A Compact Violin-Shaped Monopole Antenna for Ultra-Wideband Applications

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Article Info.

Article history:

Received Jan 25, 2024
Revised Jun 13, 2024
Accepted Jun 24, 2024

Keywords:

Ultra-Wide Band Antenna
Return Loss
fiddle-Shape Antenna
Group Delay
Microstrip Line

ABSTRACT

A case study of a miniature monopole planar fiddle or violin-shaped antenna that can be used in ultra-wideband (UWB) application is carried out. Such violin-shaped antenna is a circular patch accompanied with two circular cuts and overlapped with an elliptical patch on the top of it. It is small in size, simple in structure, feasible to construct and experimentally feasible to be manufactured and validated in lab. Furthermore, the handle of the fiddle-like structure serves as a microstrip 50**Ω** feeding line connected to the main patch structure body. However, the prototype of the designed antenna is manufactured on a substrate of a dielectric material of FR4 with a dielectric constant that equals 4.3 with dimensions of 28×18×1.6 mm3. The gain at the resonant frequencies reached different values throughout the covered frequency band; that is of (3.1 GHz up to 13.5 GHz) ranging between the values of (≈1.1 dBi up to ≈5.5 dBi) according to the return loss of the performance outcome. The empirically measured and simulated results have a suitable settlement and/or agreement and computations display that the antenna has a respectable frequency band, radiation, and characteristics of time domain in spite of the antenna's small size and simple design.

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1. INTRODUCTION

By the time the Federal Communication Commission, (FCC), approved a band frequency for ultra-wide band (UWB) uses in 2002 (3.1 GHz to 10.6 GHz), a great interest was shown by designers to develop UWB structures, especially for the indoor applications. UWB technology has concerned numerous considerations due to its exciting properties, like great data rate communications and multimedia transmission. UWB antenna is the most significant component in UWB systems; therefore, many antenna researchers have developed theories and designs to fulfil the UWB system requirements.

Researchers have developed relatively large antennas with excellent antenna properties that can provide high quality UWB characteristics [1 - 2]. Flexible dielectric materials have been used in the fabrication of UWB antennas to produce a comparatively large and flexible one that can resist bending and angular positioning [3]. For size reduction, researchers have also sacrificed some antenna properties to design highly miniaturized UWB antennas [4 - 8]. Complex designs with large number of optimization parameters have been suggested to improve the radiation characteristics [9], enhance the antenna bandwidth [10], [11], or accommodate some special uses for example, Radio Frequency Identification (RFID) applications [12] and on-body communications [13].

At this journal paper, a squeezed planar monopole antenna is designed and fabricated for ultra-wide band applications. It is a violin-formed antenna containing a circular patch with small circular cuts overlapped with a small elliptical patch. The circular cuts and the attached elliptical patch contribute to reduce the lower frequency limit of the antenna with avoiding growing the size of the antenna considerably. The length of the ground plane, located in the reverse side of the substrate, is enhanced to develop the bandwidth of the antenna by growing the higher frequency limit with minimizing the return loss at the central frequencies simultaneously.

The simulated and measured outcomes display that the suggested device insures the frequency belonging to the UWB stated by the FCC, and got quite respectable characteristics of radiation and a high gain. It has acceptable characteristics of time domain as well.

Analyses show that the antenna has a performance like those introduced by antennas having larger size [1 - 3] and those of conventional large circular and rectangular antennas. In addition, although the proposed antenna has simpler design than that proposed in [9 - 13], it has characteristics approximately like those provided by the more complex designs. In [14], the author proposes a new method to separate band in UWB antenna system. Another work was prepared by the reference [15] where a multi-antenna system utilizes combiners and dividers. Zhao Zhou et al. proposed a structure of a microstrip dipole antenna with high isolation, along with some nearby works [17 - 19]. Finally, S. H. Ali, A. H. R. Alfalahi and Y. A. Hachim have conducted a similar work on a compact waveguide-fed flexible UWB antenna for RFID applications [20]. Lastly, Acharya et al. (2022) introduced a violin-shaped UWB patch antenna for X and Ku bands, utilizing metamaterials to achieve wide bandwidth (9.42 GHz, 14.2 GHz) and high gain (up to 16 dBi) [21].

