Spectrum of Engineering Sciences
ISSN (e) 3007-3138 (p) 3007-312X Volume 4, Issue 5, 2026

AN OPTIMIZID MICROSTRIP PATCH ANTENNA DESIGN WITH ENHANCED BANDWIDH FOR 5G COMMUNICATION AND MEDICAL APPLICATIONS

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DOI:-

Keywords
Tumor Imaging, Return Loss "S11", Voltage Standing Wave Ratio "VSWR", CST Microwave Studio, Millimeter-wave (mm-wave), Microstrip Patch Antenna, 5G Connectivity

Article History
Received: 08 March 2026
Accepted: 10 April 2026
Published: 11 May2026

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Abstract
In order to meet higher bandwidth requirements, the quick development of 5G connectivity has required a move toward millimeter-wave (mm-wave) frequencies. Because of its small profile, simplicity in manufacture, and operating at high-frequency bands, microstrip patch antennas (MPAs) are becoming more famous for using in various applications. The design and development of a high-performance microstrip patch antenna working in the 5G mm-wave spectrum (>24 GHz) is the main topic of this work, with a particular focus 5G communication and possible use in early stage tumor detection. For this purpose the designed models was tuned from the 27 GHz to 28 GHz resonance frequency range using CST Microwave Studio for thorough optimized modeling and simulation. The simulation results show good performance characteristics, with a Return Loss (S11) that is consistently between -19 dB and -45 dB and a Voltage Standing Wave Ratio (VSWR) that ranges from 1.22 to 1.01. These results suggest that the optimized model offers the high sensitivity and impedance matching needed for sophisticated medical sensing as well as next-generation communication systems.

1. Introduction

Microstrip patch antennas have become a crucial part of 5G networks. Ultra-fast data transfer, low latency, and wide device connectivity are the goals of 5G technology. Because of their tiny profile, ease of integration with printed circuit boards, and suitability for portable and compact devices, microstrip patch antennas offer a number of benefits. These antennas are especially useful in situations where great efficiency and limited area are essential. Antenna systems must operate efficiently in the millimeter-wave (mm wave) spectrum, especially at frequencies like 28 GHz, 38 GHz, and 60 GHz, in order to satisfy these requirements. Designing for these high frequencies requires careful consideration of bandwidth optimization strategies, radiation behavior, and material selection. A number of design factors, such as substrate dielectric characteristics, patch geometry, and the selected feeding mechanism, affect how effective microstrip patch antennas are in 5G applications. To increase gain and decrease return loss, low-loss substrates as Rogers RT/duroid and FR-4 are commonly utilized [1].

Optimizing patch antennas for 5G performance targets has been the subject of numerous research papers. For example, a slot-loaded rectangular patch antenna with a gain of 6.5 dBi and a bandwidth of 2.1 GHz was built on a FR-4 substrate working at 28 GHz [2]. In a similar vein, a 38 GHz circular patch antenna with a defective ground structure (DGS) provides improved impedance matching and increased gain [3]. A dual-band stacked patch antenna that targets the 28 and 38 GHz bands; it is perfect for MIMO applications and exhibits low cross polarization and stable radiation patterns [4]. Using metamaterial-based EBG structures created a 60 GHz antenna that enhanced isolation and directivity, making it appropriate for high-speed, short-range wireless systems [5].

The main aim of this research is to optimize microstrip patch antennas by altering the ground and patch geometry on the thinnest substrate because the size of the antenna cannot be affected. This would enable 5G applications for IOT applications and medical applications to take high-resolution images, which is a noninvasive method compared to the traditional MIMO technique. .

2. Method and Design of Antennas.

CST Microwave Studio software has been used to develop and assess the suggested microstrip patch antenna design optimization for 5G communications and medical applications. Low reflection loss, broad bandwidth, and high radiation efficiency within the 24-28 GHz operating frequency range were the main goals.

2.1. Optimized Designs of Microstrip Patch Antenna and Their Patch Dimensions.

The three basic parts of an antenna are the ground plane, a dielectric material, and the radiating patch. Because of the conductivity and radiation efficacy of the copper (annealed) material, a typical rectangular radiating patch and a few small alterations in the form of insets were used.

