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Compact Single-Switch Reconfigurable Patch Antenna with Multi-Band Operation for Wireless Systems

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Abstract: A compact frequency-reconfigurable patch antenna is proposed for multi-band wireless applications. The antenna is designed on a single-layer FR4 substrate (24 × 30 mm²) with a partial ground plane on the same side as the radiator. By using a single copper-strip switch, the structure achieves four measured resonances at 2.45, 3.8, 10.7, and 13 GHz while remaining simple and cost-effective. The measured results show excellent impedance matching, with reflection coefficients (S11) below −25 dB and standing wave ratio values less than 2 at all operating frequencies. Unlike conventional designs requiring multiple switches or biasing circuits, the proposed configuration reduces design complexity and overall antenna size. It also provides stable quasi-omnidirectional radiation patterns, ensuring consistent performance across different scenarios. With its compact footprint, frequency agility, and reliable radiation, this antenna is well suited for Sub-6 GHz 5G, radar, and biomedical communication systems. In addition, its adaptability makes it a promising candidate for emerging applications such as Internet of Things and wearable devices, where compactness and versatility are critical.

Keywords: Reconfigurable antenna, Multi-band, Frequency agility, Compact design, Wireless communication

Introduction

The demand for reconfigurable antennas has been increasing remarkably due to their ability to adapt dynamically to the changing requirements of modern communication systems (Karthika & Kavitha, 2021; Zhang et al., 2024).These antennas can adjust several parameters—such as radiation pattern, bandwidth, gain, and polarization-thereby improving their adaptability to diverse communication environments (Shereen et al., 2022).Reconfigurability is commonly achieved using RF PIN diodes, varactor diodes, and Radio Frequency Microelectromechanical System (RF MEMS) switches (El Aoud et al., 2024; Gao et al., 2025; Marzouk et al., 2025).One of the main advantages of these antennas lies in their ability to support multiple functionalities within a compact and lightweight configuration (Awan et al., 2024; Khan et al., 2024; Saraswat & Kumar, 2020). This characteristic is particularly beneficial in systems where space and weight are constrained, such as mobile devices, satellite communications, and military platforms. By substituting several fixed-function antennas with a single reconfigurable unit, both system complexity and overall cost can be considerably reduced (Karthika & Kavitha, 2023; Chung et al., 2024)

Among the various types, frequency-reconfigurable antennas are capable of dynamically altering their operating frequency to cover multiple communication bands. This capability minimizes the need for additional filters to suppress unwanted frequencies (Benkhadda et al., 2024; Kareem Al-Gertany et al., 2021). Furthermore, these

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antennas play a crucial role in modern wireless systems that must operate over several frequency bands to support emerging technologies such as 5G, LTE, the Internet of Things (IoT), and satellite communications (Abdulhussein et al., 2023).

In recent years, various frequency-reconfigurable antenna designs have been proposed to meet the growing requirements of multiband wireless communication. Rakesh Kumar et al. (2023) presented an FR-4 patch antenna incorporating a defective ground structure and three switches to achieve eight operating bands; however, the use of multiple switches increases design complexity and necessitates additional bias networks. Similarly. (Ali et al., 2025) developed a compact multi-mode antenna for C-band, Sub-6 GHz 5G, and ISM applications using PIN diodes, though the associated biasing networks and diode losses reduce radiation efficiency. In another study, (Wang et al., 2023) introduced a graphene-based reconfigurable patch antenna with tunability between 29 and 40 GHz; nevertheless, its dependence on advanced materials and high bias voltages limits its suitability for cost-effective applications.(Bayer Keskin et al., 2025) also proposed a UWB/Ku-band monopole antenna employing PIN diodes that provides an ultrawide bandwidth but suffers from limited gain and increased fabrication complexity due to the defected ground structure.

Based on the above discussion, it is clear that most existing frequency-reconfigurable antennas rely on multiple switches, complex biasing circuits, or offer limited tuning ranges. To address these limitations, this paper proposes a compact reconfigurable patch antenna that achieves four measured resonances (2.45, 3.8, 10.7, and 13 GHz) using only a single copper-strip switch. The design combines low cost, compact size, and high gain, making it suitable for Sub-6 GHz, 5G, radar, and biomedical applications. The remainder of this paper is organized as follows: Section II presents the antenna design and methodology, Section III discusses the measured and simulated results, and Section IV concludes the work.

