Journal of Network Communications and Emerging Technologies (JNCET)
Volume 11, Issue 9, September (2021)

Design of Multiband Miniaturized Antenna using Defected Ground Structures for Mobile Communications

G. Guru Prasad
Department of Electronics & communication Engineering, Sri Chandrasekharendra Saraswathi Viswa Mahavidyalaya University, Kanchipuram, Tamil Nadu, India
guru.p6@gmail.com

G. Senthil Kumar
Department of Electronics & communication Engineering, Sri Chandrasekharendra Saraswathi Viswa Mahavidyalaya University, Kanchipuram, Tamil Nadu, India
gskkanchi@gmail.com

Published online: 13 September 2021

ABSTRACT

Multiband antennas play a significant role in various modern wireless communication systems. Commonly microstrip antenna is preferred due to its small size and low cost. But it is capable of functioning at a single resonant frequency. To function microstrip antenna in various chosen frequencies, slots were being made on a patch of different shapes and positions. Including Metamaterial technology in antenna design reduces the actual dimensions of the antenna. Embedding slots on the patch reduces the Gain of the antenna. Hence Rectangular, Circular and Elliptical shaped defected ground structures were used to enhance the antenna's Gain. In this paper, a rectangular-shaped patch antenna is designed at 2.4GHz frequency, and 18 rectangular slots of dimension 2.5mmx3.5mm are made on corner surfaces of the patch, and a dumbbell-shaped slot is made on the center of the patch. The antenna is operated at four different frequency bands 1.5GHz-2.4GHz, 3.4GHz-4.3GHz, 6.1GHz-7.9GHz, 9.4GHz-10GHz. For rectangular defected ground structure, 4.4dBi Gain is obtained. For circular defected ground structure, 4.6dBi Gain is obtained. For elliptical defected ground structure, 4.8dBi Gain is obtained. The proposed multiband miniaturized antenna can be used for mobile communications covering G.P.S., Wi-Fi, W.I.M.A.X., V.O.L.T.E. and 5G bands.

Index Terms – Multiband, Miniaturized, Slot, Defected Ground Structure, Mobile Communication.

1. INTRODUCTION

Microstrip patch antennas are highly suited for use in R.F and microwave communication systems due to their inherent advantages of low cost, multiband operation, simplicity of manufacture, and ease of integration with other circuits. However, conventional patch antennas suffer from various drawbacks, including low Gain, limited power handling capability, high loss, and narrow bandwidth. Among these shortcomings, low Gain is the fundamental reason limiting the performance of patch antennas commonly used in wireless applications [1], [2]. To boost the Gain of a standard rectangular patch antenna, we suggest modifications to the patch and ground, and we choose line feeding as the feeding mechanism. A dumbbell-shaped slot surrounded by a rectangle-shaped slot has been carved in the patch's centre to increase Gain. Later, a defective ground plane was added to the slotted patch to increase the benefit even further. The simulation results include the performance parameters of the antenna with a dumbbell-shaped slot surrounded by a rectangle-shaped slot in the patch's centre, as well as the results obtained when a faulty ground is included to demonstrate the slot effect. Compared to the previously stated antenna designs, the proposed Gain enhanced rectangular patch antenna is simpler to construct, smaller in size, and has a single layer construction, avoiding the trade-off between gain improvement and s parameter [4].

Several techniques to increasing the Gain of microstrip antennas have been investigated in other research. D.G.S. (Defected Ground Structure) is a widely utilized technique for this purpose. A DGS is realized in a microstrip antenna structure by removing a complicated or straightforward shape from the ground plane. Depending on the size and shape of the defect, the ground plane's current distribution is altered, resulting in a controlled excitation that modifies the antenna's reflection factor [10]. [8] constructed an antenna with a square patch as the radiator and two lines feeding it to maximize the reflection factor and bandwidth. On the ground, a D.G.S. is visible in the form of a pair of L-shaped slots. By optimizing the slot size and rectangular slot width, the antenna's bandwidth is enhanced. Rectangular ring antennas with a partially deficient ground have been introduced recently for dual-band operation at 3.2 and 4.6 GHz [9].

Mohamed F et.al.,[2]. It projected the Design and Implementation of Multiband Metamaterial Antennas. The antenna comprises of two U shaped slots on patch. Fr4 substrate is used with metamaterial consisting of unit cells. The proposed antenna is operated at two different frequencies. Position and separation between the slots can be adjusted to operate antenna at 4G/5G frequency bands. The advantage is it's multi-band and miniaturized. The disadvantage is it is operated at two frequencies only. RASHID SALEEM et al. [3] proposed An FSS-Based Multiband M.I.M.O. System With 3D Antennas for WLAN, WiMAX, and 5G Cellular and 5G Wi-Fi Applications projected. Here T shape and E shape slots are made on the frequency selective surface of the patch. The projected antenna is operated at the multiband, providing WLAN, WiMAX and 5G bands of frequency. The advantage is, the antenna can be used for M.I.M.O. Disadvantage is that it has poor Isolation. Abdelheq Boukarkar et al.,[5] Miniaturized Single-Fed Multiband Antenna is presented. The antenna's size is reduced by inserting small metalized vias along one edge of the radiating patch and etching inverted numerous U-shapes to achieve the antenna's multiband capability. The proposed antenna covers multiple broad frequency bands, and the size of the antenna is also reduced. The proposed antenna might be better if it provides better Isolation between frequency bands.

Daiwei Huang et.al.,[6] A Quad-Band Antenna for Metal Frame Phones with 4G, 5G, and G.P.S. It is a quad-antenna system realised without using any decoupling structure on a metal frame (P.C.B.). The antenna is operated at LTE700MHz,2.3GHz,2.5GHz, GSM850,900MHz,1800MHz,1900MHz, and 3.5 GHz bands. The proposed antenna is operated at multiband frequencies and covering all 4G, 5G and G.P.S. bands, providing better Isolation. The only drawback of the antenna is its size of 14x7 cm. Ridha Salhi et al. [7] projected A design of multiband antenna built on active metamaterials. Split ring resonators are used in a substrate to make substrate as metamaterial. Rectangular slots are made on a patch to operate at multiband frequencies. Operated at 3.14-3.35, 5.67-6.3, 7.58- 9.5 GHz bands. Surendra Kumar Painam et al. [8] projected Miniaturizing patch Antenna Employing Metamaterials and Metasurfaces. A circular patch Antenna is designed, and complementary split-ring resonators are embedded on the substrate. The antenna is operated at 6.22 GHz. The size of the antenna is reduced to 75%.

2. DESIGN OF MULTIBAND MINIATURIZED ANTENNA WITH DGS USING HFSS

In this paper, a rectangular-shaped patch antenna is designed at a 2.4GHz frequency, and 18 rectangular slots of dimension 2.5mmx3.5mm are made on the patch's corner surfaces. A dumbbell-shaped slot is made on the center of the patch using H.F.S.S. simulation software. Three types of Defected ground structures, i.e., Rectangle, circle, and ellipse, were designed for a slotted antenna.

2.1. Design of Multiband Miniaturized Antenna using Rectangular Defected Ground Structure

A rectangular-shaped slot is made on the ground plane for proper notching of frequencies. The designed slotted patch antenna is shown in below Figure 1.a. Designed slotted patch antenna with rectangular D.G.S. is shown in Figure 1.b. From Figure 1.a, 1.b, the rectangular D.G.S. was observed on the ground, 18 slots with a dumbbell-shaped slot on the patch.

