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Design of a Compact Dual Notched Semi Circular Shaped UWB Antenna

Oladiran, Sammy Olusola

Department of Information and Communication Engineering, Federal University of Technology, Akure, Nigeria.
Email: sooladiran@futa.edu.ng

ABSTRACT

This paper presents the design of a miniaturized Ultra-Wideband (UWB) antenna with dual band notched and low specific absorption rate (SAR) for body-centric wireless communication applications. The proposed antenna operates from 3.4 GHz to 14.2GHz with two notched frequencies at 5.4-5.6 GHz (Wi-Fi/ISM) and 6.5 GHz - 8.2 GHz (Wimax). The antenna's dimensions were optimized using genetic algorithm embedded in the HFSS and CST software used to achieve a compact size of 26 mm × 27 mm in semi-circular shape with radius 12mm. The SAR value was reduced by using a defected ground structure (DGS) and rectangular slots. Simulation results show that the antenna achieves a return loss of -10 dB, a minimum gain of 5 dBi and maximum gain of 7dBi at 8GHz frequency which is an indication that the proposed antenna is suitable for UWB applications.

Key words: UWB, SAR, Substrate, notched bands, body centric

1. INTRODUCTION

Antenna in wireless communication are of different types depending on the area of applications including Omni-directional antenna which radiates equally in all directions e.g. dipole and monopole, Directional antenna which focuses radiation in a specific direction e.g. parabolic and horn antenna, Semi directional antenna which combines Omni directional and Directional characteristics e.g. patch antenna and Array antenna which are multiple antennas combined for improved gain and directivity. Also in place nowadays are smart antennas which adaptively adjust beam pattern for optimal performance. But because of ease of construction low cost and other advantages patch antenna are commonly employed in wearable applications.

Ultra Wide Band (UWB) antenna have the advantages of Wide bandwidth as they operate over a wide frequency range (3.1-10.6 GHz), enabling high-data-rate transmission, they also have Low power consumption UWB antennas require lower transmission power, reducing interference and SAR (Specific Absorption Rate) values, another advantage is their comparative high gain and efficiency due to their wide bandwidth.

In their own words, Kraus, J. D., & Marhefka, R. J. (2002) defined an antenna as device that radiates or receives electromagnetic energy, and is used for communication, navigation, or other purposes." IEEE Standard 145-2013: "An antenna is a device that converts electrical energy into electromagnetic waves and vice versa, enabling communication between devices." Furthermore International Telecommunication Union (ITU) - Recommendation ITU-R V.117-4: "An antenna is a device, or system of devices, used to transmit or receive electromagnetic waves, and is an essential component of a telecommunication system."

2. LITERATURE REVIEW

2.1 ANTENNA DESIGN FOR UWB APPLICATIONS

ULTRA WIDE BAND (UWB) ANTENNA

An ultra-wideband (UWB) antenna is a device that receives signals in the frequency range between 3.1 GHz to 10.7 GHz. With the rapid development of communication technology, ultra-wideband (UWB) communication system has gained the attention and focus of researchers. UWB requires that the relative bandwidth ratio is higher than 20%, or the absolute bandwidth is greater than 0.5GHz (Chen, Z. N., et al 2004). According to Federal Communications Commission (FCC) regulations, UWB communication systems can use the frequency band from 3.1GHz to 10.6GHz. The available frequency band usually includes several civil narrowband communication bands, such as C-band satellite uplink/downlink band (5.925–6.425/3.7–4.2GHz), wireless local area network (WLAN) band (5.15–5.35GHz, 5.725–5.825GHz), and X-band satellite uplink/downlink band (7.9–8.4/7.25–7.75GHz). As the narrowband communication system occupies part of the UWB, the mutual interference between them is inevitable, so band notch UWB antenna has great research value FCC. (2002).

There are different types of UWB antennas (Guha, D., & Antar, Y. M. M.2011)

REVIEW OF PAST WORKS

Manjunathan et al (2024) carried out performance analysis of microstrip patch antenna for wireless communication. Their research showed that microstrip patch antenna had been focus of researchers in the field of wireless communication with over 1500 research articles, and textbooks on the subject matter due largely to the comparative advantages it has over other types of antenna like compactness, large bandwidth and high gain advantages. Their work showed that bandwidth of a patch antenna can be improved by thickening the substrate level, though they also found out that this may have the disadvantage of minimizing the efficiency of the antenna due to less power radiation occasioned by the significant amount of input power waster in the resistor. These identified flaws were compensated for using electromagnetic band gap EBG) structure with their unique characteristics which increases efficiency by as high as 48.8% in bandwidth.

Furthermore, Anees Abbas et al (2020) realized a compact ultra-wideband (UWB) antenna of optimized dimension of size of the compact antenna is 16 × 25 × 1.52 mm3 by using rectangular notch wireless area network (WLAN) band with controllable notched bandwidth and center frequency. They achieved UWB characteristics of the antenna by truncating the lower ends of the rectangular microstrip patch; they also used electromagnetic bandgap (EBG) structures to obtained notch characteristics of the antenna. EBG is made up of two rectangular metallic conductors mounted on the back of the radiator, and connected to the patch by shorting pins. They tuned the individual resonant frequencies of the EBGs and merged them rectangular notch to realize WLAN band with high selectivity. Their results show that the bandwidth and frequency of the rectangular notch band Their simulated and measured results show that the antenna has an operational bandwidth from 3.1–12.5 GHz for $|S11| < -10$ with a rectangular notch band from 5–6 GHz, thus rejecting WLAN band signals. Their results also showed that the antenna stable gain and radiation patterns.