Method

Proposed Antenna Design

The proposed antenna is a compact microstrip patch with a partial ground plane and a single switching element for multi-band operation. It is implemented on an FR4 substrate ($\varepsilon r = 4.3$, $\tan\delta = 0.025$) with dimensions of 30 × 24 mm² and a thickness of 1.6 mm. The antenna is excited by a 2 mm-wide microstrip feed line, while the switch is represented by a 1 × 1 mm² copper square, emulating a PIN diode. An 8 mm partial ground plane and a slot near the feed are introduced to improve impedance bandwidth and current distribution. The structure is single-port, compact, and simulated in CST Microwave Studio. The geometry of the antenna is illustrated in **Fig. 1**.

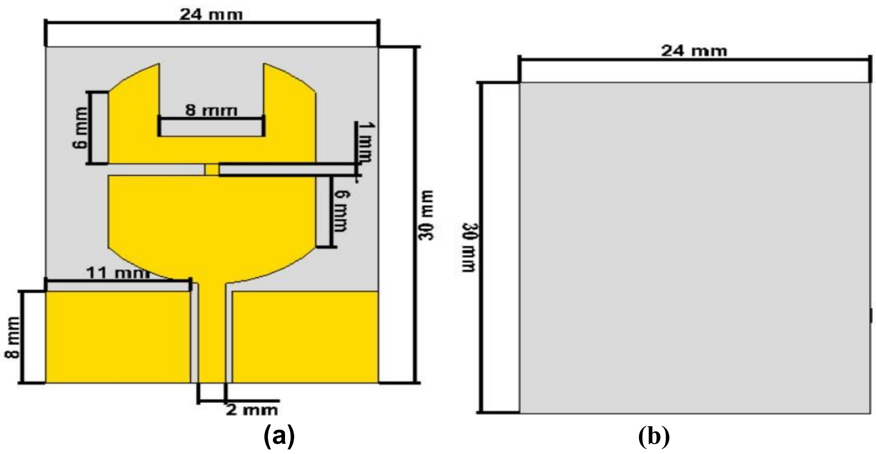
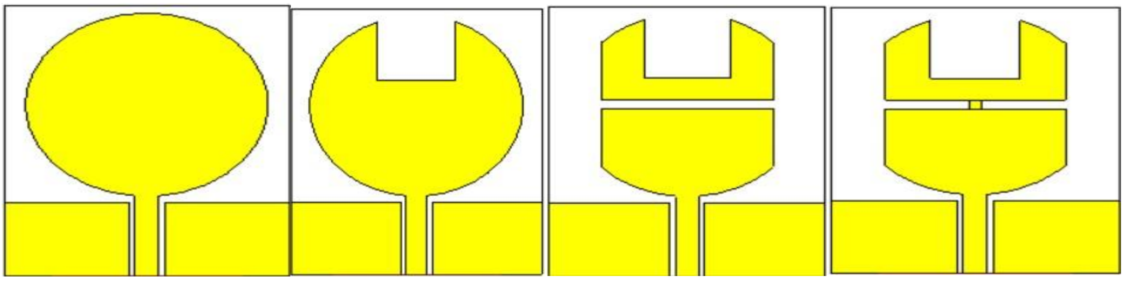


Figure 1. The proposed antenna; (a) top view (b) bottom view .

Development of Single Antenna Element

The proposed antenna design was developed through a step-by-step evolution process. The initial structure (Step 1) consists of a simple circular patch fed by a microstrip line. In Step 2, a notch was introduced at the top of the patch to improve impedance matching. In Step 3, the circular geometry was modified into a rectangular shape with slots, enhancing resonance characteristics. Finally, in Step 4, an additional section was added to the radiator, which enabled wider bandwidth and stable multiband operation. The complete design evolution is illustrated in Fig. 2



(a) (b) (c) (d)

Figure 2. Evolution of the antenna design: (a) Step 1 – initial circular patch, (b) Step 2 – notched circular patch, (c) Step 3 – modified rectangular patch, (d) Step 4 – final proposed antenna

