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A Super Wideband (26-70 GHz) Microstrip Patch Antenna for 5G Mobile Communication Applications

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In this paper, a novel wide band monopole antenna is designed to operate at the millimetric wave (mmW) frequency band with impedance bandwidth of 26-70 GHz for 5G wireless communication applications. First of all a conventional antenna is designed on full ground then it designed on partial ground with size 5mm x 10mm but both designs didn't achieve bandwidth of 50 GHz-55 GHz, The conventional antenna is a simple rectangular patch antenna with compact size 5 mm × 6.5 mm. In order to generate the wideband width of 26-70 GHz a proposed antenna is designed. The design composed of rectangular patch antenna with edge-cut technique (making slots at the corner of the patch) and introduced on partial ground plane for an improved impedance matching. The suggested microstrip antenna (proposed antenna) has been designed and examined on Rogers RT5880 substrate with dimensions 10 mm × 10 mm with dielectric constant 2.2, loss tangent 0.0009 and thickness of 1.57 mm using computer simulation tool (CST) software 2019. The results reveal that the antenna shows a return loss under – 10 dB over a range from 26-70 GHz and resonated at multiple frequencies 29 GHz, 32.8 GHz, 42 GHz, 47 GHz, 56.6 GHz, and 66 GHz. The gain varies from 6 dBi to 11.9 dBi with maximum obtained value at the frequency of 70 GHz, the antenna exhibits a broadside radiation pattern at both resonant frequencies 32.8 GHz and 56.6 GHz and realized gain are 7.24 dBi and 8.72 dBi at both frequencies respectively therefore the simulated outcomes of return loss, gain , radiation pattern and realized gain show the ability of the super wideband antenna to suit 5G mmW applications.

Keywords: Microstrip patch antenna, mmW, 5G, Wideband, Return loss, Gain, Radiation pattern.

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1. INTRODUCTION

The need for mobile telecommunication devices with the up-to-date specifications is rising rapidly. Customers would like to get very fast information and data access instantaneously [1-3]. The fifth generation (5G) evolution in wireless mobile telecommunication technology provides increasing capacity, ease network connection, high performance and tremendous data rate access [4]. The 5G application was planned to be used in a range above 6 GHz, such as 28 GHz, 38 GHz, and 60 GHz [5, 6]. Various researchers have introduced their outcomes at current mm-wave bands such as 27 GHz and 37 GHz considering that its more probable [7-11]. One of the most fundamental things in the wireless mobile telecommunication system would be the antenna structure [12]. As a result, the antenna structure needs to be shown with the best design, weightless, and compact structure to bring out the greatest performance of wireless mobile telecommunication. One of the weightless and compact antennas is the microstrip antenna structure. Microstrip patch antennas, comparing to conventional antennas, are essentially used in the evolution of new communication devices as they have the benefits of keeping minimal profile and having uncomplicated and achievable fabrication techniques [13-15].

This paper presents a compact mmW slotted microstrip patch antenna with wideband operation extended to cover V-band [16]. The input parameter of the suggested antenna generally concentrated on 5G principles, which is successfully hit the target for wireless access systems and maximum usage of frequency range with minimum transmission loss. Simulation and optimization have been performed using CST software. The coordination of this paper is as follows. In section 2, the antenna design procedures are shown with its modified dimensions. The simulation is introduced in section 3. The return loss, gain, and radiation pattern of the proposed antenna are shown in Section 4. The paper is concluded in Section 5.

2. MMW ANTENNA DESIGN

The proposed patch antenna composed of partial ground and the edge-cut technique (incorporation of partial ground technique and slots at the corners of the patch) was used to attain wide bandwidth.

2.1 Microstrip Antenna Design

The front and back views of the suggested patch antenna with their design procedures and respective dimensions are introduced in Fig. 1. The antenna is implemented on Rogers Duroid RO 5880 dielectric material with 1.57 mm thickness, 0.0009 tangent loss, and 2.2 relative permittivity.

