International Journal of Communication Systems

WILEY

RESEARCH ARTICLE

Design and Development of a Triple-Band MIMO Antenna With Metamaterial for Wearable Applications

Hari Singh[1] | Sachin Kumar[2] | Kunal Srivastava[3] | Binod Kumar Kanaujia[4] | Ashwani Kumar[5] | Gunjan Srivastava[6] | Hala Mostafa[7] | Bhawna Goyal[8]

[1]Department of Electronics, Sri Venkateswara College, University of Delhi, New Delhi, India | [2]Department of Electronics and Communication Engineering, Galgotias College of Engineering and Technology, Greater Noida, India | [3]School of Computational and Integrative Sciences, Jawaharlal Nehru University, New Delhi, India | [4]Department of Electronics and Communication Engineering, Dr. B. R. Ambedkar National Institute of Technology, Jalandhar, India | [5]Department of Electronic Science, University of Delhi South Campus, New Delhi, India | [6]Department of Electronics and Communication Engineering, Graphic Era (Deemed to be) University, Dehradun, India | [7]Department of Information Technology, College of Computer and Information Sciences, Princess Nourah bint Abdulrahman University, Riyadh, Saudi Arabia | [8]University Centre for Research and Development, Chandigarh University, Mohali, Punjab, India

Correspondence: Sachin Kumar (gupta.sachin0708@gmail.com)

Received: 16 January 2026 | **Revised:** 3 March 2026 | **Accepted:** 16 March 2026

Keywords: circular polarization | meta-material | multiple-input–multiple-output | textile antenna | wearable

ABSTRACT

A compact triple-band two-element symmetric-meander line textile multiple-input–multiple-output (MIMO) antenna (S-MLTMA) with meta-material is presented for WBAN/WLAN/ISM/wearable applications. The S-MLTMA is comprised of two rectangular-shaped resonators and meander line structures that produce resonances at 2.45 GHz and 5.80 GHz. Under the S-MLTMA, a dual-band meta-material layer operating at 2.45 GHz and 5.80 GHz is introduced. The meta-material layer consists of six unit cells arranged in an array of 2×3. The meta-material offers circular polarization at 5.80 GHz and improves impedance matching at 4.05 GHz due to the additional current path at this frequency. The designed S-MLTMA offers an impedance matching bandwidth ($S11 \leq -10$ dB) in 2.42–2.57 GHz, 3.98–4.10 GHz, and 5.69–5.88 GHz bands, circular polarization in 5.74–5.85 GHz band, isolation greater than 24.2 dB, envelope correlation coefficient (ECC) < 0.24, diversity gain (DG) ~ 10.1 dB, total active reflective coefficient (TARC) < -10 dB, and multiplexing efficiency between ± 3.0. The peak gains of the antenna at frequencies 2.45 GHz, 4.05 GHz, and 5.80 GHz are 6.11 dBi, 5.81 dBi, and 6.09 dBi, respectively. The proposed antenna is also investigated for different human-body situations including specific absorption ratio (SAR). The size of the proposed S-MLTMA is 40.0 mm $\times$ 86.0 mm. The proposed antenna could be a good candidate for wearable electronic devices in body area networks due to its small size, all textile layers, easy integration into clothes, and reasonable off-body and on-body performances.

1 | Introduction

In recent years, there has been a significant upsurge in wearable device research for off-body, in-body, and on-body applications. The wearable electronic devices are used for numerous applications such as navigation, healthcare, sports monitoring, emergency search, military communication, remote identification, entertainment, fashion, biophysical/environmental parameters, and security systems [1–3]. Wearable antenna is an essential part of such devices. A wearable antenna should be flexible, compact, lightweight, cost-effective, robust, and maintenance-free. Textile antennas have gained popularity over non-textile antennas due to their easy integration with clothing [4].

© 2026 John Wiley & Sons Ltd.