International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Design of Wireless Body Area Network UWB Antenna for Telemedicine and Mobile Health Systems

R.Rahul[1],K.G.Padmasine[2]

[1,2]*Department of Electronics and instrumentation, Bharathiar University,Coimbatore 641406, India*

DOI: https://doi.org/10.55248/gengpi.2023.4.4.34937

A B S T R A C T

A UWB antenna with electrical dimensions of 0.24 λo x 0.24 λo x 0.009 λo, a microstrip line feed at the lower edge, and an operational frequency of 3.0 GHz is suggested for a UWB application. An analytical analysis based on principles from circuit theory and the antenna cavity model is offered to support the design. The primary contribution of this study is the proposal of a wearable antenna with a large impedance bandwidth (3.0-10.6 GHz) suited for the 3.1 to 10.6 GHz UWB frequency range. Furthermore, this antenna exhibits Omni and quasi-Omni radiation patterns enabling short-range communication at a variety of frequencies (3.5 GHz and 6 GHz). A constant group delay of less than 1 ns is achieved over the whole operating impedance bandwidth of the Fabric based antenna in both side-by-side and front-to-front configurations. Linear phase consideration is provided for all cases, as well as various receiving and transmission settings. The antenna was mounted on a human body to demonstrate the effects of bending and humidity. The SAR value for its effect on the human body, which indicates the safe limit to avoid radiation effects, was determined to be 1.68 W/kg. As a result, the proposed method shows potential for telemedicine and mobile health systems.

Keywords: ultra-wideband; wearable antenna; time domain; frequency domain; SAR

1.Introduction

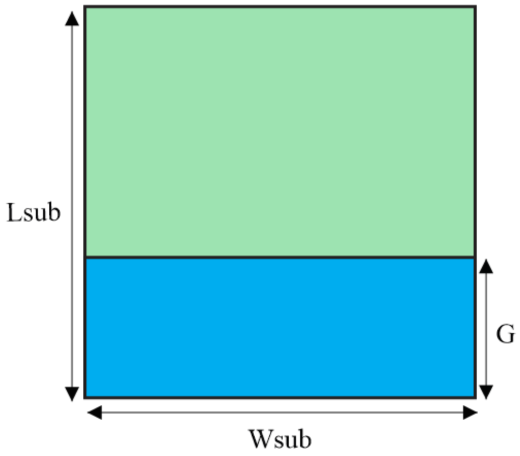
Over the years, the telemedicine and telecommunication industries have continuously changed. Wearable tiny antennas play a crucial role in wearable communication for mobile health and telemedicine systems used for continuous monitoring. Fabric-based UWB antennas offer a wide range of applications in telemedicine and healthcare systems. They can be utilized for continuous real-time patient data monitoring across small distances with high-speed data transmission and minimal power consumption. Wearable and small antennas are essential for the design and development of telemedicine systems in healthcare monitoring. Due to its key characteristics, including low cost, low power consumption, and high data rate, uwb technology is widely used. Aside from this, the entire UWB spectrum has a relatively low power spectral density, which results in less interference. Because of this, this technology has been viewed as particularly potential for wearable applications worldwide. In order to apply integration, fabric materials are used as substrate materials or conductive materials. It features low permittivity (ε_r),low loss tangent (tan(□)) and thinner thickness (h),which lower the surface wave losses and boost the performance of antenna characteristics. Because to their minimal impact on the human body, uwb antennas made from materials like cotton and denim or perforated plastic can be used as wearable technology. The primary contribution of this study is the presentation of a unique, small UWB antenna with microstrip line feed and partial ground on three different substrates. The wearable fabric-based UWB antenna operates with outstanding radiation characteristics in the frequency range of 3.1 to 10.6 GHz and has a radiation patch with modified ground.

2.Methodology

This section provides the Fabric material based antenna design and theoretical analysis. Due to the low dielectric constant of the fabric, the antenna's surface wave losses are diminished. The wearable antennas' application should be incorporated with the human body. Yet, the functioning of the antenna is impacted by the structure of the human body and the electrical characteristics of organic tissues. The rigid materials with high dielectric constant fail these criteria, and low-dielectric-constant materials came into the picture to fulfil all these requirements. The low-dielectric materials are also essential for increasing bandwidth and enabling flexibility in antennas. Consequently, the optimization approach is proposed to support the UWB antenna design. Additionally, the mathematical circuit theory analysis is also done to validate the function of the UWB Fabric material antenna. As a result, the following subsections describe the material and designing methods.

2.1 Antenna design

The proposed Fabric material antenna's rectangular patch and design for the UWB range are shown in Figures 1a and 1b. The antenna is constructed from a copper patch sandwiched between three substrates made of fabric: polyster, polyimide, and polyamaide. The upper patch serves as the radiating element, while the lower patch serves as the ground plane. These fabric substrates have a low dielectric constant, which improves the antenna's impedance and lowers surface wave losses. Consequently, these three materials are employed as substrate in the antenna design. Additionally, a 3 × 12 × 1 mm^3 microstrip line is utilised to perfectly match the impedance of the designed antenna.



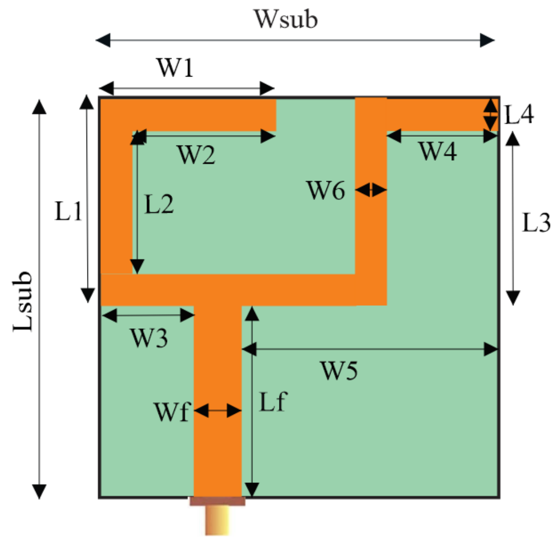


Fig. 1.0 (a) Backview **Fig 1.1 (b) Frontview**

S.No.	Parameter	Value (mm)	S.No.	Parameter	Value (mm)
1	Wsub	25	9	W_2	9
2	Lsub	25	10	W_3	6
3	L_1	13	11	W_4	7
4	L_2	9	12	W_5	16
5	L_3	11	13	W_6	2
6	L_4	2	14	W_f	3
7	L_f	12	15	G	9
8	W_1	11	16	h	1

An asymmetric microstrip line feed and a radiating patch with a partial ground plane make up the fundamental components of the fabric antenna. The evolution process yields the final structure, and several optimization-process activities, including patch length-width variation and ground variation, have been carried out using HFSS simulator under parametric investigation. By lowering the size and form of the ground plane and radiating element, the use of slotting has been shown, and the entire ground plane of the antenna affects the impedance characteristic of the antenna. Cutting a slot ((W2 × L2), two notches (W4 × L3), and Wsub − (W1 + W6 + W4) × (L4 + L2 + 1) have all improved the impedance matching.The feed position (Wf) and ground plane (G) adjustments increase the antenna's performance by achieving the optimal impedance matching.On the one hand, the final design was produced with good impedance matching compared to the primary antenna by applying the iteration method to the primary antenna. On the other hand, it can be shown that the antenna exhibits broad impedance bandwidth with maximum resonance at 3.5 and 6GHz frequency with a change in different substrates and width of ground and feedline. Hence, the suggested antenna covers the whole 3.1–10.6 GHz (UWB range) specified by the FCC. In addition, three alternative Fabric based substrates has been fabricated with copper, a perfect electric conductor with a loss tangent (tan (δ) = 0.025), a thickness of 0.035 mm, and a height of 1 mm, were used to create the antenna.

3. Results and Discussion

Using the ANSYS HFSS 3D EM tool of simulation, the given Fabric based UWB antenna is simulated on HFSS software.

3.1. Parametric Study of Fabric based UWB Antenna

In order to offer comprehensive information on the aerial design, a parametric study was conducted. Any antenna's radiating patch, cut slot, substrate, feed width, and ground can vary, which affects both the electrical characteristics and the antenna's size. As a result, the antenna's performance parameters are also modified. Several parametric analyses have been used to evaluate the performance of the aerial. To determine the suggested design, which generates a range of wideband performances, the primary antenna was put through numerous patch and ground iterations. In order to create a reasonable ground plane and ensure accurate impedance matching, several slots and notches have been removed from the radiating patch.The best impedance matching and consistent radiation qualities are offered by the 3 mm feed width.A significant variation in the ground plane is effected on antenna impedance matching at higher frequencies than at lower frequencies. By changing the ground plane from 9 mm to 10 mm with a step of 0.5 mm, proper matching is achieved at a partial ground plane value of 9 mm.The effect of varying the feed width (W_f) of microstrip-line-fed on the return loss characteristics. If the values of (W_f) are increased from 4 mm to 5 mm, the resonance frequency is shifted towards the lower band. Furthermore, at the 3.0 mm optimum value of (W_f), Consequently, an optimum value of 3.0 mm was considered in the proposed prototype.

