

DESIGN OF A NOVEL HN-SHAPE MICROSTRIP PATCH ANTENNA USING DGS TECHNIQUES AT 11 GHZ AND 20 GHZ

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ABSTRACT

The design and simulation of a novel HN-shaped patch antenna optimized for dual-band operation at 11 GHz and 20 GHz are presented in this study. The proposed design achieves a gain of 5.44 dB, a directivity of 6.50 dB, and an efficiency of 83.69%. By integrating the H- and N-geometry antennas into a single, compact structure, the antenna offers improved performance over conventional designs. These characteristics make it well-suited for satellite communications, radar systems, and high-frequency wireless applications. The software used in this work is HFSS 15 (High Frequency Structure Simulator)



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I.INTRODUCTION

Compact, efficient, and adaptable antenna designs have become essential due to the rapid evolution of high-frequency applications and satellite communications. Microstrip patch antennas have become a popular option for many wireless communications systems due to their low profile, lightweight design, and ease of manufacturing [1]. For contemporary communications systems to effectively support numerous frequency bands within a single compact structure, dual-band and multi-band antennas are becoming increasingly essential. In this work, a unique HN-shaped microstrip patch antenna with operating frequencies of 11 GHz and 20 GHz is presented for use in satellite communications and other high-frequency fields. In addition to maximizing antenna performance across these many frequency bands, the distinctive HN-shaped geometry also produces a compact design, meeting the growing need for smaller parts in contemporary communications equipment. An important novelty in the proposed design is the inclusion of a Defected Ground Structure (DGS) [2], [3]. DGS preserves the structural simplicity of the antenna while improving its impedance, bandwidth and radiation matching characteristics. Reliable communication on both target frequencies is ensured by the antenna's exceptional performance metrics, which include high gain, low reflection loss and exceptional directivity, achieved through meticulous ground plane design and optimization. Modern satellite communications relies heavily on the Ku-band (11 GHz) and Ka-band (20 GHz) [4], which are used for a variety of applications requiring fast data rates, low latency, and reliable performance.

There are particular difficulties in designing antennas for these high-frequency bands, such as minimizing electromagnetic interference, maintaining structural integrity, and being compact while keeping high efficiency [5]. With its sophisticated ground plane design and optimized geometry, the suggested HN-shaped microstrip patch antenna successfully tackles these issues and provides a workable and effective solution. Extensive simulations and studies verified the performance of the suggested antenna. The outcomes show that it can produce distinct radiation patterns at both 11 GHz and 20 GHz, as well as minimal return loss and high gain. Additionally, the design is perfect for integration into contemporary satellite communications systems and other high-frequency equipment due to its small size and lightweight construction. By merging the recognized advantages of a faulty ground structure with the novel HN-shaped geometry, this work makes a substantial contribution to the field of antenna design.

It provides a practical basis for creating dual-band microstrip patch antennas suitable for high-frequency uses, including satellite communications. This paper's remaining sections are arranged as follows: The design process, including the optimization of the defected ground structure and the HN-shaped geometry, is described in depth in Section II. The simulation results are shown in Section III along with an examination of important performance indicators such radiation patterns, gain, and reflection coefficient. By merging the recognized advantages of a faulty ground structure with the novel HN-shaped geometry, this work makes a substantial contribution to the field of antenna design. It provides a practical basis for creating dual-band microstrip patch antennas suitable for high-frequency uses, including satellite communications [6], [7]. The findings' ramifications are examined in Section IV, which also contrasts the performance of the suggested antenna with that of other designs. The work is finally concluded and future research directions are outlined in Section V.