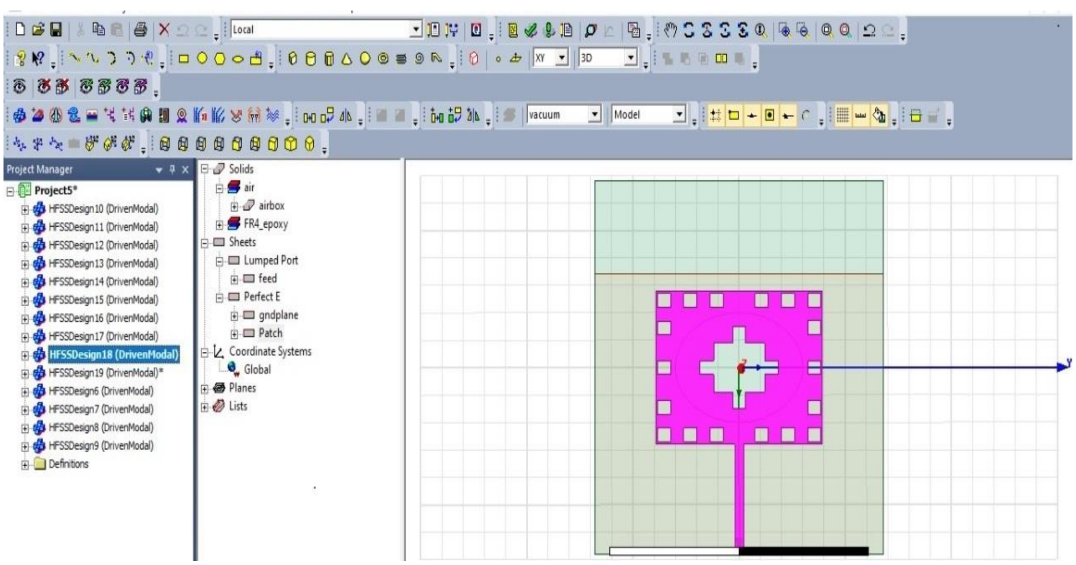

Figure 1.a: Designed Slotted Patch Antenna Rectangular D.G.S.

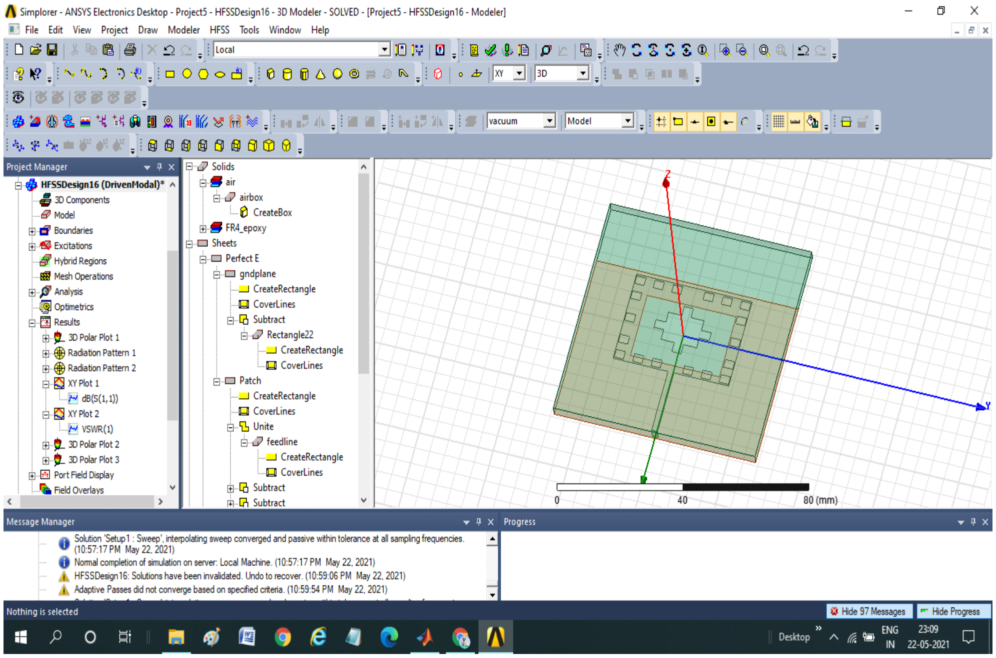

Figure 1.b: Designed Slotted Patch Antenna with Rectangular D.G.S.

2.2. Design of Multiband Miniaturized Antenna using Circular Defected Ground Structure

A circular shaped slot is made on the ground plane for proper notching of frequencies. The designed slotted patch antenna with rectangular D.G.S. is shown in Figure 2.

From Figure2, it was observed the Circular D.G.S. on the ground, 18 slots with a dumbbell-shaped slot on the patch.

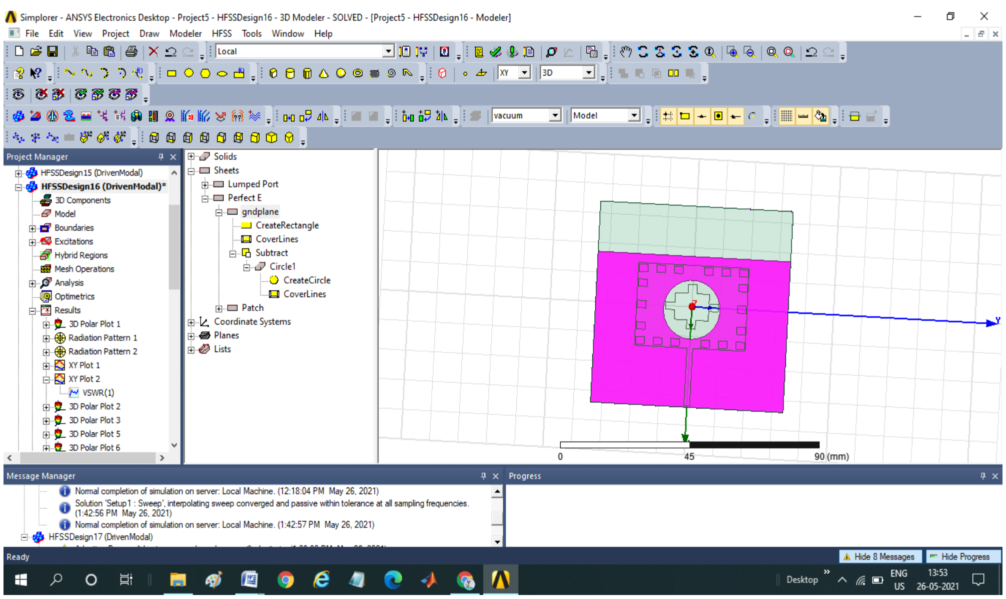

Figure 2: Designed Slotted Patch Antenna with Circular D.G.S.

2.3. Design of Multiband Miniaturized Antenna using Elliptical Defected Ground Structure

An elliptical-shaped slot is made on the ground plane for proper notching of frequencies. The designed slotted patch antenna with Elliptical D.G.S. is shown in below Figure 3. From Figure3, it was observed the Elliptical D.G.S. on the ground, 18 slots with a dumbbell-shaped slot on the patch.

