High-Performance Ka-Band Microstrip Patch Antenna for Next-Generation Networks at 33 GHz

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***Abstract*—A proposed microstrip patch antenna, powered through microstrip feeding and tailored for Ka-band applications (30–40 GHz), signifies a notable advancement in antenna technology. This work is particularly pertinent to next-generation network applications, with a specific focus on the frequency of 33 GHz. The antenna is fabricated using the Rogers RT/Duroid 5880TM substrate, renowned for its distinct attributes. Notably, it boasts a remarkably low dielectric loss tangent of 0.0009, coupled with a relative permittivity of 2.2 and a thickness measuring 1mm. These characteristics render it well-suited for antennas necessitating minimal signal attenuation, effective concentration of electromagnetic waves, and meticulous dimensional management. Simulation and thorough analysis of the antenna's performance have been conducted using Ansoft HFSS. This comprehensive assessment of radiation performance parameters is crucial to ensure that the microstrip patch antenna functions effectively within the specified Ka band frequencies, thus aligning with the requirements of next-generation network applications.**

***Index Terms*—Ka-band, Microstrip patch antenna, Next generation networks**

I. Introduction

Antennas play a pivotal role in contemporary mobile communication systems. The demand for multiband and lowprofile antennas in wireless communication systems, especially at 30 GHz to 40GHz, is essential for both industrial and military applications [1]. The proliferation of mobile communication systems has grown significantly in recent years [2] Understanding the role of antennas is imperative in any discussion of communication systems. Antennas are critical in mobile devices due to their compact size, lightweight nature, and cost-effectiveness [3]– [9]. Wireless technology is a focal point in the realm of communication systems, enabling the development of portable and mobile devices. This technological progress has greatly influenced the design of microstrip patch antennas [2], [4].In contemporary wireless applications, a variety of antennas are utilized; however, microstrip antennas, such as rectangular and circular patch antennas, are particularly esteemed for their effectiveness in microwave communications. [3].

The continuous advancements in telecommunication technology are leading to the integration of networks and services, giving rise to the concept of Next Generation Networks (NGN) [5]. Antennas are crucial components in modern mobile communication systems. There is a growing need for multiband and low-profile antennas in wireless communication systems, particularly at frequencies such as 28 GHz, to cater to the requirements of both industrial and military applications. The proliferation of mobile communication systems has grown significantly in recent years.Reference [10] describes a compact stair-step multi-finger capacitive arrangement tailored for 30 GHz millimeter-wave operations. This setup achieves a gain of 6.4 dBi and an impressive radiation efficiency of 97 percentage. In reference [11], a novel SWB (Stepped- Wedge Bowtie) antenna is proposed, achieved by combining geometric shapes with a defected ground surface. It covers a broad frequency spectrum spanning from 0.7 to 18.5 GHz. with exceptional characteristics such as ECC (Envelope Correlation Coefficient) of 0.12, isolation exceeding 30 dB, and a directive gain of approximately 9.8 dBi. This antenna is particularly suitable for portable devices in the UWB, K, and Ku bands. Reference [12] describes a broadband mm-wave MIMO antenna system for 5G networks.

The demand for high-performance communication systems in next-generation networks has driven the development of

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advanced antenna technologies operating at higher frequencies. This research addresses this need by presenting the design and comprehensive analysis of a high-performance Ka-Band microstrip patch antenna specifically tailored for Next-Generation Networks (NGNs) at the crucial frequency of 33 GHz. The antenna is crafted with a Rogers RT/Duroid 5880™ substrate, distinguished by its precise attributes: a dielectric loss tangent measuring 0.0009, a relative permittivity of 2.2, and a thickness of 1mm.. The selected frequency range of 33 GHz aligns with the requirements of NGNs, making the proposed microstrip patch antenna well-suited for emerging communication applications. Microstrip feeding is employed in the antenna design, contributing to its enhanced function ality within the Ka-Band (30–40 GHz) spectrum. To ensure a thorough evaluation, simulation and comprehensive analysis of the antenna's performance are conducted using Ansoft HFSS. This study significantly contributes to the understanding of the antenna's capabilities and its alignment with the stringent demands of NGNs. The robust methodology employed in the design, coupled with the detailed analysis of radiation parameters, ensures the antenna's effectiveness in the specified frequency range. This work is a critical step forward in advancing communication technologies for the evolving landscape of next-generation networks. The mm-wave spectrum is considered a vital technology for 5G communication, with several mm-wave bands being explored by researchers worldwide.

