International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

A Review on Design & Analysis of An Operational Quad Band UWB Antenna with Triple-Band Notch Using EBG Structure

Mr. Amit M. Patil[1], Dr. Sandhya Sharma[2], Prof. Harish S. Motekar[3], Prof. Rajkumar S. Sawant[4], Prof. Ravi S. Kolhe[5], Prof. Pandurang T. Mohite[6]

Submitted: 10/01/2024 **Revised**: 16/02/2024 **Accepted**: 24/02/2024

Abstract: The Federal Communications Commission has allocated the frequency spectrum ranging from 3.1 to 10.6 GHz for use by commercial ultra-wideband (UWB) communication equipment. Due to its low energy levels and vast bandwidth (usually higher than 500 MHz), ultra-wideband (UWB) technology has several potential uses in short-range communications. The necessary multiband operation and triple notch features are achieved by using several architectures. Many modern electronic gadgets, including cellphones, military gear, and wireless wearables, make use of microstrip patch antennas. This study compares and contrasts several ultra-wideband (UWB) antennas that use a triple-band notch, as well as various notching approaches, with more conventional antennas.

Keywords: *UWB Antenna design, Electromagnetic Band Gap (EBG), Band notch techniques, Quad Band*

1. Introduction

Antennas are the main power sources in many communication systems. Constructing a tiny, cheap antenna with accurate radiations and excellent impedance matching is no easy feat [1]. Microstrip patch antennas are appropriate for use in ultra-wideband (UWB) applications [2]. This is because they are tiny in size, have a flat form, are easy to integrate with other electrical components, and possess a number of other desired properties. There was interference in the region of 5.15 to 6.84 GHz produced by wireless local area networks (WLANs) (IEEE802.11a, HIPERLAN/2), 5G sub-6GHz (3.4 to 3.9 GHz), and X-band satellite transmission (7.94 to 8.49 GHz) prior to the construction of UWB antennas [3]. The best and cheapest way to fix this is to stop the interference at the UWB communication system. A structure called an electromagnetic band-gap (EBG) is formed across dielectric surfaces in order to block electromagnetic waves of certain frequency bands. The patches are very tiny and arranged in a thin, periodic pattern. That is why the notching of UWB antennas makes them more dependable. To circumvent interference, researchers developed a number of UWB antennas with notched bands. It is possible to use split rings for band rejection and resonant cells in microstrip lines. Coupling parasitic components to the radiator was an effort to achieve band-notched capabilities in certain research [4]. The WLAN spectrum, for example, has a bandwidth of 1 GHz and is hence unsuitable for rejection by the conventional notch due to its low selectivity for blocking interference. So, there's a lot more focus among UWB antenna designers who are aiming for acute rejection characteristics. Using a rectangular notch with good selectivity is crucial for effectively eliminating interference produced by unwanted bands in practice [5]. Rectangular notched antennas with a high selectivity for rejecting undesirable bands have been reported sporadically in recent years. To avoid bandwidth filtering between the two channels, two traditional notch bands were created at 5.2 GHz and 5.8 GHz to reject WLAN (5-6) GHz [6]. A WLAN band rectangular notch antenna is constructed using EBG structures. The rectangular notch features were achieved in the WLAN and satellite downlink frequencies by using stepped slots as the radiator. In order to keep licensed UWB bands from interfering with one another, antennas having multiple band rejecting properties are necessary. An interference-free microstrip patch antenna featuring three rectangular notch bands, two sets of EBG, and one SRR has been developed, all within the constraints of the antenna's small form factor [7].

[1] Suresh Gyan Vihar University, Jaipur, Rajasthan, INDIA
ORCID ID: 0009-0004-9341-6837
[2] Suresh Gyan Vihar University, Jaipur, Rajasthan, INDIA
ORCID ID: 0000-0002-5452-8658
[3] Bharati Vidyapeeth Deemed University, DET, Kharghar, Navi Mumbai, Maharashtra, INDIA
ORCID ID: 0009-0005-7232-3356
[4] Bharati Vidyapeeth Deemed University, DET, Kharghar, Navi Mumbai, Maharashtra, INDIA
ORCID ID: 0009-0004-6120-6296
[5] Bharati Vidyapeeth Deemed University, DET, Kharghar, Navi Mumbai, Maharashtra, INDIA,
ORCID ID:0009-0000-1382-2431
[6] Bharati Vidyapeeth Deemed University, DET, Kharghar, Navi Mumbai, Maharashtra, INDIA
ORCID ID: 0009-0001-7922-0895
Vinod.rathod@bvucoep.edu.in

2. The Requirement for Operational Bands Triple-Band Notch UWB Antenna

Microstrip antennas are cheap, simple, and compact. These microstrip antennas have a modest bandwidth, hence you require specialized designs to increase bandwidth. Over the years, a number of researchers have worked to improve the bandwidth ratio by creating various kinds of antennas [8,9]. A multitude of techniques may be used in the design of these ultra-wideband antennas. There are many distinct types of ultra-wideband (UWB) antennas that have been created. UWB antennas that are inspired by metamaterials, planar wideband antennas, multiband UWB antennas with band notch capabilities, and tiny UWB antennas based on fractals are some examples of these types of antennas [10,11,12].

