Design and analysis of a frequency reconfigurable hybrid fractal microstrip antenna with modified patch and ground plane for millimeter wave energy harvesting applications

Patan Imran KHAN [1] , Komera SUDHAKARU [1]
[1]Department of Electronics and Communication Engineering, St. Johns College of Engineering and Technology, JNTUA, Andhra Pradesh, 518360, India
Sigma J Eng Nat Sci 2026; 44(5): 3177-3194 DOI: 10.14744/sigma.2026.2150

Cite Article

Abstract

The rapid expansion of fifth-generation wireless systems and Internet of Things technologies has created a strong demand for energy-efficient and autonomous wireless devices. A key challenge in this domain is the design of compact and high-performance antennas capable of supporting millimeter-wave operation while enabling efficient radio frequency energy harvesting. In this work, a frequency-reconfigurable hybrid fractal microstrip antenna integrated with a defected ground structure is proposed to address these challenges. The antenna is reconfigurable at two different frequencies (29 GHz and 33 GHz) through the use of two PIN diodes, dynamically switching between multiple operating modes. The design is simulated using a full-wave electromagnetic solver, and experimentally verified with a fabricated prototype on a Rogers RT/duroid 5880 substrate. The proposed antenna exhibits a maximum achieved gain of 9.8 dBi in simulation and 9.12 dBi in measurement with high radiation efficiency of about 94%. It also shows wideband performance (25–35 GHz) and excellent polarization isolation (above 30 dB) in the reconfigurable mode. The obtained results are in a good agreement with simulations with small differences due to manufacturing and measurement tolerances. The novelty of this work is the synergistic integration of hybrid fractal geometry, defected ground structure and frequency reconfigurability based on PIN-diode in a single compact antenna offering higher gain, efficiency and operational flexibility over existing designs. The obtained results show that the proposed antenna is a potential candidate for integration into radio frequency energy harvesting systems and adaptive millimeter wave communication applications, which supports the development of next generation energy-autonomous wireless devices. The proposed antenna is suitable for integration into energy autonomous Internet of Things devices and adaptive fifth-generation wireless systems, enabling practical deployment in real-world scenarios.

Keywords: Defected Ground Structure; Energy Harvesting; Fifth- Generation; Fractal Antenna; Frequency Reconfigurable; Millimeter-Wave; Positive– Intrinsic–Negative Diode