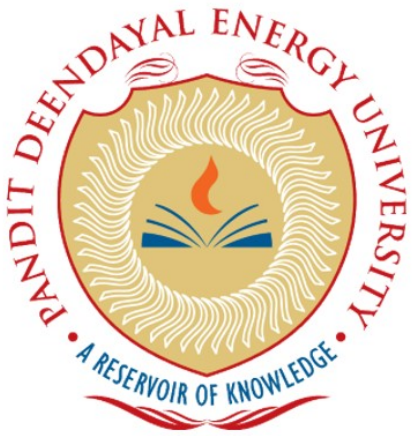
RF Engineering Project Report

Group 32



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Abstract-

This paper presents the analysis of microstrip monopoles for applications in ultra wideband systems (UWB). Antenna structures using circular and semi annular ring patches are considered. The antennas are printed on a FR4 dielectric substrate and present truncated ground planes with a small cut beneath the microstrip line feeder to improve the antenna impedance matching. Results for return loss, resonant frequency, and impedance bandwidth are calculated using an iterative full-wave formulation based on the concept of electromagnetic waves (WCIP Method) and simulated using Ansoft HFSS software. Prototypes are fabricated and measured for validation purpose. Agreement is observed between WCIP calculated, HFSS simulated and measured results, confirming the WCIP method accuracy. The performance of the developed antennas are suitable for UWB and broadband systems. Index Terms—microstrip antenna, microstrip monopole, ultrawide band, UWB, iterative method, WCIP.

Literature Survey:

The introduction discusses advancements in antenna technology, particularly focusing on microstrip monopoles. These antennas are essential for various wireless communication systems like broadband communication, and personal communication systems.

1. The development of modern wireless communication systems has led to the need for compact circuits like printed circuits and microstrip antennas to enhance transmission and reception rates.

2. Microstrip antennas typically consist of a conducting patch on a dielectric substrate mounted on a ground plane. These patches can take various shapes, including rectangles, circles, regular polygons, or complex geometries like fractals.

3. Special attention has been given to Ultra-Wideband (UWB) antennas designed for applications in the 3.1 to 10.6 GHz range. UWB devices and circuits require large bandwidths, which can cause their emissions to overlap with other radio services.

4. The work focuses on the development of UWB antennas, specifically microstrip monopoles with circular and semi-annular ring patch geometries. These antennas incorporate truncated ground planes to suit UWB applications.

5. Numerical results are obtained using the WCIP (Wave Concept Iterative Procedure) method, and simulations are conducted using Ansoft HFSS software.

6. The objective is to investigate the performance and characteristics of these UWB microstrip antennas with different patch geometries and truncated ground planes.

7. The development of such UWB antennas is crucial for accommodating the demand for high-frequency applications and ensuring efficient use of the available spectrum.

8. This research contributes to advancing wireless communication technology and meeting the requirements of modern wireless systems with a focus on UWB applications.

9. The WCIP method is widely used for designing planar circuits, relying on wave reflection and transmission principles.

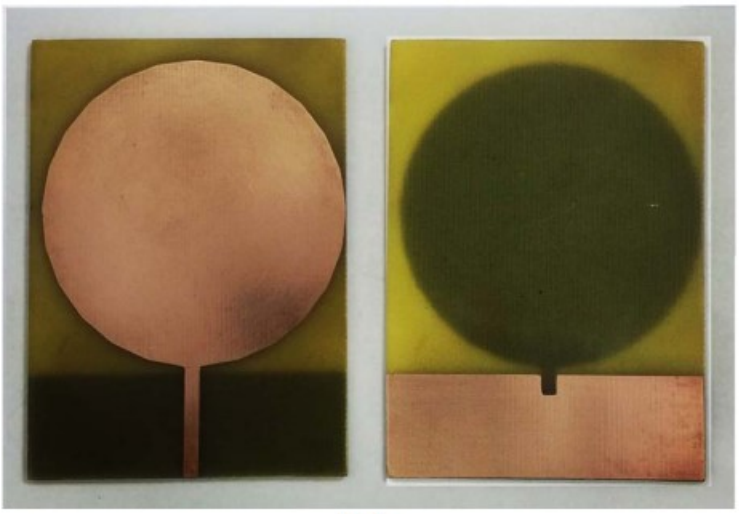
10. It has applications in analyzing microstrip antennas, filters, and frequency-selective surfaces, providing insights into performance metrics like return loss, resonant frequency, and impedance bandwidth.