Smaller wireless communication devices are seeing a surge in the development of ultra-wideband (UWB) antennas based on fractals [14,15]. Interference with other neighbouring communication systems that operate at the same frequency as the coverage zone of the UWB antennas is one of the most significant challenges that arises during the design process of these UWB antennas [16]. A few approaches have been developed for the purpose of building antennas that can reject certain bands, much like ultra-wideband (UWB) filters. There are several different methods that can be utilised in the manufacturing of antennas that display notch characteristics. Resonator structures, slots, structures that are inspired by metamaterials such as meander lines, parasitic elements, electromagnetic bandgap structures (EBG), frequency selective surfaces (FSS), and resonator structures are some of the ways that are included in this category [17,18]. These antennas may block off a single band or a multitude of frequencies. How selective the rejection bands are is directly related to how effective the techniques used were.

3. Research Approach

An overview of the various UWB antennas with triple-band notch methods and their respective operating bands is the primary goal of our research and evaluation. The following categories form the basis of the analysis in this evaluation.

1. Antenna’s impedance bandwidth

2. A small ultra-wideband antenna with low loss and high gain.

3. A notched ultra-wideband antenna that can be adjusted in real-time.

4. Review and Discussion

As mentioned in the preceding part, we have read a number of research publications that focus on operating bands and notching strategies. We will continue some terminology that has been defined by other scholars in this section.

4.1. Notching Techniques used for Antennas.

Here are some of the most popular notching techniques:

4.1.1. Electromagnetic-Band Gap (EBG)

The electromagnetic band gap (EBG) structures, which are responsible for blocking electromagnetic waves, create a thin, periodic pattern of tiny metal patches across dielectric surfaces [4,7,9,14,15,16,19].

4.1.2. The Meander Slot

An improved version of the classic folding antenna, the meander slot produces much lower frequencies than a single-element antenna of the same length would. A meander line antenna has a very high radiation efficiency [3, 7] when compared to conventional antennas that are half or quarter of a wavelength long.

4.1.3. SRR

A metamaterial's characteristic purposefully created structure is a split-ring resonator, or SRR for short. Obtaining the necessary magnetic susceptibility (magnetic response) is the goal of a variety of metamaterials operating at frequencies up to 200 terahertz [4,8,11,12,17,19].

4.1.4. Rectangular Slot

Antennas composed of microstrip patches are rectangular in shape. This dielectric substrate has a ground plane on one side, and a patch that may be of any form, whether it is planar or non-planar, on the other side. The ground plane is on one side of the substrate. The patch-opposite side has the ground plane [5].

4.1.5. U-slot

U-shaped slot patch antennas are recognised for their wide impedance bandwidths. A tiny strip patch antenna for WiMAX/WLAN applications is designed, optimised, and simulated in this work [7,19].

4.1.6. Parasitic Strips

When two strips are attached to the radiator, the antenna has the potential to produce a dual-notch band that is suitable for both lower and higher WLANs [13].

4.1.7. Stepped Slot

The antenna's radiator, which allows it to operate in an ultra-wideband frequency range, is a stepped slot. To operate in differential mode, feed the microstrip to effectively excite the stepped slot, and then radiate differential signals. All of this may happen while the procedure is underway. The stepped slot may be fed at different positions and sizes to produce different resonant modes. The modes can easily transition between each other, leading to a much broader bandwidth [18].

4.1.8. Etched Slot

It is standard practice to carve a variety of forms into the radiator or the ground to create a notched band. Some other methods include placing resonators near the feed line or radiator or folded parasitic strips. Etching a short-ended half-wavelength split-ring slot close to the stepped slot resulted in the creation of a band with a notched shape.

Consequently, this led to the development of a band that was capable of covering the wireless local area network (WLAN) without any problems. Therefore, in order to accomplish this effect, the rear of the feed line was etched with an open-ended quarter wavelength slot[10].

Various notching approaches have been examined in the review study. Using a pie chart, the researchers have classified the following notching approaches.