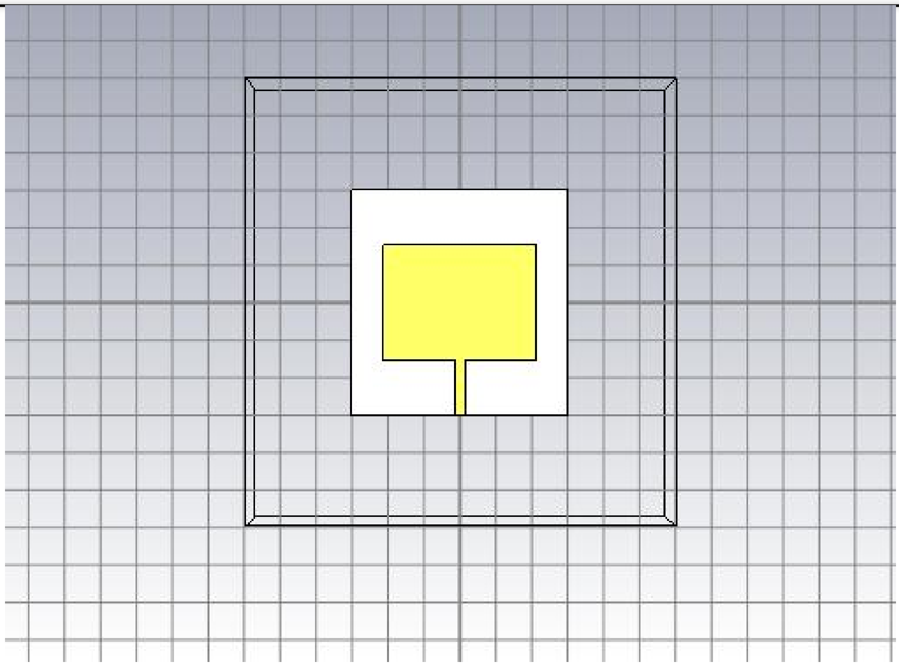


Figure.1: Front side of MSPA

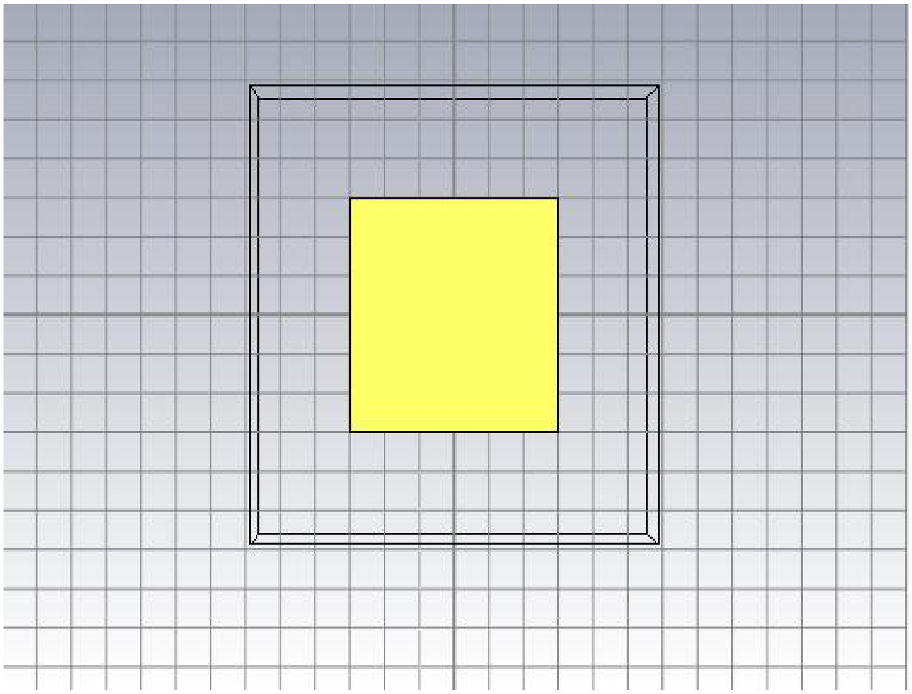


Figure 2: Back side of MSPA

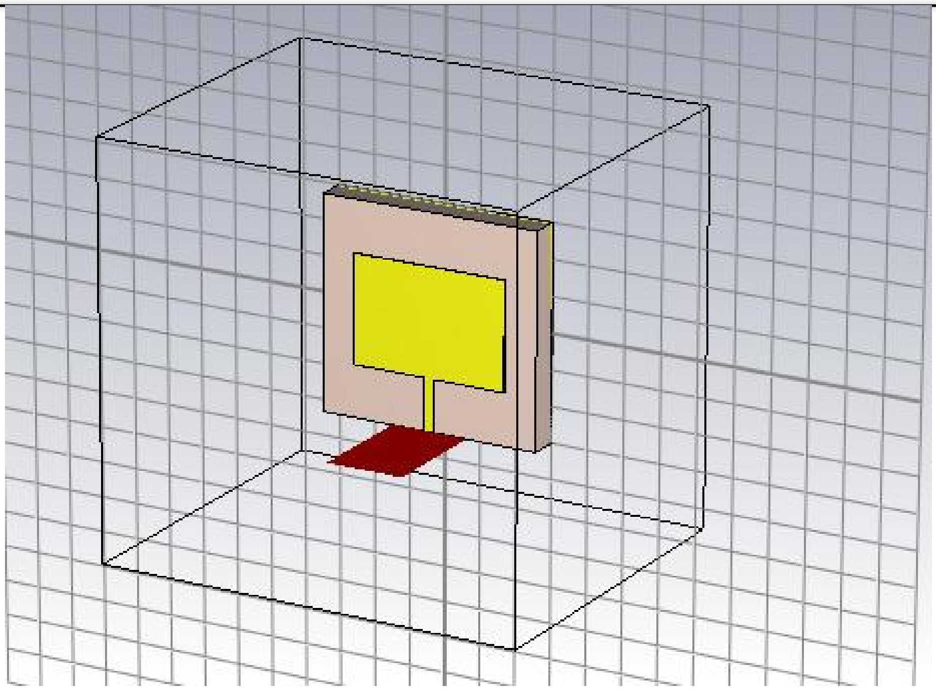


Figure.3: Side view of MSPA

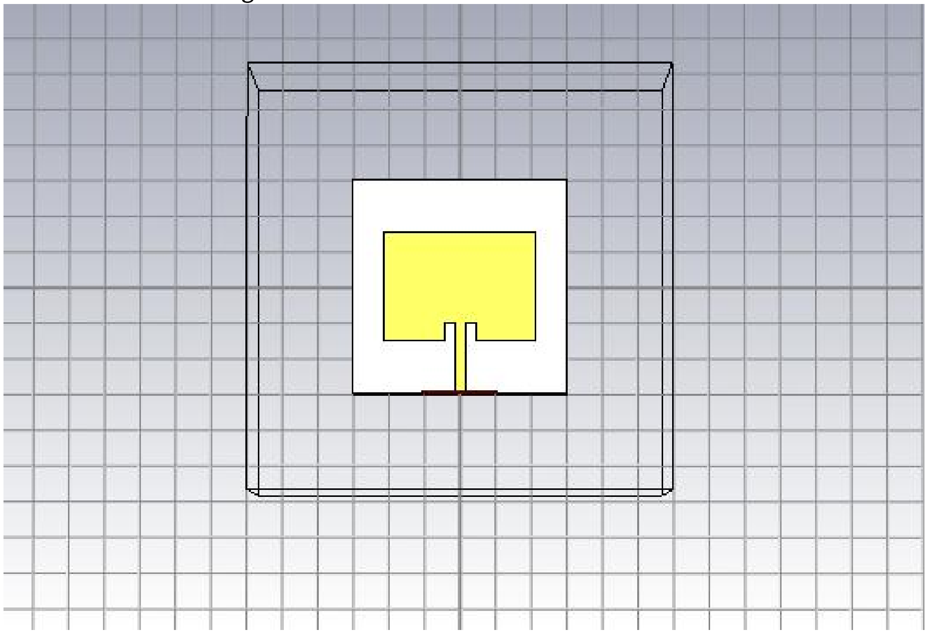


Figure.4: 02 insets from left and right with feedline

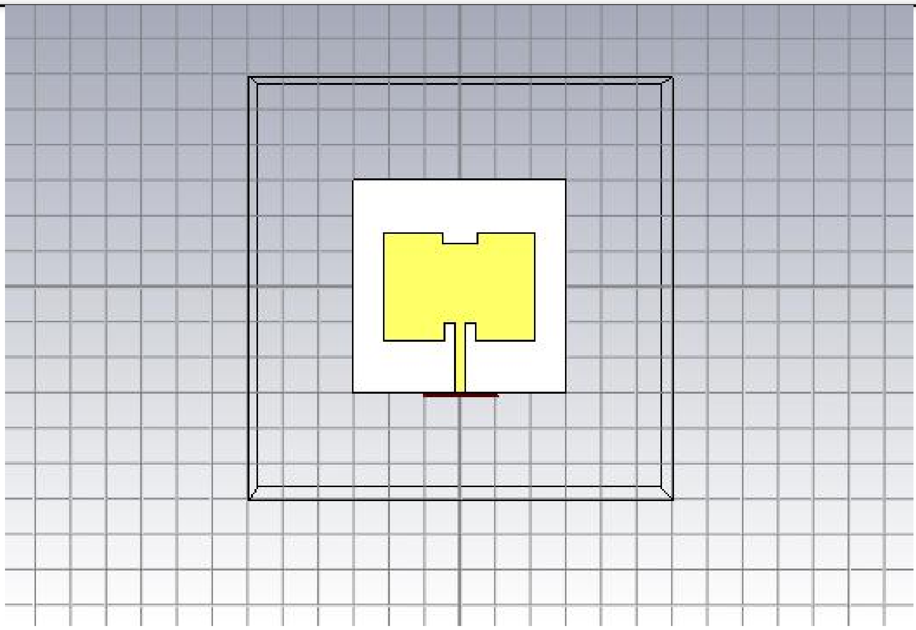


Figure.5: 03 insets two with sides of feedline and one is opposite side

2.2 Substrate Selection

There are various dielectric can impact the performance of antenna such as FR-4 (lossy), Rogers RT5880 (lossy), and Taconic TRF-43 (lossy) are considered to the best performance at 5G spectrum. Form these substance the substrate having low dielectric Ɛ=2.2 and low loss tangent δ =0.0009 was considered Rogers RT5880 (lossy).

