# Antenna Design

## Title: Compact Triband ACS-Fed Monopole Antenna Employing Open-Ended Slots for Wireless Communication


Information and Communication Technology(ICT)
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# Abstract

This report presents a compact triband printed monopole antenna designed for wireless communication, employing an asymmetric coplanar strip (ACS) feed and open-ended slots. The antenna, which has a very small footprint of 27.5 x 13 mm, consists of an ACS-fed monopole and two strategically placed open-ended slots. By carefully selecting the dimensions and positions of these slots, the antenna exhibits excellent dual stopband rejection characteristics. It provides coverage for three frequency bands: 2.35–2.53 GHz, 3.34–3.85 GHz, and 5.05–6.28 GHz, effectively encompassing the WLAN and WiMAX operation bands.

The report analyzes the principles and key parameters behind the slot design for creating notched frequency bands in detail. The measured results confirm that the proposed antenna has good omnidirectional radiation patterns with reasonable gains across its operating bands, making it suitable for integration into portable wireless communication devices.

# Literature survey

**1) Compact Triband ACS-Fed Monopole Antenna:**

- Triband Operation: The antenna is designed to operate in three distinct frequency bands(2.35–2.53, 3.34–3.85 and 5.05–6.28 GHz), making it highly versatile. These bands are specifically chosen to cover both Wireless Local Area Network (WLAN) and Worldwide Interoperability for Microwave Access (WiMAX) standards.

- Asymmetric Coplanar Strip (ACS) Feed: The antenna employs an ACS-fed monopole structure. ACS-fed antennas have a unique feed structure that can reduce the overall size of the antenna, making them suitable for compact wireless devices.

- Size and Integration: The design focuses on minimizing the physical size of the antenna while maintaining its performance. This compact form factor is crucial for integration into portable wireless devices like smartphones, tablets, or routers.

**2) Open-Ended Slots in Antenna:**

- Notched Frequency Bands: Open-ended slots are strategically incorporated into the antenna structure to create notched frequency bands. Notched bands are frequency ranges where the antenna intentionally does not operate efficiently. This is useful for rejecting or blocking signals in certain frequency ranges.

- Guided Wavelength Consideration: The design of these slots is based on the guided wavelength concept. The length of each slot is approximately one-quarter of the guided wavelength at the desired notched frequency. This specific length is chosen to achieve the desired notched band characteristics.

- Interference Rejection: Open-ended slots play a crucial role in rejecting unwanted signals within the notched bands. They operate as quarter-wavelength transmission lines, causing impedance mismatches at the notched frequencies, which leads to significant signal attenuation in those bands.

**3) WLAN (Wireless Local Area Network):**

- Frequency Bands: WLAN, or Wireless Local Area Network, is a technology used for wireless communication within a limited area, such as homes, offices, or public spaces. The 2.4/5.2/5.8-GHz frequency bands are commonly reserved for WLAN applications.

- Antenna Compatibility: The report highlights that how the antenna design is configured to operate within the WLAN frequency requirements. By covering these frequency bands, the antenna can effectively support wireless networking applications.

**4) WiMAX (Worldwide Interoperability for Microwave Access):**

- Frequency Bands: WiMAX or Worldwide Interoperability for Microwave Access, is a wireless communication standard used for providing high-speed internet access over a wide area. The frequency bands of 3.5/5.5 GHz are often associated with WiMAX.

- Antenna Compatibility: The report explains that the antenna design is also configured to cover the 3.5/5.5-GHz WiMAX bands. By operating within these frequency ranges, the antenna is well-suited for applications that require high-speed, long-range wireless connectivity.

# Theory and Calculations

The design evolution process for achieving a triband antenna involves various antenna structures, as depicted in Figure 1. All these antennas are fabricated on 1.6 mm-thick FR-4 substrates with a relative permittivity of 4.4. Their overall dimensions are compact, measuring 27.5 x 13 mm. The antenna feedline is based on the asymmetric co-planar strip (ACS) configuration, featuring a signal strip with a width of 3 mm and a gap distance of 0.3 mm, resulting in a 50-ohm characteristic impedance.

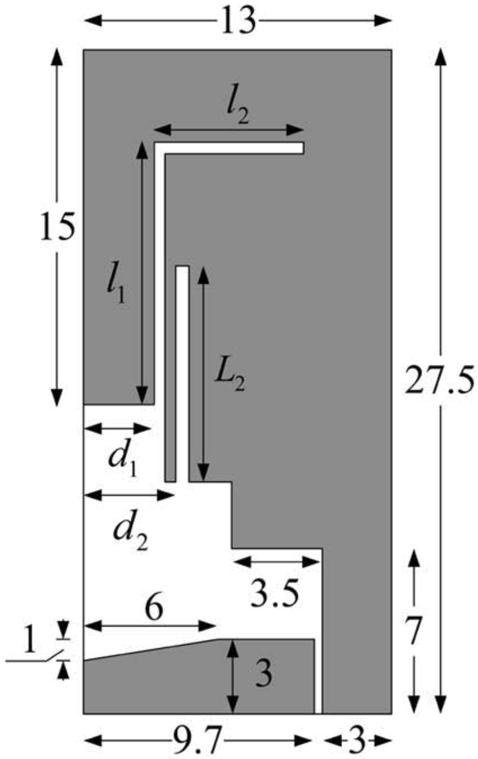


Figure 1

To achieve wide impedance bandwidths in UWB antennas, gradual structural modifications is used. In this context, the approach involves incorporating a stepped edge on the underside of the radiating patch and a beveled edge on the ground plane. These modifications are effective in improving impedance matching.