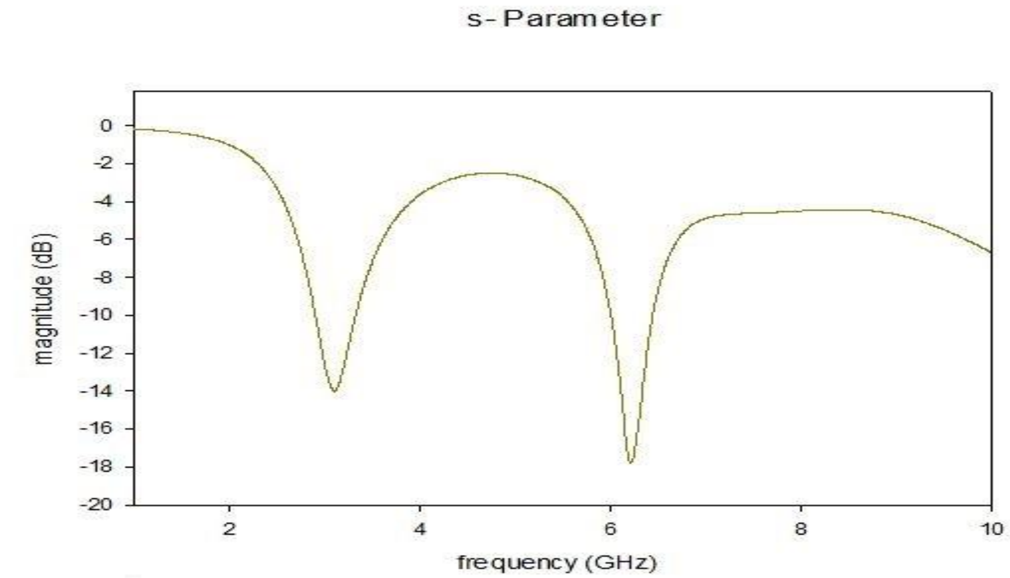


Fig 2.0 (a) Polyster 3.5 GHz

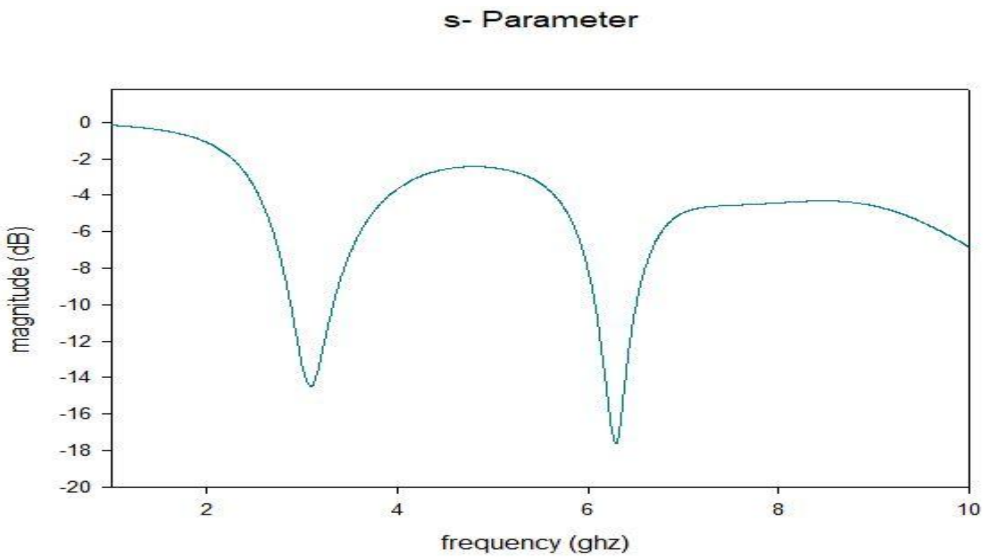


Fig 2.1 (b) Polyster 6 GHz

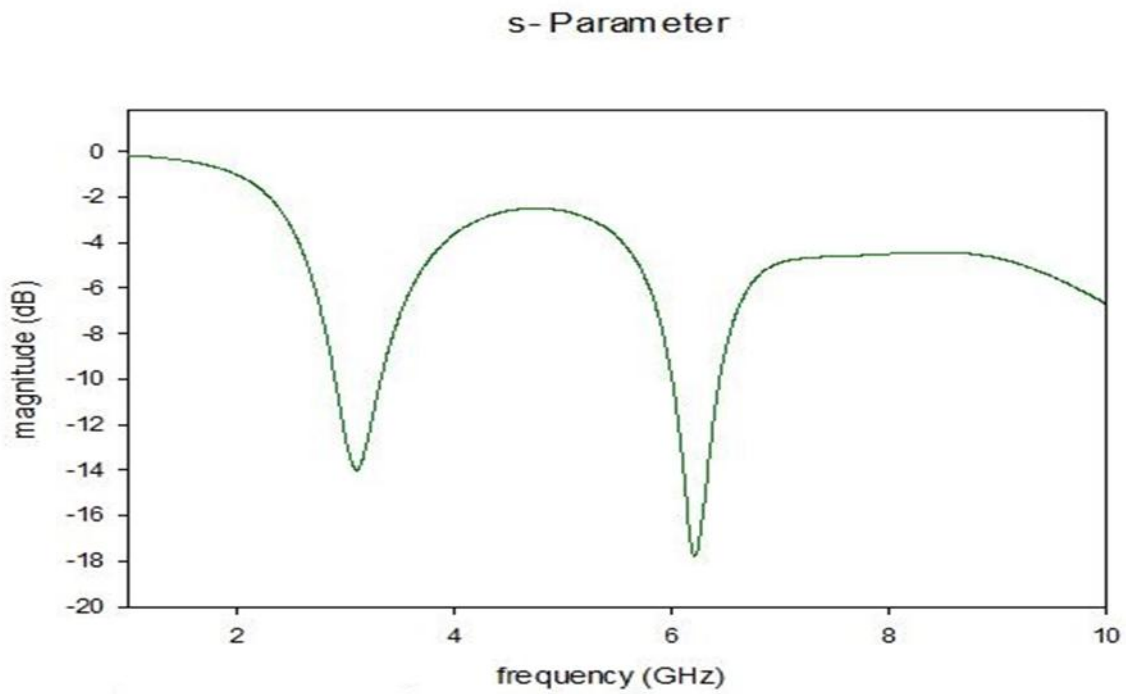


Fig 2.2 (i) Effect of variation on polystergrouund (G) 9 mm

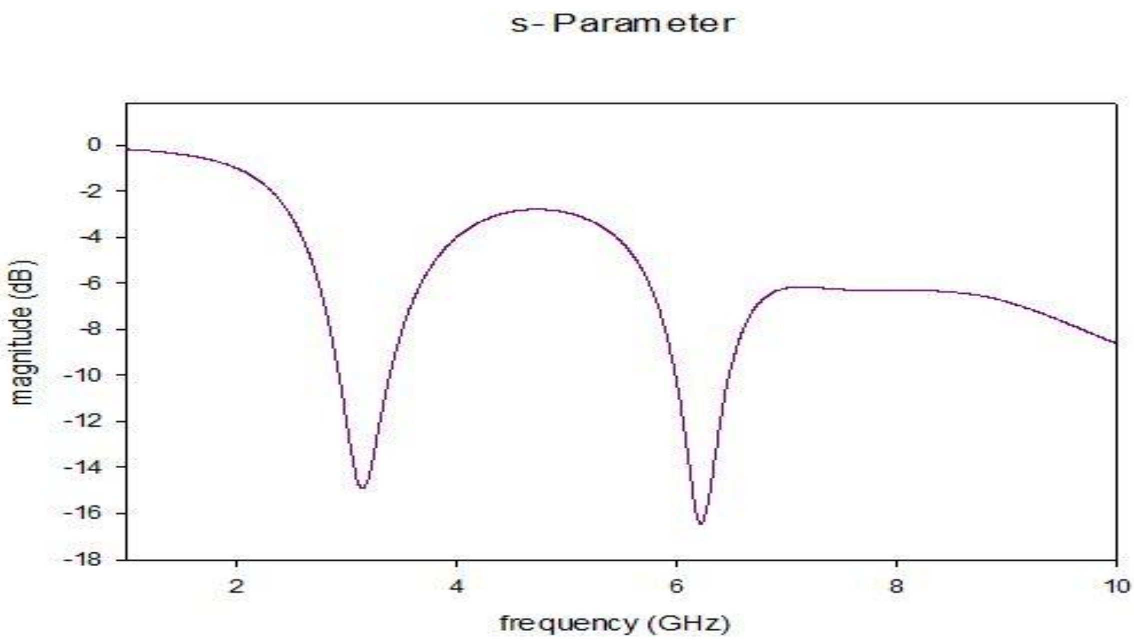


Fig 2.3 (ii) Effect of variation on polystergrouund (G) 9.5 mm

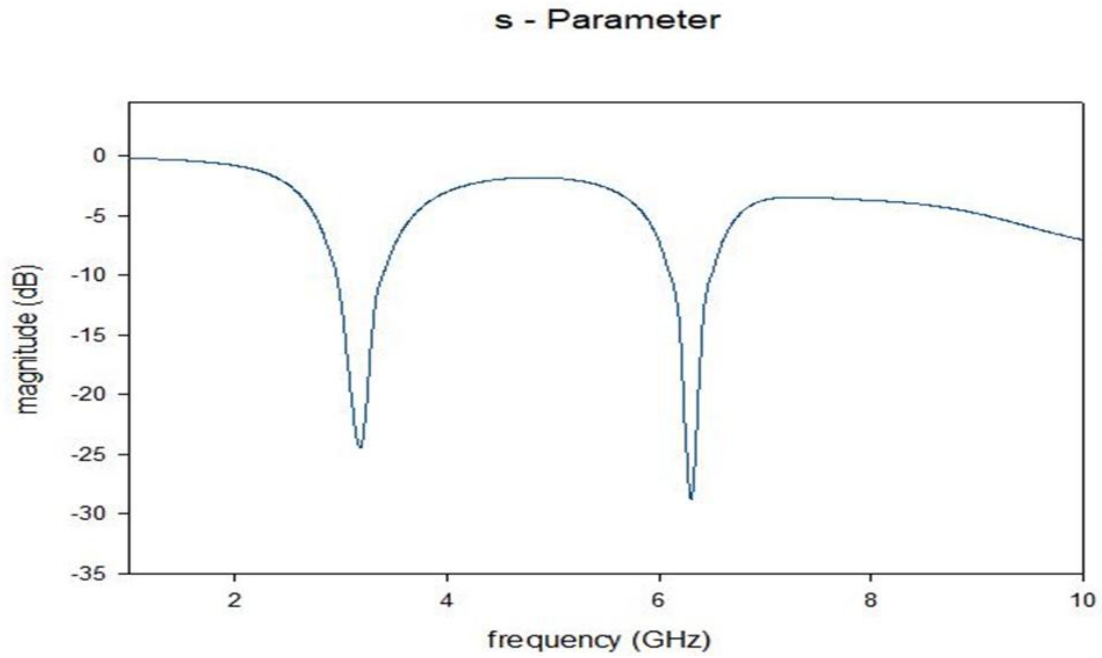


Fig 2.4 (iii) Effect of variation on polystergrouund (G) 10 mm

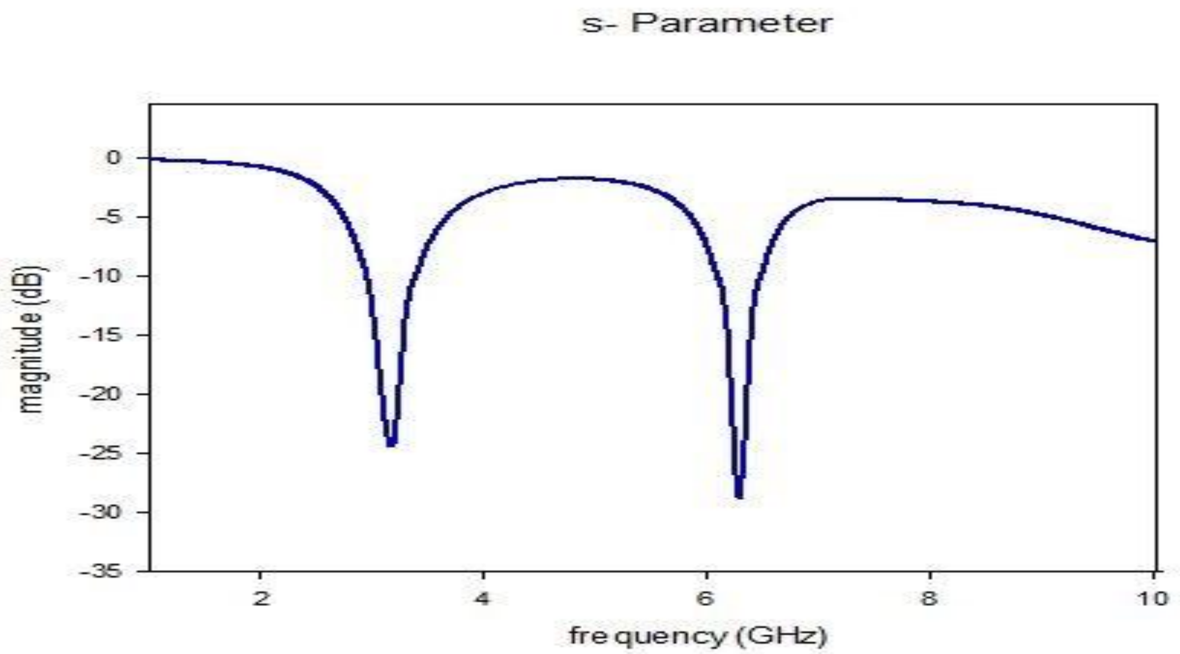


Fig 2.5 (iv) Effect of variation on polyster Feedline (Wf) 4 mm

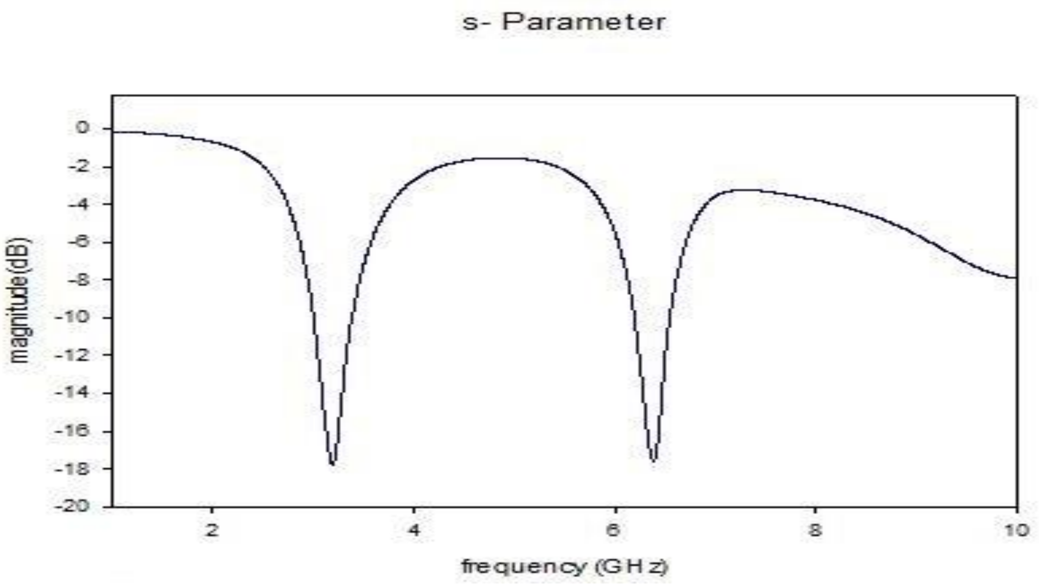