Sharma et al. (2018) proposed a key-shaped planar UWB monopole antenna with dual band-notch characteristics to address interference from WiMAX and WLAN bands. The compact antenna (18 × 20 mm²) achieves an impedance bandwidth from 2.84 GHz to 10.83 GHz, effectively removing interference from WiMAX (3.30–3.80 GHz) and WLAN (5.15–5.825 GHz). It maintains an omnidirectional radiation pattern in the H-plane and a dipole-like pattern in the E-plane, making it suitable for UWB applications [22].

The paper is prepared as following: Section II includes the proposed antenna structure, while Section III includes a parametric study to obtain an optimal design that accommodate the UWB system requirements. The measured results are discussed in chapter IV tailed by a short-term conclusion in chapter V.

2. ANTENNA DESIGN

In Fig. 1, it shows a proposed violin-shaped antenna served by a microstrip line. This antenna is simply a circular patch overlapped with an elliptical patch. This antenna is etched with a substrate layer of FR4 and relative permittivity εr=4.3 with loss tangent of 0.025, whereas the plane of ground is etched on the other side of substrate. The design is fed by a microstrip line 50Ω having a measurement of 1.8mm.The total dimensions of the suggested antenna are 1.6×28×18 mm3, which are small enough to be inserted inside any ultra-wide band device. Only three parameters have been optimized to conquer the UWB systems requirements. The optimized parameters are the circular cut radius $r1$, the elliptical patch minor radius $r2$, and the ground plane length L. $r1$=3mm, $r2$=6mm, and L=6mm are the optimum values of these three parameters (see Fig. 1).

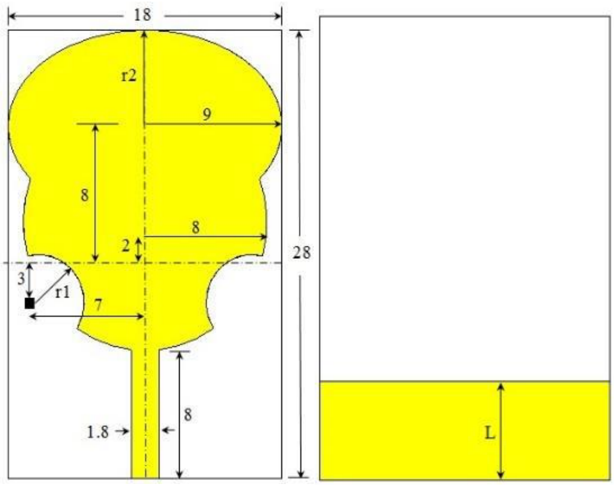

Figure 1. The suggested antenna of fiddle-like mono-pole geometry (a) anterior sight and (b) rear view (Altogether magnitudes are in mm)

3. PARAMETRIC STUDY

As stated earlier in Section II, the three parameters that can control the performance of the suggested antenna are the ground plane length, the radius of the rounded cut, and the trivial radius of the egg-shaped design. The following is a study of the effect of each parameter separately. This study has been accomplished using the CST Microwave Studio commercial simulation suite.

3.1. GROUND PLANE LENGTH (L) EFFECT

The ground plane width operates as an inductance element, with the top edge of the ground plane and the lower limit of the monopole antenna operate as conducting plates of a capacitor [16]. Therefore, by controlling the expanse between the lower level and the element of the antenna, different resonant circuits can be obtained. This demand can be attained through changing the length of the lower level. Fig. 2 shows the return loss of the proposed antenna at $r1$=3mm, $r2$=6mm, and different ground plane lengths. It is clear that the widest bandwidth occurs at L=6mm. The span of the ground plane mainly affects the central frequencies and the upper edge of the frequency belonging to the return loss.

