Ultra-Wide Band Microstrip Patch Antenna for Millimetre-Wave Band Applications

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Abstract This paper presents the design for a compact microstrip patch antenna that operates in the Ka band with dimensions (13 × 13) mm^2 and is applicable for 5G communication. The antenna resonates at a central frequency of 34.2 GHz, providing a gain of 7.5 dB. It comprises of a partial ground structure in order to provide a large bandwidth ranging from 24.1 to 49.9 GHz. This antenna has been simulated on Ansys HFSS 19.1 using Rogers RO4003, of dielectric constant 3.55, as the substrate.

Keywords 5G · Ka band · Millimetre Wave (mmWave) · Partial grounds · Ultra-wide band · Ansys HFSS

1 Introduction

Since its introduction in the 1970s, wireless communication has come a long way with its incredibly rapid advancements, slowly transforming the society into a fully connected network [1]. Consequently, this increases the demand for antennas that yield better performances in terms of the antenna size, gain, bandwidth, cost and data rate [2]. Hence, 5G or the fifth generation of wireless communication is proposed in order to obtain high data rate. Millimetre-wave band or the Ka band, that occupies the frequency spectrum from around 30–300 GHz in the electromagnetic spectrum, is suitable for 5G as it can provide a relatively larger absolute bandwidth. And most of it still needs extensive exploration [3]. It provides a bandwidth that is almost ten times more than what the 4G or the fourth-generation cellular band offers, and a higher bandwidth is required in order to reduce the amount of path loss [4, 5]. Small and low-profile antennas are optimum for mobile communication and microstrip patch antennas qualify this criterion. However, they have their own merits and demerits over

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M. Tiwari et al. (eds.), *Optical and Wireless Technologies*, Lecture Notes in Electrical Engineering 771, https://doi.org/10.1007/978-981-16-2818-4_53

the conventional antennas. Microstrip patch antennas are less expensive, low profile as aforementioned, can operate at multiple frequencies and are easy to fabricate; however, gain and efficiency are significantly low with larger losses [6]. A few of the techniques useful in order to overcome the shortcomings posed by the microstrip patch antennas have been discussed in [2]. Several designs have been explored for further enhancements in the field of 5G wireless communication. A small microstrip patch antenna resonating at millimetre-wave frequency (i.e. 28 GHz) was presented in [5], while antenna arrays were used in [7, 8]; ideal for 5G applications. In this research, a simple patch antenna for millimetre-wave band application has been proposed for 5G communication. High-frequency material, Rogers RO4003, has been used as a substrate and the antenna results have been validated using Ansys HFSS.

2 Proposed Antenna Design

In this section, the structural geometry and configuration of the design have been presented. The proposed antenna has been designed on a Rogers RO4003 substrate of thickness 1.52 mm and a relative permittivity (ε_r) of 3.55 compatible for radiation in high frequencies while both the ground and the patch are 0.035 mm thick, and the conducting material used here is PEC. The dimensions of the substrate are 13 mm × 13 mm × 1.52 mm, and Fig. 1 presents the geometric parameters of the antenna while their corresponding lengths have been listed in Table 1. The structure of the ground is one of a partial ground, as shown in Fig. 1**,** and it plays a very crucial role in increasing the bandwidth of the antenna.