The slots S1 and S2, with an open gap at the edge of the patch, are called open-ended slots. With the same width of 0.4 mm, they are used to yield notched bands at certain frequencies that are related to their lengths. The electromagnetic simulation software Ansys-HFSS is used to perform the design

**Dimenstions:**

| Parameters | Dimensions(mm) |
|---|---|
| l(length) | 13 |
| w(width) | 27.5 |
| h | 1.6 |
| l1 | 11.4 |
| l2 | 6.4 |
| d1 | 3 |
| d2 | 4 |

# Antenna 1

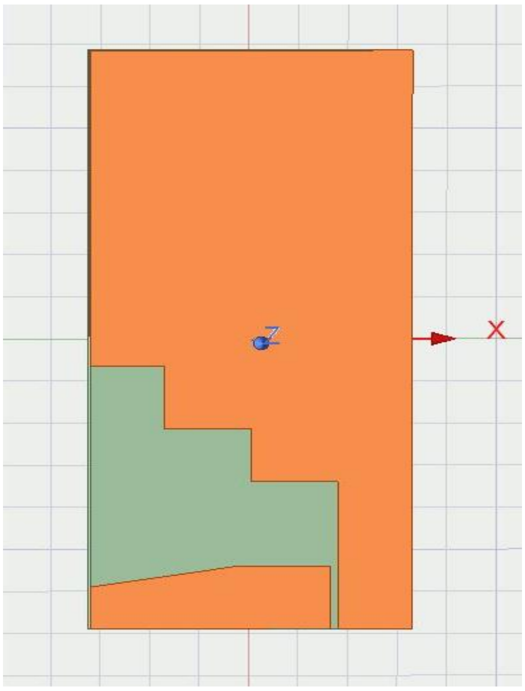
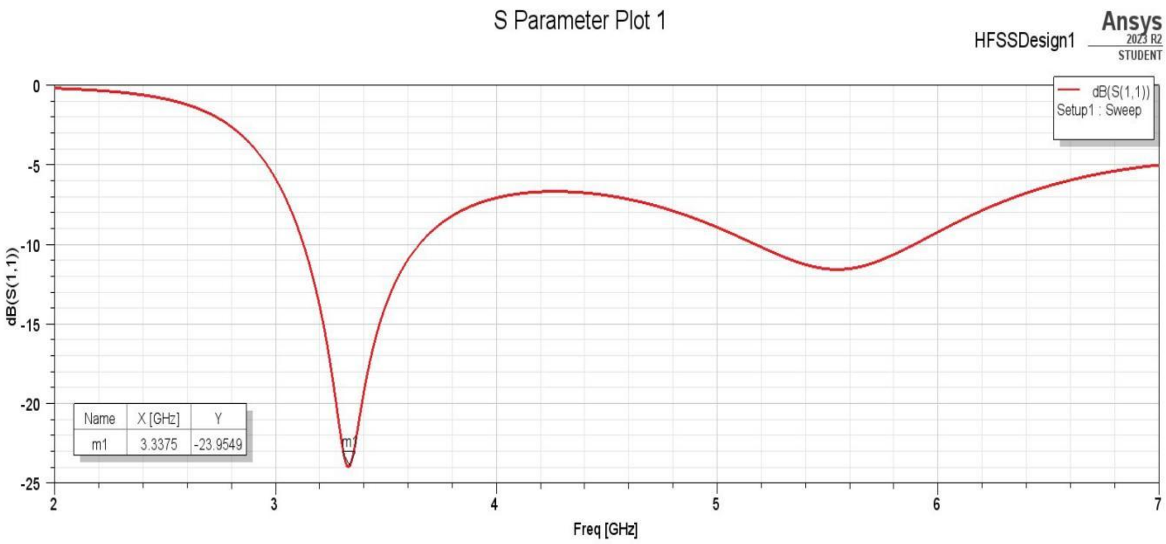



Figure 2

Antenna 1 in Fig. 2 is the original ACS-fed monopole.This design can excite two resonant modes—one is near the 3.5-GHz WiMAX frequency band, and the other is near the 5.2/5.8-GHz WLAN frequency band

**Dimensions:**

| Parts | Dimensions(mm) | | | Position |
|---|---|---|---|---|
| | X | Y | Z | (x,y,z) |
| Substrate | 13 | 27.5 | 1.6 | (-6.5, -13.75, 0) |
| Lumped Port | 13 | - | -1.6 | (-13/2, -13.75, 1.6) |
| Bounding Box | 78 | 92 | 66 | (-39, -46, -32) |