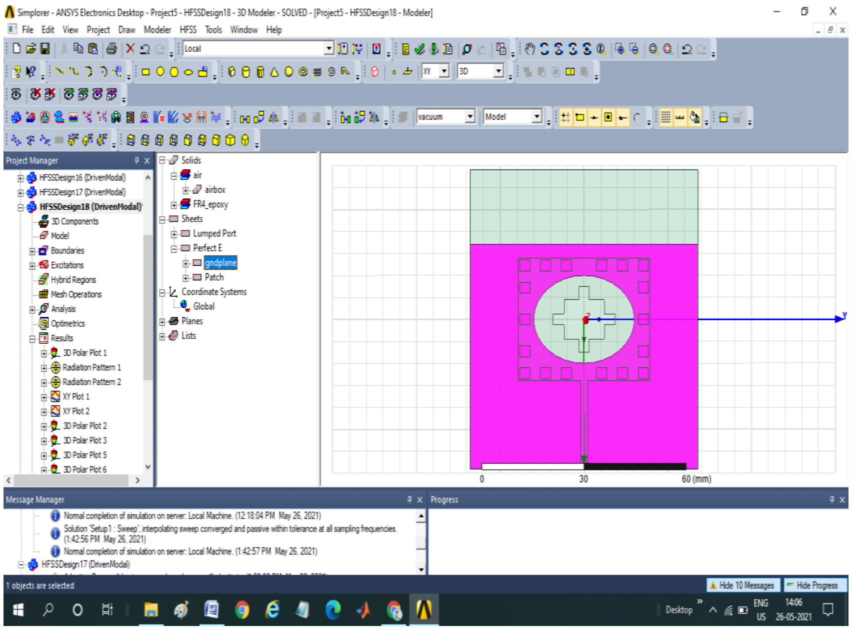

Figure 3: Designed Slotted Patch Antenna with Elliptical D.G.S.

3. SIMULATED RESULTS AND DISCUSSION

The designed Antennas are simulated from 1 to 10 GHz using H.F.S.S. V.13. Different antenna parameters like Return loss, VSWR, Radiation pattern, Gain, and Directivity were measured and plotted.

3.1. Simulated Results for Slotted Antenna with Rectangular D.G.S.

Return loss: After simulation, Return loss of slotted antenna with Rectangular D.G.S. is illustrated in Figure 4. From return loss, it was observed that the antenna is operated at four different frequency bands 1.5GHz, 3.4GHz-4.3GHz, 6.1GHz-7.9GHz, 9.4GHz-10GHz.

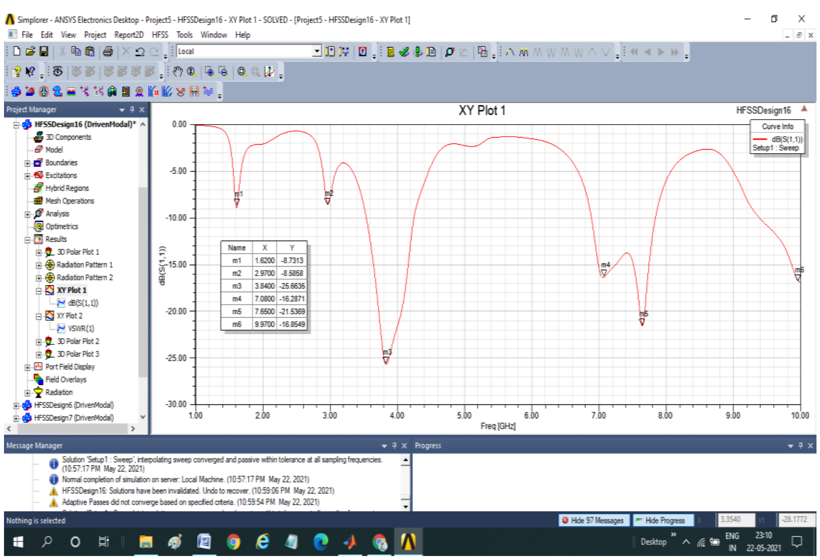

Figure 4: Return Loss Plot for a Slotted Antenna with Rectangular D.G.S.

VSWR: After simulation, the VSWR plot of the slotted antenna with Rectangular D.G.S. is shown in Figure 5. At the 1.5GHz band obtained VSWR is 1.9, at the 3.6GHz band obtained VSWR is 1.3, at 4.2GHz band obtained VSWR is 1.6, at 7.4GHz band obtained VSWR is 1.5 and at 9.4GHz band received VSWR is 1.8.

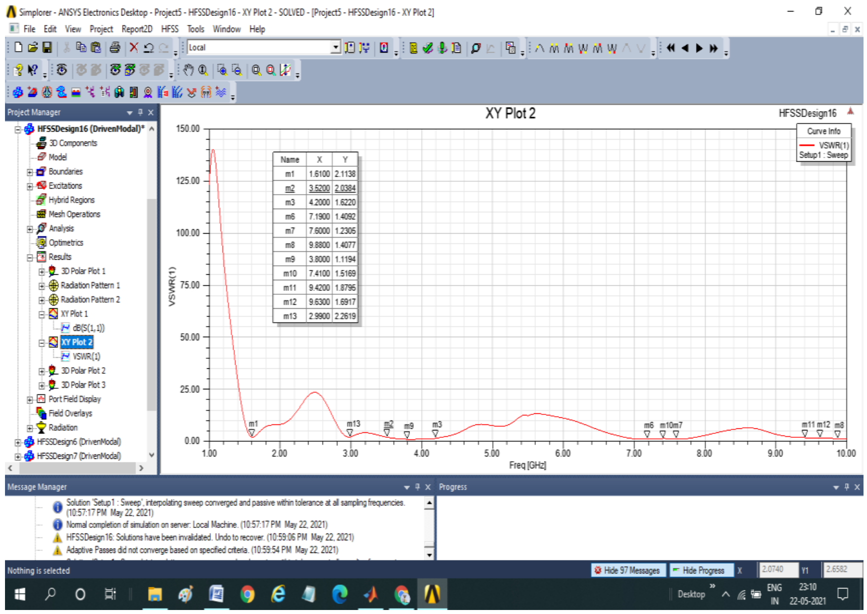

Figure 5: VSWR Plot for Slotted Antenna with Rectangular D.G.S.

Radiation Pattern: Three-dimensional radiation patterns are shown in Figure 6. Three-dimensional patterns of antenna radiation. In any direction, the radial distance from the origin represents the strength of the radiation emitted in that direction. The top illustration depicts the directing pattern produced by a horn antenna, whereas figure 6image illustrates the unidirectional pattern created by a simple vertical antenna.

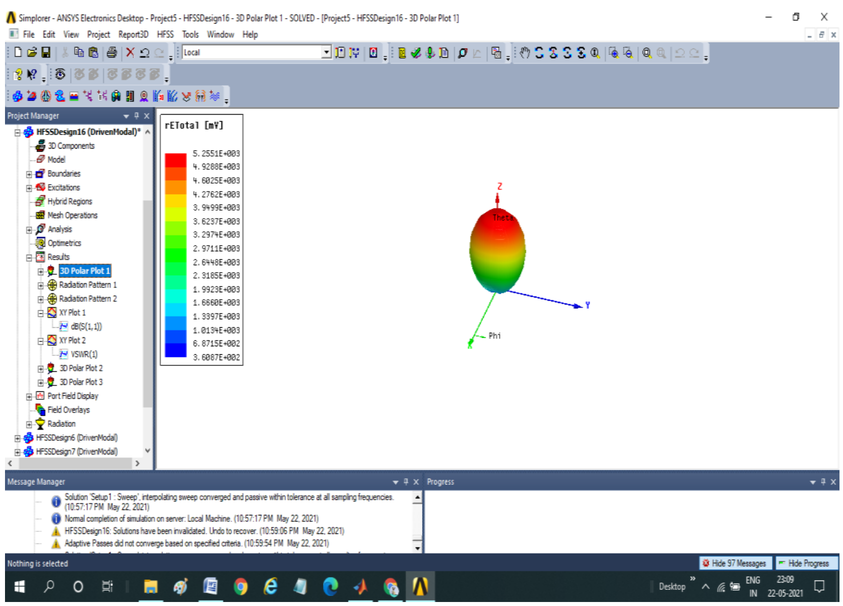

Figure 6:3D Radiation Pattern for a Slotted Antenna with Rectangular D.G.S.

