

Design and Performance Analysis of Frequency Reconfigurable Monopole Antenna

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Abstract — This paper aims to design and analyze a frequency reconfigurable printed monopole antenna incorporating a parasitic radiator. The antenna is specifically intended for applications in WLAN and Satellite communication. The antenna structure is constructed using a printed strip line, and a parasitic radiator is connected to the patch using a PIN diode. The proposed design is simulated using ANSYS HFSS. The PIN diode is modeled using HFSS as a switch to achieve frequency reconfiguration. The measured -10dB bandwidth for the reflection coefficient spans from 5.4 to 5.6GHz and 7 to 7.8GHz. These bandwidths align with the requirements for WLAN and satellite band applications, demonstrating the antenna's suitability for these communication purposes. This paper introduces a frequency reconfigurable printed monopole antenna with a parasitic radiator, offering versatility for WLAN and satellite applications. The utilization of a PIN diode as a switch for frequency tuning adds a novel aspect to the design, contributing to its adaptability and performance.

Keywords: Frequency Reconfigurable Monopole Antenna, WLAN and Satellite Communication

I. INTRODUCTION

Frequency reconfigurable antennas play a crucial role in modern wireless communication systems by offering the flexibility to adapt to various frequency bands. These antennas can dynamically adjust their operating frequencies, enabling compatibility with diverse communication standards and applications. The importance of frequency reconfigurable antennas lies in their ability to enhance spectrum efficiency, reduce interference, and optimize communication performance in dynamic and evolving wireless environments. By providing adaptability to changing frequency requirements, these antennas contribute to the efficient utilization of available spectrum resources, thereby supporting the ever-growing demand for wireless connectivity in applications such as mobile communication, satellite communication, and wireless local area networks (WLANs). Their versatility makes them valuable components in addressing the challenges posed by the increasing complexity and diversity of wireless communication systems.

Frequency reconfiguration in antennas can be achieved through various methods, each offering distinct advantages and trade-offs. One common approach involves the use of tunable components such as varactors or PIN diodes [2-5]. By incorporating these tunable elements into the antenna structure, the electrical length of certain segments can be dynamically altered, leading to a change in the resonant frequency. For example, PIN diodes can be strategically placed in the antenna design to switch between

different configurations, effectively changing the operating frequency. This method provides a practical means of achieving frequency reconfiguration with relatively simple control mechanisms.

Another method involves the use of metamaterials or reconfigurable materials in the antenna structure [6-10]. Metamaterials are engineered materials with unique electromagnetic properties not found in nature. By incorporating these materials into the antenna design, it's possible to manipulate the propagation of electromagnetic waves and, consequently, achieve frequency tuning. Reconfigurable materials, such as liquid crystals or ferroelectric materials, can change their electrical properties under external stimuli, allowing for dynamic control over the antenna's resonant frequency. This approach offers a more sophisticated means of achieving frequency reconfiguration, often providing better performance but at the cost of increased complexity in material integration and control systems. Both methods contribute to the development of versatile antennas capable of adapting to a range of communication standards and frequency bands.

This paper aims to present and discuss the design, simulation, and experimental findings of a frequency reconfigurable printed monopole antenna with a parasitic radiator. The primary objective of this research is to explore the antenna's suitability for WLAN and Satellite applications through the use of a PIN diode for frequency tuning. The proposed structure, constructed with a printed strip line and a parasitic radiator, is simulated using ANSYS HFSS, while the PIN diode is modeled as a switch to achieve frequency reconfiguration. The paper will delve into the measured -10dB bandwidth for the reflection coefficient, spanning from 5.4 to 5.6GHz and 7 to 7.8GHz, demonstrating its compatibility with WLAN and satellite band requirements.

