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Ultra-Wideband (UWB) Antenna with Integrated Band-Notch Characteristics for Interference Suppression in IoT Devices

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Abstract

A tiny Band-Notched (BN) Ultra-Wide Band (UWB) antenna with incorporated Internet of Things (IoT) has been designed for personal wireless connections and IoT applications. The antenna functions within the UWB frequency (fz) range (3.2-11.7 GHz) and IoT (2.5-2.595 GHz), exhibiting BN properties at the Wireless Local Area Networks (WLAN) fz bands (5-6.5 GHz). A novel method for incorporating IoT into a UWB BN antenna has been devised and evaluated. The UWB fz band is achieved using a standard cylindrical radiated patch and altered partial grounding planes. The IoT bands are incorporated through a tiny resonator supplemented by capacitors. To accomplish this objective, a typical slot-resonance is integrated into the radiation to reduce the impact of the WLAN fz band inside the UWB. The UWB Antenna (UWBA) has been built and manufactured, and its reaction for each scenario is presented. The UWBA demonstrates an effective irradiation structure with consistent gain within the passband. The current antenna is contrasted with cutting-edge constructions presented in the research. The antenna's compact dimensions (32 × 33 mm) render it an exemplary contender for UWB and IoT applications.

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Introduction

Ultra-Wide Band (UWB) antennas have garnered significant technical interest over the past decade owing to their extensive bandwidth, compact electrical dimensions, excellent phase linearity, cost-effectiveness, and favorable radiation patterns.[1, 12] Wireless Personal Area Networking (WPAN) technological advances, adhering to the IEEE 802.15 standard, facilitate dependable and higher-speed transmission among portable gadgets, machines, and various software programs over short distances.[2] The advancement of UWB communications technology presents a promising resolution for the IEEE802.15 requirements for WAN .[14] In 2002, IEEE802.15 established the basis for an IEEE802.15.3a Study Group, which sought to formulate a WPAN with a UWB physical tier that elevated data speed to 550 Mbps.[3]

The Internet of Things (IoT) Specialized Interest Groups (SIG) chose the Multiband Orthogonal Frequency (fz) Division Multiplexer (MB-OFDM) variant of UWB, facilitating the integration of UWB with IoT technology [10]. Studies began to include IoT in UWB antennas. The Federal Communications Commissions (FCCs) permitted the utilization of UWB transmission within the fz range of 3.2 to 10.7 GHz. The extensive fz range of UWB encompasses other interference fz bands within its fz band.[9]

This work presents a downsized UWB Band-Notched (BN) antenna functioning inside the UWB and IoT band frequencies.[16] This antenna functions effectively within the fz ranges of 2.5-2.595 GHz and 3.2-11.7 GHz, incorporating a BN band of frequencies for WLAN attenuation.[4, 19] The tiny resonator is employed to connect the IoT band with the UWB band innovatively.[11] A standard UWBA is initially built and altered into an individual notched system utilizing a Slotted Resonator (SR).[18] A resonating band for IoT is produced within a singular notched system, integrating a tiny resonator and capacitance.[8]

Background

Numerous solutions in the current literature exhibit specific limitations, such as intricate geometry, limited control over notch capacity, and strong coupling among BN systems. Antenna models employ Electromagnetic Band Gap (EBG) to resolve these issues, which are classified as a particular type of Metamaterial (MM).[5] These MMs display unique properties of band spaces and possess elevated resistance at their resonance fz. The EBG, when positioned near the antenna's feeding line, functions as a Band-Stop Filtering (BSF).[6, 20] The band-gap property can be effectively employed to produce notch bands. This functionality renders it advantageous in numerous applications, including:

- The BN features of the suggested antenna will diminish interference from various narrowband-transmission channels, such as WiMAXs and WLANs, ensuring stable communications.
- Cognitive Radios (CR) - It facilitates CR structures, circumventing licensed fz ranges while utilizing the spectrum efficiently.
- Short-Range Radar Solutions - It prevents collisions in Ground-Penetrated Radars (GPR) and provides via-wall imaging advantages.
- Wireless Body Area Networking (WBANs) - This facilitates effective signal distribution in WBANs by rejecting interference with medical telemetry technologies through a notched band .
- IoTs and Wireless Sensor Networkings (WSNs) – It can be utilized with IoT gadgets and WSN to mitigate undesired interference from conventional wireless networks.
- UWB antennas improve the system's efficiency by integrating BN features that eliminate disruptive messages while preserving broadband functionality.

