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REGULAR ARTICLE

Wideband DGS Slot Loaded Patch Antenna for High-Speed mm-wave 5G Applications

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A wideband antenna has almost or precisely the same operating parameters throughout a very large Passband. It differs from broadband antennas in that the passband is extensive, but the antenna strength and/or emission pattern do not have to remain constant across the passband. DGS refers to the faults or slots on the ground plane of microwave planar circuits. DGS has been designed to improve the performance of numerous devices and increase bandwidth. Current work presents a high-speed DGS-loaded wideband microstrip antenna that can be used in the 5G millimeter wave application in the band of frequency between 24 – 27 GHz having a return loss value of – 28.09 dB with wideband characteristic. The Ansys HFSS v15 has been used to design and measure antenna parameters. The simulation process has been done using low-cost substrate material FR4 whose dielectric constant is 4.4 and has a thickness of 0.8 mm. The designed antenna structure has dimensions of 7 mm × 7 mm × 0.8 mm. Both measured and simulated results are found to be similar. The gain of the proposed antenna is found to be 2.01 dB while radiation efficiency is measured to be greater than 90 % in the range of frequency (24 – 27 GHz). The designed antenna covers the 5G spectrum and effectively operates in n_{257}, n_{258} and n_{261} bands. In this structure wideband has been achieved by making slots onto the patch antenna and a large gain has been achieved by different dimensions of slots onto the ground plane.

Keywords: 5G communication system, Wideband patch antenna, Slot antenna, Millimeter wave, Defected Ground Structure (DGS)

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1. INTRODUCTION

5G communication systems will be used for the future. Increased bandwidth, faster data rate, video streaming content and real-time increased services on demand need the design of 5G enabled patch antenna. The millimeter-based broadband service is suitable for 5G wireless technology [1-2]. There are numerous applications including multimedia, video streaming, high-speed internet, and mobile distributed computing in the K band. Due to this, the focus has been shifted to wideband channel. Any signal having a bandwidth of more than 1 MHz generally refers to wideband. A high data rate can be achieved with the integration of a wideband system. As per world Radio Communication conference (WRC-15) the obtained result in millimeter spectrum 24.249 GHz – 27.49 GHz, 26.49 GHz – 29.49 GHz, 27.49 GHz – 28.349 GHz etc. are suitable for 5G network design [3]. The characteristics features of patch antenna such as lesser weight, larger bandwidth, low profile as well as higher gain are suitable parameters for coming 5G communication system. Thus, the modern 5G communication network makes use of a patch antenna for its application. Various techniques are reported for antenna design loaded with defective ground structure (DGS) for various wireless applications [4-5]. Various hexagonal antenna designs for wideband applications are reported in [6-8]. Dual-linearly-polarized wideband antenna for 5G network application is proposed in [9]. Omnidirectional stacked antenna with wide bandwidth has been designed for numerous wireless applications in.

Most of the above research work is reported in a lower band of frequency which is not suitable for 5G communication standard. In this present research work the authors have designed novel DGS-loaded wideband slotted patch antenna in K band application suitable for future 5 G wireless applications for enhanced data rates. The designed antenna covers n_{258} (24.499 to 27.499 GHz), n_{261} (27.499 to 28.349 GHz). In addition to this, it shows high radiation efficiency, stable radiation pattern, suitable VSWR, and high gain which are best suited for millimeter-wave 5 G application.

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2. EFFECT OF SLOTS IN ANTENNA

Slot-loaded antenna gives better performance in terms of return loss, VSWR, resonance frequency, and increased bandwidth performance as compared to the conventional rectangular patch antenna. Bandwidth has been increased with the help of a slot loaded onto the patch of antenna and gain has been enhanced by the DGS technique on to the ground plane. The achieved gain has been enhanced in the present work by integrating different slots and high permittivity substrate.

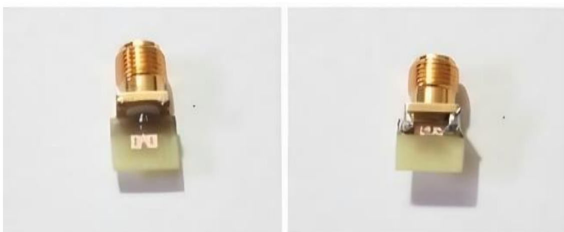

Fig. 1 – Design of proposed fabricated 5G antenna

Table 1 – Dimension of patch antenna without slot

Dimension	Value(mm)
Width of substrate (*WS*)	7
Length of substrate (*LS*)	7
Width of ground plane (*WG*)	7
ground plane length (*LG*)	2
Width of patch (*W*)	3.28
Length of Patch (*L*)	2.15
Length of x-mission line (L_t)	1.37
Width of x-mission line (W_t)	0.58
Width of Feed (*WF*)	1.55
Length of FeedLF	1.48

