

A HIGH PERFORMANCE HEXAGONAL MICROSTRIP PATCH ANTENNA WITH ENHANCED BANDWIDTH AND VSWR FOR KU-BAND SATELLITE APPLICATIONS

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DOI: <https://doi.org/10.5281/zenodo.19511367>

Keywords

Ku Band, Microstrip Antenna, Satellite Communication, Patch Antenna, Return loss, Radiation and Frequency.

Article History

Received: 15 February 2026

Accepted: 25 March 2026

Published: 11 April 2026

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Abstract

One major reason for the increasing use of microstrip patch antennas in the existing satellite communication system is due to their compactness, lightweight nature, and ease of fabrication. In this study, an innovative microstrip patch antenna for satellite communication in Ku band was designed and analyzed. The design and simulation of the antenna were performed using CST studio suite software. The resonant frequency obtained from the antenna is 16.056 GHz, where the return loss and voltage standing wave ratio are -42.98 dB and 1.014, respectively. Furthermore, the antenna has bandwidth of 2.52 GHz, gain of 5.78 dBi, and directivity of 6.25 dBi. Based on comparative study of the designed antenna with the reference antenna, it can be concluded that the proposed antenna performs better than the reference antenna in terms of bandwidth and S-parameters.

1. Introduction

The Hexagonal Microstrip patch antennas have gained enormous importance in the field of Satellite Communication Systems owing to their compact size, flat profile, lightweight nature, and ease of manufacturing. In this regard, hexagonal microstrip patches have been found extremely beneficial at high frequencies due to some advantages over others, like improved radiating properties, increased bandwidth, and effective use of the substrate [1]. The hexagonal geometry, which is important for satellite payload integration, makes it perform efficiently but

occupying little space when compared to traditional square or round patches [2]. However, these hexagonal microstrip patches still face certain challenges such as limited bandwidth, limited gains, and impedance mismatch, thereby reducing their efficiency in Ku-bands (12-18 GHz). This frequency band is used for various purposes such as internet service provision, high-speed data transfer, and television broadcasts via satellites [3]. Antennas with high operating bandwidth, low S11 value, good VSWR characteristics, and efficient radiation properties need to be designed to cater for emerging requirements of the current satellite

communication system [4]. Various approaches to overcome these limitations have been suggested in several literature sources; some of the strategies include using sophisticated feed mechanism, patch geometry variation, and substrate material alteration [5]. Nonetheless, there are quite a number of modern techniques which are unable to merge the three parameters mentioned above. This problem is evident when designing hexagonal microstrip antennas used in Ku band applications [6]. The aim of this project is to develop, simulate and optimize a high performance hexagonal microstrip patch antenna using the CST software. The proposed antenna is best suited for high-speed Ku band satellite communications due to its ability to enhance maximum gain, directivity, bandwidth and VSWR [7]. Through the development of this antenna, modern satellite communication systems will be improved by overcoming limitations of

conventional ones [8].

Methodology and Antenna Design

The proposed antenna design for Ku-Band satellite communications application has been modeled and analyzed using CST Microwave Studio software. The primary aim was to have low reflection loss, wide bandwidth, and good radiation efficiency within the 12-18 GHz operational frequency range.

2.1 Antenna Geometry

Three essential parts that make up an antenna include the radiating patch, a dielectric material, and the ground plane. Due to the conductivity nature and radiation effectiveness of a hexagon-shaped copper (annealed), it was used as the radiating patch instead of using a regular rectangular radiating patch.

