Comparison of different feeding techniques for a patch antenna at an X frequency band to evaluate its quantitative impact on the antenna's parameters

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Abstract: In this paper, the comparison of different feeding techniques for a patch antenna, at X frequency band, to evaluate its quantitative impact on the different antenna parameters is presented. When different feeding techniques are applied at the X band spectrum to improve the impedance matching the performance of various characteristics parameters such as radiation pattern, gain, beam width etc are influenced. To find how much these are influenced a comparative analysis is carried out and results are presented in this paper. For investigation purpose, the patch antenna and the various feeding techniques were designed on Roger (RT5880) substrate at 8 GHz resonating frequency.

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1. Introduction

Microstrip patch antennas remain extensively used in various frequency bands (C, S, X, Ku etc.) for different wireless applications such as communications, aircraft, spacecraft, satellite, and military etc. The main reason of its extensive usages is that it offers various advantage such as it has a very small size, low weight and easy to fabricate using modern printed circuit technology (Abohmra et al., 2019).

Generally, Microstrip antenna consists of a radiating patch element mounted on a dielectric substrate material. The various substrates materials having the dielectric constants values between $2.2 \leq \varepsilon\_r \leq 12$ can be used to design the microstrip patch antennas (Bai, Cheng, Ding, & Zhang, 2020). Planar radiating patch element can be made of different geometrical shapes such as rectangular, square and circular. To radiate antenna signal effectively and for impedance matching purpose these different shapes need to be fed with some proper feeding configuration. Two categories of feeding techniques; connecting (Microstrip line, coaxial probe) and non-connecting (Aperture coupled, and proximity coupled) can be applied (Chatterjee & Kundu, 2017). When these different feeding techniques are applied, at the various frequency spectrums, to improve the impedance matching, the performance of various characteristics parameters such as radiation pattern, gain, beam width etc. are influenced. Therefore, whenever a new antenna applications need to be developed it is important to know these influences (Basilio, Khayat, Williams, & Long, 2001).

A microstrip patch antenna is designed using an aperture coupled feed technique for 2.4 GHz frequency range (Civerolo & Arakaki, 2011; Krishnaveni & Manimegalai, 2020). The aperture coupled technique has better performance as compare to microstrip & probe fed configuration (Kumar, Kaur, & Singh 2013). Debajyoti et al. compared two feeding techniques (proximity coupled feed and aperture coupled feed) of the microstrip patch antenna and found proximity coupled feed gives much higher return loss as compared to aperture coupled patch antenna (Chatterjee & Kundu, 2017).

(Mandal et al., 2012) designed and analyzed microstrip patch antenna using a different technique for matching of impedance among patch and feed line by using coaxial line and microstrip line and recommended that the coaxial feed line gives good impedance matching (Biswas & Sen, 2019).

These investigations are presented for the various frequency bands. In this paper, investigations are carried at an X band frequency and results are presented. The patch at an X band frequency i.e. 8GHz are designed by applying the four feeding techniques i.e. Microstrip line, coaxial probe, proximity couple and aperture couple feed technique.

Then, quantitative impact on the antenna parameters of these techniques are compared with each other and investigations results are presented.

2. Patch antenna and different feed configuration basics

A simple rectangular patch antenna consists of four parts (Motin, Hasan, Habib, & Sheikh, 2013; Shimu & Ahmed, 2016); a rectangle form patch element, having certain length and width dimensions, used to radiating the fed signals, dielectric substrate having a certain relative permittivity (ε_r) and tangent loss (δ) value, a ground plane on back of substrate (not visible in figure 1) utilized to block radiations on back of substrate and a feeding point or a port to provide power from source to the radiating element. A simplified model is shown in Fig. 1.
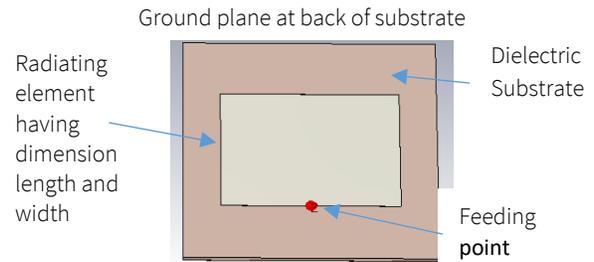
Figure 1. Element of Microstrip for radiating radiations.

Whenever a patch antenna needs to be designed, the first step is to find the dimensions for radiating the desired frequency. For rectangular patch it is required to find the width (W) and length (L) of the radiating element (Mikulasek & Lacik, 2011). These values depend on the substrate's dielectric values (relative permittivity ε_r and tan loss value (δ)) and its height (h). The detail to calculate the required dimension for the resonance frequency (f_0) are given as follows.

The width of a patch antenna, W, can be easily determined by using (Sidhu & Sivia, 2016)

$$W = \frac{c}{2f_o\sqrt{\frac{\varepsilon_r+1}{2}}} \tag{1}$$

Then next step is to calculte the overall length of the patch L. It can be determined using foloowing equation.

$$L = L_{eff} - 2\Delta L \tag{2}$$

Where ΔL represents the length that is extend due to the edge radiation effect, and L_{eff} effective length that can be determined using following equation.

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}} \qquad (3)$$

The effective dielectric constant (ε_{reff}), can be evaluated as follows. (Sidhu & Sivia, 2016)

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1 + 12\frac{h}{w}\right]^{1/2} \qquad (4)$$

And ΔL extended length caused by edge radiation can be determented using following euation.:

$$\Delta L = 0.412\, h\, \frac{(\varepsilon_{reff}+ 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \qquad (5)$$

Using the above mentioned analytical equations, for the investigating frequency point i.e. 8 GHz fthe dimension of the raditing patch element for the considered substrate (detailed mentioned in table) were calculated and are given in Table 1.

Table 1. The detail of considered substrate and the calculated dimensions of the patch antenna at 8 GHz frequency.

Resonate frequency	8 GHz
Substrate material	Roger
ε_r	2.2
Substrate height	1 mm
Loss tangent	0.0009
Width of the patch	14.8mm
Length of the patch	12.1 mm

Then the electrical model was developed and its 3D numerical EM calculations were calculated and results will be presented in next section.

At the edge, the input is not 50 ohm therefore that need to matched, so that with high efficiency or with minimum reflections, the applied source could be matched with the connected load impedance. To performance this task various feeding were developed and are being utilized. But the problem by attaching these feeding techniques is that these them self-radiate or couple the EM signals which interact the radiating patch element radiation hence the output of antenna is modified and the designed radiating elements are changed. Which needed to determine the specific performance characteristic of the designed antenna system.

For excitation, the patch antenna is designed to operate at a resonance frequency of 8GHz. For this purpose, the length of the patch is taken as 12.1 mm on x axis. The width of its patch is taken as 14.8 mm on Y-axis. The height of the dielectric substrate for patch is taken as 1 mm on Z-axis and the value of dielectric constant (εr) is 2.2. The excitation patch of antenna is feed by either a probe feed or an edge feed. If the patch is

table 4 being excited by feed, the distribution of charges is developed among the bottom of the patch & the ground plane as positively charged and the negatively charged. In this Research work, the edge feed is used to investigate the effect of excitation on the resonant behavior of different feeding techniques on the micro strip patch antenna so that it becomes polarized and the E-plane along the field direction & the H-plane would be perpendicular (Patel & Upadhyaya, 2019). It was found that the highest impedance was at the edge of the antenna and the maximum radiation resonates with the proximity feed coupled antenna as compared to the other feeding techniques.

2.1. Coaxial probe feed
The schematic of the coaxial feed technique for the patch antenna is shown in Fig. 2. In this method, the coaxial feed line of a desired values (mostly a 50 Ohm coaxial connector) is directly attached with the patch element at a point where its input impedance is matched with the applied source output impedance.
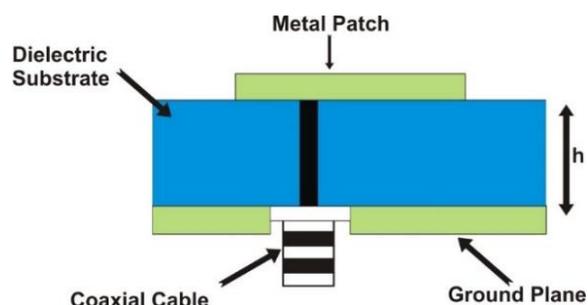
Figure 2. The coaxial probe feed line.

How away from the edge the point need to connected in patch can be calculated by following equation;

$$R_{in(y=y_0)} = R_{in(y=0)}\, cos^2\left(\frac{\pi}{L}\, y_0\right) \qquad (6)$$

At the considered frequency, the dimension for the 50 ohm connector are Inner conductor, r_i equals to 0.1 mm and out conductor, r_0, equals to 0.23mm. It is connected 5mm away from the edge as shown in Fig. 2. The specification of Coaxial feed and microstrip patch antenna is given in Table 2 and 3.

Table 2. Specification of Coaxial feed.

Name	Specification
Frequency	8 GHz
Patch width W	14.08 mm
Patch length L	12.1 mm
Substrate thickness h_1	1mm
Inner conductor r_i	0.1mm
Outer conductor r_o	0.23mm

2.2. Microstrip feed line

In this technique, impedance of the patch is matched using the microstrip feed line as shown in Fig 3. This line is used to transform the edge impedance to a value that is matched with applied source impedance value. The length of the attached line is quarter wavelength and have the transformed impedance value given as follows-

$$Z_T = \sqrt{Z_0 Z_{ant}} \tag{7}$$

Where Z_0 is source impedance, Z_{ant} is impedance of the patch element and Z_T is impedance of transformed impedance microstrip line (Basilio et al., 2001, Inclán-Sánchez, Vázquez-Roy, & Rajo-Iglesias, 2009).
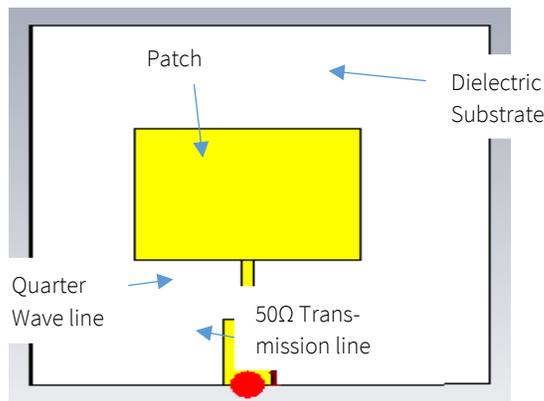
Figure 3. A Microstrip feed line.

