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Smart Reconfigurable Antennas for IoT Applications

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Abstract: This research examines the design and efficacy of a frequency-reconfigurable antenna for Internet of Things (IoT) applications. The antenna is designed to function across many frequency bands and is reconfigurable to accommodate diverse communication standards and environmental circumstances. The antenna design comprises a monopole with a single PIN diode and a 50Ω feed line. The diode's state alteration enables the antenna to be adjusted for dual-band and wideband operation. The antenna's performance was assessed using simulation. The antenna exhibited effective impedance matching, satisfactory gain, and consistent emission patterns across many frequency bands. The antenna has modest dimensions of 26 mm by 19 mm by 1.6 mm. The frequency range is from 2.95 GHz to 8.2 GHz, whilst the dual-band mode encompasses 2.7-3.8 GHz and 4.57-7.4 GHz. The maximum gain is 1.57 dBi for the wideband mode exhibiting an omnidirectional radiation pattern. The maximum gain of the dual-band mode is 0.87 dBi at 3 GHz and 0.47 dBi at 6 GHz, exhibiting an omnidirectional radiation pattern.

Keywords: *Wideband Antenna, Dual-Band, Reflection Coefficient, IoT Applications.*

INTRODUCTION

A reconfigurable antenna is an antenna that may be electronically modified to function at various frequencies or radiation patterns. These antennas are designed to accommodate fluctuating signal environments, including varying frequencies, polarizations, or radiation directions. Reconfigurable antennas often include one or many tuning components, like varactors, PIN diodes, or MEMS (Micro-Electro-Mechanical Systems) switches, to alter their working frequency or radiation pattern. Altering the design of these components enables the antenna to be re-tuned for operation at various resonance frequencies or to modify its radiation pattern to concentrate energy in a particular direction. [1], [2]. Various configurations of reconfigurable microstrip antennas have been introduced in recent years [3], [7]. Microstrip antennas are extensively used due to their slim, economical, lightweight, and low-profile characteristics, rendering them ideal for space-constrained applications. applications [8], [9].

Reconfigurable antennas provide several benefits compared to conventional fixed antennas, such as enhanced flexibility, adaptability, and usefulness. They are applicable in several domains, including wireless communication systems, radar, and satellite systems, where their capacity to withstand adverse circumstances enhances the performance and dependability of the whole system. The design and execution of reconfigurable antennas pose significant challenges, including meticulous optimization of the antenna structure, tuning components, and control circuitry. Moreover, reconfigurable antennas may exhibit greater complexity and expense relative to fixed antennas [10].

Reconfigurable antennas may be used in Internet of Things (IoT) applications to adjust their functionality to fluctuating channel environments, hence enhancing wireless communication performance. In IoT systems, reconfigurable architectures

Antennae may facilitate devices to function across several frequency bands or communication protocols in response to changing environmental circumstances. The design of a frequency-reconfigurable multimode antenna requires meticulous consideration of several parameters, including frequency range, dimensions, bandwidth,

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gain, radiation pattern, impedance matching, cost, and tuning methodologies. The antenna must rapidly and effectively transition between various configurations while sustaining optimal performance regarding gain, efficiency, and radiation pattern [13]. Frequency reconfigurable multimode antennas provide a viable approach for wireless communications in IoT devices, allowing operation across several frequency bands and modes while adapting to variable channel circumstances. Below are some significant instances of IoT applications using reconfigurable antennas [14], [15], [16], [17]:

1. Smart homes and buildings: Reconfigurable antennas may adjust to various wireless communication protocols, like Wi-Fi, ZigBee, or Bluetooth, to guarantee dependable wireless connectivity among IoT devices.
2. Industrial IoT: Reconfigurable antennas facilitate wireless communication in adverse conditions characterized by significant interference or signal attenuation by modifying the antenna's emission pattern or frequency spectrum.
3. Healthcare: Reconfigurable antennas may enhance wireless communication dependability and minimize interference in wearable medical equipment, such as biosensors.

