UWB Antenna with Integrated Quadruple Notch Bands

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Abstract. Ultra-Wideband (UWB) communications have inherently very wide bandwidth and the frequency range for UWB communication can vary, but it often falls within the range of 3.1 GHz to 10.6 GHz. Microstrip antenna is widely used in UWB antenna design and can be used in an various applications, including aircraft, spacecraft, satellite, missile, mobile radio, and wireless communications. A quadruple notch band planar UWB antenna for wireless body area networks (WBANs) is proposed to solve the interference problem between UWB and narrowband communications, such as WiMAX (3.30–3.70 GHz), C band (3.7–4.2 GHz), WBAN (2.4 GHz), WLAN (5.47–5.725 GHz, 5.725–5.825 GHz), ISM band (5.725–5.875 GHz), Xband Satellite communication application (7.9–8.4 GHz). Thus the performance of antenna is improved by reducing the interference of other signals. The gain of the proposed antenna is −3.0 to −1.2 dBi.

Keywords: UWB · notch band · Microstrip antenna

1 Introduction

Ultra-Wideband (UWB) antennas are a type of wireless communication antenna designed to transmit and receive signals over a broad frequency range, covering a vast spectrum of frequencies. These notches are intentional gaps in the antenna's frequency response, where the antenna does not efficiently radiate or receive signals. Wireless Body Area Network (WBAN) systems are gaining attention as a promising field of study due to their extensive use in medical, health monitoring, entertainment, and remote sensing applications. Nonetheless, to function effectively, WBAN systems necessitate high data transfer rates while consuming minimal power. Ultra-Wideband (UWB) technology offers fast data transmission, minimal power spectral density, wide bandwidth, and resilience to multipath fading. These features contribute to fulfilling the demands of WBAN systems.

X. Cheng (Ed): BROADNETS 2024, LNICST 601, pp. 54–63, 2025.
https://doi.org/10.1007/978-3-031-81168-5_6

1.1 Related Works

Over the past few years, several methods have been introduced for integrating notch bands into UWB antennas. In the work presented by reference [1], an intricately designed compact Ultra-Wideband (UWB) extended gap ridge horn (EGRH) antenna, manufactured using 3D printing, is elaborated upon for its application in biological measurements on the human body. In [2], a miniaturized MIMO antenna tailored for UWB applications, which incorporates triple band-notched characteristics to reduce interference from specific frequency bands. The compact design and experimental validation make it a promising candidate for use in modern wireless communication systems. The design aims to provide a wide frequency bandwidth, enhanced performance, and interference rejection capabilities by the incorporation of SRR and CSRR structures [3–7]. A CPW-fed Circular-Like Slot Antenna designed for wideband performance and dual band-notched characteristics. The antenna's ability to operate across a broad frequency range while rejecting signals in specific bands [8–14]. A compact frequency-reconfigurable UWB antenna with 8 different operating states [15], allowing it to cover a wide range of frequency bands while maintaining compatibility with UWB communication standards. In [16], novel compact UWB planar monopole antenna is designed that incorporates a ribbonshaped slot for improved performance. The antenna's compact design and enhanced characteristics make it a promising choice for modern wireless communication systems requiring wide bandwidth and efficient signal. A recently developed and constructed Vivaldi antenna, designed for ultra-wideband (UWB) multiple-input multiple-output (MIMO) applications, incorporates distinctive dual band-notched features as detailed in references [17–23]. The antenna offers UWB performance while providing the ability to customize its interference rejection capabilities to address specific frequency bands [24–30]. In this article, we have proposed a UWB antenna with integrated quadruple notch bands for Wireless Body Area Network (WBAN) applications in the medical and healthcare domains. By integrating quadruple notch bands, the antenna will mitigate interference issues and comply with regulatory requirements, ensuring interference-free communication within the WBAN environment. The goal is to achieve a compact, low-profile design that can be seamlessly integrated into small, wearable medical devices, without compromising performance or biocompatibility. The use of four notch bands enhances the overall radio performance of the UWB antenna. It helps in achieving a cleaner and more robust signal, reducing bit error rates, and increasing the overall communication range and reliability.