Table 3. Specification of the microstrip patch antenna.

Name	Specification
Frequency	8 GHz
Patch width W	14.08 mm
Patch length L	12.1 mm
Width of the transmission line W_f	0.83 mm
Length of the transmission line L_f	4.9 mm
Width of antenna W_o	3.1mm
Length of antenna L_o	5.47mm

2.3. Aperture couple feed

To avoid the impact of EM fields radiated from the microstrip line with patch this technique is applied. In this technique the feeding line is attached on the back of ground plane separated using a substrate and a slot is created in the ground plane to couple the signal from feeding line to the patch (Civerolo & Arakaki, 2011). The length and width of slot impact the loading with the patch (Yon, Awang, Ali, Subahir, & Kamaruddin, 2016).

Design and modeling of aperture couple feed: The aperture coupled rectangular antenna consists of two dielectric substrates (Errifi, Baghdad, Badri, & Sahel, 2015), both are made up of Roger material having dielectric constant $\varepsilon r = 2.2$ mm with (30×30×1) mm^3 dimensions. These 2 dielectric substrates of the same thickness are separated by ground plane made of the copper thickness of 0.1 mm. A microstrip feed line of length L_f = 18mm and width W_f = 1.5mm is mounted on a lower substrate (Darimireddy, Reddy, & Prasad, 2015; Gummalla, Stoytchev, Achour, & Poilasne, 2010). A rectangular aperture of a length F_1 = 6mm and width F_w= 1.05 mm and stub length L_{stub} = 2.5 mm. Fig. 4 shows the top view, bottom view, and slot or an aperture, and the specification of Aperture feed antenna is given in Table 4.

(a) (b)

(c)
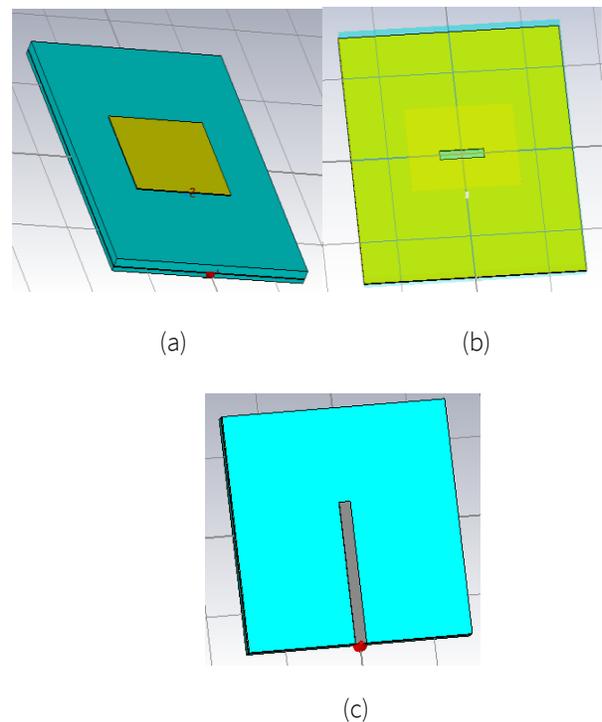
Figure 4. Modeling of aperture couple feed;
(a) Top view, (b) Ground plane with slot; (c) Bottom view.

Table 4. Specification of Aperture feed antenna.

Name	Specification
Frequency	8 GHz
Patch width W	14.08 mm
Patch length L	12.1 mm
Substrate thickness h_1	1 mm
Substrate thickness h_2	1 mm
The width of stripline W_f	1.5 mm
The length of the feed line L_f	18 mm
The width of aperture F_w	1.05 mm
The length of aperture F_1	6mm
Stub length L_{stub}	2.5mm

2.4. Proximity couple feed

Design and modeling of proximity couple feed: Fig. 5 shows the structure of proximity coupled patch antenna, where the 2 dielectric substrates of the same thickness 1 mm and same dielectric constant $\varepsilon r = 2.2 \, mm$ are separated through the microstrip feed line. The length of the feed line is L_f = 15.6 mm, the width of stripline W_f = 2.8 mm. The feedline is centered with respect to radiating patch. The specification of proximity couple feed antenna is given Table 5.
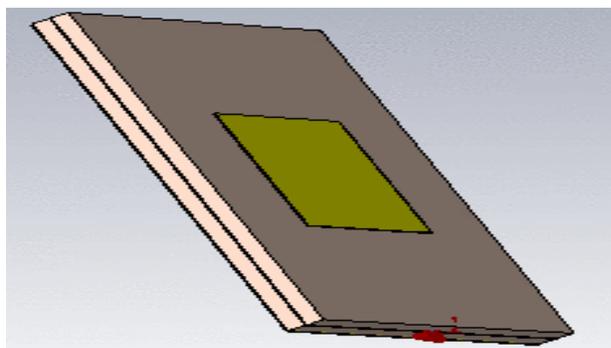
Figure 5. The geometry of proximity couple.

Table 5. Specification of proximity couple feed antenna.

Name	Specification
Frequency	8 GHz
Patch width W	14.08 mm
Patch length L	12.1 mm
Substrate thickness h_1	1 mm
Substrate thickness h_2	1 mm
The width of stripline W_f	2.8 mm
The length of the feed line L_f	15.6 mm

3. Results and discussion

As already mentioned in section 1, when different feeding techniques are applied at the X band spectrum to improve the impedance matching of a radiating patch element, the performance of various characteristics parameters such as radiation pattern, gain, and beam width are influenced of the designed patch radiating antenna element due to the undesired EM radiations produces by these feeding line them self. To find this, a comparative analysis is carried out and results are presented in this section. First the results of a signal patch are presented then the results of impedance matching with various feeding is discussed and finally the comparison will be presented.

3.1. The patch radiating element

The impedance of the patch antenna describes the frequency is resonant at 8 GHz with the impedance of 193.2 Ohms shown in Fig. 5. For better performance, it is necessary to properly match the impedance at 50 ohm using various feeding techniques (Pan & Zheng, 2017).

S-parameter of the patch antenna: Fig. 6, S-parameter calculation has been performed for radiating the patch antenna. The return loss for the patch antenna is -8.32 dB at frequency 8.42 GHz. The value of the reflection coefficient is more than -10 dB; which, indicates that power is rejected back toward the antenna. To overcome these reflections using feeding techniques that appropriately match with the patch.

The gain of the patch antenna: The 3D and polar plot of the patch antenna is shown in Fig. 7. The simulated gain of a patch antenna according is 8.13 dB at 8 GHz frequency. The polar plot shows that the simulated antenna radiates maximum power towards the main lobe. Through the polar plot, the main lobe direction at the value of 178.00 and the angular width is 73.20 degrees is shown in the polar plot.

VSWR of the patch antenna: *VSWR* is an indication of the actual voltages that occur in a transmission line system when radio waves are being reflected. Fig. 8 shows the *VSWR* path against the frequency which graphically describes how the antenna matches when it is connected to the transmission line. The value of *VSWR* is 2.24 at the desired frequency.

3.2. Performance evaluation of the various feeding techniques:

The simulation of all four feeding techniques is performed using *CST* studio and the results of each feeding technique are described.

Simulation results of microstrip feed: The microstrip feed is the technique for matching characteristics impedance at 50 Ohms. The feed is directly connected to patch.

The impedance of Microstrip feed: Fig. 9 shows the impedance is approximately 52.2 $\mathit{\Omega}$ and resonates at 8.316 GHz frequency; the patch is matched with microstrip feed. The results of the patch antenna are summarized in Table 6. And *VSWR* is shown in Fig. 10.

Table 6. Results for the patch antenna.

Result	Impedance $\mathit{\Omega}$	Gain dB	Main lobe Degree	Return loss dB	VSWR
Single patch element	193.2	8.1	179	-8.32	2.2
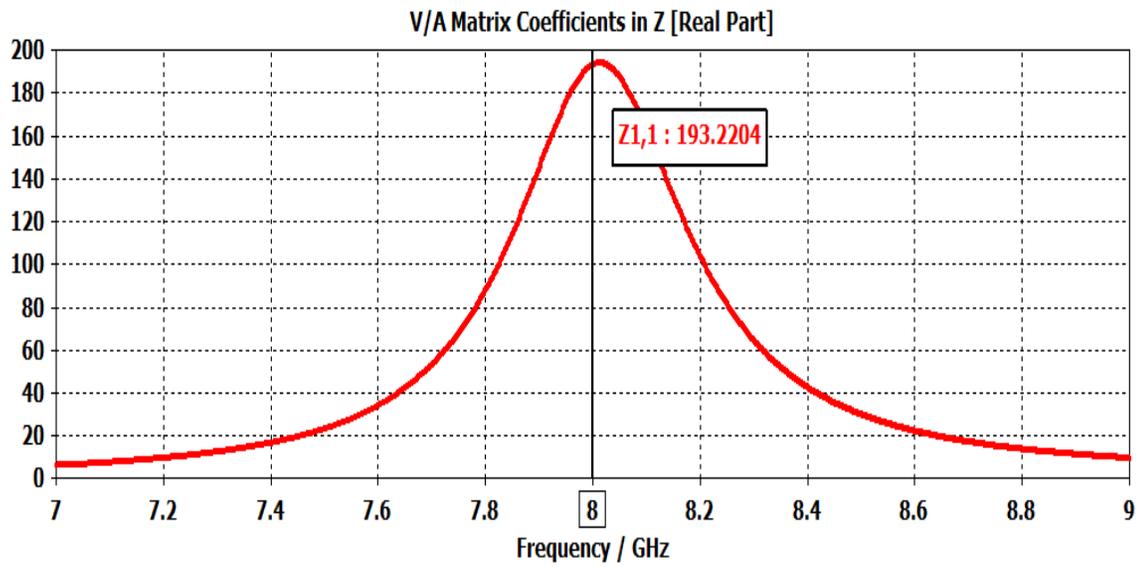
Figure 6. The impedance of the patch antenna.
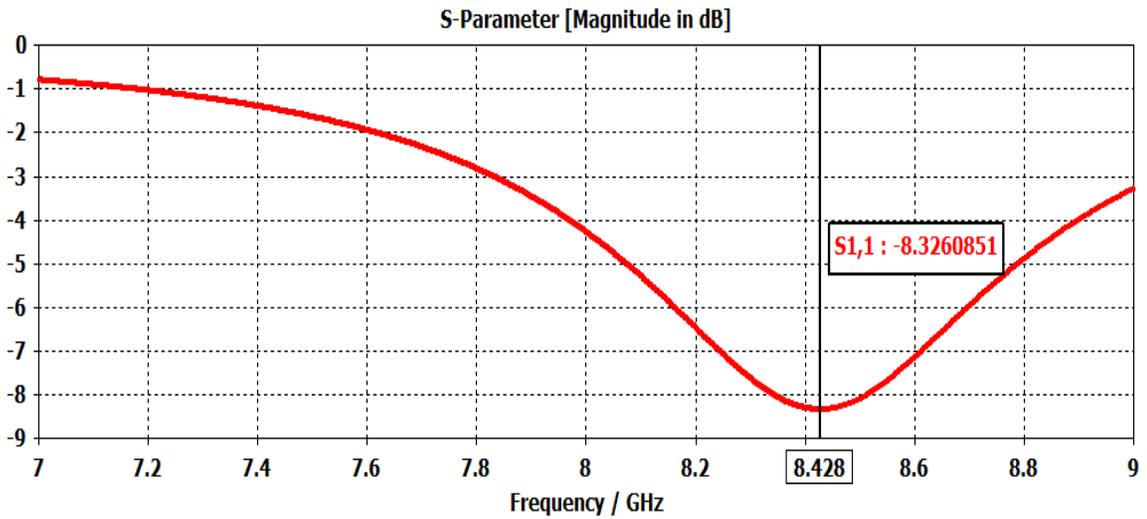
Figure 7. S-parameter of the patch antenna.