II. METHODOLOGY

In the development of a frequency reconfigurable monopole antenna designed for wireless applications, ANSYS HFSS was utilized to create the antenna structure. The antenna is specifically designed on an FR4 epoxy substrate, known for its cost-effectiveness and widespread availability, possessing a relative permittivity of 4.4 and a dielectric loss tangent of 0.02. The dimensions of the rectangular patch are specified as 9mm x 9mm x 0.1mm, while the substrate is 15mm x 17mm x 1mm. The partial ground plane, measuring 5mm x 15mm x 0.1mm, enhances the antenna's performance. To achieve frequency reconfiguration for wireless applications, a parasitic element (radiator) is introduced atop the rectangular patch, with dimensions of 8.8mm x 0.5mm x 0.1mm. The dimensions of the parasitic element are carefully tuned to achieve the desired frequency reconfiguration, particularly

tailored for WLAN applications. Crucially, a PIN diode is incorporated into the design, serving as a switch to facilitate the dynamic adjustment of frequencies, enhancing the antenna's adaptability and performance in various wireless communication scenarios.

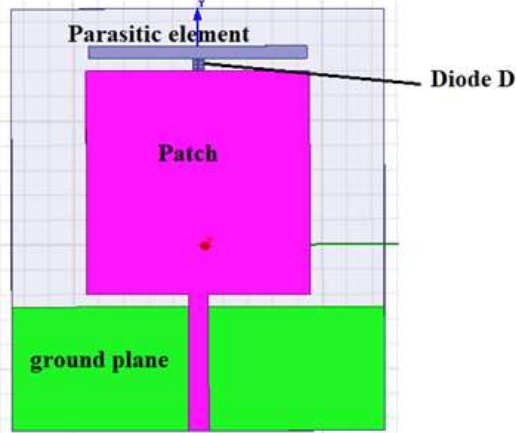


Fig. 1: Proposed Reconfigurable Antenna

III. RESULTS AND DISCUSSIONS

The design (Fig. 1) closely resembles the condition when the diode is in the ON state. In terms of antenna performance, it is imperative for the return loss to exceed -10dB across the entire operating bandwidth, a standard requirement in communication applications. The simulated return loss plot, depicted in Fig. 2, serves as a visual representation of the antenna's performance characteristics, providing insights into its ability to efficiently handle signals and communicate effectively within the specified frequency range.

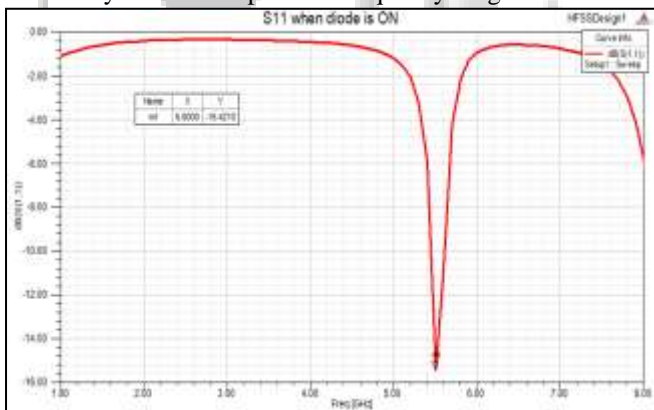


Fig. 2: Return Loss when diode is ON

In Fig. 2, the antenna demonstrates a notably low return loss, registering at -15.42dB specifically at 5.5GHz. This observation indicates an enhanced efficiency of the antenna at this particular frequency. In the process of calculating the overall bandwidth, attention is directed towards identifying specific frequencies where the curves intersect the $S_{11} = -10\text{dB}$ line. In this case, the critical frequencies are pinpointed at 5.4GHz and 5.6GHz. Consequently, the determined bandwidth of the antenna system is calculated to be 0.2 GHz, providing crucial insights into its operational range and frequency coverage.

