ISAP 2023 1570915640

Dual-Band MIMO Decagonal C-Shaped CSRR Metamaterial Textile Antenna for WLAN and 5G Applications

1st Hamza A. Mashagba
Faculty of Electronic Engineering & Technology, Advanced Communication Engineering (ACE) Centre of Excellence
Universiti Malaysia Perlis
Perlis, Malaysia
gasabhamz@gmail.com

2nd Hasliza A Rahim
Faculty of Electronic Engineering & Technology, Advanced Communication Engineering (ACE) Centre of Excellence
Universiti Malaysia Perlis
Perlis, Malaysia
haslizarahim@unimap.edu.my

3rd Mohd Najib Mohd Yasin
Faculty of Electronic Engineering & Technology, Advanced Communication Engineering (ACE) Centre of Excellence
Universiti Malaysia Perlis
Perlis, Malaysia
najibyasin@unimap.edu.my

4th Sarun Narongkul
Faculty of Industrial Technology
Songkhla Rajabhat University
Songkhla, Thailand
sarun.ch@skru.ac.th

5th Liyana Zahid
Faculty of Electronic Engineering & Technology, Advanced Communication Engineering (ACE) Centre of Excellence
Universiti Malaysia Perlis
Perlis, Malaysia
liyanazahid@unimap.edu.my

6th Nur Hidayah Ramli
Faculty of Electronic Engineering & Technology, Advanced Communication Engineering (ACE) Centre of Excellence
Universiti Malaysia Perlis
Perlis, Malaysia
hidayahramli@unimap.edu.my

***Abstract*— This study proposed an enhanced two-port dual-band textile Multiple-Input Multiple-Output (MIMO) antenna integrated with a metamaterial unit cell of symmetric decagonal C-shaped Complementary Split-Ring Resonator (CSRR) structure in terms of gain. The proposed MIMO antenna achieves an impedance bandwidth of 6.3% and a maximum up to 18.2% for lower and upper bands, respectively, at port 1. Mutual Coupling (MC) of less than -20 dB for both ports is obtained. The proposed antenna offers high realized gain of 5.6 dBi and 8 dBi at 2.45 GHz and 3.5 GHz, respectively, compared to existing dual-band MIMO textile antenna. Good diversity characteristics in respect of Envelope Correlation Coefficient (ECC) less than 0.001, and Diversity Gain (DG) of about 10 dB are achieved.**

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

I. Introduction

Metamaterial (MTM) is recently been integrated to the antenna structure in order to enhance the radiation pattern, bandwidth, gain, isolation and Mutual Coupling (MC) [1]. The rotation and line patch were incorporated into the recent proposed dual-band two-port MIMO textile antenna to reduce the MC of MIMO configuration [2]. However, the designed antenna has lower gain especially at lower frequency. Thus, this research proposes a dual-band MIMO MTM textile antenna to improve gain of the two MIMO components.

II. Methodology and Results

The initial proposed antenna is based on [2], operating in dual-band mode, centred at 2.45 for the Wireless Local Area Network (WLAN) lower band, and at 3.5 GHz for Fifth Generation (5G) as the upper band, as shown in Figure 1. Felt textile is used as the substrate and is sandwiched between 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}.The dual-operating frequency based on SR bar slotted structure is described in detailed as in [2]. Then a MTM unit cell with symmetric decagonal CSRR structure is modelled based on [3] to demonstrate Single Negative (SNG) permittivity property in enhancing gain, as shown in Figure 2. The structure is placed between two waveguide ports on the positive and negative z-axis in order to determine the effective parameters of the CSRR. The decagonal C-shaped CSRR MTM unit cell is incorporated into the two-port dual-band MIMO textile antenna, as shown in Figure 1.

A. Metamaterial Unit Cell Analysis and S-Parameter Analysis of MIMO Configuration

Figure 3 shows the simulated result of S11 of the proposed MIMO decagonal C-shaped CSRR MTM antenna. The results show that the bandwidth is 6.3% and a maximum up to 18.2% for lower and upper bands, respectively, at port 1. Figure 3 also show that the MC is achieved less than -20 dB in both bands. Meanwhile, for the upper band, lower MC is obtained with MC<-30 dB for all ports of MIMO configurations.

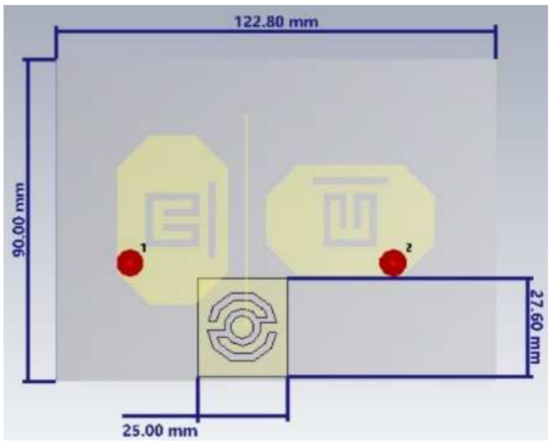


Figure 1. Proposed MIMO MTM textile antenna.

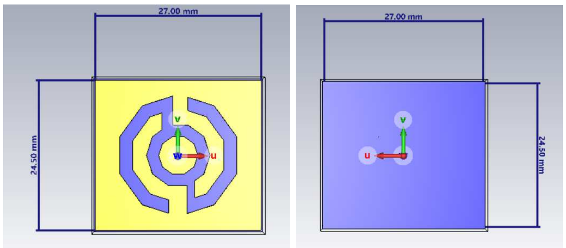


Figure 2. Decagonal C-shaped CSRR MTM unit cell.