Subhash et al (2024) used two bevels of a semi-circle engraved with stepped cut monopole antenna to develop a reconfigurable multiband notched semi-circle engraved UWB antenna for wireless communication application. They used L-shaped and Ladder shaped stubs of quarter wavelength on the patch to achieve notching characteristics in the 5G band of 3.40 – 3.70 GHz (n78) and 4.84 – 5.70 (n46). By also incorporating a half wavelength C-shaped slot and I-shaped stub on the patch, they were able to achieve another notch band at 3.88 – 4.32 (n77, C band) and 7.10 – 7.61 GHz (X band, satellite downlink). Subhash (2024) also used eight PIN diodes to regulate the multi operations modes which allows it to switch into single/double/triple/quadruple m band notch characteristics. The overall dimension of their work is 0.2 x 0.37 mm2 using Rogers RT/duroid 5880 substrate. Their simulated and measured, and calculated equivalent circuit showed significance agreement in terms of high gain, stable radiation pattern all through the UWB band.

In addition, Azza Elnaggar (2024) reported the development of a textile two port multiple input multiple output MIMO half circle UWB antenna with corrugated borders for biomedical diagnostics applications. In their work they used orthogonal polarization technique to reduce the mutual coupling effect, enhance signal quality and make imaging more accurate. They injected a low pass filter for out of band rejection using a 50 ohms coplanar waveguide as elements. The antenna was developed on textile materials using conducting fabrics to achieve flexibility for the antenna. The dielectric material used was cotton of tangent value 0.0025. The optimized dimension was 40 x 40 x 0.3 and their results showed a wide bandwidth of between 2.5 – 12 GHz coupled with omnidirectional radiation pattern, maximum gain of 6dBi and 96% efficiency.

Sesha Vidhya (2023) analyzed the performance of a triple band miniaturized hexagonal UWB antenna for wireless body worn applications to mitigate the significant challenges human body causes for both wearables and implantables antenna devices. The antenna was fabricated using FR4 substrate with dimensions with dimensions 24 x 25 x 1.6 and they achieved a frequency bandwidth of 3 – 9 GHz with a reflective coefficient of -15dB and gain of 2.5dBi. They also found the antenna SAR to be 2 W/kg and without SRR were found to be 3.5 W/kg.

3.1 METHODOLOGY

Standard equations for patch antenna (as shown in equations 1 to 7) were used to design the dimensions of the various parts of the antenna. The design was optimized using HFSS and CST studio software leading to a compact, miniaturized UWB antenna that is significantly safe in terms of radiation effect on human body. Theory of size optimization, rejection of interference bands using slot notching techniques to eliminate undesirable frequency bands and careful selection of substrate materials to improve the SAR the antenna were all applied in achieving the design objective of the proposed antenna.

3.2 ANTENNA CONFIGURATION

The designed antenna consists of FR4 substrate with permittivity (δ) of 4.4 and thickness of 1.6mm as dielectric material, semi-circular patch with a H slot, defected ground structure (DGS), rectangle microstrip feed line, two notched frequencies achieved using a H-shaped slot for 5.15-5.825 GHz and a U-shaped slot for 7.725-8.275 GHz.

3.3 DUAL NOTCHED FREQUENCY UWB ANTENNA DESIGN

To design the proposed antenna the following methods were undertaken step by step viz:

i. determination of antenna size and shape by calculations using standard equations iii – vi,

ii. optimization of the calculated sizes and shape using genetic algorithm embedded in HFSS and CST software through multiple iterations and simulations of different sizes and shapes of designed patch antenna and comparing results to achieve desired compactness,

iii. achieve desired bandwidth of at least 10 GHz with desired gains at different frequencies and other performance evaluation metrics by using ground defected structure (GDS) technique,

iv. notching of undesirable frequency bands of ISM of frequency and WIMAX of frequency bands using H and U slots in the patch and the feed line,

v. careful selection of the optimal substrate of the dielectric material to achieve low SAR and compactness of the antenna by simulating the antenna and analyzing the results using different substrate materials.

3.4 ANTENNA DESIGN CALCULATIONS

The radiating patch, the feedline, and the ground of the antenna dimensions were calculated as shown in the equations iii - x

The effective radius of the patch is given by

$$a_e = a\left[1 + \left[\frac{2h}{\pi\epsilon_r}\right]\ \mathrm{In}\left[\frac{\pi a}{2h}\right] + 1.7726^{1/2}\quad\right] \qquad (1)$$

3.5 RADIUS OF THE PATCH

FR4 (lossy) as the substrate has a permittivity $\epsilon_r\ of$ 4.4, and height of dielectric optimized as 1.6mm. The dimension of the semi-circular patch is calculated using equations….

$$\lambda = \frac{c}{f_0 f_r} \text{ where } f_0 = \frac{3\times10^8}{2.4\times 10^9} = 0.125\text{mm}\left[\epsilon_{reff}\frac{\epsilon_{reff}+0.3}{\epsilon_{reff}-0.258}\frac{(\epsilon_{eff}+3)\left(\frac{W}{h}+0.264\right)}{(\epsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)}\right] \qquad (2)$$