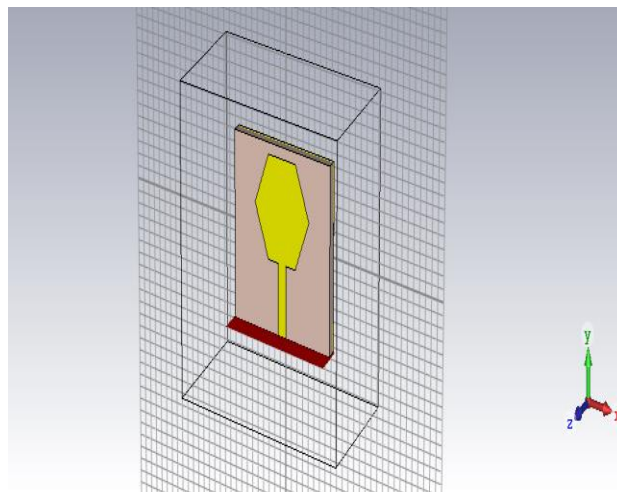


Figure 1 Geometry of proposed Antenna

2.2 Substrate Selection

A number of dielectric substrates such as FR-4 (lossy), Rogers RT5880 (lossy), and Taconic TRF-43 (lossy) have been considered in terms of their effect on the performance of the antennas. The substrate selected as the best one among these based on its low dielectric constant $\epsilon_r = 2.2$ and low $\tan \delta$ of 0.0009 is the Rogers RT5880 substrate.

2.3 Ground Plane Design

For minimizing the losses due to surface waves and providing better reflection capability, Perfect Electric Conductor (PEC) ground plane was used. For improving the return loss performance, diameter of the grounds was increased.

2.4 Feeding Technique

The Microstrip line feed was used to excite the patch. The Microstrip line feed method has the features of simplicity, fast impedance matching, and reliable high frequency operation. In order to

minimize the reflections in the input ports, an impedance value of 50 Ohms was used to construct the feed line.

2.5 Simulation and Optimization

To emulate behavior in free space, the antenna was modeled assuming open boundary conditions, with the ambient medium being vacuum. The patch and ground sizes were then varied using parametric sweeps until desired performance was achieved. For an operating frequency of 16.056 GHz, the optimized antenna exhibited:

Return Loss (S_{11}): -42.98 dB
Voltage Standing Wave Ratio (VSWR): 1.014
Bandwidth: 2.52 GHz
Gain: 5.78 dBi

Directivity: 6.25 dBi

The surface currents are produced on the hexagonal patch due to the operation of the antenna through the microstrip feed line. These electromagnetic waves help transmit the current to free space. This antenna can be used for satellite communication applications in the KU-band.

Antenna parameters are shown in Table 1.

Parameter	Notation	Calculated Value(mm)
Width of ground	W_g	16.737
Length of ground	L_g	14.792
Height of ground	H_g	0.015
Height of substrate	H_s	1.2
Width of patch	W_p	6.737
Length of patch	L_p	4.792
Width of feed line	W_f	1.352
Gap b/w patch & Feed line	G_{pf}	1
Insert feed line	F_i	1.5
Radius of patch	R_o	4.732

2. Results and Discussion

With the use of CST Microwave Studio, the recommended hexagonal microstrip patch antenna was developed and modeled to operate in the Ku-band (12-18 GHz). The outstanding performance of the antenna in terms of its radiation characteristics, bandwidth, and impedance matching can be seen from the simulation results. In addition, at the resonant frequency of 16.056 GHz, it was discovered that the return loss (S_{11}) of -42.980 dB was achieved, which means that there were almost no impedance mismatch and minimal reflection. There was only a minimal impedance mismatch in the antenna because its Voltage Standing Wave Ratio (VSWR) was equal to 1.014, thus ensuring that effective power transfer took place. The achieved

bandwidth of 2.52 GHz, which is significantly higher than what is usually achieved with microstrip patch antennas, is one of the best results. As for radiation properties, the antenna resulted in 6.25 dBi of directivity and 5.78 dBi of gain simulation. They both reflect the effectiveness and the direction of radiation of the proposed antenna.

Moreover, the radiation pattern and surface currents at the resonance frequency for the antennas are depicted in Figures [1, 2, 3] and [4, 5], which proves their good operation and assists in the antenna design process. All in all, this information shows how well the proposed antenna meets the desired criteria required for satellite communication.

