IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Design And Simulation Of Multiband Patch Antenna For Wireless Applications

1 A. Madhuri, 2 T. P. S. V. Venkatesh, 3 A. V. Vinay Kumar, 4 T. Karthik, 5 Ch. Gowri

1,2,3,4 **Students**, Dept. of ECE, Godavari Institute of Engineering and Technology (A), Rajahmundry, AP.
5 **Assistant Professor**, Dept. of ECE, Godavari Institute of Engineering and Technology (A), Rajahmundry, AP.

ABSTRACT

This project explores the design and simulation of a multiband patch antenna suitable for wireless applications, including Wi-Fi, Bluetooth, and satellite communications. With the growing demand for compact, efficient, and versatile antennas in modern communication systems, the patch antenna was chosen due to its compact size, ease of fabrication, and suitability for multiband operation. The research gives different design configurations to optimize the antenna's performance across multiple frequency bands.

The primary objective is to develop an antenna that operates efficiently across a wide range of frequency bands, ensuring it can support multiple wireless technologies. This project uses a different range of frequencies for various applications. The frequency range of Wi-Fi is 5 GHz, the frequency range of Bluetooth is 2.4 GHz and the frequency range of satellite communications is 4 GHz-6 GHz (for C-Band). The goal is to achieve high efficiency, low return loss, and stable radiation patterns across the targeted frequency bands.

The scope of this project is a single antenna that can be used for various wireless applications like Wi-Fi, Bluetooth and Satellite communications. The results of the designs are validated through simulations and practical measurements, demonstrating their effectiveness for real world wireless systems.

KEYWORDS: multiband patch antenna, wireless applications, antenna design, frequency bands, simulation, return loss, radiation pattern.

INTRODUCTION

A multiband patch antenna is a type of antenna that is designed to operate at multiple frequency bands. These antennas are widely used in wireless communication systems because they can transmit and receive signals over various frequencies, making them highly versatile. Traditional antennas are typically designed for a single frequency band, but a multiband patch antenna can work across several bands, making it ideal for modern communication technologies that need to operate on different frequencies simultaneously.

The main advantage of multiband patch antennas is their ability to reduce the size and complexity of communication systems. Instead of using multiple antennas for different frequency bands, a single multiband antenna can serve multiple purposes, which simplifies the overall design. This capability is especially important in applications like mobile phones, satellite systems, and wireless networking, where space and performance need to be balanced efficiently.

Designing multiband patch antennas using HFSS typically involves adjusting the shape, size, and structure of the patch. This includes introducing features such as slits, notches, or parasitic elements to achieve the desired resonant frequencies. HFSS allows for precise tuning and optimization of these design elements, ensuring that the antenna performs efficiently across different frequency bands.

As demand for more advanced wireless technologies grows, multiband patch antennas continue to be a crucial component in ensuring seamless connectivity across different platforms.

1 LITERATURE SURVEY

[1] Sajjad et al. [2021] – Designed a multiband microstrip patch antenna for wireless communication, operating at 2.4 GHz, 3.5 GHz, and 5 GHz, which are suitable for Wi-Fi, Bluetooth, and LTE applications. The antenna was simulated using HFSS (High-Frequency Structure Simulator), achieving efficient impedance matching and low power consumption across all bands.

[2] Reddy et al. [2019] – Proposed a dual-band patch antenna for WLAN and Bluetooth applications, operating at 2.4 GHz and 5 GHz. The antenna was designed using CST Microwave Studio, ensuring good radiation efficiency and impedance matching for both frequency bands, making it ideal for wireless communication systems with low power consumption.

[3] Patel et al. [2020] – Designed a multiband patch antenna suitable for future 5G wireless communication, operating at 3.5 GHz, 4.8 GHz, and 5.9 GHz, targeting 5G New Radio (NR) applications. The antenna's design was optimized using Ansys HFSS, providing high gain and wideband performance at all frequencies while maintaining low power requirements for high-frequency use.

[4] Kumar et al. [2018] – Created a compact multiband antenna for wireless communication, operating at 2.4 GHz (Wi-Fi), 5 GHz (Wi-Fi), and 5.8 GHz (ISM). The design was simulated using MATLAB and HFSS, resulting in excellent impedance matching and minimal reflection loss, making it efficient for short-range wireless communication devices.

[5] Singh et al. [2022] designed a compact multiband antenna for IoT wireless communication, operating at 868 MHz, 2.4 GHz, and 5 GHz, covering IoT protocols such as Zigbee, Wi-Fi, and Bluetooth. The antenna was simulated using CST Studio Suite, and the results showed good radiation efficiency, wide bandwidth, and low power consumption suitable for IoT applications.

[6] Verma et al. [2021] developed a multiband antenna for wireless sensor networks, operating at 1.8 GHz (GSM), 2.4 GHz (Bluetooth), and 5.8 GHz (Wi-Fi). Using HFSS for simulation, the design achieved broad impedance bandwidth and low reflection loss, making it ideal for smart city applications with low power needs for continuous wireless sensor operations.

[7] Sharma et al. [2017] designed a multiband microstrip patch antenna for WLAN and Bluetooth, operating at 2.4 GHz, 5 GHz, and 5.8 GHz. The antenna, designed using CST Microwave Studio**,** showed good radiation efficiency and impedance matching, ensuring reliable performance for short-range wireless communication systems.

[8] Soni et al. [2019] designed a U-shaped multiband patch antenna for 5G and IoT applications, operating at 3.5 GHz, 4.8 GHz, and 5.9 GHz. Simulated using HFSS, the antenna demonstrated high gain and low power consumption, making it suitable for modern 5G and IoT communication systems.

[9] Jain et al. [2020] proposed a multiband patch antenna for vehicular communication, operating at 2.45 GHz, 5.5 GHz, and 6 GHz. The design, optimized with CST Microwave Studio, provides good impedance matching and radiation efficiency, making it suitable for vehicle-to-vehicle (V2V) communication systems with low power consumption.

[10] Zhang et al. [2021] designed a compact multiband antenna for wireless mobile applications, operating at 1.8 GHz (GSM), 2.4 GHz (Wi-Fi), and 5 GHz (Wi-Fi). The antenna was simulated using HFSS, ensuring low power consumption and efficient operation across all frequency bands, making it ideal for mobile devices that require compact, energy-efficient antennas.