The semi-circular patch antenna radius is determined from the expression

$$\text{a} = \frac{F}{\left[1+\left[\frac{2h}{\pi\epsilon_r}\right]\mathrm{In}\left[\frac{F\pi}{2h}\right]+1.7726\quad\right]^{1/2}} \qquad (3)$$

$$W = \frac{c}{2f_r\sqrt{\frac{\epsilon_r+1}{2}}} = \qquad (4)$$

The length of the patch of the antenna is given as equation

$$\text{L} = L_{eff} - 2\Delta L \qquad (5)$$

where

$$L_{eff} = \frac{\text{c}}{2f_r\sqrt{\epsilon_{reff}}} \qquad (6)$$

Where effective dielectric constant ϵ_{reff}

$$\epsilon_{reff} == \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2}$$

The length extension $\Delta L = 0.412\text{h x}\left[\epsilon_{reff}\frac{\epsilon_{reff}+0.3}{\epsilon_{reff}-0.258}\frac{(\epsilon_{eff}+3)\left(\frac{W}{h}+0.264\right)}{(\epsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)}\right]$

We can also calculate the effective dielectric constant from the equation

$$\epsilon_{reff} == \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2}$$

Calculation of the length of extension is

$$\Delta L = 0.412\text{h x}\left[\epsilon_{reff}\frac{\epsilon_{reff}+0.3}{\epsilon_{reff}-0.258}\frac{(\epsilon_{eff}+3)\left(\frac{W}{h}+0.264\right)}{(\epsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)}\right] \qquad (7)$$

3.6 ANTENNA MODELLING SOFTWARE

EM simulation tools are used to predict antenna performance in a specific environment. There are a number of software that are available for modeling of antenna including CST-MS, HFSS and others. These software are based on different algorithms including Finite Distance Time Domain (FDTD) which algorithm is built on solving differential equations, Finite Integration technique (FIT) which is integral equation based, Methods of Moments (MoM) which is also based on solving integral equation and Finite Element Method (FEM) which algorithm is based on differential equation. In this work HFSS and CST software were used for size and shape optimization simulations and performance metrics analysis

Using the calculated values the antenna was designed using different shapes with the sizes and the optimized size and shape after analyzing all the simulations results are summarized in table and shown in table 1

Parameter	**Value (mm)**
Radius of patch (R)	13
X position (Xp), Y position (Yp) of patch	-12 , 0
Length of substrate (L)	27
Width of substrate (W)	26
Partial ground plane (L_p)	11.5
Width feed line (W_f)	3
Length feed line (L_f)	13
Length of slot (L_s)	3
Width of slot (W_s)	4
Width of U slot (W_{Us})	5
Length U slot (W_{Us})	4.45
Length of H slot (L_{Hs})	6.4
Width of H slot (L_{Hs})	7.77

The designed antenna using HFSS software with these optimized dimensions given in the table 1 is as shown in figure 1

Figure 1: Antenna patch and feedline

Figure 2: Antenna ground

The antenna shown in figures 1 and 2 were subjected to parameter analysis to determine the performance and it was discovered that the S1,1 parameters showed that the bandwidth of operation of this antenna was low as it was between 3GHz and 9 GHz which translates to just 6GHz of bandwidth. In other to improve this, further modification of the antenna was necessary and the method employed was to create a defected ground that will increase the bandwidth. This was achieved by cutting the ground into half and using ground defected structure at the centre of the ground of the antenna with dimension 3mm x 4mm as shown in figures 3 and 4 respectively.

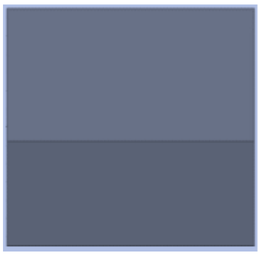


Figure 3: Antenna ground halved

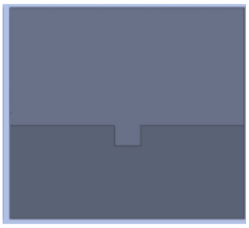


Figure 4: Antenna ground with DGS slot

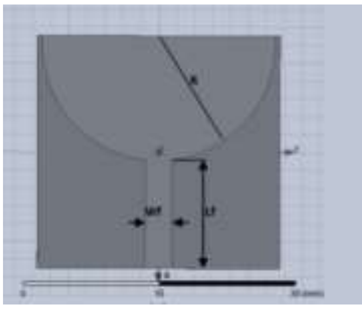


Figure 5: Antenna geometry showing radiator and feedline

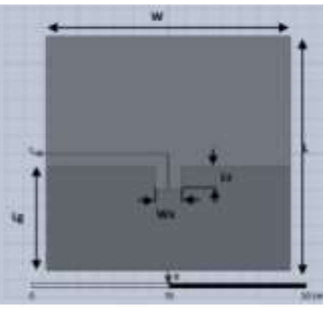


Figure 6: Antenna ground geometry with DGS slot

Geometry of the antenna (figures 5 and 6) before the notching slots H and U were introduced in the patch and the feed line respectively.