# Antenna 2

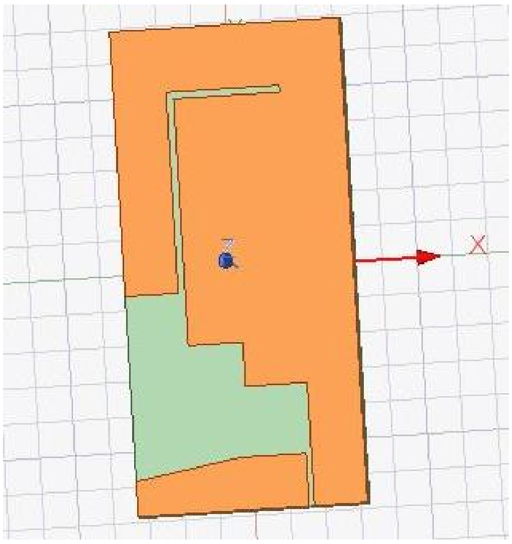


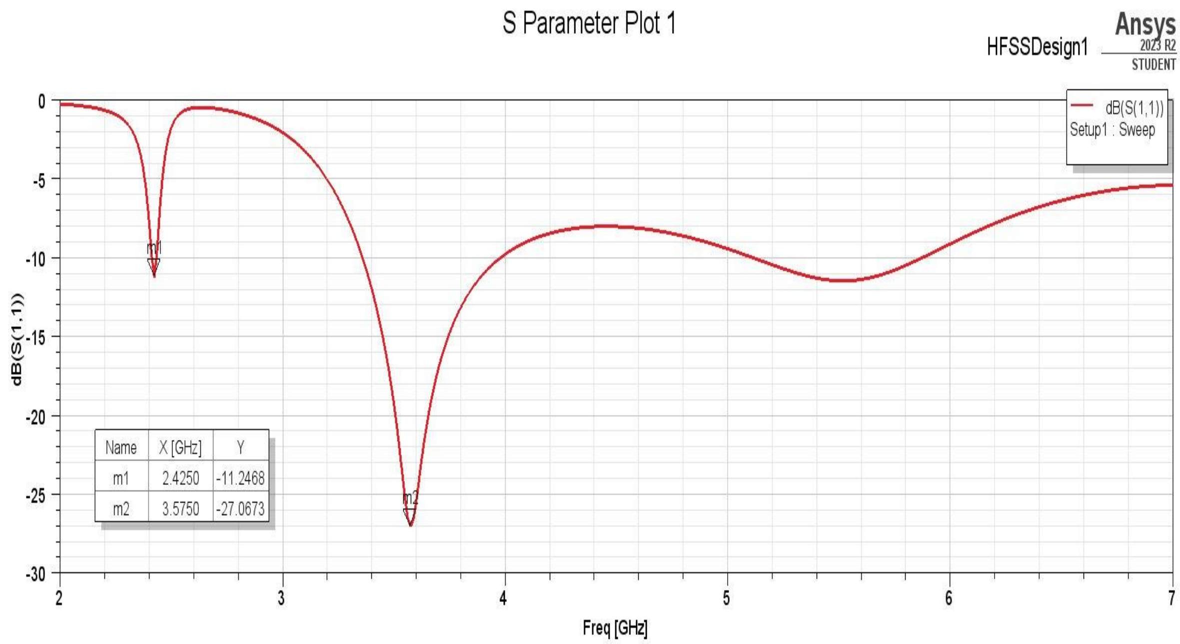

Figure 3

In Antenna 2(fig.3), an L-shaped slot S1 is etched in order to satisfy the lower frequency for WLAN application. It generates a notched band at about 2.75 GHz and changes the impedance characteristics nearby, making the impedance match near 2.4 GHz greatly improved. Thus, the 2.4-GHz WLAN band is easily covered without enlarging the antenna size.

**Dimensions:**

| **Parts** | **Dimensions(mm)** | | | **Position** |
|---|---|---|---|---|
| | **X** | **Y** | **Z** | **(x,y,z)** |
| Substrate | 13 | 27.5 | 1.6 | (-6.5, -13.75, 0) |
| Lumped Port | 13 | - | -1.6 | (-13/2, -13.75, 1.6) |
| Bounding Box | 78 | 92 | 66 | (-39, -46, -32) |

Slot S1:
l1=11.4mm
l2=6.4mm
d2-d1=(4-3)mm=1mm



S Parameter Plot 1
HFSSDesign1
Ansys
2023 R2
STUDENT
dB(S(1,1))
Setup1 : Sweep
m1
m2
Name
X [GHz]
Y
m1
2.4250
-11.2468
m2
3.5750
-27.0673
dB(S(1,1))
Freq [GHz]
0
-5
-10
-15
-20
-25
-30
2
3
4
5
6
7

# Antenna 3

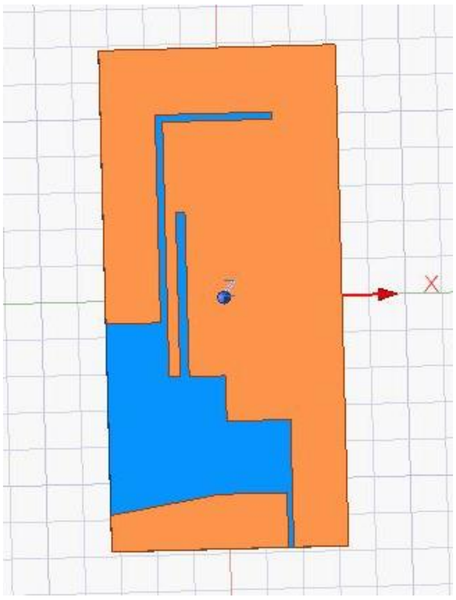



Figure 4

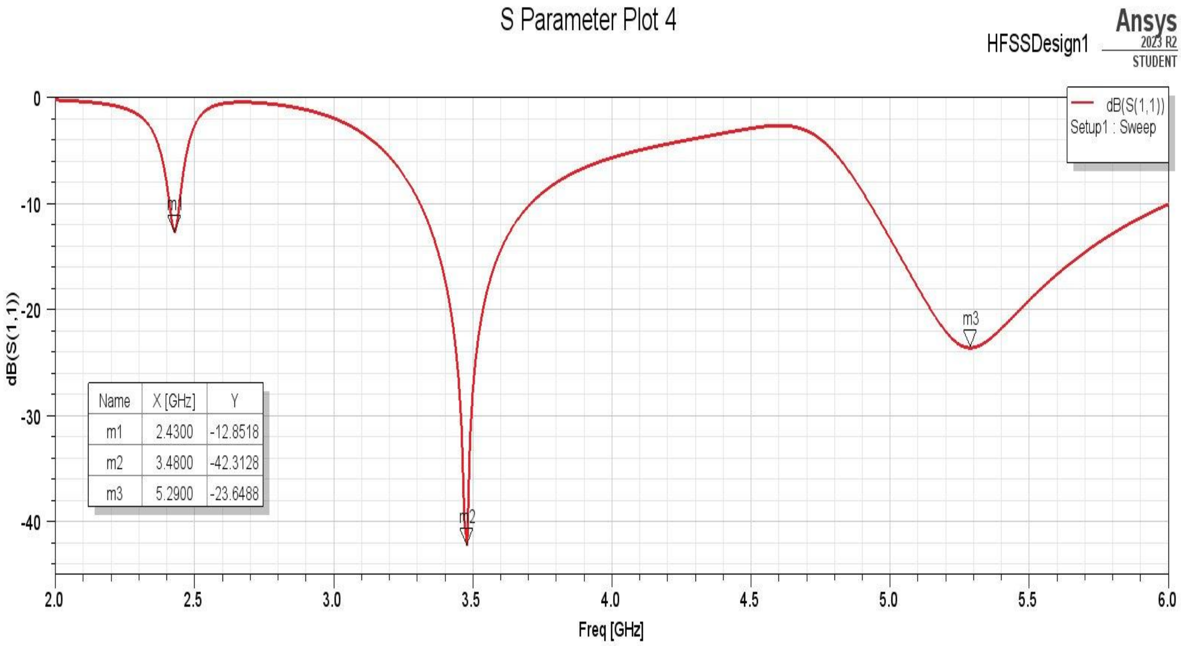
In Antenna 3(Fig. 4), the second open-ended slot S2 is embedded for generating another notched band near 4.70 GHz to reject the interference and improve the impedance match near 5.5 GHz. Then, the Antenna 3 (proposed antenna) is capable of generating three separate bands to cover the 2.4/5.2/5.8-GHz WLAN bands and the 3.5/5.5-GHz WiMAX bands. The configuration of the slots is shown in Fig.