11. Simulations using HFSS software help predict antenna behavior, and physical prototypes validate the accuracy of the calculated and simulated results.

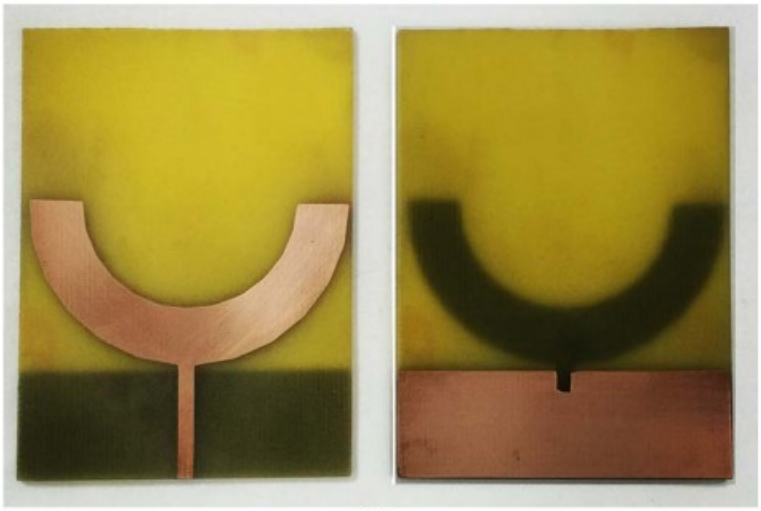
12. The method's ability to achieve good agreement between calculations, simulations, and measurements underscores its effectiveness in microstrip antenna design and characterization.

Theory:

Explanation of Antenna Design:



(a)



(b)

Fig. 1(a) shows the reference antenna, which consists of an antenna with a circular patch with radius of 30 mm and a truncated ground plane with a small rectangle cut beneath the microstrip line antenna feeder. Fig. 1(b) shows the semi annular ring antenna geometry. It is formed removing the upper half of the circular patch (Fig. 1(a)) and then removing a semicircular slot at the antenna patch, constituting a semi annular ring patch antenna. The antenna is printed on a FR4 dielectric substrate with relative permittivity $\varepsilon r = 4.4$ and thickness $h = 1.57$ mm. The antenna dimensions are shown in Fig. 1.

WCIP Formulation:

1. WCIP is an iterative numerical technique used in planar microwave circuit analysis.

2. It is based on the ratio of transmission and reflection of incident (A) and reflected (B) electromagnetic waves at the circuit interface.

$$\vec{B}_i = \hat{S}\vec{A}_i + \vec{A}_0 \qquad (1)$$

$$\vec{A}_i = \hat{\Gamma}\vec{B}_i \qquad (2)$$

3. Equations (1) and (2) form the core of the WCIP method, with (1) representing the circuit's impact on wave relationships and (2) representing the influence of the surrounding media.

4. The scattering operator Sˆ accounts for boundary conditions in different regions of the circuit interface.

5. The reflection operator Γˆ considers propagation conditions of the media surrounding the circuit interface.

6. The WCIP method involves an iterative process that transforms between spatial and modal domains, and the equations (1) and (2) are computed in each iteration until convergence is achieved.

7. Fourier transform is used to facilitate the transformation between spatial and modal domains for field components.

Antenna Design:

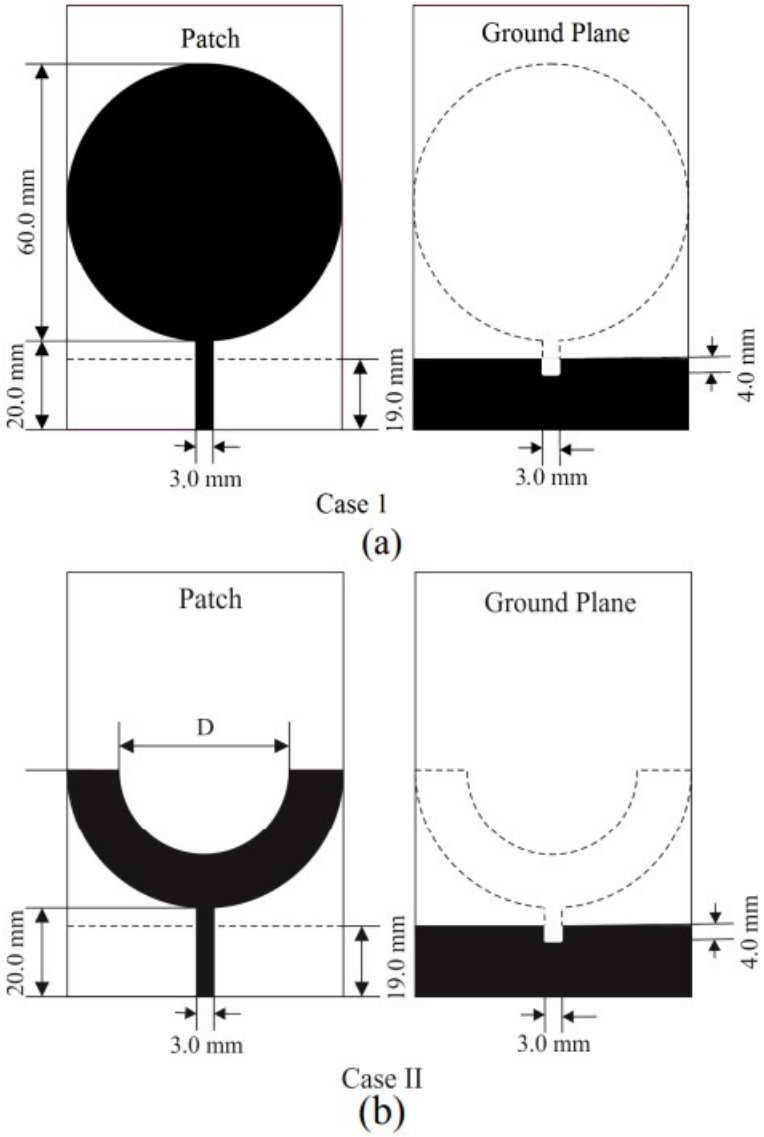
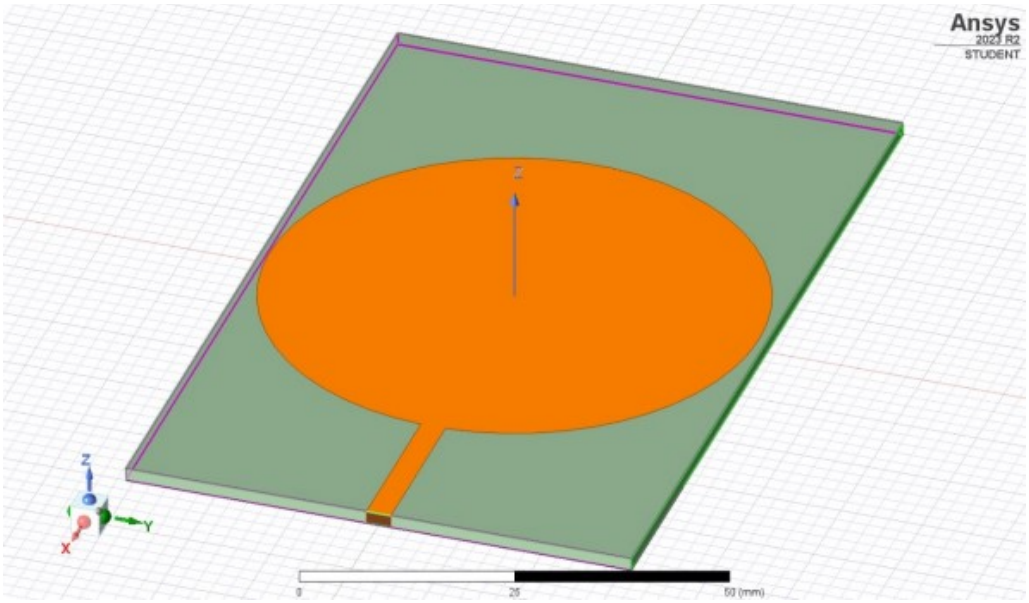


