International Journal of Innovation Scientific Research and Review
Vol. 06, Issue, 05, pp.6338-6341, May 2024
Available online at http://www.journalijisr.com
SJIF Impact Factor 2023: 6.599

ISSN: 2582-6131

Research Article

ENHANCING 5G CONNECTIVITY WITH MULTI-SLOTTED PATCH ANTENNAS: SUB-6GHZ AND SUB-7GHZ WIRELESS APPLICATIONS

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Received 05th March 2024; Accepted 06th April 2024; Published online 25th May 2024

ABSTRACT

This paper presents a low-profile multi-slotted patch antenna for fifth-generation (5G), Sub-6 GHz/Sub-7 GHZ and- long term evolution (LTE) communication applications. The studied antenna comprised of a stepped patch and a ground plane. The antenna is fabricated on an FR4 substrate with a relative permittivity of 4.3 and a thickness of 1.5mm. The simulated and measured results are in good agreement, which validates the design. The antenna has a size of 20*30*1.5 mm3 and is fed by a Microstrip line. To attain the required operating band, three slots have been inserted within the patch. The insertion of the slots enhances the capacitive effect and helps the prototype antenna to achieve an operating band ranging from 3.19 to 9.4 GHz (S11 less than 10 dB). The wide band antenna presented in this paper offers omnidirectional stable radiation patterns, good gains, and efficiency with a compact size which make this design an ideal contender for wireless fidelity (WiFi), wireless local area network (WLAN), LTE, and sub-6 GHz 5G communication applications.

Keywords: Antenna, Microstrip Patch, Multi-Slot, Wide Bandwidth, 5G, Sub-6 GHz, Sub-7 GHz.

INTRODUCTION

This research paper focuses on the design and implementation of a novel antenna solution, the” Multi-Slotted Patch Antenna,” tailored specifically for 5G applications within the sub-6GHz and sub-7GHz frequency bands. These frequency ranges are of paramount significance in 5G technology, offering an ideal balance between signal propagation and data capacity [1]. The Multi-Slotted Patch Antenna represents a crucial step forward in addressing the unique challenges posed by 5G wireless networks, including enhanced spectral efficiency, increased data throughput, and seamless connectivity in diverse environments [2-3]. The fifth generation (5G) of cellular networks is expected to provide a significant improvement in performance over previous generations, with peak data rates of up to 10Gbps and ultra-low latency. To support these requirements, 5G networks will use a variety of new technologies, including new radio frequency (RF) bands and new antenna designs. 5G has a valuable impact on the applications that lie under the characterization of high data rate, wide band width, and stable gain. The 5G network includes the frequency bands such as n77 (3.3GHz–4.2GHz), n78 (3.3GHz–3.8GHz), and n79

The Millimeter Wave offer slighting-fast data rates above 2Gbps and huge capacity, while the low-band offers good 5G coverage and mid -band offers a blend of both. It is clear that to attain the target of ultra -fast data rates, the use of a 5G millimeter Wave spectrum is desirable. However, some crucial challenges must be fulfilled before the implementation of mm Wave mobile communications. Before the finalization of mm Wave technology for 5G communications, sub-6 GHz is the go-to 5G technology in the near term. As the sub-6 GHz 5G communication can send high data rates over long distances, it is suitable to be used in both urban and rural areas.

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In the sub-6GHz band, the UK has already auctioneda3.4–3.6GHz band for commercial uses, and in the first quarter of 2020, they have a plan to adopt a 3.6–3.8 GHz band. In the mid-band, Italy, Spain, Romania, and Hungary have already deployed the 3.6–3.8 GHz band, France has started using the3.46–3.8 GHz band, Switzerland, Greece, Sweden, Finland and Ireland.

Table 1 Sub-6 GHZ 5g Frequency Bands For various Areas

Area	RangeGHz
USA	3.7-4.2
Europe	3.4–3.8
Japan	3.6–4.1 and 4.5–4.9
India	3.3–3.6
China	3.3–3.6 and 4.8–5
South Korea	3.4–3.7 and 3.7–4
Australia	3.4-3.7

ANTENNA DESIGN

The antenna is designed as multi-slotted and a partial ground plane as displayed in Figure1. The proposed design comprises a rectangular steeped radiator. The antenna is etchedonan FR-4 dielectric substrate having a thickness of 1.5mm with permittivity of 4.3 and a loss tangent of 0.02. The ground of the antenna plane with side length is on the back side of the double-sided substrate. Three slots have been made as W1 × L1,W2 × L2, and W3 × L3 are symmetrically placed on the patch of the antenna. The antenna is fed with a 50-ohm characteristic (4.4GHz–5.0GHz) for sub-6GHz5G applications [4]. For applications above 5 GHz, the n96 band falls under sub-7 GHz and ranges from 5.9 to 7.1GHz [5]. impedance and is matched along with the patch. The SMA connector is connected to the feed line for the excitation of the antenna.