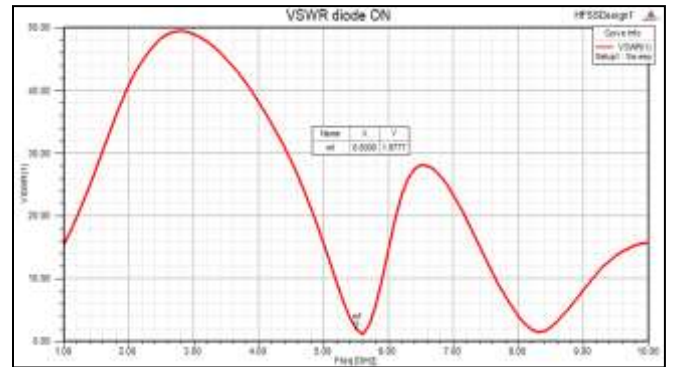


Fig. 3: VSWR when diode is ON

Examining Fig. 3, it is evident that the Voltage Standing Wave Ratio (VSWR) for the antenna when the diode is ON is recorded at 1.9, specifically at 5.5GHz. This observation leads to the conclusion that the feed line is impeccably matched to the antenna input at this frequency, ensuring optimal signal transmission. Moving to Fig. 4, the radiation pattern of the antenna when the diode is ON closely resembles that of a monopole antenna. This indicates a consistent radiation pattern, with no discernible change in characteristics when the diode is toggled between the ON and OFF states. The stability in radiation pattern highlights the robustness of the antenna's performance across different operational states.

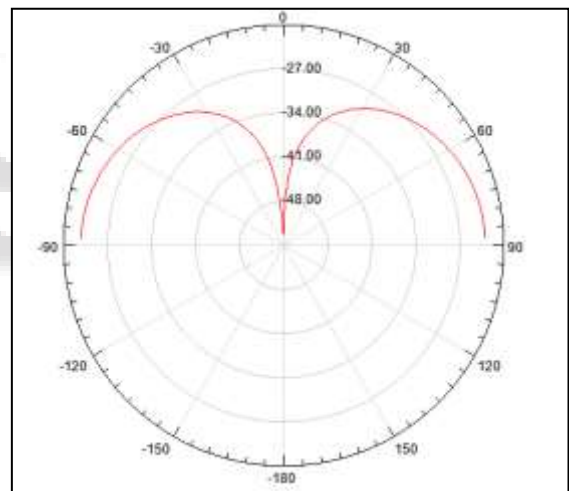
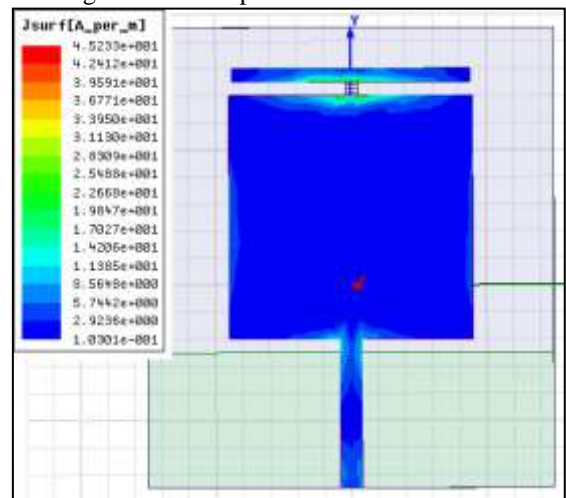


Fig. 4 Radiation pattern when diode is ON



(a)

