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An Inset and CPW Fed Slotted Patch Antenna at 38 and 60 GHz bands for 5G Wireless Communications

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ABSTRACT

A compact dual band millimeter wave slotted patch antenna resonating at 38-43 GHz and 57-64 GHz bands is proposed. The patch is excited by different feed mechanisms like inset feed and grounded coplanar waveguide (cpw) feed giving very good impedance matching at the two 5G frequencies. Attained return loss and gain was found to be higher than related works in literature. The antenna was etched on thin RT Duroid substrate of minimum loss tangent so as to get maximum performance with minimum loss. This antenna is a promising candidate for next generation 5G applications.

KEYWORDS: Millimeter Antenna, 5G, Inset feed

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INTRODUCTION

The growth of wireless technology has been at a tremendous pace over the past few decades. First generation wireless technology employed analog signals which had security issues. This could be overcome by 2G which enabled short messaging service and 3G which facilitated multimedia transfer and video calling. With the advent of 4G, data rate increased to around 1 Gigabyte per second for stationary users and 100 Megabytes per second for mobile users.

The emergence of 5G technology, will, no doubt, revolutionise the face of wireless communication. Fifth generation technology will offer increased data rate (10 Gigabytes per second), wide coverage, reduced energy consumption and low latency or data transfer time (1 millisecond). The currently used wireless spectrum of sub-6 GHz frequencies has become overcrowded and will not be able to handle the increasing number of users. So millimetre frequencies ranging from 30 GHz to 300 GHz offer a convincing solution to accommodate the increasing mobile traffic. Frequency spectrum allotted for 5G mobile communication in India are the bands ranging from 24.25 to 29.5 GHz, 37-43 GHz and 60-67 GHz. Here comes the role of millimetre wave antennas which are highly compact with a reasonable radiation efficiency. This paper discusses the development of a millimeter wave antenna whose resonant frequencies fall in the above-mentioned 5G bands.

PREVIOUS RELATED WORK

Yassine et.al [5] proposed a millimetre wave antenna of dimensions 20 mm x 20mm x 1.6 mm on FR4 substrate with microstrip feed. Return loss of -18.27 dB was attained at 10.15 GHz with a gain of 4.46 dBi. But FR4 substrate is too lossy at high frequencies. [6] proposed a dual band antenna of dimensions 19 mm x 19 mm x 0.787 mm on RT Duroid with microstrip feed yielding return loss and gain values of – 28 dB and 5.5 dBi at 10.15 GHz and -25 dB and 8.03 dBi at 28 GHz respectively. Shivangi et.al [7] came up with a dual band antenna of dimensions 11mm x 8 mm x 0.5 mm on RT Duroid with inset feed which resonated at 28 GHz (return loss of -21 dB) and 50 GHz (return loss of -31 dB). Attained gain was 4.46 dBi.

Our proposed antenna has dimensions 10 mm x 10 mm x 0.254 mm and to the best of our knowledge, is the first dual band millimeter wave antenna resonating at 37- 40 GHz and 60-67 GHz bands. A very good return loss of upto -45 dB could be attained along with a gain of 7.87 dBi.

DESIGN AND SIMULATION

An inset fed and CPW (coplanar waveguide) fed dual band slotted patch antenna are etched on Rogers RT Duroid 5880 substrate of thickness 0.254 mm, dielectric constant 2.2 and loss tangent 0.0009 as shown in figure 1a and 1b. RT Duroid has been opted as the substrate material due to its low loss tangent. At high frequencies, it is better to use thin substrates with low loss tangent. CPW feeding method is superior to microstrip feeding as it has less radiation leakage and dispersion. Coplanar structure of CPW facilitates easy integration of shunt and series components into antennas. The optimised dimensions of the patch using CST Microwave Studio are tabulated in Table 1. All dimensions are in mm.

