Title: Miniaturized tri-band integrated microwave and millimeter-wave MIMO antenna loaded with metamaterial for 5G IoT applications

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Abstract: This study presents a revolutionary tri-band combined microwave (MW) and millimeter wave (MMW) multiple-input-multiple-output (MIMO) antenna. The antenna is built on a Rogers RT-5880 substrate with dimensions of 32 × 32 × 1.6 mm^3. This integration increased the isolation from 18 dB to 27 dB in the MW band and 28 dB–40 dB in the MMW band. The effective bandwidths for the MW and MMW bands were initially 3.3–3.7 GHz, 5.45–9.2 GHz, and 24–28 GHz, respectively. The MTM increased these bandwidths to 2.6–4.1 GHz, 5.3–11.3 GHz for the MW band, and 22.5–29.3 GHz for the MMW band. In addition, the realized gain increased significantly, from 1.5 dBi, 3.5 dBi, and 6.5 dBi to 4.5 dBi, 6.1 dBi, and 11 dBi at 3.5 GHz, 6.9 GHz, and 28 GHz. The antenna's overall efficiency increased by 10–12 % across all operational bandwidths. The suggested antenna has excellent diversity performance, with an envelope correlation coefficient of less than 0.0002, a diversity gain greater than 9.998, and a channel capacity loss of less than 0.12 bits/s/Hz. The proposed antenna addresses the increasing demand for IoT devices by efficiently supporting both MW and MMW frequency bands, offering high performance in wireless communication and modern infrastructures. The proposed design not only improves connectivity and efficiency in IoT devices but also supports the Sustainable Development Goals (SDGs) by contributing to the development of smart city infrastructure (SDG 11) and fostering innovation and sustainable industrial practices (SDG 9), thereby promoting sustainable development and industrial innovation.

Keywords: 5G internet of things, Microwave-millimeter waves, MIMO antenna, Sustainable cities, Metamaterials and metasurfaces, Sustainable development Goals (SDGs)

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