To create the rejection of unwanted bands of frequencies which were ISM and WIMAX bands, chosen purposely to avoid interference of the antenna when being used for on body applications in different environments, two slots H with dimensions were cut in the radiating patch and U with dimensions were cut in the feed line as shown in figure 5, 6 and 7

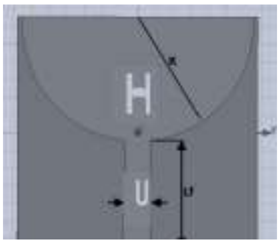


Figure 7: Geometry of with notching slots H and U were introduced in the patch and the feed line

4.1 RESULTS AND DISCUSSION

The following graphs show the performance of the antenna at the three different stages of the design viz;

Stage i. : Antenna design with the optimized dimensions without slots

Stage ii: Antenna halved with DGS slot in the ground

Stage iii: Antenna with H and U slots for dual frequency notched

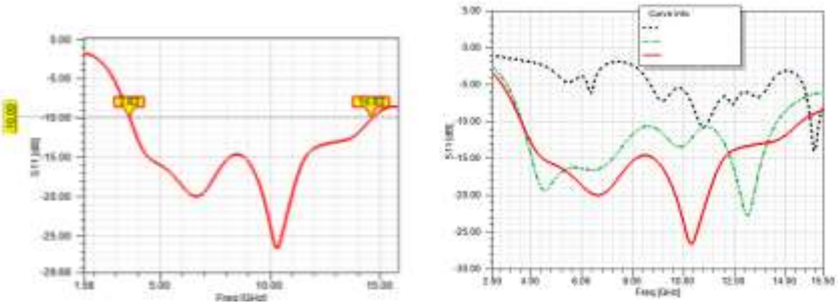


Figure 8 and 9: S11 plots of the three stages of the design of the antenna

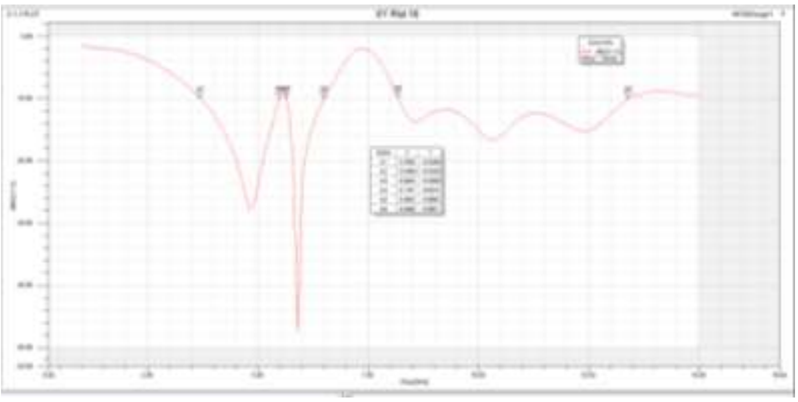


Figure 10: Reflection coefficient or return loss of the antenna plot

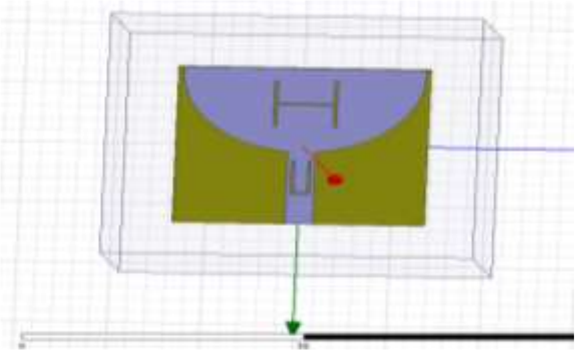


Figure 11: Front view of the design in HFSS

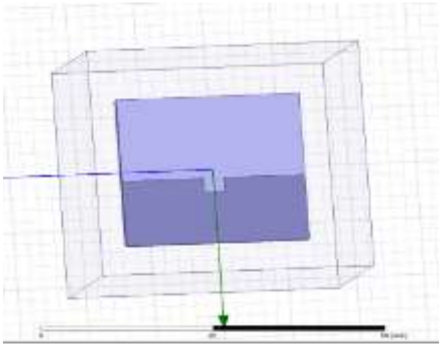


Figure 12: Back view of the design in HFSS

Figure 10 shows the S1,1 plot of the antenna, this reflection coefficient also called return loss is a critical parameter in evaluating the performance of a UWB antenna as it represents the ratio of the reflected wave to the incident wave at the antenna's input port. It also indicates the impedance matching between the patch and the feedline. In other words the S11 determines the bandwidth of the antenna, the antenna efficiency and impedance matching. The result from simulation showed that between the frequency bands 3.2GHz to 13.7 GHz there was a return loss of -10dB or less which indicates that the designed antenna achieved a 10.5GHz bandwidth which makes the antenna usable in ultra wide band (UWB) range. The plot also showed that the frequency between 3GHz -5.1GHz which is WIMAX band and ISM band were above -10dB were notched.

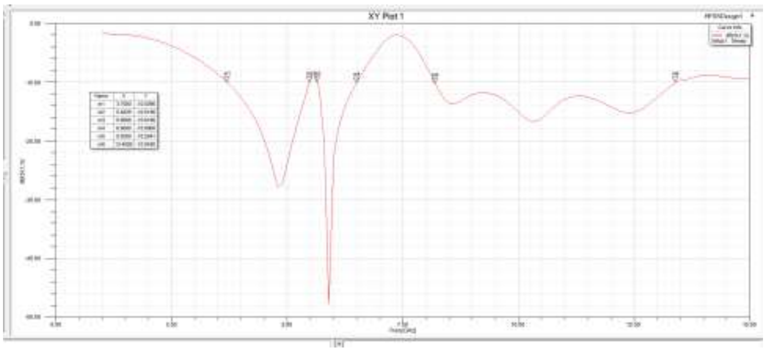


Figure 13: Reflection coefficient (S1,1) of the antenna showing double notches

Figures 14 to 16 showed the current distributions of the antenna in different frequency range between the operating bandwidth. The distributions showed that at the two notched frequency the concentration was strongest in figures which shows the bands were notched.