2 ANTENNA DESIGN

2.1 EXISTING WORK

The antenna design shown is a rectangular microstrip patch antenna with a slotting technique applied at the center, where a microstrip line feed is used. The antenna design uses a microstrip line inset feed technique for excitation. In this method, the microstrip feed line is extended into the patch through a notch or slot cut into the lower edge of the rectangular patch. This type of feeding involves directly connecting the patch with a conducting strip that delivers the input signal. The slot in the middle of the patch and the extension of the microstrip feed line into the patch indicate the microstrip line feed method, which is simple and commonly used in such designs due to ease of fabrication and integration. The return loss plot demonstrates the reflection characteristics of the antenna over a frequency range. The graph indicates a sharp dip at approximately 2.39 GHz with a return loss value of around -24 dB. This means the antenna is well-matched at this frequency and reflects very little power, allowing efficient radiation. A return loss lower than -10 dB is generally acceptable, so this result shows the antenna is effectively resonating at the desired 2.4 GHz frequency range.

The gain plot in 3D reveals how the antenna radiates power in space. The gain value reaches approximately 2.9 dB, which is within the expected range for a microstrip patch antenna. The red and orange shades in the plot correspond to regions of higher gain, primarily along the z-axis, which is perpendicular to the surface of the patch, indicating directional radiation suitable for point-to-point communication. The radiation pattern in polar form confirms the directional nature of the antenna. It shows a main lobe in the forward direction with a gain of about 2.917 dB and smaller side lobes. This pattern is typical for patch antennas, providing focused radiation in a particular direction with minimal back lobe radiation, which is useful for efficient transmission and reception in wireless applications. This performance is particularly valuable in wireless communication, where signal integrity and efficient transmission are crucial. The narrow bandwidth is typical for microstrip patch antennas, although the slotting method in the patch can be used to introduce additional resonant modes or improve bandwidth. The efficiency indicated by the return loss suggests that most of the power from the feed is successfully radiated into free space.

The gain plot in 3D shows a mostly hemispherical pattern, with radiation focused along the Z-axis, indicating that the antenna is radiating efficiently in one principal direction, suitable for applications where coverage in a specific area is required. The 2D radiation pattern further confirms this, showing a lobe directed at 0 degrees with minor variations at other angles, typical for patch antennas with a coaxial feed. The overall design is efficient, compact, and practical for real-world use in devices that operate at 2.4 GHz, providing a good balance between gain, return loss, and radiation characteristics.