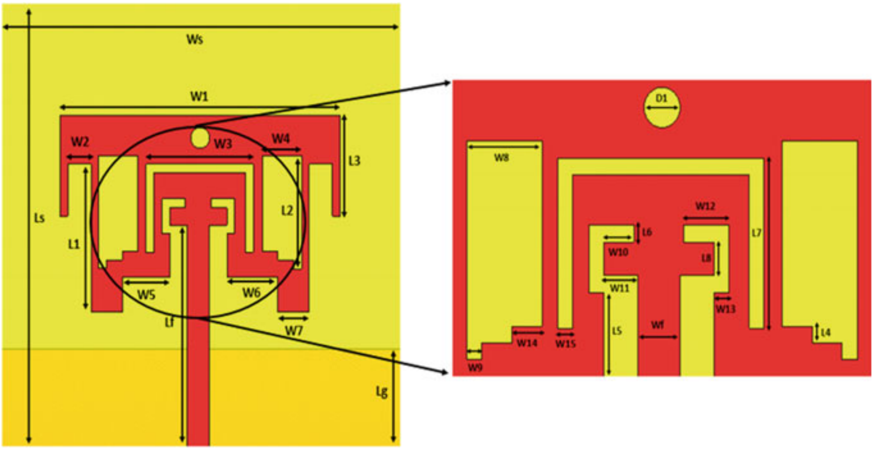

Fig. 1 Geometry of the proposed antenna

Table 1 Parameters of the proposed antenna

Parameter	Value (mm)	Parameter	Value (mm)	Parameter	Value (mm)
*L*1	4.25	*Lg*	2.95	*W*5	1.53
*L*2	3.25	*Ws*	13	*W*6	1.64
*L*3	2.9016	*Wf*	0.7	*W*7	1
*L*4	0.25	*D*1	0.6	*W*8	1.25
*L*5	1.25	*W*1	9	*W*9	0.25
*L*6	0.25	*W*2	0.75	*W*10	0.5
*L*7	2.53	*W*3	3.435	*W*11	0.565
*L*8	0.5	*W*4	1.25	*W*12	0.75
Ls	13			*W*13	0.25

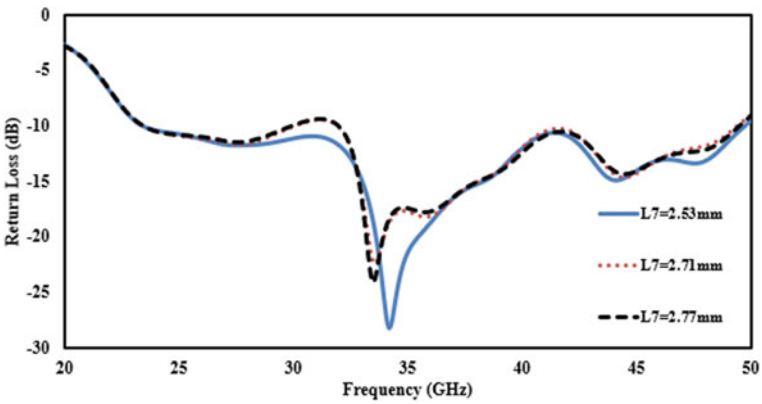

Fig. 2 Effects of L7 on antenna performance

2.1 Parametric Analysis

2.1.1 Effects of Variation in L7

The analysed results for variations in L7 have been shown in Fig. 2. We notice that the change has a slight difference in the return loss but a significant variation in the −10 dB bandwidth. Based on this, L7 = 2.53 mm has been chosen since this parametric value provided the best bandwidth and return loss.

2.1.2 Effects of Variation in D1

Figure 3 depicts the variation of S_{11} parameters for different values of D1. As we can notice, change in D1 influences the return loss. From Fig. 4, we notice that as D1

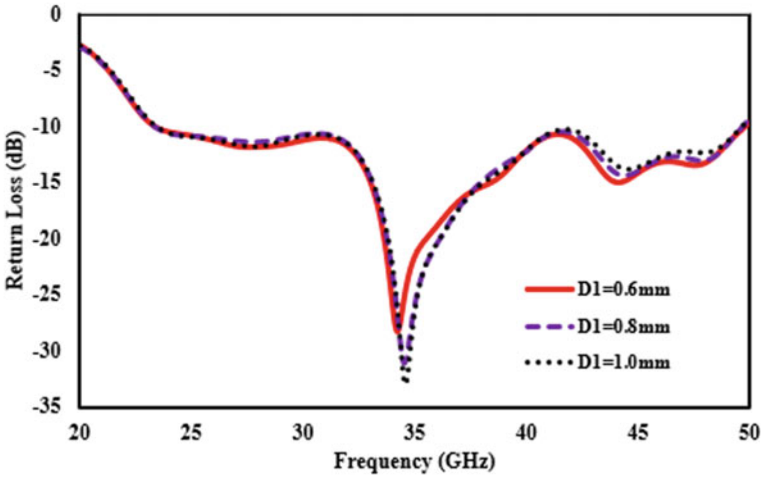

Fig. 3 Effects of D1 on antenna performance

increases, the upper band in the graph slightly shifts to the lower side. However, we choose $D1 = 0.6$ mm as the most appropriate dimension due to the best impedance matching it offers.