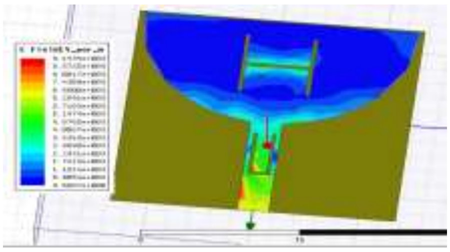


Figure 14: Surface current distribution

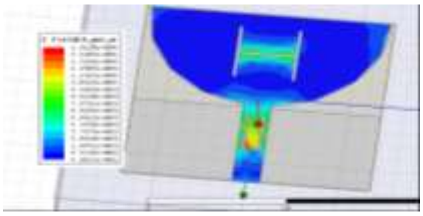


Figure 15: Surface current distribution Figure 16: Surface current distribution

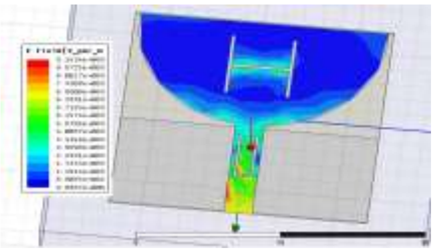


Figure 16 shows the radiation pattern of the antenna.

The plot showed that the antenna demonstrates a directional radiation pattern which is highly desirable for antenna used in body centric applications. Directional antenna will concentrate the radiation in a determined direction and this quality is explored in UWB to reduce the harmful effects of the EM radiation on human body by directing the radiation to a particular area without affecting other areas.

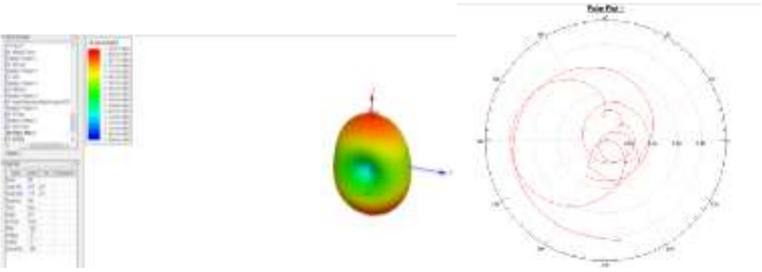


Figure 17: Radiation pattern of the antenna

The radiation pattern gain of the antenna was plotted at different frequencies and superimposed on one another to show the radiation patter in 2D as shown in figure 19 which also corroborates the 3D and Smiths chart plots results earlier shown in figure 17 and 18.