Principle of Reconfiguration

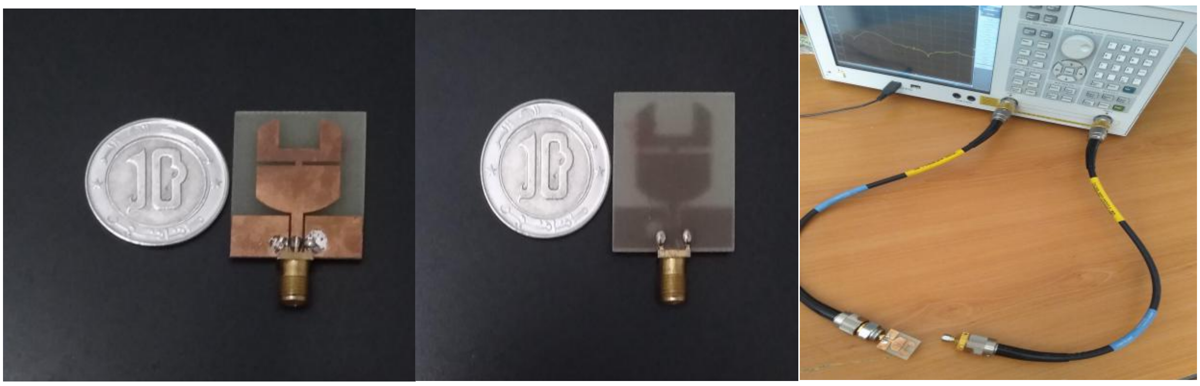
The proposed antenna achieves frequency reconfiguration through a simple structural approach. Instead of employing active components such as PIN diodes or varactors, a small copper strip is inserted between the feedline and the outer radiating element. By connecting or disconnecting this strip, the effective current distribution and electrical length of the antenna are modified, resulting in a shift of the resonance frequency. This method provides a cost-effective and reliable solution while avoiding the biasing circuits and complexity usually required for reconfigurable designs.

Simulation Setup

The proposed antenna design was simulated using CST Microwave Studio. The finite integration technique (FIT) was employed to solve Maxwell's equations in the frequency domain. Open boundary conditions were applied to mimic free-space propagation. The frequency range of interest was set to cover both the ISM and sub-6 GHz bands. The simulation setup included the definition of the excitation port, mesh refinement for accurate results, and monitoring of key parameters such as reflection coefficient (S11), radiation patterns, SWR, and efficiency.

Results and Discussion

To validate the simulation performance, the prototype of the proposed antenna was fabricated and measured. The measurements were conducted using the E5071 ENA series Vector Network Analyzer (VNA).



(a) (b) (c)

Figure 3. Fabricated antenna prototype: (a) top view, (b) bottom view, and (c) measurement setup with VNA

The measured reflection coefficient shows resonances at 2.45 GHz, 3.8 GHz, 10.7 GHz, and 13 GHz. Compared to the simulated results, slight frequency shifts can be observed, especially at higher frequencies. These discrepancies can be attributed to production inaccuracies, substrate parameter variations, and connector effects.

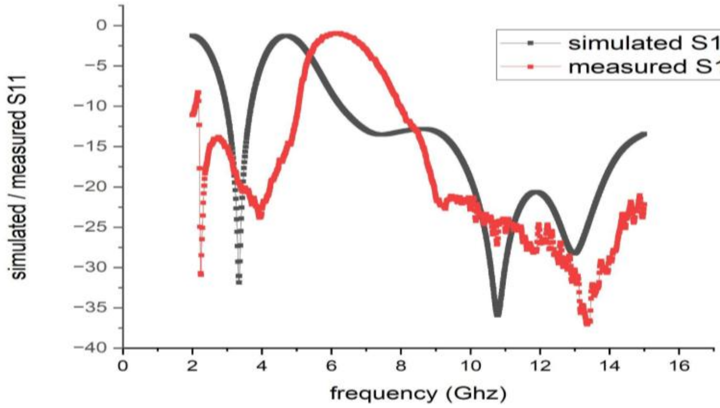


Figure 4. Simulated and measured S11 of the proposed antenna

Simulated and Measured VSWR Performance

Figure 5 illustrates the simulated and measured VSWR of the proposed antenna. The results show that the VSWR remains below the acceptable threshold of 2 across the operating frequency bands. A slight shift is observed between the simulated and measured responses, which can be attributed to connector losses, and measurement conditions.

