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An Omni-directional Rectangular Patch Antenna for 5G/WiFi/WiMAX Applications

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Abstract— This paper represents an omni-directional rectangular patch antenna for lower 5G/WiFi/WiMAX applications. The antenna is simulated by using CST v. 2018. The antenna is mounted on Rogers RT 5880 with thickness of 0.79mm, relative permittivity of 2.2, thermal conductivity of 0.2 [WK/m], loss tangent ($\tan \delta$) of 0.0009. The dimension of the antenna is $36 \times 31 \times 0.79$ mm³. It operates with a huge bandwidth of 3259.3 MHz, which exhibits the operating frequency range from 2.9971 GHz to 6.2564 GHz. The gain and the directivity are 3.011 dB and 3.499dBi at 4.08 GHz. The antenna shows VSWR of 1.041, average radiation efficiency of $\approx 93.2\%$ throughout the entire band. Considering all the characteristics, it can be regarded as a suitable candidate for lower 5G/WiFi/WiMAX applications.

Index Terms—5G; Rectangular patch antenna; Partial ground plane; omni-directional radiation pattern; CST.

I. INTRODUCTION

Wireless communication is now transitioning from fourth generation to fifth generation mobile technology for major leverage social transformations in education, industry, healthcare and other social improvements. Over the last few years, 5G innovation has become a great influence in the field of electromagnetic wave propagation, antenna theory and design. Hence, 5G technology is the latest generation of modern technology to grant excessive data rate, low latency, greater potential and in addition it gives appropriate satisfactory services. Since a microstrip patch antenna (MPA) has become a most remindful research subject due to its sustainable gain, larger bandwidth and lesser radiation loss parameter for 5G devices [1-2]. MPAs are widely used in 3G, 4G, 5G, WiFi, WLAN and WiMAX applications for its lightweight, cost effective, robust, dual polarization, support multiband and pinpoint control of radiation patterns [3-4]. The microstrip patch antennas have some limitations like narrow bandwidth, low gain and efficiency, additional radiation from feeds and junctions, and small power handling capacity [5-7]. The authors in [8] designed, tested and fabricated a low low-profile antenna for LTE and Sub-6 application having the size of $30 \times 20 \times 1.5$ mm³ based on FR4 substrate. The antenna possesses the frequency range from 3.15-5.55 GHz which covers all the 5G such as LTE, Sub-6 GHz, WiFi/WiMAX/lower 5G applications. In [9], a low-profile planar antenna was designed by using CST, with an overall size of $35 \times 20 \times 0.8$ mm³ and based on FR4 substrate. The

antenna gives the operating band from 2.99 - 5.89 GHz which covers the lower 5G band including WiFi/WiMAX applications. The antenna possesses high gain and the omni-directional pattern. A dual wideband dipole antenna and meta surface based MIMO system is presented in [10]. It has a size of $60 \times 60 \times 7.92$ mm³ and the corresponding antenna operates in dual frequency ranges, 3.1–6.2 GHz and 7.1–8.7 GHz. An inset feed rectangular array antenna is designed for WiFi/WiMAX applications [11]. It operates on dual band (3.58 - 3.65 GHz and 2.412 - 2.478 GHz). The antenna possesses comparatively large volume ($88.27 \times 171.4 \times 1.67$ mm³). A novel shaped MPA is designed and fabricated in [12] for 5G applications. The simulated and measured bandwidths are 1.77 GHz and 350 MHz respectively. Another low profile multi-slotted patch antenna is introduced by using FR4 substrates material [13]. The size of it is $30 \times 24 \times 1.5$ mm³ which exhibits the operating range 3.15 - 5.61 GHz.

In this Paper, a MPA having 2.9971-6.2564 GHz frequency band is developed for lower 5G/WiFi-5 (5.15–5.85 GHz) /WiFi-6 (5.925-7.125 GHz)/WiMAX rel 2 (3.4-3.6 GHz) applications. The overall size of the selected antenna is comparatively low ($36 \times 31 \times 0.79$ mm³) and it possesses a huge bandwidth (3259.3 MHz) which is a prime strength of the design. It is designed by using CST. The information sequence is organised as follows: design of the MPA is described in II section. Then, required simulation results and the performance estimation are depicted in III section. Finally, the section IV deals with conclusion with future scope.