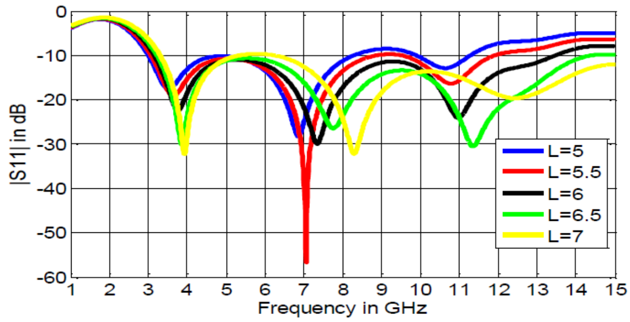

Figure 2. Return loss of the proposed antenna at r1=3mm, and r2=6mm, and different ground plane lengths

3.2. EFFECT OF THE CIRCULAR CUT RADIUS R1

The circular cut can prolong the current path passing through the circular patch circumference without adding any additional component to the antenna. Thus, adding the circular cut can recover the lesser edge of the return loss frequency. Figure 3 exhibits the return loss of the violin-shaped antenna at L=6mm, $r2$=6mm, and different values of circular cut radii. Although $r1 = 4mm$ provides better lower frequency edge than that of $r1 = 3mm$, the bandwidth at this value is significantly smaller. Therefore, the optimum value of circular cut radius is chosen to be $r1 = 3mm$.

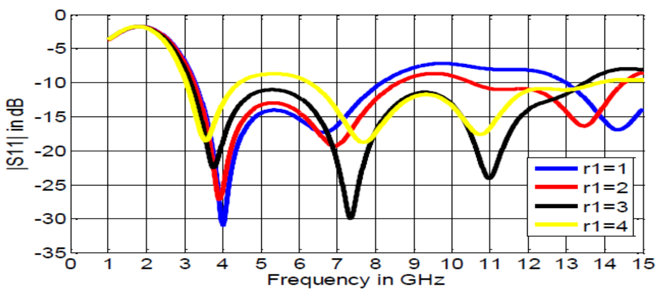

Figure 3. Return loss of the suggested antenna at L=6mm, and r2=6mm, and different circular cut radii

3.3. EFFECT OF THE ELLIPTICAL PATCH MINOR RADIUS R2

The minor radius of the elliptical patch can directly affect the lower frequency edge since it controls the antenna length. Fig. 4 displays the return loss of the suggested design at $L = 6mm$, $r1 = 3mm$, and different values of elliptical patch minor axis. It is clear that as the minor axis increases, the lower edge decreases. $r2 = 6mm$ is selected to be the optimum value since the lower edge reaches $3.1GHz$ which represents the lesser limit of the FCC frequency band specified to the applications of the UWB.

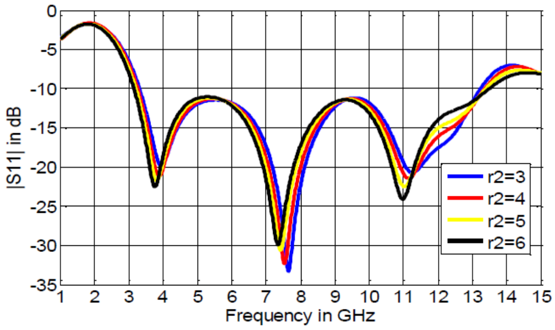

Figure 4. Return loss of the suggested design at L=6mm, and r1=3mm, and different elliptical patch minor axis

In the study, three key optimization parameters were identified for the fiddle-shaped UWB monopole antenna: the ground plane length (L), the circular cut radius (r1), and the elliptical patch minor radius (r2). Each of these parameters was fine-tuned to enhance the antenna's performance. Adjusting the ground plane length (L) to 6 mm optimized the impedance matching, leading to the widest bandwidth and lowest return loss across the UWB frequency range. The circular cut radius (r1), set at 3 mm, extended the current path on the antenna's surface without increasing its size, effectively lowering the lower frequency edge and enhancing bandwidth. Finally, the elliptical patch minor radius (r2) was optimized at 6 mm, which controlled the antenna's length and improved the lower frequency edge, ensuring coverage of the entire UWB spectrum. Collected together, these optimizations resulted in a compact antenna with improved impedance matching, broader bandwidth, and better overall performance suitable for various UWB applications.