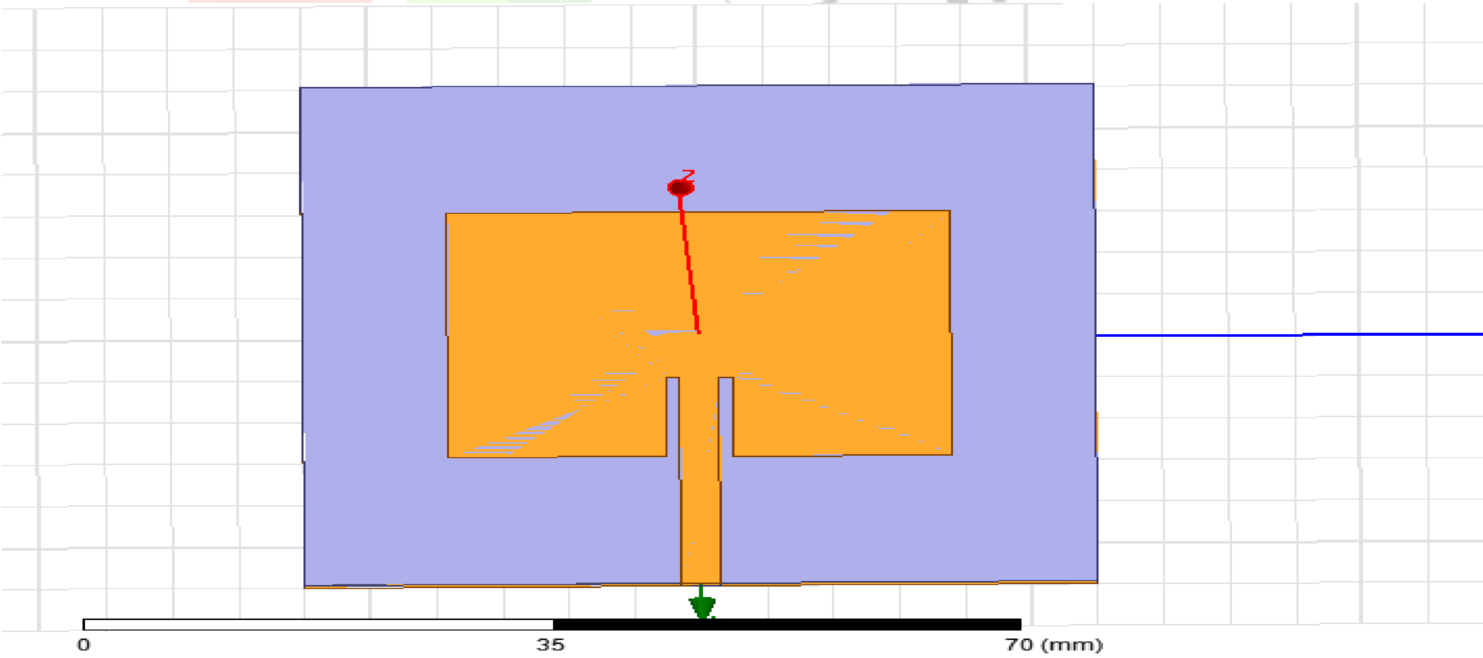


Fig 2.2.1: HFSS Design of Existing Method

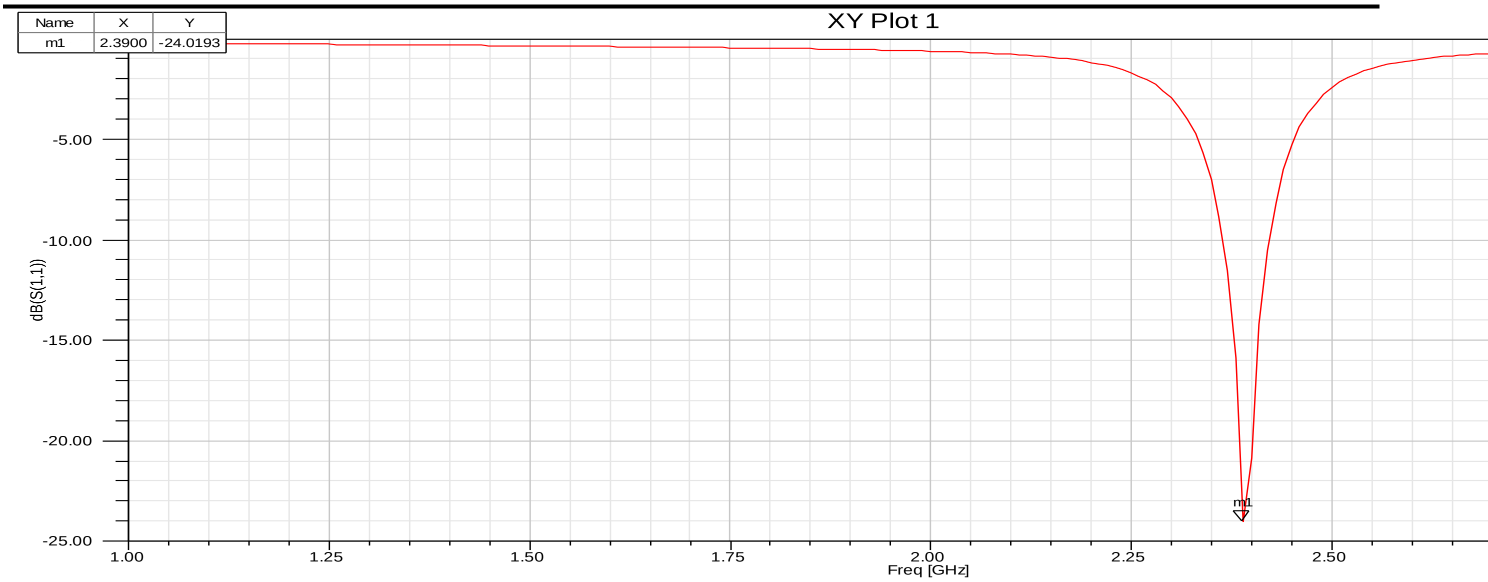


Fig 2.2.2: Return Loss at 2.39 GHz

Fig 2.2.3: 3D Polar Plot at 2.39 GHz

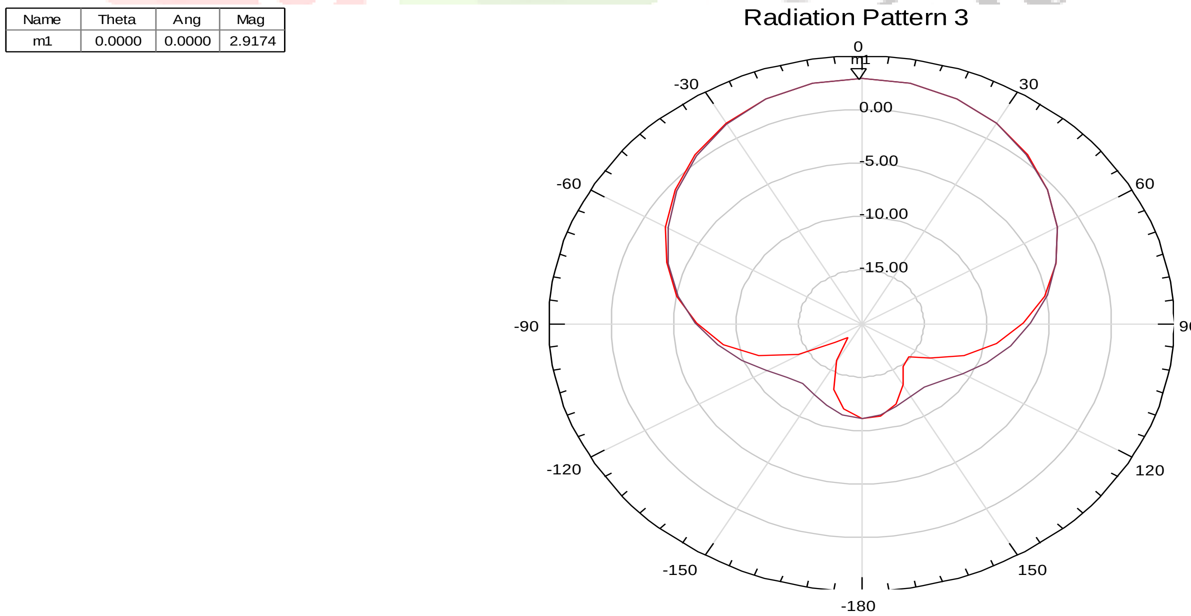


Fig 2.2.4: Radiation Pattern at 2.39 GHz

S.No	Parameter	Description	Value (mm)
1	Wg	Width of the ground plane	60
2	Lg	Length of the ground plane	60
3	Wp	Width of the patch	38
4	Lp	Length of the patch	29.4
5	Wf	Width of the feed	3
6	Lf	Length of the feed	30

Table 2.1.1: Values of different parameters

2.2 PROPOSED WORK

The proposed work multiband microstrip patch antenna was designed and simulated using ANSYS HFSS software for wireless communication applications. The antenna uses planar feed as the narrow strip connected directly to the rectangular patch, extending from the bottom edge toward the center of the patch. The antenna incorporates a Defected Ground Structure (DGS) with five square slots, each of dimension 3.33 mm, as seen in the design layout. These slots are strategically placed to enhance the bandwidth and improve performance at specific frequency bands. These slots are symmetrically positioned around the feed line to disturb the surface current distribution, thereby enhancing the electromagnetic coupling and generating multiple resonant frequencies. The introduction of DGS also helps in suppressing higher-order harmonics and improving the overall bandwidth of the antenna. Simulation results were carried out using ANSYS HFSS, where the return loss (S11) was analysed over a frequency range of 1 GHz to 5 GHz. The return loss plot indicates three significant resonant frequencies at 2.38 GHz, 3.65 GHz, and 4.61 GHz, with corresponding return loss values of -26.40 dB, -17.67 dB, and -17.96 dB respectively. The sharp dip at 2.38 GHz reflects excellent impedance matching with minimal reflection, making this frequency highly effective for 2.4 GHz ISM band applications such as Wi-Fi and Bluetooth. The other resonant frequencies support additional wireless applications, indicating that the antenna supports multiband functionality efficiently.