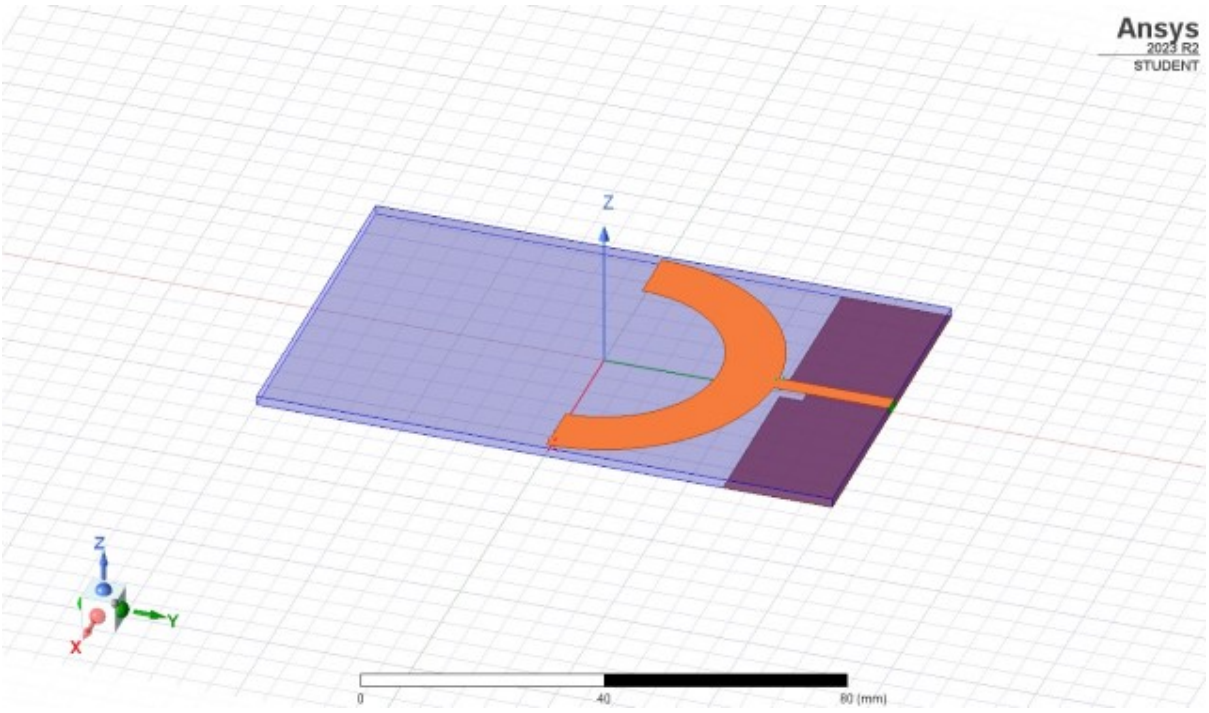
Fig. 1. Analyzed microstrip antenna geometries with (a) circular patch and (b) semi annular ring patch.

Software Design:

(Circular)



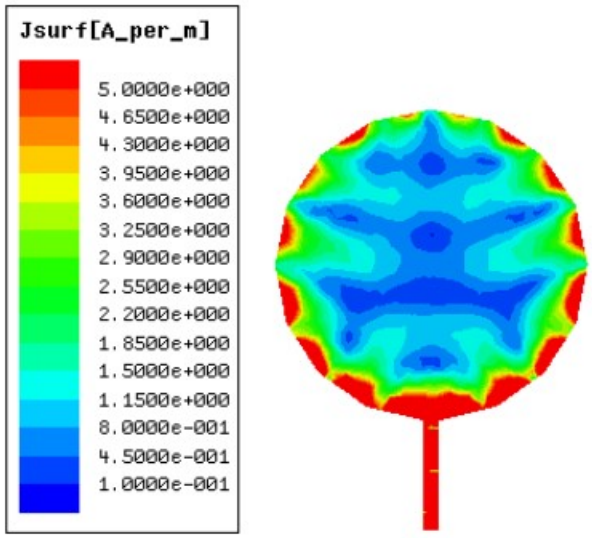
(Semi annular)



