Two-Port Hexagonal Bar Slotted Dual-Band MIMO Textile Antenna for WBAN and 5G Applications

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***Abstract*— This paper presents a dual-band textile Multiple-Input-Multiple-Output (MIMO) antenna for Wireless Body Area Network (WBAN) and Fifth Generation (5G) applications. The MIMO antenna consists of two hexagonal patch elements, each integrated with a bar slot to operate in dual-band mode at 2.45 GHz and 3.5 GHz. The dimension of each patch is 48.5 x 30 mm². This antenna is made fully by an all-textile with radiating elements by the conductive textile. The proposed MIMO textile antenna achieves the satisfactory results such as Reflection Coefficient (S_{11}) <-10 dB, very low MC < -30 dB, Envelope Correlation Coefficient (ECC) < 0.001, and Diversity Gain (DG) of about 10 dB. The simulated results show that the proposed design covers the operating impedance bandwidth of about 6.3% and 6.2% in the 2.45 GHz and 3.5 GHz. The peak realized gain of 5.5 dBi is attained.**

Keywords—5G, antennas, bioelectromagnetics, metamaterials, MIMO antenna, textile antenna, wearable antenna, wearable

I. Introduction

The multiple elements of MIMO wearable antennas need to be spaced as close as possible to achieve compactness while maintaining good over-all performance. However, the closely spaced elements will result in higher radiation interaction, leading to higher MC. Several MC reduction techniques have been proposed in the literature. They include the modification of the antenna structure by adding Electromagnetic Bandgap (EBG) [1], introducing slot [2], neutralization lines [5] metamaterial structure [3] parasitic elements [4] hybrid techniques combining Defected Ground Plane Structures (DGS), stubs [5] and Split Ring Resonators (SRR) [6]. Thus, this research proposes a two-port hexagonal bar slotted dual-band textile MIMO antenna utilizing a hybrid technique [7] to significantly reduce MC.

II. Methodology and Results

The initially proposed antenna is based on a single hexagonal bar slotted, operating in dual-band mode, centered at 2.45 for WBAN lower band, and at 3.5 GHz for 5G as the upper band, as shown in Fig. 1. Felt textile is used as the substrate and is sandwiched between the top radiator and a full ground plane. It has a relative permittivity (ε_r) of 1.44, a loss tangent ($tan\delta$) of 0.044, and a thickness (H) of 3 mm. The conductive elements are formed using ShieldIt Super electro-textile from LessEMF Inc., which is 0.17 mm thick and features an estimated conductivity (σ) of 1.18×10^5 Sm^{-1}. A detailed design procedure can be summarized in four steps, as follows:

- First, the dimensions of the patch without a hexagonal slot are calculated based on the upper band resonance.
- Second, the probe feeding structure is optimized to have a suitable resistance matching in the upper band.
- Third, the hexagonal shape and the bar slot are added to broaden the bandwidth to provide operation in the appropriate bands.
- Fourth, the dimensions of the hexagonal-shaped slot are selected and tuned to function as circular coupling behavior in the lower band.

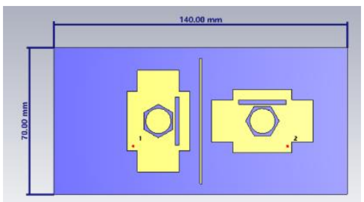


Fig. 1. Proposed Hexagonal Bar Slotted tow-port Dual-Band MIMO Textile Antenna.

XXX-X-XXXX-XXXX-X/XX/$XX.00 ©20XX IEEE

2024 International Symposium on Antennas and Propagation (ISAP) | 979-8-3503-6477-4/24/$31.00 ©2024 IEEE | DOI: 10.1109/ISAP62502.2024.10846397

A. Hybrid Technique of MC and S-Parameter of MIMO Configuration Analyses

Fig. 2 (a) shows the simulated result of S_{11} of the proposed MIMO antenna with a small edge-to-edge gap of $0.1\lambda_{guided}$. The results show that the bandwidth is 6.3% and a maximum of up to 6.2% for lower and upper bands, respectively, at port 1. Fig. 2 (b) shows that the MC achieves less than -30 dB in both bands for all ports of MIMO configurations.