Fig 2.6 (v) Effect of variation on polyster Feedline (Wf) 4.5 mm

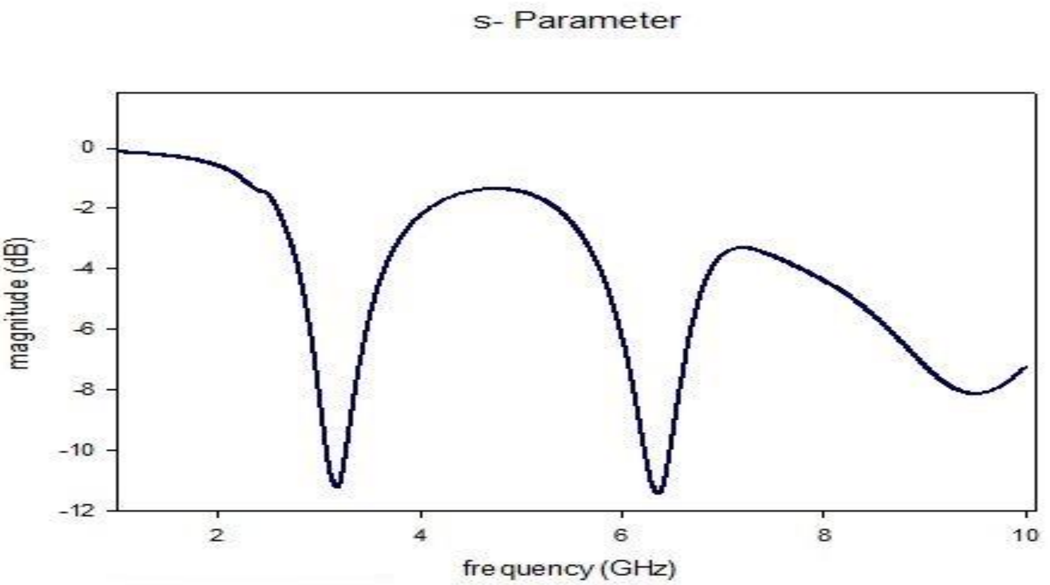


Fig 2.6 (vi) Effect of variation on polyster Feedline (Wf) 5 mm

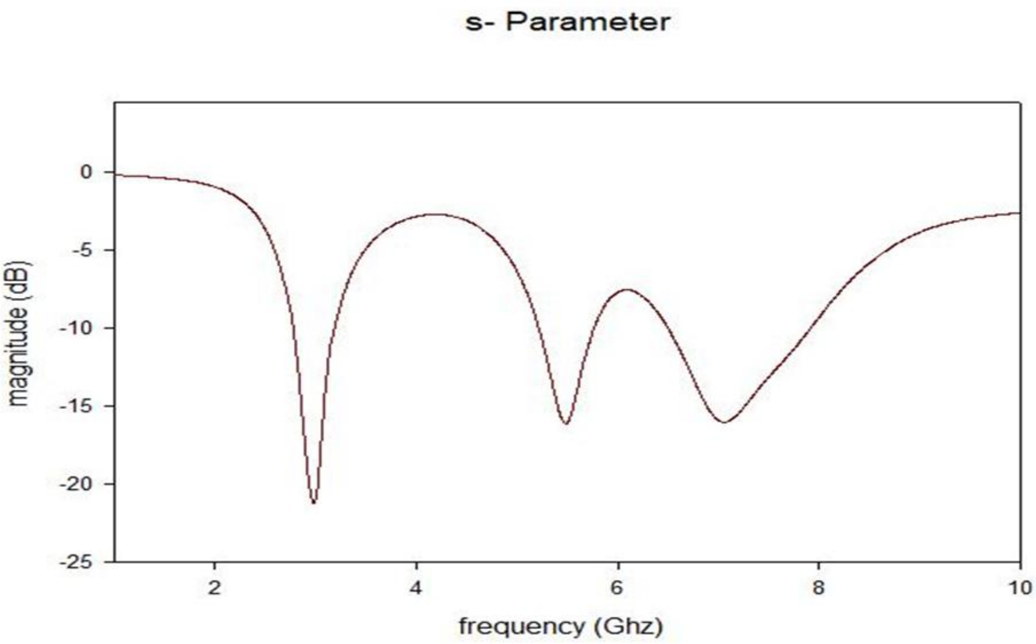


Fig 3.0 (c) polyimide 3.5 GHz

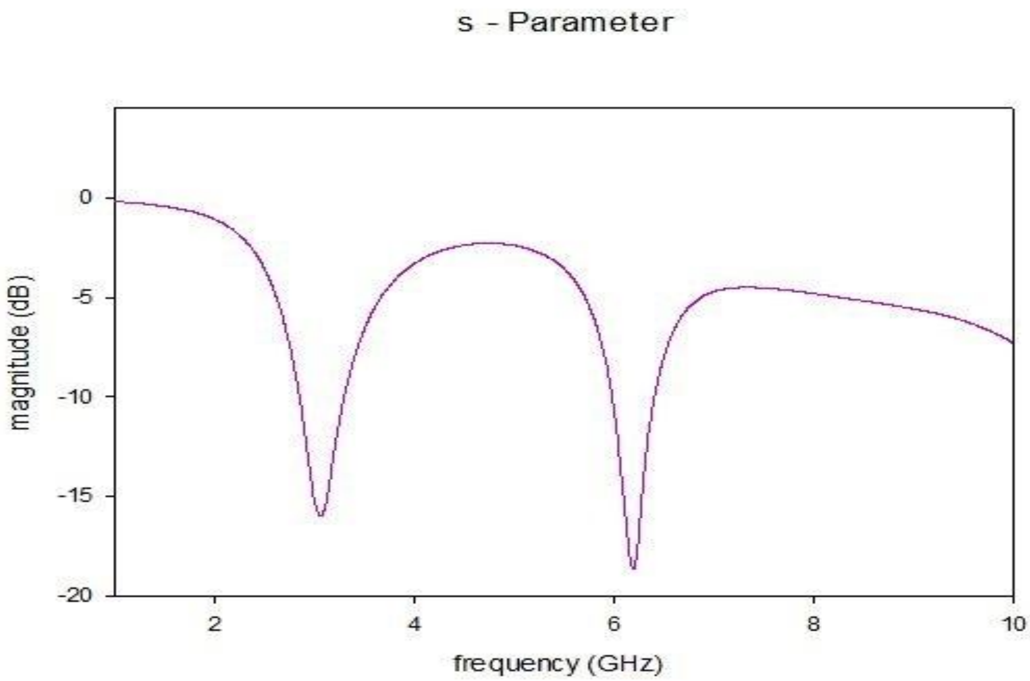


Fig 3.1 (d) polyimide 6 GHz

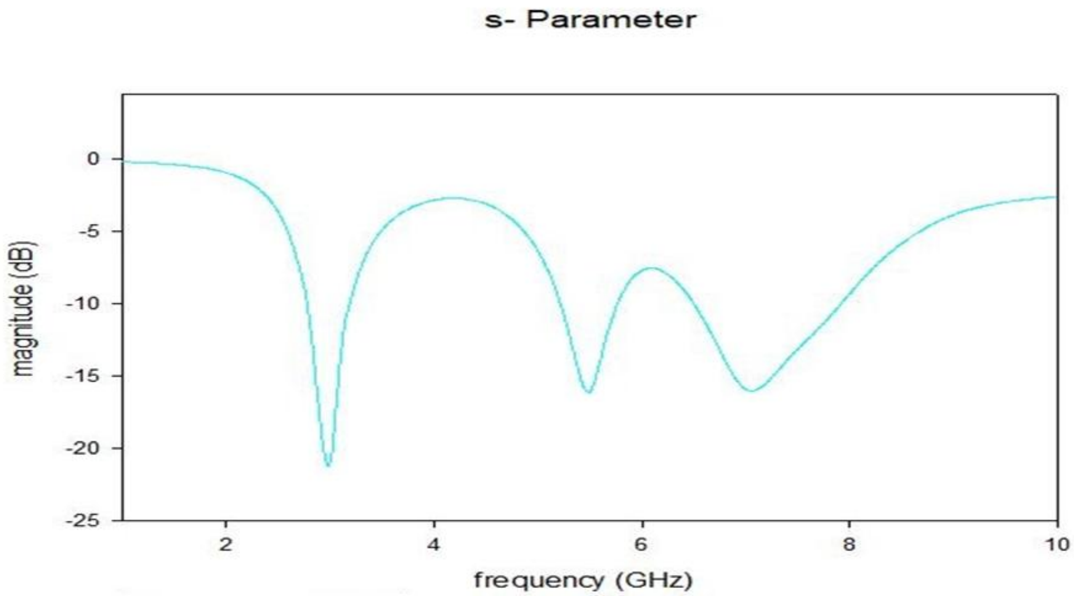


Fig 3.2 (i) Effect of variation on polyimidegrouund (G) 9 mm

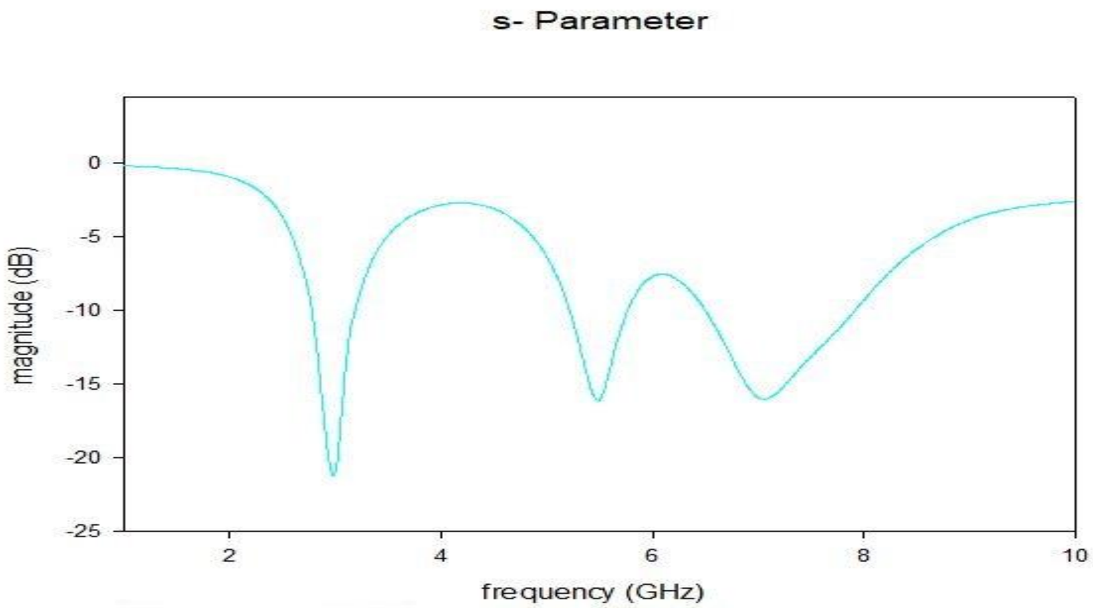
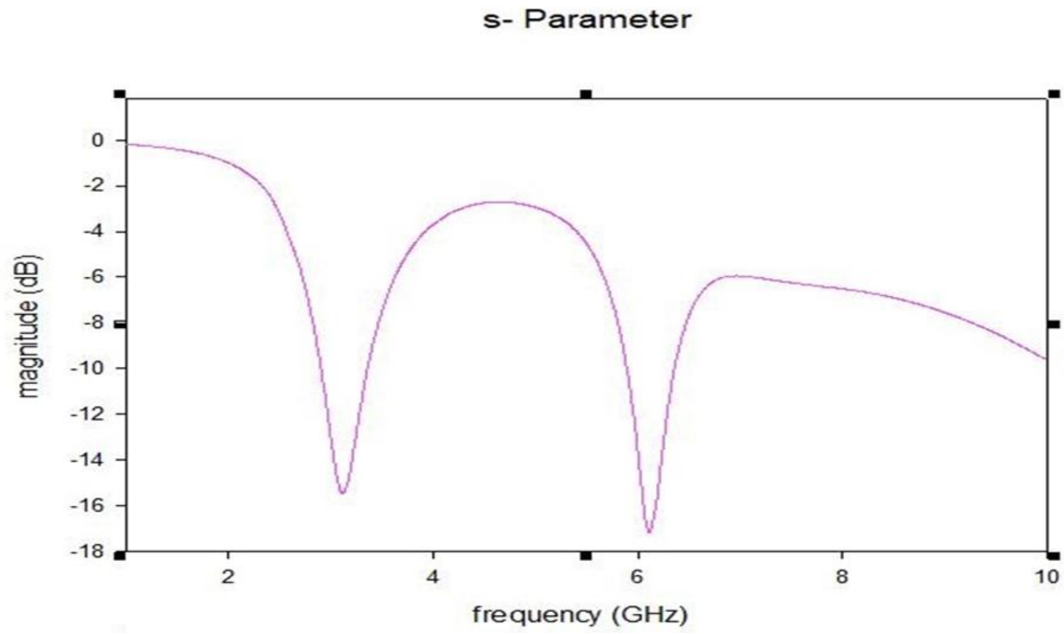


Fig 3.3

(ii) Effect of variation on polyimidegrouund (G) 9.5 mm

Fig **3.4**
(iii)