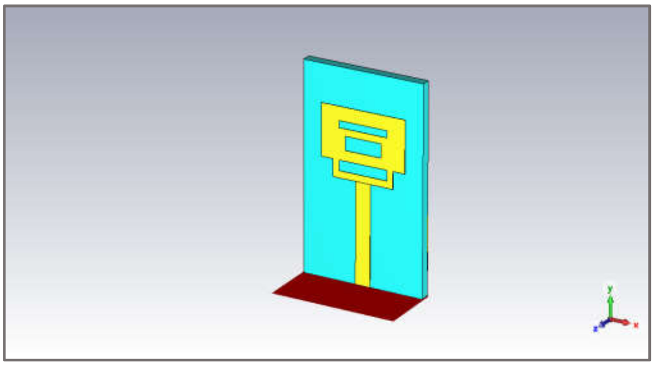

Fig.1. Antenna Design Structure

The details of the dimensions of the antenna are listed in table1. For the antenna to fulfill the requirements of the 6G/Sub-7G band operations, it must have multiple resonances in its respective operating band. To understand the working principle, the antenna radiating patch of size WP*(LP+L4) is a monopole antenna. The ground of the antenna has having dimension of Wg×Lg. The width of the ground is 20mm and the length of the antenna is13mm.

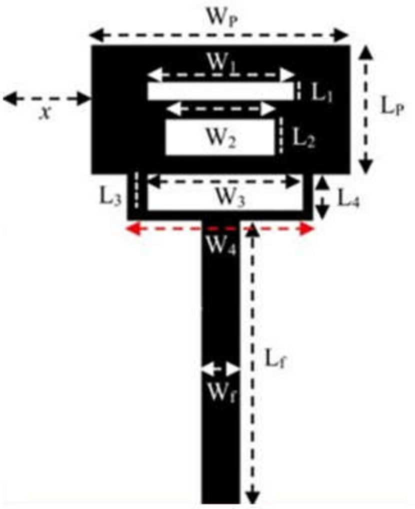

Fig.2. Antenna Design Structure

Table II Design Parameters Of The Proposed Antenna

Parameters	Valuemm	Parameters	Valuemm
Sbx	20	L3	1.5
Sby	30	L4	2.5
Antx	14	X	5.0
Anty	9.5	X1	3
W1	8	X2	3
W2	6	X3	4
W3	8	X4	4
W4	10	X5	1
Wf	2.5	X6	1
Lg	13	Y1	2
Lf	14.5	Y2	1
L1	1	Y3	1
L2	2	Y4	1

RESULTS AND DISCUSSION

The overall performance of the antenna is analyzed and optimized in CST Studio. The dimensional parameters of the studied antenna such has the size of the patch, slots, ground plane, and feed line are optimized to achieve the required sub-7G/6G band. The utilization of S-parameters is employed to articulate the connection between various ports, particularly in situations where it is crucial to characterizea network based on amplitude and phase frequencies, as opposed to voltages and currents. The simulated S-parameters with different values of width of the patch, WP. As the patch serves as the resonating circuit for upper frequencies, the width, WP can change the input impedance results in a variation of impedance bandwidth. It can demonstrate better S11 value with the wider operating band. The Simulated result of the maximum reflection coefficient is -22.13332 dB at 5.86497 GHz frequency. The antenna has a wide bandwidth from 3.101GHz to 9.403277 GHz comprising a 6.3GHz bandwidth.

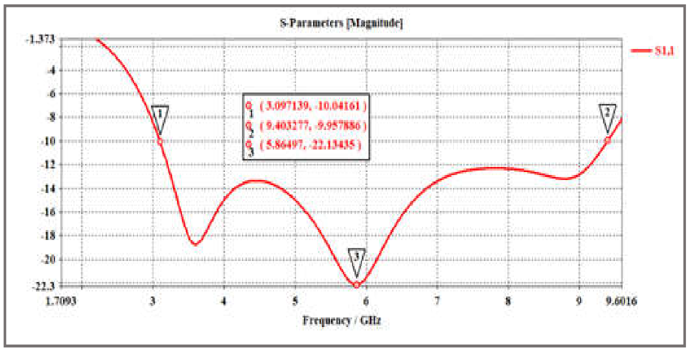

Fig.3. S11 Simulation results

To experimentally measure the performance a fabricated antenna is tested with a Vector Network Analyzer N5227A to measure the S,11. The measured result of the maximum reflection coefficient are -22.13332 dB at 5.86497 GHz frequency. This wide impedance band width can cover the existing 5G bands as well as all sub-6 G band applications. Discrepancies between the two outcomes primarily a rise from fabrication errors, imperfect soldering, and the influence of the RF feeding cable.