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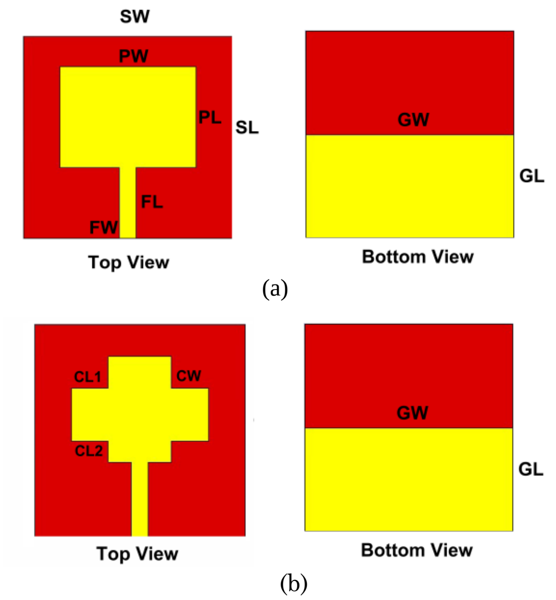

Fig. 1 – Antenna design layout (a) conventional patch. (b) proposed patch

Table 1 – Optimized dimensions of the conventional and suggested antenna

Parameters	Conventional antenna (mm)	Suggested Antenna (mm)	Description
SW	10	10	Substrate width RT5880
SL	10	10	Substrate length RT5880
SH	1.57	1.57	Substrate thickness RT5880
MT	0.035	0.035	Copper thickness
GW	10	10	Ground plane width
GL	5	5	Ground plane length
PW	6.5	6.5	Patch width
PL	5	5	Patch length
FW	0.8	0.8	Feedline width
FL	3.5	3.5	Feedline length
CW	–	1.75	Edge Cut width
CL1	–	1.5	Edge cut 1 length
CL2	–	1	Edge cut2 length

3. SIMULATION

The proposed antenna has been simulated using software CST Microwave Studio 2019. The antenna has been stimulated with microstrip feedline instead of coaxial probe feed. Design procedures have been established in Fig. 1 to carry out the suggested antenna. The return loss characteristics comparison between conventional antenna on full ground, conventional antenna on partial ground and proposed antenna on partial ground is depicted in Fig. 2. The figure shows that conventional antenna on full ground & partial ground didn't achieve bandwidth from (50-55) GHz, while when the edge cut technique & partial ground have been introduced 'proposed antenna' leads to achievement of a wide impedance bandwidth (26-70) GHz.

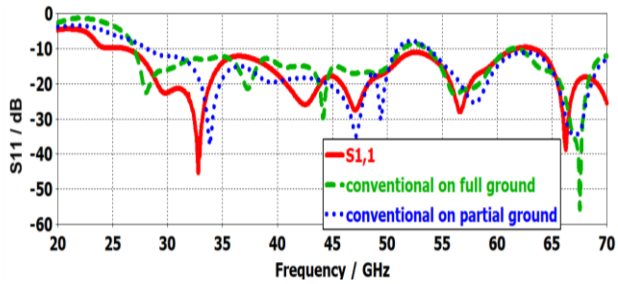

Fig. 2 – Simulated S11 outcomes of the conventional antenna on full ground, conventional antenna on partial ground and the suggested antenna on partial ground

4. RESULTS AND DISCUSSION

This section introduces the impedance and radiation characteristics of the suggested antenna. The proposed antenna is having the ability to perform at super wideband ranging from 26 GHz-70 GHz which make it appropriate for mmW applications.

4.1 Return Loss

Fig. 3 shows the simulated return loss vs. frequency. It has been noticed that the suggested antenna provides wideband characteristics which covers a – 10 dB from 26-70 GHz and resonated at frequencies of 29 GHz, 32.8 GHz, 42 GHz, 47 GHz, 56.6 GHz, and 66 GHz. Furthermore, Fig. 3 depicts that the S11 values at the aforementioned resonance frequencies are – 21.53 dB, – 34.94 dB, – 27 dB, – 27.25 dB, – 27.74 dB and – 39.1 dB, respectively.