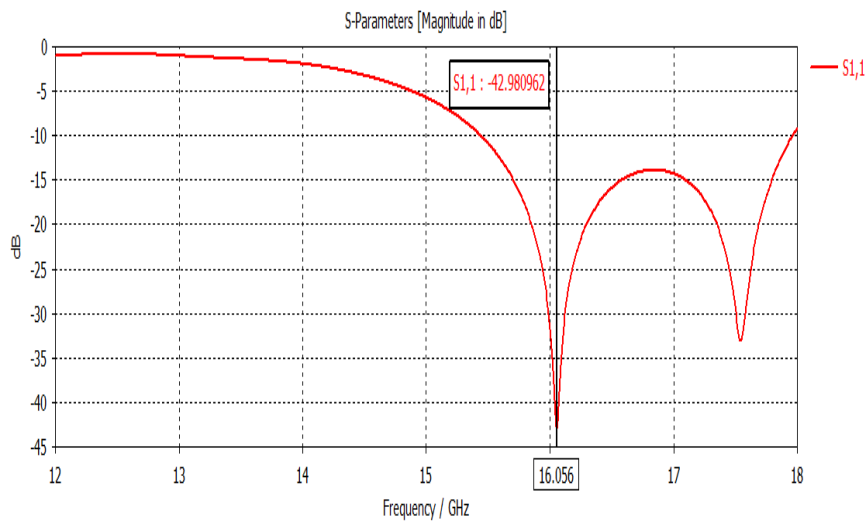


Figure 1. Return loss of antenna should always be lesser than -10dB.

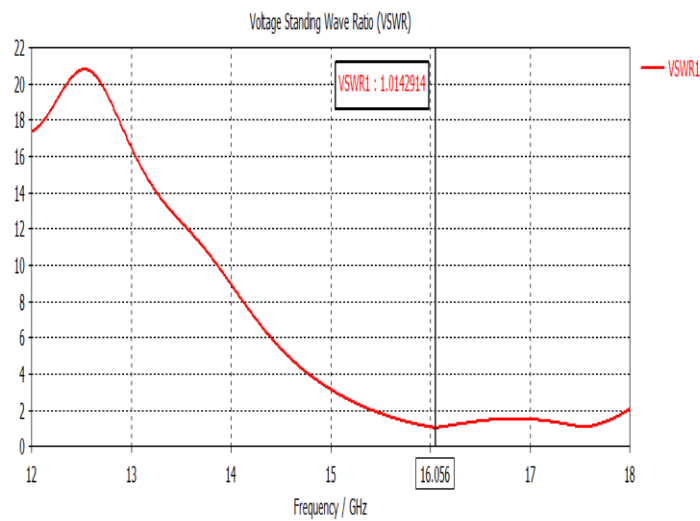


Figure 2. VSWR of the antenna must be practically be between the values of 1 and 2.