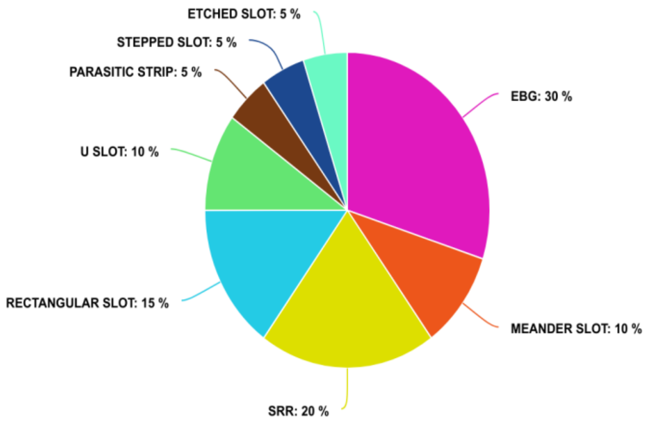

Fig. 1. Notching Techniques used for Antenna

Based on Fig. 1. To reject numerous bands, researchers employed several notching approaches. The three most popular notching structures among researchers are the electromagnetic band gap, the meander slot, and the slip ring resonance.

4.2 A review of the literature on performance comparison

This review study is being conducted with the intention of demonstrating a UWB antenna that has two notch bands that can be toggled while the center frequency is being modified. In this case, the band-notched UWB antennas' adjustable and switchable features are combined. When notching frequencies, most researchers have employed EBG structures. Classification and the development of the new antenna may benefit from this data. After conducting tests on the Electromagnetic band gap (EBG) structure, Slip ring resonator, and Meander slots, we came to the conclusion that the tuning accuracy and notching processes need to be improved. Because modern research methods necessitate deeper investigation. An exact mechanism is needed for a compact antenna, increased gain, perfect tuning, and quad band.

Table 1. The performance Comparison Chart

Reference Antennas	Notching Techniques	Antenna Size (mm)	No. of Notching Bands	Notch Bands (GHz)
[03]	Meander Slot	40×38×1.6	3	3.29–4.83, 5.15–6.84, 7.94–8.49
[04]	SRR and EBG	20×26×1.52	3	3.4–3.9, 5.15–5.825, 7.25–7.75
[05]	Rectangular slots	26×30×1.6	2	5.18–5.82, 7.25–8.39
[07]	Meander line EBG and U slots	34.9×31.3×1.6	4	2.53–3.15, 3.23–3.68, 3.92–4.30, 5.49–6.19
[08]	Slots and SRR	54 x 47 x 1	3	2.23-2.45, 3.26-3.48, 5.54-5.88
[09]	EBG$_s$	24x24x1.6	3	3.3-4.0, 5.1-5.8, 7.2-7.8
[11]	SRR	40 X 30 X 0.78	4	3.39-3.82, 50.13-5.40, 5.71-5.91, 7.5-8.61
[12]	Slots and SRR	41.5×32×1.6	4	3.3–3.7, 5.15–5.35, 5.725–5.825, 7.25–7.75
[13]	Parasitic Strip	30 x 22 x 3	3	3.26-3.71, 5.15-5.37, 5.78-5.95
[16]	EBG$_s$	50 x 42 x 1.6	3	3.3-3.8, 5.15-5.82, 7.1-7.9
[17]	SRR on the feed line	50 x 50 x 1.57	2	5.15-5.82, 6.2-6.9
[18]	Stepped Slot	28 x 18 x 0.8	2	5.1-6.0, 7.83-8.47
[19]	EBG, U slot, SRR	25 × 25× 1.6	2	5.94–7.5, 8.02–10.46

Table 1 provides a comprehensive overview of the several notching approaches that have been used by researchers.

5. Conclusion

This study describes and studies several kinds of UWB antennas that use band notch methods to prevent narrowband interference. For constructing an ultra-wideband (UWB) antenna, a combination of an electromagnetic band gap construction, a meander slots and slip ring resonator was used. This antenna is equipped with a triple-rectangular notch band that can cover the satellite uplink band, as well as 5G and WLAN. When it comes to reducing electromagnetic noise in electronic equipment, most researchers have turned to EBG structures. To continually tune the operating bands, a band notched UWB antenna switches between two notch bands at the same time.

References

[1] T. Gayatri;G. Srinivasu;D.M.K. Chaitanya;V.K. Sharma, "Design and Analysis of a Compact Wrench Shaped UWB Antenna for Spectrum Sensing in 3.1GHz to 10.6GHz", IEEE International RF and Microwave Conference (RFM), DOI: 10.1109/RFM50841.2020.9344798,2020.

[2] M. M. Hasan Mahfuz;Md Mohiuddin Soliman;Md Rafiqul Islam, "Design of UWB Microstrip Patch Antenna with Variable Band Notched Characteristic for Wi-MAX Application", IEEE Student Conference on Research and Development (SCOReD), DOI: 10.1109/SCOReD50371.2020.9250947,2020.