2.3 Ground Plan Design

Copper (anneled) was an excellent choice to utilize as a ground plan because surface waves can transmit to a greater extent. The patch modification and low substrate thickness allow copper to minimize return loss and achieve some higher gain.

2.4 Feeding Technique

The patch was excited by the microstrip feedline. Simple, quick impedance matching, and dependable high frequency performance are the characteristics of the microstrip feedline technique. The feedline was built with at the impedance of 50 Ohms in order to reduce reflections in the input ports.

2.5 Simulation and Optimization

The antenna was modelled with open boundary conditions and a vacuum ambient medium to simulate in free space. Parametric modifications were used to change the patch until the desired performance was obtained. From three designs the third modified design exhibited excellent performance. At 27.76 GHz, the return loss S_{11}: -45 dB, VSWR: 1.011, Gain: 7.298 dBi, Directivity: 7.656 dBi, Total efficiency: -0.3749, Bandwidth: 2.46 GHz at S11 (-10 dBi).

The surface current transmits from the feedline to the patch and responsible to produce electromagnetic waves which transmit into the free space with very high frequency. This optimized design of a microstrip patch antenna can be used for 5G communication and high-resolution imaging of tumor cells with greater noninvasive penetration.

Antenna Parameters

Parameters	Representations	Values
Permittivity of Roger RT Droid (5880)	Ɛ	2.20
Width of ground	Wg	6mm
Length of ground	Lg	6mm
Height of ground	Hg	0.0175mm
Width of substrate	Ws	6mm
Length of substrate	Ls	6mm

Height of substrate	Hs	0.787mm
Length of patch	Lp	3.063mm
Width of Patch	Wp	4.236mm
Width of feedline	Wf	0.3mm
Length of feedline	Lf	1.4685mm
Inset length in design: 02	IL	0.5mm
Inset width in in design: 02	IW	0.3mm
Inset length in design: 03	IL	0.5mm
Inset width in in design: 03	IW	0.5mm
Inset length in opposite side of feedline in design: 03	IL	0.3mm

3. Results and Discussion

In one single model three distinct patches with some modifications were created using CST microwave studio in the form of simulation. These simulations run between 27 and 28 GHz, which has been shown to be millimeter wave and associated with the Ka band (18.0 to 40 GHz). It has been shown that optimizations was necessary to obtain the final simulation that operates and carries out the intended application. The third simulation of microstrip patch antenna had a resonant frequency of 27.78 GHz, an excellent return loss of S11: -45 dB, a voltage standing wave ratio that was close to the ideal value of 1 as determined by the graph, a VSWR of 1.011, and a moderate gain of 7.298dBi.The Roger RT Duriod 5880 material's extremely thin thickness may help control the size of the microstrip patch antenna, which was a crucial requirement for this device. The directivity was also in the moderate region, which was crucial for directional signals in medical applications. The measured directivity was 7.656 dBi. The total efficiency of simulated model was -0.3749, this mean that the simulated antenna has overall efficiency nearly equal to 91.73%. The measured bandwidth was very broader which was equal to 2.46 GHz at -10 dBi.