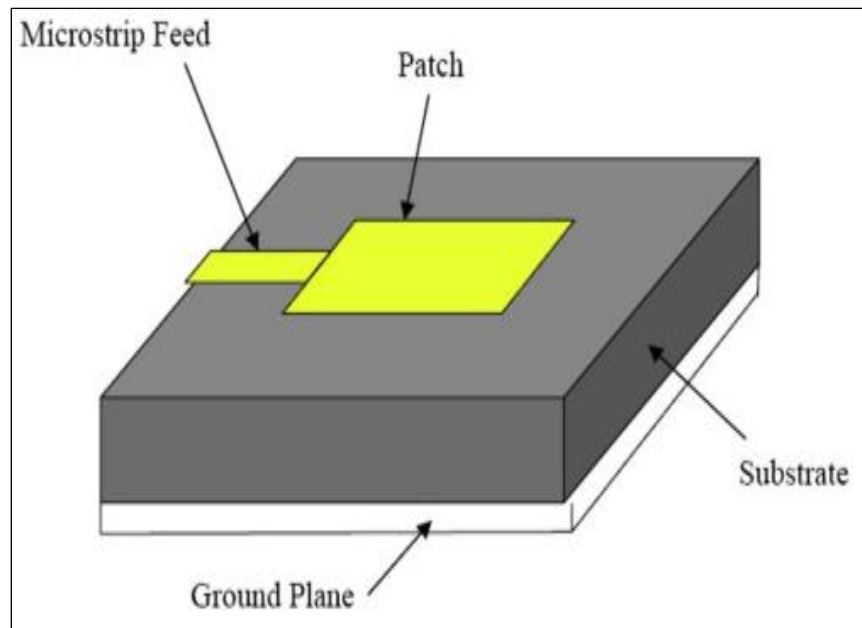


Figure 1: Rectangular Microstrip patch antenna.
Source: [3].

II. ANTENNA DESIGN

II.1 DESIGN CONCEPT

The proposed HN-shaped microstrip patch antenna is designed to operate at two frequencies, specifically 11 GHz and 20 GHz, for satellite communication applications. The HN form was chosen for its ability to provide enhanced electromagnetic coupling and support multiple resonance modes, which is essential for achieving dual-band operation. The design leverages a Defective Ground Structure (DGS) to further improve impedance matching and bandwidth performance while maintaining a compact size [6], [8].

Substrate material: The antenna is constructed using an FR4 substrate, which has the following properties:

Relative permittivity (ϵ_r): 4.4

Loss tangent ($\tan\delta$): 0.02

Thickness (h): 1.6 mm

FR4 is a cost-effective material with reliable dielectric properties, making it suitable for high-frequency designs up to 20 GHz.

Antenna structure: The antenna includes the following elements:

Patch: The HN-shaped patch is etched on the top layer of the substrate. The dimensions of the arms and connection segments of the H and N shapes are optimized to resonate at 11 GHz and 20 GHz.

Ground Plane: The bottom layer comprises a faulty ground structure, consisting of strategically placed circular slots on a rectangular to improve radiation characteristics and suppress higher order harmonics [9].

Power Mechanism: A microstrip line feed is used, which ensures efficient energy transfer to the patch while simplifying the manufacturing process.