**Dimensions:**

| Parts | Dimensions(mm) | | | Position |
|---|---|---|---|---|
| | X | Y | Z | (x,y,z) |
| Substrate | 13 | 27.5 | 1.6 | (-6.5, -13.75, 0) |
| Lumped Port | 13 | - | -1.6 | (-13/2, -13.75, 1.6) |
| Bounding Box | 78 | 92 | 66 | (-39, -46, -32) |

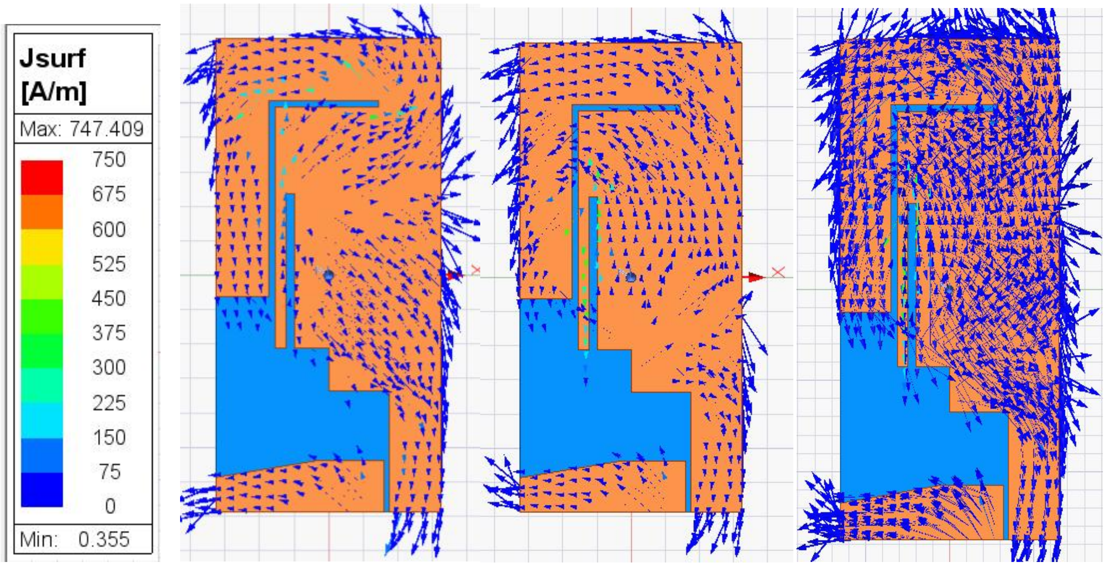
Slot S1:
l1=11.4mm
l2=6.4mm
d2-d1=(4-3)mm=1mm

Slot S2:
l2=6.4mm



S Parameter Plot 4
HFSSDesign1
Ansys
2023 R2
STUDENT
dB(S(1,1))
Setup1 : Sweep
m1
m2
m3
Name | X [GHz] | Y
m1 | 2.4300 | -12.8518
m2 | 3.4800 | -42.3128
m3 | 5.2900 | -23.6488
dB(S(1,1))
0
-10
-20
-30
-40
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
Freq [GHz]

# Simulation and Measurement Results




(a) (b) (c)

Figure 5: Current distributions on radiating patch of proposed antenna at (a) a passband frequency at 5.5 GHz,(b) the first notched band at 2.75 GHz, and (c) the second notched band at 4.70 GHz.

As shown in Fig. 5(a), the distribution of the surface currents is uniform at a pass-band frequency of 5.5 GHz (outside of the notched bands). When the antenna works at 2.75 GHz, large surface currents density are observed along the L-shaped slot S1, but nearly no current on the slot S2 and elsewhere of the radiation patch as shown in Fig. 5(b). This demonstrates that the first notched band is produced by the slotS1 . A similar result is observed in Fig. 5(c), the slot S2 introduces the second notched band. This clearly validates our design concept of the proposed antenna.

**Variable L1:**

- It is observed that the lower notched band can be controlled only by adjusting the length of the slot S1, which shifts down from 2.97 to 2.61 GHz as L1 increases from 15.8 to 19.8 mm.
- It demonstrates that the slot S1 produces the lower notched band. The effect of the position of slots is also simulated and analyzed. As indicated in Fig. 6&7, the position of the slot S1 has a great effect on bandwidth of the lower notched frequency band.

For L1=15.8mm

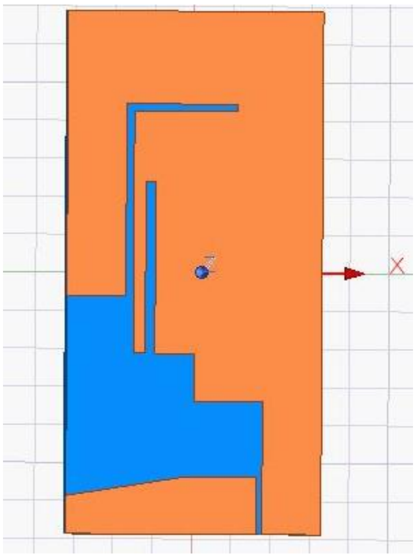
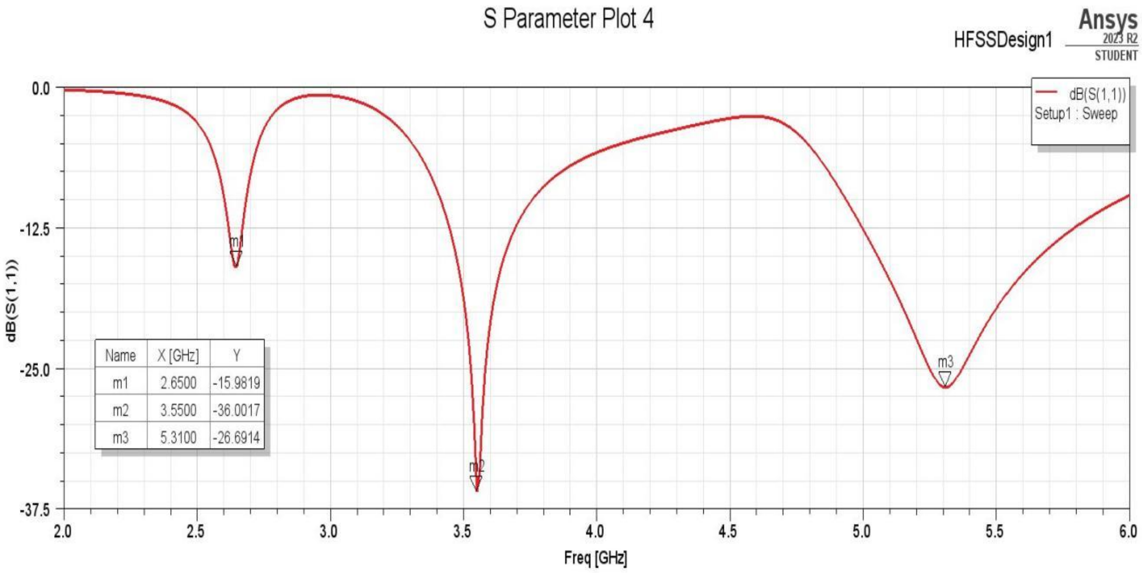


