SSRG International Journal of Electrical and Electronics Engineering
ISSN: 2348-8379/ https://doi.org/10.14445/23488379/IJEEE-V10I6P106

Volume 10 Issue 6, 50-57, June 2023


*Original Article*

# Wearable, Flag-Shape Microstrip Antenna with Slot in the Ground Plane for Medical Devices

Archana Tiwari[1], A.A. Khurshid[2]

[1, 2]*Electronics Engineering Department, Shri. Ramdeobaba College of Engineering and Management, Nagpur, India*

[1]*Corresponding Author : tiwariar@rknec.edu*

Received: 02 April 2023 Revised: 15 May 2023 Accepted: 07 June 2023 Published: 30 June 2023

***Abstract*** - *This work validates a wideband antenna that can be worn for medical telematics. The flag-shaped antenna constructed of the RT-duroid material with the modified ground is 34 mm by 22 mm by 0.8 mm. In order to increase the operational bandwidth and decrease the resonant frequency of a typical rectangular patch, rectangular slots are added to the partial ground plane. Providing an impedance bandwidth (-10dB) of 200 MHz, the design works at 2.48 GHz. The suggested antenna retains high efficiency (93% at 2.49 GHz) and gain (2.50 dBi). High efficiency, moderate gain, and simple design are the primary contributions.*

***Keywords*** - *Flag-shaped antenna, Medical application, Microstrip patch, Rogers RT/Duroid 5880.*

## 1. Introduction

Due to simplicity in design, affordability, and compatibility, rectangular patch antennas are more widely used [1-5]. Antennas are frequently used in wireless devices that are small, uniform, and inexpensive [6-8]. Applications for medical monitoring employ wideband, low-profile antennas [9-12]; it has been demonstrated that bending has negligible impacts on the antenna's reflection coefficient, bandwidth, gain, and efficiency [13, 14]. A microstrip patch's layout and the benefits of semi-flexible RT/Duroid are discussed in the paper [15-17] due to the rising demand for mobile and wireless transmission [18-19]. A Planar dual-band, low-profile, dual-polarized antenna is suggested in [20], considering future 4G and 5G technologies. In [21], RT/Duroid 5880 and copper are used as the base materials in a flag-shaped microstrip patch antenna. Due to their low dielectric constant and minimal dielectric loss, RT/Duroid 5880 laminations are frequently used in high-frequency and broadband applications. RT/Duroid as the substrate material is proposed primarily for biomedical applications due to its advantages, including its use for electrical properties over a broad frequency range and suitability for high moisture environments. Utilizing a partial ground plane, the proposed design is used for both wideband [22, 23] and multiband features.

The claimed antenna area is more significant to be appropriate for wearable technology, and the previously mentioned antennas occasionally fall short in compactness, according to the literature reviewed above, in light of compact designs. Wearable gadget antennas need to be small, light, and aesthetically pleasing. It is difficult to make a small, bendable, maximum gain linearly polarized antenna. This can be explained by the competing goals because there may not be the best solution considering all goals.

Following is the breakdown of the paper section: in subsection two, design geometry is explained; briefly, subsection 3 discusses the experimentation and fabrication results and presents comparative performance analysis; subsection 4 covers the conclusion and future scope.

## 2. Antenna Geometry

The top view of the suggested flag-shaped patch with an internal slit and the L-shaped ground at the antenna's bottom side is shown in Figure 1. The substrate is made of a semi-flexible substance called RT/Duroid 5880, which has a 0.8-mm diameter and $\varepsilon_r$ of 2.2. A transmission line (50 ohms) supported by a portion of the ground plane excites the emitting element. The antenna's dimensions are 34 mm by 22mm by 0.8 mm. Utilizing common microstrip patch equations, the radiator's seed dimensions were determined [24-26]. The suggested antenna is an altered variant of the typical rectangle patch antenna. The antenna's total size and impedance are decreased by modifying the ground line, and the primary radiator is etched with slits. The details of the dimension of the substrate, both ground line and patch, are listed in Table 1.