II.2 DESIGN PARAMETERS

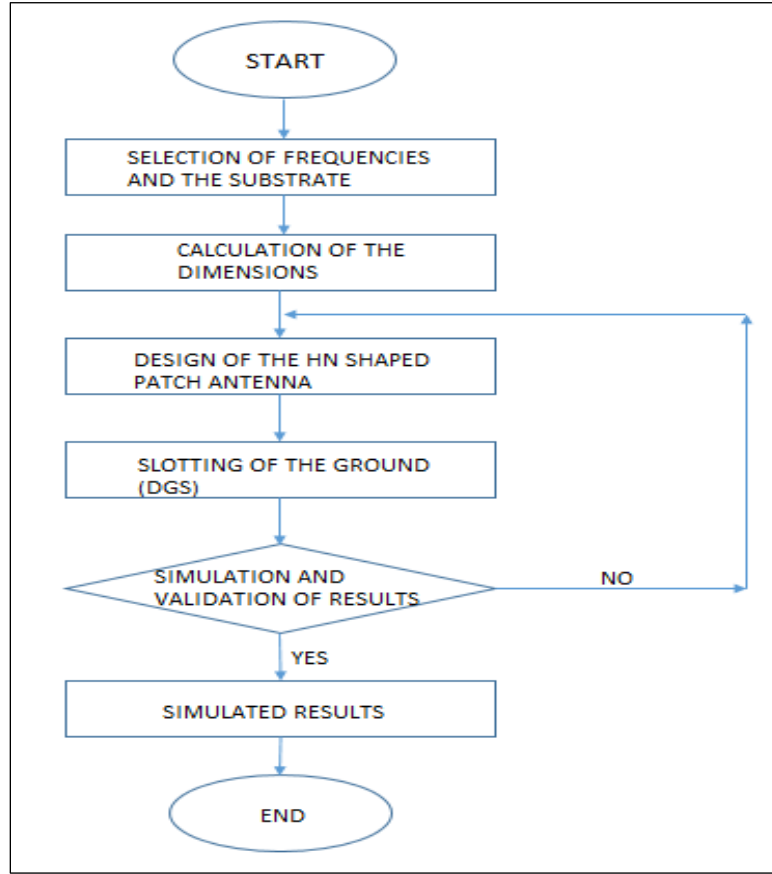


Figure 2: Flowchart of the design process.
Source: Authors, (2026).

The dimensions of the antenna are listed in Table 1. They were determined by iterative simulations in HFSS 15 to obtain optimal performance.

The equations below will let us know how we can calculate the dimensions of the patch antenna [10] Source: Authors, (2026).

$$W = \frac{c}{2f} * \sqrt{\frac{2}{\epsilon_r + 1}} \quad (1)$$

$$L = \frac{c}{2f} \left(\frac{\epsilon_r + 1}{2} - \frac{\epsilon_r - 1}{2} \sqrt{1 + 12 \frac{h}{w}} \right)^{-\frac{1}{2}} - 2\Delta L \quad (2)$$

Where:

W is the width of the patch antenna

L is the length of the patch antenna

f: frequency

h is the height of the substrate

C is the speed of light

The dimensions of the substrate, the following equations will help us know how to calculate

$$L_g = 6h + L \quad (3)$$

$$W_g = 6h + W \quad (4)$$

Ls and Ws are respectively the length and width of the substrate

Table 1: Antenna parameters.

Parameters		Values (mm)
Substrate	A	8
	B	9
Patch	C	1.6
	D	5.5
	E	0.6
	F	0.4
	G	4
	H	1
	I	0.25
	J	2.5
	K	1.5
	L	2.24
	M	6
Ground	N	2.09
	O	1.58
	P	0.29
	Q	0.556
	R	0.707

Source: Authors, (2026).

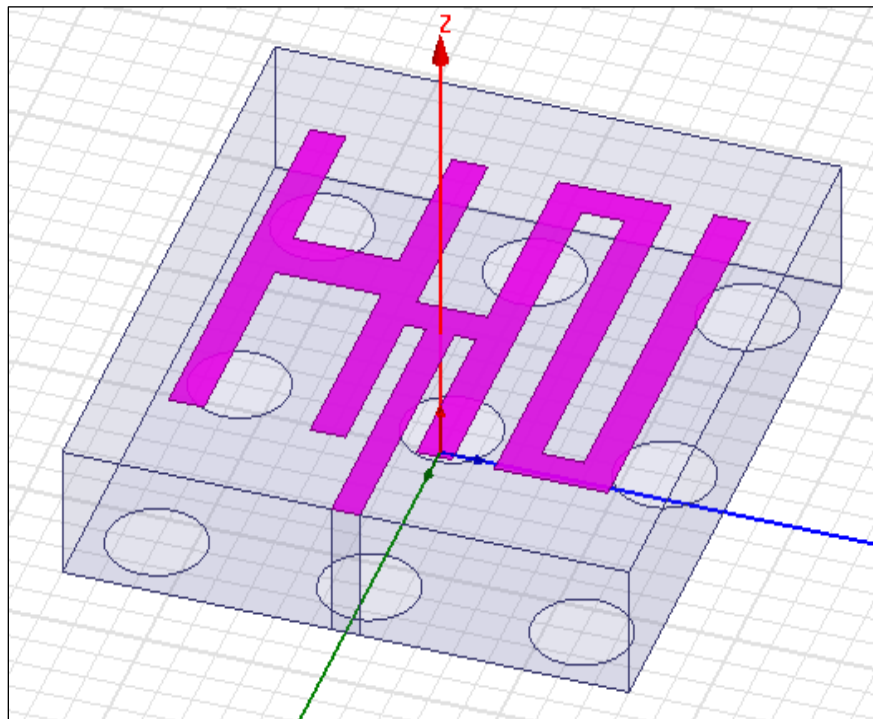


Figure 3: Proposed antenna in HFSS 15.