Agriculture: Reconfigurable antennas may enhance wireless communication in agricultural IoT systems, such as precision farming, by modifying the antenna's emission pattern to concentrate energy in a specified direction.

The design of reconfigurable antennas for IoT applications requires meticulous attention to communication protocols, frequency ranges, and the ambient circumstances in which the antenna functions. Recent years have seen substantial study on the deployment of multimode reconfigurable antennas for IoT purposes. These antennas are capable of functioning across many frequency bands and communication protocols, making them appropriate for diverse IoT applications.

In [14], the authors introduce a frequency-reconfigurable antenna that integrates an open loop filter with a hairpin bandpass filter. The reconfigurability is facilitated by PIN diodes under different switching circumstances, with the antenna intended to resonate at 2.47 GHz, 7.18 GHz, 12.14 GHz, 3.42 GHz, 14.55 GHz, and 8.4 GHz. A multipurpose small antenna with a programmable pattern was presented in [18]. The feeding network is modified, and the ground plane serves as a reflector to alter the pattern. The antenna is redesigned to resemble a credit card for compatibility with emerging Internet of Things devices. The proposed reconfigurable antenna utilizes four PIN diodes, and the configuration efficiencies are attained using an economical, lossy FR-4 substrate. A reconfigurable printed antenna for portable IoT applications was presented in [19]. A design for a smart-printed monopole antenna with an air gap separation and a hexagonal matching load (HML) is proposed. A coplanar waveguide feeds the patch, while two PIN diodes link the HML to the ground plane to regulate surface current movement and facilitate antenna reconfiguration. A low-profile frequency reconfigurable monopole antenna working in the microwave frequency range was proposed in [20]. The suggested configuration is fabricated on a FR-4 substrate, with four PIN diodes integrated between the transmitting patches to facilitate the exchange of various operational modes. The suggested design encompasses single, dual, and triple bands. At the designated resonant frequency (or frequencies), the engineered antenna exhibits a gain ranging from 1.2 to 3.6 dBi and an efficiency of 84%, with overall dimensions of $40 \times 32 \times 1.6$ mm^3. The antenna is applicable in both IoT-enabled systems in smart cities and contemporary portable fifth-generation (5G) devices, owing to its compact dimensions and compatibility with different wireless protocols.

These studies illustrate the potential of multimode reconfigurable antennas for Internet of Things applications. The reconfigurability of these antennas allows operation across numerous frequency bands and communication protocols, enhancing their flexibility and adaptability. The antennas' modest dimensions and broad functionality make them appropriate for many IoT devices. Nonetheless, further study is required to enhance the design and efficacy of these antennas and to assess their performance in practical IoT applications.

This article proposes a tiny frequency-reconfigurable antenna for IoT applications. A solitary PIN diode is used to adjust the current of the radiating patch, hence facilitating a wideband mode in the ON state. The OFF state of the PIN diode produces two monopoles of varying lengths, enabling the antenna to function in dual-band mode. The diode is situated on a groove etched onto the antenna patch to modify the electrical length of the radiating element by adjusting the surface current distribution based on its state. The antenna dimensions are 26 mm x 19 mm × 1.6 mm, with two operational modes. The operating range for the ON-state is 2.95 to 8.2 GHz, while the OFF-state offers dual-band functionality at 3 GHz and 6 GHz for WiMAX and WLAN applications. Section II delineates the stages involved in the design of the proposed frequency reconfigurable antenna. Section III delineates the configurations of PIN diodes, their states, and their operational modes. Figure illustrates the configuration of the proposed antenna. A monopole patch antenna is used to achieve a broad bandwidth, distinguished by its partial ground plane. The configuration of the monopole patch antenna generally comprises the following principal components: radiating element, ground plane, dielectric substrate, and feed line. The radiating element is a metallic patch situated on the upper layer of a dielectric substrate. The rectangular metal patch of the proposed antenna is supplied via a microstrip line in the upper layer of the substrate. The ground plane of a monopole patch antenna is a conductive layer situated on the inferior layer of the dielectric substrate. The ground plane functions as a reflective surface for electromagnetic radiation emitted by the patch. The dielectric substrate is an insulating substance that separates the radiating

A parametric research has been conducted in Section IV to identify the best parameter values for the proposed design. Section V discusses the simulated results of the proposed antenna, along with a comparison to pertinent studies. Section VI encapsulated this work succinctly.