3.1. S11 Parameters of simulation 1,2 and 3

Simulation .01

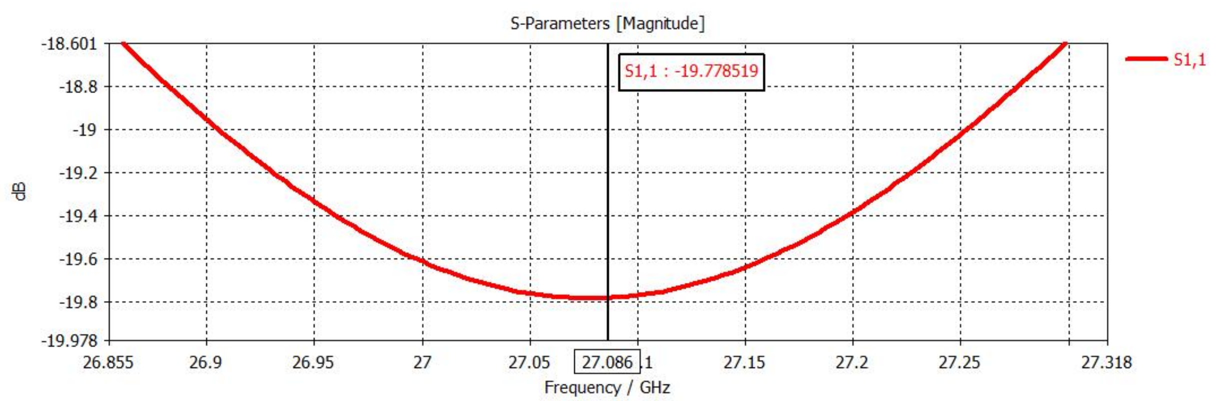


Figure.4

The return loss of simulations 1, 2, and 3 revealed that the inset directly affects the antenna's performance. In simulation 01, the band width value was 2.41 GHz at -10 dBi, indicating a wider band width. The return loss S11 was roughly equal to -19 dBi, indicating excellent matching at frequency 27.086 GHz. This match also showed that nearly all of the power transmitted by the microstrip antenna in the form of mm electromagnetic waves. The graph highlighted that resonance had a pure parabolic dip form.

Simulation.02

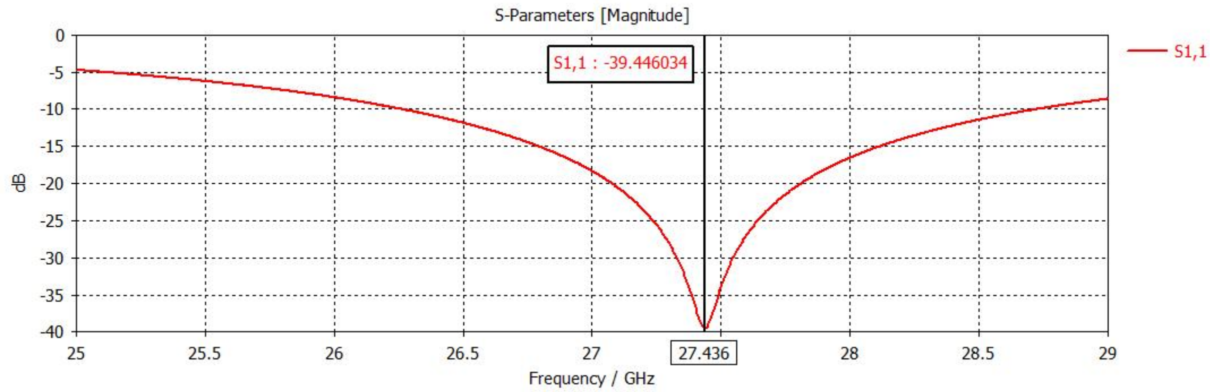


Figure.5

In simulation 02 the value of band width was 2.42 GHz which was almost equal with simulation 01 2.41GHz at -10dBi, the graph has shown same wider band width this means that antenna can operate from 26.2 to 28.6 GHz frequency and resonant at 27.4 GHz that was slightly greater than from model one 27.0 GHz, the return loss has also been reduced and reached at -39.44 dBi while the previous model has shown -19.7dBi.Which was less than almost -19.67 of previous model hence the more power transmit model 02 antenna on two insets with right and left side of the feedline.

Simulation.03

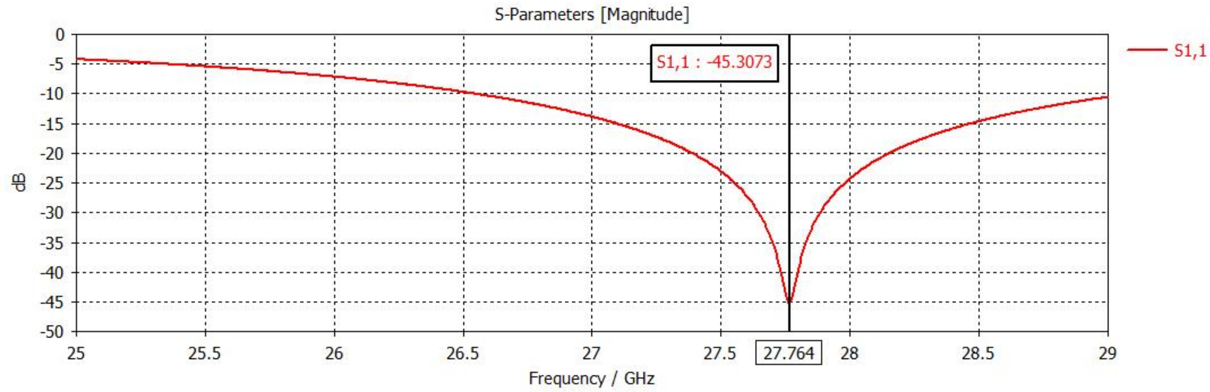
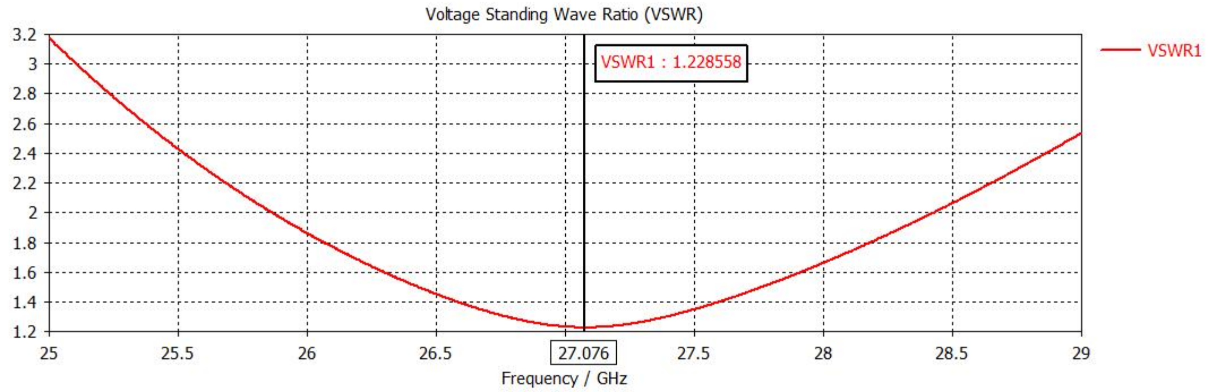