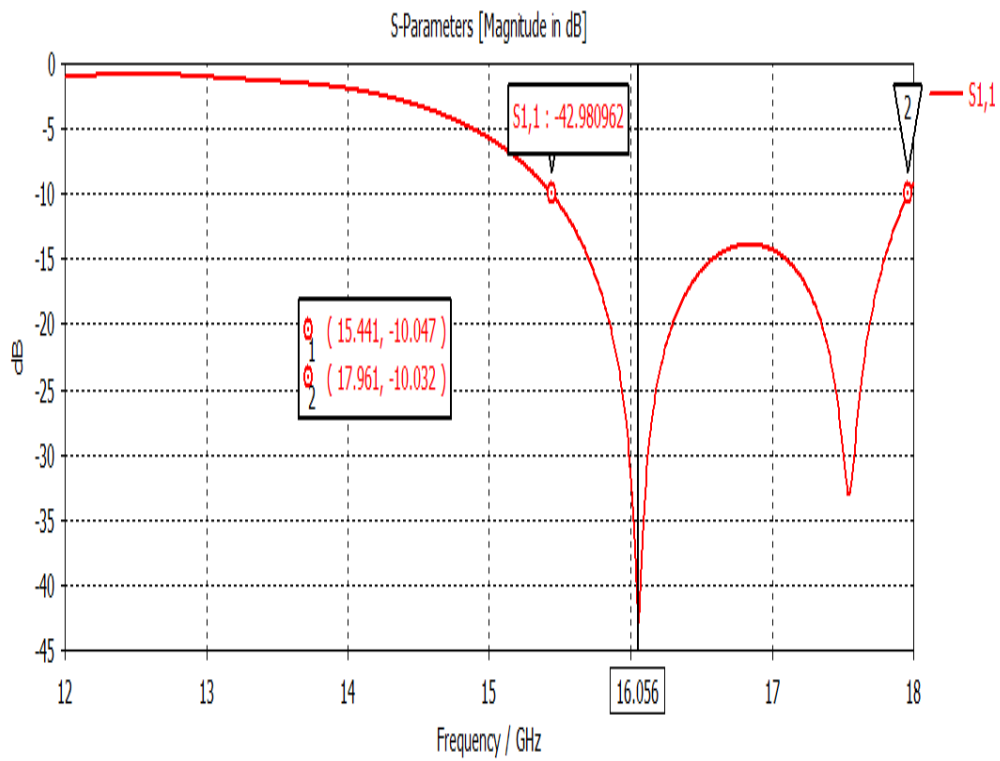


Fig.3 Bandwidth

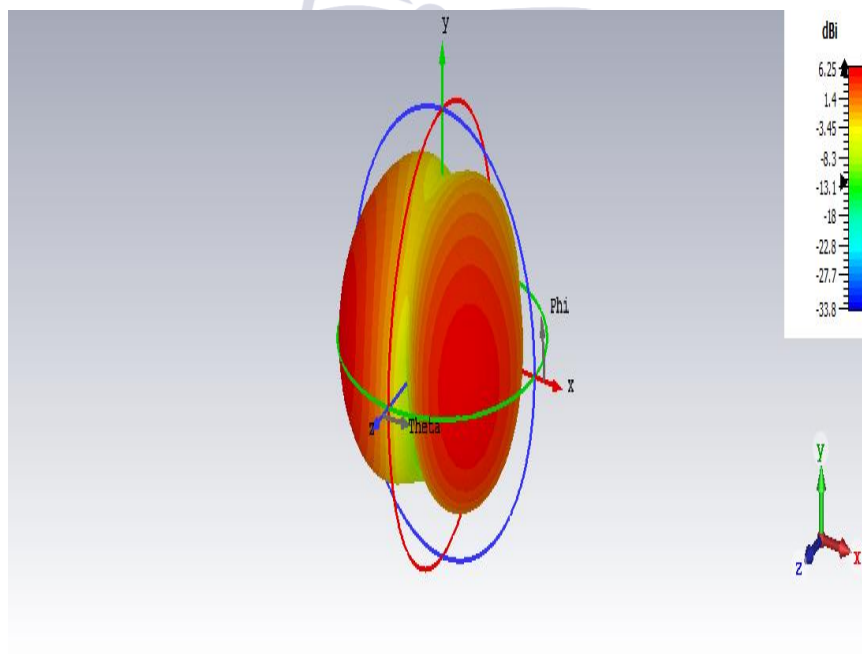
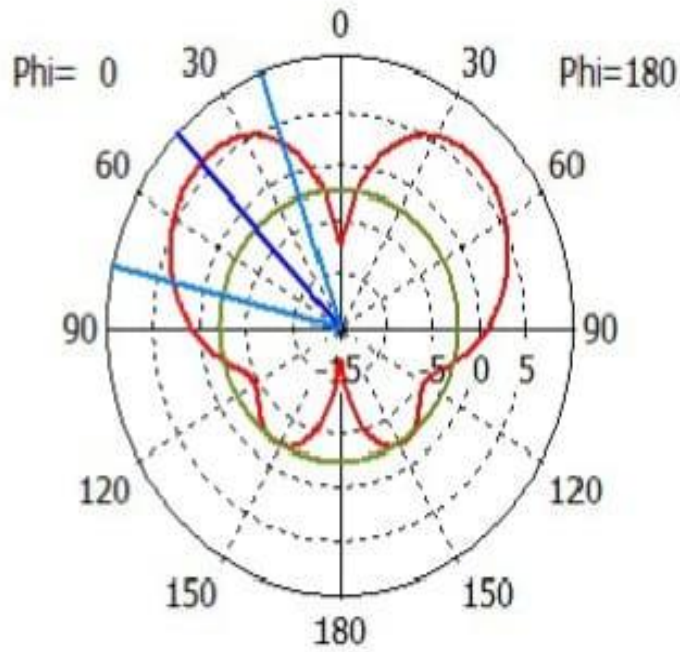