ANTENNA DESIGN

element from the ground plane. The feed line is a transmission line connecting the monopole patch antenna to the transmitter or receiver. The foundational design is derived from the fundamental configuration of the rectangular monopole antenna seen in Fig. 2(a), using the economical FR4 substrate, characterized by a dielectric constant of 4.3, a loss tangent of 0.025, and a thickness of 1.6 mm. The characteristic impedance of the microstrip feed line is established at 50 Ω. The proposed antenna's total dimensions are 26mm × 19mm, with the basic values detailed in Table I. Figure 2(b) illustrates the reflection coefficient of the first design, with a -10dB bandwidth spanning from 2.98 to 8.37 GHz. The standard design formulae for the initial monopole antenna with a center frequency of fo=3.5 GHz are as follows [21]:

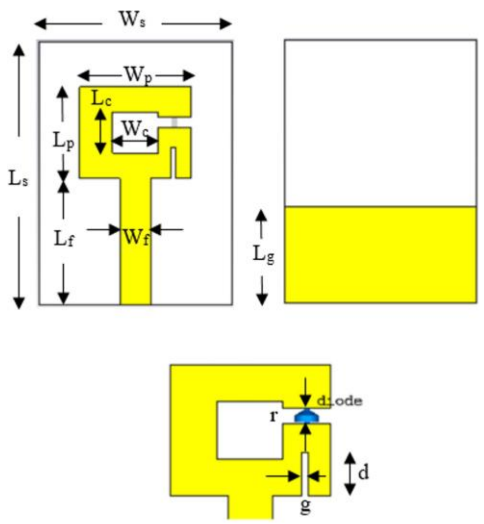


Fig. 1. The proposed antenna structure.

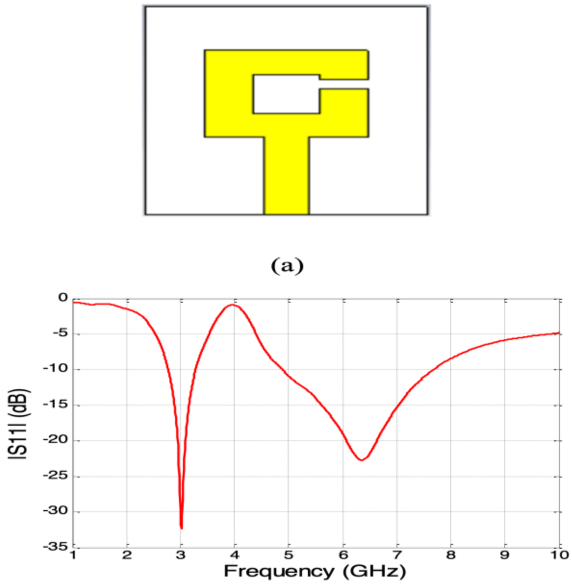
TABLE I.The initial dimensions of the proposed antenna

Parameter	Dimension (mm)	Parameter	Dimension (mm)
W_s	19	L_p	9
L_s	26	L_f	12
L_g	9.5	W_f	3
W_p	11		