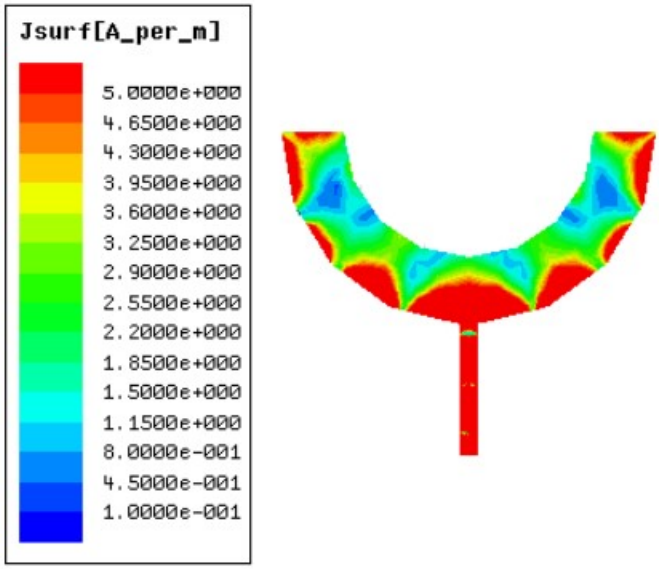
Simulation Results:

Surface Current Densities on the patches of microstrip monopole antennas

From research paper:

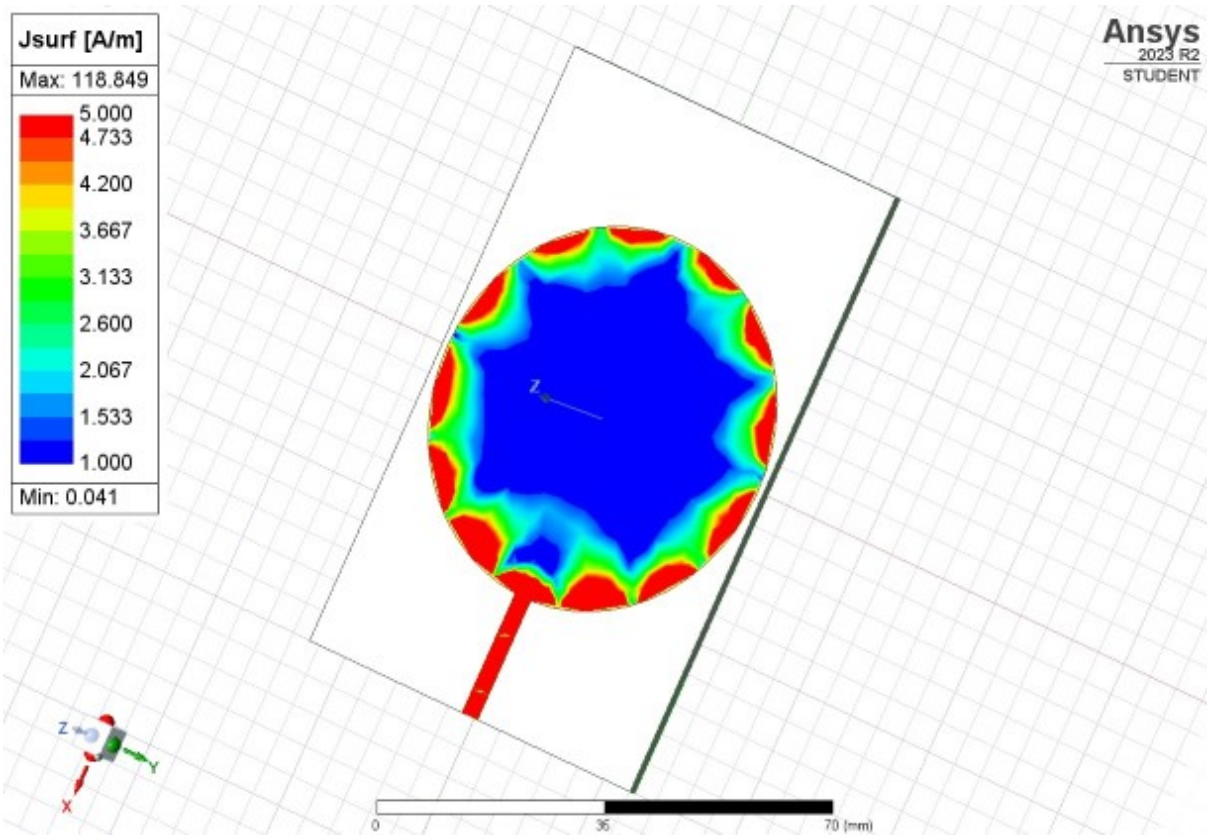


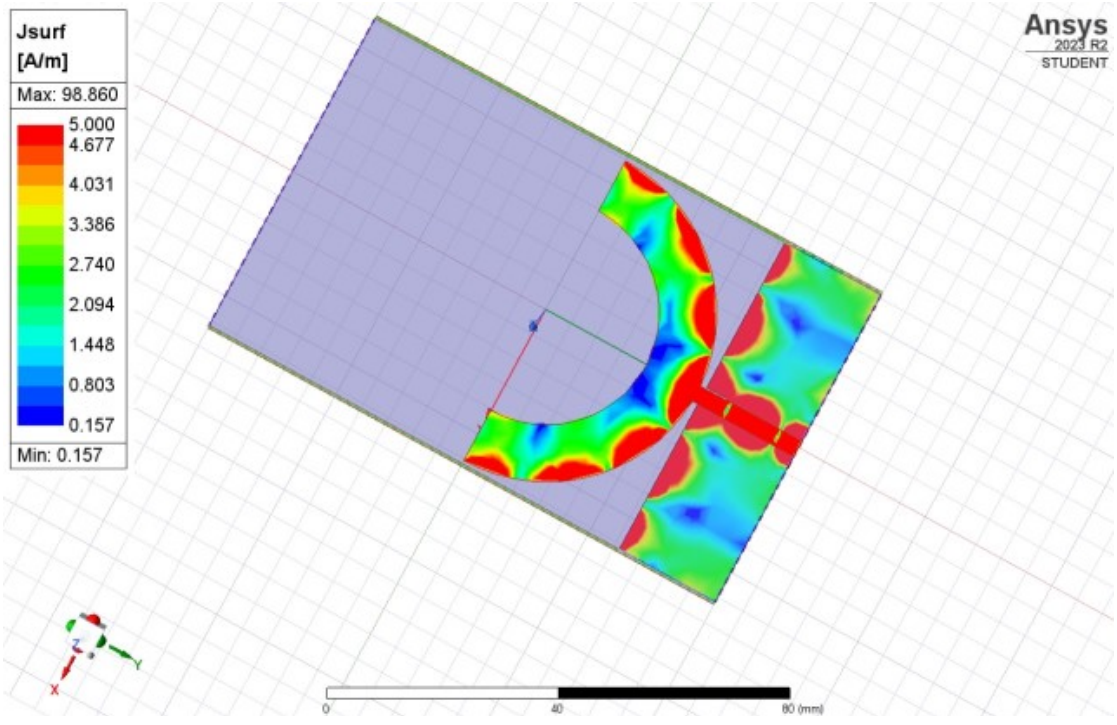
(a)



(b)

Simulated:


Jsurf [A/m]
Max: 118.849
5.000
4.733
4.200
3.667
3.133
2.600
2.067
1.533
1.000
Min: 0.041
Ansys
2023 R2
STUDENT
Z
Y
X
0
36
70 (mm)


Jsurf
[A/m]
Max: 98.860
5.000
4.677
4.031
3.386
2.740
2.094
1.448
0.803
0.157
Min: 0.157
Ansys
2023 R2
STUDENT
Z
Y
X
0
40
80 (mm)