B. Realized Gain

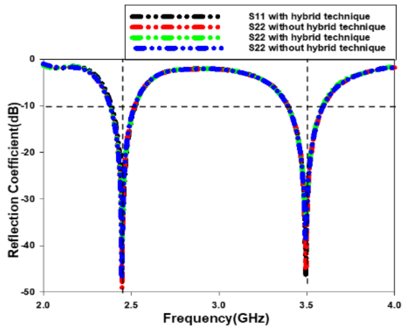
Fig. 3 shows the proposed MIMO antenna in terms of realized gain. The realized gain of 2.7 dBi and 5.5 dBi in the lower and upper band, respectively.

C. MIMO Diversity Characterization

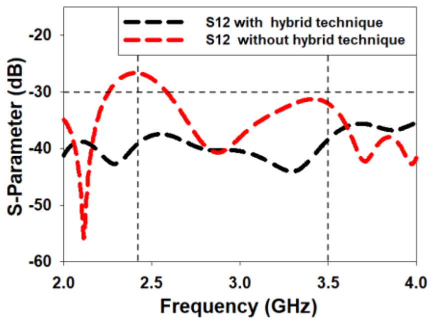
The MIMO antenna is further assessed by measuring the ECC and DG to examine the correlation between antenna elements [7]. It can be observed that the ECCs are well below 0.001, satisfying the minimum value of ECC<0.5, as shown in Fig. 4. DG is 10 dB for both bands.

III. Conclusion

This study proposes a two-port hexagonal bar slotted textile MIMO antenna for on-body WBAN and 5G applications. This antenna is designed by combining two hexagonal structures each integrated with a bar slot. MC of the MIMO antenna is significantly reduced by rotating the patch element and adding a line patch between the antenna elements. Most importantly, the resulting optimized structure is simple and can be implemented as a textile antenna. Assessments of this antenna in terms of MIMO parameters such as realized gain, ECC, and DG also validate that this antenna can be potentially applied in the next generation of 5G wearable devices.



(a)



(b)

Fig. 2. Simulated results for gap of $0.1\lambda_{guided}$ with and without hybrid technique (a) S_{11}, S_{22} and (b) S_{12}.

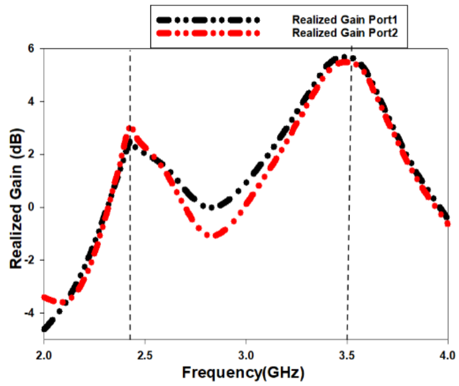


Fig. 3. Realized gain of the proposed antenna and two-port MIMO antenna.

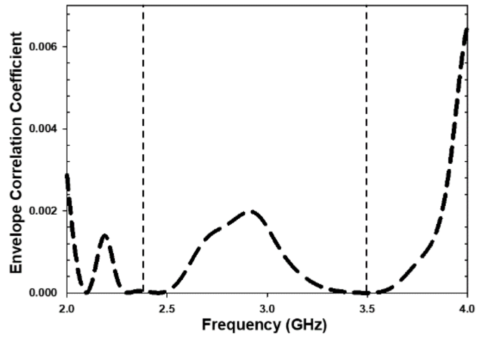


Fig. 4. MIMO diversity characterization on ECC.

Acknowledgment

The authors would like to acknowledge the financial support under INTERES grant from Songkhla Rajabhat University and KS Co. Ltd [grant no. 9008-00042]. KS Co. Ltd supports knowledge of the test and measurement for new technologies.

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