Source: Authors, (2026).

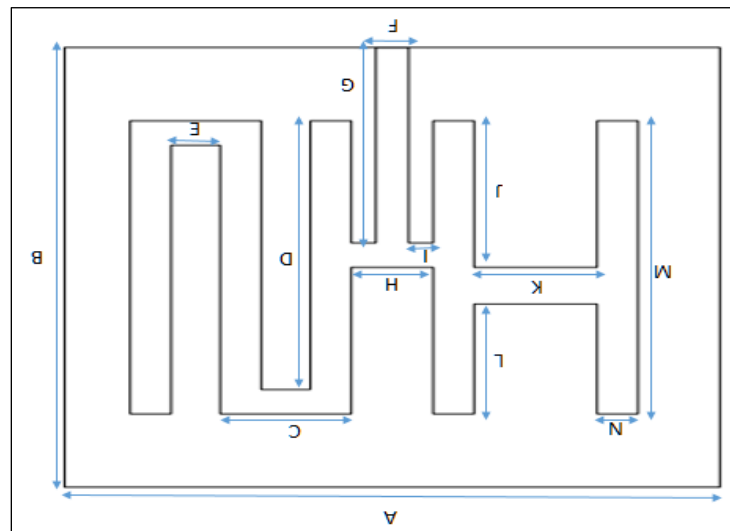


Figure 4: Patch part of the proposed antenna.
Source: Authors, (2026).

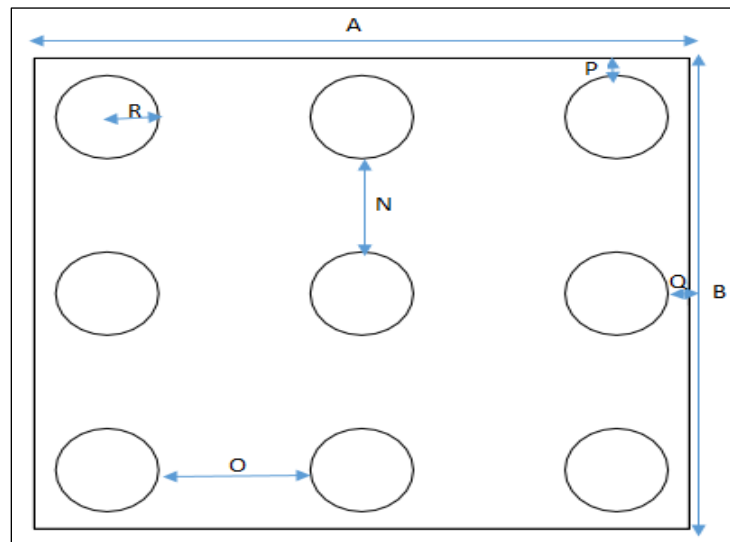


Figure 5: DGS ground plane of the proposed antenna.
Source: Authors, (2026).

II.3 SIMULATION TOOLS

The antenna design and optimization were carried out using HFSS (High-Frequency Structure Simulator), a leading electromagnetic simulation tool. HFSS enables accurate modeling of antenna behavior across target frequency bands and provides key performance metrics such as:

- Reflection coefficient (S11)
- Radiation diagram
- Gain and directivity
- Bandwidth

Process optimization

The optimization process involved:

Initial design: The HN shape was sketched and defined parametrically.

Resonance tuning: The dimensions of the H and N segments have been adjusted to achieve resonance at 11 GHz and 20 GHz.

DGS Integration: Slots were introduced in the ground plane, and their sizes and positions were optimized for better bandwidth and impedance matching.

Validation: The simulated results were validated to ensure consistency and convergence.