Fig.4. Directivity in 3-D Pattern

Farfield Directivity Abs (Phi=0)



Theta / Degree vs. dBi

Figure 5. 2D- radiation pattern

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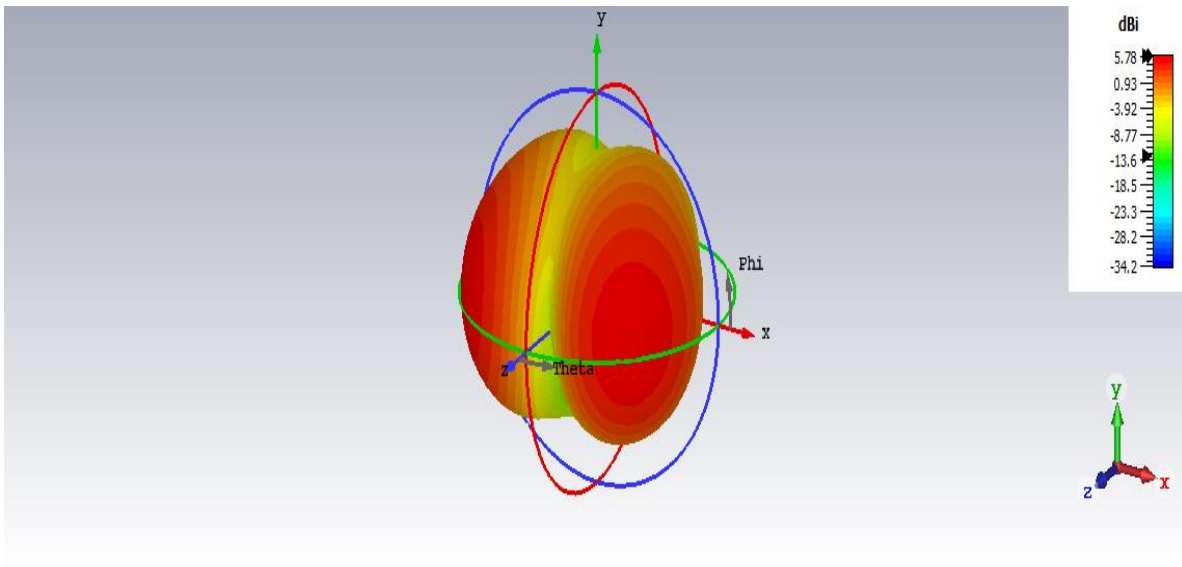


Figure 5 Gain

Table 2 Outcomes of the proposed MPA

S-Parameter (S11)	-42.980 dB
VSWR	1.014 dB
Bandwidth	2.52GHz
Directivity	6.25 dB
Gain	5.78 dB

4.2 Comparison with Reference Antenna

The design was tested by comparing the proposed antenna with a Reference Antenna whose design has been published in literature. The parameters of interest include the bandwidth, return loss, VSWR, gain, and directivity of the antennas.

4.2.1 Bandwidth Comparison

Compared with the reference antenna, the designed hexagonal antenna possesses a significantly higher bandwidth of 2.52 GHz. The design improvement by minimizing surface wave loss and improving current distribution leads to a larger bandwidth for the new hexagonal design. Hence, the Ku-band bandwidth of the designed antenna is higher.