Farfield Gain Abs (Phi=90)

—— farfield (f=8) [1]

Frequency = 8
Main lobe magnitude =   8.14 dB
Main lobe direction = 178.0 deg.
Angular width (3 dB) =   73.2 deg.
Side lobe level = -22.6 dB
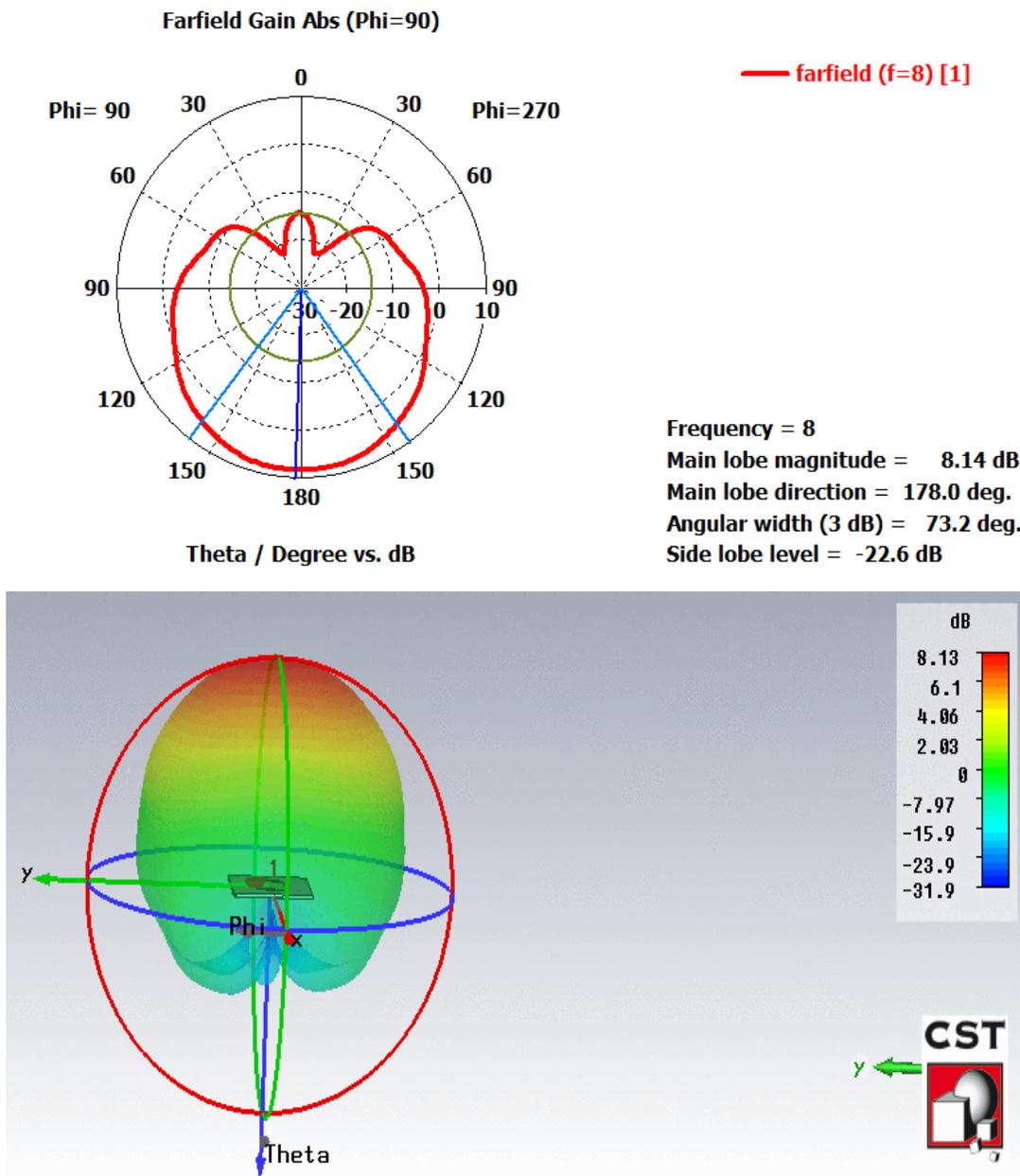
Figure 8. The gain of the patch antenna.

S-parameter of Microstrip feed: Fig. 11 shows S-parameter calculation has been performed for the radiating patch antenna. The return loss for Strip-line patch antenna is ($S_{11} = -28.2dB$) at frequency 8.37 GHz which is less than -10dB. The value of the reflection coefficient indicates that impedance appropriately matches and maximum power transfer to the load.

The gain of Microstrip feed: 3D and polar plot of microstrip feed are shown in Fig. 12. The gain represents how well the antenna radiated power in a specific direction and the simulated gain is 7.03 dB, the simulated antenna radiates maximum toward the main lobe. Therefore, the main lobe focused at the angle of 165.00 and an angular width of 80.10.

VSWR of Microstrip feed: Fig. 13 shows the VSWR path against the frequency which graphically describes how the antenna matches when it is connected to the transmission line. The value of VSWR is 1.08 at the desired frequency and the standard value is ≤ 2. The value obtained from VSWR is low and it shows a better result.

Comparison of the patch vs Microstrip feed: The comparative results for the patch antenna with the microstrip feeding technique are shown in Table 7.

Table 7. Comparison of the patch vs microstrip feed.

Feeding Technique	Impedance Ω	Gain dB	Main lobe Degree	Return loss dB	VSWR
Single Patch Element	193.2	8.1	179	-8.32	2.2
Microstrip	52.2	7.03	165	-28.2	1.08

3.3. Simulation results of coaxial probe feed

The coaxial probe feed is very rarer in a patch antenna because the feed can be located anywhere in the top of the patch antenna. The proposed antenna is fabricated on Roger substrate having thickness 1 mm and the value of the dielectric constant is 2.2, and loss tangent of 0.009. The simulation result of the coaxial probe feed is discussed below.

The impedance of coaxial feed: Fig. 14 shows the impedance of the coaxial probe feed. The impedance of coaxial feed is 53.6 ohm at 8.172 GHz frequency. As the dimensions of the inner conductor, the outer conductor is too small at a higher frequency, the peak value is not at a specific frequency and its move towards the right.

S-parameter of coaxial probe feed: S-parameter calculation has been performed for the coaxial patch antenna. Fig. 15 shows that the return loss for a coaxial patch antenna is ($S_{11} = -14.8\ dB$) at frequency 8.12 GHz which is less than -10 dB. It can be analyzed from the graph that return loss of coaxial

probe feed has no considerable impact on antenna performance.

The gain of coaxial probe feed: The simulated gain of the coaxial antenna according to Fig. 5 is 8.1 dB, Fig. 15 shows the 3D and polar plot of coaxial feed. The simulated antenna radiates maximum toward the main lobe. The main lobe focused at the angle of 17.00 and an angular width of 73.50.

VSWR of coaxial probe feed: Fig. 16 shows the VSWR path against the frequency which graphically describes how the antenna matches when it is connected to the transmission line. The value of VSWR is 1.44 at the desired frequency and the standard value is ≤2.

Comparison of the patch vs Coaxial feed: The comparative results for the patch antenna with coaxial feed are shown in Table 8.

Table 8. Comparison of the Patch Vs Coaxial feed.

Feeding Technique	Impedance Ω	Gain dB	Main lobe Degree	Return loss dB	VSWR
Single Patch Element	193.2	8.1	179	-8.32	2.2
Coaxial	53.7	8.1	173	-14.8	1.4

3.4. Simulation results of aperture couple feed

This type of feeding technique is also used to match the antenna with the transmission line at 50 Ohms characteristics impedance. The simulation results discuss how much impact on antenna performance.

The impedance of the Aperture couple feed: Fig. 17 shows the impedance of aperture couple feed which describes the frequency is resonant at 8 GHz with characteristics impedance of 49.89 Ohms. The radiating patch is properly matched with the transmission line.

S-parameter of aperture couple feed: S-parameter calculation has been performed for aperture couple feed antenna. The return loss for aperture couple feed antenna is ($S_{11} = -45.2\ dB$) at frequency 8.01 GHz. Fig. 18 shows more negative return loss, the gain antenna in a particular direction. The aperture couple feed antenna has more negative return loss so it has less impact on the antenna performance than the other two feeding techniques.

The gain of aperture couple feed: The 3D and polar plot of aperture coupled feed are shown in Fig. 19. The gain represents how well the antenna radiated power in a specific direction and the simulated gain is 7.06 dB. The simulated antenna radiates maximum toward the main lobe. The main lobe focused at the angle of 175.00 and an angular width of 70.40.