Gain: The simulated Gain of slotted antenna with Rectangular D.G.S. is as shown in Figure 8. From the simulated plot it was observed that the Gain of the slotted antenna is about 4.3 dBi.

Directivity: The simulated Directivity of the slotted antenna with Rectangular D.G.S. is as shown in Figure 9. From the simulated plot it was observed that the Directivity of the slotted antenna is about 7.5 dBi.

E Field and H Field distribution on Patch: E Field and H Field distribution of slotted antenna for rectangular D.G.S. on Patch is shown in Figures 9.a and 9.b.

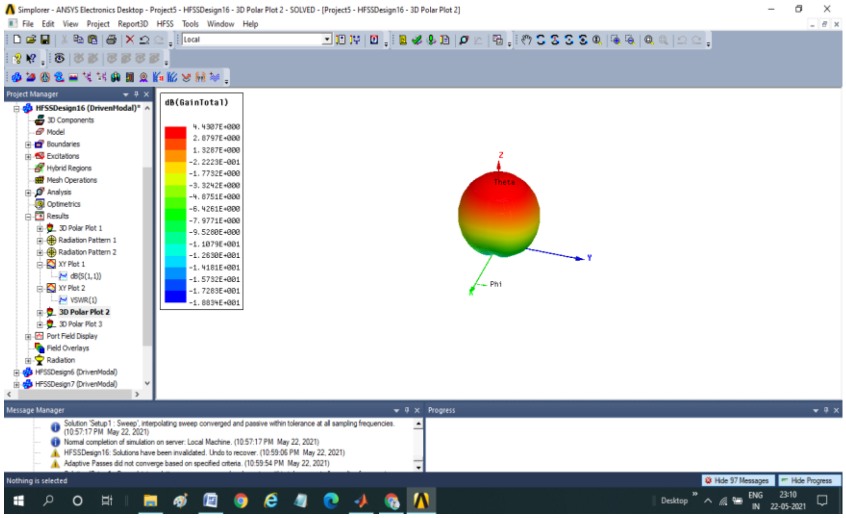

Figure 7: Gain of Slotted Antenna for Slotted Antenna with Rectangular D.G.S.

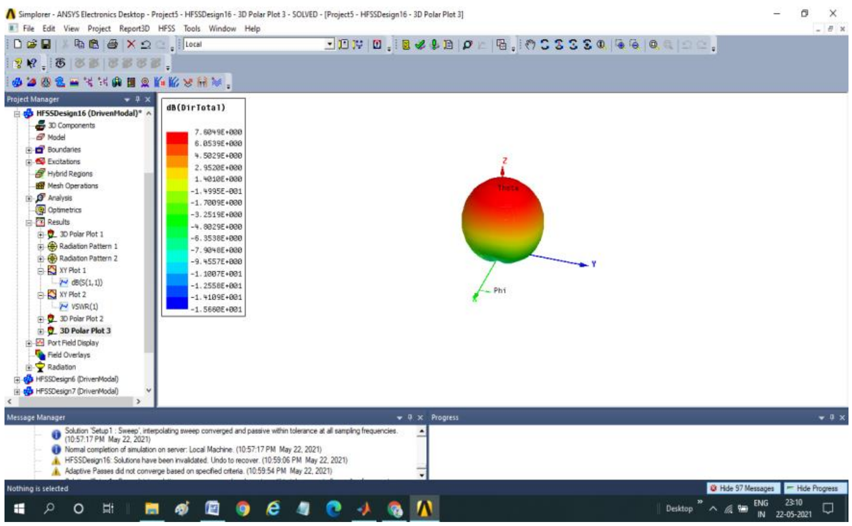

Figure 8: Directivity of Slotted Antenna for a Slotted Antenna with Rectangular D.G.S.

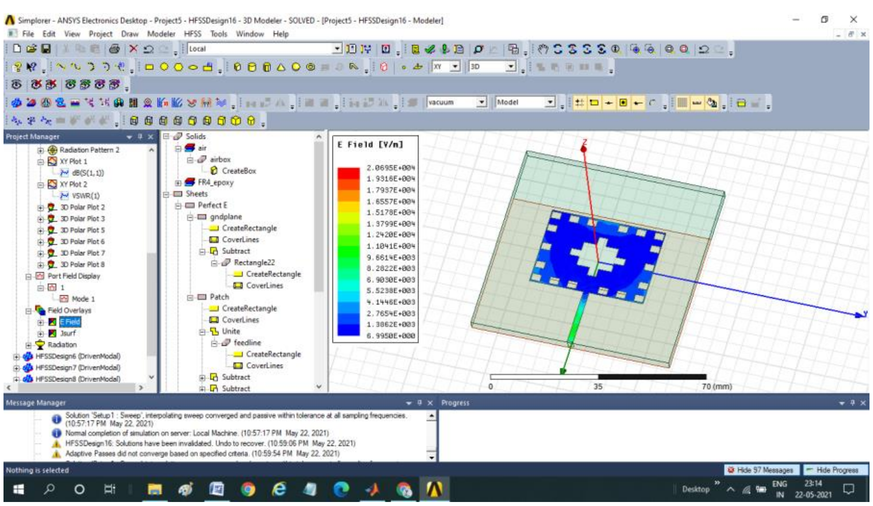

Figure 9.a: E Field

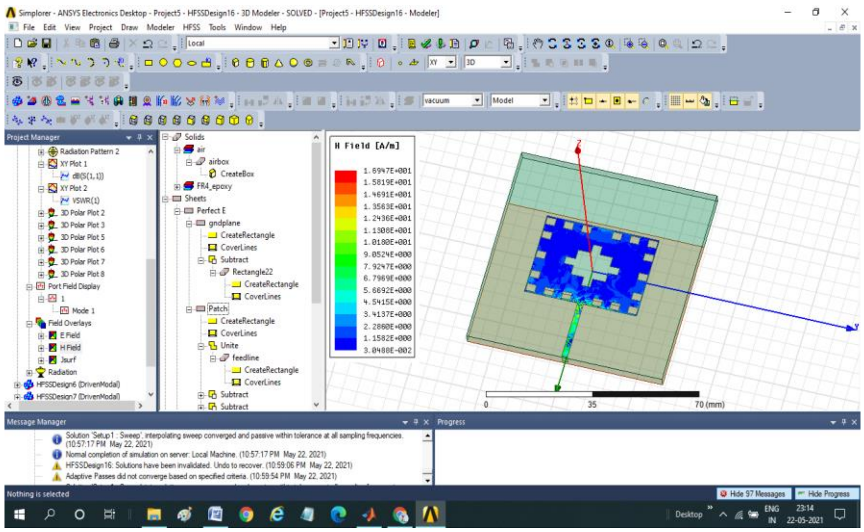

Figure 9.b: H Field

3.2. Simulated Results of a Slotted Antenna with Circular D.G.S.

Return loss: After simulation, the return loss of slotted antenna with Circular D.G.S. is shown in Figure 10. From return loss, it was observed that the antenna is operated at eight different frequency bands 1.9GHz-2.1GHz, 3.6GHz-4GHz, 6.7GHz-7.3GHz, 9.9GHz-10GHz.