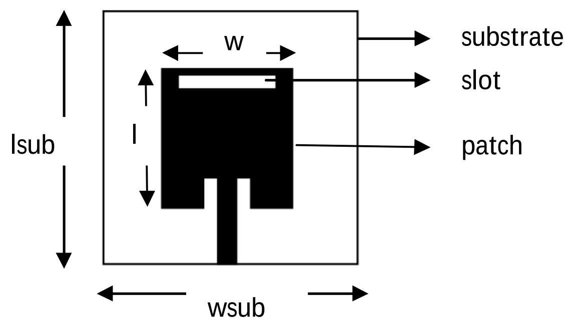

Figure 1a. Inset Fed Millimetre Wave Antenna

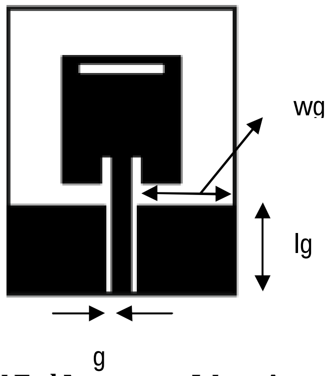

Figure 1b.CPW Fed Millimetre Wave Antenna

Table 1: Dimensions of the Patch

Parameters	Value (mm)
Patch length (l)	5.57
Patch width (w)	5.2
Slot length	3.8
Slot width	0.5
Feedline length	3.415
Feedline width	0.8
Inset length	1.2
Inset width	0.5
Cpw gap (g)	0.3
Cpw ground length (lg)	3.8
Cpw ground width (wg)	4.3

The unslotted patch resonated at 52 GHz with broadside radiation pattern. As current distribution is maximum in proximity to the top radiating edge, cutting a slot close to that edge was found to modify the current paths to achieve desired resonant frequencies Its surface current distribution is modified and the fundamental resonant mode of the patch is disturbed to introduce two new frequencies at 5G band, one at the lower end (38.5 GHz) and other at the higher end (61 GHz) supporting TM10 and TM02 modes respectively. Both frequencies fall in the allocated 5G spectrum. While 37-40 GHz band has the advantage of less atmospheric attenuation of signals, 57-64 GHz band offers high speed secure data transfer and WiFi.

SIMULATION RESULTS

Return loss characteristics, surface current, farfield radiation pattern and radiation efficiency of the millimetre wave antenna for both feeds are analysed in this section.

Return Loss

The scattering parameter S11 is an indication of the amount of power reflected from the antenna. For the proposed antenna, S11 was found to be -45.56 dB at 38.48 GHz and -40.04 dB at 61.05 GHz as shown in Figure 2. So there is good impedance matching at the above-mentioned frequencies.

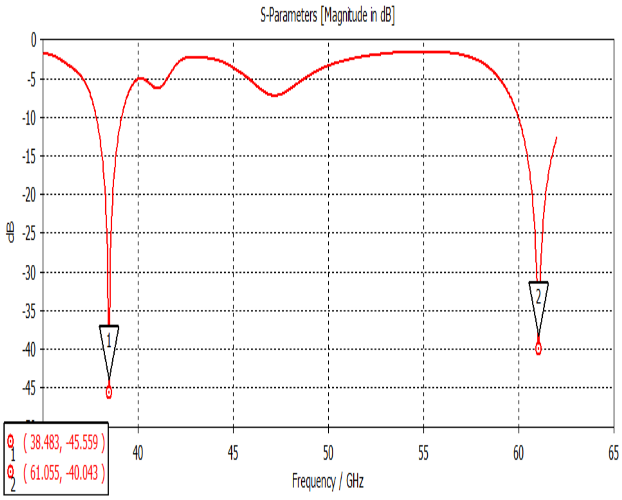

Figure 2 Simulated Return Loss Curve for Both Feeds

Surface current and Radiation pattern

In the unslotted patch, maximum surface current was concentrated close to the top radiating edge. After cutting the slot, patch resonated at desired frequencies. Electric field is normal to patch surface. Dominant mode is TM mode. In TMmn notation, m and n represent the number of half wave variations in x and y direction respectively. Surface currents and farfield patterns associated with resonant frequencies of 38.4 GHz and 61.05 GHz are illustrated in figures 3, 4a and 4b respectively.

TM10 mode was observed at 38.4 GHz with broadside radiation pattern of directivity 7.87 dBi. A higher mode TM02 could be observed at 61 GHz with radiation pattern of directivity 5.997 dBi. Being a higher order mode, it exhibits some endfire characteristics.