Voltage Standing Wave Ratio (VSWR)

VSWR1 : 2.2437966
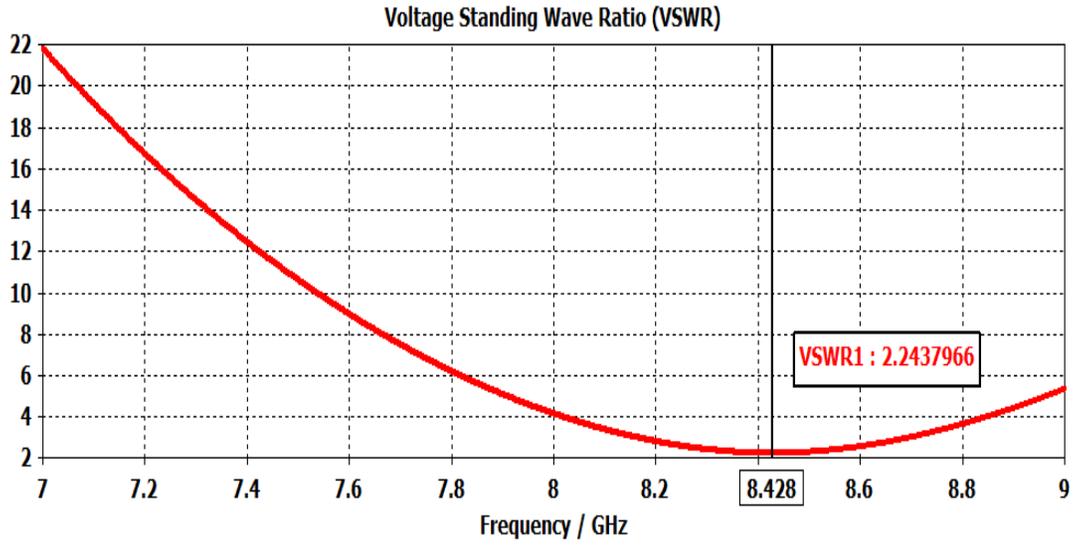
Figure 9. *VSWR* of the patch antenna.

V/A Matrix Coefficients in Z [Real Part]

Z1,1 : 52.251818
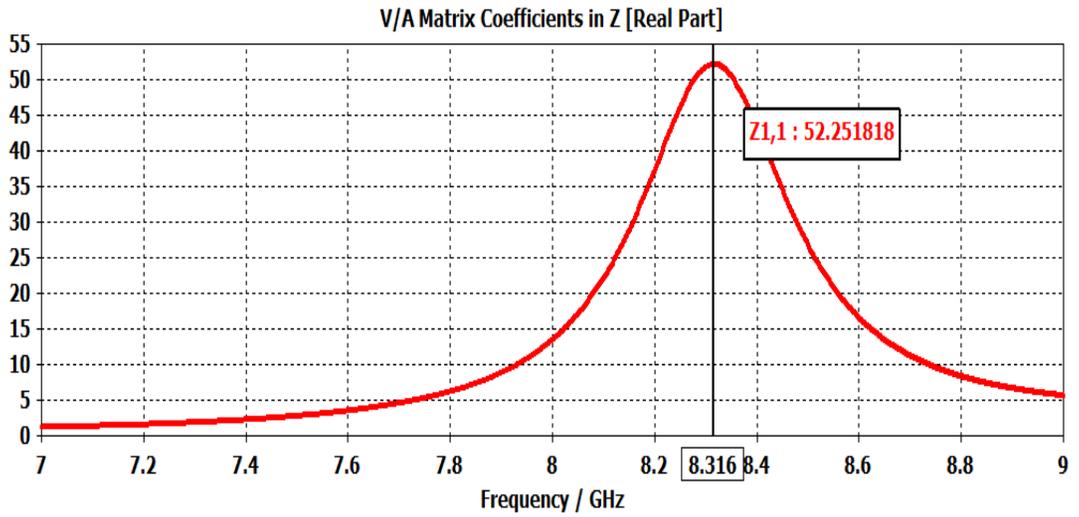
Figure 10. The impedance of Microstrip feed.
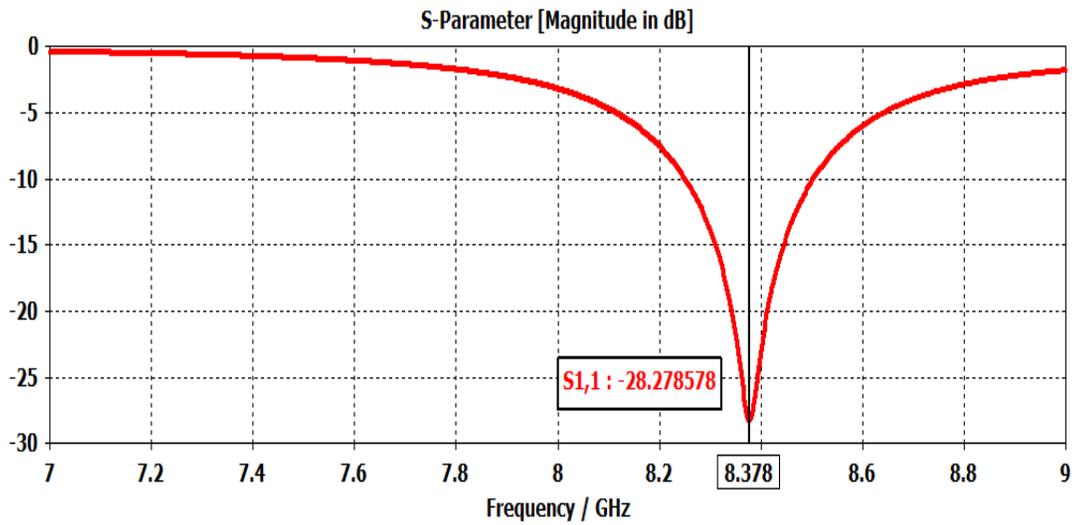
Figure 11. S-parameter of Microstrip feed.
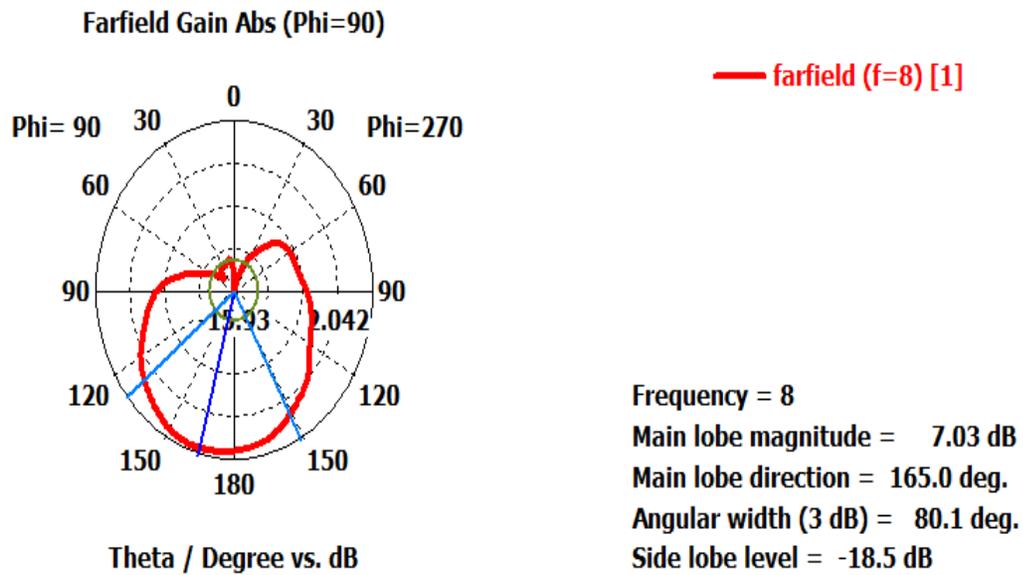
Figure 12. The gain of Microstrip feed.

Voltage Standing Wave Ratio (VSWR)

VSWR1 : 1.0802003

8.378

Frequency / GHz
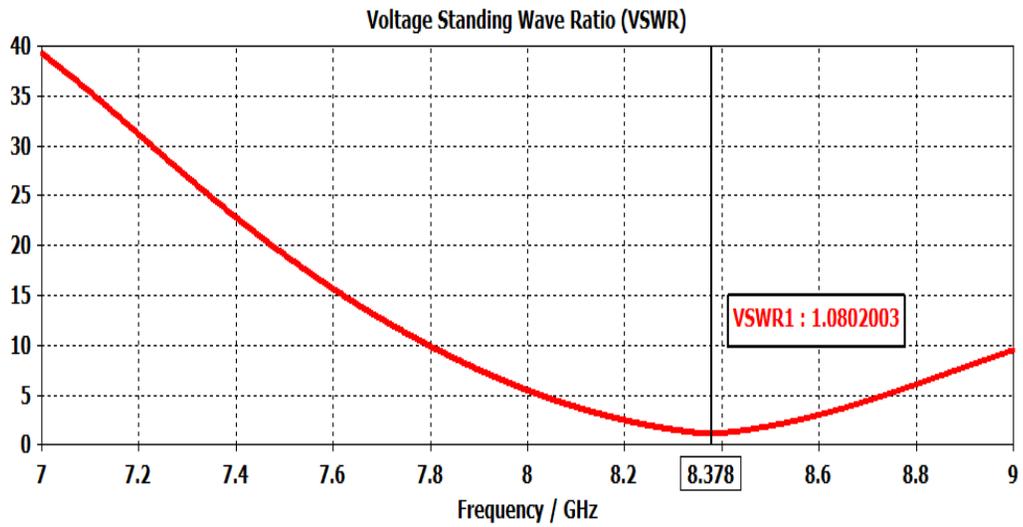
Figure 13. VSWR of microstrip feed.