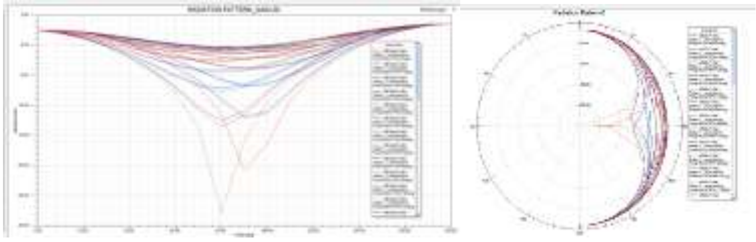


Figure 18: Radiation pattern of the antenna

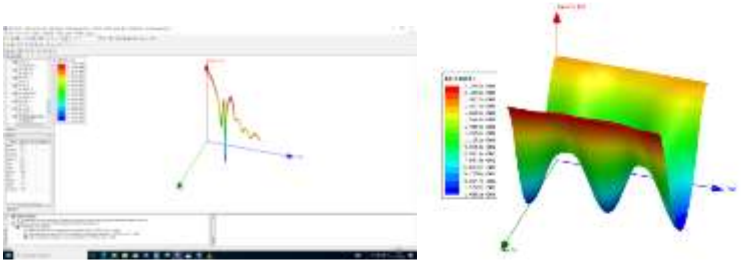


Figure 19: Radiation pattern of the antenna

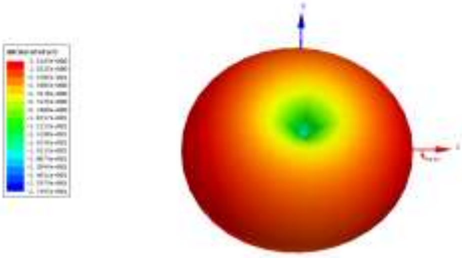


Figure 20: Radiation pattern of the antenna

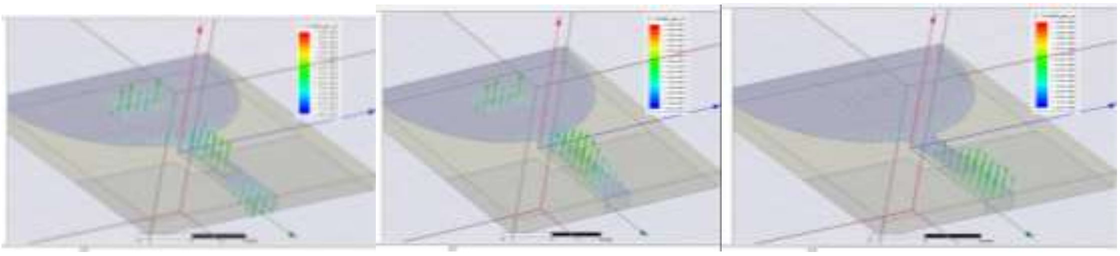
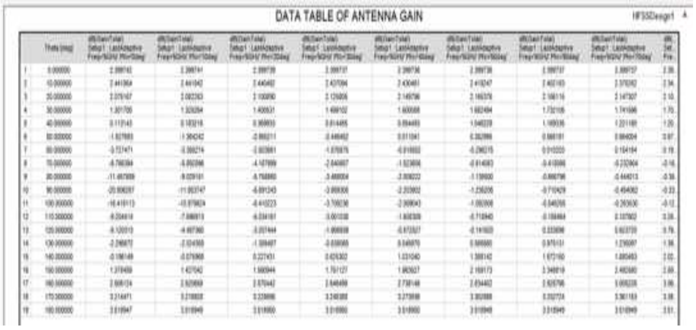


Figure 21: Field distribution plots of the antenna

The gain of the antenna was very high at frequencies with values ranging from as shown in stacked plots figures 22 and 23. The gain was tabulated for different frequencies in table 1



DATA TABLE OF ANTENNA GAIN

Table 1

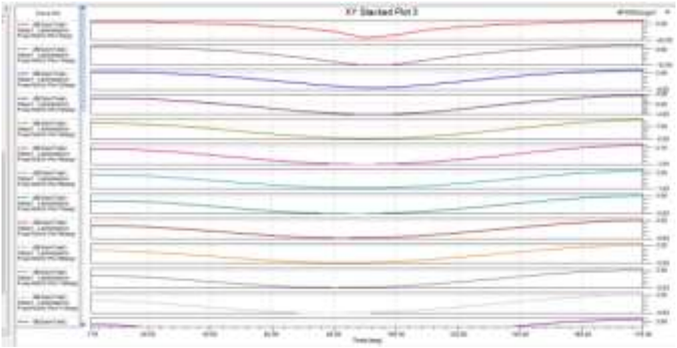
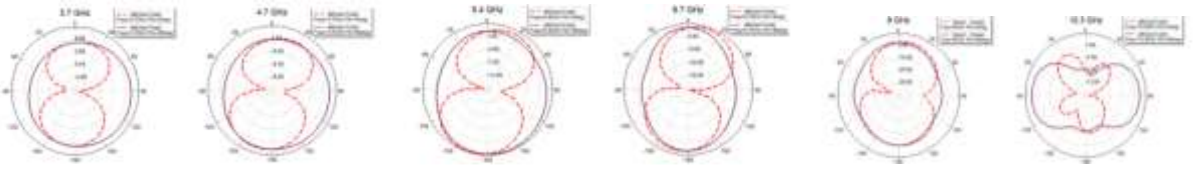


Figure 11: Stacked plot of radiation pattern of the antenna

Table 2: Data table of the Antenna gain for different frequencies



5. CONCLUSION

This paper presented the design of a dual notched frequency low SAR ultra wide band antenna for body centric application with an optimized overall dimension of 26 x 27 mm using FRA substrate. The dual band notched were achived by cutting H and U slots in the radiator and feedline respectively and using a rectangulaar ground defected structure (DGS) at the ground plane The bandwidth of operation the design achieved operated between the frequency range of 3.1 GHz to 13.8 GHz and with a maximum gain of 7 dBi at 8GHz. The proposed antenna exhibited a directional radiation pattern which was consistent in all the frequencies at various orientations of thetha and phi angles.The simulation and experimental results showed that there was no significant variation between the simulated results and the experimental set up results indicating the developed antenna was very suitable for body centric purposes as it was compact, operated within a bandwidth of 10.5 GHz and low SAR of 1.6/10kg/w.

RECOMMENDATION

It is recommended that further works be carried out on UWB antenna design for body centric application by exploring the possibilities of integrating quantum optimization algorithm into the design process. Human phantom models were used in the simulation of this research, it is recommended that further works be done using actual human body for validation purposes. It is also recommended that the etching of the antenna during development be done without using acidic etchants as this was found to have significant impact in altering the chemical structure of the FR4 substrate thereby affecting the results. A 3D printing of the antenna board is recommended for further works. Also it is hereby recommended that efforts should be made towards producing hybrid materials for the substrate from simulated materials for better efficiency and improved results.

REFERENCES

Abbasi, Q. H., Rehman, M. U., Xiaodong, Y., Alomainy, A., Qaraqe, K., & Serpedin, E. (2013). Ultra wide band band-notched flexible antenna for wearable applications. IEEE Antennas and Wireless Propagation Letters, 12, 1606–1609.