The gain performance was evaluated, and a maximum gain of 3.31 dB was observed, which is a desirable value for many wireless applications, ensuring efficient transmission and reception of signals. The 3D gain plot demonstrates a stable and nearly omnidirectional radiation pattern, favouring broader coverage with less signal degradation. The compact size of the slots and their symmetrical arrangement contribute to maintaining the overall dimensions of the antenna within practical limits while still achieving high performance. The proposed design, due to its simple structure, ease of fabrication, and multiband capability, is suitable for deployment in modern wireless communication systems where efficient spectrum utilization and compactness are required. The use of DGS proves to be an effective technique for improving the antenna's performance without the need for additional components or complex geometries. The achieved results validate the design's effectiveness in terms of return loss, gain, and radiation characteristics, making it a promising candidate for future wireless technologies.

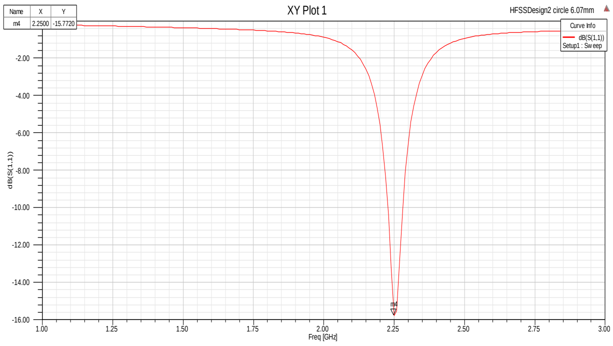
S.No	Parameter	Description	Value (mm)
1	Wg	Width of the ground plane	80
2	Lg	Length of the ground plane	60
3	Wp	Width of the patch	38
4	Lp	Length of the patch	28.8
5	Wf	Width of the feed	1.4
6	Lf	Length of the feed	30
7	Ws	Width of the square	3.33
8	Ls	Length of the square	3.33

Table 2.2.1: Values of different parameters

3 METHODOLOGY

3.1 Subsequent Trails and Results

I have tried some shapes with the microstrip inset feed (Existing Work). They are as below:



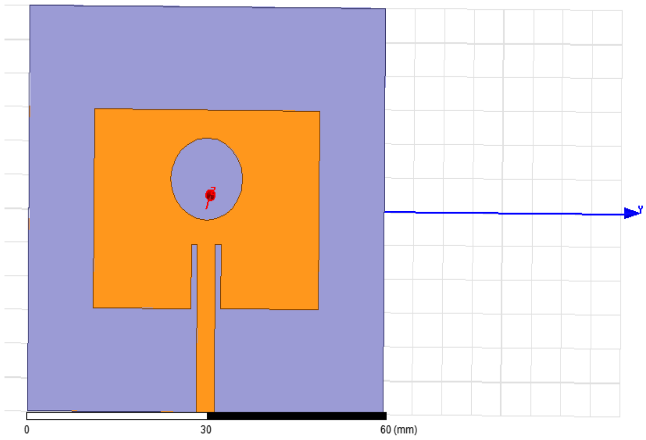
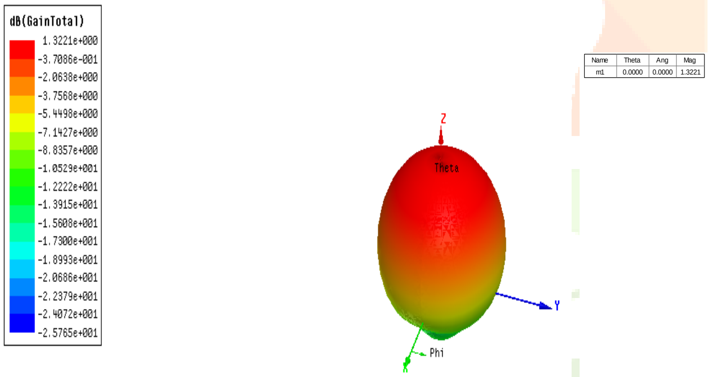


Fig 3.1.1: HFSS Design (Radius of circle = 6.07 mm) **Fig 3.1.2: Return Loss at 2.25 GHz**



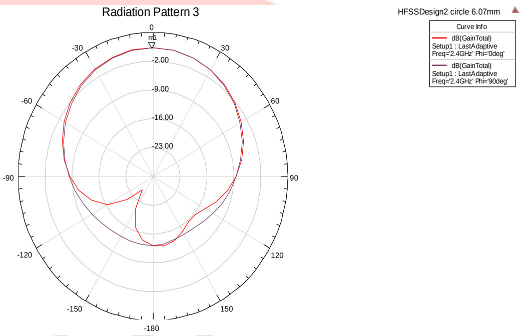
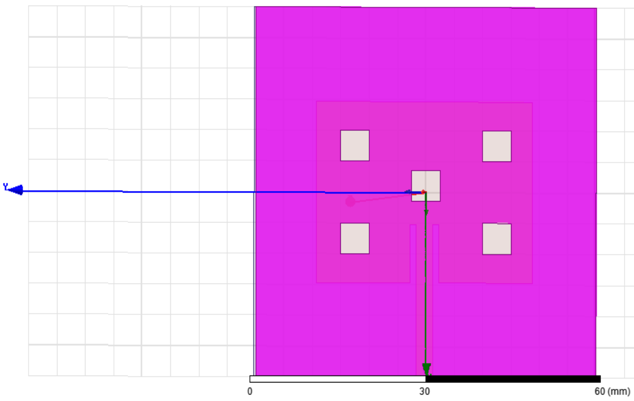


Fig 3.1.3: 3D Polar Plot at 2.25 GHz **Fig 3.1.4: Radiation Pattern at 2.25 GHz**



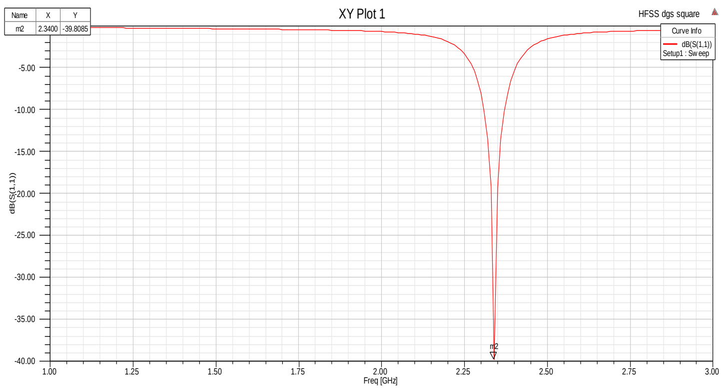
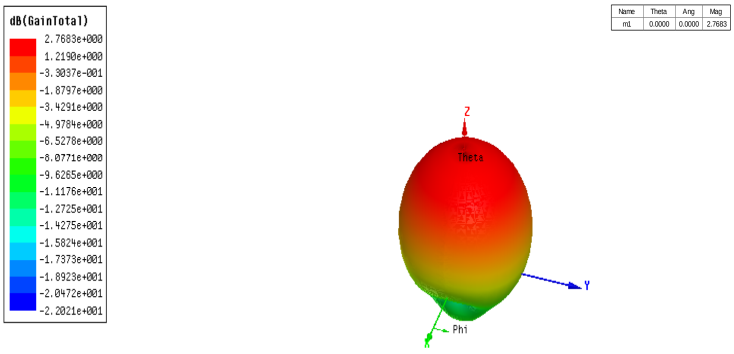