V/A Matrix Coefficients in Z [Real Part]

Z1,1 : 53.696432

8.172

Frequency / GHz
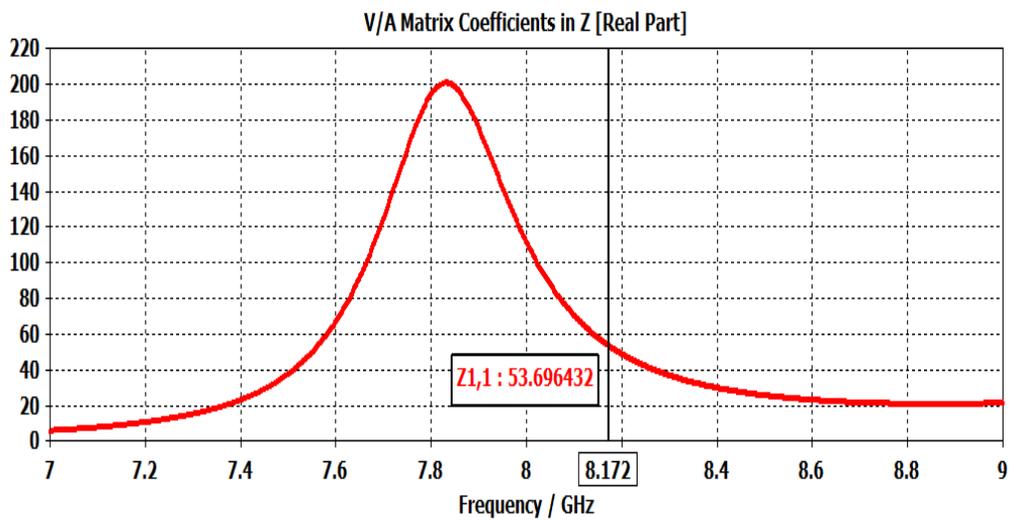
Figure 14. The impedance of Coaxial feed.

S-Parameter [Magnitude in dB]

S1,1 : -14.814435

Frequency / GHz
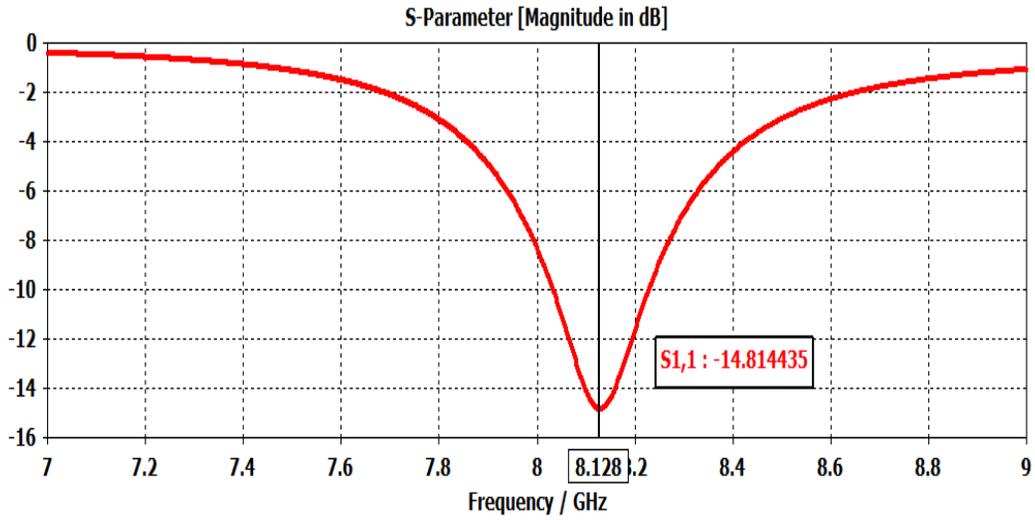
Figure 15. S-parameter of Coaxial feed.

Farfield Gain Abs (Phi=90)

farfield (f=8) [1]

Theta / Degree vs. dB

Frequency = 8
Main lobe magnitude =   8.1 dB
Main lobe direction = 173.0 deg.
Angular width (3 dB) =   73.5 deg.
Side lobe level = -22.3 dB
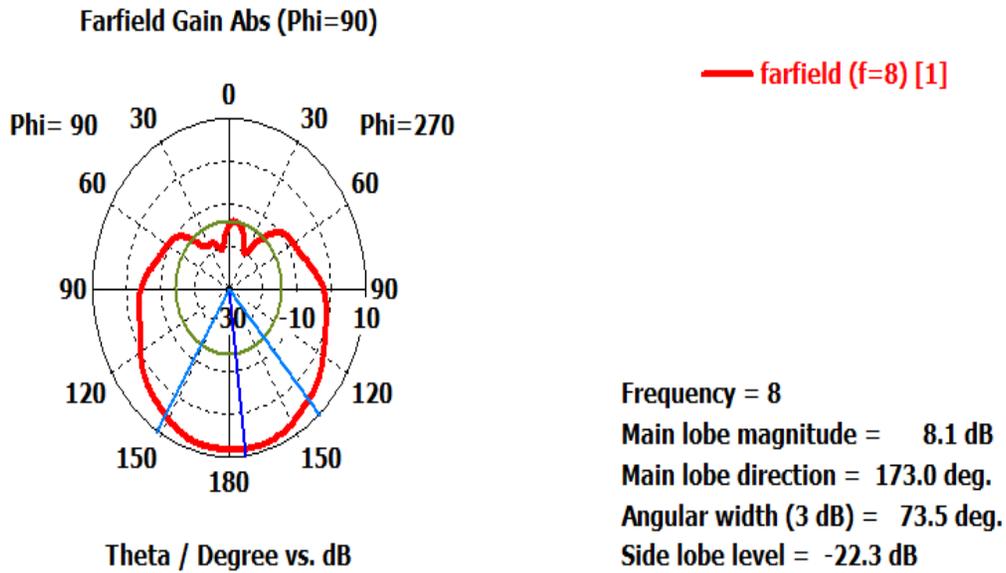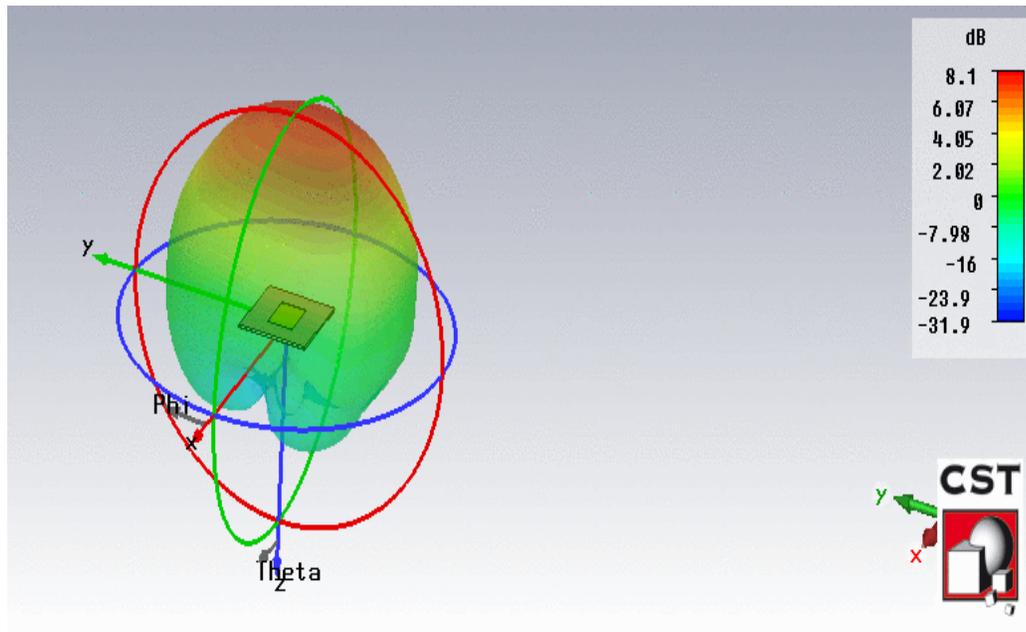
Figure 16. The gain of coaxial probe feed.
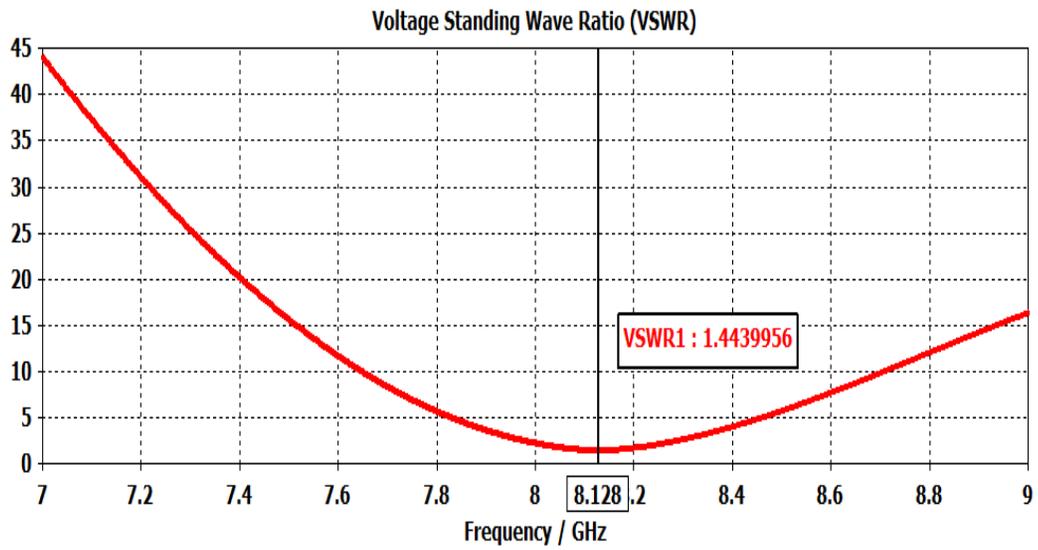
Figure 17. *VSWR* of coaxial probe feed.
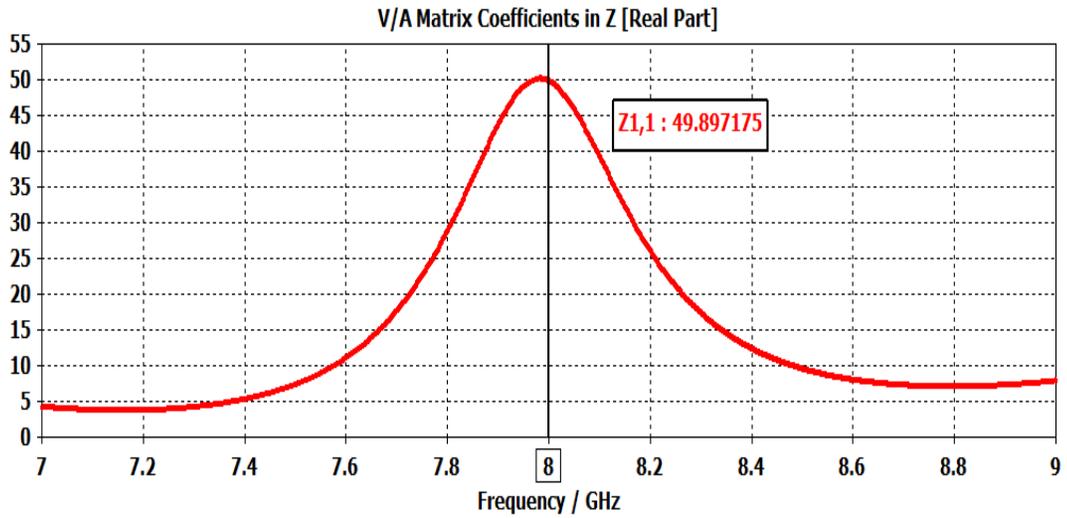
Figure 18. The impedance of the aperture couple feed.
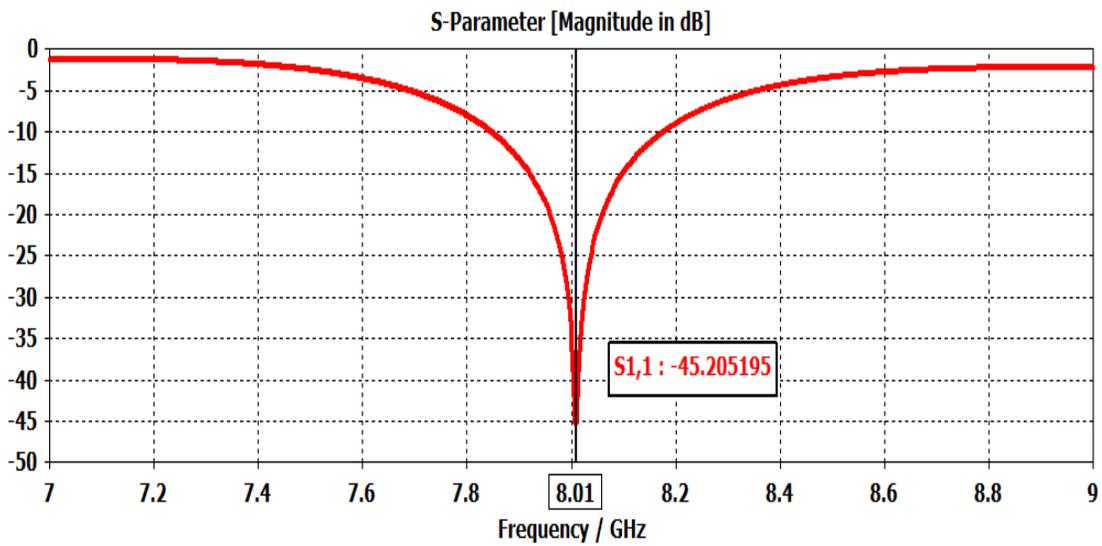
Figure 19. S-parameter of aperture couple feed.