Figure 6:L1=15.8mm




For L1=19.8mm

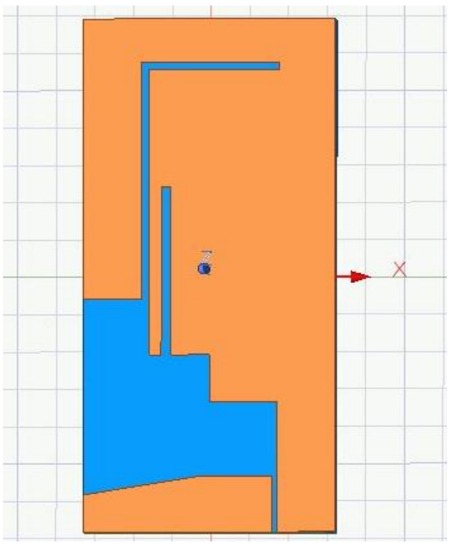
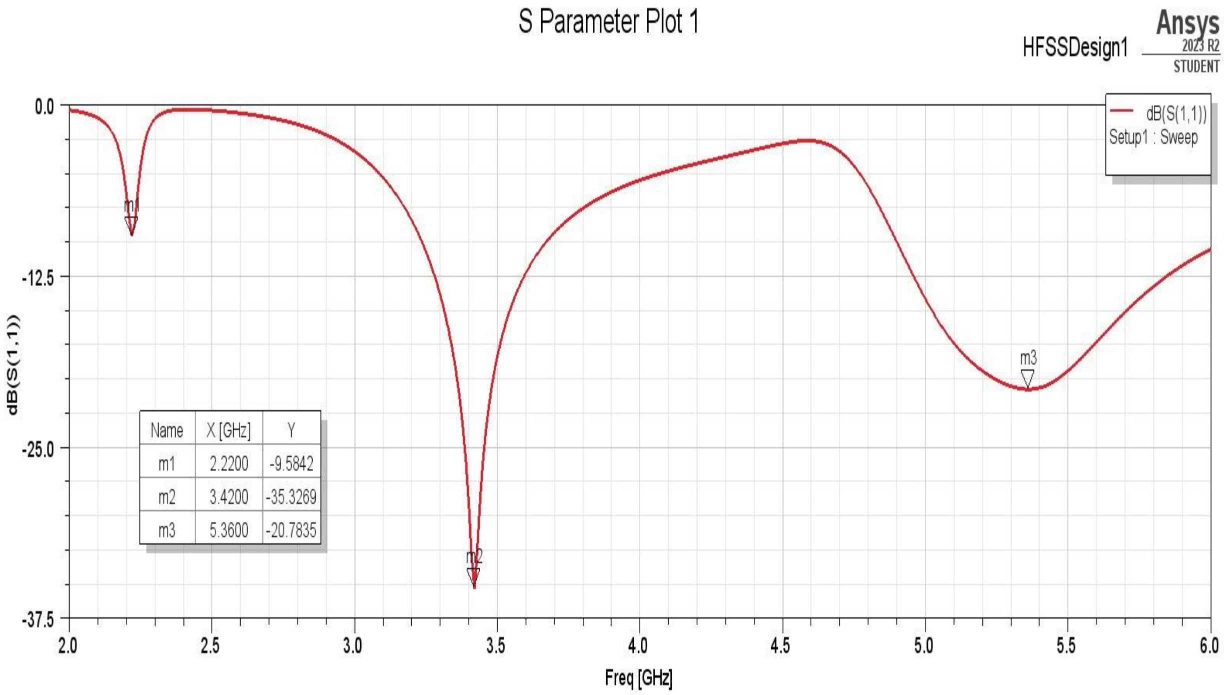


Figure 7: l1=19.8mm




**Variable D1:**

- When the slot S1 moves toward the feedline (d1 increases), the bandwidth of lower notched frequency increases from 410 to 720 MHz. At the same time, the bandwidth of upper notched band becomes a little narrower, which is possibly due to the changing coupling between the two slots.
- Though the working bandwidth of the middle band is broaden as the d1 increases, the maximum of d1 is restricted to 3 mm since continual increase of will lead the overlap between S1 and S2. (Fig. 8&9)

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For d1=1mm

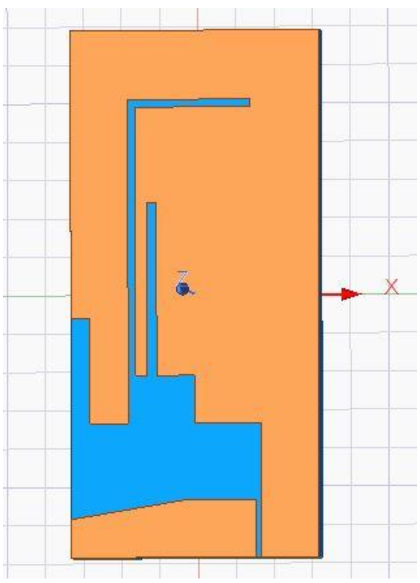
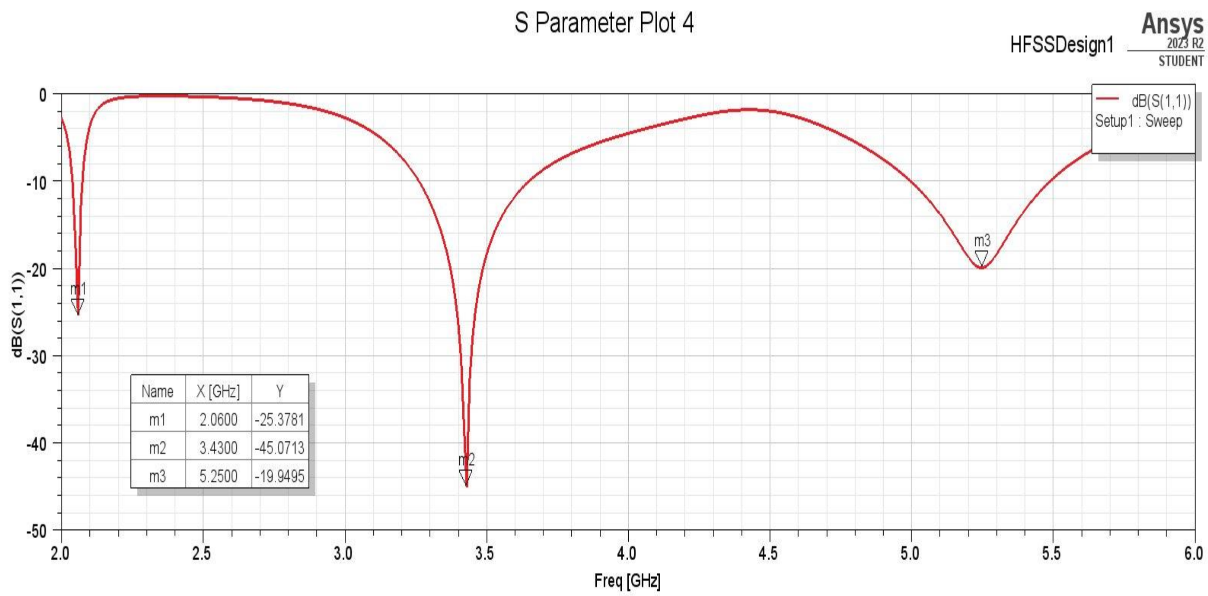