Fig 3.1.5: HFSS Design (L*W of Squares = 5mm) **Fig 3.1.6: Return Loss at 2.34 GHz**



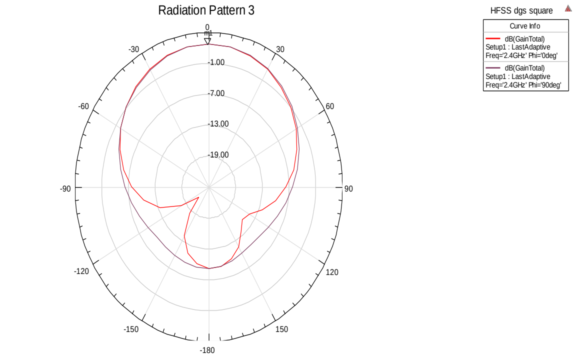
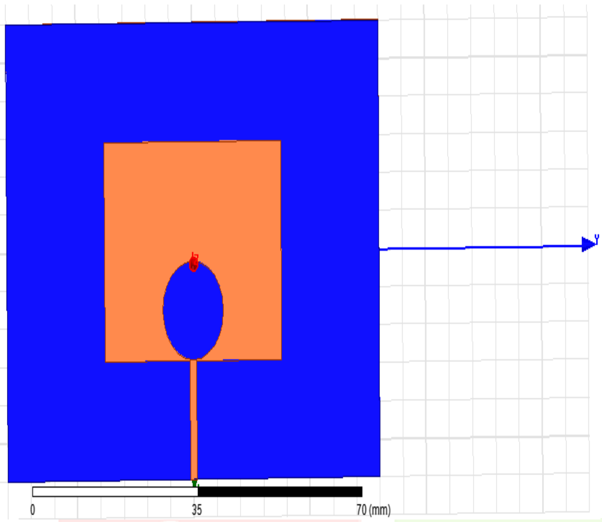


Fig 3.1.7: 3D Polar Plot at 2.34 GHz **Fig 3.1.8: Radiation Pattern at 2.34 GHz**

After trying all these shapes, I changed the feed from microstrip inset feed to planar feed in order to achieve the multiband. The results are as below:



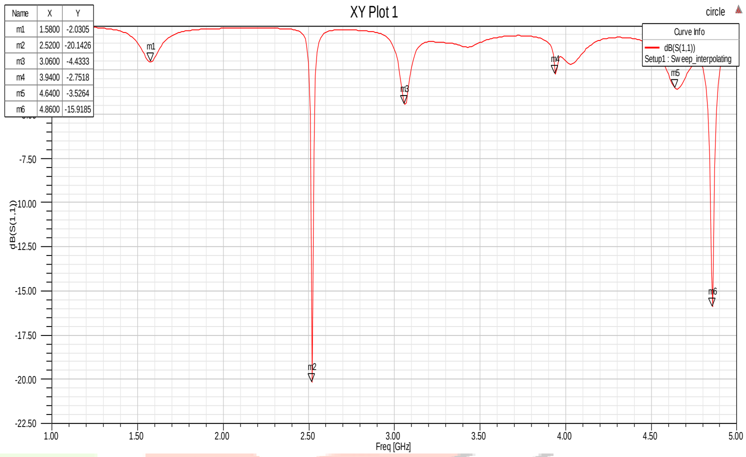
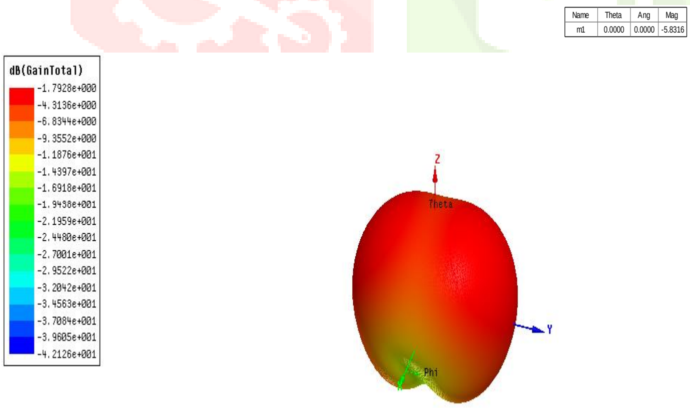


Fig 3.1.9: HFSS Design (Radius of circle = 6.5mm) **Fig 3.1.10: Return Loss at multiple frequencies**



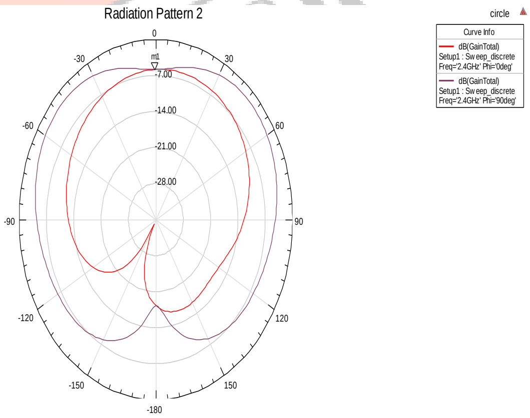
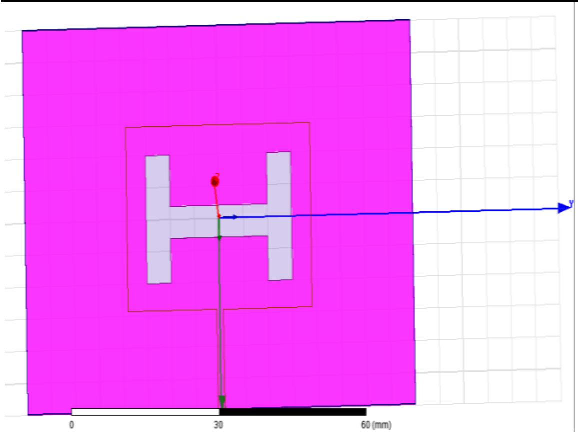