III.RESULTS AND DISCUSSIONS

The performance of the proposed HN-shaped microstrip patch antenna was evaluated using ANSYS HFSS 15, focusing on its operation at two frequencies of 11 GHz and 20 GHz. The results demonstrate the antenna's suitability for satellite communications applications, with notable performance metrics including gain, directivity, efficiency, and bandwidth. These measures are summarized and analyzed below.

III.1 REFLECTION COEFFICIENT (S11) AND VSWR

Simulated S11 results reveal excellent impedance matching at target frequencies:

At 11 GHz, the S11 value is approximately -12.35 dB, indicating the minimum reflected power, and at 20 GHz, the S11 value is around -16.52 dB, which means strong resonance.

The antenna has a bandwidth of 10.7 GHz to 11.13 GHz on the 11 GHz band and 19.7 GHz to 20.6 GHz on the 20 GHz band. This provides a fractional bandwidth of approximately 3.9% and 4.5%, respectively, which is sufficient for satellite communication needs. The equations below will show us how to calculate fractional bandwidth (BW (%))

$$BW(\%) = \frac{f_h - f_l}{f_c} \quad (5)$$

$$f_c = \frac{f_h + f_l}{2} \quad (6)$$

With f_c , f_h and f_l , respectively, central, highest, and lowest frequencies

Voltage standing wave ratio (VSWR) is an essential parameter for evaluating impedance matching. For the proposed antenna. The VSWR is approximately 2.5 dB, indicating that the reflected power is low enough for efficient operation. A VSWR value less than 3 is generally acceptable for practical applications, and the obtained value of 2.5 demonstrates good performance. The equation below helps us calculate the S11 or Γ and the reflected power

$$\Gamma = \frac{VSWR - 1}{VSWR + 1} \quad (7)$$

$$\Gamma = \frac{2.5 - 1}{2.5 + 1} = \frac{1.5}{3.5} = 0.429$$

Reflected power:

$$P_{\text{reflected}} = \Gamma^2 = (0.429)^2 = 0.184 \quad (8)$$

$$P_{\text{transmitted}} = 1 - \Gamma^2 = 1 - (0.429)^2 = 0.816 \quad (9)$$

This means that 18.4% of the power is reflected and approximately 81.6% is transmitted.

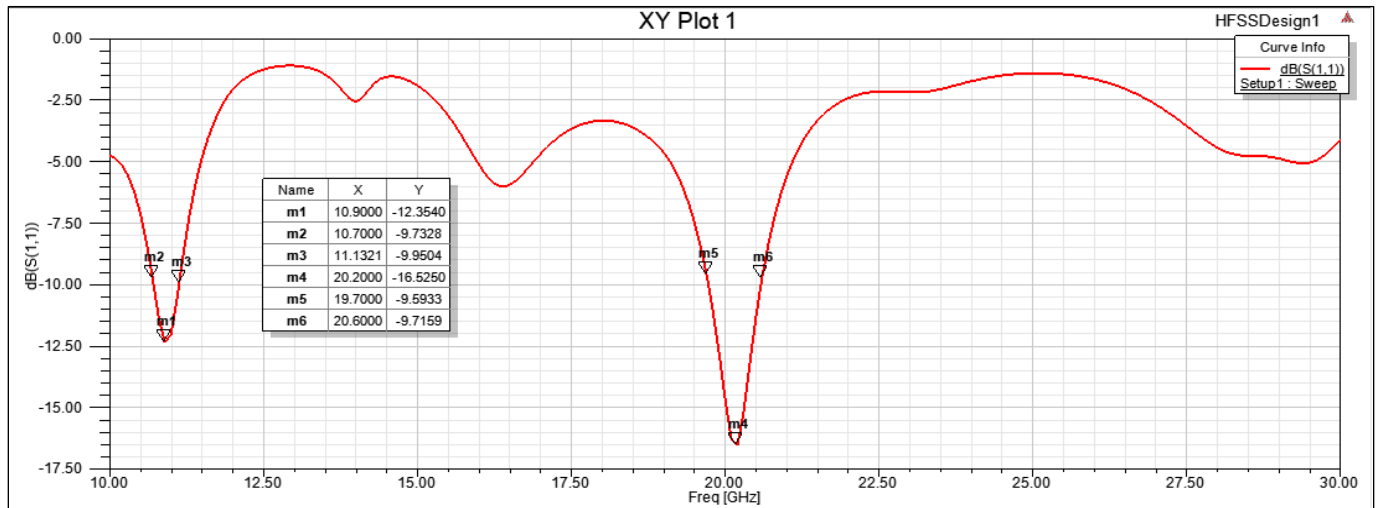


Figure 6: S11 of the proposed antenna.
Source: Authors, (2026).