Figure 8: d1=1mm




For d1=2mm

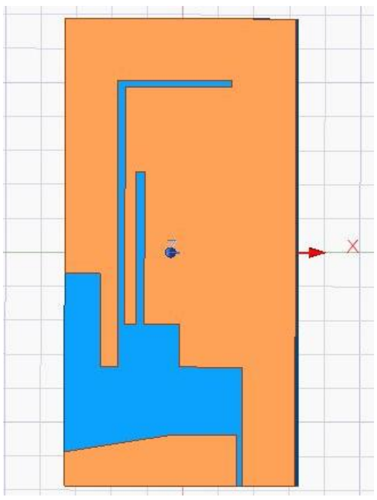
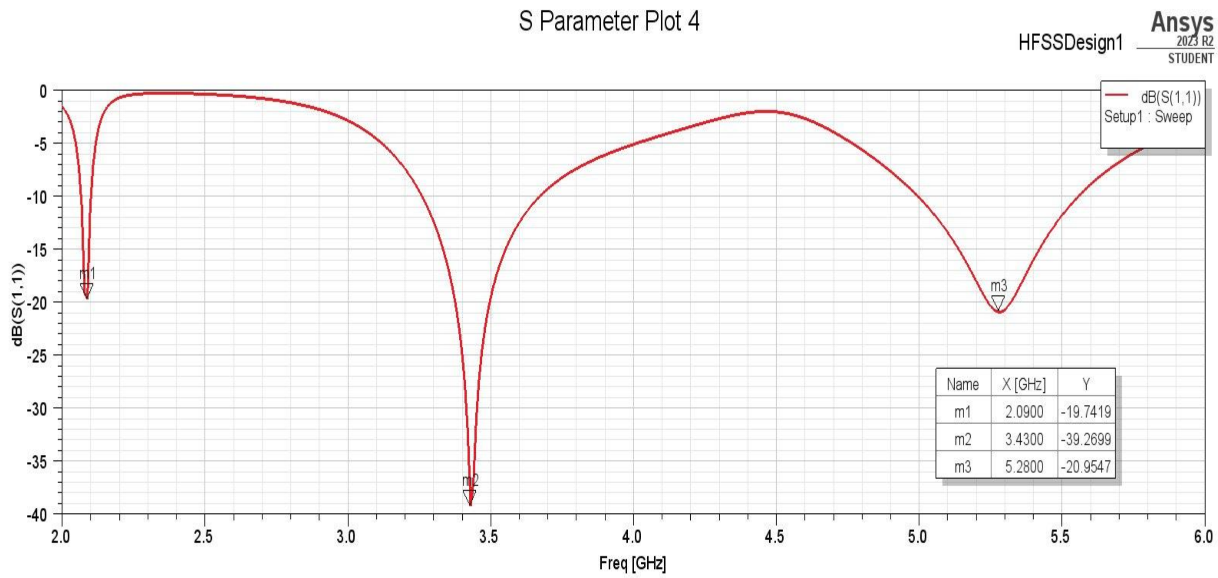


Figure 9: d1=2mm



Comparison of results of the antenna from the research paper with simulated antenna for variable L1

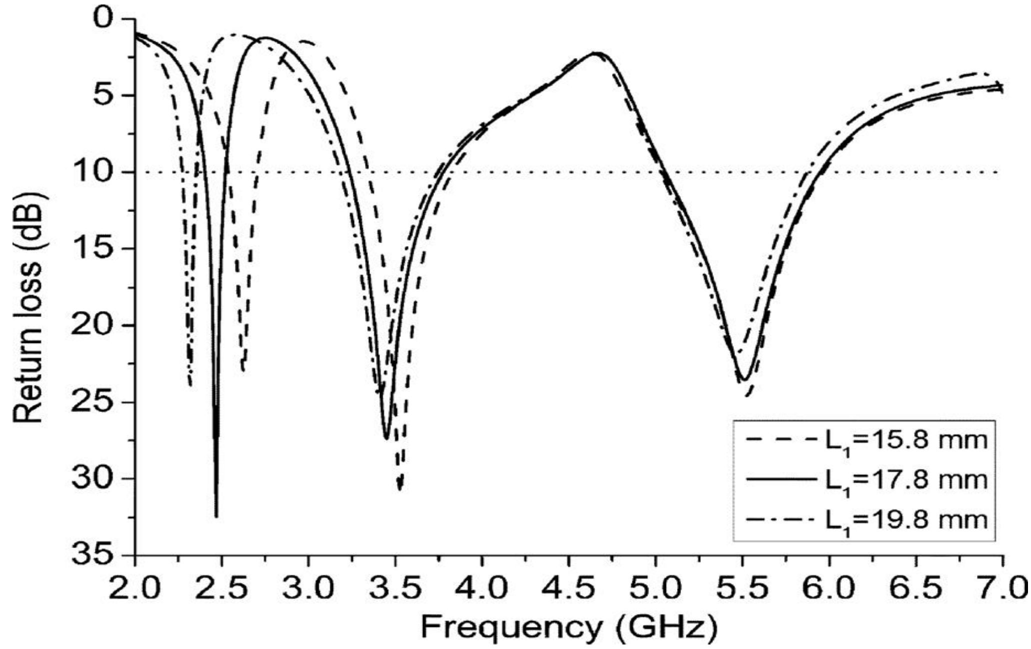



Figure 10 : return losses of the proposed antenna for various L1 as per research paper

