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DESIGN AND OPTIMIZATION OF A C-SHAPED MICROSTRIP PATCH ANTENNA FOR KU-BAND SATELLITE COMMUNICATIONS WITH ENHANCED IMPEDANCE MATCHING

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Abstract
Microstrip patch antennas are widely used in modern satellite communication due to their small size, low profile, and ease of manufacturing. This paper presents the design and analysis of a Microstrip antenna appropriate for Ku-band (12-18GHz) satellite communication applications. The recommended design was produced using CST software and has a resonance frequency of 12.918GHz, a return loss (S11) of −43.4003dB, and a VSWR of 1.013, all of which show excellent impedance matching. The antenna outperforms the reference design in essential properties, particularly bandwidth and S-parameters, with a broad bandwidth of 0.83 GHz, gain of 5.21 dBi, and directivity of 7.08 dBi. The results show that the recommended antenna is a reliable and effective choice for high-data-rate satellite communication systems.

1. Introduction

Because of its extensive coverage, dependability, and capacity to deliver communication services in isolated and rural locations, satellite communication has emerged as a crucial component of contemporary wireless networks. Applications such as television broadcasting, internet connectivity, navigation systems, weather monitoring, and defense communication rely significantly on satellite linkages. The antenna is one of the most important parts of any satellite communication system since it directly influences the efficiency, quality, and range of the signals that are sent and received. Due to its low profile, light weight, small size, and ease of manufacture, microstrip patch antennas have attracted a lot of interest in satellite applications in recent years. They are very well suited for incorporation into contemporary satellite and ground terminal systems because of these characteristics. Microstrip patch antennas have advantages over traditional antennas, including planar structure, low cost, and compatibility with microwave integrated circuits. However, a significant drawback of simple microstrip patch antennas is their comparatively low gain, which limits how well they work in long-distance satellite communication systems.

To address this constraint, numerous solutions have been proposed in the literature, including the use of modified patch shapes, slotting techniques, parasitic elements, layered structures, and array arrangements. These strategies aim to optimize the radiation characteristics and improve the overall gain of the antenna while retaining a compact structure. Optimizing the patch shape is a straightforward and efficient method of enhancing antenna performance without adding to the complexity of the system. In this work, a microstrip patch antenna for high-gain satellite applications is built and studied. The Ku-band frequency range, which is frequently utilized in satellite communication systems, is where the suggested antenna functions. The design is constructed using a typical dielectric substrate and is simulated using a full-wave electromagnetic solver. The main purpose of this work is to maximize the antenna gain while keeping the structure compact and suitable for actual satellite communication applications.

Impedance matching analysis is used to support the evaluation of the proposed antenna's performance, which is mostly assessed in terms of gain. The simulated findings show that the suggested design outperforms a traditional reference antenna in terms of gain, which makes it a viable option for high-gain satellite communication systems.

2. Methodology and Antenna Design

The suggested antenna for Ku-band satellite communication applications was designed and simulated using CST Microwave Studio. The main objective was to achieve low return loss, broad bandwidth, and superior radiation efficiency in the 12–18 GHz operating frequency range.

2.1 Antenna Geometry

The suggested C-shaped patch is made to have a low-profile structure while improving return loss S_{11} and directivity. By adding a center slot to the patch, the C-shape increases radiation efficiency by redistributing surface currents. To resonate at the intended Ku-band frequency, the patch dimensions are optimized using typical microstrip antenna design concepts.

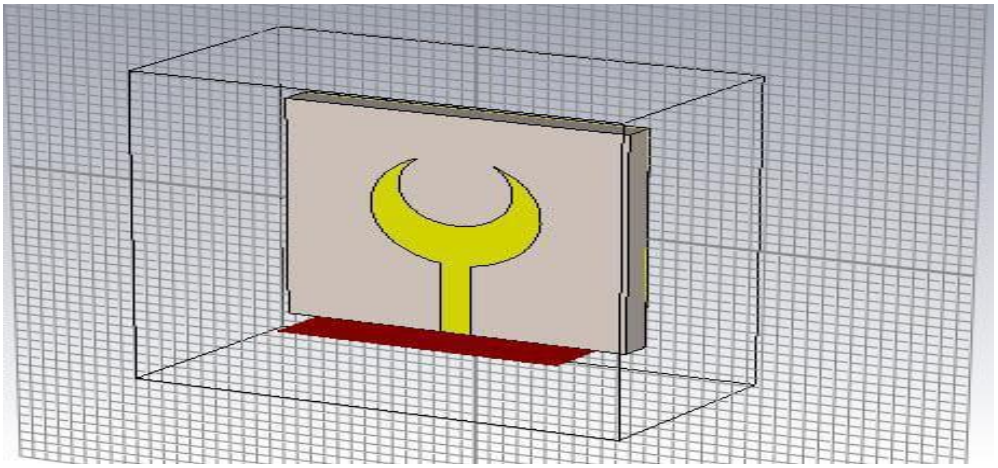

Figure 1 Geometry of proposed Antenna

2.2 Design Equations

The dimensions of the microstrip patch are calculated using standard formulas:

Patch Width (W)

$$W = \frac{C_o}{2fr\sqrt{\frac{Er+1}{2}}}$$

The formula for effective dielectric constant

$$E_{REFF} = \frac{Er+1}{2} + \frac{Er-1}{2}\left(1+12\frac{h}{w}\right) - 0.5$$

The formula for length of the Patch antenna

$$L = L_{EFF} - 2\Delta L$$

2.3 Substrate Selection

The suggested C-shaped microstrip patch antenna is developed on a dielectric substrate to achieve excellent return loss and effective impedance matching for Ku-band satellite applications. After assessing various substrate materials, Rogers RT5880 (lossy) is selected due to its low relative permittivity ε_r=2.2 and very low loss tangent tan δ=0.0009 which decrease dielectric losses and boost radiation efficiency.