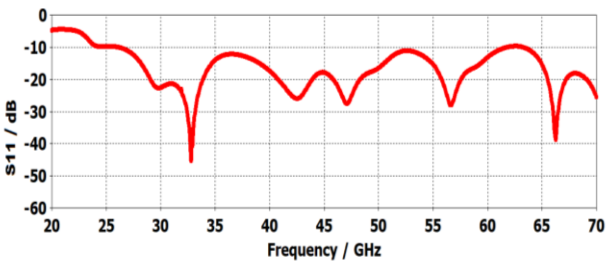

Fig. 3 – Simulated return loss of the proposed antenna

4.2 Gain Verses Frequency

The gain verses frequency for the proposed antenna is presented in Fig. 4. The figure reveals that gain values at resonant frequencies 29, 32.8, 42, 47, 56.6, and 66 GHz are 6.7, 7.3, 8.7, 8, 7.2 and 10 dBi, respectively. Moreover, the gain varies from 6 dBi to 11.9 dBi with a maximum obtained value of 11.9 dBi at the frequency of 70 GHz.

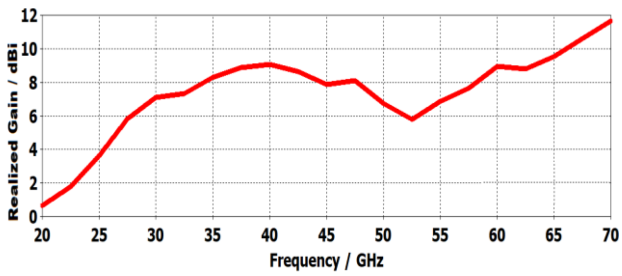

Fig. 4 – Simulated result of a gain vs frequency.

4.3 Radiation Pattern of Proposed Antenna

The radiation pattern of the suggested antenna at both frequencies 32.8 GHz & 56.6 GHz are presented in figure 5, 6, 8, and 9. The antenna exhibits a broadside radiation pattern at *E*-plane ($\varphi = 90$) & *H*-plane ($\varphi = 0$) which means the appropriate radiation in all directions.