Many studies have been conducted on switching notched bands in UWBA, wherein a unique resonator was developed to provide transitions between single or dual, continually tunable functionalities.[15] The study was conducted using a combination of IoT and UWBA. They created a compact, lower-profile planar UWBA with incorporated IoT functionality. The UWBA was reported to function within the fz ranges of 2.5-2.55 GHz for IoT and 3.2-11.5 GHz for UWB bands. They included IoT into the UWBA by utilizing a stub-loading resonance. The UWBA demonstrated an effective radiation profile.[21] The antenna was substantial, measuring 44 × 48 mm, and was supplied by a 50-ohm microstrip-fed line. They constructed a UWBA and integrated IoT to function within the 2.5-2.55GHz and 3.2-11.5GHz fz ranges. The UWBA was engineered with traditional octagonal patches and altered ground planes.[7] A quarter-wavelengths strip resonance was incorporated at the middle of the patches to facilitate IoT integration within the UWBA. They then added a SR into the feedline to attain BN. The dimensions of this UWBA were 39 × 32 × 1.7 mm, exhibiting commendable time domain precision [17]. They suggested antennae for UWB and IoT featuring notched-bands (NB) at 5.2/5.7 GHz and 7.3/7.7 GHz. Dual NBs were achieved by etching a single SR onto the UWBA feedlines. The Transmission-Line-oriented MM (TL-MM) was integrated with the UWBA to facilitate IoT functionality. The UWBA dimension was substantial, attributed to TL-MM loading, with a 39.3 × 45.7 mm^2 size. The UWBA functioned within the 2.52-2.6 GHz (IoT) and 3.2-11.5 GHz (UWB) fz ranges, exhibiting favorable radiation properties.[13]

The study proposed a fork-structured printed UWBA with embedded IoT technology. The antenna dimensions were 43 × 25 × 1.7 mm^2 and functioned within the fz ranges of 3.2-10GHz (UWB) and 2.4-2.6GHz (IoT). The standard method of incorporating a quarter-wavelength strip at the center of the planned UWB antenna was employed. They developed a tiny UWBA with integrated IoT functionality. The IoT was incorporated via strip lines into the circular patches. The antenna dimensions were 42 × 34 × 1.2mm^2 and functioned within the fz ranges of 3.2-11.7GHz (UWB) and 2.3-2.6GHz (IoT). Implementing IoT by strip loading significantly compromised the radiation profiles at elevated frequencies inside the UWB range.

Proposed UWB Antenna with BN Features

To attain electrically adjustable dual BN features of the suggested UWBA. A unique UWBA featuring tunable BN properties has been presented based on construction D, called construction G for simplicity. The suggested dual BN UWB antennae consists of a semicircular ring-shaped radiated patch featuring an elliptical position, along with double Split Ring Resonators (SRRs) adjacent to the microstrip feeding line on the upper substrate level, and a Defected Grounding Structure (DGS) with