II. PROPOSED ANTENNA DESIGN

The omni-directional antenna is constructed on Rogers RT 5880 substrate material. All the metallic layers (patch, ground plane and feed line) are made of Copper annealed with thickness 0.035mm. It consists of a rectangular main patch element with three parallel bars and it is fed by a microstrip line as presented in Fig. 1(a). A rectangular slotted partial ground plane is used in the design. The partial ground not only reduces the MPA volume but also increases the bandwidth. The total volume of the proposed antenna is 881.64 mm³. The radiating rectangular patch dimension, length (A) \times width (B) = 9×16 mm². Top view is shown in Fig. 1(a) with necessary indications. The width of the parallel bars are 1 mm and the length of three parallel bars are 8 mm, 6 mm and 5 mm which are denoted by C, D and E, respectively, in Fig. 1(b). The

dimension of the ground plane is $19 \times 31 \text{ mm}^2$. In the ground plane, there is a slot having length (x) = 2 mm and width (y) = 3 mm as illustrated in Fig. 1(d). The partial ground plane with a small rectangular slot is not only maintained the impedance bandwidth but also return loss level as well as its capacitive coupling [14-15]. The width of the feeder (W_f) is 2.4 mm and length of the feeder is 20 mm. In the design, port excitation coefficient $k=8.68$ (range: 4.6-8.68) is used during port creation. It is compulsory that the line impedance should be equal to 50Ω . All the simulations have been conducted by CST microwave studio suite 2018. All the necessary design parameters and symbols are incorporated in Table I.

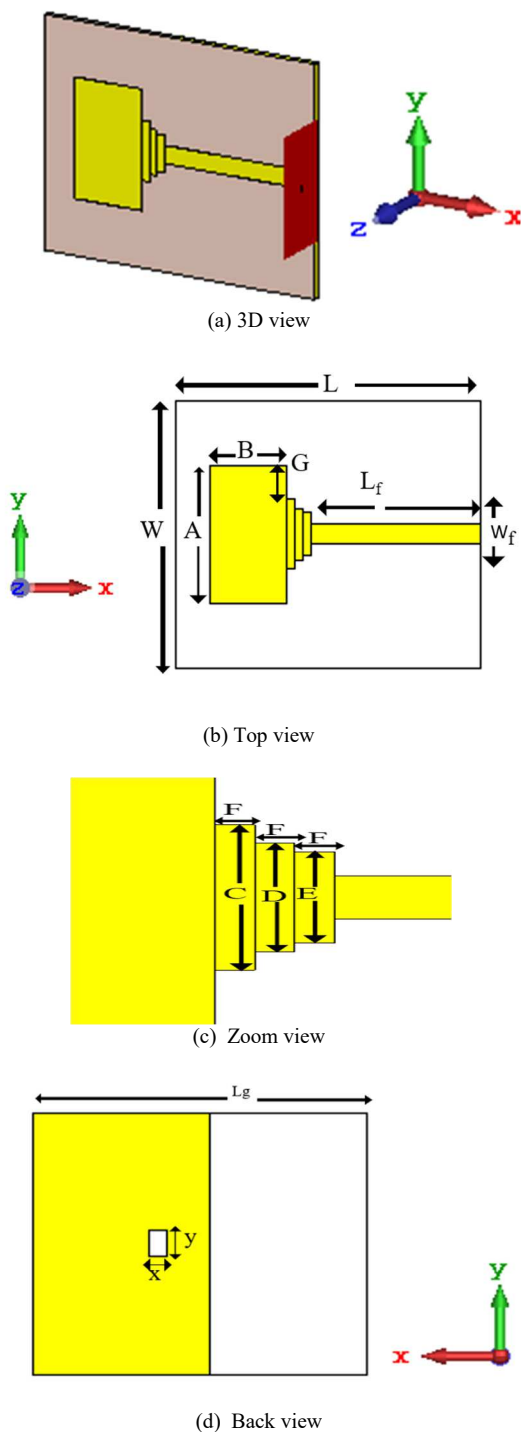


Fig. 1. Proposed antenna.