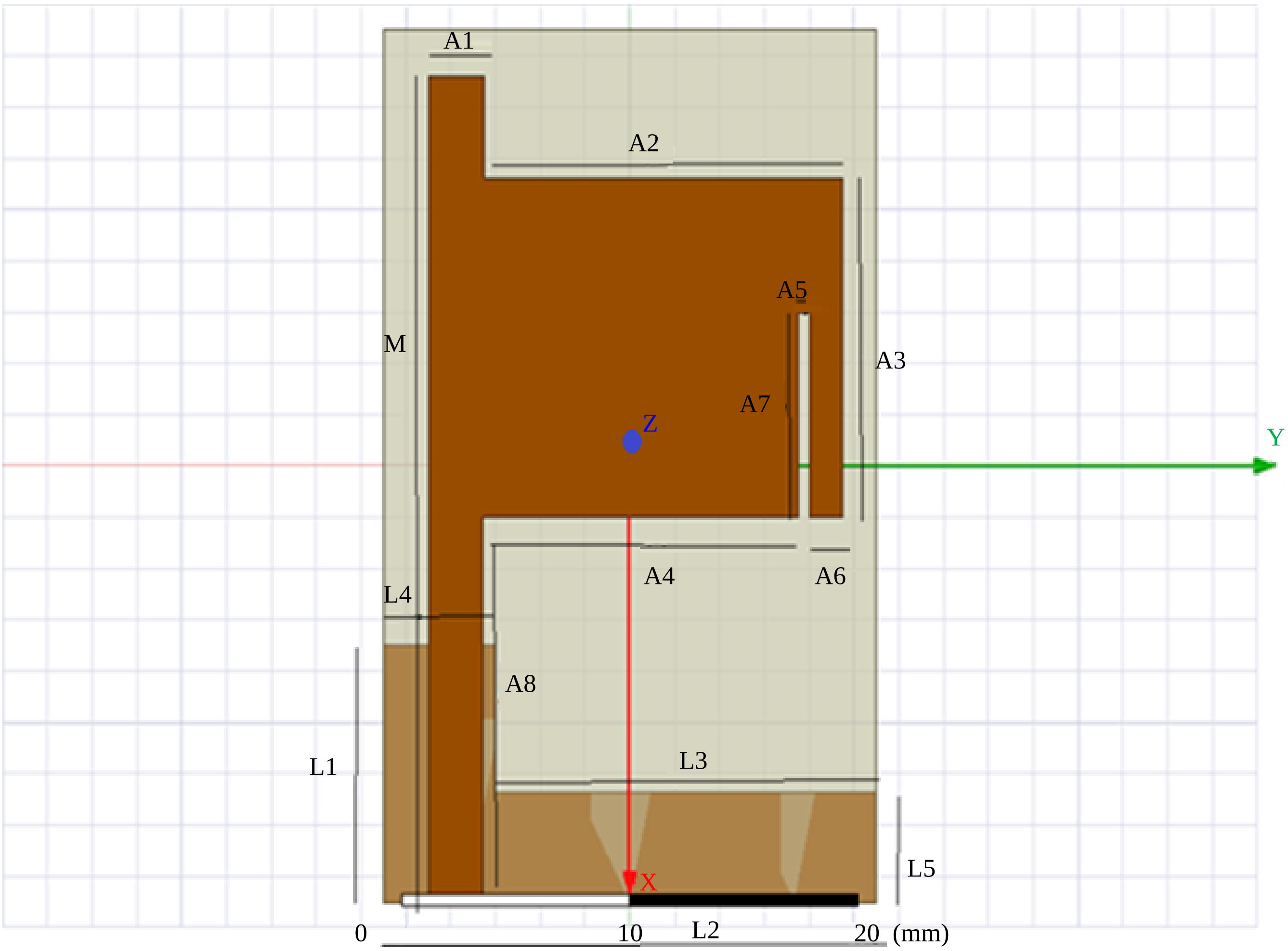


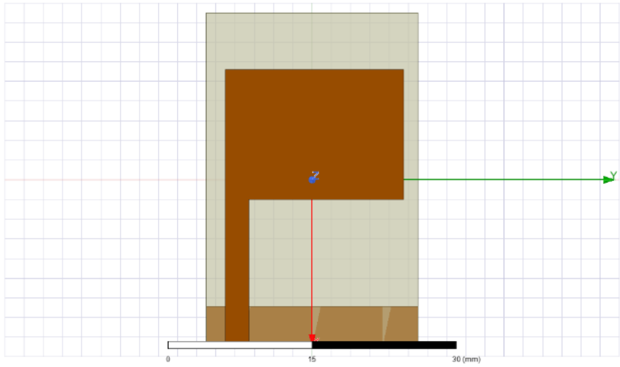

**Fig. 1 Proposed flag-shaped patch on a semi-flexible antenna**

**Table 1. The dimension of the substrate, both ground line and patch**

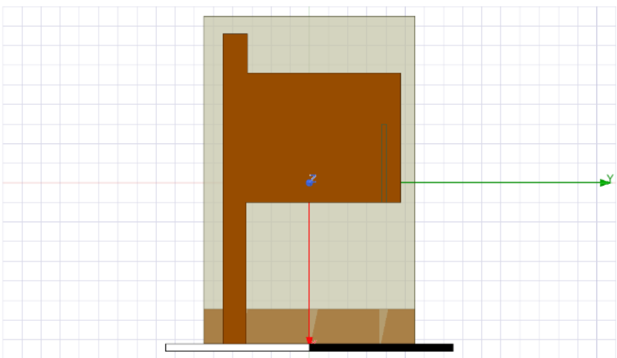
| Specifications for Antenna | Design Elements | Size (mm) |
|---|---|---|
| Primary radiating patch | M<br>$A_1$<br>$A_2$<br>$A_3$<br>$A_4$<br>$A_5$<br>$A_6$<br>$A_7$<br>$A_8$ | 32.2<br>2.5<br>16<br>13.2<br>14.1<br>0.5<br>1.5<br>08<br>15 |
| Ground plane | L1<br>L2<br>L3<br>L4<br>L5 | 10<br>22<br>17<br>05<br>4.3 |

## 3. Antenna Design and Analysis

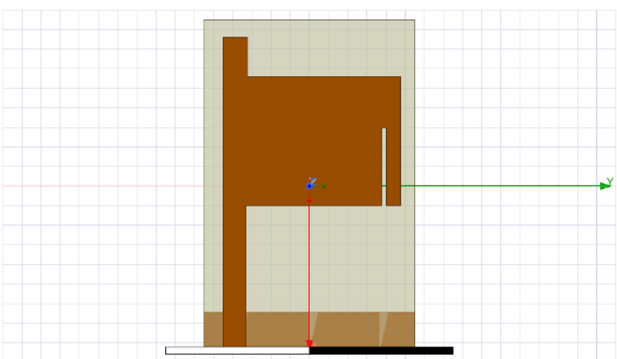
Figure 2 shows the design evolution stages. A straightforward rectangle patch antenna with a truncated ground plane served as the basis for the design taking the reference of a monopole flag-shaped patch with partial. Ground plane [21]. The antenna had a resonance in that iteration I at about 2.8 GHz, however, the antenna's fit with the resonance frequency was poor. In iteration II, a rectangular section was connected to the top of the patch to accomplish matching impedance and miniaturization. In iteration II, the antenna had a resonance at 2.6 GHz. In iteration III, the antenna was further altered by removing a rectangular section of the long slit from the patch's bottom side and the 2.5 GHz. resonance frequency in iteration III was achieved. In iteration IV, the antenna underwent a few modifications. An additional stub