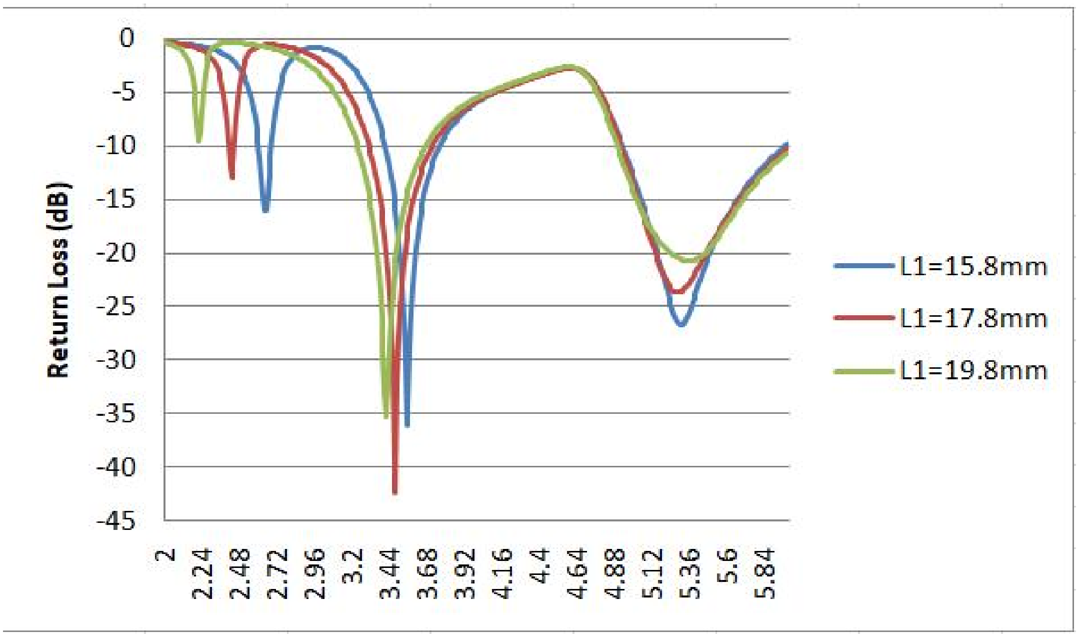



Figure 11: Simulated return losses of the proposed antenna for various L1

Comparison of results of the antenna from the research paper with simulated antenna for variable D1

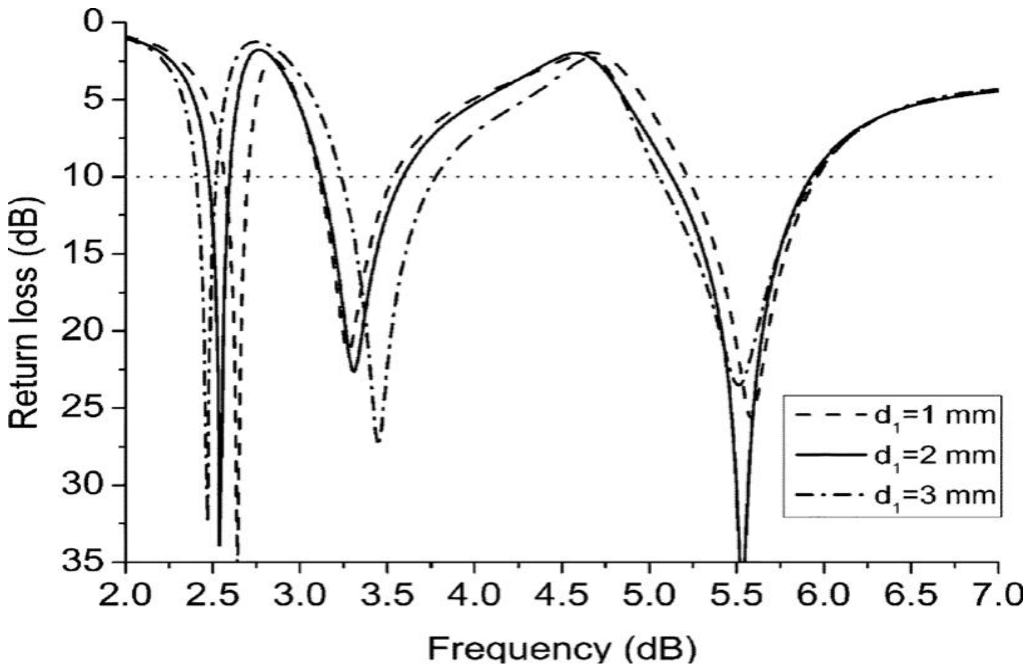



Figure 12: return losses of the proposed antenna for various D1 as per research paper