TABLE I DESIGN PARAMETER LIST

Description	Symbol	Weight (mm)
Substrate length	L	36
Substrate width	W	31
Patch length	A	9
Patch width	B	16
Bar-1 length	C	8
Bar-2 length	D	6
Bar-3 length	E	5
Bar width	F	1
Edge to edge distance between bar-1 and rectangular main patch	G	4
Ground plane length	L_g	19
Slot length	x	2
Slot width	y	3
Substrate thickness	h	0.79
Feed line width	W_f	2.4
Feed line length	L_f	20

III. SIMULATION AND ANALYSIS

All the simulations and parametric study of the designed antenna is accomplished by CST-MWS software. The reflection coefficient ($|S_{11}|$) of the proposed Omni-directional rectangular patch antenna for lower 5G/WiFi/WiMAX applications is depicted on Fig 2. It shows that the centre resonant frequency is 4.08 GHz and it's operating range is 2.9971 GHz to 6.2564 GHz. The reflection coefficient is -33.935 dB at resonant point 4.08 GHz. The MPA has a wide bandwidth of 3.2593 GHz.

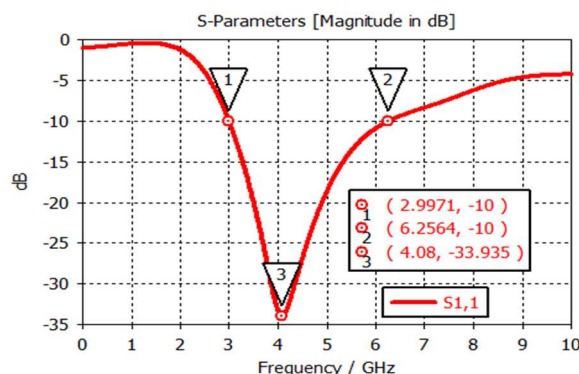
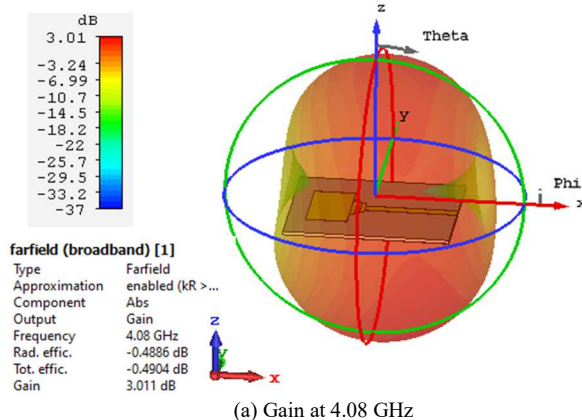


Fig. 2. $|S_{11}|$ vs. frequency



(a) Gain at 4.08 GHz

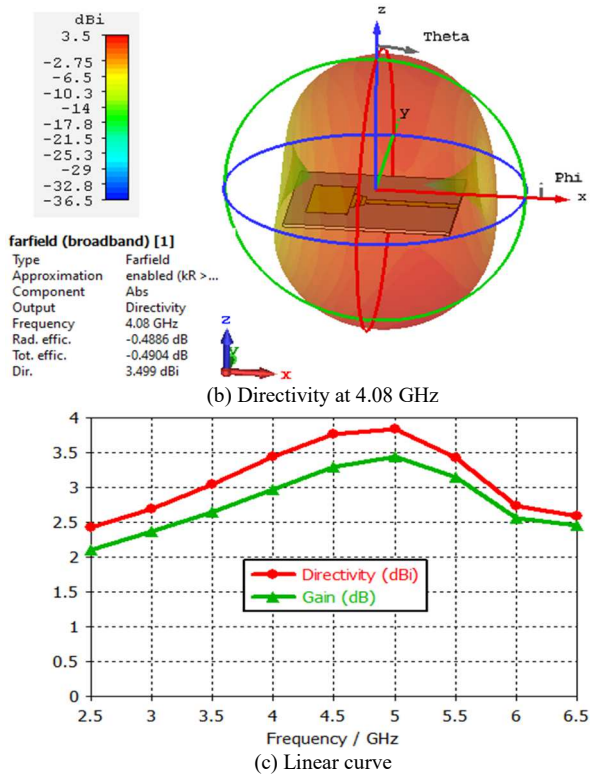


Fig. 3. Gain and directivity (3D and linear)