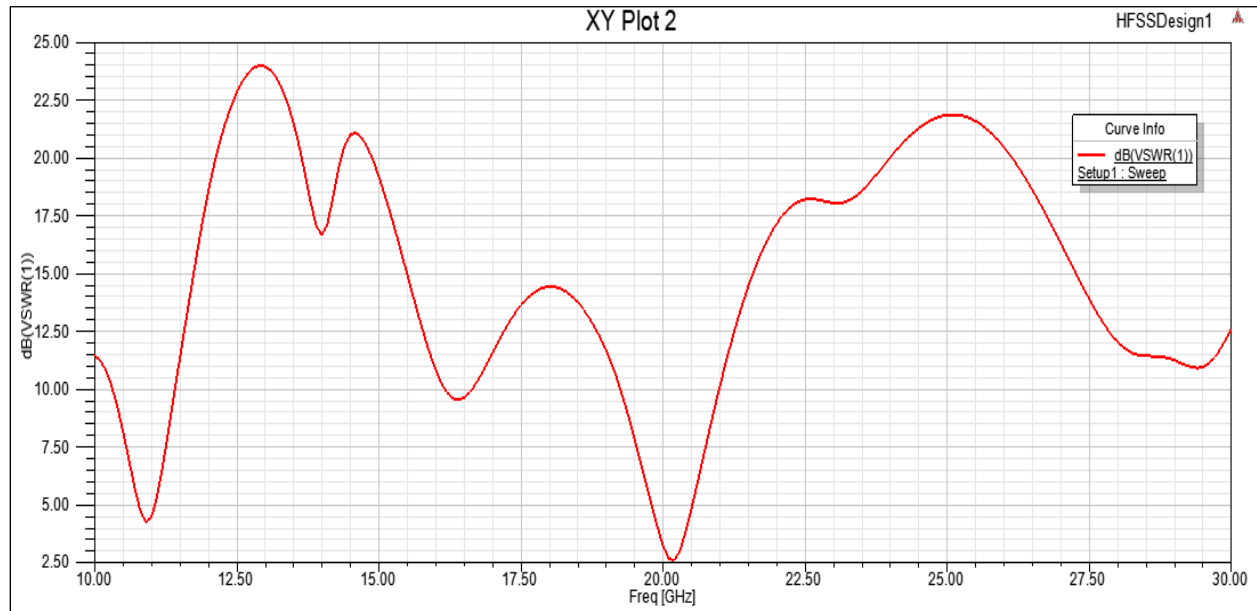


Figure 7: VSWR of the proposed antenna.
Source: Authors, (2026).

The bandwidth characteristics of the antenna are as follows, based on the figure 6:

11 GHz Band: The antenna operates efficiently in the range of 10.7 GHz to 11.13 GHz, providing a bandwidth of 430 MHz

20 GHz Band: The antenna supports operation in the range of 19.7 GHz to 20.6 GHz, resulting in a bandwidth of 900 MHz

III.2 GAIN AND DIRECTIVITY

The antenna achieves a gain of 5.44 dB suitable for reliable signal transmission in satellite links and providing improved performance at higher frequencies. The gain performance is attributed to the HN-shaped patch, which supports efficient radiation, and the defective ground structure (DGS), which suppresses unwanted modes.