4. MEASURED RESULTS

Figure 5 shows the fabricated violin-shaped antenna appended to an SMA connecter, whereas Figure 6 compares the simulated and the measured losses of return of the suggested device. The measured outcomes have been obtained utilizing (HEWLETT PACKARD 8719 A) Analyzer Vector Network at Missouri University. Like simulated return loss, the measured return loss has three resonant frequencies overlapping with each other. The bandwidth of the computer-generated return loss of the suggested antenna is equal to $10.4GHz$ over a frequency range of $3.1-13.5GHz$. However, the measured bandwidth is equal to $10.1GHz$ along the frequency range from $2.9GHz$ to $13GHz$, which surpasses the UWB frequency range. There is a small discrepancy between the experimental and computer-generated results because of features like the manufacture acceptance, unsatisfactory SMA soldering connecting device that leads to close circle route amid the connector and the feeding line and the dielectric factor unbalanced differences through the range of the frequency.

Figure 5. The prototype of the suggested antenna

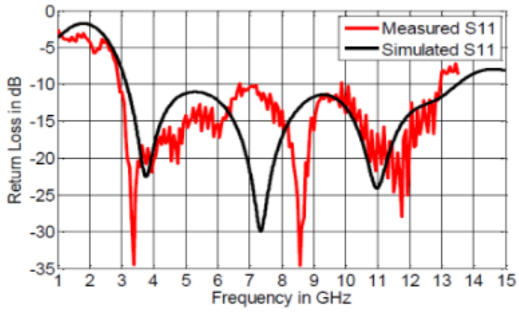

Figure 6. The experimental and virtual returning loss of the proposed device

Figure 7 illustrates the responding frequency of the computer-generated and experimental gain of the suggested antenna. The design has a reasonable gain through the whole bandwidth over that the antenna works especially the frequency band that is designated for the UWB uses. The simulated and measured power patterns at f=3.8GHz, f=7.4GHz, and f=11GHz are demonstrated in figure 8. This figure shows an all-directional H-plane pattern of power and bi-directional E-plane shape of power that are almost like the power pattern of the conventional dipole antenna. At higher resonances, the E-plane power pattern starts to be distorted because the antenna surface current concentrates in specific positions along the antenna circumference unlike the first resonant at which the current concentrated only in the lower side of the device. The simulated and measured power patterns discrepancy is caused by multi-reflections coming from the surrounding objects inside the anechoic chamber. The omnidirectional H-plane power pattern makes the antenna to be a perfect candidate for UWB portable devices since this pattern allows the antenna to be more position independent.

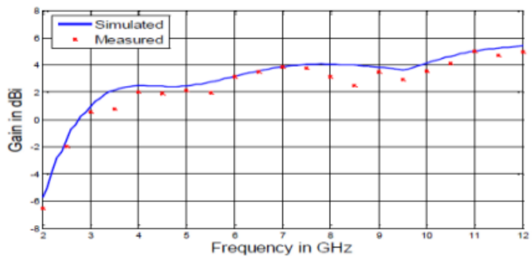

Figure 7. The simulated and measured gain (in dBi) of the suggested device as a function of Frequency