The gain and directivity depicted in Fig. 3(a) and 3(b). It possesses the gain and directivity 3.011 dB and 3.499 dBi at resonant frequency 4.08 GHz. The gain and directivity curve throughout the entire operating wideband is shown in Fig. 3(c) which indicates the linear curve representation of the antenna. It also shows that the directivity is greater than the gain and gain never goes below 2.5 dB within the operating range. The maximum gain is 3.45 dB and maximum directivity is 3.85 dBi at 5 GHz.

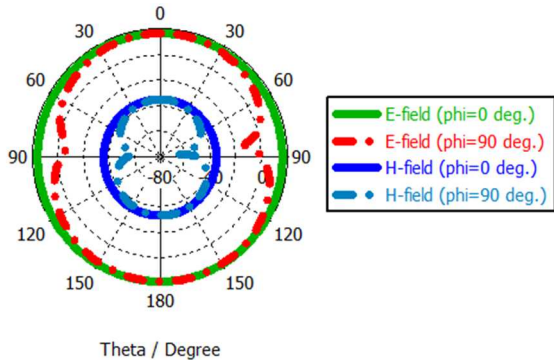


Fig. 4. Fields of the antenna

The polar plot of the radiation pattern (fields) is depicted in Fig. 4. The major lobe is focussed at 164° for $\phi=0^\circ$ and 180° for $\phi=90^\circ$. The 3 dB angular beamwidth at 79.4° for $\phi=0^\circ$ and side lobe level is -1.2 dB. The major lobe magnitude is at 17.8 dBV/m at $\phi=0^\circ$ and 17.3 dBV/m at $\phi=90^\circ$. Similarly, for the H field patterns, the major lobe magnitude is -33.7 dB/A at $\phi=0$ and -34.2 dB/A at $\phi=90^\circ$. It can be said that the four polar plots specify the omni-directional antenna which radiates all directions perpendicular to the x-axis. The proposed omni-directional MPA can be a very good choice for lower 5G/WiFi/WiMAX applications. The VSWR is 1.041 at 4.08 GHz. The VSWR is always a real and positive number ($1 < \text{VSWR} < 2$). The radiation efficiency is shown in Fig. 5 which indicates it's a very efficient antenna. The efficiency

never goes below 90%. The average efficiency is 93.2% and maximum efficiency is 96.2%. The utmost surface current is 54.839 A/m at centre frequency 4.08 GHz as presented in Fig. 6. The impedance-parameters of the proposed antenna are shown in Fig. 7. The real part, imaginary part and polar values of the Z-parameters are 48.941, -1.6096 and $49.63 \angle 357.9$ deg. at resonant frequency 4.08 GHz which specifies the real part of Z-parameter is approximate to 50Ω and the imaginary part of Z-parameter is approximate to 0. The overall result of the proposed Omni-directional antenna is shown in Table II. The Table III reveals one of the main strengths of the MPA and it is larger bandwidth. It has good gain as an omni-directional antenna and uses low loss Rogers RT 5880 dielectric material as substrate.