PARAMETRIC STUDY

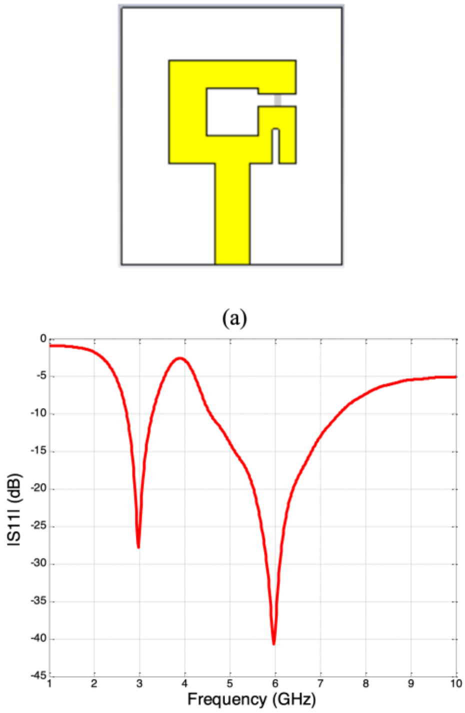
The dimensions of an antenna are crucial in defining its operational features, such as radiation pattern, bandwidth, and impedance matching. The specified measurements include the length and breadth of the radiator, the length of the partial ground, the dimensions of the feed line, and the length and width of the slits.

The introduction of a slit in the antenna radiator substantially affects the antenna's operational properties.



(b)

Fig. 2. (a) A small slit for integrating diode and (b) the reflection coefficient response.



(b)

Fig. 3. (a) The second slit on the lower corner and (b) The reflection coefficient response.

Figure illustrates the influence of slit width g and slit length d on the reflection coefficient response of the antenna in the ON state. Figure 8 illustrates the influence of slit width g and slit length d on the OFF-state antenna reflection coefficient response. The dual-band response and the wideband response are both influenced by the fluctuation of the parameter d. In wideband mode, the bandwidth diminishes as the value of d grows. In dual-band mode, it regulates the matching of the secondary resonant frequency due to the slit being positioned at the shorter monopole, which is responsible for generating that frequency. At a distance of 3mm, a broad bandwidth for the wideband mode and favorable matching qualities for the dual-band mode are assured. In both wideband and dualband configurations, the parameter g has little impact on both modes; nevertheless, g=0.5 mm yields superior matching compared to other values, particularly at the second resonant frequency.

Antenna dimensions are essential elements that must be tuned to get the appropriate operational characteristics.

A meticulous parametric analysis of antenna dimensions may facilitate the design of antennas that are efficient, small, and optimally suited for IoT applications. The final construction of the proposed antenna is optimized, as shown in Table II, based on the parametric research. The CST Microwave Studio program is used to get all simulation results [23].

RESULTS

Figure 9 depicts the antenna reflection coefficient in the diode ON-state. The -10 dB bandwidth of the antenna spans from 2.95 GHz to 8.2 GHz. In the OFF state, the effective length of the radiator is modified due to changes in surface current distribution, resulting in a dual-band response that resonates at 3 GHz and 6 GHz, with reflection coefficient values of -27.78 dB and -40.7 dB, respectively, as illustrated in Fig. 10. The fractional bandwidths are 19% at 3 GHz and 47% at 6 GHz.

Figure illustrates the predicted surface current distributions of the proposed antenna in the OFF state. At 3 GHz, the bulk of the current is focused in the longer monopole, but at 6 GHz, it is mostly concentrated in the shorter monopole and the lower slit. Furthermore, Fig. 12 illustrates the suggested antenna's surface current distributions in the ON-state at the three resonant frequencies. The initial resonant frequency yields a current that encompasses the whole patch. Concurrently, the second and third resonant frequencies produce current concentrations in two and three distinct locations, respectively, along the patch's edge.

CONCLUSION

This work presents the design of a small frequency-reconfigurable antenna with dual-band and wideband operating modes. The antenna patch structure is altered based on the ON and OFF states of the PIN diode. The antenna operates in dual frequency bands of 3 GHz and 6 GHz while the switch is in the OFF position. Simultaneously, the antenna functions in wideband mode when the PIN diode is in the ON state.
The wideband mode exhibits a peak realized gain of 1.57 dBi with an omnidirectional radiation pattern, while the dual-band mode achieves a peak gain of 0.85 dBi, again with an omnidirectional radiation pattern. These findings render the antenna highly compatible with portable IoT WIMAX and WLAN devices. The suggested antenna has many benefits, including compact dimensions, affordability, and straightforward design, rendering it appropriate for integration with various IoT devices.