Farfield Gain Abs (Phi=90)

— farfield (f=8) [1]

Phi= 90   Phi=270

Theta / Degree vs. dB

Frequency = 8
Main lobe magnitude = 7.06 dB
Main lobe direction = 175.0 deg.
Angular width (3 dB) = 70.4 deg.
Side lobe level = -16.1 dB
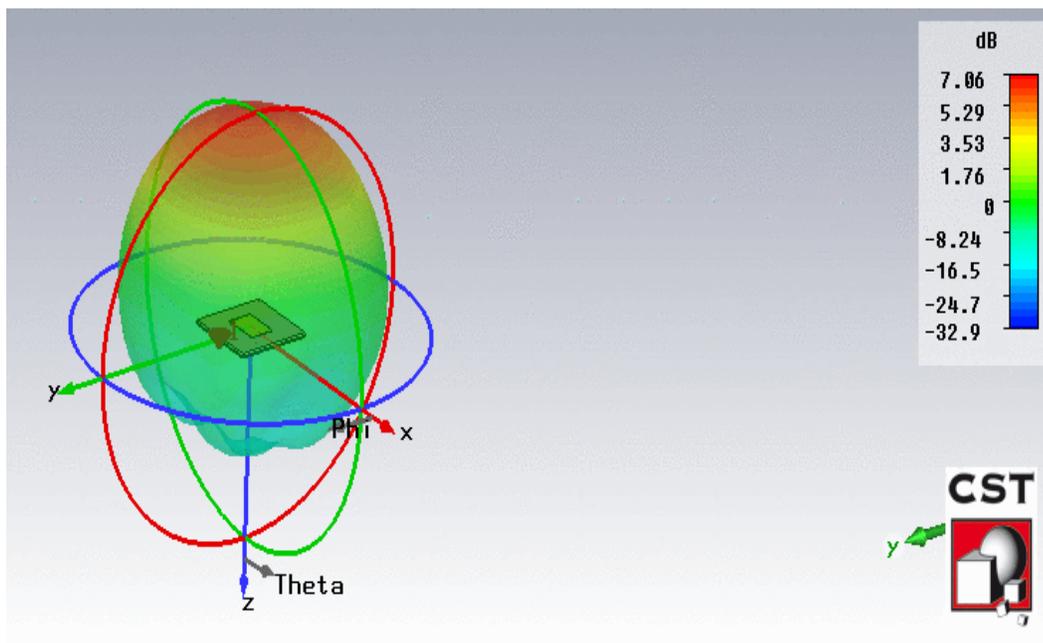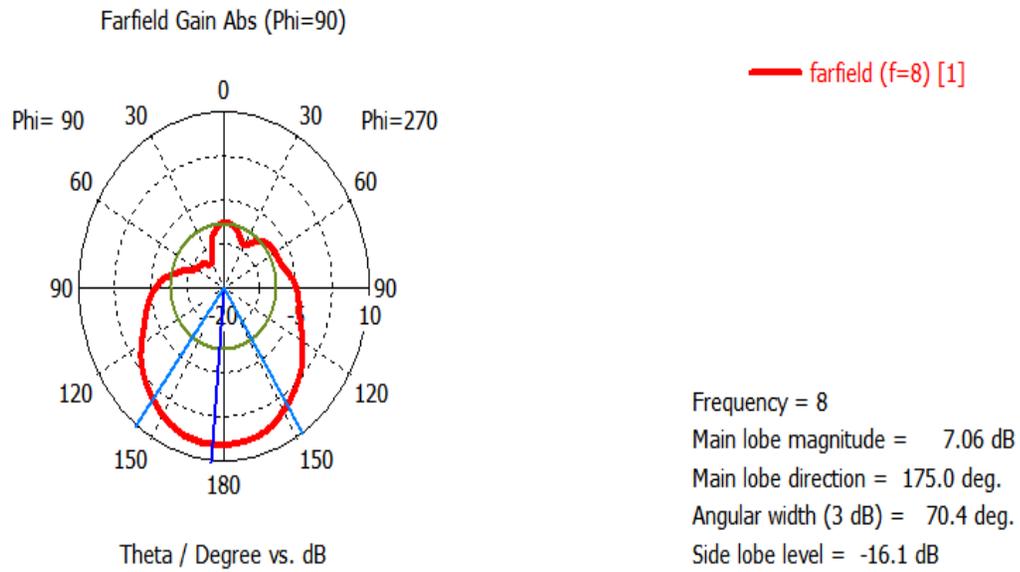
Figure 20. The gain of aperture couple feed.

VSWR of aperture couple feed: Fig. 20, the *VSWR* path against the frequency which graphically describes how the antenna matches when it is connected to the transmission line. The value of *VSWR* is 1.03 at the desired frequency and it ≤2.

Comparison of the patch vs aperture feed: The comparative results for the patch antenna with an aperture feed technique is shown in Table 9.

Table 9. Comparison of the patchantenna vs aperture feed.

Feeding Technique	Impedance Ω	Gain dB	Main lobe Degree	Return loss dB	VSWR
Single Patch Element	193.2	8.1	179	-8.32	2.2
Aperture	49.8	7.06	175	-45.2	1.01

3.5. Simulation results of proximity couple feed

Proximity coupled antennas have a number of advantages like wider bandwidth with dual-band operation, low surface wave losses, low losses from the feed-in comparison with coaxial feeding and produces linear and circular polarization. By varying the width of Strip-line, the height of different substrate and stub length different results conclude.

The impedance of Proximity couple feed: The impedance of proximity couple feed which describes the frequency is resonant at 8 GHz with characteristics impedance of 50.2 Ohms, Fig. 21, and the patch is properly matched with the transmission line.

S-parameter of proximity couple feed: S-parameter calculation has been performed for proximity couple feed antenna. The return loss for aperture couple feed antenna is $(S_{11} = -60.7dB)$ at frequency 8GHz.

Fig. 22 shows the impedance of proximity couple feed which is higher at frequency of 8GHz. Further, Fig. 23 shows more negative return loss, the gain antenna in a particular direction. The proximity couple feed antenna has more negative return loss so it has less impact on the antenna performance than the other three feeding techniques.

The gain of proximity couple feed: Fig. 24, the proximity couple feed has a maximum gain of 7.45 dB at a frequency of 8.01 GHz. The simulated antenna radiates maximum toward the main lobe. The main lobe directed at the angle of 179.00 and an angular width of 78.50.

VSWR of proximity couple feed: Fig. 25 shows the *VSWR* path against the frequency which graphically describes how the antenna matches when it is connected to the transmission line. The value of *VSWR* is 1.001 at the desired frequency and its standard value is less than 2.

Comparison of the patch antenna vs proximity feed: The comparative results for the patch antenna with the proximity feed technique is shown in Table 10.

A comparative analysis is made between all four feeding techniques in terms of gain, impedance, return loss and *VSWR* of patch antenna with various feeding techniques are presented in Table 11.

Table 10. Comparison of the patch antenna vs proximity feed.

All feeding techniques	Impedance Ω	Gain dB	Main lobe Degree	Return loss dB	VSWR
Single Patch Element	193.2	8.1	179	-8.32	2.2
Proximity	50	7.45	179	-60.7	1.00

Table 11. Comparative result.