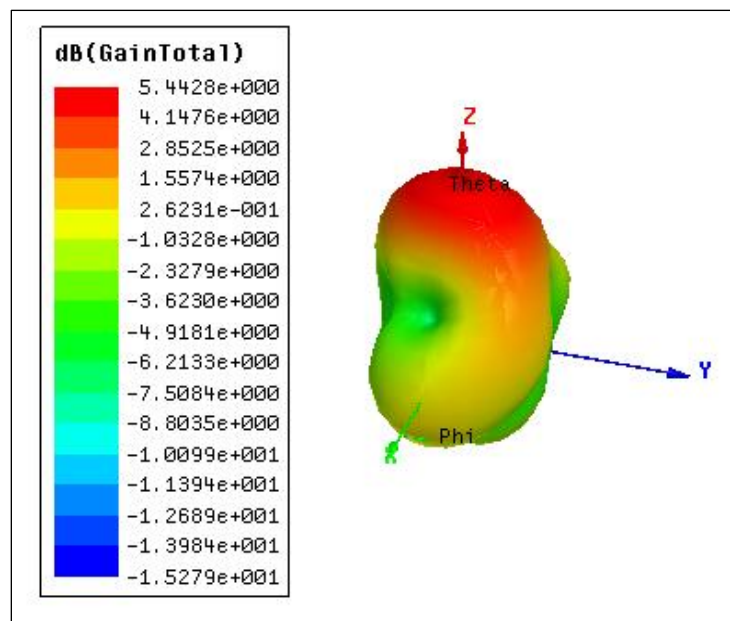


Figure 8: Gain of the proposed antenna.
Source: Authors, (2026).

The directivity value is 6.50 dBi indicating focused radiation in the intended direction and reflecting the antenna's ability to maintain directionality at higher frequencies. These values demonstrate that the antenna efficiently converts input power into radiated power in specific directions.

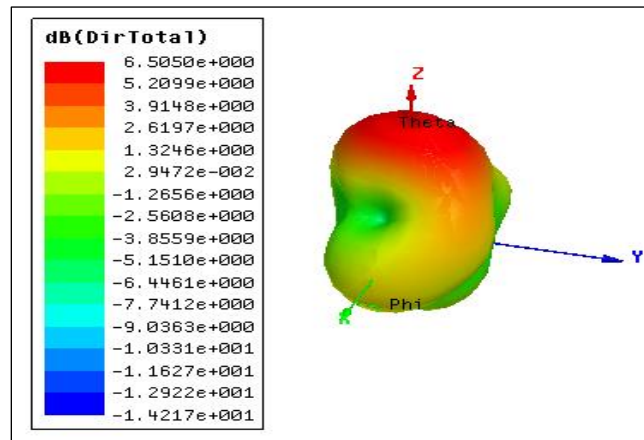


Figure 9: Directivity of the proposed antenna.

Source: Authors, (2026).

III.3 RADIATION EFFICIENCY

The radiation efficiency of an antenna quantifies how effectively the antenna converts input power into radiated power. It is defined as the ratio between the power radiated by the antenna and the total power supplied to it. The proposed design achieves high efficiency 83.69% through low dielectric and ohmic losses. These values indicate that the majority of the input power is radiated rather than dissipated, which is essential for good satellite communication performances.

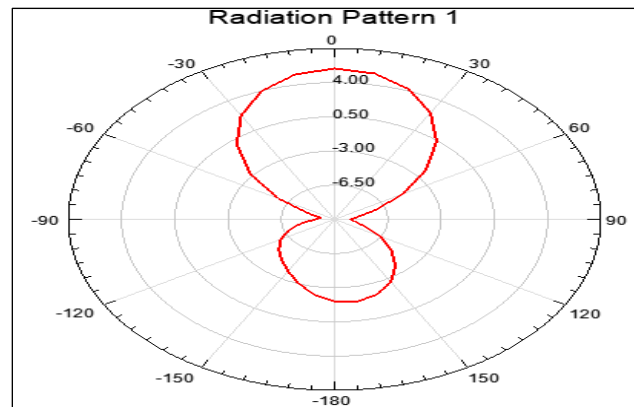


Figure 10: Radiation pattern of the proposed antenna at $\Phi = 90$ degrees.

Source: Authors, (2026).