Various frequency bands are utilized for wireless communication, including the 28 GHz band spans from 27.5 to 29.5 GHz, the 38 GHz band ranges from 36 to 40 GHz, the 60 GHz band covers frequencies from 57 to 64 GHz, and the E-band operates within the ranges of 71–76 GHz and 81–86 GHz. [13]. In the context of these bands, a novel antenna with 4 x 4 dual-band MIMO antenna, specifically tailored for operation within the 28 and 38 GHz frequency bands, is presented in the cited reference [14]. This antenna boasts wide bandwidths of 14.3% and 5.26% at the respective frequencies. To enhance isolation between antenna elements, a circular patch Electromagnetic Band Gap (EBG) cells are integrated into the design, contributing to improved overall performance.

II. Antenna Design

The design of the antenna involves the utilization of Rogers RT/Duroid substrate, with dimensions of 8 mm x 8 mm, featuring a relative permittivity (ϵ_r) of 2.2 and a loss tangent (tan(δ)) of 0.0009. The substrate maintains a height of 1 mm, while the incorporation of a defected ground structure aims to reduce ground dimensions on the underside. As depicted in Fig. 1, the antenna is compact, and its optimized parameters are outlined in Table 1. A square patch featuring a rectangular slot, this design simplifies the microstrip antenna structure and reduces overall costs.

Unlike traditional microstrip antennas that exhibit a single resonance, limiting bandwidth, this design intentionally resonates at multiple frequencies, enhancing broadband performance. The resonance frequencies manifest as dips in the return loss curve, indicating sustained resonance for Ka-band frequencies.

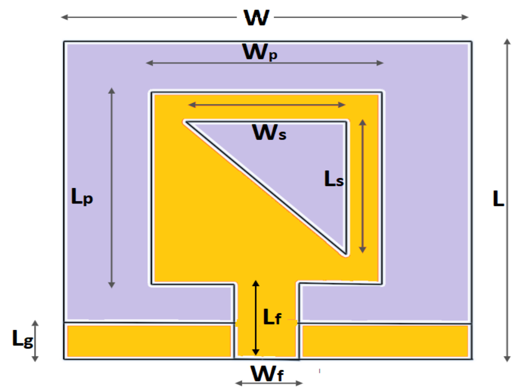

Fig. 1. The proposed Ka - band atnenna

TABLE I
THE OPTIMIZED KA-BAND ANTENNA PARAMETERS

Parameters	Units (mm)	Parameters	units (mm)
L	8	L_f	2
W	8	W_f	1.4
L_p	5	L_s	3.5
W_p	5	W_s	3.5
h	1	L_g	1.7

The antenna design process, outlined in Figure 2, involves three steps:
step 1:Initiating with antenna 1, a square patch of dimensions 8 x 8 mm ^{2} resonates within the frequency band of 32.3 GHz to 39 GHz.
step 2: To enhance the impedance bandwidth, portions of square patch antenna 1 are removed to create antenna 2, but Fig. 3 shows that the impedance bandwidth remains poor.
step 3: Introducing a triangular slot in the square patch antenna causes resonance at 34.6 GHz with approximately -41 dB return loss. Although Ka-band is not yet achieved, further optimization of the triangular slot with specific parameters is conducted to improve Ka-band frequencies. The design steps, along with return loss versus frequency (Fig. 3), depict the evolution of the antenna design.