2 Antenna Configuration and Design

The design of the antenna under consideration is depicted in Fig. 1, outlining the specific design parameters. This antenna features a printed elliptical radiator incorporating two inverted L-shaped stubs aimed at introducing two notch bands and enhancing the lower operating frequency. Inverted L-shaped stubs in the antenna design serve to optimize impedance matching, control the radiation pattern, tune frequencies, and reduce the antenna's overall size. Various methodologies have been proposed to integrate these notch bands into UWB antennas. One common technique involves etching suitable structures onto either the patch or the ground plane. Figure 1 illustrates the fundamental structure of the proposed antenna. In a UWB antenna fed through a coplanar waveguide (CPW) and integrated with a stub-loaded meander line resonator, a triple-notch band configuration is suggested. This is achieved by incorporating stubs and slots in the radiating patch and introducing parasitic stubs in the ground plane. Alternatively, another approach involves inserting resonator structures, such as split ring resonators, to create the desired notch bands. To obtain four notch bands the structure is modified by adding a slot on the ground plane as shown in Fig. 1. Adding a slot on the ground plane of an antenna can create a notch band, also known as a stop band or frequency notch. A notch band refers to a specific frequency range where the antenna's response is significantly attenuated, causing a dip or "notch" in its frequency response. This can be a useful feature for suppressing interference from certain frequency bands or for avoiding specific frequency regions. The refined design parameters for the proposed antenna structure are outlined as follows: W = 12 mm, L = 19 mm, d1 = 10.8 mm, P1 = 4.5 mm, d2 = 7.7 mm, P2 = 1 mm, d3 = 3.9 mm, P3 = 3.5 mm, S = 0.5 mm, Wf = 1.9 mm, Lf = 7.39 mm.

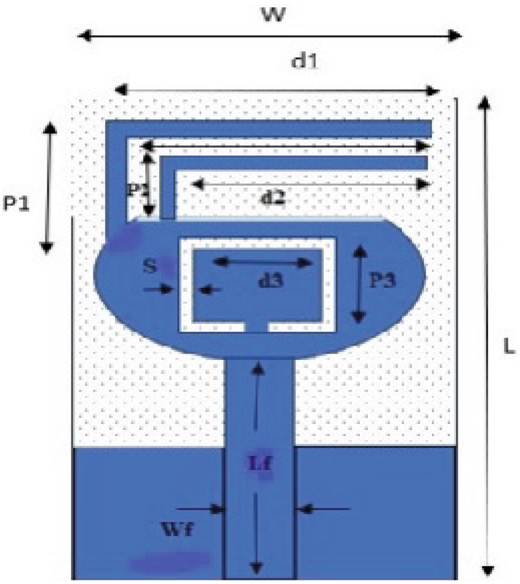

Fig. 1. Structure of proposed antenna

3 Simulated Results and Analysis

The Fig. 2 shows the reflection coefficient plot of the final structure. The reflection coefficient plot provides valuable insights into the impedance matching and reflection characteristics of the UWB antenna. The observed reflection coefficient aligns well with the simulated counterpart, indicating a consistent agreement between measurement and simulation. Minor discrepancies at higher frequencies could be attributed to substrate losses, as well as potential errors during measurement and fabrication processes. Parametric results of an antenna refer to the specific measurable characteristics and performance metrics obtained from analysis, simulation, or measurement of the antenna's behavior. These results provide quantitative information about how the antenna performs in its intended operating environment and under specific conditions.

Table 1. Parametric analysis

	Radius	Bandwidth	dimension change
1	4.9 mm	6.4 GHz	L = 19 mm, Lf = 7 mm
2	5 mm	5.7 GHz	L = 17 mm, d1 = 9.5 mm
3	5.2 mm	5.6 GHz	L = 16.7 mm, P2 = 0.7 mm
4	5.5 mm	5.2 GHz	L = 14 mm, Wf = 1.5 mm

Changing the length of the antenna structure, specifically the radiating element, can have a significant impact on the antenna's performance and characteristics. The Table 1 shows the changes in lengths we have made. Parametric results of an antenna refer to the specific measurable characteristics and performance metrics obtained from analysis, simulation, or measurement of the antenna's behavior. Parametric results of an antenna refer to the specific measurable characteristics and performance metrics obtained from analysis, simulation, or measurement of the antenna's behavior. Optimizing the design parameters of an antenna structure involves balancing factors like frequency range, radiation pattern, polarization, impedance matching, environmental conditions, size, manufacturability, and regulatory compliance to achieve desired performance goals. It requires iterative design, simulation, prototyping, and testing processes to fine-tune the antenna for efficient operation in real-world scenarios.