All feeding Techniques	Impedance Ω	Gain dB	Main lobe Degree	Return loss dB	VSWR
Single Patch Element	193.2	8.1	179	-8.32	2.2
Microstrip	52.2	7.03	165	-28.2	1.08
Coaxial	53.7	8.1	173	-14.8	1.4
Aperture	49.8	7.06	175	-45.2	1.01
Proximity	50	7.45	179	-60.7	1.00
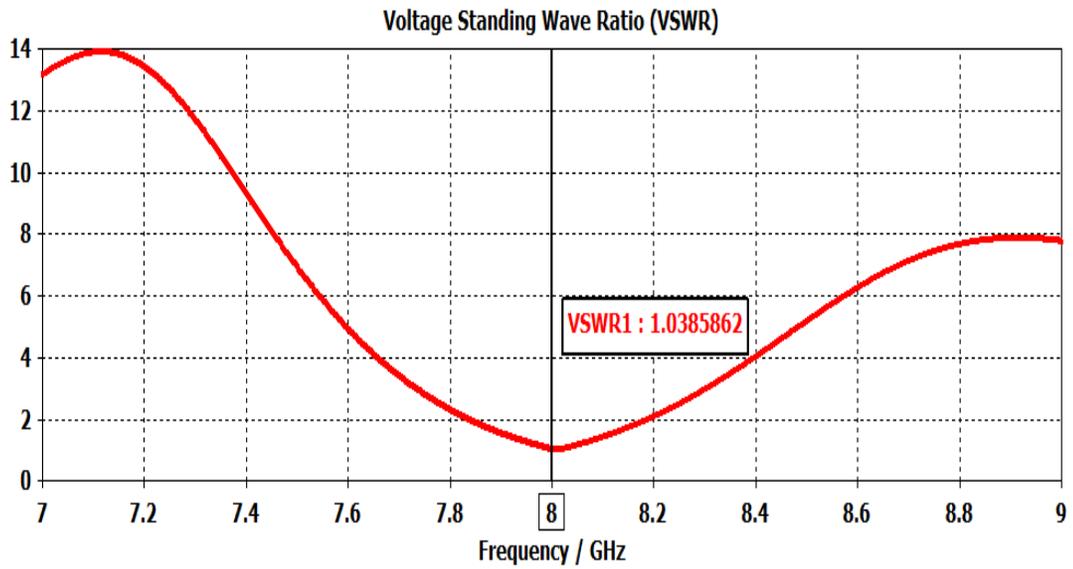
Figure 21. VSWR of aperture couple feed.
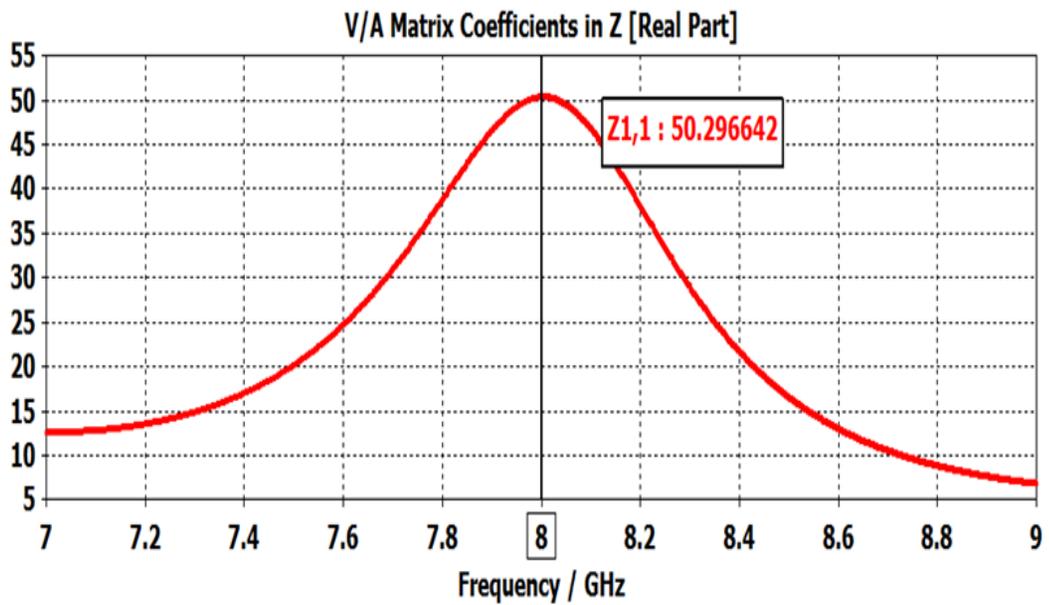
Fig. 22 The impedance of the proximity couple feed.

S-Parameter [Magnitude in dB]

S1,1 : -60.724172

Frequency / GHz
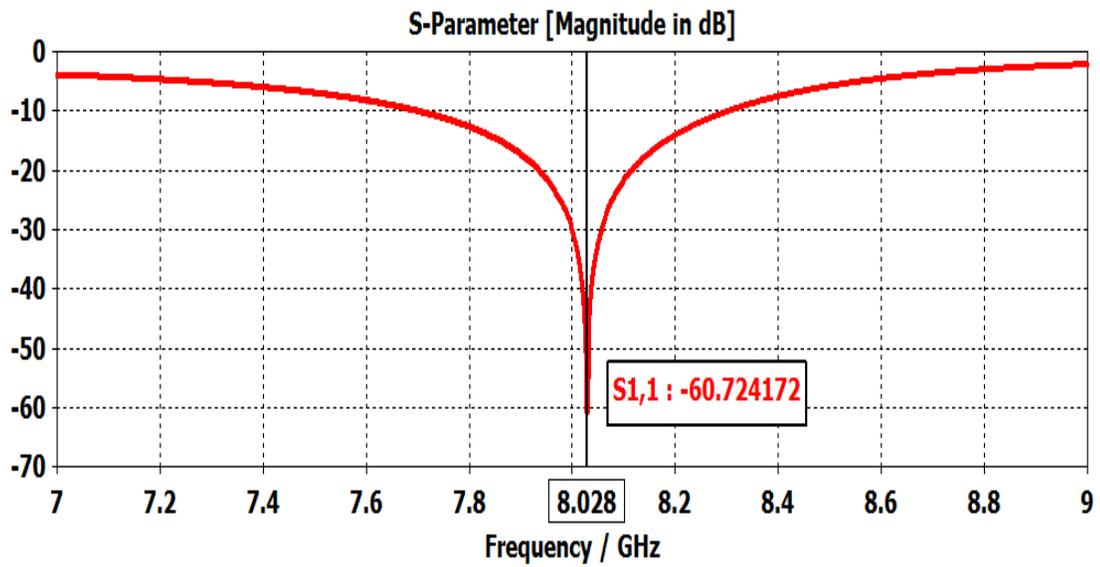
Figure 23. S-parameter of proximity couple feed.

Farfield Gain Abs (Phi=90)

— farfield (f=8) [1]