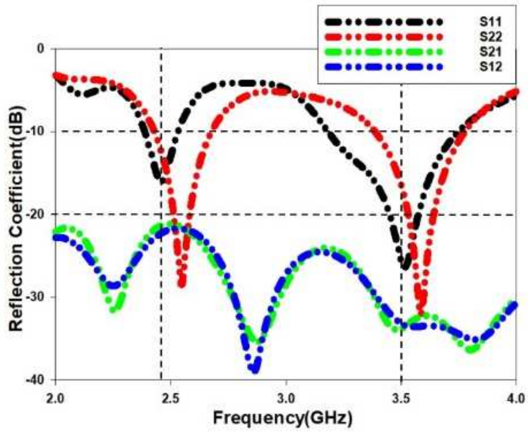


Figure 3. Simulated results for gap of $0.1\lambda_{guided}$ S11, S22, S21 and S12.

B. Realized Gain and Radiation Pattern

Figure 4 shows the comparison of the proposed MIMO antenna with and without MTM unit cell in terms of realized gain. The realized gain is enhanced by two times for lower band and 37.9% for upper band compared to the MIMO antenna without MTM [2], as shown in Figure 4. Figure 5 shows the antenna radiation pattern at both operating frequencies. The results show directive radiation of all elements at Port 1 and Port 2 with small back lobes.

C. MIMO Diversity Characterization

The MIMO antenna is further assessed by measuring the ECC (ρ_e) and DG in order to examine the correlation between antenna elements [2]. It can be observed that the ECCs are well below 0.001, satisfying the minimum value of ECC<0.5, as shown in Figure 6. DG is 10 dB for both bands.

Conclusion

This study introduces a dual-band textile antenna with MTM for MIMO applications, aiming to enhance gain with MC<-20 dB. Subsequent assessments of the proposed antenna by considering MIMO diversity analysis such as ECC, and DG, confirm its potential to be integrated to WLAN/ Wireless Body Area Network (WBAN) and the next generation of 5G wearable devices.

Acknowledgment

The authors would like to acknowledge the financial support under INTERES grant from Universiti Malaysia Perlis (UniMAP) [grant no. 9001-00752], and Songkhla Rajabhat University (SKRU) in collaboration with Keysight Southern (KS) Co. Ltd [grant no. 9008-00042]. KS Co. Ltd supports knowledge of the test and measurement for new technologies.

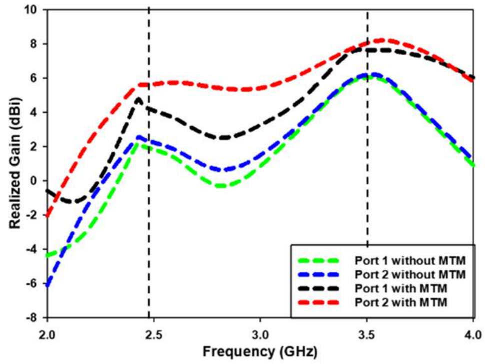
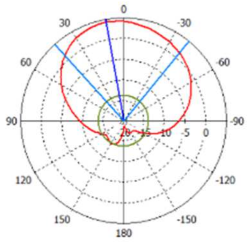
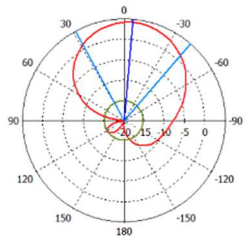


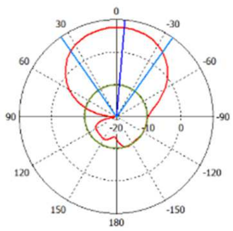
Figure 4. Realized gain of the proposed antenna and two-port MIMO antenna without MTM.



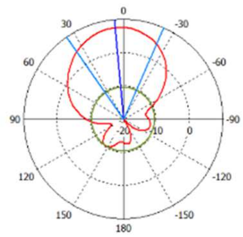
(a) Frequency= 2.45 GHz, E-Plane (port 1, φ =0°)



(b) Frequency= 2.45 GHz, E-Plane (port 1, φ =90°)

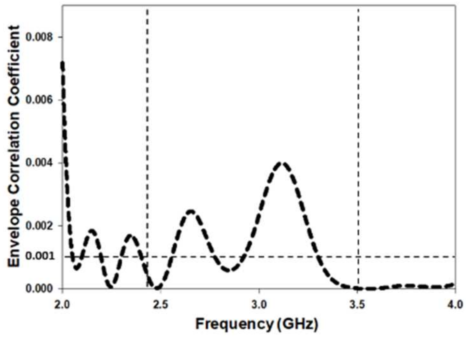


(c) Frequency= 3.5 GHz, E-Plane (port 1, φ =0°)



(d) Frequency= 3.5 GHz, E-Plane (port 1, φ =90°)

Figure 5. Radiation pattern of the proposed MIMO antenna.



(a)

Figure 6. MIMO diversity characterization on ECC.

References

[1] M. M. Hasan et al., "Gain and isolation enhancement of a wideband MIMO antenna using metasurface for 5G sub-6 GHz communication systems," Sci. Rep., vol. 12, Art. No: 9433, June 2022.

[2] H. A. Mashagba et al., "A hybrid mutual coupling reduction technique in a dual-band MIMO textile antenna for WBAN and 5G applications," IEEE Access, vol. 9, pp. 150768-15078, November 2021.

[3] Hossain, K. et al., "Decagonal C-shaped CSRR textile-based metamaterial for microwave applications," CMC-Comput. Mater. Contin, vol. 71, no. 1, pp. 1677-1693, 2022