Effect of variation on polyimidegrouund (G) 10 mm

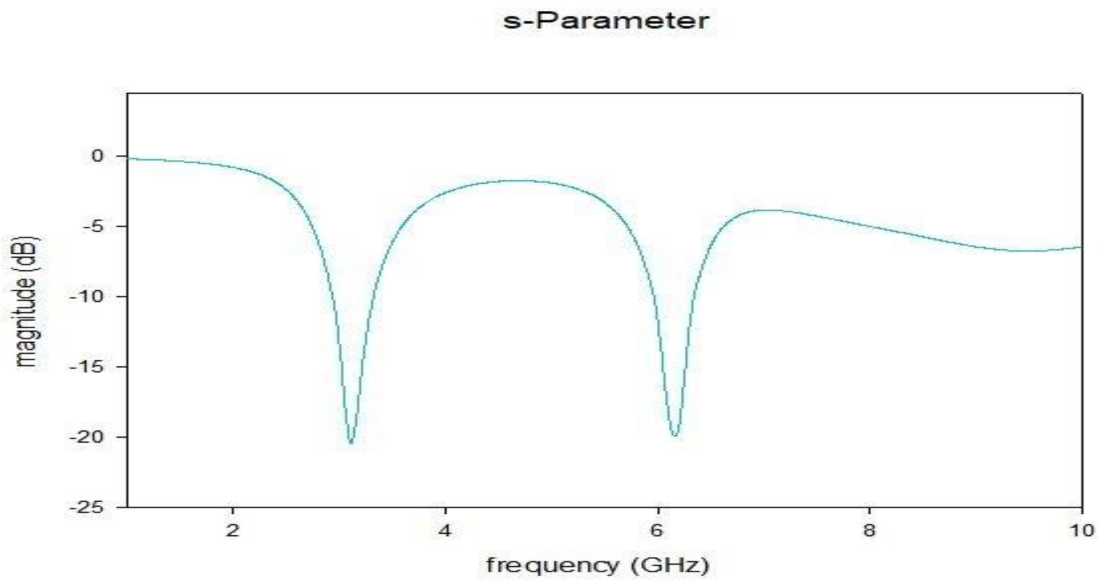


Fig 3.5 (iv) Effect of variation on polyimide feedline (Wf) 4 mm

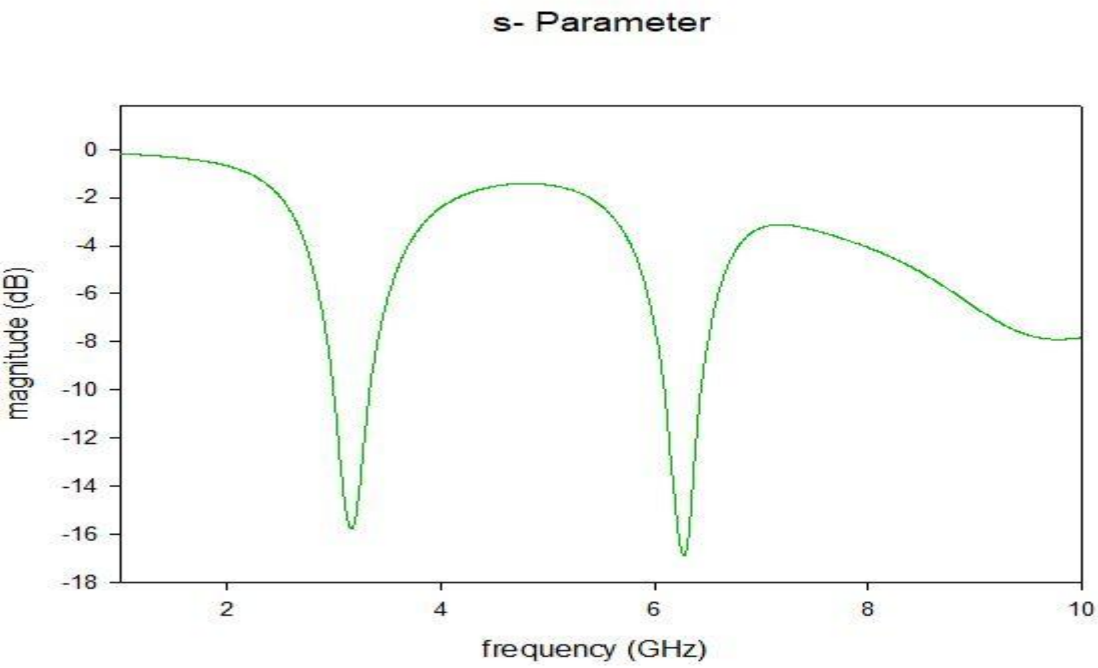


Fig 3.6 (v) Effect of variation on polyimide feedline (Wf) 4.5 mm

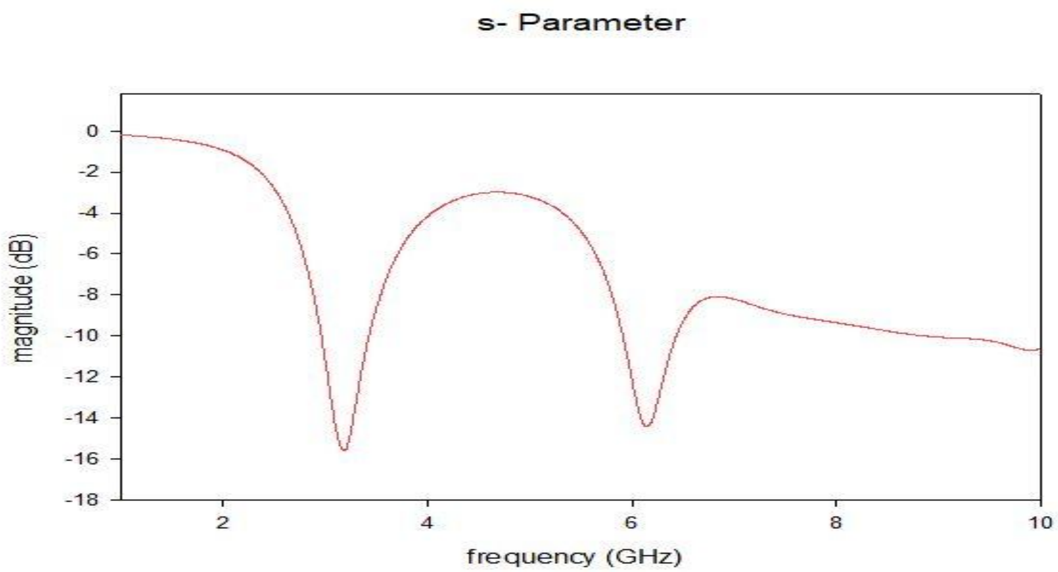


Fig 4.0 (i) Polyamide 3.5 GHz

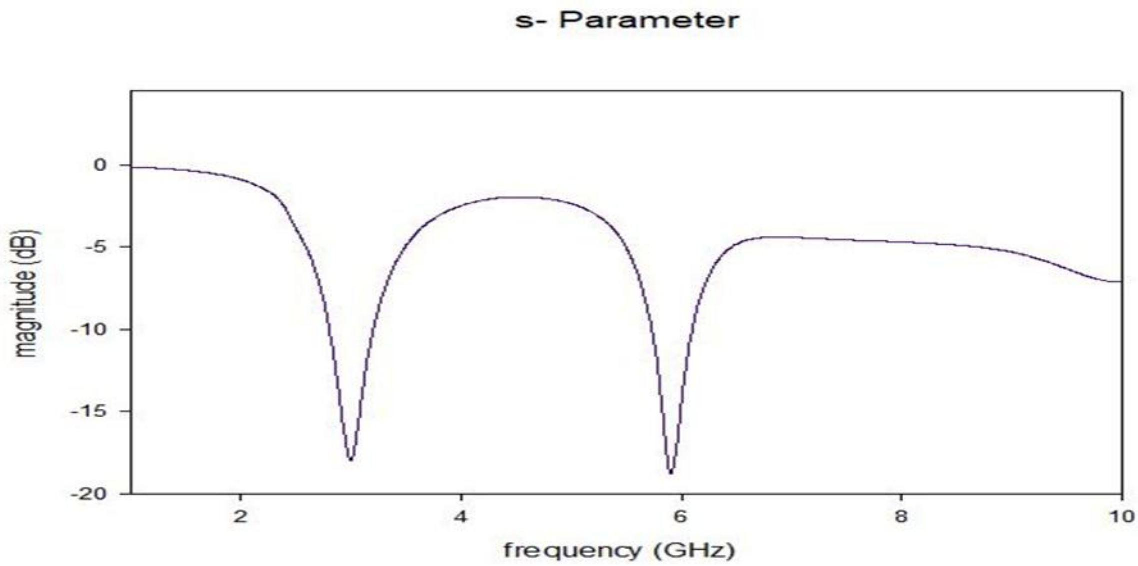


Fig 4.1 (ii) Polyamide 6 GHz

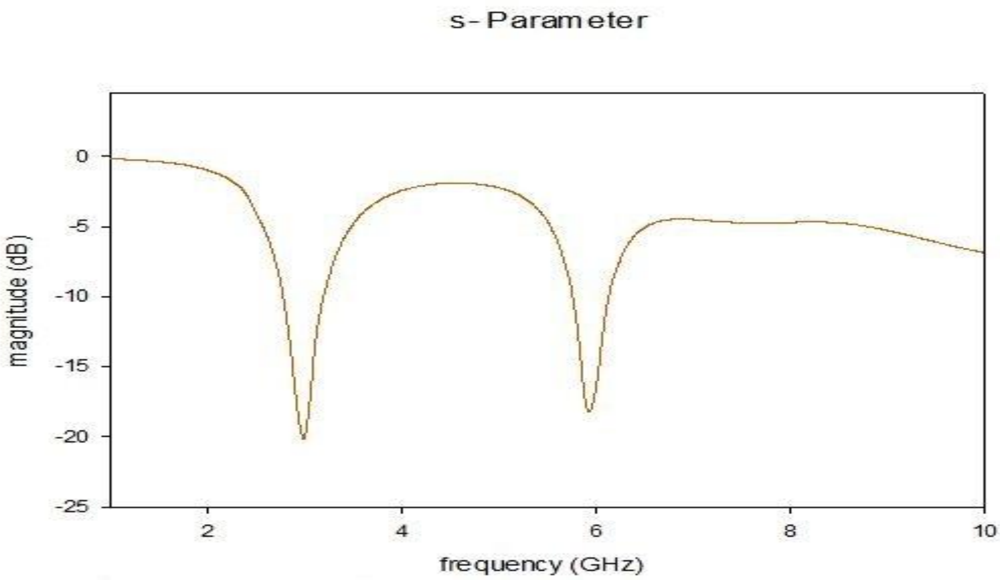


Fig 4.2 (i) Effect of variation on polyamidegrouund (G) 9 mm

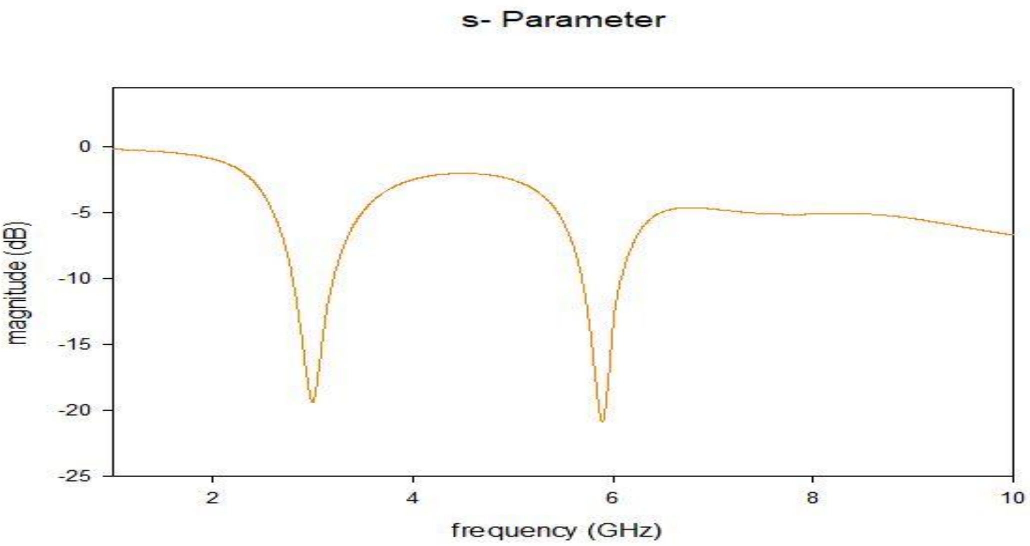


Fig 4.3 (ii) Effect of variation on polyamidegrouund (G) 9.5 mm

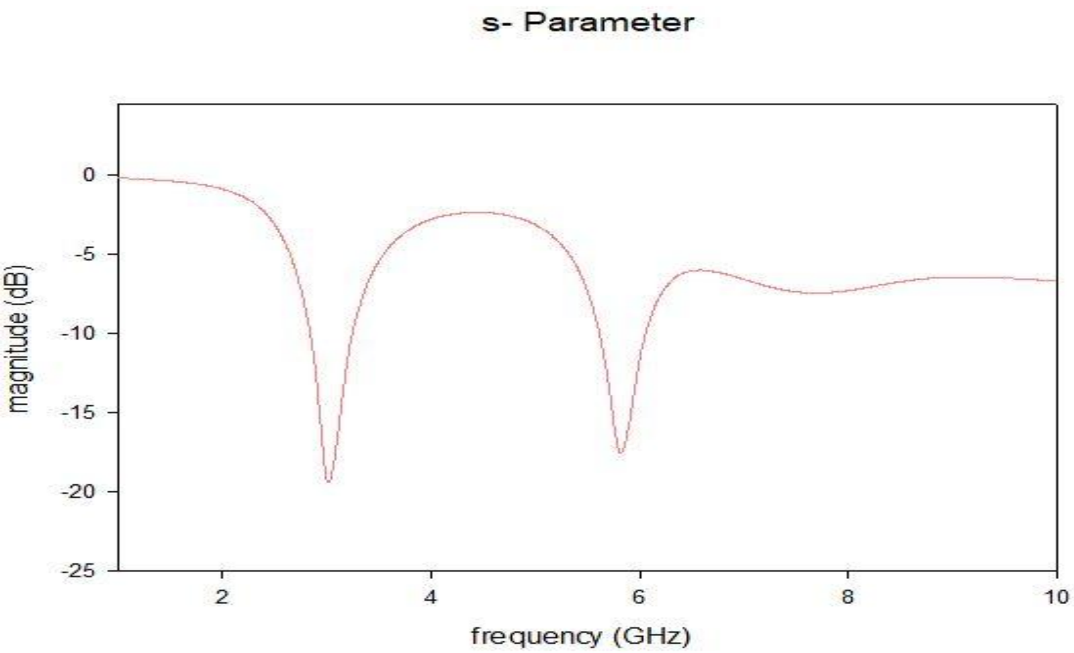


Fig 4.4 (iii) Effect of variation on polyamide grouund (G) 10 mm

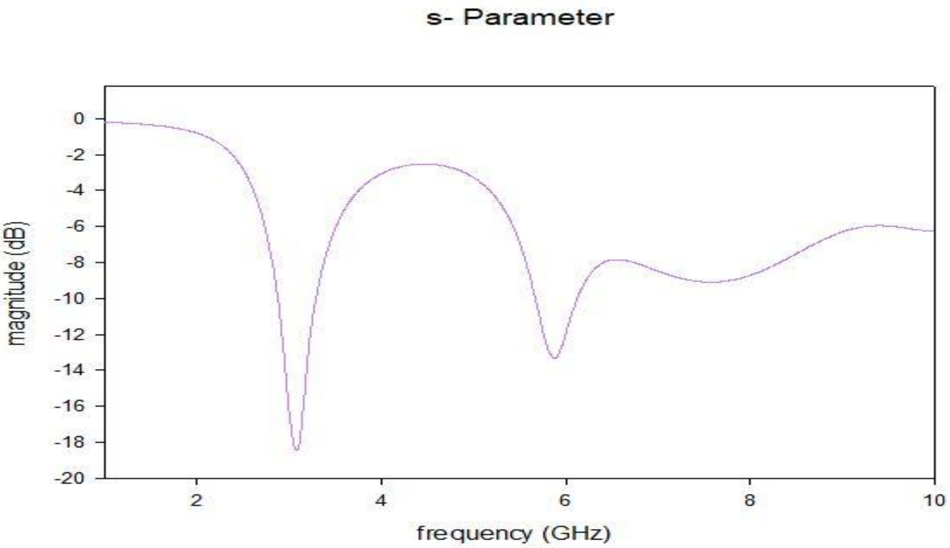


Fig 4.5 (iv) Effect of variation on polyamide feedline (Wf) 4 mm

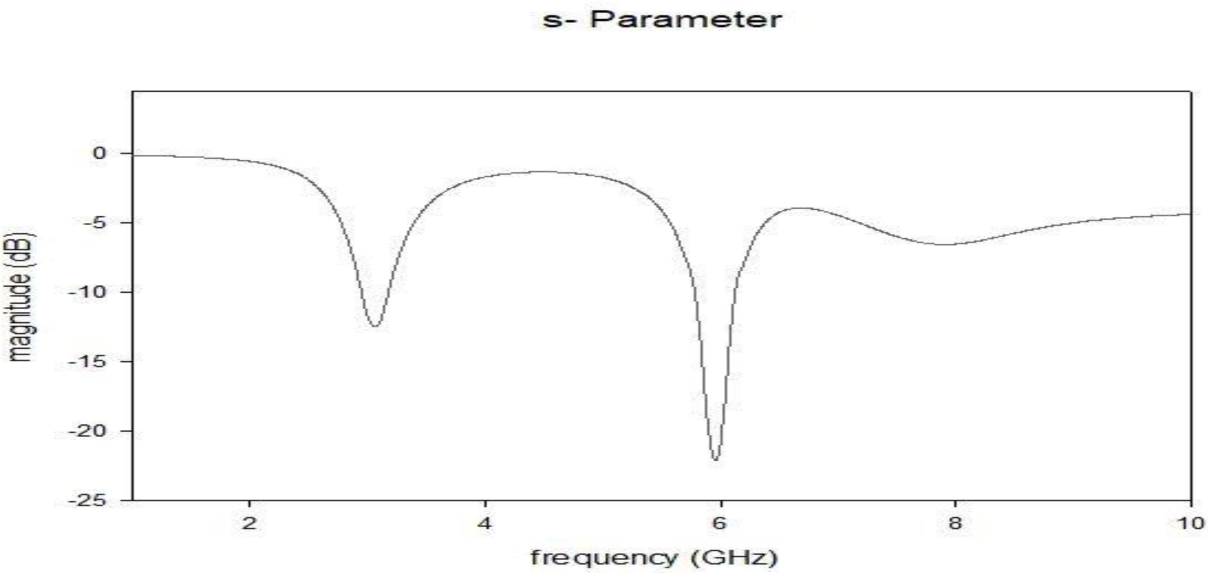


Fig 4.6 (v) Effect of variation on polyamide feedline (Wf) 4.5 mm

3.2. Radiation Pattern

Two radiation pattern plots of the resonating frequencies (3.5 GHz, 6 GHz) are illustrated. The H-plane (x-z plane) and E-plane (y-z plane) are selected to explain the antenna radiation patterns. Figure 5.0 shows the antenna E-field and H-field patterns at 3 GHz, which signifies that an omnidirectional pattern in the H-field and slight variation in E-field pattern has been observed, respectively. A quasi-omnidirectional pattern, and, at 6 GHz, omnidirectional patterns in H-planes and E-planes are found, which signifies that the proposed antenna can receive signals from all directions. On the other hand, on-body performance of the antenna is also affected by the lossy component of biological human body tissues, which absorbs the energy from electromagnetic radiation**.**