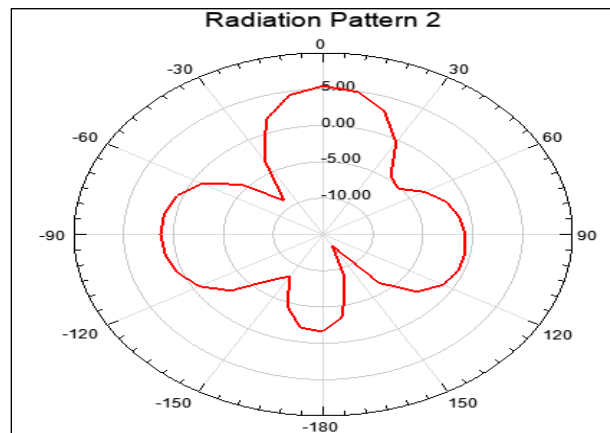


Figure 11: Radiation pattern of the proposed antenna at $\Phi = 0$ degree.

Source: Authors, (2026).

The integration of the defective floor structure played a central role in achieving superior performance measures. The DGS effectively expanded the bandwidth and improved impedance matching while maintaining a compact size. The HN-shaped patch contributed to dual-frequency operation, an essential feature for modern satellite communications systems requiring flexible use of frequencies.

III.4 COMPARISON WITH EXISTING WORKS

Let's examine the suggested HN shape microstrip patch antenna in comparison to other antennas that have been documented in the literature, particularly those designed for satellite communications applications, dual-frequency operation, or integration with defected ground structure (DGS), in order to make a meaningful comparison. Important factors including gain, bandwidth, efficiency, size and VSWR are the focus of the comparison. The results are summarized in the table 2 below.

Table 2: Comparison with related works.

Parameters	[1]	[3]	[10]	Proposed antenna
Antenna size (mm ²)	45 x 35	50 x 40	35 x 30	9 x 8
Operating frequencies	10 GHz, 18 GHz	12 GHz, 18 GHz	11.5 GHz 20.5 GHz	11 GHz, 20 GHz
Bandwidth	310 MHz 500 MHz	200 MHz 300 MHz	400 MHz 750 MHz	430 MHz 900 MHz
Gain (dB)	4.5	3.8	5.1	5.44
Directivity (dB)	5.5	4.8	6.3	6.5
VSWR	3	2.9	2.6	2.5
DGS	Yes	No	Yes	Yes
Efficiency (%)	79.4	75.6	82.1	83.69

Source: Authors, (2026).

A comparative analysis with existing designs demonstrated the superior performance of the proposed antenna, especially in terms of achieving higher bandwidth and efficiency while maintaining a simple and compact structure.

IV.CONCLUSION

This paper presents the design and performance analysis of a novel HN-shaped microstrip patch antenna operating at dual frequencies of 11 GHz and 20 GHz, optimized for satellite communication applications. The integration of the HN-shaped patch and defected ground structure (DGS) significantly improved the antenna performance in terms of bandwidth, gain, and efficiency while maintaining a compact size. The results validate the potential of the proposed HN-shaped microstrip patch antenna for deployment in satellite communication systems, providing a robust solution for high-frequency dual-band operation. Future work may explore further optimization of circular polarization and multi-band operation to improve its versatility for advanced satellite systems.

V.AUTHOR'S CONTRIBUTION

Conceptualization: Touko Tcheutou Stephane Borel, and Rashmi Priyadarshini

Methodology: Touko Tcheutou Stephane Borel, and Rashmi Priyadarshini

Investigation: Touko Tcheutou Stephane Borel., and Rashmi Priyadarshini

Discussion of results: Touko Tcheutou Stephane Borel, Rashmi Priyadarshini

Writing – Original Draft: Touko Tcheutou Stephane Borel., and Rashmi Priyadarshini

Writing – Review and Editing: Touko Tcheutou Stephane Borel, Rashmi Priyadarshini.

Resources: Touko Tcheutou Stephane Borel, and Rashmi Priyadarshini

Supervision: Touko Tcheutou Stephane Borel, and Rashmi Priyadarshini

Approval of the final text: Touko Tcheutou Stephane Borel, Rashmi Priyadarshini

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