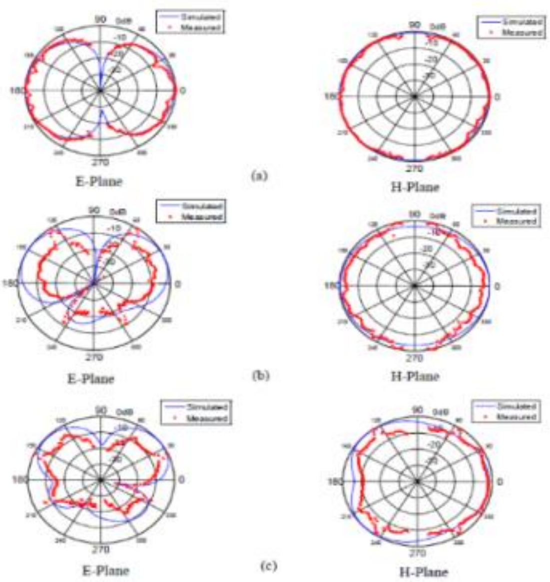

Figure 8. The simulated and empirical power patterns of the recommended device at (a) 3.7 GHz, (b) 7.3GHz and (c) 11.0 GHz

Table 1. Comparison of UWB Antennas

Antenna Type	**Bandwidth (GHz)**	**Average Group Delay (ns)**	**Gain (dBi)**	**Radiation Pattern**	**Reference**
Proposed Fiddle-Shaped Antenna	10.4 (3.1-13.5)	6.2	2.5-4.8	Omnidirectional (H-plane), Bidirectional (E-plane)	This study
Violin Type UWB Patch Antenna (Acharya et al., 2022)	9.42, 14.2	6.1	Up to 16	Omnidirectional	[21]
Flexible and Conformal Printed Monopoles (Hachi et al., 2017)	9.6 (3.2-12.8)	6.3	2.3-4.6	Omnidirectional	[1]
Disk Loaded Monopole (Hashimoto et al., 2020)	9.8 (3.0-12.8)	6.4	2.4-4.7	Omnidirectional	[2]
CPW-Fed UWB Microstrip Antenna (Gautam et al., 2013)	10.2 (3.1-13.3)	6.5	2.4-4.7	Omnidirectional	[7]
Flexible Tunable Microstrip Antenna (Masihi et al., 2020)	9.7 (3.0-12.7)	6.1	2.0-5.0	Omnidirectional	[3]
UWB Band-Notched Antenna (Nouri & Dadashzadeh, 2011)	9.8 (3.1-12.9)	6.2	2.4-4.9	Omnidirectional	[4]
Planar Elliptical UWB Monopole (Lages et al., 2011)	9.5 (3.2-12.7)	6.1	2.2-4.5	Omnidirectional	[9]
Key Shaped Planar UWB Monopole Antenna (Sharma et al., 2018)	8.0 (2.84-10.83)	6.3	Up to 4.33	Omnidirectional (H-plane), Dipole-like (E-plane)	Sharma et al., 2018

Bandwidth: The proposed fiddle-shaped antenna offers an impressive bandwidth of 10.4 GHz, effectively covering the UWB frequency range (3.1-13.5 GHz). This broad bandwidth is competitive and surpasses several existing designs, making it highly suitable for a wide range of UWB applications.

Group Delay: The average group delay of 6.2 ns is better than or comparable to other leading UWB antennas, indicating minimal signal distortion. This ensures reliable real-time communication, a crucial factor for high-performance UWB systems.

Gain: The proposed antenna achieves a gain ranging from 2.5 to 4.8 dBi, which is on par with or better than other state-of-the-art UWB antennas. For instance, the design by Masihi et al. achieves a gain of 2.0-5.0 dBi, but the proposed antenna maintains a more consistent gain across the entire bandwidth. This consistent and robust gain ensures adequate signal strength and enhances communication reliability, positioning the proposed design as superior in performance.

Radiation Pattern: The omnidirectional radiation pattern in the H-plane and bidirectional pattern in the E-plane make the proposed antenna highly effective for portable and mobile applications. This pattern ensures consistent performance regardless of the device orientation, which is a significant advantage over some other designs. For example, the antenna by Lages et al. and Acharya et al. also demonstrates omnidirectional patterns, but the proposed antenna's combination of pattern stability and wide bandwidth underscores its superior suitability for diverse UWB applications.