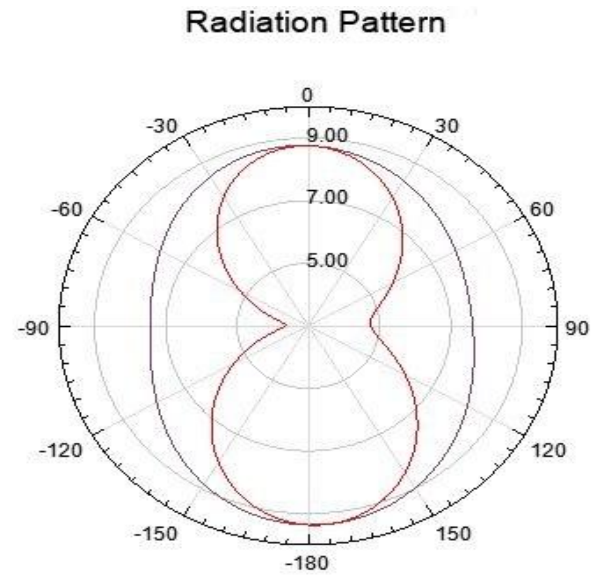


Fig 5.0 (a) Polyster 3.5 GHz

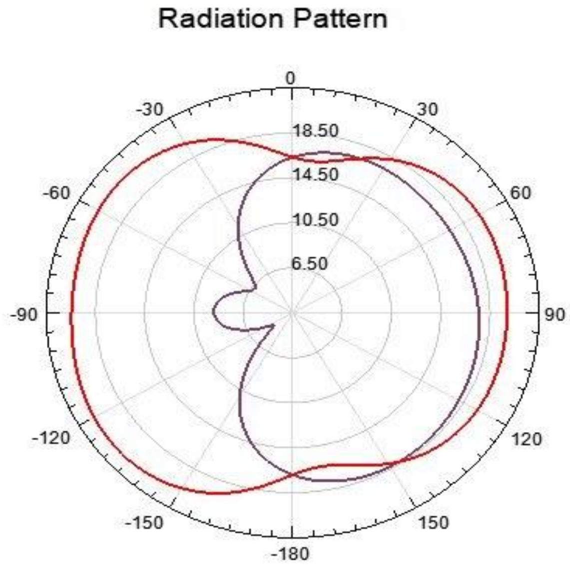
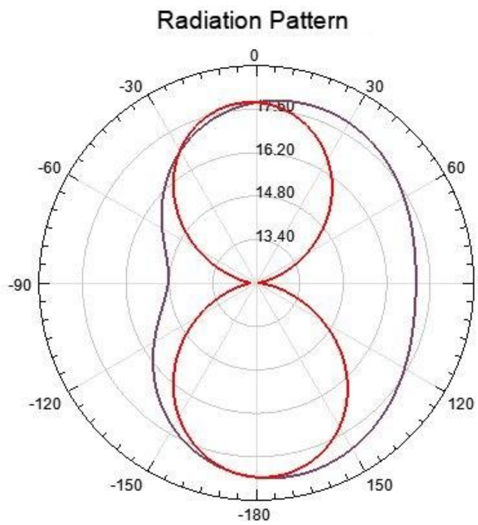


Fig 5.1 (b) Polyster 6 GHz



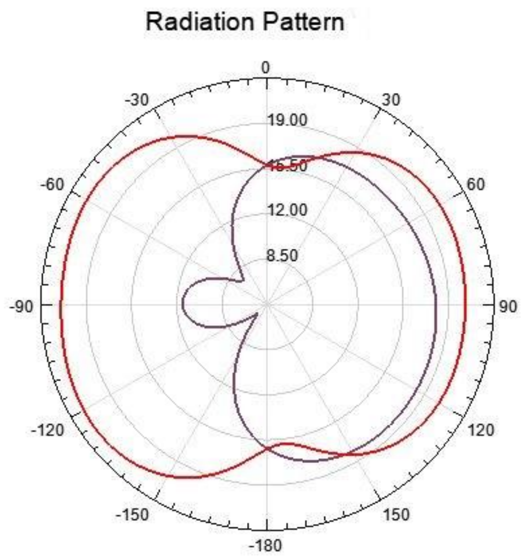


Fig 6.0 (c) Polymide 3.5 GHzFig 6.1(d) Polymide 6 GHz

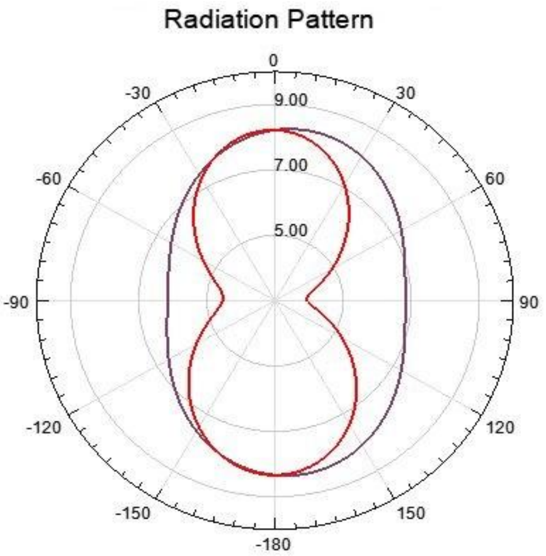


Fig 7.0 (e) Polyamide 3.5 GHz

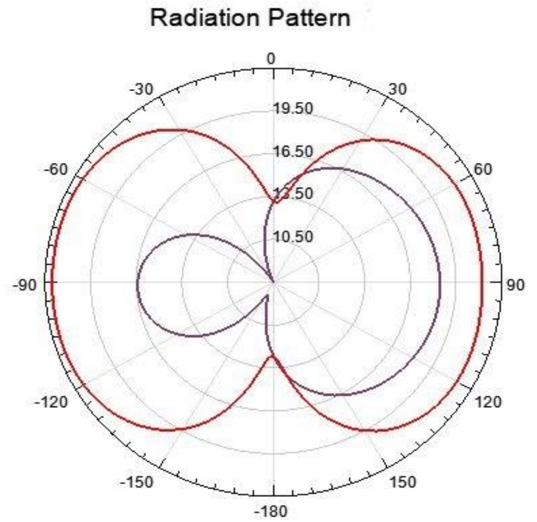


Fig 7.1 (f) Polyamide 6 GHz

3.3. Gain

If the gain of the antenna is 0 dBi, which means it offers an omnidirectional radiation pattern. On the one hand, when the gain is increasing in positive values, the shape of pattern is changed to directional. On the other hand, when the gain is less than 0 dBi or represents negative values, this means there is a change of shape in radiation pattern due to back lobe variation depicts the gain of the antenna versus frequency plot, and it also reveals that the highest gain value of 9.47dBi is observed at 3.5 GHz frequency in broadside direction. It can be noticed that at, specific frequencies, the gain dropped down below 0 dBi, which confirms that the antenna does not radiate energy in the desired direction due to back lobe radiation, whereas gain is almost matched in the other part of the frequencies.