[3] Rani R. Kodali1, Polepalli Siddaiah2, and Mahendra N. G. Prasad3, "Design of Quad Band Operational UWB Antenna with Triple Notch Bands Using Meander Line Slot", Progress In Electromagnetics Research M, Vol. 109, 63–73,2022.

[4] Anees Abbas;Niamat Hussain;Jaemin Lee;Seong Gyoon, "Triple Rectangular Notch UWB Antenna Using EBG and SRR", IEEE Access (Volume: 9) DOI: 10.1109/ACCESS.2020.3047401,2020.

[5] Yadav, A., D. Sethi, R. K. Khanna, "Slot loaded UWB antenna: Dual band notched characteristics," AEU — International Journal of Electronics and Communications, Vol. 70, No. 3, 331–335, March 2016.

[6] Deqiang Yang, Huiling Zeng, Sihao Liu*, and Jin Pan, "A Vivaldi Antenna with Switchable and Tunable Band-Notch Characteristic", Progress In Electromagnetics Research C, Vol. 68, 75–83, 2016.

[7] Modak, S., T. Khan, and R. H. Laskar, "Loaded UWB monopole antenna for quad band-notched characteristics," IETE Technical Review, 1–9, 2021, doi:10.1080/02564602.2021.1878942.

[8] A. Iqbal, A. Smida, N. Mallat, M. Islam, and S. Kim, ''A compact UWB antenna with independently controllable notch bands,'' Sensors, vol. 19, no. 6, p. 1411, Mar. 2019.

[9] M. A. Trimukhe and B. G. Hogade, ''Compact Ultra-wideband antenna with triple band notch characteristics using EBG structures,'' Prog. Electromagn. Res. C., vol. 8, no. 7, pp. 1069–1075, Nov 2016.

[10] Q.-X. Chu, C.-X. Mao, and H. Zhu, ''A compact notched band UWB slot antenna with sharp selectivity and controllable bandwidth,'' IEEE Trans. Antennas Propag., vol. 61, no. 8, pp. 3961–3966, Aug. 2013.

[11] M. J. Jeong, N. Hussain, H. Bong, J. W. Park, K. S. Shin, S. W. Lee,S. Y. Rhee, and N. Kim, ''Ultrawideband microstrip patch antenna with quadruple band notch characteristic using negative permittivity unit cells,'' Microw. Opt. Technol. Lett., vol. 62, no. 2, pp. 816–824, Feb. 2020.

[12] Chakraborty, M., S. Pal, and N. Chattoraj, "Quad notch UWB antenna using combination of slots and split-ring resonator," International Journal of RF and Microwave Computer-Aided Engineering, 2019, doi:10.1002/mmce.22086.

[13] M. T. Islam, R. Azim, and A. T. Mobashsher, ''Triple band-notched planar UWB antenna using parasitic strips,'' Prog. Electromagn. Res., vol. 129, pp. 161–179, 2012.

[14] L. Peng, B.-J. Wen, X.-F. Li, X. Jiang, and S.-M. Li, ''CPW fed UWB antenna by EBGs with wide rectangular notched-band,'' IEEE Access, vol. 4, pp. 9545–9552, 2016.

[15] A. Abbas, N. Hussain, M.-J. Jeong, J. Park, K. S. Shin, T. Kim, and N. Kim, ''A rectangular notch-band UWB antenna with controllable notched bandwidth and centre frequency,'' Sensors, vol. 20, no. 3, p. 777, Jan. 2020.

[16] N. Jaglan, B. K. Kanaujia, S. D. Gupta, and S. Srivastava, ''Triple band notched UWB antenna design using electromagnetic bandgap structures,'' Prog. Electromagn. Res. C., vol. 66, pp. 139–147, 2016.

[17] J. Y. Siddiqui, C. Saha, and Y. M. M. Antar, ''Compact dual-SRR-loaded UWB monopole antenna with dual frequency and wideband notch characteristics,'' IEEE Antennas Wireless Propag. Lett., vol. 14, pp. 100–103, Sep. 2015.

[18] W.-A. Li, Z.-H. Tu, Q.-X. Chu, and X.-H. Wu, ''Differential stepped- slot UWB antenna with common-mode suppression and dual sharp- selectivity notched bands,'' IEEE Antennas Wireless Propag.

Lett., vol. 15, pp. 1120–1123, Oct. 2016.

[19] Kumar, G., D. Singh, and R. Kumar, “A planar CPW fed UWB antenna with dual rectangular notch band characteristics incorporating U-slot, SRRs, and EBGs,” International Journal of RF and Microwave Computer-Aided Engineering, Vol. 31, No. 7, doi:10.1002/mmce.22676,2021.