Figure 3 Surface Currents at 38.5 GHz and 61 GHz

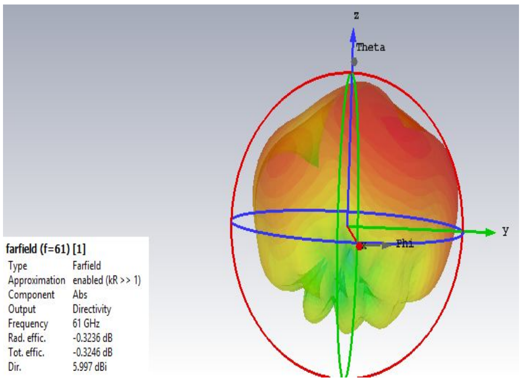

Figure 4a Farfield 3D Pattern at 38.5 GHz

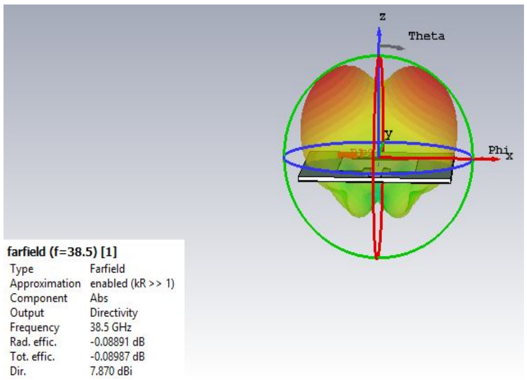

Figure 4b Farfield 3D Pattern at 61 GHz

Simulated radiation efficiency of the proposed antenna was found to be 97.97% at 38.5 GHz and 92.8% at 61 GHz .

Effect of Substrate Thickness

RT Duroid substrate of different thicknesses (h=0.254 mm, 0.8 mm and 1.6 mm) were analysed to understand its influence on resonant frequency and efficiency of the antenna at millimeter frequency range.

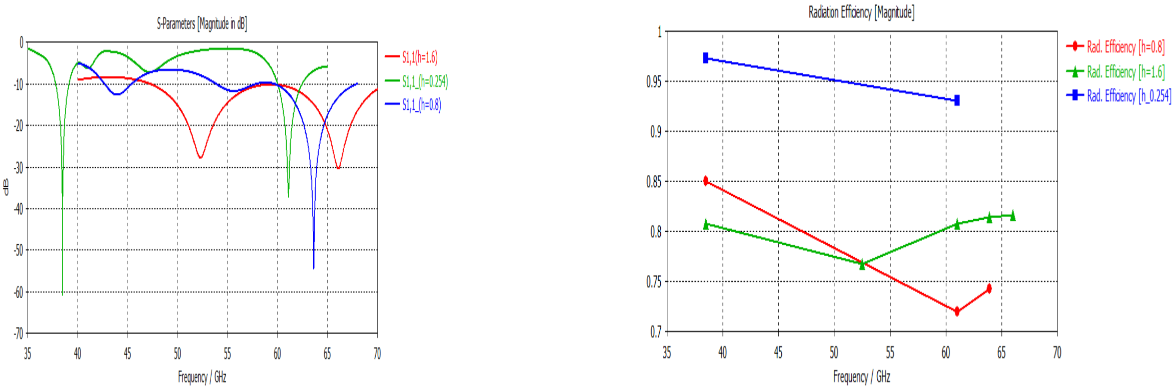

Figure 5 Effect of Substrate Thickness on Return Loss and Radiation Efficiency

As observed from figure 5, choosing minimum substrate thickness gives maximum radiation efficiency and better impedance matching at desired resonant frequencies.

Effect of Substrate Dielectric Constant

Substrates of different dielectric constants and loss tangents were analysed to observe their impacts on resonant frequency and radiation efficiency. As most of the substrates were available in standard thickness 0.8 mm, this value was kept constant. Analysed substrates were RT Duroid of ϵ_r= 2.2 and loss tangent at high frequencies, tan δ =0.0009, Rogers R04003 of ϵ_r= 3.55 and tan δ =0.002, FR4 of ϵ_r= 4.4 and tan δ =0.008 and Silicon of ϵ_r= 11.9 and tan δ =0.015.