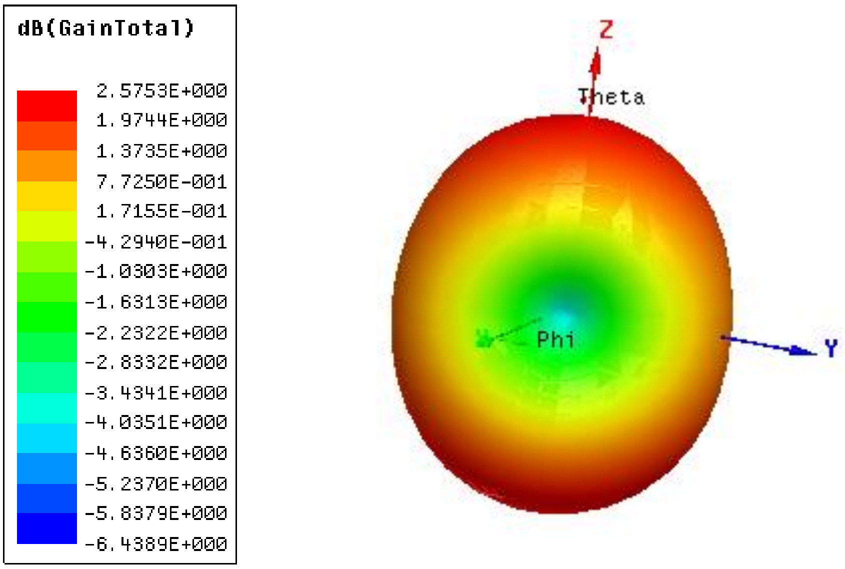


Fig 8.0 (i) Polyster 3.5 GHz

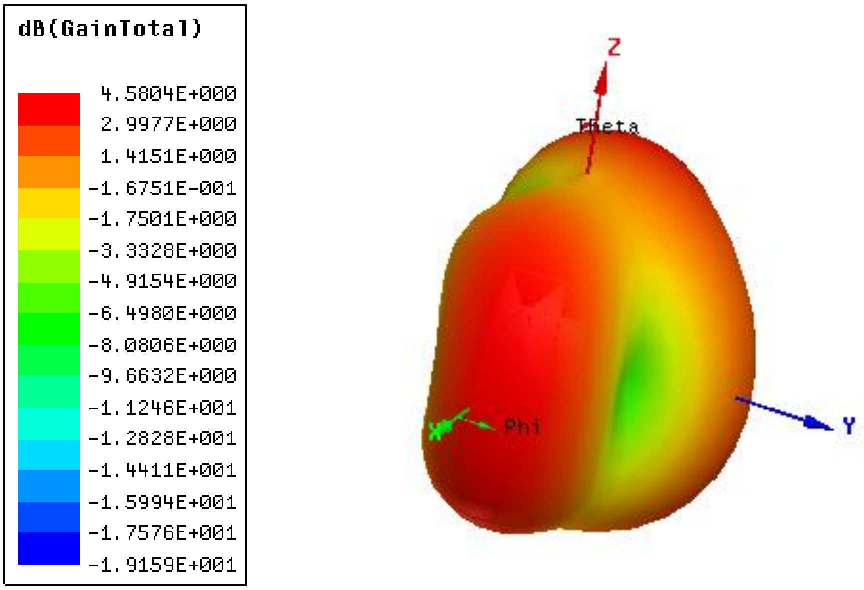


Fig 8.1 (ii) Polyster 6 GHz

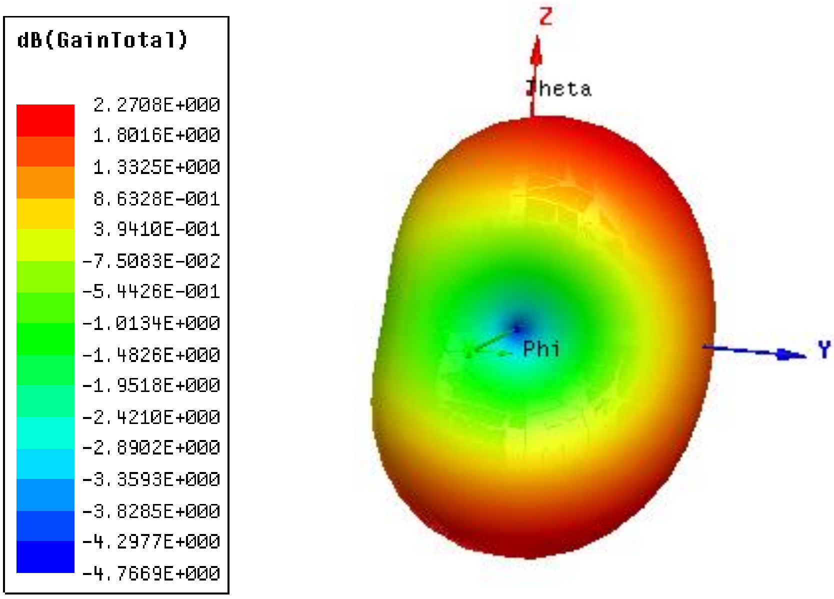


Fig 9.0 (iii) Polyimide 3.5 GHz

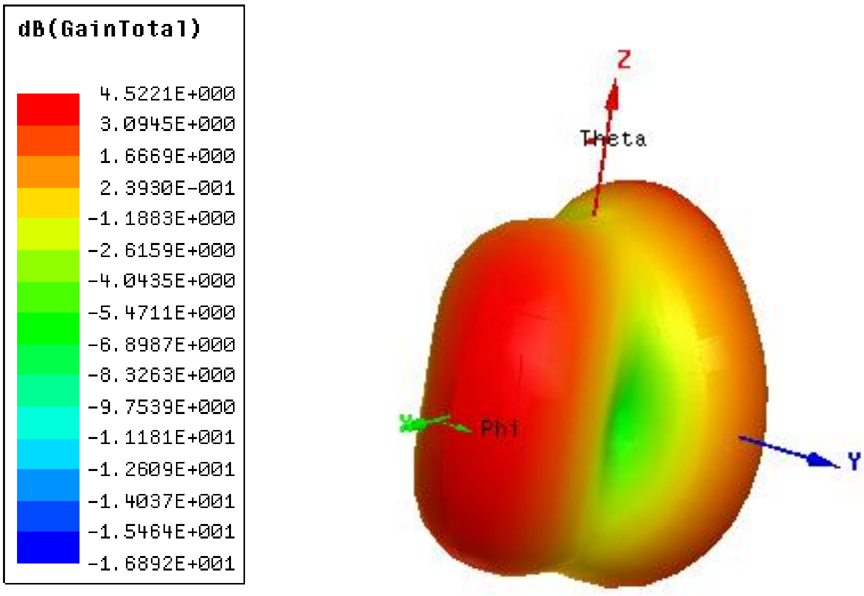


Fig 9.1 (iv) polyimide 6 GHz

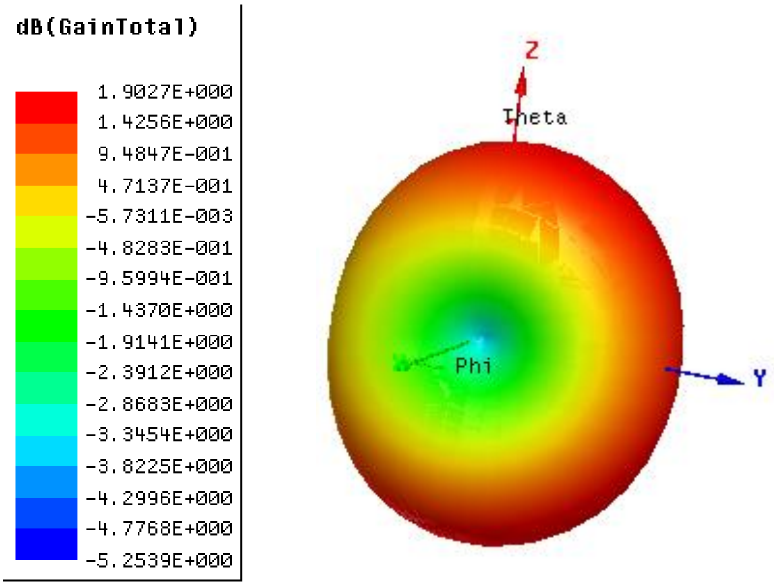
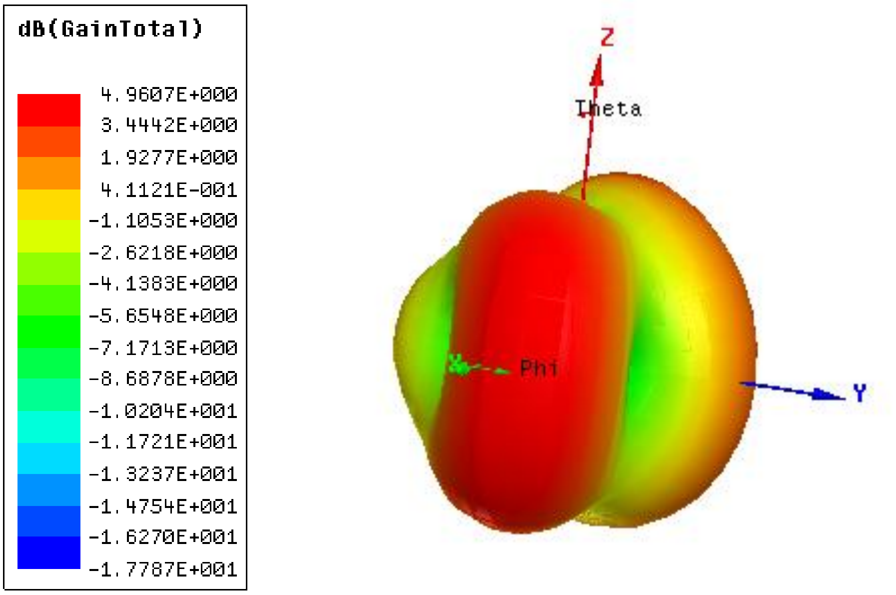


Fig 10.0 (v) Polyamide 3.5 GHz



ig 10.1 (vi) Polyamide 6 GHz

3.4.Current Distribution

The current distribution effect of the antenna is explained in Figure 11. Figure 11 shows the effect of current in the primary antenna structure, and it is observed that most of the current has focused around the microstrip line feeding point and left corner of the ground plane.Moreover, the distribution of current on the radiator and right corner of the ground at frequency of 3.5 and 6 GHz, which has a significant effect on antenna impedance matching, Thus results in proper impedance matching.