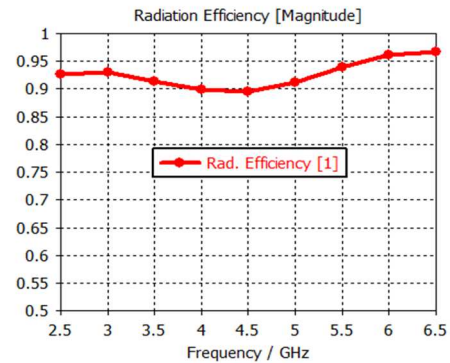


Fig. 5. Efficiency of the MPA

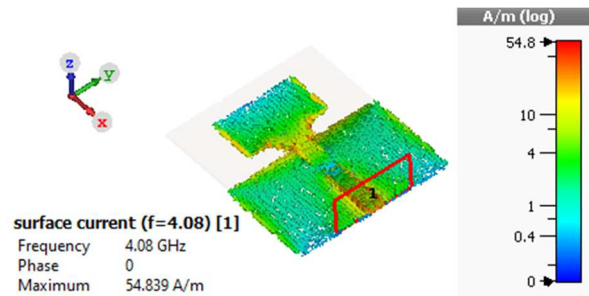
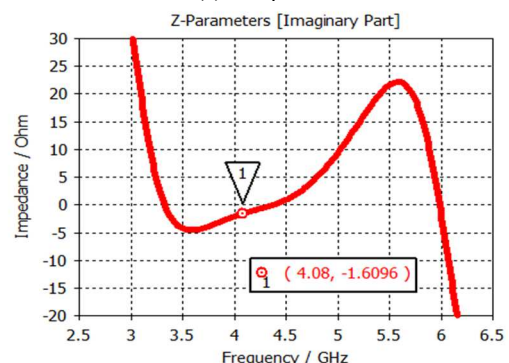


Fig. 6. Surface current at 4.08 GHz



(a) Real part



(b) Imaginary part

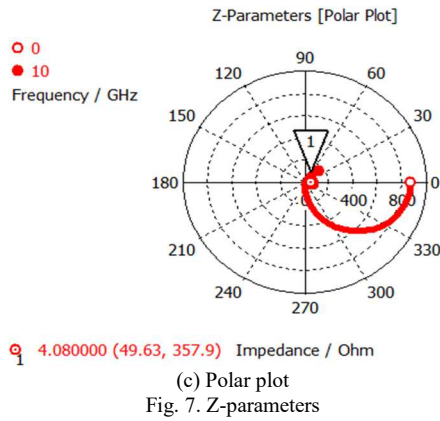


TABLE II KEY FINDINGS OF THE ANTENNA.

Description	Weight (mm)
Lower cut off (dB)	2.9971
Upper cut off (dB)	6.2564
Bandwidth (GHz)	3.2593
Resonant frequency	4.08
Return loss (dB)	-33.935
VSWR	1.041
Gain(dB) at 4.08 GHz	3.011
Directivity(dBi) at 4.08 GHz	3.499
Average radiation efficiency (%)	93.2

TABLE III COMPARISON.

Parameter	Ref. Number				This work
	[9]	[12]	[13]	[16]	
Year	2020	2019	2020	2021	2021
BW (GHz)	2.9	1.78	2.46	2.73	3.2593
Operating Frequency Range (GHz)	2.99	2.8	3.15	2.7073	2.9971
	-	-	-	-	-
Substrate material	5.89	4.6	5.61	5.4377	6.2564
	FR4	FR4	FR4	Rogers RT 5880	Rogers RT 5880
Gain (dB)	2.5	1.89	2.36	2.65	3.011
Centre frequency	3.80	3.008	4.80	3.23	4.08
Return loss (dB) at centre frequency	-45	-41.35	-41	-31.91	-33.935
VSWR	<2	1.5	<2	1.0521	1.041

IV. CONCLUSION AND DISCUSSION

An omni-directional rectangular MPA with a small rectangular slotted partial ground plane is characterised and analysed for lower 5G/WiFi/WiMAX applications. The volume of the proposed antenna is $36 \times 31 \times 0.79 \text{ mm}^3$ (881.64 mm^3) with a huge bandwidth of 3259.3 MHz, a good VSWR of 1.041 ($1 < \text{VSWR} < 2$ within entire BW) which is close to unity 1, a gain of 3.011 dB and directivity of 3.499 at 4.08 GHz. The proposed antenna's average radiation efficiency is 93.2% and it's minimum value is 90%. The proposed antenna's radiation pattern is omni-directional which has an important role in the lower 5G applications such as mobile as well as for WiFi and WiMAX applications. A

MIMO antenna can be designed and fabricated by using the proposed antenna as an extension of this work.

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