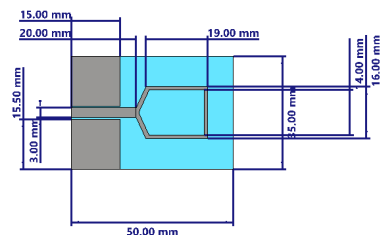


Figure 1. Detailed layout of the proposed printed antenna, top view

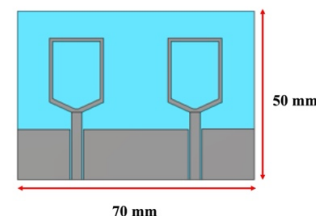


Figure 2. Detailed layout of the proposed printed MIMO antenna, top view

The substrate's thickness was determined with an Electronic Outside Micrometer, measuring $h = 0.19 \text{ mm}$. For the conductive elements, a printed silver conductor (ACI FS0142) with excellent conductivity was utilized.

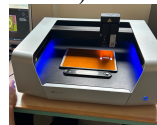


Figure 4.
Voltera
NOVA
Printer

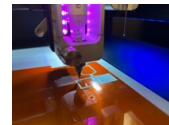


Figure 5.
MIMO
Antenna
Manufacturing



Figure 6. Measuring
the scattering
parameters with
Agilent Technologies
Microwave Analyzer,
N9916

The antenna pattern designed with CST is imported into Nova Software, which generates tool paths, enables real-time adjustments, and produces a compatible digital file for smooth printing. After setting the dispensing height and aligning the print head, the software executes the antenna pattern printing process. After printing, the prototype was placed in an oven at 60°C for 20 minutes to facilitate the curing of the silver ink.

III. ANTENNA PERFORMANCE ANALYSIS

This section analyzes the performance of the proposed printed MIMO antenna performance in terms of scattering parameters; reflection coefficient (S_{11}), transmission coefficient (S_{21}), envelope correlation coefficient, diversity gain, and radiation pattern.

A. Scattering Parameters

The performance of the printed MIMO antenna is simulated on CST Studio and the measurements are done with Agilent Technologies' FieldFox Microwave Analyzer; N9916A as a Vector Network Analyzer shown in Figure 6.

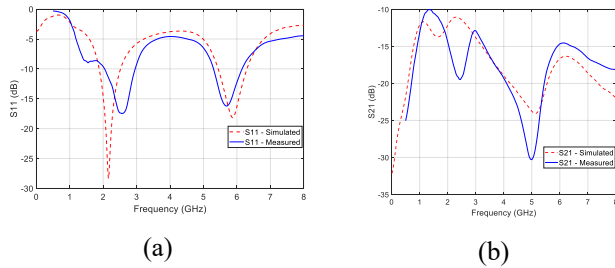


Figure 7. The scattering parameters of printed MIMO antenna (a) reflection coefficient (S_{11}), (b) transmission coefficient (S_{21}).

The measured and simulated scattering coefficients, reflection coefficients (S_{11}) and transmission coefficients (S_{21}) of the MIMO antenna are shown below in Figure 7 (a) and (b), respectively. It operates in dual bands at 2.4 GHz and 5.8 GHz, covering impedance bandwidths of 2.07–2.93 GHz and 5.33–6.12 GHz. There are two resonant frequencies located at about 2.56 GHz and 5.67 GHz are observed with return losses reaching -17.46 dB and -16.21 dB, respectively. It is also noted that there is a small shift in the resonant frequency in the measurements with respect to the simulated ones.

B. Surface Current Distribution

Surface current distribution of the printed MIMO antenna is investigated in this section to illustrate effectiveness of isolation. In a compact and closely spaced antenna elements, flow of the surface currents from an excited port to the other ports will cause mutual coupling. This undesired effect will degrade the diversity performance of the MIMO system [1]. The surface current distributions for the MIMO antenna are simulated at 5.8 GHz and shown in Figure 8 (a) and (b). The current surface distribution representation is color coded (red represents the strongest).

C. Envelope Correlation Coefficient

Envelope Correlation Coefficient (ECC) is used as a performance metric to characterize and measure the system performance, channel quality and efficiency of the MIMO system. Higher values cause degradation in the MIMO diversity system performance. From the practical perspective, ECC values less than 0.5 indicates the good performance. This low ECC value over frequency band makes this antenna very suitable for MIMO applications.

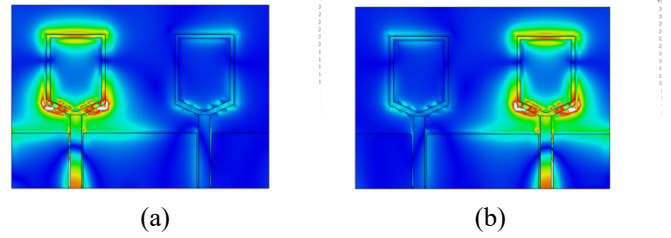


Figure 8. Simulation of Surface Current Distributions on the printed MIMO antenna 5.8 GHz. (a) first antenna is excited, and the second antenna is terminated, (b) second antenna is excited, and the first antenna is terminated.

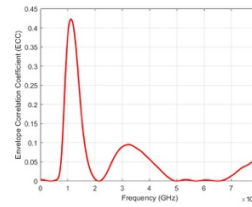


Figure 9. ECC of MIMO antenna.

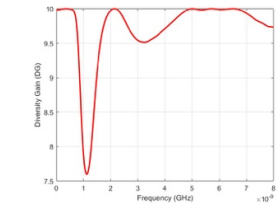


Figure 10. Diversity Gain of the MIMO antenna.

D. Diversity Gain, Gain and Radiation Pattern

Diversity gain (DG) is a key performance metric that reflects the reliability of MIMO system performance. The DG of the proposed MIMO antenna, illustrated in Figure 10, is nearly 10 at the dual-band frequencies. These results demonstrate that the proposed MIMO antenna meets the requirements for practical applications. Figure 11 shows the simulated gain of the MIMO antenna, which achieves approximately 3.5 dB at 2.56 GHz and 6.2 dB gain at 5.67 GHz. These results meet the requirements for MIMO communication system applications. Furthermore, Figure 12 displays the simulated 3D radiation pattern of the realized gain at 5.8 GHz.

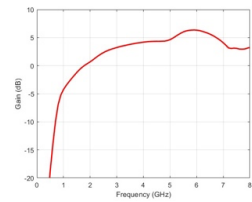


Figure 11. Simulated gain over the radiating band of MIMO antenna

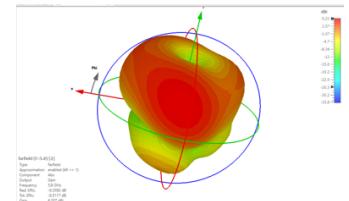


Figure 12. Simulated 3D view of the realized gain radiation pattern at 5.8 GHz

IV. CONCLUSION

In conclusion, a two-element printed MIMO antenna was implemented on a polyimide substrate. The antenna demonstrates good performance in terms of reflection coefficients and impedance bandwidth. Key diversity performance metrics for MIMO antennas, such as ECC and diversity gain, were found to be within acceptable limits. The proposed antenna is well-suited for wearable devices, medical applications, and various military uses.

References

- [1] A. J. Paulraj, D. A. Gore, & H. Bolcskei. (2004, February). An overview of MIMO communications - a key to gigabit wireless Proc. of the IEEE, vol. 92, no. 2, pp. 198–218