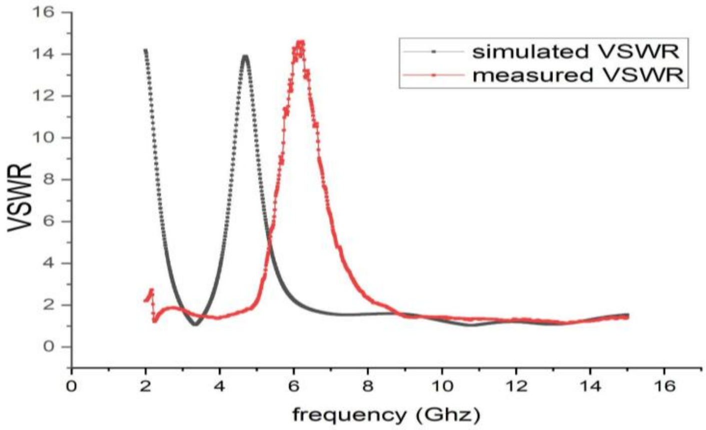
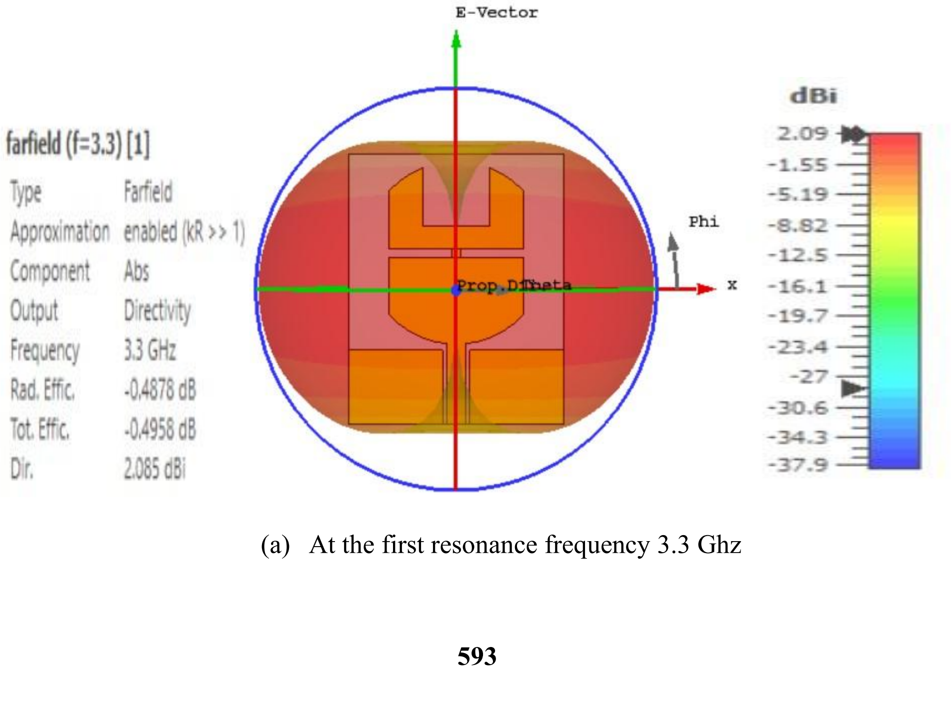
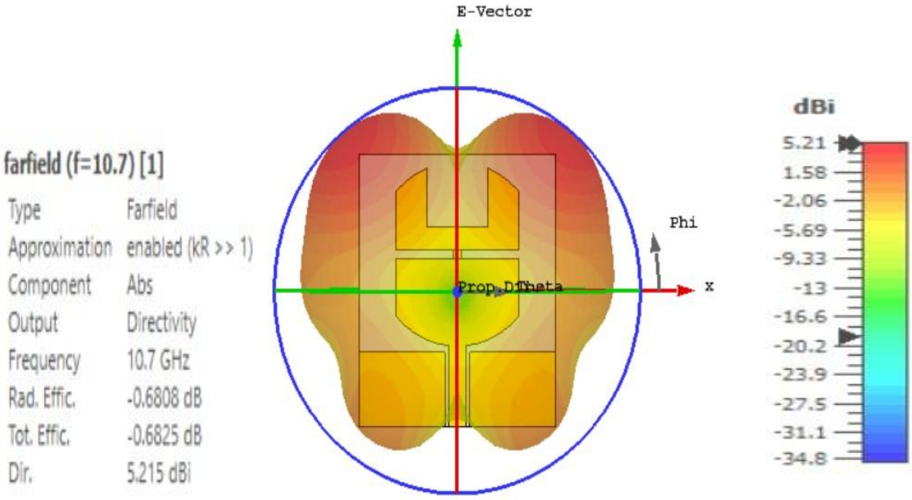