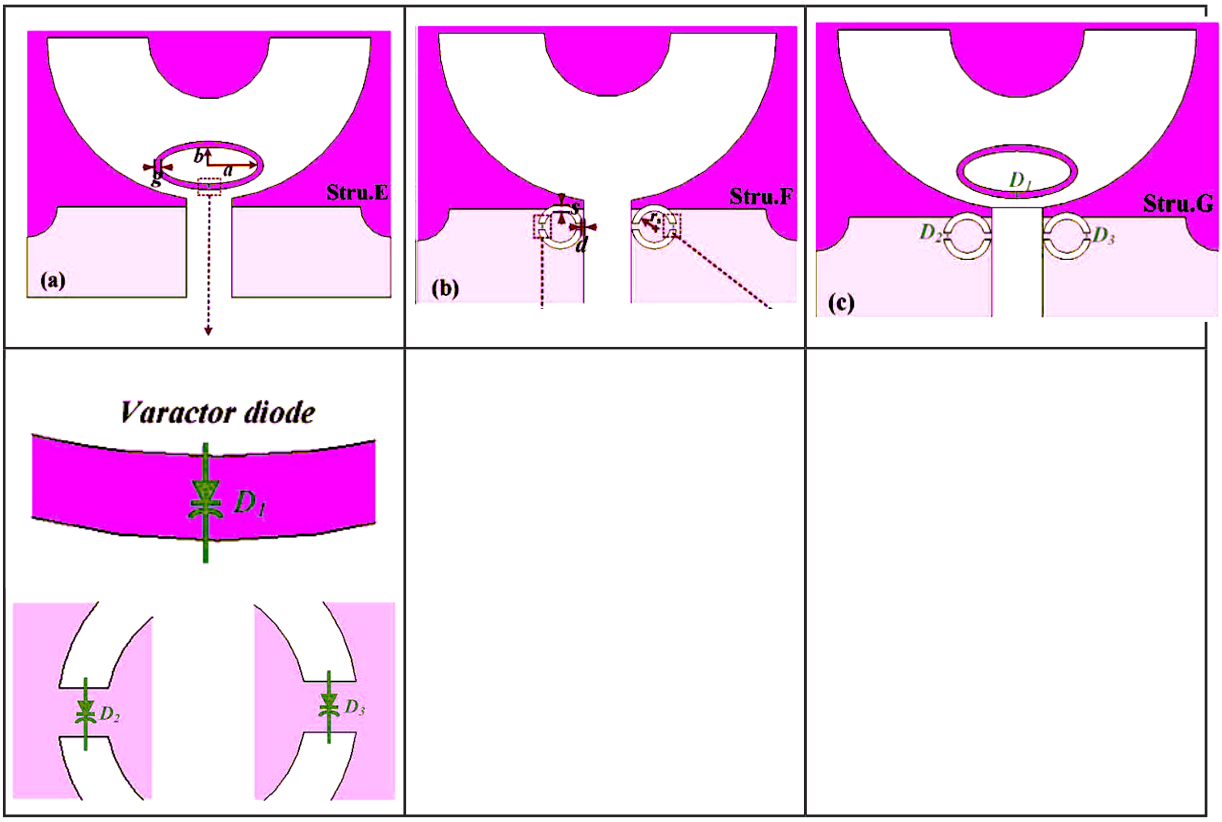

Fig. 1. Schematic diagram (a) Structure E, (b) F, (c) G, (d) Microscopic view[8]

reduced corner edges and a rectangular slot on the lower substrate level. Autonomous tunability of double BN features has been realized by incorporating three varactor diodes (VD) into the Elliptical-Shaped Slots (ESS) and dual SRRs within structure G. The ideal variables for the ESS and SRRs are a = 7mm, b = 4mm, g = 2mm, r = 3.7mm, d = 0.3mm, and s = 2mm. The sequential design process of the UWBA featuring adaptable BN features is illustrated in Fig. 1. It offers a significant framework for swiftly optimizing UWB BN antenna layouts.

To begin with, A singular BN UWB microstrip antenna has been constructed by incorporating an ESS within the semicircular radiating patches and positioning a varactor diode in the slot's gap. This antenna configuration is referred to as structure E for ease of reference. The varactor diode's analogous circuit design and circuit characteristics are examined in further detail. The basic equivalent circuits of the VD are represented by the Resistors-Inductors-Capacitors (RIC) series scheme in Computer Simulation Technology (CST), where R denotes the series resistance and C signifies the junction capacitors, which are of primary interest. L denotes a package inductor. The specification indicates that the normal values for Ry and L are 0.863 and 0.8 nH, respectively, for the VD. The capacitor C varies in the modeling, corresponding values of 3.78 pF, 1.28 pF, and 0.74 pF correlating to inverted bias voltages of 0, -5, and -25 V. The choice of an appropriate VD significantly impacts the efficiency of the suggested UWBA. The leading cause is that the parasitic characteristics, especially the series resistor (R), influence impedance matching, and a comprehensive study will be addressed thereafter. A DC bias system is essential for VD to ensure a more stable operational condition. The impedance value is set at 250, which is utilized to mitigate the excess power of the VD. The substantial DC blocked capacitance is configured at 1500 pF to attenuate high-fz harmonics from the DC power source. The two inductors (L=0.2 μH) function as RF chokes to inhibit the RF signal from traversing the DC biasing circuitry.

To elucidate the effectiveness of the suggested UWBA with dual BN features, the modeled surface power dispersion at the notched fz (2.9GHz, 5.2GHz) and passing-band fz (2.1GHz, 9.2GHz) is analyzed. The outside current is concentrated on the ESS within the semicircular ring-like radiated patches at 2.94GHz. This results in the inability to transmit electromagnetic irradiation into open space, producing the first BN fz. The robust surface current is concentrated on the twin SRRs adjacent to the microstrip feeding line. The resistance at the central frequencies of the subsequent NB fz band approaches zero when the width of the surface power channel on the SRR equals one-quarter of the wavelength at the NB center frequencies.

The additional BN was activated. Notably, the notched feature has been augmented by the substantial subsurface current surrounding the SR architecture and the double SRR architecture. The outermost power is equally distributed throughout various regions of the antenna's radiative patches, indicating that the suggested antenna exhibits favorable radiating performance features at these fz locations. The real and imaginary components of impedance approach zero in the NBs focused at 2.94GHz and 5.2GHz, confirming the significant resistance mismatches at these notch frequencies and the successful rejection of electromagnetic radiation.