The Fig. 2 shows the analysis the results which indicates the range of frequencies over which the antenna operates efficiently. The accurate results were not obtained at first but after changing the lengths randomly the desired results are obtained as per given range.

The Fig. 3 shows the parametric results obtained when changes in dimensions are done as per the given table in accordance to attain the perfect notch bands at required frequencies.

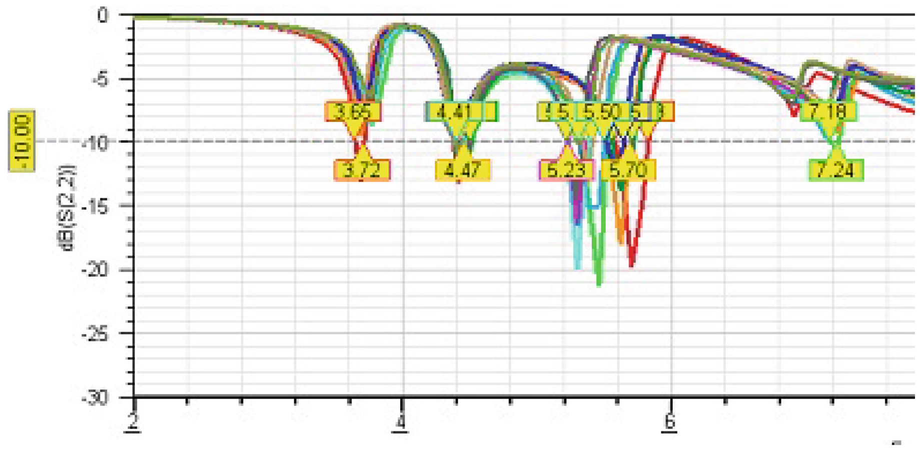

Fig. 2. Parametric analysis by the change of lengths

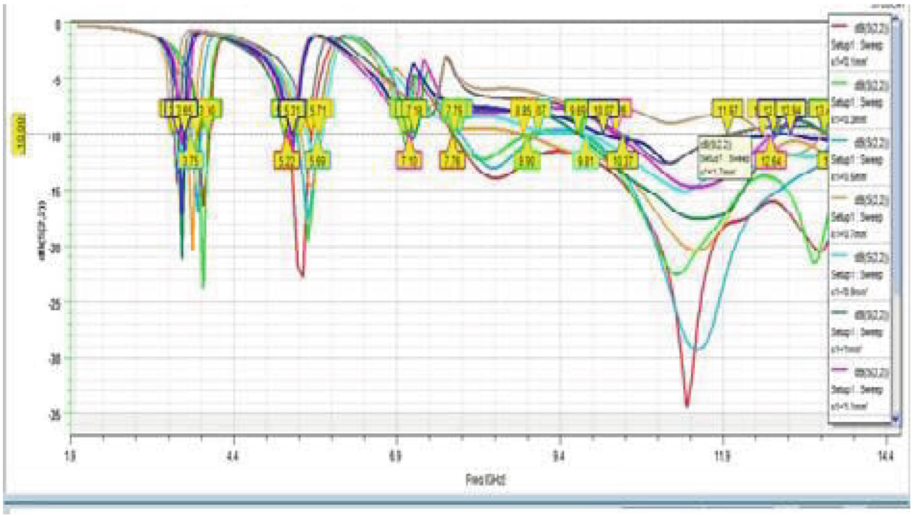

Fig. 3. Parametric analysis by the change of position of slots

The Fig. 4 shows the reflection coefficient plot of the final structure. The reflection coefficient plot provides valuable insights into the impedance matching and reflection characteristics of the UWB antenna. The obtained reflection coefficient findings closely align with the simulated results, indicating a