Figure.6

In simulation 03 the value of band width was 2.46 GHz which was greater than previous two simulations with slightly margin 0.4 and 0.5 at -10dBi this has been proved that patch inset was able to make it broader band width of antenna. This graph also shown that the resonant frequency also increased and reached at 27.76 GHz which was almost equal to the 28 GHz. The main shift has been achieved in return loss that had been decreased and reached at -45.30 dBi while the previous model has shown, -33.44dBi, -19.7dBi. Hence, the antenna best match with this resonant frequency and deliver excellent operation for 5G mm waves. This was proved that the shape extra inset (5 by 3mm) opposite side of feedline improved the performance of antenna to transmit electromagnetic waves with excellent efficiency that was equal to the 91%.

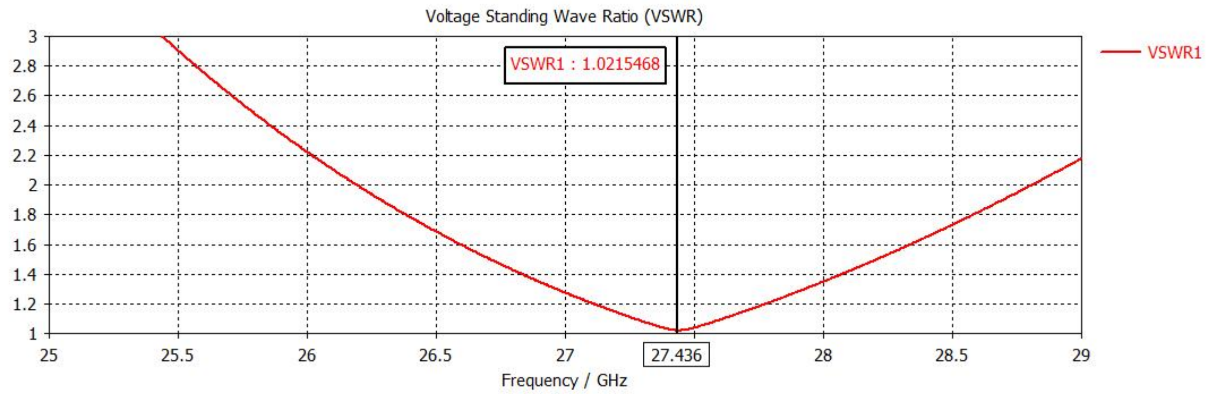
3.2. Voltage Standing Wave Ratios (VSWR) of Simulation 1, 2 & 3.