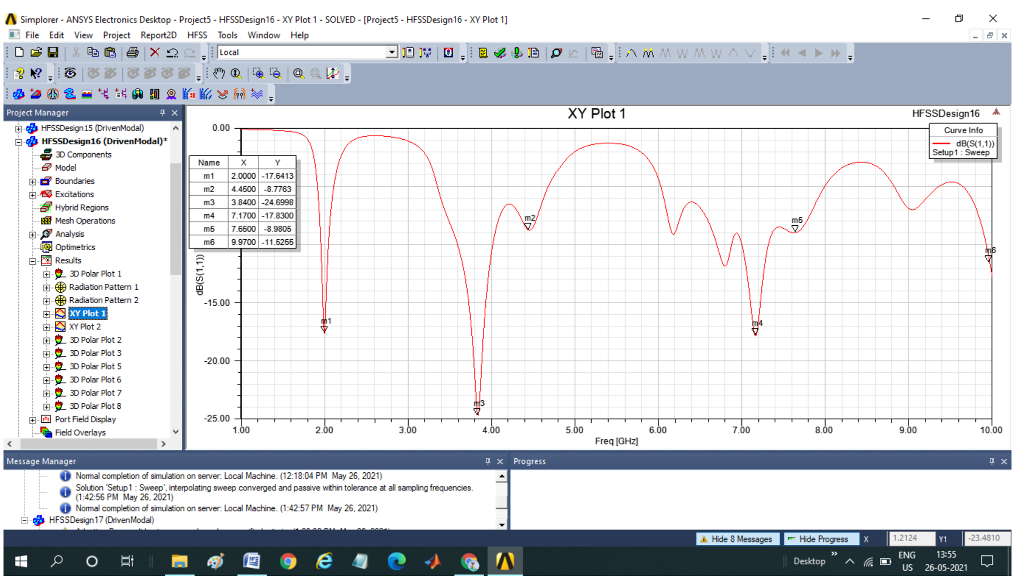

Figure 10: Return Loss Plot of the Slotted Antenna with Circular D.G.S.

VSWR: After simulation, the VSWR plot of the slotted antenna with Circular D.G.S. is shown in Figure 11. It was observed that at 2GHz band obtained VSWR is 1.4, at 3.4GHz band received VSWR is 1.3, at 7.1GHz band got VSWR is 1.3, at 8.2GHz band obtained VSWR is 1.5 and at 9.2GHz band received VSWR is 1.9.

Radiation Pattern: Radiation Pattern: Three-dimensional radiation patterns of the slotted antenna with Circular D.G.S. are shown in Figure 12.

Gain: The simulated Gain of slotted antenna with Circular D.G.S. is shown in Figure 13. From the simulated plot, it was observed that the Gain of the antenna is about 4.4dBi.

Directivity: The simulated Directivity of the slotted antenna with Circular D.G.S. is shown in Figure 14. From the simulated plot, it was observed that the Directivity of the antenna is about=7.6dBi.

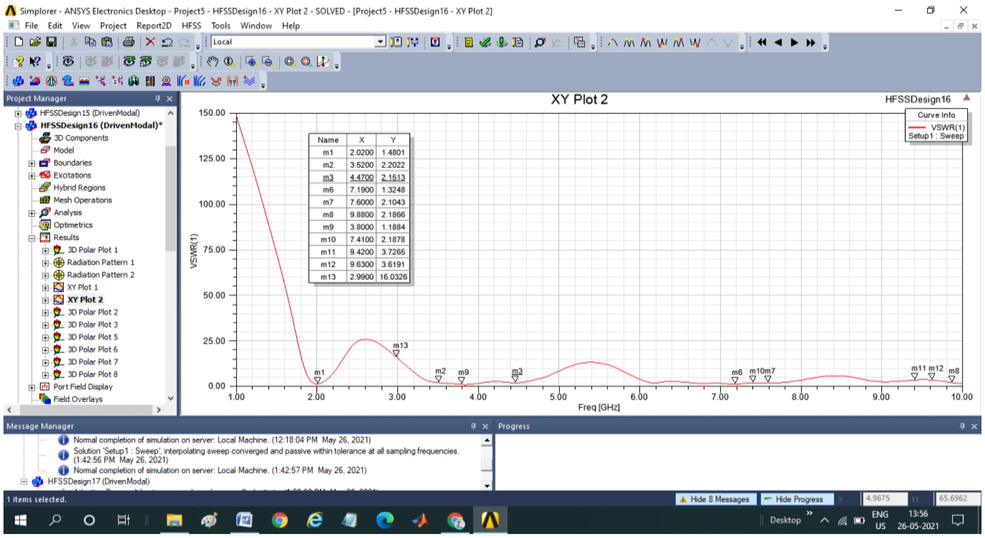

Figure 11: VSWR Plot of the Slotted Antenna with Circular D.G.S.

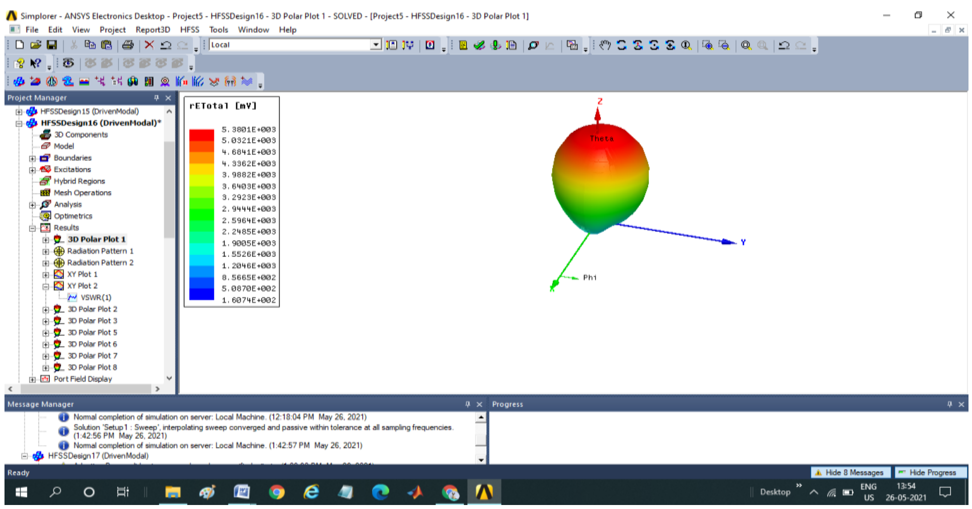

Figure 12: 3D Radiation Pattern of Slotted Antenna with Circular D.G.S.