3 Result Analysis

In this paper, an ultra-wide band antenna using Rogers RO 4003 as the substrate and PEC as the conducting material was designed using the concept of partial grounds in order to obtain a fractional bandwidth of 69.72% from 24.01 to 49.9 GHz. The antenna provides a gain of 7.5 dB at the central frequency, i.e. 34.2 GHz and a peak gain of 8.01 dB, and a maximum return loss of 28.42 dB. The simulated results of the S_{11} parameters and the gain are reported in Fig. 4.

Some of the previously published work on the millimetre-wave band has been shown in Table 2. In this table, it is clearly visible that the proposed design has a wide bandwidth and compact size.

4 Conclusion

A wide band microstrip patch antenna with a compact structure has been proposed in this paper. With the help of using partial grounds, a fractional bandwidth of 69.72% was achieved while varying the length L7 helped match the impedance to 48.9 Ω. Due to its good radiation characteristics and an exceptionally large bandwidth from

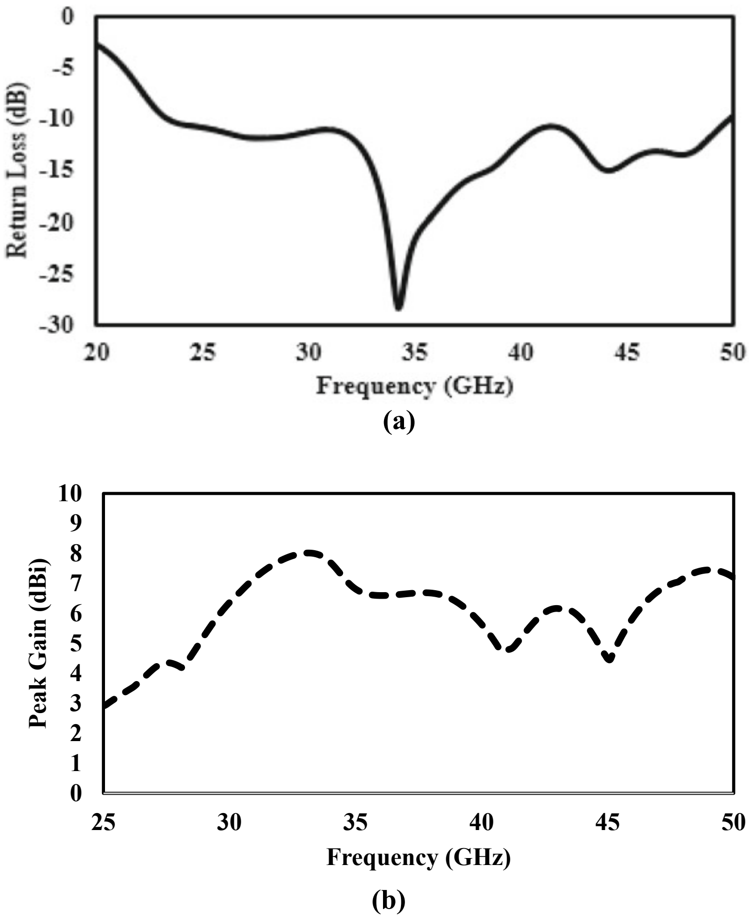

Fig. 4 Simulated results **a** return loss S_{11}, **b** peak gain plot

Table 2 Comparison of proposed design with the previous work

References	Size (mm^2)	Gain (dB)	Frequency (GHz)	Return loss (dB)	Bandwidth (GHz)
[2]	6 × 6.25	6.9/7.4	38/54	15.5/12	1.94/2.05
[5]	5.5 × 4.5	6.72	28	18.25	1.1
[9]	41.3 × 36	13	28.4	30	11.8
[10]	15.8 × 13.1	4.06	28	20	-
[11]	20 × 20	12.48	28	30	2.4
This work	13 × 13	7.5	34.2	28.42	25.8

24.1 to 49.9 GHz with return loss better than 25.8 dB, this antenna can be used for 5G communications in the millimetre-wave band spectrum.

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