Figure 6 Effect of Substrate Dielectric Constant on Return Loss and Radiation Efficiency

From figure 6, it is clear that substrates with low dielectric constant and minimum loss tangent gives maximum impedance matching and radiation efficiency at desired frequencies.

So RT Duroid 5880 having dielectric constant 2.2 and minimum loss tangent with thickness 0.254 mm has been chosen as the substrate material for the proposed millimetre wave antenna.

FABRICATED ANTENNA

The photograph of fabricated antenna is shown in figure 7. Fabrication is done through photolithography and subsequent etching on PCB. It is a highly compact dual band antenna which can radiate at 5G frequencies.1.85 mm coaxial connector was soldered and measurements were done using Agilent N5227A 67 GHz Vector Network Analyzer.

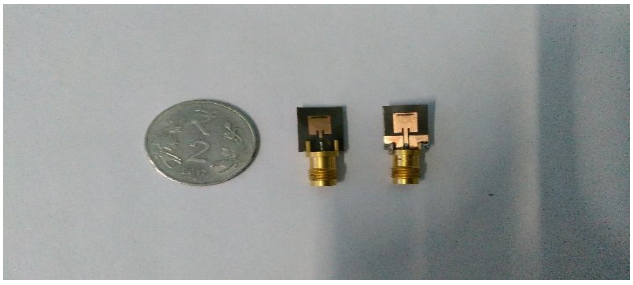

Figure 7 Fabricated Antenna

MEASURED RESULTS

Return loss curves in dB for frequency range obtained during measurement of both inset and cpw fed antenna from 67 GHz VNA are shown in figure 8. Measured results are almost in good agreement with simulated results. Slight shift in resonance frequencies may be attributed to extreme sensitivity of RF components at millimetre frequencies.

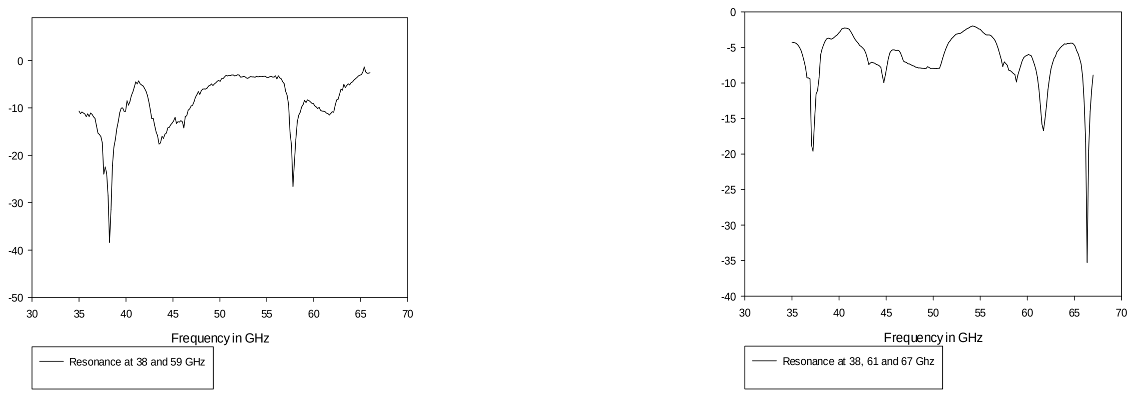

Figure 8 Measured Return Loss for Inset Fed and CPW Fed Antenna

CONCLUSION

The proposed millimetre wave slotted dual band patch antenna exhibited good return loss characteristics of the order of -45 dB in the 5G bands. Slot was introduced in proximity to the top radiating edge to produce two new frequencies by perturbing the current paths. Two modes could be observed, the one at lower frequency being TM10 yielding broadside radiation pattern and the one at higher frequency being TM02, a higher order mode, yielding partial broadside and partial endfire characteristics. A reasonable radiation efficiency could also be attained. As cpw fed antenna could yield all the desired characteristics with low radiation leakage enabling better integration of series and shunt components, it may be considered as a better candidate for millimetre wave applications.

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