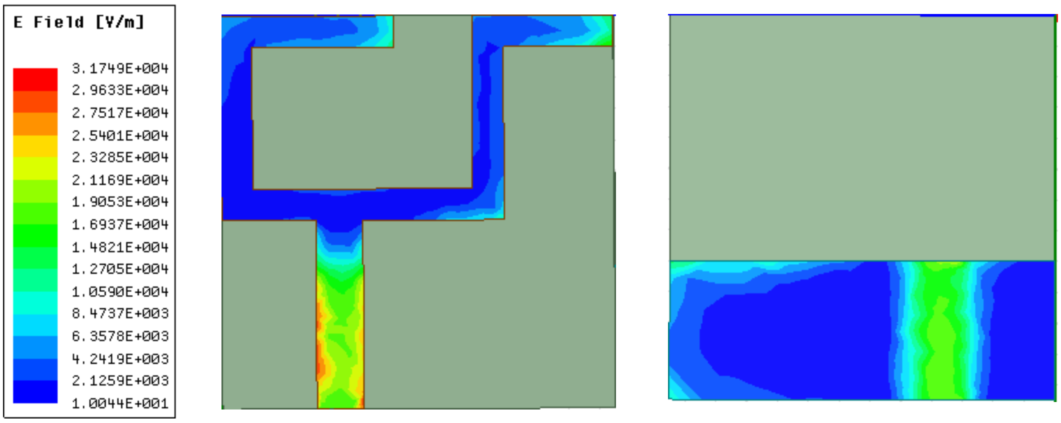


Fig 11.0 (a) Polyster 3.5 GHz

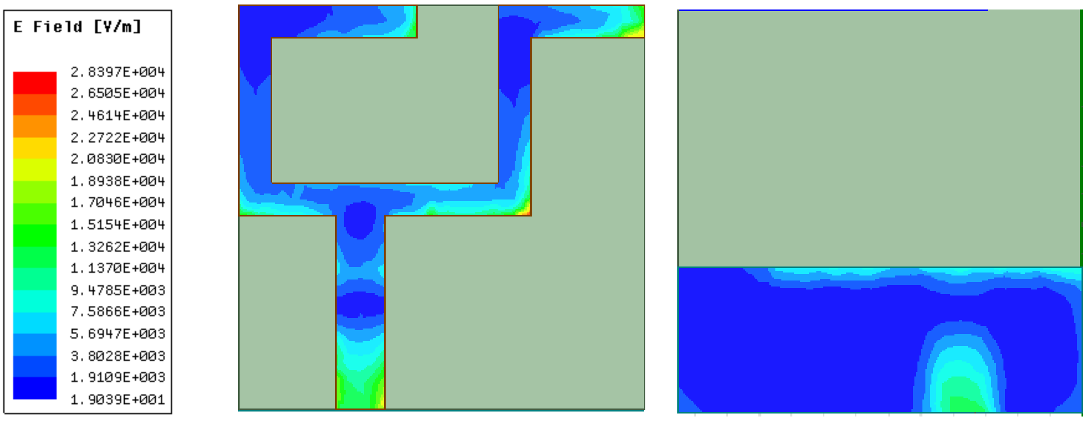


Fig 11.1 (b) Polyster 6 GHz

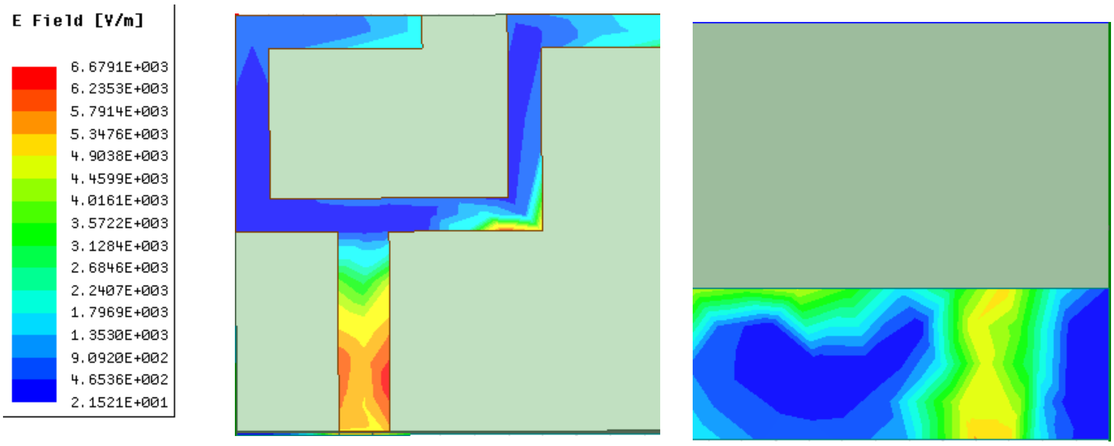


Fig 12.0 (c) Polymide 3.5 GHz

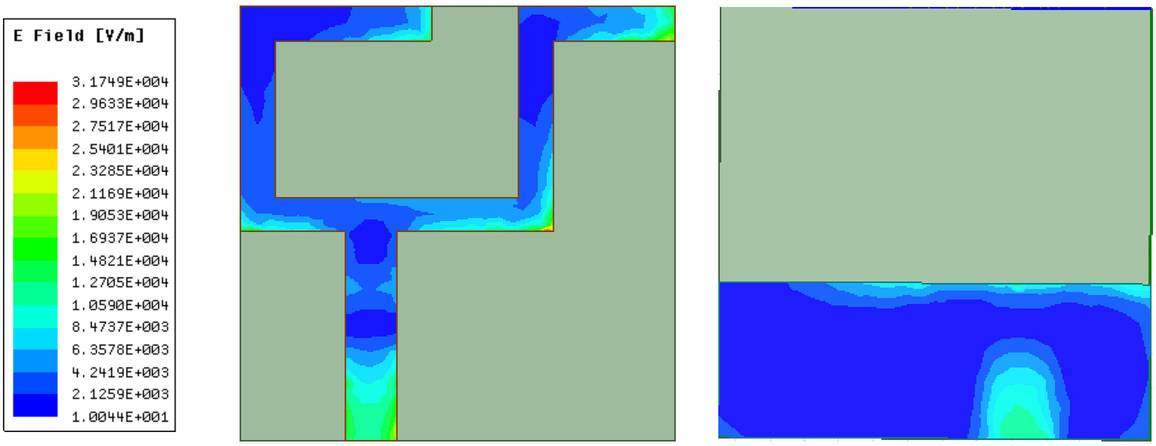


Fig 12.1 (d) Polymide 6 GHz

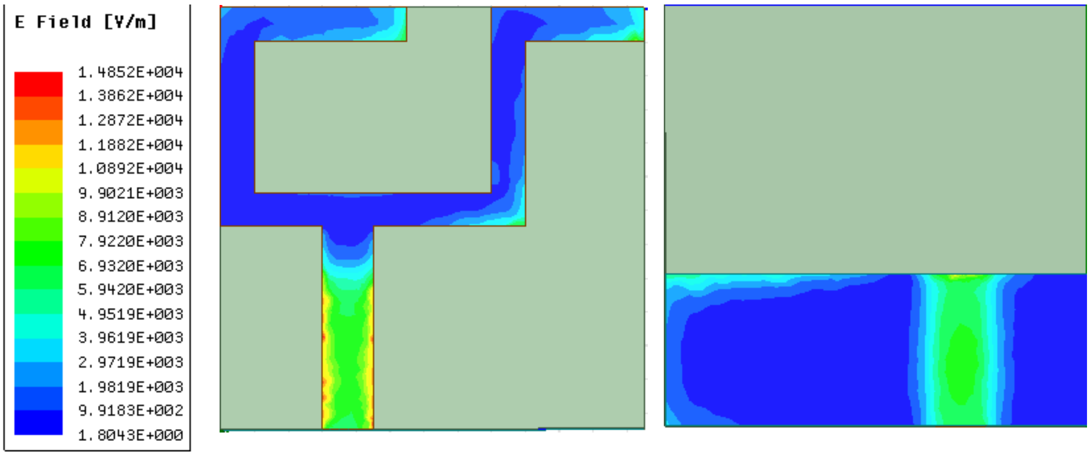


Fig 13.0 (d) Polyamide 3.5 GHz

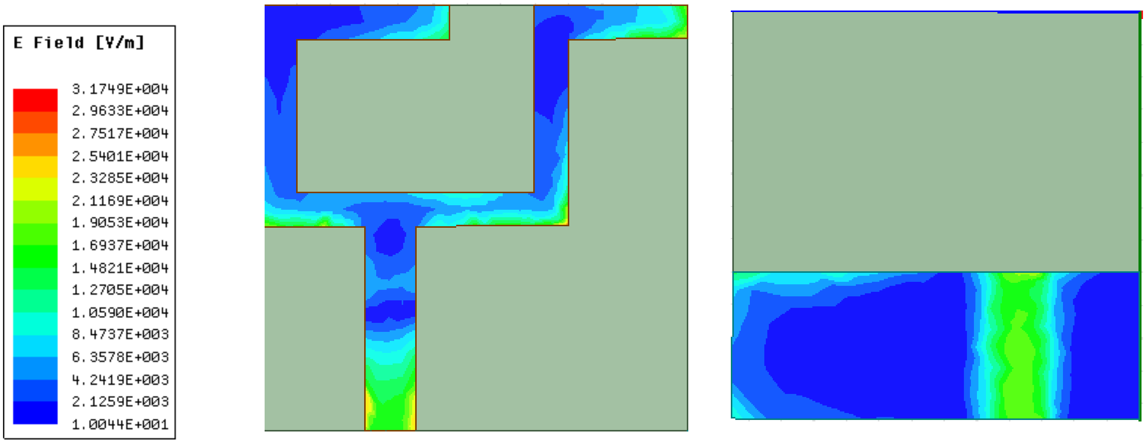


Fig 13.1 (e) Polyamide 6 GHz

4. Conclusion

In this manuscript, the development of compact Fabric based antenna has been designed, which is applicable for the UWB application. The mathematical analysis was completed through circuit theory using the cavity model of antenna, which validates the proposed design. Different slots and notches were removed from the radiating patch, presenting a justified ground plane, and impedance-matching performance through current distribution was presented.

The proposed antenna has a significant impedance bandwidth which covers the complete UWB range (3.1–10.6 GHz) designated by the FCC, and has a maximum gain of 28.7 dBi at 6.3 GHz frequency. The time-domain characteristic was also presented to state the pulse distortion phenomena of the developed antenna. The phase of the designed antenna was found to be linear and constant group delay less than 1 ns was achieved. The SAR value of the antenna was tested to show the radiation effect on the human body, and it was found that the SAR value of the antenna is 1.6018 W/Kg, which is less than 2 W/Kg according to the International Electrotechnical Commission (IEC) standard. This point explains the outcomes of this antenna, which distinguishes itself from other antennas. With these results, we propose this wearable Fabric based antenna for telemedicine and mobile health systems.

References

1. Bharadwaj, R.; Swaisaenyakorn, S.; Parini, C.; Batchelor, J.C.; Alomainy, A. Impulse Radio Ultra-WidebandCommunications for Localization and Tracking of Human Body and Limbs Movement for Healthcare Applications. *IEEE Trans. Antennas Propag.* **2017**, *65*, 7298–7309. [CrossRef]

2. Gao, Y.; Zheng, Y.; Diao, S.; Toh, W.-D.; Ang, C.-W.; Je, M.; Heng, C.-H. Low-Power Ultrawideband WirelessTelemetry Transceiver for Medical Sensor Applications. *IEEE Trans. Biomed. Eng.* **2010**, *58*, 768–772. [CrossRef]

3. Jalil, M.E.; Rahim, M.K.A.; Abdullah, M.A.; Ayop, O. Compact CPW-fed Ultra-wideband (UWB) antenna using denim textile material. In Proceedings of the 2012 International Symposium on Antennas and Propagation (ISAP), Nagoys, Japan, 29 October–2 November 2012; pp. 30–33.

4. Amit, S.; Talasila, V.; Shastry, P. A Semi-Circular Slot Textile Antenna for UltraWideband Applications.In *Proceedings of the 2019 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio ScienceMeeting*; Institute of Electrical and Electronics Engineers (IEEE): Piscataway, NJ, USA, 2019; pp. 249–250.

5. Soh, P.J.; VandenBosch, G.A.; Higuera-Oro, J. Design and evaluation of flexible CPW-fed Ultra Wideband(UWB) textile antennas. In *Proceedings of the 2011 IEEE International RF & Microwave Conference*; Institute of Electrical and Electronics Engineers (IEEE): Piscataway, NJ, USA, 2011; pp. 133–136.

6. Singh, V.K.; Dhupkariya, S.; Bangari, N. Wearable Ultra Wide Dual Band Flexible Textile Antenna for WiMax/WLAN Application. *Wirel. Pers. Commun.* **2016**, *95*, 1075–1086. [CrossRef]

7. Bolaños-Torres M, Á.; Torrealba-Meléndez, R.; Muñoz-Pacheco, J.M.; del Carmen Goméz-Pavón, L.; Tamariz-Flores, E.I. Multiband Flexible Antenna for Wearable Personal Communications. *Wirel. Pers. Commun.* **2018**, *100*, 1753–1764. [CrossRef]

8. Ahmed, O.; Sebak, A.-R. A Printed Monopole Antenna with Two Steps and a Circular Slot for UWBApplications. *IEEE Antennas Wirel. Propag. Lett.* **2008**, *7*, 411–413. [CrossRef]

9. Cheng, S.; Hallbjorner, P.; Rydberg, A. Printed Slot Planar Inverted Cone Antenna for Ultrawideband Applications. *IEEE Antennas Wirel. Propag. Lett.* **2008**, *7*, 18–21. [CrossRef]

10. Azim, R.; Islam, M.T.; Misran, N. Compact Tapered-Shape Slot Antenna for UWB Applications. *IEEE Antennas Wirel. Propag. Lett.* **2011**, *10*, 1190–1193. [CrossRef]

11. Bod, M.; Hassani, H.R.; Taheri, M.M.S. Compact UWB Printed Slot Antenna With Extra Bluetooth, GSM, and GPS Bands. *IEEE Antennas Wirel. Propag. Lett.* **2012**, *11*, 531–534. [CrossRef]

12. Sung, Y. UWB Monopole Antenna with Two Notched Bands Based on the Folded Stepped ImpedanceResonator. *IEEE Antennas Wirel. Propag. Lett.* **2012**, *11*, 500–502. [CrossRef]

13. Emadian, S.R.; Ghobadi, C.; Nourinia, J.; Mirmozafari, M.H.; Pourahmadazar, J. Bandwidth Enhancement ofCPW-Fed Circle-Like Slot Antenna with Dual Band-Notched Characteristic. *IEEE Antennas Wirel. Propag. Lett.* **2012**, *11*, 543–546. [CrossRef]

14. Nguyen, T.; Lee, N.H.; Park, H.C. Very Compact Printed Triple Band-Notched UWB Antenna With Quarter-Wavelength Slots. *IEEE Antennas Wirel. Propag. Lett.* **2012**, *11*, 411–414. [CrossRef]

15. Tsai, C.-L.; Yang, C.-L. Novel Compact Eye-Shaped UWB Antennas. *IEEE Antennas Wirel. Propag. Lett.* **2012**, *11*, 184–187. [CrossRef]