Analysis of Time Domain Features and Impact on Real-Time Communication Applications

Time Domain Features

By aligning double identical antenna devices within the anechoic chamber, the group delay of the antenna is measured in different alignments. This is done to highlight the characteristics of time domain of the suggested design. Figure 9 illustrates the group delay for face-face, face-side, and side-side arrangement schemes. In fact, the group delay characterizes the derivation one of the of the transmission factor phase $S21$. For the three alignment structures, the average value of the group delay is equal to 6.2 nsec with a very small deviation over the entire FCC band of frequency stated to UWB uses. The three alignment schemes verify that the suggested designed antenna is not accumulating great misrepresentation regarding the pulse of the input because the frequency components of the transmitted pulse are transferred from the transmitter to the receiver relatively all together.

Impact on Real-Time Communication Applications

In real-time communication applications, such as UWB systems, maintaining signal integrity is paramount. The group delay characteristics of the proposed antenna demonstrate minimal distortion and phase variation across the frequency band, which are critical for the following reasons:

Signal Integrity: The small deviation in group delay ensures that the transmitted pulse experiences minimal dispersion, preserving the integrity of the signal. This is essential for maintaining high data rates and accurate signal transmission in UWB communication systems.

Synchronization: Real-time communication systems rely on precise timing for synchronization between the transmitter and receiver. The consistent group delay helps in maintaining synchronization, reducing the likelihood of timing errors.

Low Latency: The average group delay of 6.2 ns indicates that the antenna introduces minimal latency, which is beneficial for applications requiring real-time processing and low-latency communication, such as multimedia transmission and real-time data streaming.

Interference reduction: Stable group delay across the frequency band helps in reducing interference with other systems operating in nearby frequency bands. This is particularly important in environments with multiple overlapping communication systems.

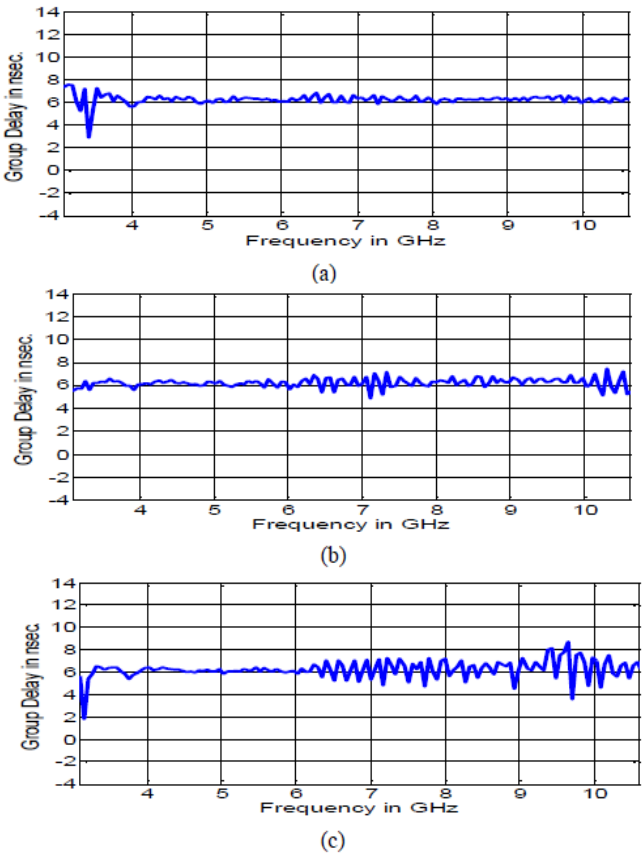

Figure 9. Group delay measuring of double of the suggested antenna lined up (a) Face-Face, (b) Face-Side, and (c) Side-Side