Simulation.01



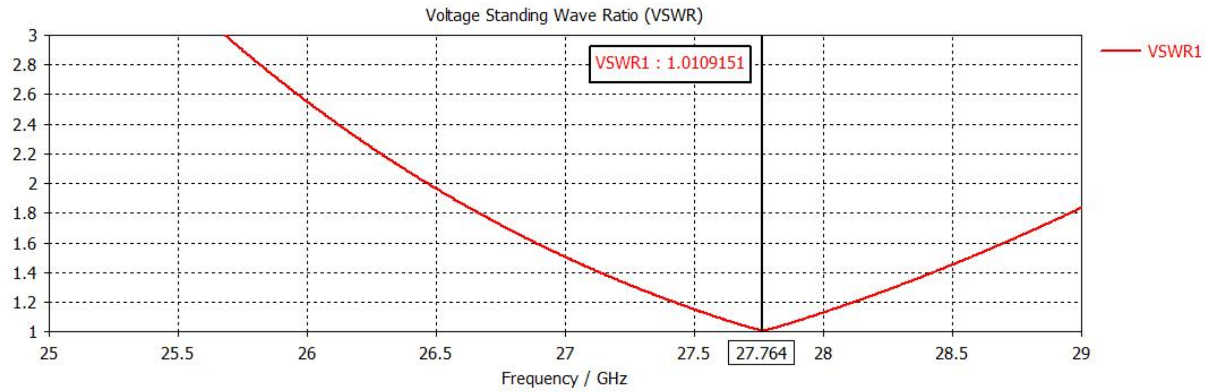
The ideal VSWR is equal to 1, here in this simulations 01 that was resonant at 27.07 has 1.22 of VSWR, which was less than 0.22 from 1 and close to the optimal state. This graph also demonstrated how the antenna's impedance and feedline signals matched at 50 Ω. This is a crucial parameter two antenna design for specific applications such as radar, satellite communication, and tumor imaging.

Simulation.02



In simulation 02 VSWR has 1.02, which was obtained at the resonant frequency of 27.43 GHz, it indicated that the insets increased the radiating patch edges and allowed them to best match with the feedline and system impedance at 50 Ω. Hence, the simulated model performed excellent well in comparison to the previous simulated model.

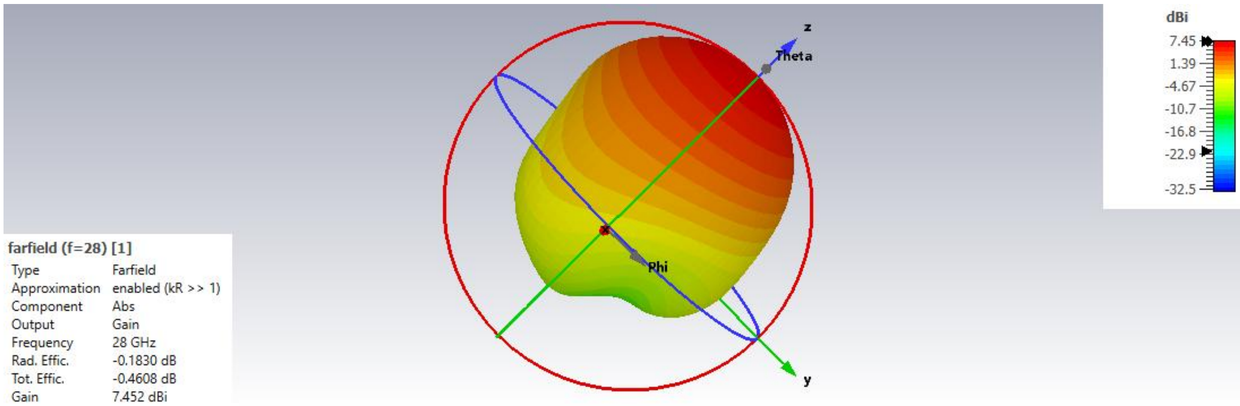
Simulation.3



In simulation 03 the VSWR was 1.01 that measured at the resonance frequency of 27.76 GHz it was lower than that of earlier simulations 1.22 and 1.02 and quite near to the ideal value 1. It has been confirmed that the radiating patch edges increased with the number of insets, enabling them to best match with feedline and system impedance at 50 Ω. the simulated model performed exceptional in comparison to the previous simulated both models.