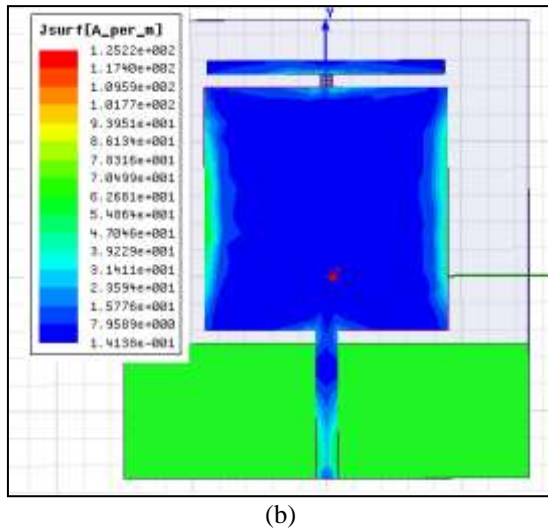


Fig. 5: (a) current plot when diode is ON, (b) current plot when diode is OFF

In Fig. 5 (a) and (b), the current plots on the monopole antenna are presented when the diode is in the ON and OFF states, respectively. When the diode is turned ON, Fig. 5 (a) illustrates that currents flow from the patch to the parasitic radiator. This dynamic current flow leads to an expansion in the overall dimensions of the patch, resulting in a decrease in frequency. Consequently, in this scenario, the operating frequency of the antenna undergoes a switch from 7.4GHz to 5.5GHz. Conversely, when the diode is in the OFF state, as depicted in Fig. 5 (b), there is no current flow directed to the parasitic radiator. Consequently, the operating frequency of the antenna remains consistent with the originally designed frequency of 7.4GHz. This observed behavior highlights the effective frequency reconfiguration mechanism facilitated by the presence or absence of current flow to the parasitic radiator, providing valuable insights into the antenna's adaptability and operational dynamics.

Parameters	Diode ON	Diode OFF
Operating frequency	5.5GHz WLAN Application	7.4GHz Satellite Application
Bandwidth	0.2GHz	0.8GHz
Radiation pattern	Monopole like	Monopole like
VSWR	1.9	1.3
Current	Current flows to parasitic radiator	No current flow

Table 1: Summary of the simulation results

The presented Table 1 encapsulates crucial parameters characterizing the behavior of the frequency reconfigurable monopole antenna in both Diode ON and Diode OFF states. When the diode is activated (Diode ON), the antenna operates at 5.5GHz, rendering it suitable for WLAN applications. In contrast, with the diode deactivated (Diode OFF), the antenna functions at 7.4GHz, aligning it for use in Satellite applications. The bandwidth of the antenna experiences variation between the two states, measuring 0.2GHz in Diode ON and expanding to 0.8GHz in Diode OFF. The radiation pattern remains consistently "Monopole-like" in both states, signifying stability in the antenna's radiation characteristics. Notably, the Voltage Standing

Wave Ratio (VSWR) reflects favorable matching when the diode is OFF, as indicated by the lower VSWR value of 1.3. The current flow patterns further differentiate the states, with current directed to the parasitic radiator in Diode ON, causing a frequency shift, while Diode OFF sees no such current flow, maintaining the antenna's original design frequency. This comprehensive analysis highlights the antenna's adaptability and performance in response to dynamic frequency reconfiguration needs.

IV. CONCLUSION

In conclusion, the developed frequency reconfigurable monopole antenna demonstrates notable versatility and adaptability, catering to both WLAN and Satellite applications through dynamic frequency adjustments. The analysis of operating frequencies, bandwidth, radiation patterns, VSWR, and current flow patterns in Diode ON and Diode OFF states provides a comprehensive understanding of the antenna's behavior. The antenna's ability to seamlessly transition between 5.5GHz for WLAN and 7.4GHz for Satellite applications, coupled with a judiciously controlled bandwidth, showcases its potential for diverse communication scenarios. The "Monopole-like" radiation pattern consistency signifies robust performance in different operational states. Notably, the lower VSWR in Diode OFF underscores superior matching to the transmission line, enhancing overall efficiency. This research contributes valuable insights into the practical application of frequency reconfigurable antennas, emphasizing their importance in modern wireless communication systems. The proposed antenna design, with its effective frequency reconfiguration mechanism, holds promise for optimizing spectrum utilization and addressing the dynamic requirements of evolving communication standards.

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