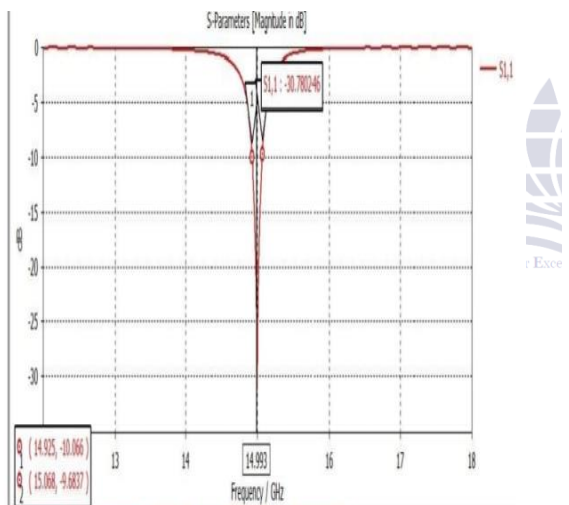


Figure 5. Bandwidth of proposed Hexagonal Antenna

Bandwidth range of the proposed hexagonal microstrip antenna, which is greater within the ku band, is shown in Figure 5. Bandwidth range of the reference antenna, which is less than the bandwidth range of the proposed antenna, is shown in Figure 6.

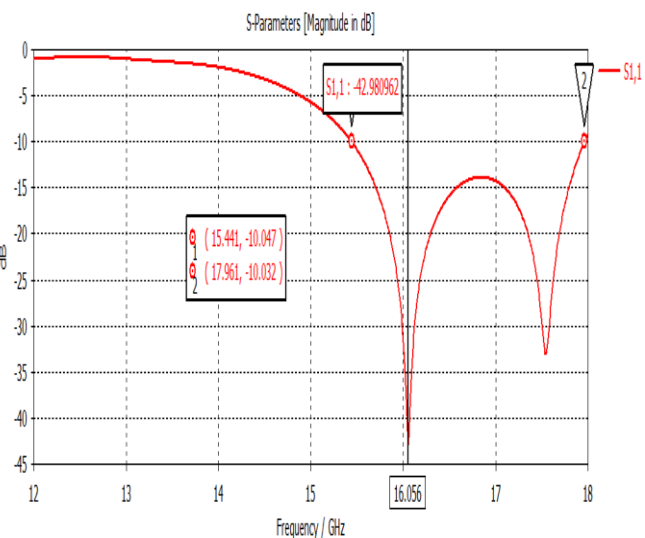


Figure 6. Bandwidth of reference Antenna

4.2.2 S-Parameter (Return Loss) Comparison

Bandwidth for the hexagonal shape microstrip antenna is demonstrated in Fig. 5, where it can be observed that there is a wider frequency coverage within the Ku-band compared to the reference antenna. The bandwidth for the reference antenna is shown in Fig. 6.