resonator in the form of a rectangle was coupled to the ground plane to lengthen it. By including in the ground plane, a rectangle resonator, the antenna's 10 dB bandwidth was also boosted. The antenna used in iteration IV (the suggested antenna) operated at 2.48 GHz with an impedance bandwidth (-10dB) of 200 MHz.



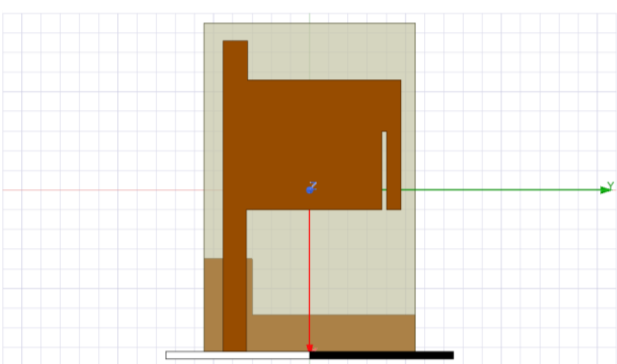
**Iteration I**



**Iteration II**



**Iteration III**



**Iteration IV**

**Fig. 2 Proposed flag-shaped patch on a semi-flexible antenna design evolution**

The dimensions and position of the ground line and the emitting element determine how well a monopole antenna resonates. Full-wave electromagnetic simulator (HFSS 20) was used to optimize the evolution stages of the radiator and ground plane of the antenna for improved 2.48 GHz impedance matching and broad impedance bandwidth.

A simulation was conducted using HFSS 20 software after design iterations for a patch in the form of a flag. The suggested flag-shaped semi-flexible patch's return loss plot for the simulated trial versus frequency is shown in Figure 3. The generated 2D and 3D gain plots and Smith chart of a flag-shaped semi-flexible patch are shown in Figures 4, 5 and 6, respectively. It is clear from testing that the chosen design yields the best results considering the return loss parameter vs frequency response. After simulating the trial, it was discovered that the return loss was -11.68 dB at 2.49 GHz, with a 2.5 dB gain and 200 MHz bandwidth.