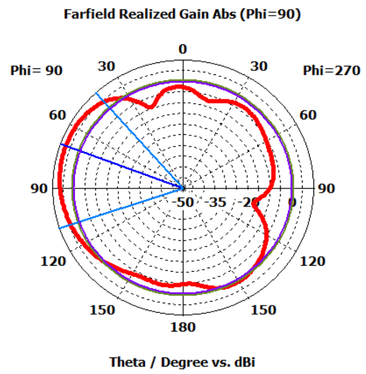

Fig. 5 – *E*-Plane of proposed antenna at 32.8 GHz

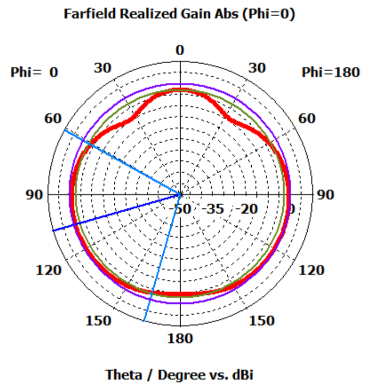

Fig. 6 – *H*-Plane of proposed antenna at 32.8 GHz

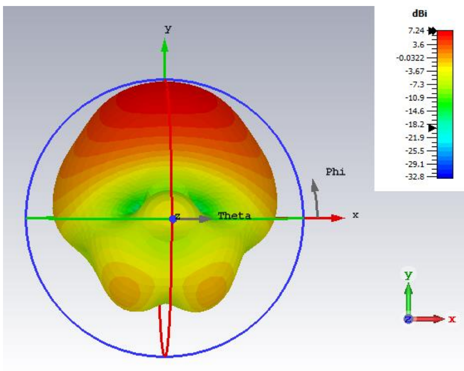

Fig. 7 – Realized gain (3D) of proposed antenna at 32.8 GHz

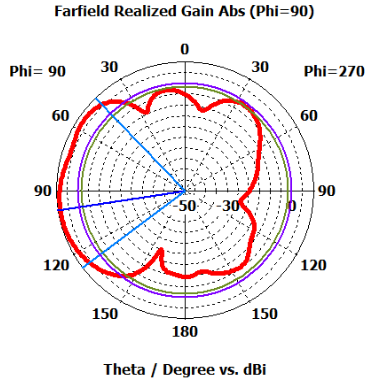

Fig. 8 – *E*-Plane of proposed antenna at 56.6 GHz

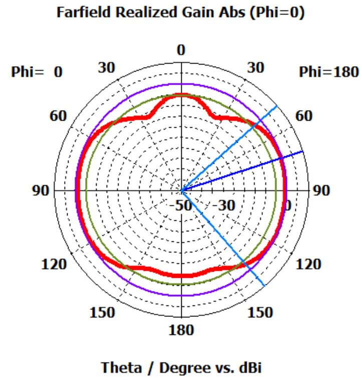

Fig. 9 – *H*-Plane of proposed antenna at 56.6 GHz

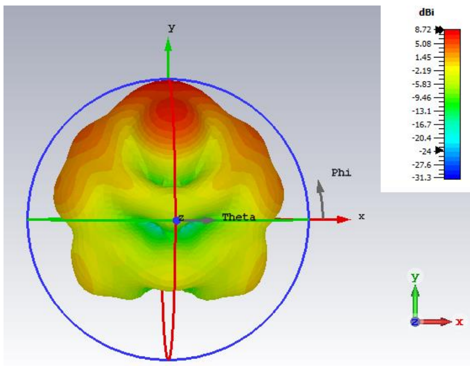

Fig. 10 – Realized gain (3D) of proposed antenna at 56.6 GHz

5. CONCLUSION

This paper includes a microstrip patch antenna with edge cut technique used for 5G mmW applications. The suggested antenna has the ability to perform at super bandwidth from 26-70 GHz. The simulated result of proposed antenna gives return loss 21.53 dB, 34.94 dB, 27 dB, 27.25 dB, 27.74 dB and 39.1 dB at 29 GHz, 32.8 GHz, 42 GHz, 47 GHz, 56.5 and 66 GHz respectively. The gain performance has reached 11.9 dBi at the frequency of 70 GHz. The suggested antenna satisfied the conditions of mmW to perform at the bandwidth (26-70 GHz). Moreover, the obtained results of the proposed antennas confirmed its highly preferability for mmW applications and 5G technology systems. Consequently, this model is applicable for 5G mobile applications with high performance and low cost of fabrication.

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Надширокосмугова (26-70 ГГц) мікросмугова патч-антена для додатків мобільного зв'язку 5G

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У статті запропонована розробув нової широкосмугової монопольна антена розроблена для роботи в діапазоні частот міліметрових хвиль (ммВт) із смугою пропускання опору 26-70 ГГц для програм бездротового зв'язку 5G. Перш за все, звичайна антена розроблена на повній землі, потім вона розроблена на частковій поверхні з розміром 5 мм × 10 мм, але обидві конструкції не досягли смуги пропускання 50 ГГц-55 ГГц. Звичайна антена – це проста прямокутна антена з компактним розміром 5 мм × 6,5 мм Для створення широкосмугової ширини 26-70 ГГц запропонована антена розроблена. Конструкція складається з прямокутної патч-антени з технікою обрізання країв (роблення прорізів у куті патча) та розміщеної на частковій площині заземлення. для покращеного узгодження імпедансу. Запропонована мікросмужкова антена (пропонована антена) була розроблена та перевірена на підкладці Rogers RT5880 з розмірами 10 мм x 10 мм з діелектричною проникністю 2,2, тангенсом втрат 0,0009 і товщиною 1,57 мм за допомогою програмного забезпечення інструменту комп'ютерного моделювання (CST) 2019. Результати показують, що антена демонструє зворотні втрати нижче – 10 дБ у діапазоні від 26-70 ГГц і резонувала на кількох частотах 29; 32,8; 42; 47; 56,6 і 66 ГГц. Підсилення змінюється від 6 до 11,9 дБ з максимальним отриманим значенням на частоті 70 ГГц, антена демонструє широку діаграму спрямованості на обох резонансних частотах 32,8 і 56,6 ГГц, а реалізоване посилення становить 7,24 дБ та 8,72 дБ на обох частотах відповідно, отже, змодельовані результати зворотних втрат, посилення, Діаграма спрямованості випромінювання та реалізоване посилення показують здатність суперширокосмугової антени відповідати додаткам 5G ммВт.

Ключові слова: Мікросмугова патч-антена, ммВт, 5G, Широкосмуговий діапазон, Зворотні втрати, Підсилення, Діаграма спрямованості.