2.4 Ground Plane Design

A Perfect Electric Conductor (PEC) ground plane was utilized to guarantee ideal reflection and lower surface wave losses. The ground dimensions were enhanced to enhance reflection loss and impedance matching.

2.5 Feeding Technique

The antenna is powered by a microstrip feed line, which simplifies manufacture and provides precise impedance matching. In order to maximize radiated power and reduce return loss, the feed placement is optimized.

2.6 Simulation and Optimization

The CST full-wave electromagnetic solver is used to simulate the antenna.
Ku band (12~18GHz) is the frequency band.
Boundary conditions: Restrictions on radiation in open spaces
Optimization: To optimize return loss and bandwidth, patch sizes, power supply locations, and slot geometries are adjusted. Adaptive grid offers reliable results.
To show improvements in return loss, VSWR, and bandwidth, the suggested design is contrasted with a reference rectangular patch antenna.
Return Loss (S_{11}): −43.4003dB
VSWR: 1.013
Bandwidth: 0.83GHz
Gain: 5.21dBi
Directivity: 7.08dBi

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Antenna parameters are shown in Table 1.

Parameter	**Notation**	**Calculated Value(mm)**
Width of ground	Wg	24
Length of ground	Lg	24
Height of ground	Hg	0.015
Height of substrate	Hs	2.5
Length of patch	Lp	8
Width of feed line	Wf	2.056

3. Results and Discussion

Return loss, VSWR, and bandwidth—all crucial factors for satellite communication applications—were assessed for the suggested C-type microstrip patch antenna. The antenna achieves a return loss of -42.4 dB, which is far better than the reference design (-30.7 dB), according to simulation findings, showing excellent impedance matching.

A near-perfect match and little signal reflection were indicated by the SWR of 1.013. Additionally, this antenna offers a wide operational bandwidth of 0.836 GHz, which is substantially greater than the reference bandwidth of 0.143 GHz, resulting in better signal coverage and stability. The findings verify that the C-shaped structure successfully enhances antenna performance in these crucial domains. Although the gain is slightly lower than the reference, the gains in adaptability and throughput make the design very appropriate for Ku-band satellite applications. This antenna offers dependable satellite communications and has a well-focused emission pattern. Overall, the proposed design shows better efficiency and promise for practical implementation.

Table 2: Return loss Comparison

Antenna Type	Return Loss
Reference Patch Antenna	-30.7dB
Proposed Antenna	-43.4003dB

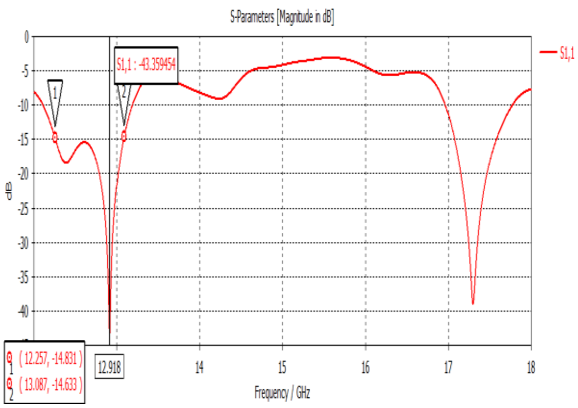

Figure1 Return loss of Proposed MPA

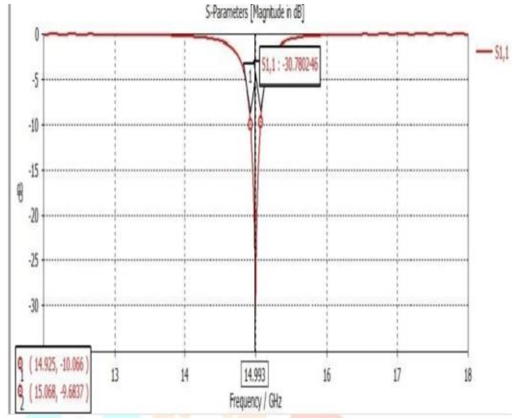

Figure2 Return loss of reference MPA

Conclusion

In this study, a C-type microstrip patch antenna was built and investigated for Ku-band satellite communication applications. The suggested design performs traditional reference patches in these crucial areas with its excellent return loss (-42.4 dB), near-perfect impedance matching (VSWR = 1.013), and broad operational bandwidth of 0.836 GHz. Although the strength of the suggested C-type antenna (5.21 dB) is slightly lower than that of the reference design (6.30 dB), the enhanced bandwidth, return loss, and VSWR make the proposed design a reliable and efficient solution for satellite communication systems. Improved impedance matching and wideband performance enable robust and efficient signal transmission, making it suited for today's satellite communications requirements. Overall, the study shows that the C- Shaped Microstrip patch antenna, which offers better matching, a large bandwidth, and dependable operation, is a viable option for satellite applications.

Future Work

The gain of the proposed C-shaped microstrip patch antenna is marginally lower than that of the reference design, despite its outstanding return loss, VSWR and wide bandwidth. Future studies can focus on using techniques like array topologies, parasitic elements, or stacked patches to increase the gain. To verify the simulation results in real-world situations, the antenna can also be built and measured. In order to handle diverse satellite frequency bands, the design can also be optimized for multi-band operation. Compact and miniaturized versions can be produced for small satellite terminals. Finally, combining the antenna with satellite communication systems could improve coverage and link performance. These techniques will guarantee that the antenna is practical and incredibly effective for contemporary satellite applications.

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