Commercial Applications and Industry Adoption

The proposed fiddle-shaped UWB monopole antenna, with its compact size and wide bandwidth, has significant commercial prospective across various industries. In consumer electronics, it can enhance the performance of smartphones, tablets, and wearable devices by enabling high-speed data transfer and precise location tracking. The antenna's robust performance and stable time domain features make it suitable for IoT applications, such as smart home devices and industrial IoT systems, ensuring reliable wireless communication. In healthcare, the antenna can be integrated into medical devices for patient monitoring and wearable health trackers. The automotive industry can utilize this antenna for Vehicle-to-Everything (V2X) communication, improving in-car connectivity and safety features. Additionally, public safety and emergency services can benefit from the antenna's reliable communication capabilities in rescue operations and emergency response systems. Lastly, the entertainment and gaming sectors can leverage this antenna for VR/AR devices and wireless audio/video streaming, enhancing user experiences with seamless connectivity and low latency. These applications highlight the antenna's versatility and its potential adoption in various consumer electronics and industry-specific devices.

Furture modifications

Future improvements for the proposed fiddle-shaped UWB monopole antenna could focus on several key areas to enhance performance. First, optimizing the antenna's geometry through suitable computational methods could further reduce size while maintaining or improving bandwidth and gain. Material innovations, such as utilizing substrates with lower loss tangents or flexible materials, could improve efficiency and allow for more useful applications, including wearable technology. Moreover, incorporating reconfigurable elements like tunable capacitors or switches could enable dynamic adjustment of the antenna's frequency response, making it adaptable for various communication standards. Enhancing the antenna's radiation pattern by refining the ground plane design could improve omnidirectional performance and reduce interference. Finally, integrating the antenna into multi-antenna systems could provide benefits like spatial diversity and improved signal reliability, particularly in challenging environments. These potential modifications and optimizations would make the antenna more robust and versatile for future communication technologies.

5. CONCLUSION

A miniature fiddle-shaped antenna device with an enhanced ground plane length, and radii of the violin bases is suggested in this study with a few optimization parameters. The device insurances the F-C-C band of frequency stated for the ultra-wide band uses, and can be attached to any UWB gadget used for indoor applications. The measured and simulated outcomes expose that the suggested device includes a larger bandwidth frequency than the device stated for ultra-wide band uses, respectable domain of time features hence the device does not gather great amount of misrepresentation to the entering signal because of the tiny abnormality in the group delay, and acceptable characteristics of radiation since the antenna contains an omni-directional pattern of radiation in plane-H that is appropriate for transportable applications.

REFERENCES

[1] A. Hachi, H. Lebbar and M. Himdi, “Flexible and conformal printed monopoles for reconfigurable antennas,” 2017 11th European Conference on Antennas and Propagation (EUCAP), 2017.

[2] T. Hashimoto, N. Michishita, H. Morishita and T. Koshi, “Disk Loaded Monopole Antenna Installed in Metal Cylinder,” 2020 International Symposium on Antennas and Propagation (ISAP), 2021.

[3] S. Masihi, M. Panahi, D. Maddipatla, A. K. Bose, X. Zhang, A. J. Hanson, B. Narakathu, B. J. Bazuin and M. Z. Atashbar, “Development of a Flexible Tunable and Compact Microstrip Antenna via Laser Assisted Patterning of Copper Film,” IEEE Sensors Journal, Vol. 20, Issue. 14, 2020.

[4] Nouri, A., and G. Dadashzadeh, “A Compact UWB Band-Notched Printed Monopole Antenna With Defected Ground Structure,” IEEE Antennas and Wireless Propagation Letters, Vol. 10, 1178-1181, 2011.

[5] Tammam, E., K. Yoshitomi, A. Allam, M. Alsayed, H. Kanaya, and K. Yoshida, “A Highly Miniaturized Planar Antenna With Dual Band-Notched Using Two Slot Types for UWB Wireless Communications,” IEEE Proceedings of AMPC, Kauhsiung, Taiwan, 726-728, Dec. 4-7 2012.

[6] Tammam, E., K. Yoshitomi, A. Allam, M. Alsayed, H. Kanaya, and K. Yoshida, “Miniaturization of a UWB Antenna with Dual Band-Notched at WLAN/WiMAX Frequency Bands,” IEEE International Conference on Electronics Design, Systems, and Applications, 115-120, 2012.