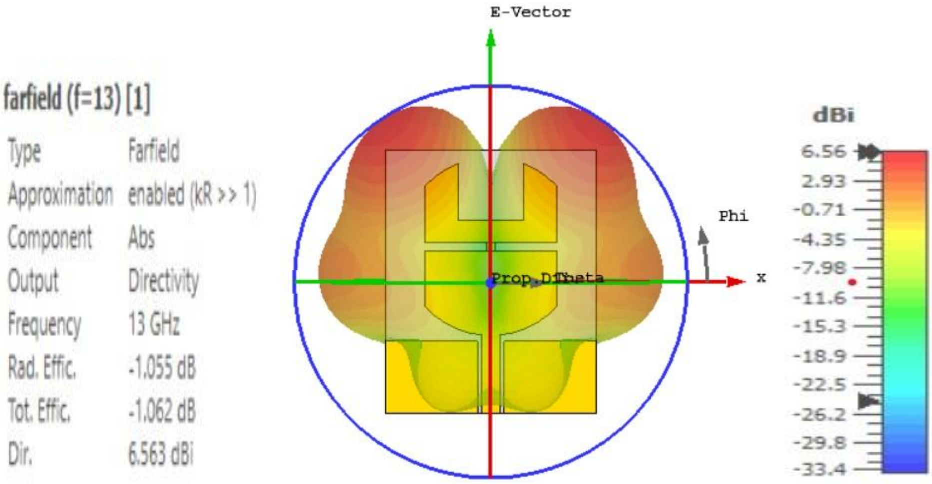
Figure 5. Simulated and measured VSWR of the proposed antenna



(a) At the first resonance frequency 3.3 Ghz



(b) At the second resonance frequency 10.7 Ghz



(c) At the third resonance frequency 13 Ghz

Figure 6. Radiation patterns of the proposed antenna at different resonance frequencie

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Conclusion

This paper has presented the development of a compact frequency-reconfigurable patch antenna realized on a low-cost FR4 substrate. By employing a single copper-strip switch, the design succeeds in providing multi-band operation without the complexity of multiple switching elements or intricate biasing networks. The proposed structure not only reduces hardware complexity and footprint but also ensures reliable impedance matching, efficient radiation behavior, and adequate gain across all targeted frequency bands. Overall, the achieved results highlight the antenna's potential as a practical solution for emerging wireless platforms, particularly in Sub-6 GHz 5G connectivity, radar sensing, and biomedical communication systems.

Recommendations

The proposed compact reconfigurable antenna demonstrates reliable performance across four frequency bands with a simplified switching mechanism. It is recommended for practical deployment in Sub-6 GHz 5G modules, compact radar units, and biomedical devices where size and cost constraints are critical. Future implementations may further benefit from integrating an actual PIN diode instead of the copper-strip emulation, as well as exploring flexible substrates to enable wearable or implantable use cases.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

Conflict of Interest

* The authors declare that they have no conflicts of interest

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References

Abdulhussein, A. J., Farhan, M. J., & Ali, G. M. (2023). Design and implementation of a frequency reconfigurable antenna using PIN switch for sub-6 GHz applications. *Open Engineering, 13*(1), 20220453.

Ali, E. M., Awan, W. A., Abbas, A., Abbas, S. M., & Mohamed, H. G. (2025). Compact frequency-agile and mode-reconfigurable antenna for C-band, sub-6-GHz-5G, and ISM applications. *Micromachines, 16*(6), 724.