## 4. Fabrication Results and Analysis of Comparative Performance and Experimentation

The proposed antenna was developed using RT/Duroid 5880 (dielectric constant = 2.2) semi-flexible material, as shown in Figure 7 (front and rear sides). The suggested antenna was characterized using the Vector Network Analyzer (VNA) from Keysight Technologies (50 SMA connection to the microstrip line input). A measurement was made of the antenna's free-space reflection coefficient. Figure 8 shows the reflection coefficient in space and the resonant frequency. At the operating band, the findings from simulation and measurement agreed with the bandwidth of 200 MHz and 500 MHz, respectively. Figure 9 shows the Smith chart plot of the fabricated prototype where the impedance of 50 ohms is matched as per the antenna requirements. Table 2 contrasts the work's simulated and measured outcomes for better understanding—the measured findings and the simulation's result line up perfectly. A comparison of the work's simulated and measured results is displayed in Table 2 for better comprehension—the measured findings and the simulation's result line up perfectly. Table 3 contrasts the suggested design's compactness and simplicity with the other researchers' reported work.

**Table 2. Simulations and measurements outcomes comparing table**

| Parameters of comparison | Resonant frequency | Bandwidth | Reflection-coefficient |
|---|---|---|---|
| Simulated Results | 2.48 GHz | 200 MHz | -11.68 dB |
| Measured Results | 2.477 GHz | 500 MHz (approx.) | -32.21 dB |