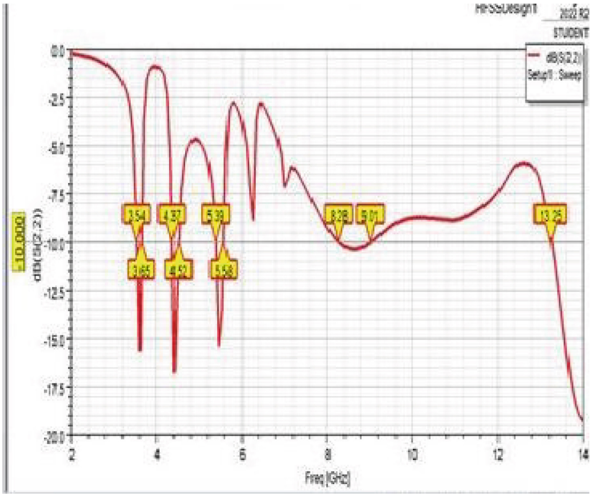

Fig. 4. Reflection Coefficient plot of the final antenna design

satisfactory agreement between the measured and simulated reflection coefficients. Minor discrepancies at higher frequencies could potentially be attributed to substrate losses, as well as errors during the measurement and fabrication processes.

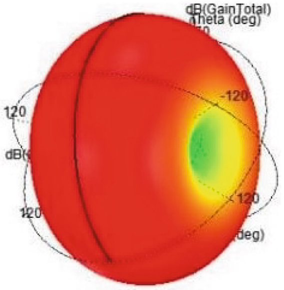

Fig. 5. Gain plot

The Fig. 5 shows the gain plot at 5.6 GHz. The gain of an antenna is a critical parameter that quantifies its ability to radiate electromagnetic energy in a specific direction. It represents the amplification or concentration of power in the direction of interest compared to an ideal isotropic radiator. In this report, we analyze the gain characteristics of the UWB antenna at a frequency of 5.6 GHz. The analysis focused on determining the antenna's gain at a specific frequency of interest This frequency was chosen due to its significance in WLAN applications.

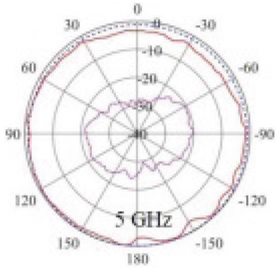

Fig. 6. Azimuth Pattern

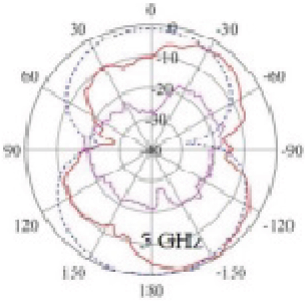

Fig. 7. Elevation Pattern

The Fig. 6 shows the H plane or Azimuth pattern. The azimuth pattern is also known as the azimuthal radiation pattern or the horizontal radiation pattern. It represents the radiation characteristics of an antenna in the horizontal plane, which is typically the plane parallel to the ground. The H-plane, or horizontal plane, is often considered parallel to the ground because it helps optimize antenna performance in certain applications, particularly those where horizontal coverage is more critical than vertical coverage.

The Fig. 7 shows the E plane or Elevation pattern. The elevation pattern, also called the elevation radiation pattern or the vertical radiation pattern, represents the radiation characteristics of an antenna in the vertical plane, which is typically the plane perpendicular to the ground.

4 Conclusion

The UWB antenna with integrated quadruple notch bands presented in this report presents an innovative solution for achieving wideband performance with the added benefit of interference mitigation. The ability to suppress specific frequencies provides a valuable advantage in crowded wireless environments, ensuring high-quality communication and reliable signal transmission. While the antenna's performance and characteristics have been extensively evaluated through simulation, real-world testing and validation will be necessary to confirm its suitability for specific practical applications. Overall, this UWB antenna design holds great promise for addressing the challenges of modern wireless communication, and it paves the way for further advancements in the field of antenna technology. Some areas of interest for further studies on UWB antennas with notches may include investigating different techniques to optimize notch designs, such as the use of different materials, shapes, or geometries to achieve desired notch characteristics while maintaining UWB performance, exploring methods to enhance the bandwidth of UWB antennas with notches while ensuring efficient rejection of unwanted frequency bands.

4.1 Applications

- Remote Health Monitoring
- Telemedicine
- Body Area Communication

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