References:

[1] . Duaa H. Abdulzahra *, Falih M. Alnahwi, Abdulkareem S. Abdullah, Design of CompactWideband/Bi-Band Frequency, Reconfigurable Antenna for IoT Applications, Iraqi Journal for Electrical and Electronic Engineering, Vol. 19 | Issue 2 | December 2023

[2] Alnahwi, A. Abdulhameed, and A. Abdullah, "A com- pact integrated uwb/reconfigurable microstrip antenna for interweave cognitive radio applications," *Interna- tional Journal on Communications Antenna and Propa- gation*, vol. 8, pp. 81–86, 2018.

[3] L. Ge and K. Luk, "A band-reconfigurable antenna based on directed dipole," *IEEE Transactions on Antennas Propagation*, vol. 62, no. 1, pp. 64–71, Jan. 2014.

[4] A. Boufrioua, "Smart miniaturized wideband/multiband and reconfigurable antennas for modern applications," *Nova Science Publishers, Incorporated*, 2018.

[5] G. Jin, C. Deng, J. Yang, Y. Xu, and S. Liao, "A new differentially-fed frequency reconfigurable antenna for wlan and sub-6ghz 5g applications," *IEEE Access*, vol. 7,

pp. 56539–56546, 2019.
[6] C. Wang, J. C. Yeo, H. Chu, C. T. Lim, and Y. Guo, "De- sign of a reconfigurable patch antenna using the move- ment of liquid metal," *IEEE Antennas Wireless Propa- gation Letter*, vol. 17, no. 6, pp. 974–977, Jun. 2018.
[7] W. A. Awan, N. Hussain, S. A. Naqvi, A. Iqbal,
R. Striker, D. Mitra, and B. D. Braaten, "A minia- turized wideband and multi-band on-demand reconfig- urable antenna for compact and portable devices," *AEU- International Journal of Electronics and Communica- tions*, vol. 122, p. 153266, 2020.
[8] F. Juma'a and F. Alnahwi, "Design and simulation of butterfly-shaped filtenna with dual band notch for portable uwb applications," *Iraqi Journal for Electri- cal and Electronic Engineering*, vol. 17, no. 1, pp. 1–7, 2021.
[9] N. E. Abdulhussein and A. S. Abdullah, "Design of a wide dual-band coplanar probe feed antenna for wlans applications," *In the 3rd Scientific Conference of Electri- cal and Electronic Engineering Researches (SCEEER)*,
pp. 13–16, 2020.
[10] A. Ghaffar, X. J. Li, W. A. Awan, S. I. Naqvi, N. Hus- sain, B. C. Seet, M. Alibakhshikenari, F. Falcone, and
E. Limiti, "Design and realization of a frequency recon- figurable multimode antenna for ism, 5g-sub-6-ghz, and s-band applications," *Applied Sciences*, vol. 11, no. 4,
p. 1635, 2021.
[11] F. M. Alnahwi, A. A. Abdulhameed, H. L. Swadi, and
A. S. Abdullah, "A planar integrated uwb/reconfigurable antenna with continuous and wide frequency tuning range for interweave cognitive radio applications," *Ira- nian Journal of Science and Technology, Transactions of Electrical Engineering*, vol. 44, no. 2, pp. 729–739,
2020.
[12] F. Alnahwi, A. Abdulhameed, H. Swadi, and A. Abdul- lah, "A compact wide-slot uwb antennawith reconfig- urable and sharp dual-band notches for underlay cog- nitive radio applications," *Turkish Journal of Electri- cal Engineering and Computer Sciences*, vol. 27, no. 1,
pp. 94–105, 2019.