Awan, W. A., Islam, T., N. Alsunaydih, F., Alsaleem, F., & Alhassoonc, K. (2024). Dual-band MIMO antenna with low mutual coupling for 2.4/5.8 GHz communication and wearable technologies. *PLOS ONE, 19*(4), e0301924.

Bayer Keskin, S. E., Koziel, S., & Szczepanski, S. (2025). Frequency reconfigurable PIN diode-based Reuleaux-triangle-shaped monopole antenna for UWB/Ku band applications. *Scientific Reports, 15*(1), 6555.

Benkhadda, O., Saih, M., Reha, A., Ahmad, S., Chaji, K., Singh, H., & Al-Gburi, A. J. A. (2024). A miniaturized reconfigurable antenna for modern wireless applications with broadband and multi-band capabilities. *Progress In Electromagnetics Research M, 127*, 93–101.

Chung, M.-A., Lin, C.-W., Yang, C.-W., & Meiy, I.-P. (2024). Wearable reconfigurable antennas with multi-mode switching for sub-6GHz, V-band, and D-band applications. *IEEE Access, 12*, 115448–115464.

El Aoud, S. E., Abbaoui, H., Benkhadda, O., Attioui, S., El Assri, N., Ibnyaich, S., Zeroual, A., Ismail, M. M., & Al-Gburi, A. J. A. (2024). Design of a crescent moon-shaped reconfigurable patch antenna using a PIN diode for 5G sub-6 GHz and multistandard wireless applications. *Progress In Electromagnetics Research B, 109*, 81–93.

Gao, M., Yuan, H., Nan, J., Niu, H., & Ge, C. (2025). A dual-port millimeter-wave frequency reconfigurable array antenna. *Progress In Electromagnetics Research C, 154*, 221-228.

Kareem Al-Gertany, Q. H., Farhan, M. J., & Jasim, A. K. (2021). Design and analysis a frequency reconfigurable octagonal ring-shaped quad-port dual-band antenna based on a varactor diode. *Progress In Electromagnetics Research C, 116*, 235-248.

Karthika, K., & Kavitha, K. (2021). Reconfigurable antennas for advanced wireless communications: A review. *Wireless Personal Communications, 120*(4), 2711-2771.

Karthika, K., & Kavitha, K. (2023). Design and development of parasitic elements loaded quadband frequency and pattern reconfigurable antenna. *International Journal of RF and Microwave Computer-Aided Engineering, 2023*, 1-10.

Khan, S. F., Khan, B. M., & Mairaj Rasool Khan, T. (2024). Low profile high gain RHCP antenna for L-Band and S-Band using rectangular ring metasurface with backlobe suppression. *PLOS ONE, 19*(2), e0297957.

Marzouk, M., Nejdi, I. H., Rhazi, Y., Saih, M., Nasir, J. A., Daher, A., Hussein, M. I., Zakaria, Z., & Al-Gburi, A. J. A. (2025). Low-profile reconfigurable UWB fractal antenna enhanced by parasitic elements for wireless applications. *Progress In Electromagnetics Research Letters, 126*, 37-48.

Rakesh Kumar, P., Sunitha, P., & Prasad, M. V. S. (2023). Compact reconfigurable patch antenna for wirelesss applications. *Progress ın Electromagnetics Research C, 138*, 161-174.

Saraswat, R. K., & Kumar, M. (2020). A metamaterial loaded hybrid fractal multiband antenna for wireless applications with frequency band reconfigurability characteristics. *Frequenz, 74*(11–12), 401-416.

Shereen, M. K., Khattak, M. I., Zubir, F., & Basit, A. (2022). A novel single-feed hybrid reconfigurable microstrip patch antenna for 5G mobile communication and radio frequency energy harvesting applications at 28/38GHz. *PLOS ONE, 17*(1), e0260407.

Wang, X., Wu, L., Chen, H., Wang, W., & Liu, Z. (2023). Frequency-reconfigurable microstrip patch antenna based on graphene film. *Electronics, 12*(10), 2307.

Zhang, M., Xu, G., & Gao, R. (2024). Reconfigurable antennas for wireless communication: Design mechanism, state of the art, challenges, and future perspectives. *International Journal of Antennas and Propagation, 2024*(1), 3046393.

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