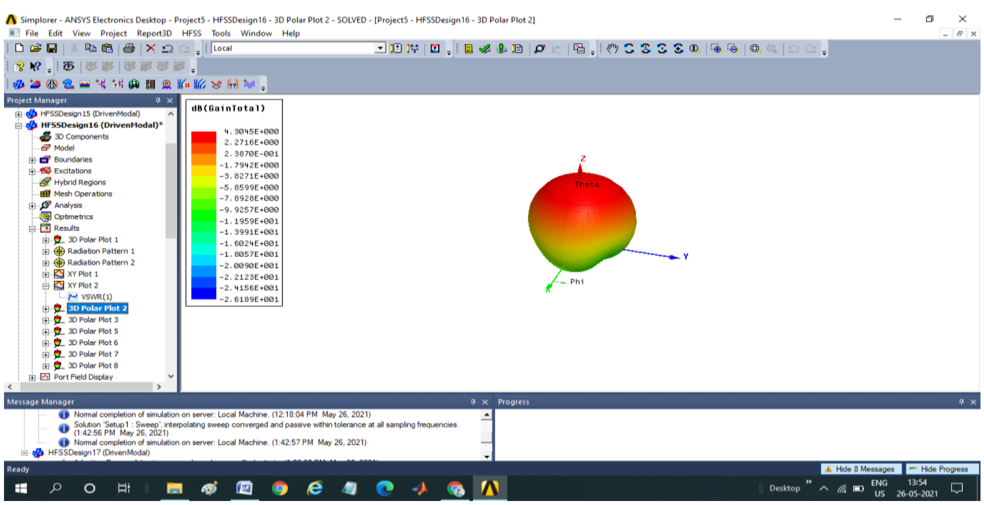

Figure 13: Gain of the Slotted Antenna after First Iteration

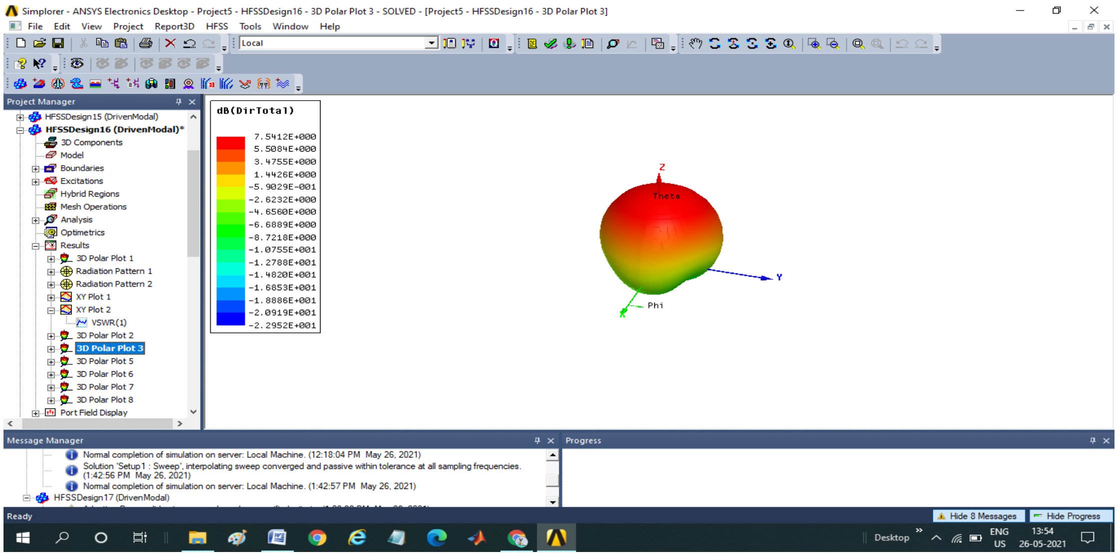

Figure 14: Directivity of the Slotted Antenna after the First Iteration

3.3. Simulated Results of Slotted Antenna with Elliptical D.G.S.

Return loss: from simulation, the return loss of slotted antenna with Elliptical D.G.S. is exhibited in Figure 15. From return loss, it was observed that the antenna is operated at four different frequency bands 1.7GHz-1.8GHz, 3.3GHz-4.3GHz, 6.6GHz-7.6GHz, 9.7GHz-10GHz.

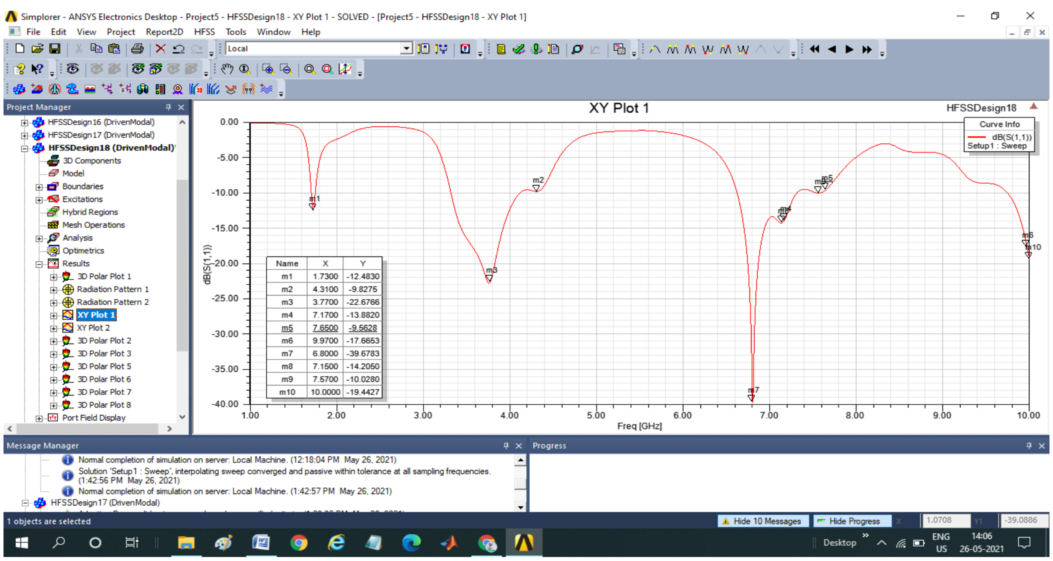

Figure 15: Return Loss Plot of the Slotted Antenna with Elliptical D.G.S.

VSWR: After simulation, the VSWR plot of the slotted antenna with Elliptical D.G.S. is shown in Figure 16. It was observed that at 1.7GHz band obtained VSWR is 1.6, at 3.4GHz band obtained VSWR is 1.5, at 7.1GHz band obtained VSWR is 1.5 and at 9.8GHz band obtained VSWR is 1.5.

Radiation Pattern: Three-dimensional and Two-dimensional radiation patterns of the slotted antenna with Elliptical D.G.S. are shown in below Figure 17.

Gain: Simulated Gain of the slotted antenna with Elliptical D.G.S. is as shown in Figure 18. The simulated plot observed that the Gain of the slotted antenna with Elliptical D.G.S. is about 4.6dBi.

Directivity: The simulated Directivity of the slotted antenna with Elliptical D.G.S. is as shown in Figure 19. From the simulated plot, it was observed that the Directivity of the antenna is about=7.8dBi.

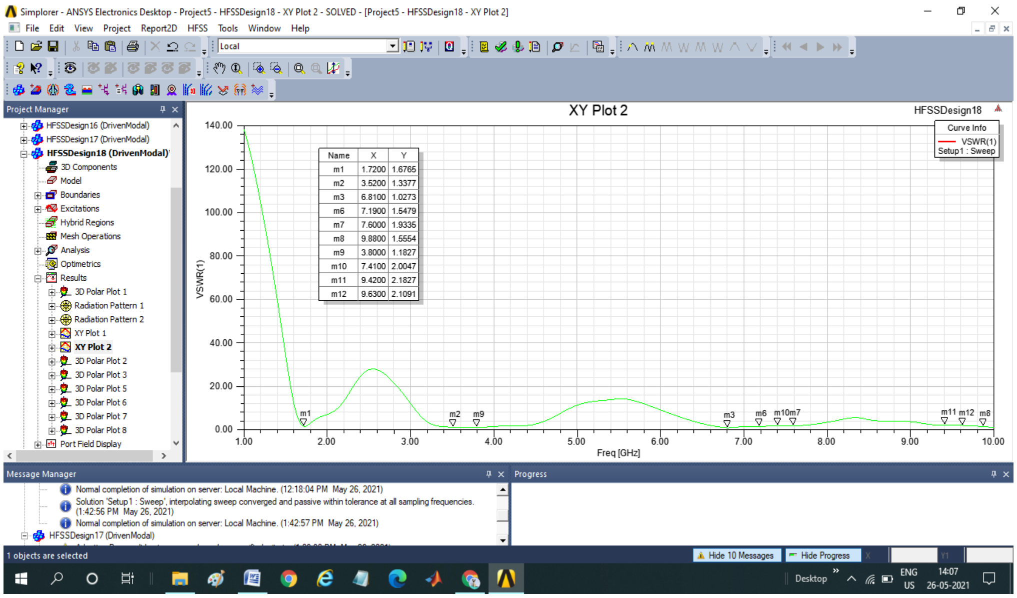

Figure 16: VSWR Plot of Slotted Antenna with Elliptical D.G.S.