Fig 3.1.11: 3D Polar Plot at multiple frequencies **Fig 3.1.12: Radiation Pattern at multiple frequencies**



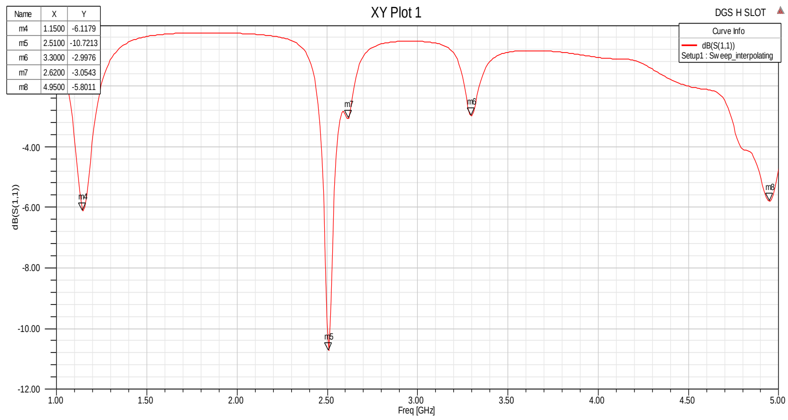
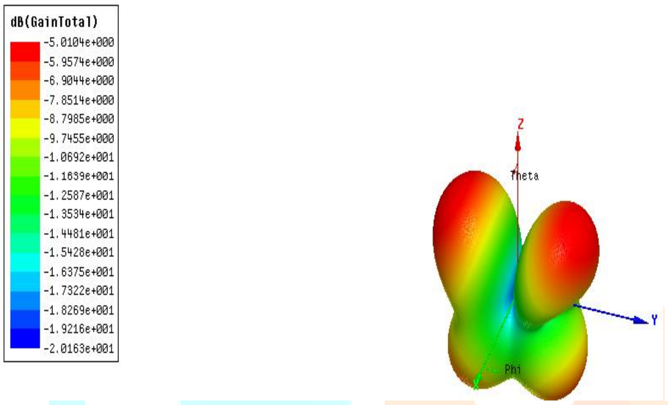


Fig 3.1.13: HFSS Design (H-Shape slotting) **Fig 3.1.14: Return Loss of H-Slot**



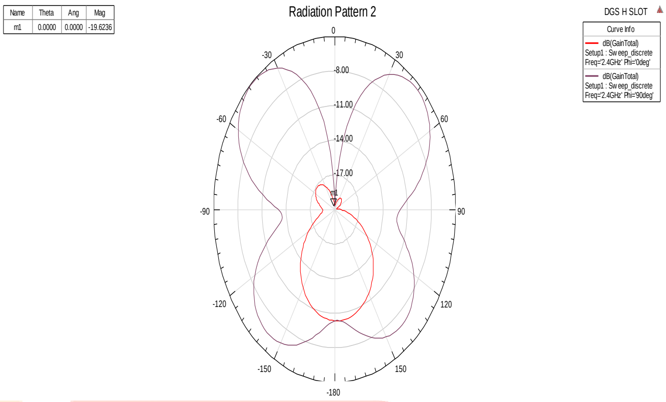


Fig 3.1.15: 3D Polar Plot of H-Slot **Fig 3.1.16: Radiation Pattern of H-Slot**

4 SIMULATION RESULTS

The antenna incorporates a Defected Ground Structure (DGS) with five square slots, each of dimension 3.33 mm, as seen in the figure 4.1.

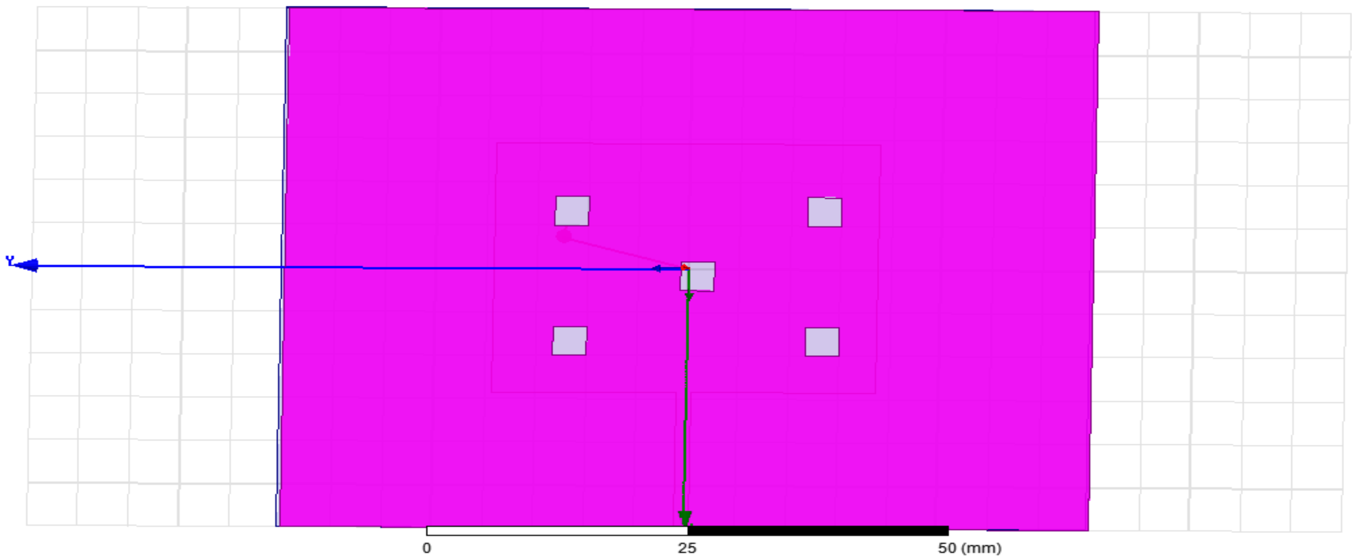


Fig 4.1: HFSS Design of Multiband (L*W of Squares = 3.33mm)

By simulating the design, four different resonant frequencies are obtained as indicated in figure 4.2. The three resonant frequencies are 2.38 GHz, 3.65 GHz and 4.61 GHz respectively.