[7] Gautam, A., S. Yadav, and B. Kanaujia, “A CPW-Fed Compact UWB Microstrip Antenna,” IEEE Antennas and Wireless Propagation Letters, Vol. 12, 2013.

[8] Chen, D., and C. Cheng, “A Novel Compact Ultra-Wideband (UWB) Wide Slot Antenna with Via Holes,” Progress In Electromagnetics Research, Vol. 94, 343-349, 2009.

[9] Lages, A., M. Kawakatsu, and V. Dmitriev, “Planar Elliptical UWB Monopole Antenna with High Efficiency,” IEEE Microwave and Optoelectronics Conference, 208-212, 2011.

[10] Yang, X., L. Liu, S. Cheung, and Y. Sun, “A Simple UWB Monopole Antenna using Half-elliptical Radiator,” IEEE International Workshop on Antenna Technology, 145-149, 2013.

[11] Nordin, M., M. Islam, and Misran N., “Design of a Compact Ultra-Wideband Metamaterial Antenna Based on the Modified Split Ring Resonator and Capacitively Loaded Strips Unit Cell,” Progress in Electromagnetics Research, Vol. 136, 157-163, 2013.

[12] Toccafondi, A., A. Garufo, and C. Giovampaola, “Coplanar Waveguide-fed Compact Antenna for UWB RFID Applications,” IEEE 17th European Conference on Antennas and Propagation, 3048-3049, 2013.

[13] Shay, W., S. Jan, and J. Tarng, “A Reduced-Size Wide Slot Antenna for Enhancing Along-Body Radio Propagation in UWB On-Body Communications,” IEEE Transactions on Antennas and Propagation, vol. 62, no. 3, 1194-1203, 2014.
[14] Jakub Sorocki, Ilona Piekarz, Slawomir Gruszczynski, Krzysztof Wincza, “Miniaturized directional filter multiplexer for band separation in UWB antenna systems,” IEEE International Symposium, Antennas and Propagation (ISAP), 2015.
[15] Paolo Valerio Testa, Corrado Carta, Marvin Barahona, Frank Ellinger, “0.5–20-GHz UWB Distributed Combiners and Dividers for Multi-Antenna Transceivers,” IEEE Transactions on Microwave Theory and Techniques, 3087 – 3098, Volume: 65, Issue: 9, 2017.
[16] Begaud X., Ultra Wide Band Antennas, Wiley: New Jersey, 2011.
[17] Zhao Zhou, Zhaohui Wei, Zhaoyang Tang and Yingzeng Yin, “Design and Analysis of a Wideband Multiple-Microstrip Dipole Antenna with High Isolation,” IEEE Antennas and Wireless Propagation Letters, Vol. 18, Issue:4, 2019.
[18] Hatice-Andreea Topal, “Performance Analysis of Short-Circuited Microstrip Dipole on Different Dielectric Substrates,” 2023 Power Quality and Electromagnetic Compatibility at Low Frequency (PQEMC-LF), 2023.
[19] J. Chen, Z. Liang and Y. Li, “High-gain microstrip magnetic dipole antenna with metal grating,” 2022 IEEE Conference on Antenna Measurements and Applications (CAMA), 2022.
[20] S. H. Ali, A. H. R. Alfalahi and Y. A. Hachim, “A Miniaturized Compact Wideband Partial Ground Antenna Used in RFID Systems,” TJES, Vol. 27, No. 2, 2020.
[21] Acharya, P., Kumar, J., & Dahiya, V., “A Novel Violin Type UWB Patch Antenna for X & Ku Bands using metamaterial,” Second International Conference on Artificial Intelligence and Signal Processing (AISP), 2022, DOI: 10.1109/AISP53593.2022.9760653
[22] Sharma, M., Awasthi, Y.K., Singh, H., Kumar, R., & Kumari, S. (2018). Key shaped planar UWB monopole antenna with dual band-notch characteristics. International Journal of Ultra Wideband Communications and Systems, 3(4), 225-236. DOI: 10.1504/IJUWBCS.2018.10013842

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