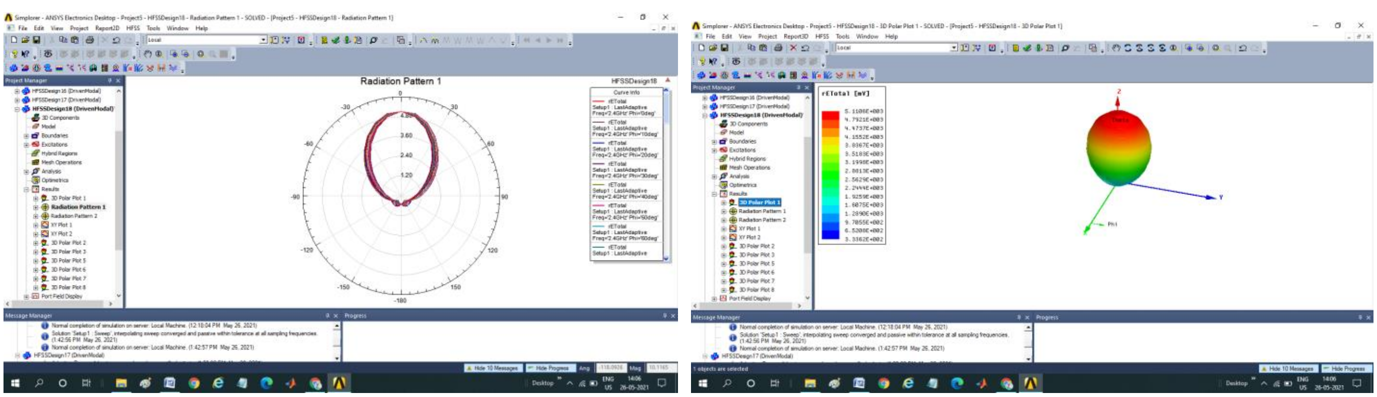

Figure 17: 2D, the 3D Radiation Pattern of the slotted Antenna with Elliptical D.G.S.

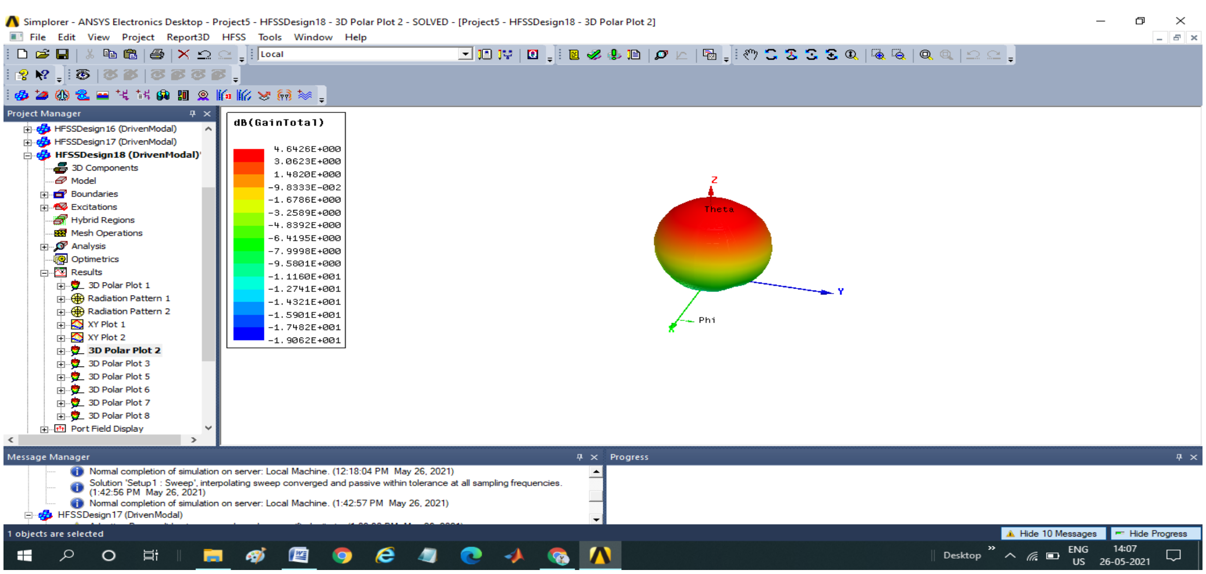

Figure 18: Gain of the Slotted Antenna with Elliptical D.G.S.

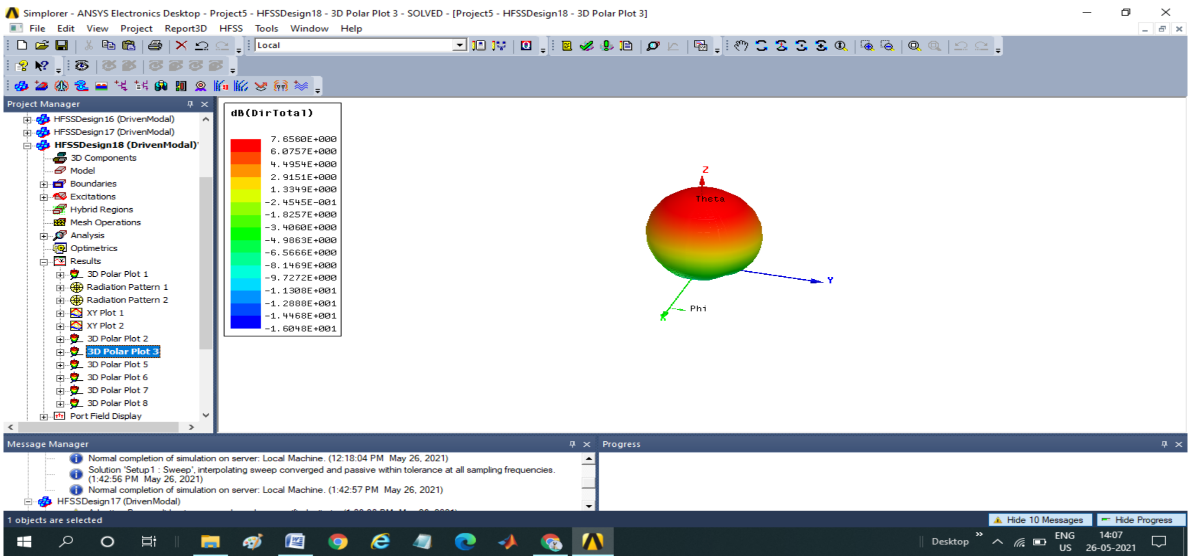

Figure 19: Directivity of Slotted Antenna with Elliptical D.G.S.

3.4. Comparison of Simulated Results

Table 1 shows the comparison of simulated results.