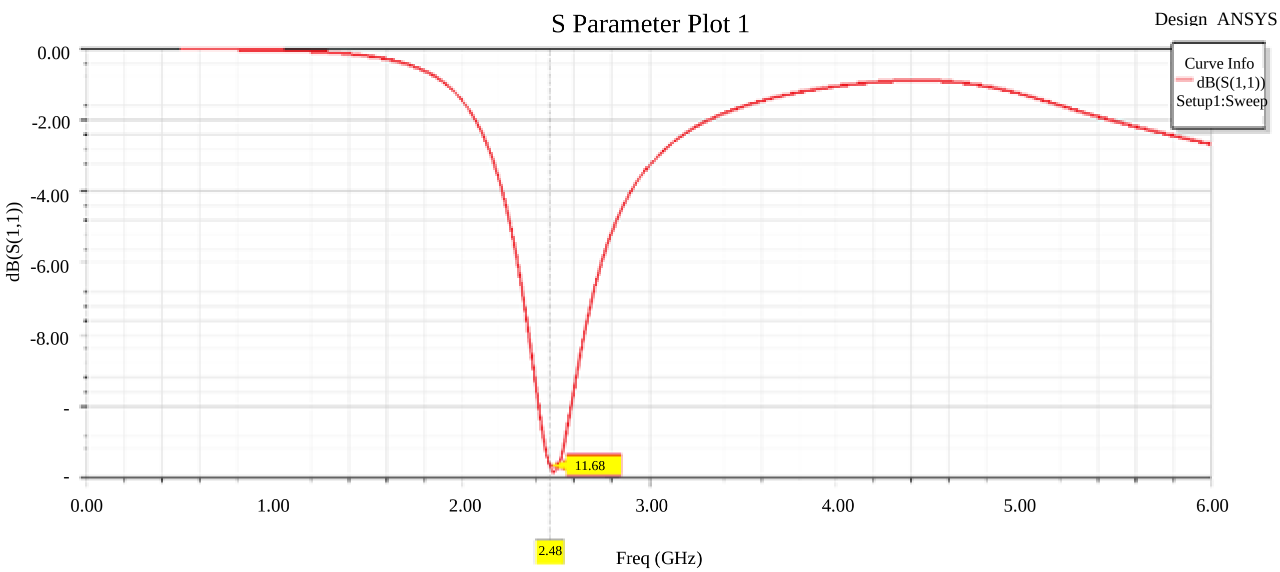



**Fig. 3 Results from a simulation for a flag-shaped patch's reflection coefficient versus frequency**

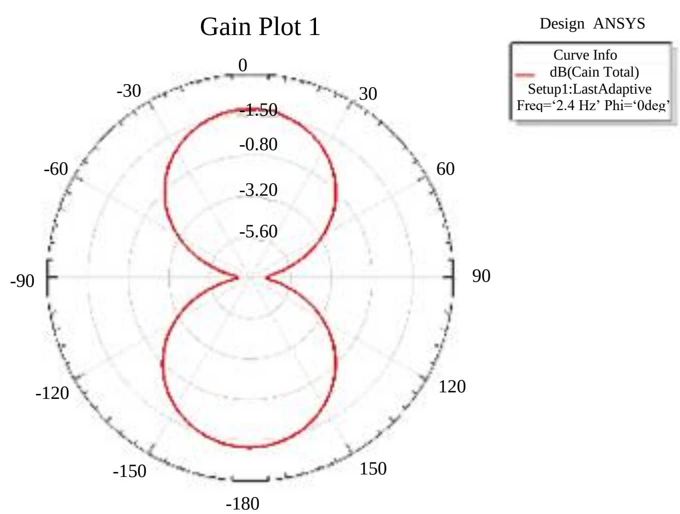



**Fig. 4 Results of a 2D gain plot simulation of the flag-shaped patch**

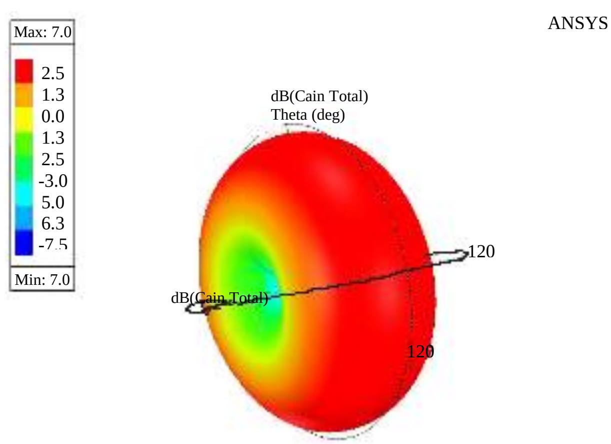



**Fig. 5 Results of a 3D gain plot simulation of the flag-shaped patch**

| Name | Freq | Ang | Mag | RX |
|---|---|---|---|---|
| m1 | 2.5400 | 45.7318 | 0.1488 | 1.2008 + 0.2618i |

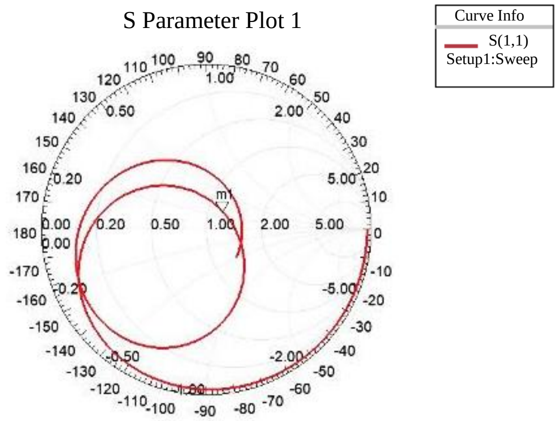



**Fig. 6 Smith chart plot of the proposed design**

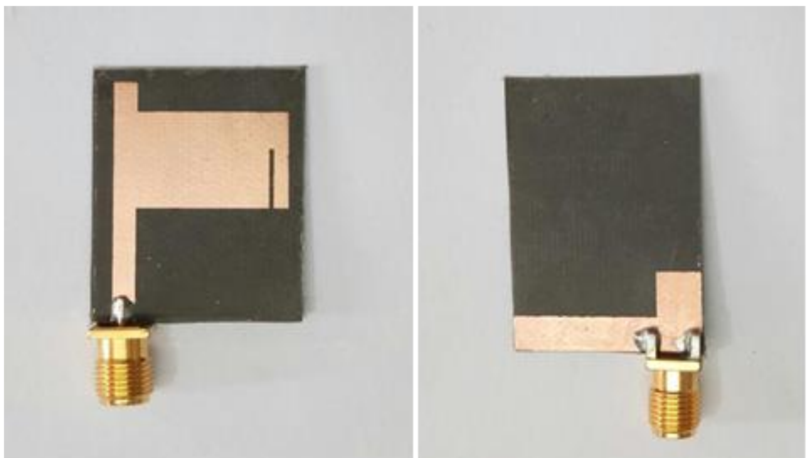


**Fig. 7 Front and back view of a fabricated prototype of a flag-shaped patch**

**Table 3. Comparing the suggested prototype with existing literature**

| Parameter | [27, 28] | [29] | [30] | Suggested prototype |
|---|---|---|---|---|
| Antenna Dimensions (mm) | 150 x 150 x 1.6 | 39 x 39 x 0.503 | 60.63× 60.63 × 0.16 | 34 x 22 x 0.8 |
| Resonant Frequency (GHz) | 2.45 | 2.45 | 0.762 | 2.47 |
| Substrate Material | Rogers RT5880 | Rogers RT5880 | Rogers RT5880 | Rogers RT5880 |
| Gain | 10.17 dBi | 2.06dBi | 1.2 dBi | 2.5 dBi |
| Bandwidth | 120 MHz | 7.75% impedance bandwidth | 0.759 to 0.767 GHz | 500 MHz |
| Antenna Design | Rectangular ring patch | Koch fractal geometry | Split-ring resonator (SRR) | Flag Shaped Patch |
| Design Complexity | Complex | Complex | Complex | Simple |