Adham R Azeez, Sadiq Ahmed, AM Zalzala, Zaid A Abdul Hassain, Taha A Elwi (2023) Design of High Gain UWB Vivaldi Antenna with Dual Band-Notches Characteristics. International Journal on Engineering Applications 11 (2), 2023

Aparna Panja, Arnab De, Koyndrik Bhattacharjee, Partha Pratim Sarkar, (2023) Design and Performance Analysis of a Miniaturized UWB Monopole Antenna with Embedded Octagonal Slot and DGS for Various Wireless Applications Advances in Microwave Engineering, 45-69, 2023

Ashim Kumar Biswas, Subhraneel Biswas, Sourish Haldar, Arnab Nandi (2024) A highly decoupled flexible 4-element MIMO antenna with band notched characteristics for ultra wide-band wearable applications AEU-International Journal of Electronics and Communications 173, 154985, 2024

Azim, R., Islam, M. T., & Misran, N. (2011). Ground modified double-sided printed compact UWB antenna. Electronics Letters, 47(1), 9–11.

Azza H Elnaggar, Anwer S Abd El-Hameed, Mohamed A Yakout, Nihal FF Areed (2024) Development and comprehensive evaluation of a dual-port textile UWB MIMO antenna for biomedical use Optical and Quantum Electronics 56 (7), 1099, 2024

Behera B.K, SK Dash, JR Panda, SN Mishra, J Siddartha Varma, PK Patra (2024) A UWB Dual Notched Antenna with H-Shaped Strip and U-Shaped Slot for Application in Wireless System 2024 2nd International Conference on Device Intelligence, Computing and Communication Technologies (DICCT), 376-380

Gamio, J., Parron, J., & Soler, J. (2010). Human body effect on implantable antennas for ISM band applications: Models comparison and propagation losses study. Progress in Electromagnetics Research, 110, 437–452.

Hao, Y., & Foster, R. (2008). Wireless body sensor networks for health monitoring applications. Physiological Measurement, 29, R27–R56.

Hasan Mahfuz, Md Shazzadul Islam, Islam Md Rafiqul, (2021) Design of UWB microstrip patch antenna with variable band notched characteristics TELKOMNIKA (Telecommunication Computing Electronics and Control) 19 (2), 357-363,

Hemant Kumar Varshney, Sachin Agrawal, Dharmendra Kumar Jhariya (2023) Design a UWB Antenna with Band Notch Characteristics for MIMO Applications 2023 9th International Conference on Signal Processing and Communication (ICSC), 78-83,

Hiwa Taha Sediq, Javad Nourinia, Changiz Ghobadi (2022) A novel shaped antenna for designing UWB-MIMO system in microwave communications AEU-International Journal of Electronics and Communications 152, 154249

Licul, S., Noronha, J. A. N., Davis, W. A., Sweeney, D. G., Anderson, C. R., & Bielawa, T. M. (2003). A parametric study of time-domain characteristics of possible UWB antenna architectures. In IEEE 58th vehicular technology conference (VTC) (Vol. 5, pp. 3110–3114).

Manish Sharma, Tathababu Addepalli, Rajasekhar Manda, T Vidyavathi (2023) A detailed insight of 2× 2 high isolation wideband dual notched band MIMO antenna with evolution initiated by theory of characteristics mode International Journal of Microwave and Wireless Technologies 15 (8), 1392-1411, 2023

Manish Sharma, Kanhaiya Sharma, Prabhakara Rao Kapula, Anand Nayyar, Muhammad Bilal (2023) Dual-Wide Multi-Band (DWMB) four-port flexible MIMO antenna for on-body multiple wireless applications including high diversity performance PloS one 19 (11), e0309690, 2024

Malathi Kanagasabai, Padmathilagam Sambandam, Mohammed Gulam Nabi Alsath (2023) Compact ultra-wideband pattern diversity antenna for body-centric communications International Journal of Microwave and Wireless Technologies 15 (2), 245-254, 2023

Muhammad Irshad Khan, Muhammad Irfan Khattak, Saeed Ur Rahman, (2020) Design and investigation of modern UWB-MIMO antenna with optimized isolation Micromachines 11 (4), 432,

Manish Sharma, Vikas Janghu, Naresh Kumar (2023) Dual notched four-port multiband reconfigurable MIMO antenna with novel fork-radiator and Ω-shaped ground IETE Journal of Research 70 (1), 185-198, 2024

Madhumitha Jayaram, Keren Naomi Devnesh, Bhagyaveni (2023) Design of a uwb antenna utilising fractal geometry and ebg structures for wireless applications 2023 International conference on intelligent systems for communication, IoT and Security (ICISCoIS), 185-189, 2023

Miraç Dilruba Geyikoglu (2023) A novel UWB flexible antenna with dual notch bands for wearable biomedical devices Analog Integrated Circuits and Signal Processing 114 (3), 439-450,

Pankaj Jha, Anubhav Kumar, Asok De, Rakesh Kumar Jain (2021) Design of UWB antenna based on CSRR and EBG notch for prevention of undesired band 8th International Conference on Signal Processing and Integrated Networks (SPIN), 982-986

Pankaj Kumar, S Shilpi, Abhas Kanungo, Varun Gupta, (2022) A novel ultra wideband antenna design and parameter tuning using hybrid optimization strategy Wireless Personal Communications 122 (2), 1129-1152,

Peshal Nayak, Sudhanshu Verma, Preetam Kumar (2021) A study of ultrawideband (uwb) antenna design for cognitive radio applications Xiv preprint arXiv:2106.15272,