Antenna Type	D.G.S. type	Operating Frequency Bands	VSWR at Operating Frequency	Gain	Directivity
Slotted Antenna with Rectangular DGS	Rectangle	1.5GHz, 3.4GHz-4.3GHz, 6.1GHz-7.9GHz, 9.4GHz-10GHz.	1.5GHz - 1.9, 3.6GHz - 1.3, 4.2GHz - 1.6, 7.4GHz - 1.5, 9.4GHz 1.8.	4.3dBi	7.5dBi
Slotted Antenna with Circular D.G.S.	Circle	1.9GHz-2.1GHz, 3.6GHz-4GHz, 6.7GHz-7.3GHz, 9.9GHz-10GHz.	2GHz - 1.4, 3.4GHz - 1.3, 7.1GHz - 1.3, 8.2GHz - 1.5, 9.2GHz - 1.9.	4.4dBi	7.6dBi
Slotted Antenna with Elliptical DGS	Ellipse	1.7GHz-1.8GHz, 3.3GHz-4.3GHz, 6.6GHz-7.6GHz, 9.7GHz-10GHz.	1.7GHz - 1.6, 3.4GHz - 1.5, 6.8GHz - 1.2, 7.1GHz - 1.5, 9.8GHz - 1.5.	4.6dBi	7.8dBi

Table 1 Comparison of Simulated Results

4. CONCLUSION

Multiband Miniaturized antenna with Rectangular, Circular and Elliptical shaped defected ground structures has been designed and simulated using H.F.S.S. software, and various parameters like return loss, Gain, Directivity, radiation pattern is measured. The projected antenna has achieved excellent impedance matching, stable radiation pattern, and assured return loss. The simulated results show that the antenna operated at four different frequency bands 1.5GHz-2.4GHz, 3.4GHz-4.3GHz, 6.1GHz-7.9GHz, 9.4GHz-10GHz. For rectangular defected ground structure, 4.4dBi Gain is obtained. For circular defected ground structure, 4.6dBi Gain is obtained. For the elliptical defected ground structure, 4.8dBi Gain is obtained. The proposed multiband miniaturized antenna can be used for mobile communications covering G.P.S., Wi-Fi, W.I.M.A.X., V.O.L.T.E. and 5G bands.

REFERENCES

[1] Changxuan Han; Deshan Tang; Zhixian Deng; Huizhen Jenny Qian; Xun Luo "Filtering Power Divider With Ultrawide Stopband and Wideband Low Radiation Loss Using Substrate Integrated Defected Ground Structure" IEEE Microwave and Wireless Components Letters , Volume: 31, Issue: 2, Feb. 2021.

[2] Chandrakanta Kumar, Debatosh Guha, "Mitigating Backside Radiation Issues of Defected Ground Structure Integrated Microstrip Patches". IEEE Antennas and Wireless Propagation Letters, Volume: 19, Issue: 12, Dec. 2020.

[3] Jingtao Zeng; Kwai-Man Luk "A Simple Wideband Magnetoelectric Dipole Antenna With a Defected Ground Structure" IEEE Antennas and Wireless Propagation Letters, Volume: 17, Issue: 8, Aug. 2018.

[4] Mohamed F. Abo Sree, A.M.M.A. Allam, Hesham A. Mohamed "Design and Implementation of Multiband Metamaterial Antennas" IEEE Antennas and Wireless Propagation Letters 2020.

[5] RASHID SALEEM, MUHAMMAD BILAL, HASSAN TARIQ CHATTHA "An F.S.S. Based Multiband M.I.M.O. System Incorporating 3D Antennas for WLAN/WiMAX/ 5G Cellular and 5G Wi-Fi Applications" Special.The section on Antenna and Propagation For 5g And Beyond, 2019

[6] Abdelheq Boukarkar, Xian Qi Lin, Yuan Jiang, and Yi Qiang Yu Miniaturized Single-Feed Multiband Patch Antennas IEEE Transactions on Antennas and Propagation, VOL. 65, NO. 2, FEBRUARY 2019.

[7] Daiwei Huang, Zhengwei Du and Yan Wang "A Quad-Antenna System for 4G/5G/GPS Metal Frame Mobile Phones" IEEE Antennas and Wireless Propagation Letters 2019.

[8] Ridha Salhi, Mondher Labidi, Fethi Choubani "A design of multiband antenna based on active metamaterials." Optical materials, ELSEVIER 2018.

[9] Surendra Kumar Panam and Chandramohan Bhuma "Miniaturizing a Microstrip Antenna Using Metamaterials and Metasurfaces" IEEE Antennas & Propagation Magazine 2020.

[10] Khandelwal, M. K., B. K. Kanaujia, S. Dwari, S. Kumar, and A. K. Gautam, "Analysis and design of wideband Microstrip-line-fed antenna with the defected ground structure for Ku band applications," International Journal of Electronics and Communications, Vol. 68, No. 10, 951– 957, October 2014.

[11] Kumar, M. and V. Nath, "Analysis of low mutual coupling compact multiband microstrip patch antenna and its array using defected ground structure," Engineering Science and Technology, an International Journal, Vol. 194, No. 2, 866–874, June 2018.

[12] Chakraborty, S., S. Pal, and M. Chakraborty, "High-performance D.G.S. based compact microstrip patch antenna," Proceedings of 1st International Science & Technology Congress 2014, 405–409, Elsevier Publications 2014, 2014.

[13] Garg, R., I. Bahl, and M. Bozzi, Defected Ground Structure (D.G.S.): Microstrip Lines and Slotted Lines, ArtechHouse,305–341,2018.

Authors

G. Guru Prasad Received B.Tech degree in Electronics and Communication Engineering from JNTUH, Hyderabad in the year 2008 and M.Tech in Electronics Instrumentation and Communication Systems from Sri Venkateswara University, Tirupati in the year 2010. He worked as a Transmission Engineer at ERICSSON India Pvt. Ltd, Bangalore. He worked with Ericsson 2G/3G GSM network equipments and did number of Airtel projects like Migration from Classic node to Traffic node, AXX and HICAP using Mini Link software and done projects like connecting new Micro wave links using Traffic and Classic Nodes. He is Zonal Head for 4 districts in north Karnataka like Davanagere, Hobli, Bellari, Gadag and Haveri.He designed 8x8 Microstrip Patch Antenna Array for Winf Profiller Radar, operating at 430 MHz at the National Atmospheric Research Laboratory, Gadanki, Department of Space, ISRO. This Radar has been installed at Cochin, Kerala for weather forecast. He worked as Assistant Professor in department of ECE from 2011 to 2019. He published more than 20 papers in reputed international journals. He presented 8 papers in international conferences and 5 articles in National conferences. His research areas of interest are design and simulation of Multi-band Antennas, Electrically small Antennas, Image and Video Processing, communication Networks. He is currently working as Panchayat Secretary (G.VI) Digital Assistant, Panchayat Raj Department, Government of Andhra Pradesh, since November 2019. He is a lifetime member of the Indian Society for Technical Education (ISTE) and the Indian Science Congress Association (ISCA).

Dr. G. Senthil Kumar Received Ph.D degree in Electronics and Communication Engineering from Sri Chandrasekharendra Saraswathi Viswa Mahavidyalaya, Kanchipuram, in 2017. He is working as Associate Professor in the Department of ECE, Sri Chandrasekharendra Saraswathi Viswa Mahavidyalaya, Kanchipuram since 2004. He published more than 30 papers in reputed international journals. Presented 12 papers in international conferences and 10 papers in National conferences. His research areas of interest lies in Wireless Communications -Wireless Systems and Spread Spectrum, MIMO Techniques, Multi-Carrier Modulation and Diversity combining (OFDM and MC-CDMA), Multi-user detection, Channel modeling, Limited feedback systems, Statistical Communications. VLSI Design – Electronic Design Automation (EDA, CAD for VLSI).