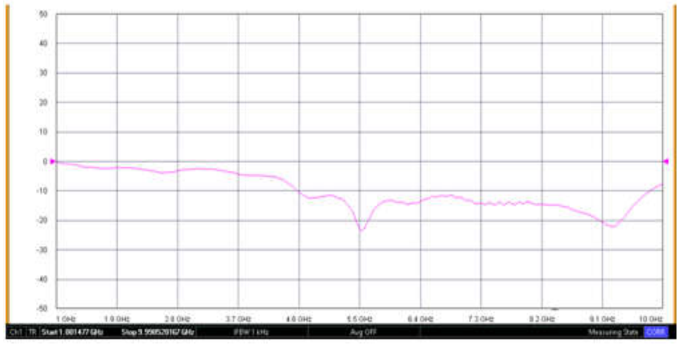

Fig.4. Measured results

A comprehensive parametric study has been conducted to examine the effects of different dimensional parameters on impedance matching characteristics. Since slot-3 primarily induces dual resonant modes to attain the necessary operating band, its dimensions and placement significantly impact antenna performance and are subject to investigation. At the same time, the effect of patch and ground plane size is also studied. The ground plane size is very sensitive in the designing of the wide band antenna. The radiation characteristics of the proposed antenna are measured in an anechoic chamber to measure the Far-Field radiation parameters.

Fig.5. Measurement of Fabricated Antenna in Anechoic Chamber

Directivity is a characteristic of an antenna or optical system that gauges the extent to which the emitted radiation is focused in a singular direction. The directivity of the antenna is 4.257 dBi at the resonating frequency is 5.8649 GHz. The measurement is shown in the figure.

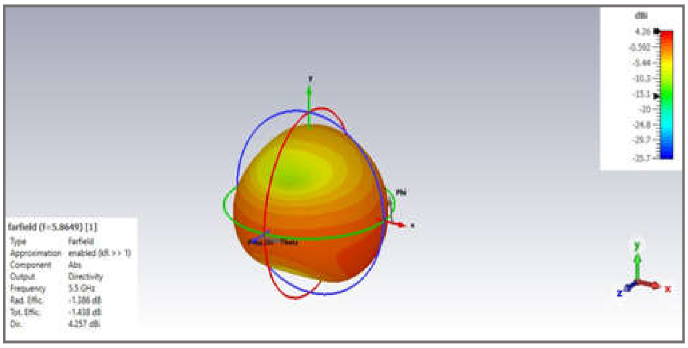

Fig.6. Directivity Pattern of the Antenna

The Gain of an antenna stands out as a crucial performance metric, amalgamating the antenna's directivity, radiation pattern, and the maximum radiation intensity it generates relative to that of alosslessi so tropic radiator powered at an equivalent level. The simulated Gain of the antenna measured at the resonating frequency is 2.871dBi. Obviously, the designed antenna is more compact than those

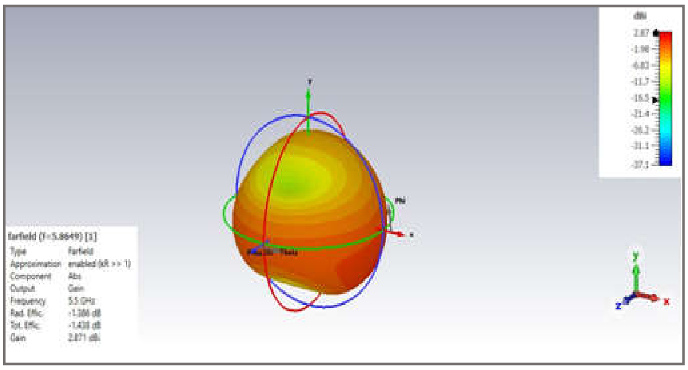

Fig.7.Gain Pattern of the Antenna

reported in [7–13,15,16] while maintaining wider operating band width sufficient to cover all the sub-6GHz 5G bands. Though some of the reported designs achieved higher gain and efficiency, their large size, complex structure, and 3D profile limit their uses in portable communications devices. Moreover, the antenna ere ported in [8,9,13,15] do not cover all the sub-6GHz bands.