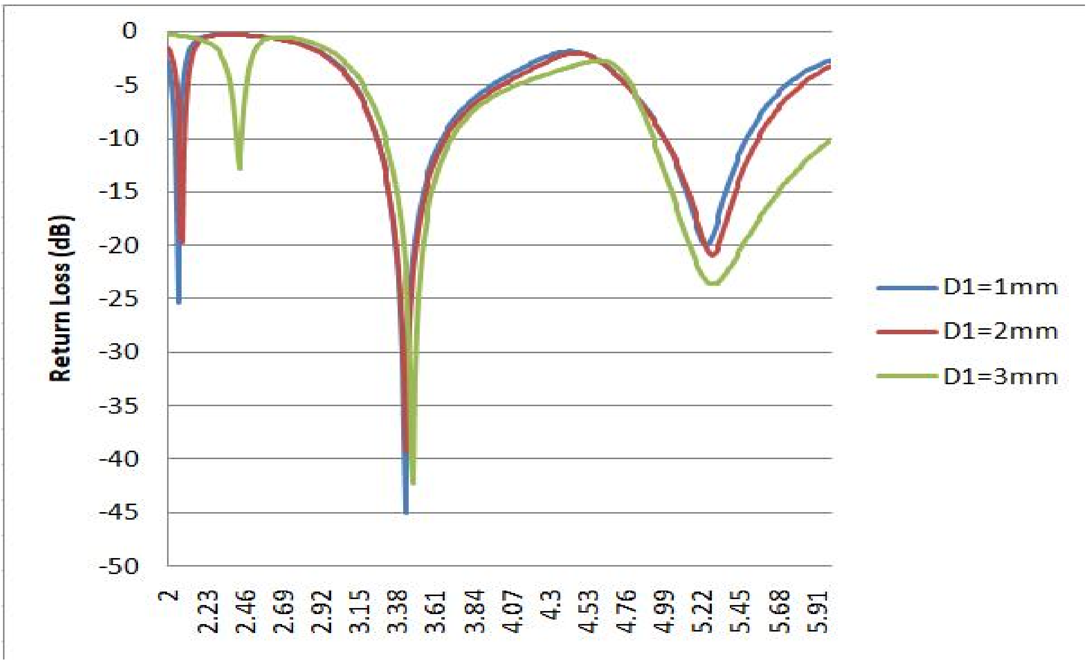



Figure 13: Simulated return losses of the proposed antenna for various D1

Radiation patterns of the fabricated antenna in xy-plane (E-plane)

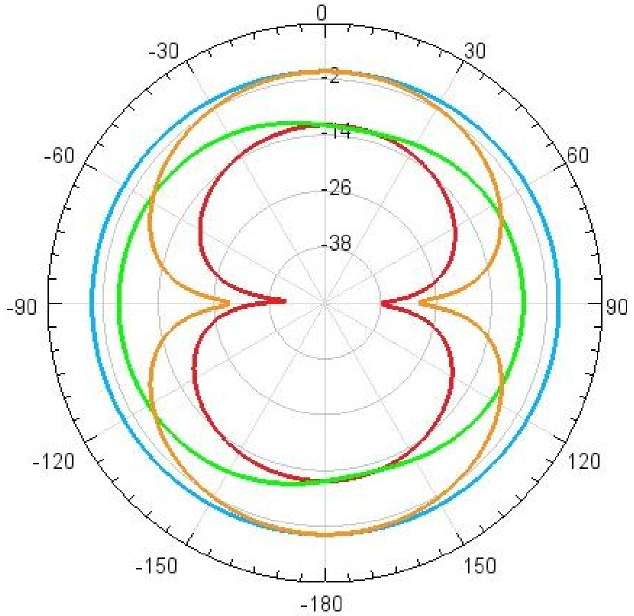



Figure 14: Measured normalized radiation patterns of the proposed antenna at 2.4 GHz

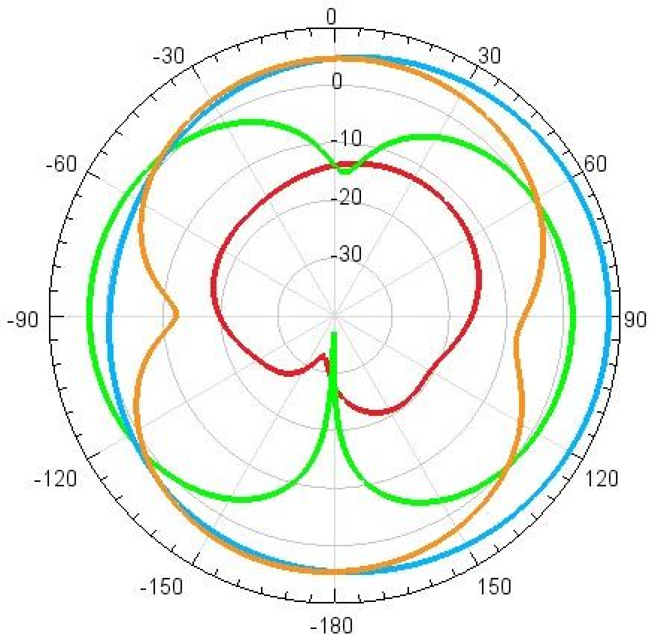



Figure 15: Measured normalized radiation patterns of the proposed antenna at 3.5 GHz

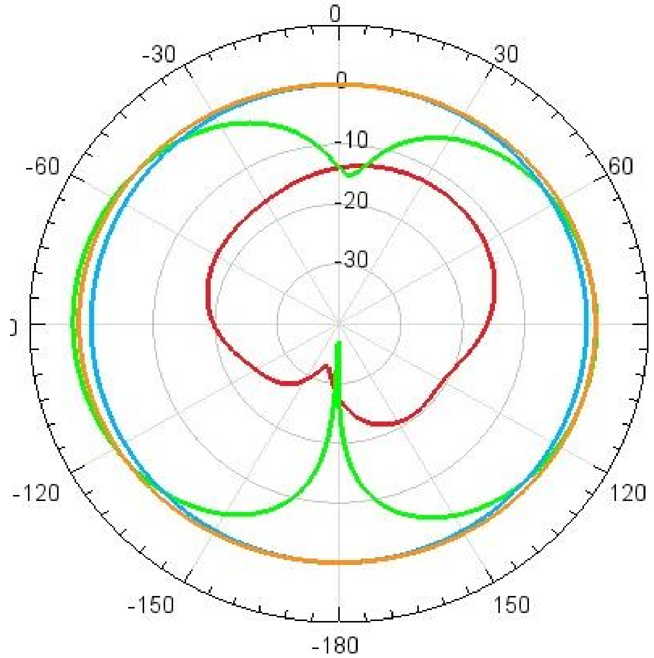


Figure 16: Measured normalized radiation patterns of the proposed antenna at 5.5 GHz

Fig. 14,15,16 exhibits the measured normalized radiation patterns of the fabricated antenna in xy-plane (E-plane) at 2.4, 3.5, and 5.5 GHz, respectively.

# Conclusion

The proposed triband antenna is replicated and its shown in Fig.2,3,4. The simulated and measured return loss against frequency of this antenna is given in fig. 11,13. The principle and key parameters of the slot in achieving notched bands are analyzed in detail. Measured results demonstrate that the antenna can achieve three sufficient impedance bandwidths, good omnidirectional radiation characteristics(fig.14,15,16), and reasonable gains(for frequencies 2.4, 3.5, and 5.5 GHz ). As results, the compact antenna design stands out as a compelling option for use in both WLAN and WiMAX applications.

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