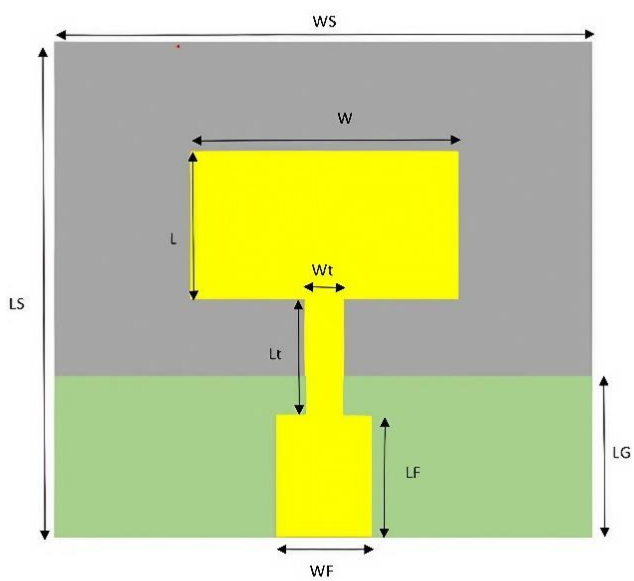

Fig. 2 – Design geometry of proposed antenna patch without slot

Table 2 – Dimension of patch antenna with slot

Slot	Dimensions (mm)
a_1	1.2 × 0.1
a_2	0.3 × 0.2
a_3	0.7 × 0.6

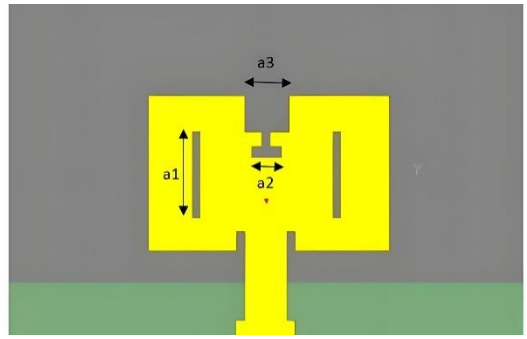

Fig. 3 – Design geometry of proposed antenna patch with slot

Table 3 – Dimension of patch antenna with slot on the ground plane

Slot	Dimension (mm)
G_1	1 × 0.2
G_2	0.4 × 0.2
G_3	0.5 × 0.2
G_4	0.4 × 0.2
G_5	1.4 × 0.1
G_6	0.5 × 0.2
G_7	0.2 × 1.8
G_8	1.2 × 0.2
G_9	1 × 0.2

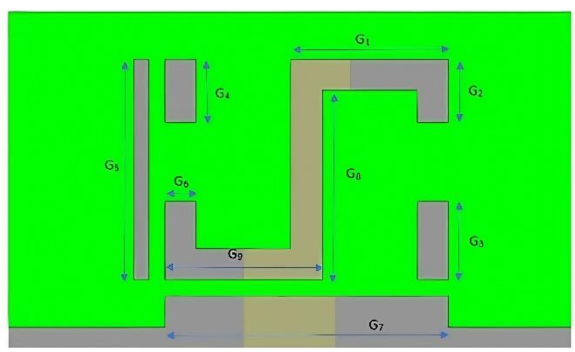

Fig. 4 – Design geometry of the proposed antenna patch with slots on the ground plane

3. RESULT AND OBSERVATION

3.1 Parametric Analysis of Simulated Antenna

Ansys HFSS has been used for the analysis and optimization of antenna parameters. The various parameters of the antenna have been measured in both simulated as well as fabricated antenna for desired K band (24 – 27 GHz) of operation for enhanced data rates for wireless 5G applications.