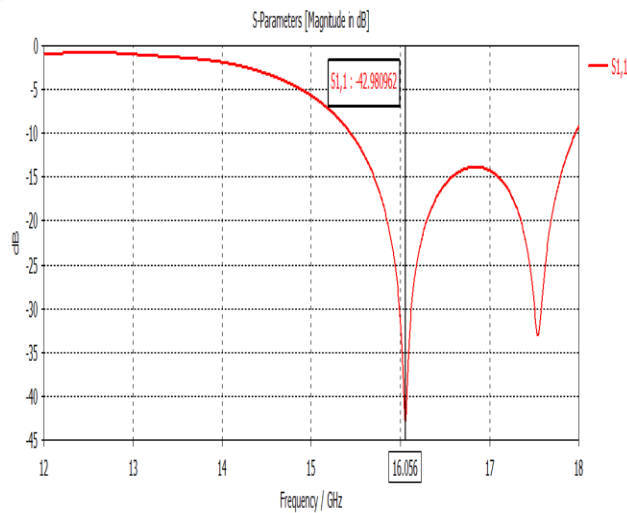


Figure 7. Return Loss (S11) of proposed Antenna

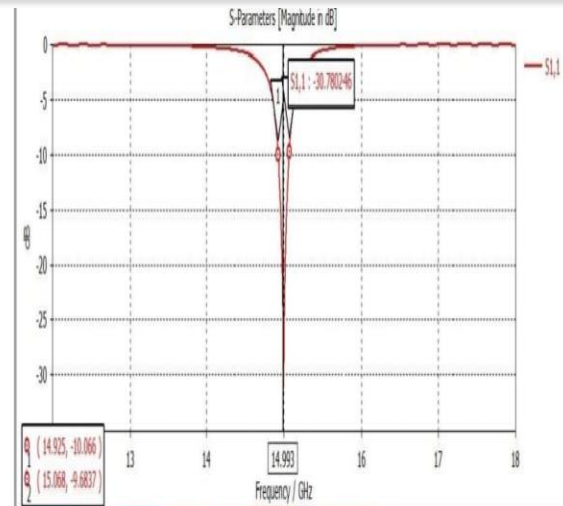


Figure 8. Return loss of Antenna reference

The Loss of Return (S11) graph of the suggested hexagonal microstrip antenna is illustrated in figure 7, with its largest value being -42.98 dB at 16.056 GHz. The reference antenna loss of return (S11) graph, with a higher (less negative) S11 value than that of the above, suggests poor impedance matching.

4.2.3 Voltage Standing Wave Ratio (VSWR) Comparison

The Voltage Standing Wave Ratio (VSWR) is a crucial statistic for evaluating a microstrip antenna's impedance matching capability. A VSWR value close to unity indicates improved power transmission and less reflection losses.

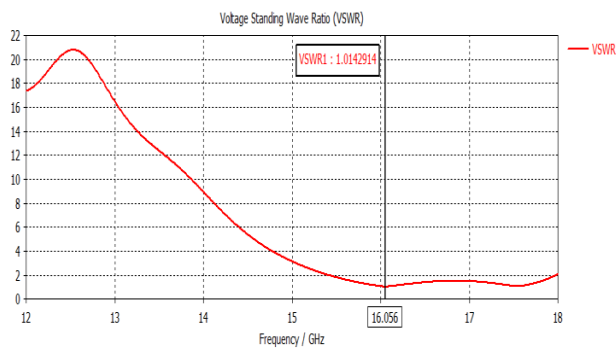


Figure 9. VSWR of proposed Antenna

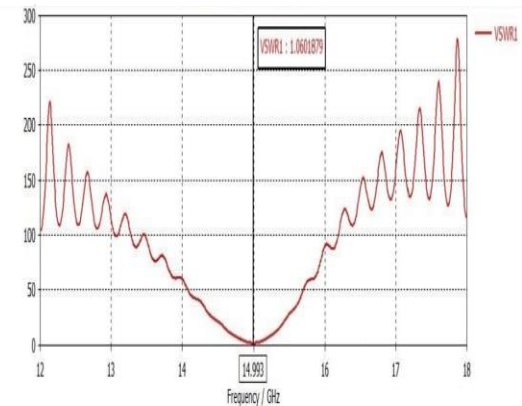


Figure 10. VSWR of Reference Antenna

Figure 9 and Figure 10 illustrate the variation of VSWR in the case of the suggested hexagonal microstrip antenna compared to the reference antenna. It becomes quite evident that with respect to the lower VSWR value at resonance, the antenna shows better matching properties. Also,

VSWR < 2 results in an increase in bandwidth compared to the reference antenna.

Conclusion

A highly efficient microstrip patch antenna for Ku-band satellite communications has been developed. The proposed antenna operates at a

frequency of 16.056 GHz with a return loss of -42.98 dB and a VSWR of 1.014, making it an excellent choice for use in various satellite communication applications. When compared to the reference model, the proposed antenna outperformed it in all critical parameters, including bandwidth, S-parameters, gain, and directivity. The results indicate that the proposed design is appropriate for current satellite communication systems that require high data transmission rates.

Author Contribution

All the authors contributed equally in various sections of the research paper.

Conflict of Interest:

Authors of this paper declare no conflict of interest.

Funding Agency:

This research paper is composed of simulation results obtained by using CST Microwave software studio but not funded by any organization or institution.

Acknowledgment

This work was supported by the Department of Physics and Electronics at Shah Abdul Latif University. The authors express their sincere gratitude to Dr. Yousuf Khushk, Vice Chancellor of SALU Khairpur, for providing a conducive research environment and continuous support throughout this study.

Future Work

The suggested antenna can be built and tested experimentally in future studies. Researching multi-band functioning, creating antenna arrays to boost coverage and gain, and integrating the antenna with useful satellite communication systems are some other advancements. Efficiency and bandwidth can be further increased by improving substrate material and patch shape.

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