Prakash Kumar, Pramod Kumar, Tanweer Ali, Pradeep Kumar, Shweta Vincent (2021)

Ultrawideband antennas: Growth and evolution Micromachines 13 (1), 60,

Premalatha Bantupalli, Srikanth Gimmadi, Abdul Subhani Shaik (2024) Design of UWB Antenna with Band Rejection Characteristics Using EBG Structures Journal of The Institution of Engineers (India): Series B, 1-9

Raghav Dwivedi, DK Srivastava, VK Singh (2024) A Nested Orbicular Shaped Textile Antenna with Centered Hexagonal Slot, DGS and Enhanced Bandwidth for ISM, Wi-Fi, WLAN & Bluetooth Applications Iranian Journal of Science and Technology, Transactions of Electrical Engineering, 1-23, 2024

Raju Pandey, Ashim Kumar Biswas, Ujjal Chakraborty (2024) Non-conventional leather substrate based high isolation wideband MIMO antenna for body-centric applications AEU-International Journal of Electronics and Communications 170, 154871, 2023

Ramya Vasudevan, V Nagaraju (2024) Design and investigation of UWB antenna with triple notched band for 5G wireless communication Electromagnetics, 1-29, 2024

Sahar Saleh, Tale Saeidi, Nick Timmons, Bader Alali, Faroq Razzaz, (2024) Compact ultra-wide band two element vivaldi non-uniform slot MIMO antenna for body-centric applications Results in Engineering 24, 102839

Sesha S Vidhya, S Rukmani Devi, KG Shanthi, S Santhi (2023) Performance analysis of triple-band miniaturized hexagonal ultra-wideband antenna for wireless body worn applications Automatika: časopis za automatiku, mjerenje, elektroniku, računarstvo i komunikacije 64 (4), 1089-1094, 2023

Shahid Basir, Ubaid Ur Rahman Qureshi, Fazal Subhan, Muhammad Asghar Khan, (2024) A novel monopole ultra-wide-band multiple-input multiple-output antenna with triple-notched characteristics for enhanced wireless communication and portable systems Sensors 23 (15), 6985, 2023

Shivkant Thakur, Rajan Mishra, Sanjay Kumar Soni (2023) Sensitivity enhancement of an antenna sensor by using sextuple notch bands for application in cancer detection Engineering Research Express 5 (4), 045026, 2023

Shay, W.-T., Chen, K.-H., & Tarng J.-H. (2014). Wide slot antennas for UWB on-body communications. In IEEE antennas and propagation society international symposium (APSURSI) (pp. 1817–1818), July, 2014.

Subhash Shrimal, Renu Agrawal, Indra Bhooshan Sharma, Joohi Garg, MM Sharma (2024)

A Reconfigurable Multi-Band Notched Semi-Circle Engraved UWB Antenna for Wireless Applications Scientia Iranica

Surajit Mukherjee, Avisankar Roy, Smarajit Maity, Tapas Tewary, (2023) Design of dual band-notched UWB hexagonal printed microstrip antenna International Journal of Microwave and Wireless Technologies 15 (3), 526-534, 2023

Sumon Modak, Vikrant Kaim, Taimoor Khan, Binod Kumar Kanaujia, (2024) Design and Performance Measurement of Worn-on-Body Instrumental Ultra-Miniaturized UWB Wearable Patch for e-Health Monitoring IEEE Access, 2024

Thyla B, PK Jaya Soumeyaa, T Jennifer, S Maharishi, V Thulasi Bai (2023) Design of UWB antenna for wireless capsule endoscopy Materials Today: Proceedings 80, 1617-1622, 2023

Tuovinen, T., Berg, M., Salonen, E., Hamalainen, M., & Linatti, J. (2014). Conductive layer under a wearable UWB antenna: Trade-off between absorption and mismatch losses. In IEEE 8th international symposium on medical information and communication technology (ISMICT) (pp. 1–5), April, 2014.

Umar Musa, Shaharil Mohd Shah, Huda A Majid, Mohamad KA Rahim, (2023) Wearable Dual-Band Frequency Reconfigurable Patch Antenna for WBAN Applications. Progress In Electromagnetics Research M 120, 2023

Venkatesh Pandi Ravichandran, Narmadha Velayudham, Padmavathy Velayudham (2024) On the design and analysis of a miniaturized ultra-wideband (UWB) antenna using quatrefoil-shaped nonuniform meta-surfaces for body-centric communications International Journal of Communication Systems 37 (6), e5712

Venkatesh P, Narmadha TV (2024) Design of a compact sigma slotted dual-mode UWB antenna for wireless body area network applications International Journal of Microwave and Wireless Technologies 16 (2), 203-216,

Walaa M Hassan, Ayman Ayd R Saad, Ahmed A Ibrahim (2023) Ultra-wide band flexible antenna applicable for dual-band on-body communications International Journal of Microwave and Wireless Technologies 15 (4), 609-622, 2023

Woo, S., Baek, J., Park, H., Kim, D., & Choi, J. (2013). Design of a compact UWB diversity antenna for WBAN wrist-watch applications. In International symposium on antennas & propagation (ISAP)(pp. 1304–1306).

Yousif Mohsin Hasan, Kareem Dhahir Rahi, Alyaa Abduljawad Mahmood (2023) Rectangular antenna with dual-notch band characteristics for UWB applications AIP Conference Proceedings 2591 (1), 2023