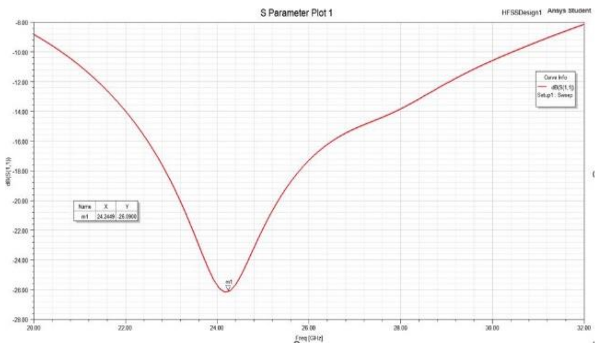

Fig. 5 – Simulated Scattering parameter S_{11} of anticipated antenna

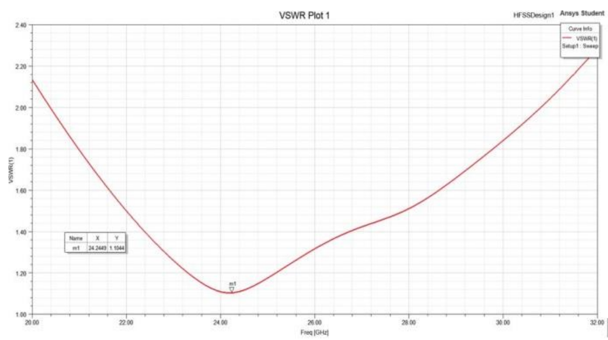

Fig. 6 – Simulated VSWR of anticipated antenna

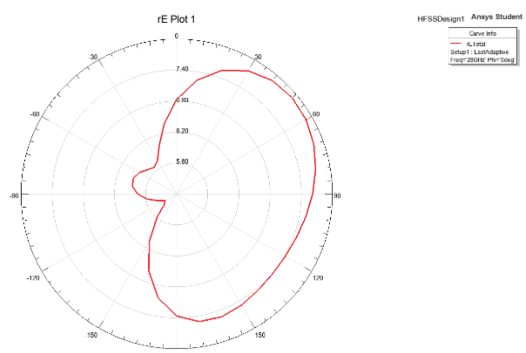

Fig. 7 – Radiation Pattern of anticipated antenna

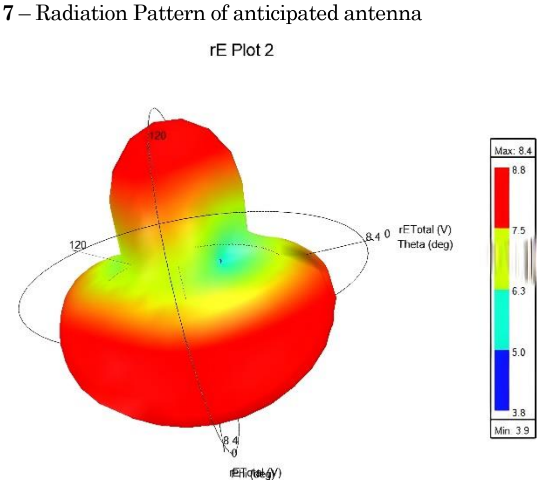

Fig. 8 – 3-dimensional Polar Plot of anticipated antenna

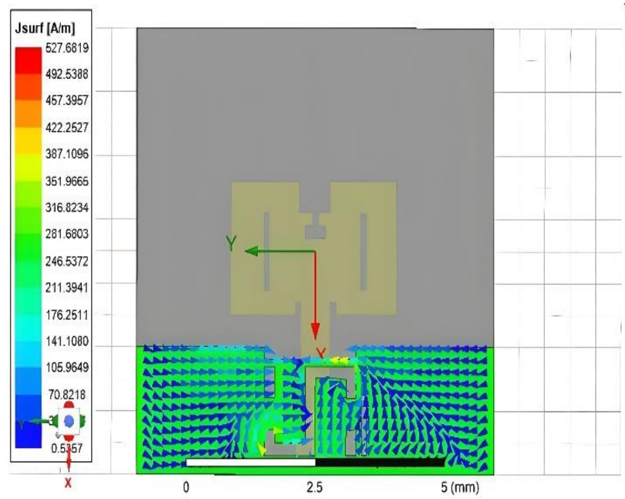

Fig. 9 – Surface current distribution of anticipated antenna at 24.5 GHz on the ground plane

3.2 Parametric Analysis of Fabricated Antenna

The proposed antenna after designing has been fabricated for practical operation of the antenna. Fig. 10 shows the design of the anticipated antenna with feed (a) front view, (b) back view.