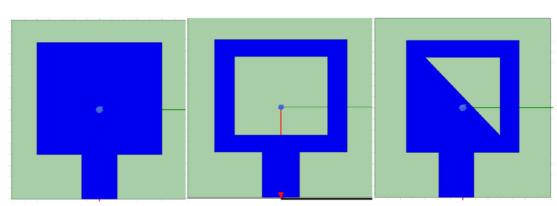

Fig. 2. The design steps for the proposed Ka - band antenna

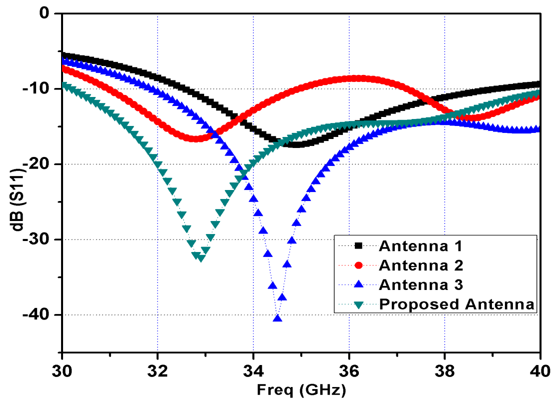

Fig. 3. Return loss (S_{11}) in dB versus frequency for the proposed Ka-band antenna

III. RESULTS AND DISCUSSION

The Ka-band antenna is developed by introducing a triangular slot into the square patch antenna. In Figure 4, the impact of varying the slot length (Ls) on the antenna's performance is depicted. As the value of Ls is adjusted incrementally from 2.25 mm to 3.5 mm, in steps of 0.25 mm, resonance within the 30 GHz - 39 GHz range is observed. When Ls is set to 2.5 mm, resonance is observed at 33.6 GHz, showing a return loss dip of -49 dB, signaling the necessity for increased bandwidth. Subsequent analysis reveals that the optimal length for the triangular slot is 3.5 mm.

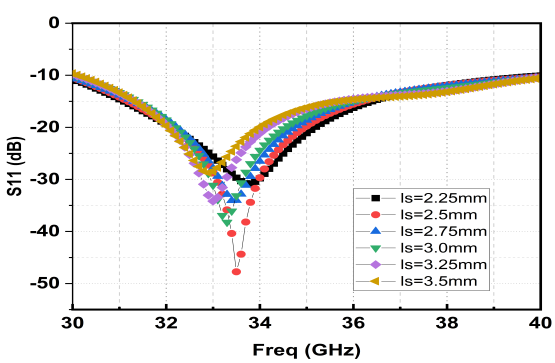

Fig. 4. Effect of (Ls) triangular slot in square patch antenna.

Likewise, Figure 5 demonstrates the impact of adjusting the slot width (Ws) within the range of 2.25 mm to 3.5 mm, in increments of 0.25 mm. The graph reveals that the maximum impedance bandwidth is achieved when Ws is set to 3.5 mm. The 50-ohm antenna impedance is obtained through the feed line. Figure 6 demonstrates the variation in feed line width (Wf) from 1 mm to 1.6 mm in steps of 0.1 mm, revealing that the optimal width is 1.4 mm. The feed line, positioned at the substrate center, significantly influences performance, with optimal results observed when g (offset from center) is 0 mm. Figure 7 indicates that the best match for the feed line occurs when g is 0 mm. The triangular slot

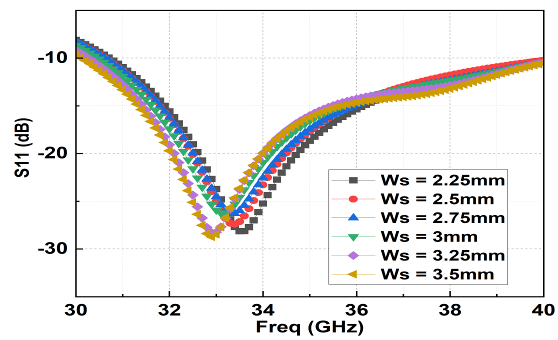

Fig. 5. Effect of (Ws) triangular slot in square patch antenna.

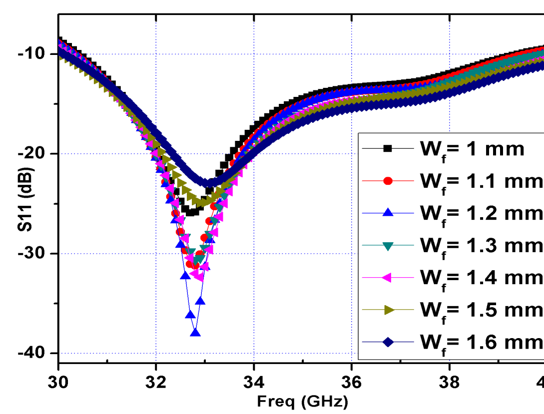

Fig. 6. Effect of Wf for the Ka- band antenna .