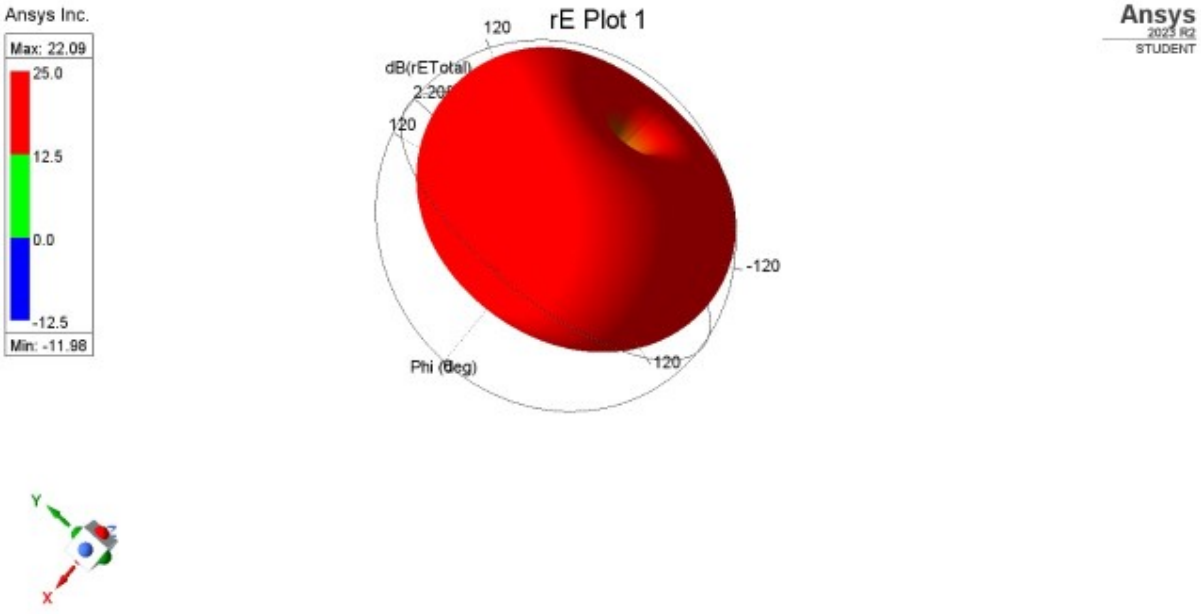
Plot of S11 for circular antenna

Simulated:

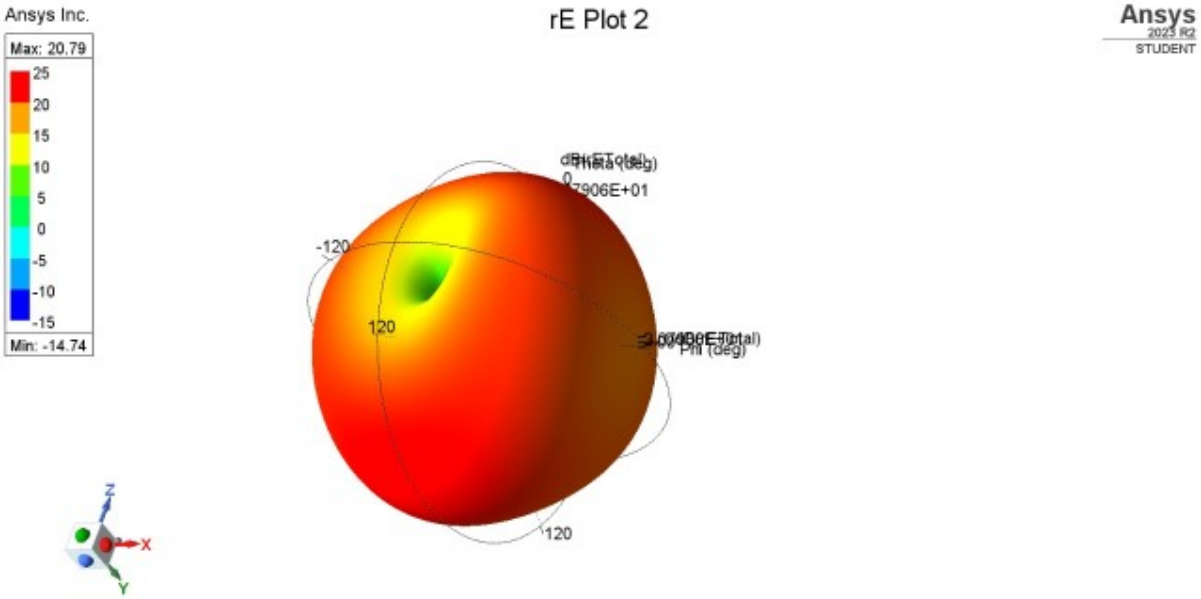
Plot of S11 when d=40mm (Semi annular)

Simulated:

Radiation pattern of circular antenna:



Radiation pattern of semi annular antenna:



Conclusion:

A numerical assessment of microstrip monopole antennas featuring circular and semi-annular ring patches was conducted and analyzed. The analysis was carried out utilizing the WCIP method. By incorporating truncated ground planes, these antennas demonstrated broad bandwidth characteristics. Additionally, the introduction of slots and modifications to the patch structure created frequency notches, effectively isolating the antenna's resonance bands. The results obtained through simulations using HFSS software and actual measurements were compared with the results derived from the WCIP method, revealing a high level of agreement between them.