The measured antenna is resonating at 24.65 GHz at the return loss of – 28.01 dB which is well in agreement with the simulated result of the antenna using Ansys HFSS. Fig. 15 shows the resulting VSWR of the anticipated antenna whose value is below 2 for the desired K band (24 – 27 GHz) band of operation. Both the simulated and measured value of the scattering parameter and VSWR are found to be matched for the practical design of slotted patch antenna for enhanced high-speed data rate for 5G wireless applications.

a b

Fig. 10 – Design geometry of proposed antenna with feed (a) Front view, (b) back view

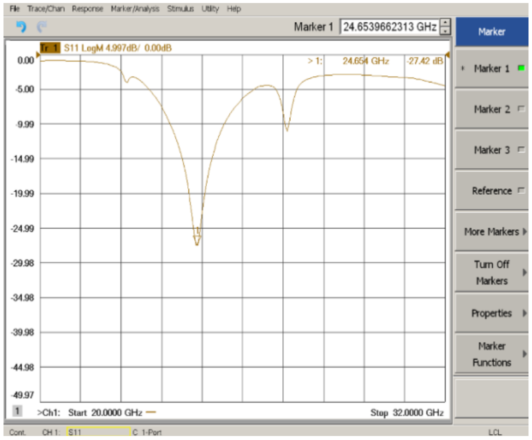

Fig. 11 – Measured Scattering parameter S_{11} of the proposed antenna

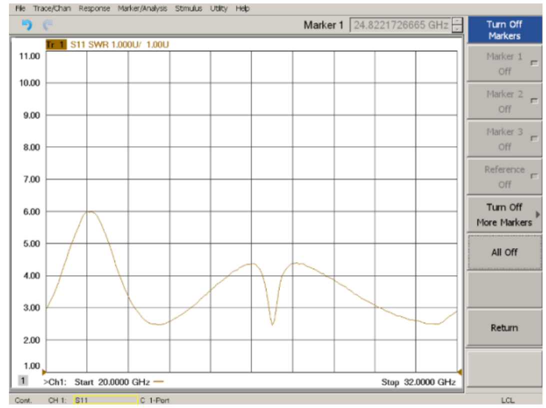

Fig. 12 – Measured VSWR of anticipated antenna

4. CONCLUSION

In this article, high speed DGS loaded wideband patch antenna is designed for future 5G millimeter wave application. The designed antenna covers 5G spectrum and effectively operates in n_{257}, n_{258} and n_{261} band.

In this structure wideband has been achieved by making slots on to the patch antenna and a large gain has been achieved by different dimensions of slots onto the ground plane. The designed antenna structure has dimensions of 7 mm × 7 mm × 0.8 mm. The antenna shows a return loss value of – 28.09 dB with wideband characteristics and, a gain of 2.01 dB along with radiation efficacy of more than 90% throughout the entire K band (24 – 27 GHz). Both measured and simulated results are found to be similar. Therefore, the proposed antenna is fabricated and suitable for future 5G high-speed millimeter-wave applications.

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Широкосмугова щілинна мікросмужкова антена з дефектною опорною поверхнею (DGS) для високошвидкісних міліметрових застосувань 5G

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Широкосмугова антена характеризується майже постійними робочими параметрами в дуже широкому діапазоні частот (пасбенді). Вона відрізняється від широкосмугових антен тим, що хоча пасбенд є значним, силу сигналу та/або діаграму випромінювання не обов'язково зберігати незмінними в усьому діапазоні. DGS (Defected Ground Structure) – це щілини або вирізи в опорному (земляному) шарі мікрохвильових планарних структур. Така структура використовується для покращення характеристик пристроїв та розширення смуги пропускання. У даній роботі представлено високошвидкісну широкосмугову мікросмужкову антену з DGS, призначену для застосування в міліметровому діапазоні 5G у частотному діапазоні 24 – 27 ГГц, з коефіцієнтом зворотних втрат – 28,09 дБ, що вказує на добру узгодженість. Проєктування й моделювання антенних параметрів проводилося в Ansys HFSS v15 з використанням дешевого підкладкового матеріалу FR4 (діелектрична проникність 4,4, товщина 0,8 мм). Розміри запропонованої антени складають 7 мм × 7 мм × 0,8 мм. Отримані експериментальні та симульовані результати узгоджуються. Встановлено, що коефіцієнт підсилення становить 2,01 дБ, а ефективність випромінювання перевищує 90% у діапазоні 24 – 27 ГГц. Антена ефективно покриває спектр 5G, зокрема діапазони n_{257}, n_{258} та n_{261}. Широкосмугова характеристика досягається за рахунок щілин на патчі антени, а збільшення підсилення забезпечується завдяки специфічним вирізам на опорній площині.

Ключові слова: Система зв'язку 5G, Широкосмугова патч-антена, Щілинна антена, Міліметрові хвилі, Дефектна опорна структура (DGS).