Theta / Degree vs. dB

Frequency = 8
Main lobe magnitude =   7.45 dB
Main lobe direction = 179.0 deg.
Angular width (3 dB) =   77.1 deg.
Side lobe level = -12.7 dB
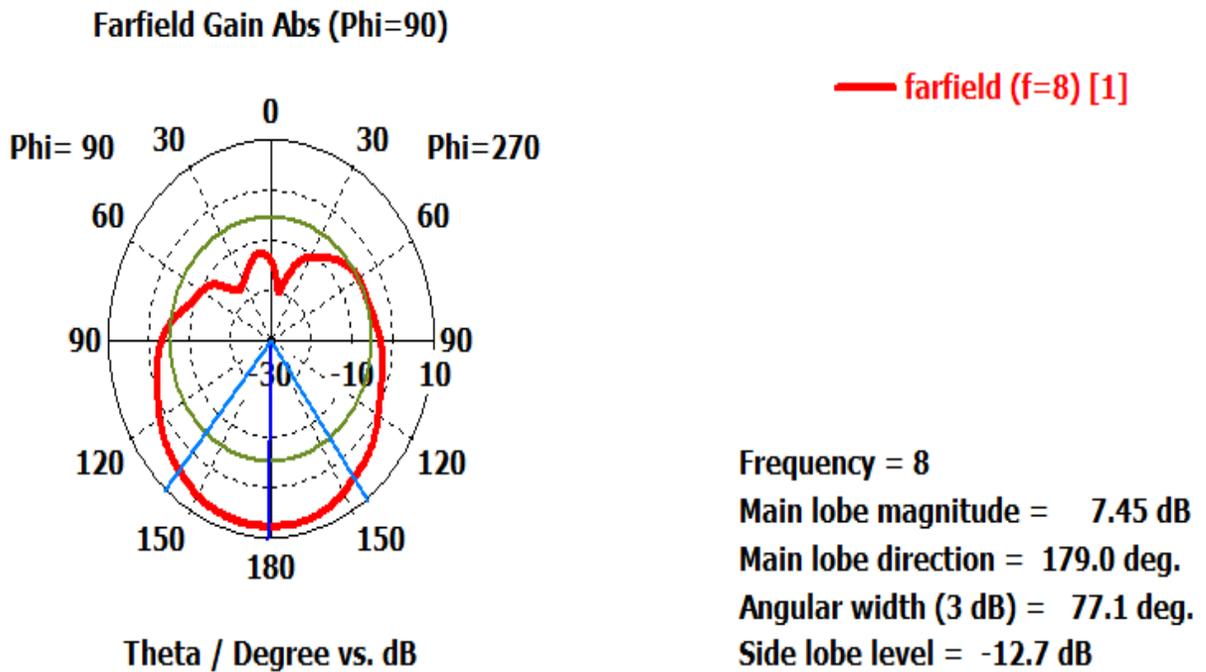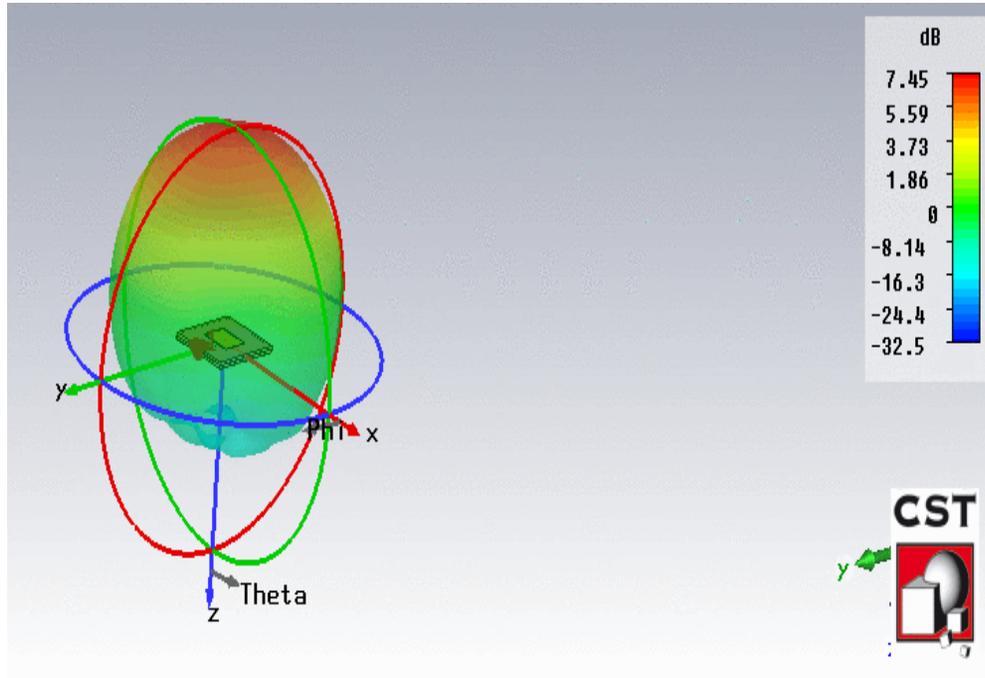
Figure 24. The gain of proximity couple feed.
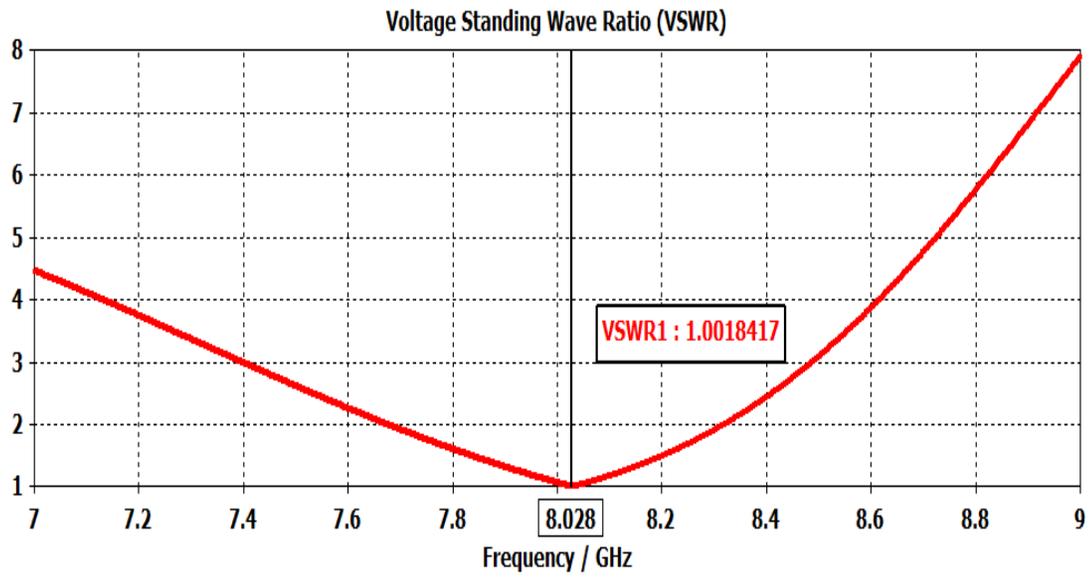
Figure 25. VSWR of Proximity couple feed.

4. Conclusions

In this paper, the comparison of different feeding techniques for the patch antenna, at X frequency band, to evaluate its quantitative impact on the different antenna parameters is presented. The single radiating patch antenna has a high gain of 8.13 dB at 8 GHz frequency and radiated maximum power in the main lobe direction which is 178.0 degrees. From the comparative analysis, it is found that the impact on the radiation gain of a single patch antenna is less when the system is fed using proximity couple feed as compared to microstrip, coaxial and aperture. The coaxial probe feed has higher gain 8.1 dB and no effect on gain radiation but return loss ($S_{11} = -14.8\ dB$) are less compared to other feeding techniques. A proximity couple patch antenna and an aperture coupled patch antenna has more negative return loss ($S_{11} = -60.7$) and ($S_{11} = -45.2\ dB$) and provide better impedance matching as compared to the coaxial and microstrip technique. The proximity couple patch antenna has a minimum impact of various parameters at the X-band compared to the other feeding techniques.

Future work: Find out some analytical ways on how to design the feeding technique especially (aperture couple and proximity couple).

Acknowledgments

References

Abohmra, A., Jilani, F., Abbas, H., Ghannam, R., Heidari, H., Imran, M. A., & Abbasi, Q. H. (2019). Low-profile Flexible Perovskite based Millimetre Wave Antenna. 2019 IEEE MTT-S *International Microwave Biomedical Conference (IMBioC), 1*, 1–4. https://doi.org/10.1109/IMBIOC.2019.8777839

Bai, C. X., Cheng, Y. J., Ding, Y. R., & Zhang, J. F. (2020). A Metamaterial-Based $ S/X $-Band Shared-Aperture Phased-Array Antenna With Wide Beam Scanning Coverage. *IEEE Transactions on Antennas and Propagation, 68*(6), 4283–4292. https://doi.org/10.1109/TAP.2020.2970096

Basilio, L. I., Khayat, M. A., Williams, J. T., & Long, S. A. (2001). The dependence of the input impedance on feed position of probe and microstrip line-fed patch antennas. *IEEE Transactions on Antennas and Propagation, 49*(1), 45–47. https://doi.org/10.1109/8.910528

Biswas, M., & Sen, M. (2019). Fast and accurate model for a coax-fed rectangular patch antenna with varying aspect ratio, feed location and substrate electrical parameters. *Journal of Electromagnetic Waves and Applications, 33*(4), 428–453. https://doi.org/10.1080/09205071.2018.1554512

Chatterjee, D., & Kundu, A. K. (2017). Performance analysis and comparative study of microstrip patch antenna using aperture coupled and proximity coupled feeding methodology. 2017 *International Conference on Computer, Communication and Signal Processing (ICCCSP)*, 1–7. https://doi.org/10.1109/ICCCSP.2017.7944065

Civerolo, M., & Arakaki, D. (2011). Aperture coupled patch antenna design methods. *2011 IEEE International Symposium on Antennas and Propagation (APSURSI),* 876–879. https://doi.org/10.1109/APS.2011.5996415

Darimireddy, N. K., Reddy, R. R., & Prasad, A. M. (2015). Design of triple-layer double U-slot patch antenna for wireless applications. *Journal of Applied Research and Technology, 13*(5), 526–534. https://doi.org/10.1016/j.jart.2015.10.006

Errifi, H., Baghdad, A., Badri, A., & Sahel, A. (2015). Design and analysis of directive microstrip patch array antennas with series, corporate and series-corporate feed network. *International Journal of Electronics and Electrical Engineering, 3*(6), 416–423. https://doi.org/10.12720/ijeee.3.6.416-423

Gummalla, A., Stoytchev, M., Achour, M., & Poilasne, G. (2010). *Metamaterial antenna arrays with radiation pattern shaping and beam switching.*

Inclán-Sánchez, L., Vázquez-Roy, J.-L., & Rajo-Iglesias, E. (2009). Proximity coupled microstrip patch antenna with reduced harmonic radiation. *IEEE Transactions on Antennas and Propagation, 57*(1), 27–32. https://doi.org/10.1109/TAP.2008.2009654

Krishnaveni, G., & Manimegalai, B. (2020). Efficient and optimized design of a stacked patch microstrip antenna for next generation network applications. *Journal of Ambient Intelligence and Humanized Computing*, 1–7. https://doi.org/10.1007/s12652-020-01788-4

Kumar, A., Kaur, J., & Singh, R. (2013). Performance analysis of different feeding techniques. *International Journal of Emerging Technology and Advanced Engineering*, *3*(3), 884–890.

Mandal, A., Ghosal, A., Majumdar, A., Ghosh, A., Das, A., & Das, S. K. (2012). Analysis of feeding techniques of rectangular microstrip antenna. *2012 IEEE International Conference on Signal Processing, Communication and Computing (ICSPCC 2012)*, 26–31. https://doi.org/10.1109/ICSPCC.2012.6335619

Mikulasek, T., & Lacik, J. (2011). Microstrip patch antenna fed by substrate integrated waveguide. *2011 International Conference on Electromagnetics in Advanced Applications*, 1209–1212. https://doi.org/10.1109/ICEAA.2011.6046523

Motin, M. A., Hasan, M. I., Habib, M. S., & Sheikh, M. I. (2013). Design of a modified rectangular patch antenna for quad band application. *2013 International Conference on Informatics, Electronics and Vision (ICIEV),* 1–4. https://doi.org/10.1109/ICIEV.2013.6572671

Pan, Y., & Zheng, S. (2017). A compact quasi-isotropic shorted patch antenna. *IEEE Access, 5*, 2771–2778. https://doi.org/10.1109/ACCESS.2017.2651149

Patel, U., & Upadhyaya, T. K. (2019). Design and analysis of compact μ-negative material loaded wideband electrically compact antenna for WLAN/WiMAX applications. *Progress In Electromagnetics Research, 79*, 11–22. https://doi.org/10.2528/PIERM18121502

Shimu, N. J., & Ahmed, A. (2016). Design and performance analysis of rectangular microstrip patch antenna at 2.45 GHz. *2016 5th International Conference on Informatics, Electronics and Vision (ICIEV)*, 1062–1066. https://doi.org/10.1109/ICIEV.2016.7760161

Sidhu, A. K., & Sivia, J. S. (2016). Microstrip Rectangular Patch Antenna for S and X band applications. *2016 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET)*, 248–251. https://doi.org/10.1109/WiSPNET.2016.7566130

Yon, H., Awang, A. H., Ali, M., Subahir, S., & Kamaruddin, S. (2016). Comparative analysis for multilayer stacked substrates microstrip patch antenna. *2016 IEEE Asia-Pacific Conference on Applied Electromagnetics (APACE),* 34–37. https://doi.org/10.1109/APACE.2016.7916456