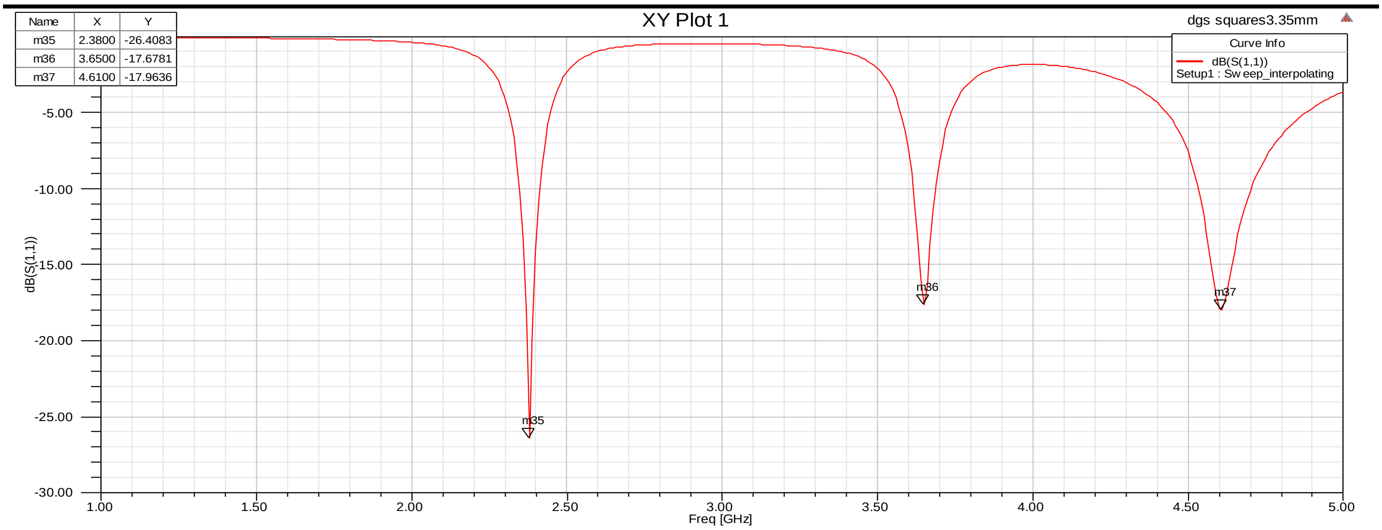


Fig 4.2: Return Loss at 2.38 GHz, 3.65 GHz and 4.61 GHz frequencies

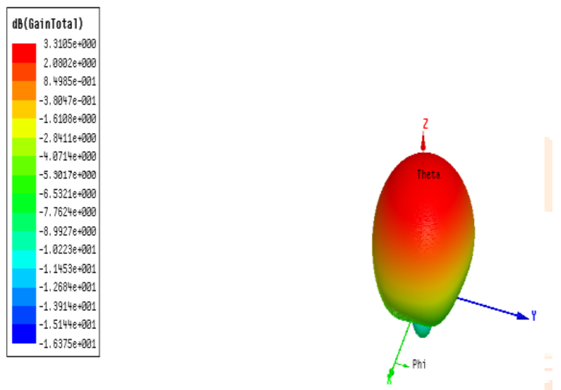


Fig 4.3: 3D Polar Plot of Multiband

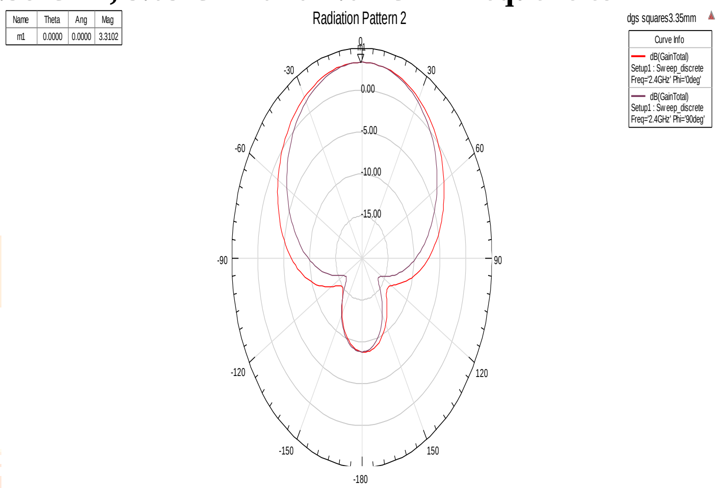


Fig 4.4: Radiation Pattern of Multiband

S.No	Frequency(GHz)	S11(dB)	VSWR	Directivity
1	2.38 GHz	-26.40 dB	1.09	6.43
2	3.65 GHz	-17.67 dB	1.30	5.2 – 5.5
3	4.61 GHz	-17.96 dB	1.28	5 – 5.5

Table 4.1: Return loss, VSWR and directivity of different frequencies

5 CONCLUSION AND FUTURE SCOPE

A Microstrip patch antenna which can be operated at three different frequencies is designed using Ansys HFSS software and fabricated. The resonant frequencies obtained are 2.38 GHz, 3.65 GHz and 4.61 GHz. The antenna demonstrated good performance in terms of return loss, gain, and bandwidth at the targeted frequency bands, particularly around 2.4 GHz, which is widely used for Wi-Fi, Bluetooth, and other wireless technologies. The simulation results confirm that the designed antenna meets the requirements for multiband operation and is suitable for integration into compact wireless devices. The antenna was carefully modelled to achieve efficient performance across multiple frequency bands, ensuring good return loss, stable gain, and adequate bandwidth. The use of HFSS software enabled precise simulation and optimization of the antenna's dimensions and parameters, which led to a design that meets the essential criteria for modern wireless communication needs. The results obtained from the simulation confirm that the antenna is capable of operating effectively across multiple bands, thus making it a viable choice for compact and efficient wireless devices.

The project also demonstrates how simulation tools like HFSS can simplify the complex process of antenna design and provide accurate predictions of real-world behaviour, which saves time and resources in the development phase. The antenna structure achieved multiband operation without significant complexity, which is advantageous for integrating the antenna into space-constrained electronic systems.