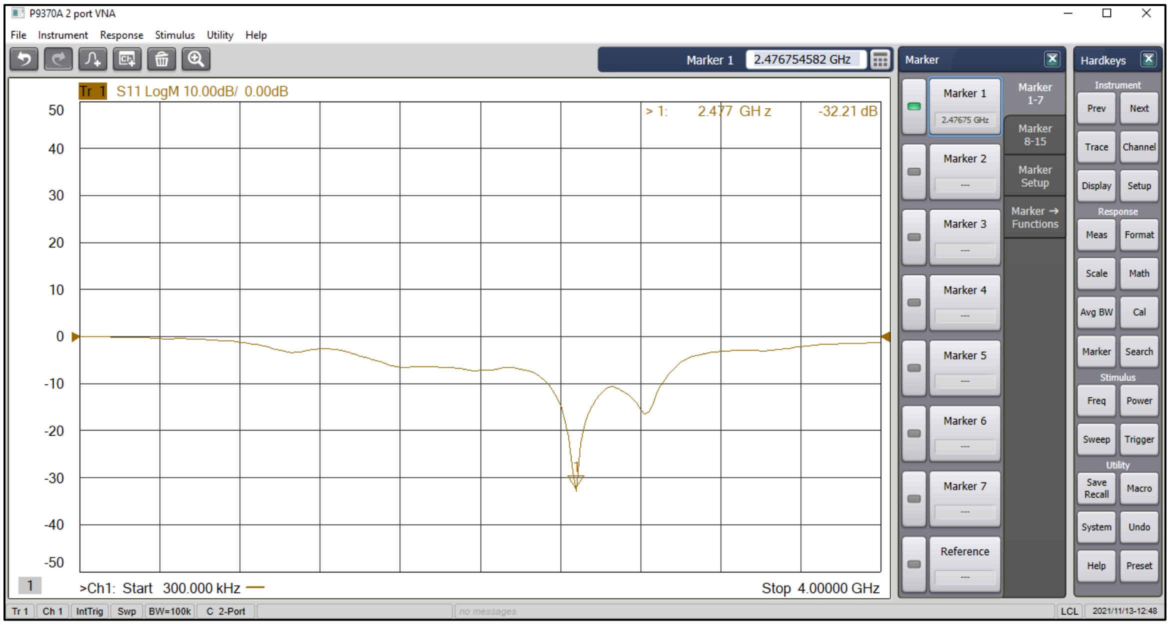
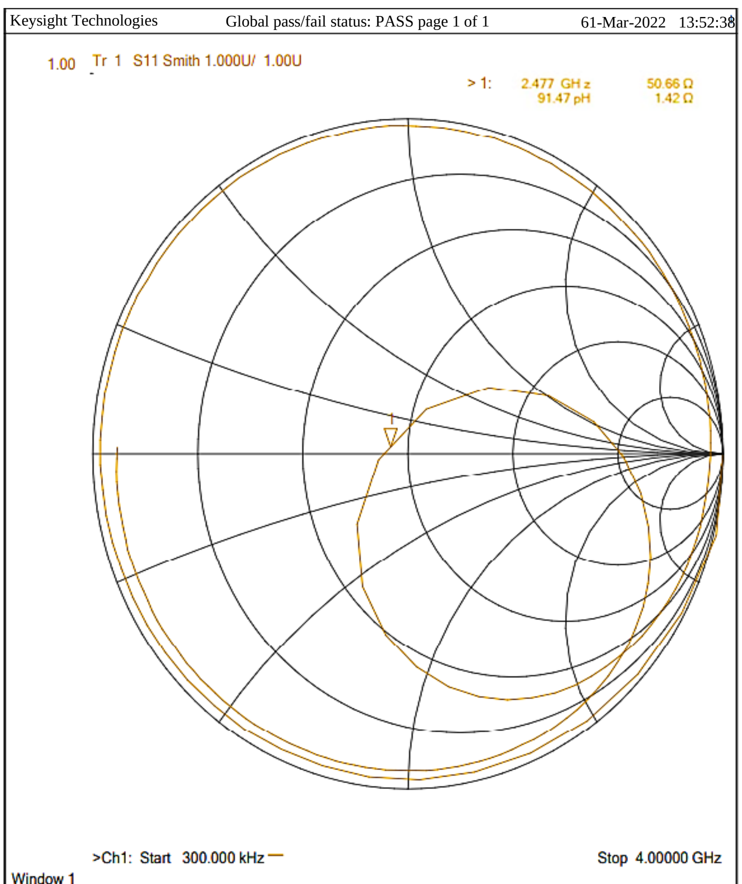