Discussions

The UWBA were built and improved utilizing the publicly accessible electromagnetic program, HFSS. The original UWBA was designed and effectively encompassed the entire UWB fz band. Fig. 2 illustrates the reflection rate of the standard UWBA, indicating its operational fz range from 3.2GHz to 11.7GHz. A single notched UWBA was built using the traditional SR approach. The actual length of the SR aligns with the 5.6 GHz central fz of the WLAN fz range. The SR underwent parametric optimization. A downsized novel resonance was integrated into the partial grounding area, with its length to the 3.0 GHz fz band. An IoT-integrated UWB BN antenna was produced by incorporating capacitance into the tiny resonator. The UWBA of the capacitor was modified and improved dynamically. This antenna functions within the UWB spectrum (3.2-11.7 GHz) and IoT range (2.5-2.595 GHz), exhibiting BN features in the WLAN fz band (5.2-7.1 GHz).

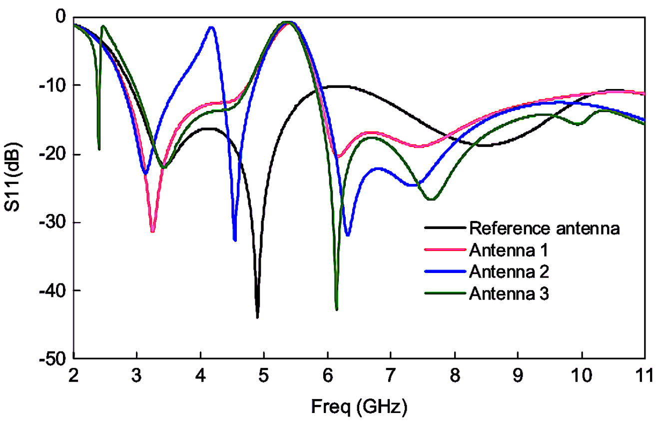

Fig. 2. Reflection coefficient analysis of different antennas

The IoT-integrated UWB BN antennas were built and evaluated. The observed reaction was juxtaposed with the simulated response. Fig. 3 illustrates that the analyzed findings align closely at the UWB and IoT frequencies. At elevated frequencies inside the UWB band, a deviation from the simulated reaction was seen. The reaction was both valid and effective.

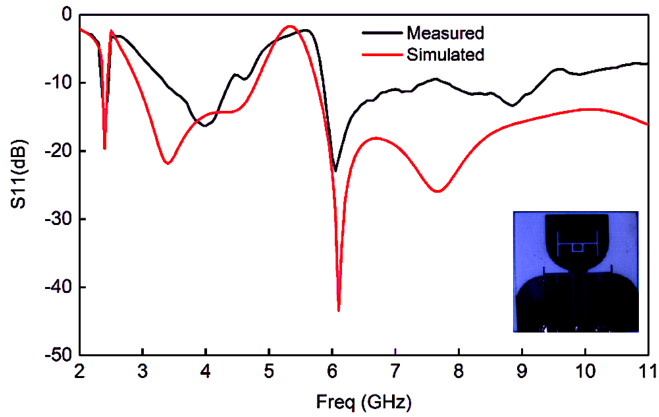

Fig. 3. Reflection coefficient analysis

The radiation characteristics of the IoT incorporated BN UWBA were assessed at various frequencies in anechoic chambers, specifically at 2.5GHz (IoT), 4.7 GHz (UWB), and 7.4GHz (UWB). The configuration was modified to measure the radiation shapes at both surfaces at each one-degree increment. Augmenting measuring sites and reducing the step size significantly improved the consistency and element. The recorded radiation structure was clear and uniform throughout the IoT and UWBA fz ranges. The antenna steadily increases within the 2.5 GHz (IoT) passbands and 3.2-11.7 GHz (UWB). The attenuation in antenna gain can be observed in the WLAN fz spectrum, corroborating the notching phenomenon. The antenna gain is associated with the resonator configuration, both with and without capacitors.

Conclusion

A tiny BN UWB antenna with incorporated IoT was designed for wireless connections and UWB uses. The UWBA functions within the UWB fz range (3.2-11.7 GHz) and is compatible with IoT (2.5-2.595 GHz), exhibiting BN capabilities in the WLAN fz range (5.2-6.5 GHz). A novel method for integrating IoT into a UWBA BN \ has been devised and examined. The IoT band is in a UWBA with a tiny resonator supplemented by capacitance. A traditional SR is incorporated into the radiators to mitigate WLAN disturbance. The antenna is developed and built, with the simulated reaction aligned with the real-world performance. The UWBA has an effective radiation shape with consistent gain within the passband. The antenna's compact size (32x33mm) renders it an exemplary contender for UWB and IoT applications.

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