Future Scope

Looking ahead, there is significant scope for further enhancement of this design. The antenna can be fabricated and its performance can be tested under real-world conditions to validate the simulation results. Further optimization of design parameters can improve the gain, efficiency, and miniaturization for specific applications. In addition, the design can be adapted for use in the rapidly growing field of Internet of Things (IoT), where compact and efficient antennas are highly desirable. Future advancements can also involve using advanced materials such as metamaterials or flexible substrates, which can open possibilities for wearable or conformal antennas. Moreover, by introducing tunable elements like PIN diodes or MEMS switches, the antenna can be made reconfigurable, allowing it to adapt dynamically to different frequency requirements, which is crucial for devices supporting multiple communication standards. This design could also be extended to support higher frequency bands such as those used in 5G and emerging 6G technologies, including millimetre wave frequencies, which would broaden its applicability in future wireless networks. Thus, the project provides a solid foundation for further exploration and innovation in the field of multiband antenna design.

6 REFERENCES

1. Asif, S., Iftikhar, A., Rafiq, M.N., Braaten, B.D., Khan, M.S., Anagnostou, D.E., and Teeslink, T.S., "A Compact Multiband Microstrip Patch Antenna with U-Shaped Parasitic Elements," Proceedings of the IEEE Antennas and Propagation Society International Symposium, 2015, pp. 617-618.
2. Giannakopoulos, G., and Shaikh, K.M., "Design Multiband Monopole and Microstrip Patch Antennas using High Frequency Structure Simulator," arXiv preprint arXiv:2412.06667, 2024.
3. Sonagara, J.S., Shah, K.H., Suvariya, J.D., and Patel, S.K., "Reconfigurable High Gain Split Ring Resonator Microstrip Patch Antenna," arXiv preprint arXiv:1802.02083, 2018.
4. Ozturk, E., and Saka, B., "Multilayer Minkowski Reflectarray Antenna with Improved Phase Performance," arXiv preprint arXiv:2009.12343, 2020.
5. Guha, D., Biswas, M., and Antar, Y.M.M., "Microstrip Patch Antenna with Defected Ground Structure for Cross Polarization Suppression," IEEE Antennas and Wireless Propagation Letters, vol. 4, pp. 455-458, 2005.
6. Hou, D.-B., Xiao, S., Wang, B.-Z., Jiang, L., and Wang, J., "Elimination of Scan Blindness with Compact Defected Ground Structures in Microstrip Phased Array," IET Microwaves, Antennas & Propagation, vol. 3, no. 5, pp. 828-833, 2009.
7. Dutta, D., Rafidul, S., Guha, D., and Kumar, C., "Suppression of Cross-Polarized Fields of Microstrip Patch across All Skewed and Orthogonal Radiation Planes," IEEE Antennas and Wireless Propagation Letters, vol. 19, no. 1, pp. 98-102, 2020.
8. Pasha, I., Kumar, C., and Guha, D., "Mitigating High Cross-Polarized Radiation Issues over the Diagonal Planes of Microstrip Patches," IEEE Transactions on Antennas and Propagation, vol. 68, no. 6, pp. 4536-4541, 2020.
9. Guha, D., Banerjee, A., and Kumar, C., "Higher Order Mode Excitation for High-Gain Broadside Radiation from Cylindrical Dielectric Resonator Antennas," IEEE Transactions on Antennas and Propagation, vol. 60, no. 1, pp. 71-77, 2012.
10. Guha, D., and Antar, Y.M.M., "Four-Element Cylindrical Dielectric Resonator Antenna for Wideband Monopole-Like Radiation," IEEE Transactions on Antennas and Propagation, vol. 54, no. 9, pp. 2657-2662, 2006.
11. Guha, D., and Antar, Y.M.M., "New Half-Hemispherical Dielectric Resonator Antenna for Broadband Monopole-Type Radiation," IEEE Transactions on Antennas and Propagation, vol. 54, no. 12, pp. 3621-3628, 2006.
12. Guha, D., Antar, Y.M.M., Ittipiboon, A., Petosa, A., and Lee, D., "Improved Design Guidelines for the Ultra Wideband Monopole-Dielectric Resonator Antenna," IEEE Antennas and Wireless Propagation Letters, vol. 5, pp. 373-376, 2006.
13. Guha, D., Banerjee, A., Kumar, C., and Antar, Y.M.M., "New Technique to Excite Higher-Order Radiating Mode in a Cylindrical Dielectric Resonator Antenna," IEEE Antennas and Wireless Propagation Letters, vol. 13, pp. 1083-1086, 2014.
14. Gupta, P., Guha, D., and Kumar, C., "Dualband Cylindrical Dielectric Resonator Antenna Employing HEM11δ and HEM12δ Modes Excited by New Composite Aperture," IEEE Transactions on Antennas and Propagation, vol. 63, no. 12, pp. 5924-5928, 2015.

15. Gupta, P., Guha, D., and Kumar, C., "Dielectric Resonator Working as Feed as Well as Antenna: New Concept for Dual-Mode Dual-Band Improved Design," IEEE Transactions on Antennas and Propagation, vol. 64, no. 4, pp. 1411-1416, 2016.

16. Zhong, S.S., Cui, J., and Song, K., "Design of Compact Multiband Patch Antenna Using Metamaterial Structures for Wireless Applications," IEEE Transactions on Antennas and Propagation, vol. 68, no. 5, pp. 3456–3463, 2020, doi: 10.1109/TAP.2020.2972432.

17. Singh, V., and Rani, S., "HFSS-Based Simulation of Multiband Patch Antenna for IoT Devices," in 2021 IEEE International Conference on Smart Technologies and Systems for Next Generation Computing (ICSTSN), pp. 123–127, IEEE.

18. Wang, Y., Chen, X., and Luo, Y., "A Compact UWB Patch Antenna with Dual Notch Bands Using Complementary Split Ring Resonator," IEEE Antennas and Wireless Propagation Letters, vol. 14, pp. 914–917, 2015.

19. Sharma, R., and Jain, S., "Design and Simulation of Dual Band Patch Antenna for Wireless Applications," in 2022 IEEE International Conference on Recent Advances in Microwave Theory and Applications (RAMTA), pp. 78–82, IEEE.

20. Alibakhshikenari, M., Virdee, B.S., and See, C.H., "A Comprehensive Survey on Multiband, Wideband, and UWB Antennas for Modern Wireless Communication," IEEE Access, vol. 7, pp. 164558–164593, 2019, doi: 10.1109/ACCESS.2019.2952551.