**Fig. 8 Return loss plot of flag-shaped patch prototype**




| Channel Settings | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Channel | Sweep Type | Points | Start (kHz) | Stop (GHz) | IF BW (kHz) | Sweep Time (s) | Pow 1 (dBm) | Pow 2 (dBm) |
| 1 | LinFreq | 201 | 300.000000 | 4.000000 | 100.000000 | 0.013265 | -5.000000 | -5.000000 |

| Trace Attributes | | | | | |
|---|---|---|---|---|---|
| Window | ID | Trace | Channel | Correction | Options |
| 1 | 1 | S11 | 1 | C 2-Port | |

**Fig. 9 Smith chart plot of flag-shaped patch prototype**

## 5. Conclusion

For wearable biomedical equipment, a low-profile, wideband antenna is demonstrated. Adding rectangular slits to the traditional rectangle patch made it possible to miniaturize the antenna and boost the bandwidth by coupling a rectangular-shaped resonator to the ground line. With a bandwidth of 200 MHz, the designed antenna reverberated at 2.48 GHz. The suggested antenna maintained an acceptable gain and impedance matching in the open air. Due to its small size, semi-flexibility, and gain, the suggested wideband antenna is a favourite selection for wearable technology. Between simulated and measured findings, there was a good agreement. Regarding planar solid-state devices, this design is lightweight, simple to manufacture, and suitable for mass manufacturing. The suggested method's use in the design of adaptable antennas would be the subject of further study.

## Acknowledgement

The authors would like to acknowledge testing support from DST-FIST level 0, supported laboratory during this research work at the institute.

## References

[1] Nicolas Fortino et al., "Design Optimization of UWB Printed Antenna for Omnidirectional Pulse Radiation," *IEEE Transactions on Antennas and Propagation*, vol. 56, no. 7, pp. 1875-1881, 2008. [CrossRef] [Google Scholar] [Publisher Link]

[2] Javed Iqbal et al., "Bandwidth Enhancement and Generation of CP by using Parasitic Patch on Rectangular DRA for Wireless Applications," *IEEE Access*, vol. 7, pp. 94365-94372, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[3] Zhongbao Wang et al., "An Accurate Edge Extension Formula for Calculating Resonant Frequency of Electrically Thin and Thick Rectangular Patch Antennas with and without Air Gaps," *IEEE Access*, vol. 4, pp. 2388-2397 2016. [CrossRef] [Google Scholar] [Publisher Link]

[4] Rubaya Khatun, Mahfujur Rahman, and Abu Zafor Md. Touhidul Islam, "Design of a Compact Rectangular Microstrip Patch Antenna for 2.45 GHz ISM Band," *International Journal of Recent Engineering Science*, vol. 8, no. 3, pp. 30-35, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[5] M. Firoz Ahmed, M. Hasnat Kabir, and Abu Zafor Md. Touhidul Islam, "Effect of the Substrate Material and Thickness on the Performance of the Rectangular Patch Microstrip UWB Antenna," *International Journal of Recent Engineering Science*, vol. 8, no. 4, pp. 15-18, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[6] Ismahayati Adam et al., "Investigation on Wearable Antenna under Different Bending Conditions forWireless Body Area Network (WBAN) Applications," *International Journal of Antennas and Propagation*, vol. 2021, pp. 1-9, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[7] Abdulrahman S. M. Alqadami et al., "Compact Unidirectional Conformal Antenna Based on Flexible High Permittivity Custom-Made Substrate for Wearable Wideband Electromagnetic Head Imaging System," *IEEE Transactions on Antennas and Propagation*, vol. 68, no. 1, pp. 183-194, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[8] Sang-Jun Ha, and Chang Won Jung, "Reconfigurable Beam Steering using a Microstrip Patch Antenna with a U-Slot for Wearable Fabric Applications," *IEEE Antennas and Wireless Propagation Letters*, vol. 10, pp. 1228-1231, 2011. [CrossRef] [Google Scholar] [Publisher Link]

[9] Diana P. Tobon, Tiago H. Falk, and Martin Maier, "Context Awareness in WBANs: A Survey on Medical and Non-Medical Applications," *IEEE Wireless Communications*, vol. 20, no. 4, pp. 30-37, 2013. [CrossRef] [Google Scholar] [Publisher Link]

[10] Haider R. Raad et al., "Flexible and Compact AMC Based Antenna for Telemedicine Applications," *IEEE Transactions on Antennas and Propagation*, vol. 61, no. 2, pp. 524-531, 2013. [CrossRef] [Google Scholar] [Publisher Link]