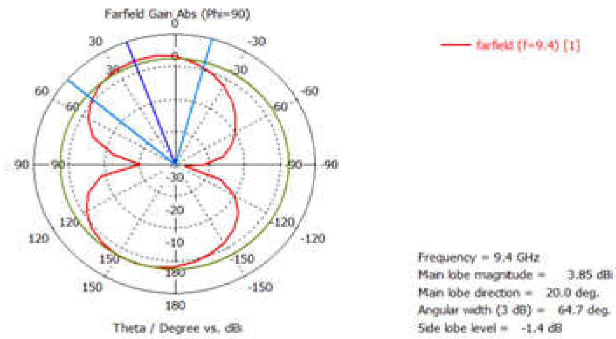

Fig.8. Simulated Results of Co-polarization Azimuth plane at 5.4GHz

The radiation patterns of the proposed antenna in the E-plane and the H-plane are measured at two resonance frequencies of 5.4 and 9.3 GHz. Figure11 demonstrates the measured and two-dimensional radiation pattern at 5.4 and 4.80GHz. From the plot, it can be observed that the designed antenna exhibits almost Omni directional radiation patterns with nulls in the bore-site directions. Moreover, the cross-polarization component is remark ably smaller than the co-polarized component. Despite some nulls, the designed antenna exhibits stable radiation pat- terns over the operating band which is a primary requisite for Sub/6G wireless communication applications.

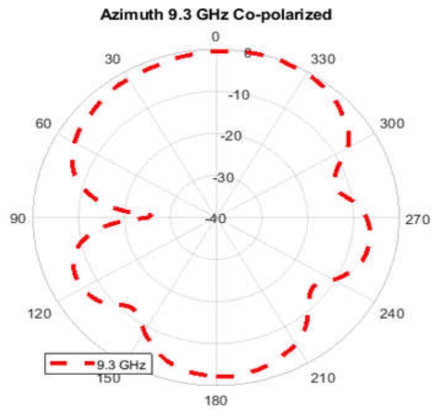

Fig.9. Measured Results of Co-polarization Azimuth plane at 9.3 GHz

In some cases, current may be distributed over a surface. For example, the radio-frequency current on a conducting patch of the antenna with sufficiently high conductivity can be modeled as a uniform surface current existing on the surface current distribution. The maximum surface current distribution is 75.5328A/m.

Table III Comparison Of The Proposed Antenna (Antenna-2) With Some Of The Previous Work

Ref.	Frequency GHz	Antenna Size mm*mm	Bandwidth GHz	Gain dBi
[6]	3.12	50*80	2.5	2.44
[7]	3.12	77*70.11	N/A	4.57
[8]	5.65	52.92*55.56	0.135	7.15
[9]	2.4	80*80	0.072	7.91
Proposed Work	5.86	20*30	6.3	2.87

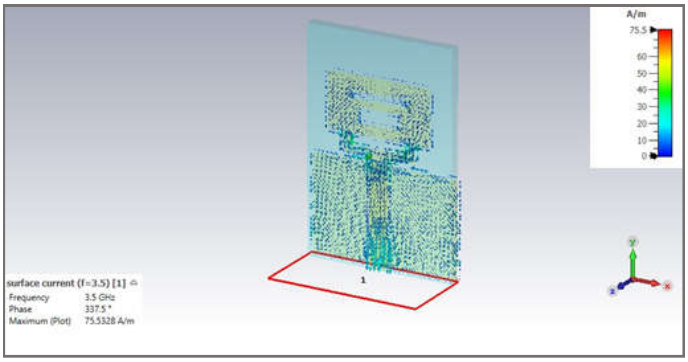

Fig.10. Maximum Surface Current Distribution

CONCLUSION AND FUTURERE COMMENDATION

A low-profile multi-slotted antenna for LTE and sub-6/Sub-7GHz, G 5G applications are designed, fabricated, and measured. The configuration of the suggested antenna consists of a stepped rectangular radiating element featuring three slots, and a partial ground plane, and is printed on both sides of an FR4 microwave substrate. The outcomes demonstrate effective coupling between the multi-slotted patch and from the results that the multi-slotted patch coupled well with the ground plane and the presented antenna can achieve a wide operating band of 3.1–9.4GHz, forth communications networks of Sub-6GHz/Sub-7GHZ,5G bands, WiFi, WLAN, and LTE bands of 22/42/ 43/46. The proposed antenna has a moderate gain of 2.87 dBi. This is lower than the gain of some other multi-slotted patch antennas, such as the antenna in [12], which has again of 7.17 dB. However, the proposed antenna is still capable of providing sufficient gain for 5G, Sub-6GHz/Sub-7GHz Wireless applications.

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