IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 17, Issue 5, Ser. I (Sep. – Oct. 2022), PP 01-04
www.iosrjournals.org

Inset – Fed Rectangular Microstrip Antenna Optimizedat 28 GHz for 5G Communication Systems

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Abstract: *In this research, an inset-fed rectangular microstrip antenna is designed and optimized in order to use with 5G communication systems. The proposed antenna is designed and optimized at 28 GHz centered frequency. The optimaldimensions are 3.285 mm and 4.232 mm for patch length and width respectively with microstrip line width of 0.4481mmand length of 4.037 mm. inset distance is varying in order to control input impedance. The proposed antenna resonates at 27.9832 GHz with return loss of -18.85587 dB and bandwidth of 1.46395 GHz.*

Keywords*: Microstrip Antenna, Patch Antenna, Inset-Fed, Optimization, Millimeter, Return Loss, Bandwidth, 5G.*

Date of Submission: 20-08-2022 Date of Acceptance: 04-09-2022

I. Introduction

Microstrip patch antenna is suitable antenna types that can be used with 5th generation of communication systems due to its low profile and light weight.Main challenge that facing antenna designers is how to enhance the bandwidth of patch antenna in order to meet the requirements of 5th generation which includes providing high coverage and availability. In this paper, a single microstrip patch element is designed and optimized at 28 GHz by using CST Studio.[1] [2] [3]

5th generation systems depend on spectrum in many different bands. These ranges are: sub-1 GHz, 1 – 6 GHz and above 6 GHz. 28 GHz band is a part of the third group that also known millimetric wave band. What makes it such a valuable resource for mobile networks is the amount of spectrum available. [5] [6]

II.Methodology

The design of proposed Antenna is depending on essential parameterswhich are using to evaluate the width (W) and length (L) of rectangular patch. These parameters are: the resonant frequency (f_r), relative dielectric constant (ε_r), and substrate height (h) [1]

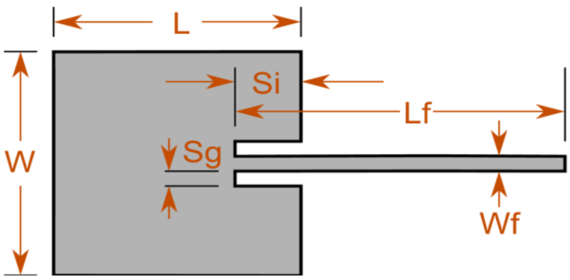

Figure (1): Proposed Patch Antenna

After choosing the resonant frequency, relative dielectric and height of substrate, we use the following approximation equations to calculate the width and length of the patch element, these equations are: [7] [8]

- For patch width, W:

$$W = \frac{C}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (1)$$

Where C is velocity of electromagnetic wave in free space, f_r is resonant frequency, ε_r is dielectric constant of the substrate.

- Effective dielectric constant, ε_{eff}:

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{\sqrt{1+12\frac{h}{W}}} \quad (2)$$

Where h is thickness of the substrate in mm, W is the width of the patch in mm

- For effective length, L_{eff}:

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}} \quad (3)$$

Electrically, antenna dimensions are longer than the physical dimensions due to fringing factor. This factor is subtracted from the effective length to give the actual length of the patch which is given by:

$$\Delta L = 0.412\frac{(\frac{W}{h}+0.264)(\varepsilon_{eff}+0.3)}{(\varepsilon_{eff}-0.258)(\frac{W}{h}+0.813)} \quad (4)$$

- For patch length, L:

$$L = L_{eff} - 2\Delta L \quad (5)$$

Where ΔL is the length extension and L is the actual length of patch antenna.
The transmission feedline length and width are calculated using equations (6) and (7) below:

$$F_i = 10^{-4}[0.001699\varepsilon_r^{\,7} + 0.13761\varepsilon_r^{\,6} - 6.1783\varepsilon_r^{\,5} + 93.187\varepsilon_r^{\,4} - 682.69\varepsilon_r^{\,3} + 2561.9\varepsilon_r^{\,2} - 4043\varepsilon_r + 6697]\frac{L}{2} \quad (6)$$

$$W_f = \frac{7.48h}{e^{(Z_0\frac{\sqrt{\varepsilon_r+1.41}}{87})}} - 1.25t \quad (7)$$

Where Z_0 is the input impedance, t is the ground thickness in mm.

- For ground plane dimensions:

$$W_g = 6h + W \quad (8)$$

$$L_g = 6h + L \quad (9)$$

Where W_g is the width of ground plane in mm, L_g is the length of the ground plane in mm.

Table (1): Optimized Dimensions of the Proposed Patch:

Parameter	**Dimensions (mm)**
Ground Plane Length, L_g	**6.571**
Ground Plane Width, W_g	**8.465**
Patch Length, L	**3.285**
Patch Width, W	**4.232**
Height of Substrate, h	**0.500**
Width of Feedline, W_f	**4.037**
Ground Thickness, t	**0.035**

III. Results and Discussion

The proposed patch antenna was modelled and simulated using CST Studio after evaluation of its dimensions by using MATLAB software.

- **Return Loss:**

the patch element resonates at 27.9832 GHz with return loss -18.85587 dB as shown in Figure (2) below. The S_{11} parameter were obtained using waveguide port configuration. The antenna is having an impedance bandwidth of 1.46395 GHz.