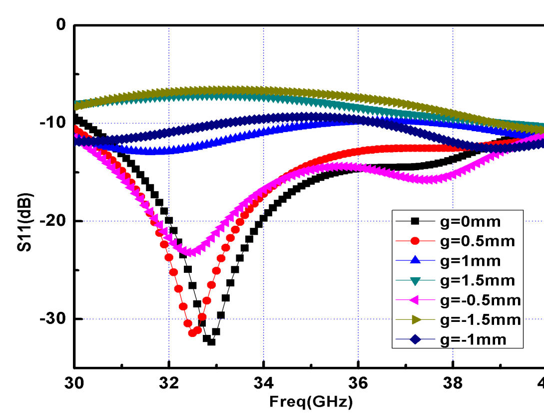

Fig. 7. Effect of g for the Ka-band antenna.

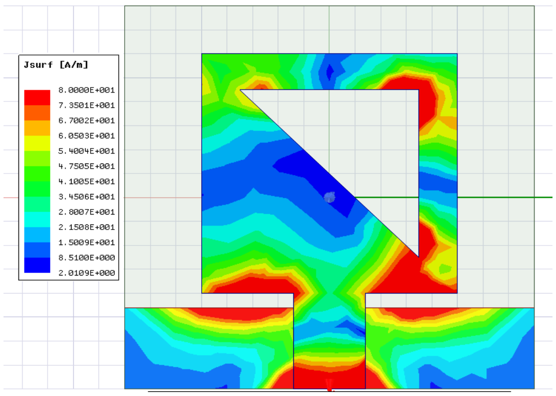

Fig. 8. Surface current at 33 GHz.

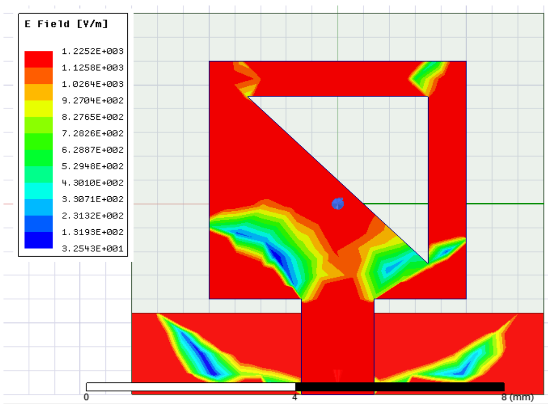

Fig. 9. E-field at 33 GHz.

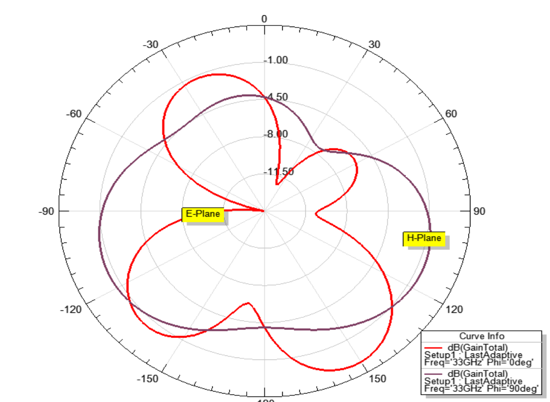

Fig. 10. Radiation pattern at 33 GHz.

supports a maximum surface current of 80 A/m, as shown in Figure 8. Additionally, Figure 9 displays electric field lines passing through the entire triangular slot, with a maximum electric field of 1.2252 kV/m.This emphasizes how essential the triangular slot is in achieving a broad frequency response, particularly with resonant points occurring at 33 GHz.

The E-plane and H-plane radiation patterns resemble the numerals eight and an omnidirectional shape, respectively, while the gain information in Figure 10 demonstrates that the proposed Ka-band antenna is well-suited for Ka-band frequency applications.

IV. Conclusion

The presented design and comprehensive analysis aim to contribute to the advancement of antenna technology, particularly in the context of next-generation networks operating at the Ka-Band frequency of 33 GHz. The utilization of advanced materials, precise geometrical design, and microstrip feeding techniques are expected to result in a high-performance antenna well-suited for the evolving landscape of communication systems. The insights gained from the simulation and analysis are crucial for ensuring the antenna's reliability and functionality in practical applications within the specified frequency range.

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