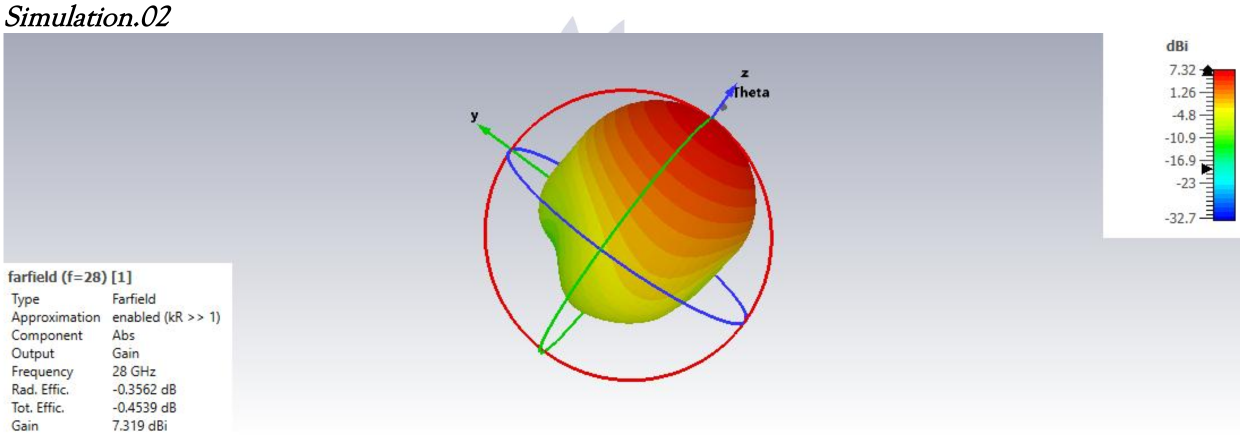
3.3. Gain of Simulated Design 1, 2 & 3

Simulation.01



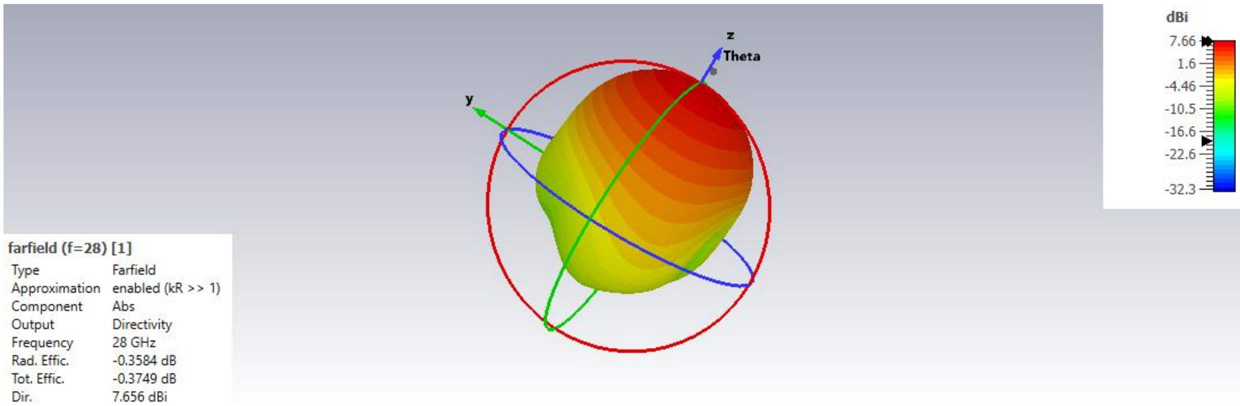
The 3-D far field plot of simulated design 01 showed a red marked at the top of bulb this was due to the maximum gain of 7.45 dBi. Additionally, this figure showed that the gain was attained at a frequency of 28 GHz, which falls within the 5G category of millimeter waves. The far field plot's shape indicated that the signal strength was somewhat directional, making it ideal for specific medical and communication applications.

Simulation.02



The 3-D far field plot of simulated design 02 has shown a red color at the top of bulb like the previous one this was also marked due to the maximum gain of 7.32dBi which was slightly less than 0.13 dBi of previous simulation, the obtained gain achieved at the same resonant frequency 28 GHz, that has been perfectly matched with 5G category of millimeter wave. The far field plot's shape indicated that the signal strength was somewhat directional but not perfectly omnidirectional as compare to the simulation 01, hence the two insets slightly reduced the gain strength and increased VSWR and S11 parameters.

Simulation.3



The maximum gain of 7.66 dBi was displayed in the most recent third model of 3-D far field plot, which was an excellent gain compared to the previous equivalent gains of 7.45 and 7.32 dBi. This gain obtained at the same resonant frequency of 28 GHz, this frequency perfectly matched with the 5G category of millimeter waves. As a result, it has been demonstrated that the third inset across from the feedline could increase the signal's gain (7.66 dBi) and directivity (7.65 dBi).This data also has confirmed that the generated signals were directional in comparison to simulation 01 and simulation 02, so the third inset increased the gain strength and directivity and was appropriate for medical imaging and 5G communication technologies.

4. Conclusion

To meet the high-frequency requirements of 5G communication and medical imaging, this study effectively optimized a microstrip patch antenna and showed that altering the patch geometry with particular insets greatly improves antenna performance. This assessment was made possible with the help of CST Microwave Studio, by which three different models were evaluated. With a remarkable return loss of -45.30 dB and a resonance frequency of 27.76 GHz, the third model proved to be the most successful design. Additionally, this modified model achieved an almost perfect VSWR of 1.011, guaranteeing better impedance matching at 50 Ω. With a maximum gain of 7.66 dBi and an overall efficiency of 91.73%. This antenna offers the directivity and penetration needed for ultra-fast 5G data transfer and high-resolution, noninvasive tumor imaging. The use of a thin Rogers RT5880 substrate successfully combined the requirement for a compact profile with high-performance metrics, making it a feasible solution for contemporary portable devices and cutting-edge medical applications.

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