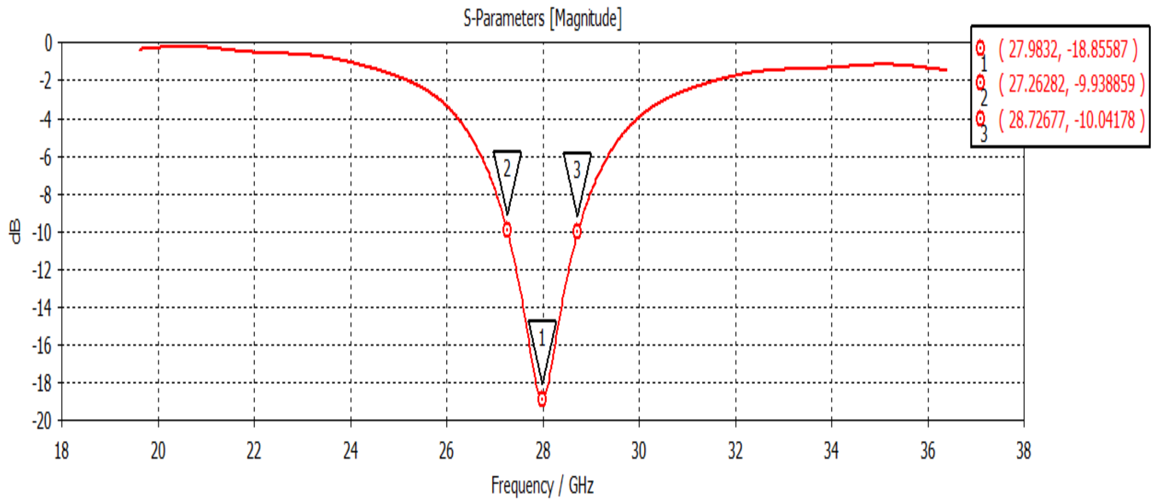

Figure (2): Return Loss (dB) VS Frequency (GHz)

- **VSWR:**

For microstrip antenna, the voltage standing wave ratio (VSWR) should be greater than 1 and not more than 2. From Figure (3) we can observe that VSWR value at 27.9832 GHz is equal to 1.46822.

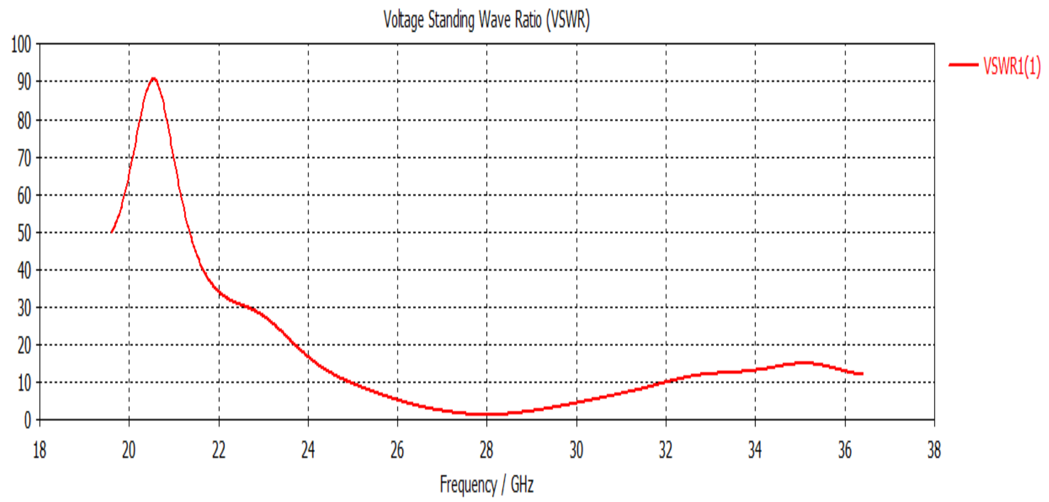

Figure (3): VSWR (dB) VS Frequency (GHz)

- **Gain:**

From Figure (4), the proposed antenna has a relative gain of 8.75 dB which is good for microstrip antenna and half power beamwidth of 67.6 deg. With sidelobe level of -15.2 dB

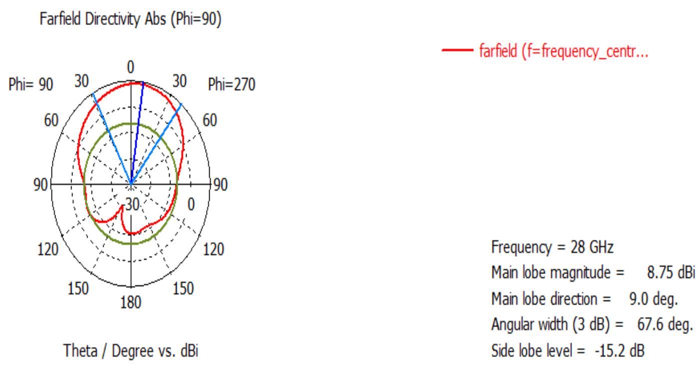

Figure (4): 3-D radiation Pattern

Table (2): Summary of Simulated Results

Antenna Parameter	Value
S_{11}	-18.85587
Bandwidth	1.46895 GHz
Gain	8.75 dB
VSWR	1.46822
Efficiency	81.86 %
HPBW	67.6 deg.

IV. Conclusion

A rectangular patch antenna element was designed and optimized at 28 GHz and resonance occurs at 27.9832 GHz with return loss about -18.85587 dB below -10 dB. This antenna has small size which it useful for miniaturization of communication system's devices. Simulated bandwidth may consider it suitable for 5th generation. The proposed antenna has an efficiency about 81.86%.

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Omer A. H, et. al. "Inset – Fed Rectangular Microstrip Antenna Optimizedat 28 GHz for 5G Communication Systems." *IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)* 17(5), (2022): pp 01-04.