[11] Adel Y. I. Ashyap et al., "Inverted E-Shaped Wearable Textile Antenna for Medical Applications," *IEEE Access*, vol. 6, pp. 35214–35222, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[12] Md. Nawaj Sharif et al., "Design and Simulation of a Circular Microstrip Patch Antenna for Breast Cancer Diagnosis," *International Journal of Recent Engineering Science*, vol. 7, no. 3, pp. 57-60, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[13] Bin Hu et al., "Bending and On-Arm Effects on a Wearable Antenna for 2.45 GHz Body Area Network," *IEEE Antennas and Wireless Propagation Letter*, vol. 15, pp. 378-381, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[14] Jaime G. Santas, Akram Alomainy, and Yang Hao, "Textile Antennas for On-Body Communications: Techniques and Properties," *In Proceeding of the Second European Conference on Antennas and Propagation*, 2007. [Google Scholar] [Publisher Link]

[15] S. H. S. Esfahlani, A. Tavakoli, and P. Dehkhoda, "A Compact Single-Layer Dual-Band Microstrip Antenna for Satellite Applications," *IEEE Antennas and Wireless Propagation Letters*, vol. 10, pp. 931-934, 2011. [CrossRef] [Google Scholar] [Publisher Link]

[16] Syeda I. Naqvi et al., "An Integrated Antenna System for 4G and Millimeter-Wave 5G Future Handheld Devices," *IEEE Access*, vol. 7, pp. 116555-116566, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[17] Liang Han, and Ke Wu, "24-GHz Bandwidth-Enhanced Microstrip Array Printed on a Single-Layer Electrically-Thin Substrate for Automotive Applications," *IEEE Transactions on Antennas and Propagation*, vol. 60, no. 5, pp. 2555-2558, 2012. [CrossRef] [Google Scholar] [Publisher Link]

[18] Mohamed El Atrash, Mahmoud A. Abdalla, and Hadia M. Elhennawy, "Gain Enhancement of a Compact Thin Flexible Reflector-Based Asymmetric Meander Line Antenna with Low SAR," *IET Microwaves Antennas and Propagation*, vol. 13, no. 6, pp. 827-832, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[19] Bancha Luadang et al., "NFC-Enabled Far-Field Antenna on PET Flexible Substrate for 3G/4G/LTE Mobile Devices," *IEEE Access*, vol. 7, pp. 171966-171973, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[20] Kashif Nisar Paracha et al., "A Low Profile, Dual-Band, Dual Polarized Antenna for Indoor-Outdoor Wearable Application," *IEEE Access*, vol. 7, pp. 33277-33288, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[21] Amor Smida et al., "Wideband Wearable Antenna for Biomedical Telemetry Applications," *IEEE Access*, vol. 8, pp. 15687-15694, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[22] Wen Tao Li et al., "Inkjet Printing of Wideband Stacked Microstrip Patch Array Antenna on Ultrathin Flexible Substrates," *IEEE Transactions on Components, Packaging and Manufacturing Technology*, vol. 8, no. 9, pp. 1695-1701, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[23] Tilak Sarmah, Pranjal Borah, and Tulshi Bezboruah, "Tuning of Microstrip Patch Antenna by Adding an Extra Portion at the Upper End of the Antenna," *International Journal of Engineering Trends and Technology*, vol. 71, no. 4, pp. 474-482, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[24] Vijay Kisanrao Sambhe, Rahul Narayanrao Awale, and Abhay Wagh, "Compact U-Shape Radiating Patch with Rectangular Ground Planar Monopole Antenna," *IET the Journal of Engineering*, vol. 2015, no. 2, pp. 54-58, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[25] Constantine A. Balanis, *Antenna Theory Analysis and Design*, Wiley Inter Science Publication, 3rd Edition, 2005.[Google Scholar] [Publisher Link]

[26] Girish Kumar, and K. P. Ray, *Broadband Microstrip Antennas*, Artech House, Inc, 2002. [Google Scholar] [Publisher Link]

[27] Zhendong Ding, Dan Zhang, and Chunyu Ma, "Broadband Antenna Design with Integrated CB-CPW and Parasitic Patch Structure for WLAN, RFID, Wimax, and 5G Applications," *IEEE Access*, vol. 8, pp. 42877-42883, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[28] Pradeep Reddy, and Veeresh G Kasabegoudar, "Gap Coupled Suspended Ultra-Wideband Microstrip Antennas for 5G Applications," *International Journal of Engineering Trends and Technology*, vol. 71, no. 2, pp. 371-381, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[29] Ali Arif et al., "A Compact, Low-Profile Fractal Antenna for Wearable On-Body WBAN Applications," *IEEE Antennas and Wireless Propagation Letters*, vol. 18, no. 5, pp. 981-985, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[30] Yang Wang et al., "Design of Low-Cost, Flexible, Uniplanar, Electrically Small, Quasi-Isotropic Antenna," *IEEE Antennas and Wireless Propagation Letters*, vol. 18, no. 8, pp. 1646-1650, 2019. [CrossRef] [Google Scholar] [Publisher Link]