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A Comparative Study of the Contacting-Types Feed Network of Microstrip Patch Antenna

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ABSTRACT

A comparative study on microstrip patch antenna using coaxial feed and microstrip line (both contacting-types feed) is presented in this paper. The microstrip antenna is designed to operate at a frequency of 2.45 GHz. The two patch antennas with the same dimensions employing different feed methods were designed and fabricated. The performance of the simulated and measured results for each antenna showed good agreement. In the paper, the microstrip line and coaxial probe is studied, comparing the parameters of antenna and their effect on its characteristics i.e. return losses, VSWR, bandwidth, resonant frequency and radiation pattern. CST Microwave simulation tool is used to simulate the antenna characteristics. The microstrip line feed method gave better reflection coefficient value of -36.39 dB for simulation and -28.758 dB for measurement at a frequency of 2.45 GHz when compared to that of coaxial feed. The VSWR of the antenna with microstrip fed line is 1.02:1(simulated), 1.07:1(measured) showing that the level of mismatched for the antenna is not very high. The maximum bandwidth is achieved by microstrip line, which is 22.3% (54.6 MHz), on the other hand coaxial feed gives better gain and radiation efficiency.

Key words: patch antenna, feed method, bandwidth, WLAN, microstrip antenna

I. INTRODUCTION

When choosing the most appropriate microstrip antenna configuration for a particular application, the means of excitation of the radiating element is an essential factor that requires careful consideration. The selection of the feeding technique for patch antenna is important because it affects various parameters of the antenna. The feed system may be either co-planar with the radiating elements or situated in a separate transmission-line layer.

Several studies have surveyed many possible types of microstrip antenna feed [1] - [7]. In the contacting methods, the radio frequency power is fed directly to the radiating patch using a connecting element such as a microstrip line. In the non-contacting scheme, electromagnetic field coupling is done to transfer power between the microstrip line and the radiating patch.The four most popular feed techniques used are the microstrip line, coaxial probe (both contacting schemes), aperture coupling and proximity coupling (both non-contacting schemes).

In the paper, the microstrip line and coaxial probe is studied, comparing the parameters of antenna and their effect on its characteristics i.e. return losses, VSWR, bandwidth, resonant frequency and radiation pattern. CST Microwave simulation tool is used to simulate the antenna characteristics [8].

II. TYPE OF FEED

A brief description of the each the two contacting feed schemes are presented in the following sections.

A. Coaxial Feed

One of the common method of feeding a microstrip antenna is by means of a coaxial probe. The configuration is shown in Figure 1, where a single metallic patch is printed on a grounded substrate. A number of designs have evolved from this basic configuration. It has the advantage that the feed lies behind the radiating surface, and therefore does not itself contribute unwanted radiation. It is a very convenient method of feeding a single patch by means of a surface-mounted coaxial connector attached to the microstrip ground plane, for instance for experimental purposes. The probe is positioned at a point where the input impedance of the patch, Z_{in}, is equal to the characteristic impedance of the coaxial feed line.

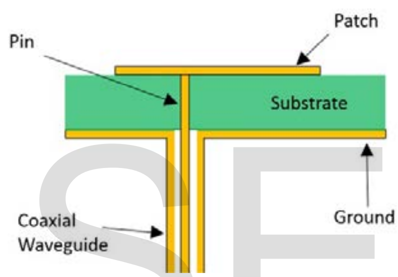


Figure 1: Coaxial feed patch antenna

Probe feed suffers from small bandwidth and the feed network. Thicker substrates can increase surface wave and generate a high cross polarization [9].

B. Microstrip-line feed

In this type of feed technique, a conducting strip is connected directly to the edge of the microstrip patch as shown in figure 2. The conducting strip is smaller in width as compared to the patch and this kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure.

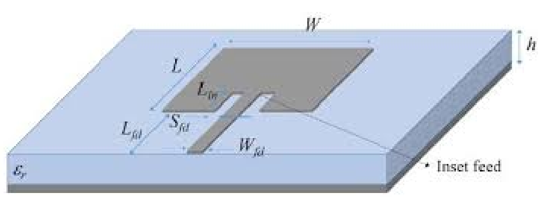


Figure 2: Microstrip line patch antenna

However, as the thickness of the dielectric substrate increases, surface wave and spurious feed radiation also increases, which affect the bandwidth of the antenna. The feed radiation also leads to undesired cross polarized radiation.

III. DESIGN PROCEDURE

Patch antennas have simple structure and the preliminary geometrical dimension calculations can be performed using analytical equations. The width of the patch antenna is given by [10].

$$W = \frac{c}{2f\sqrt{\varepsilon_r}}$$

Where c is the speed of light, f_o is the operating frequency (2.4 GHz), and ε_r is the dielectric constant of the substrate. Given the effective dielectric constant as:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 2\frac{h}{W}\right]^{-\frac{1}{2}}$$

The effective length of the patch can be calculated using:

$$L_{eff} = \frac{c}{2f\sqrt{\varepsilon_{reff}}}$$

Due to the fringing effects at the edge of the patch we have to consider the length extension that is determined by:

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

The actual length is given by:

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

The length of the ground plane is given by:

$$L_g = 6h + L$$

The width of the ground plane is given by:

$$W_g = 6h + W$$

IV. SIMULATION

In this work, the patch antennas are designed and analysed using the Finite Difference Time Domain method (FDTD) in CST Microwave Studio. A CST model of the coaxial feed antenna design is shown in Figure 3. the demensions of the simulated structure are given in Table 1.

Table 1: Patch Antenna Dimensions using the coaxial feed.

Parameters	**Value**
Patch width (Wp)	28.45 mm
Patch length (Lp)	28.45 mm
Substrate height (h)	1.6 mm
Dielectric Permittivity (ε_r)	4.4
Substrate	FR-4
Width of Ground plane (Wg)	56.9 mm
Length of Ground plane (Lg)	56.9 mm
Feed point location (x,y)	(5,0) mm

A¶ Coaxial Feed Method

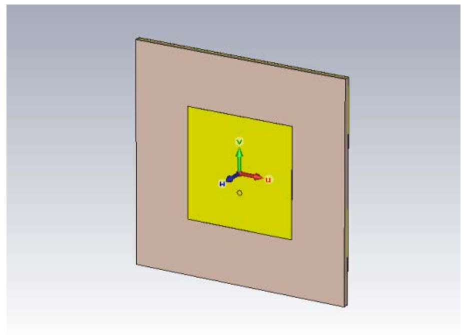


Figure 3: Coaxial Feed Simulation CST set up

Figure 4 shows the graph of reflection coefficient in dB verses frequency of the antenna. At 2.4 GHz frequency simulated the patch antenna with a coaxial feed exhibits a reflection coefficient of -22.293 dB with a bandwidth of 51.8 MHz. Figure 5 shows the VSWR verses frequency. At 2.4 GHz frequency simulated shows the VSWR of 1.18.Figure 6a shows the radiation pattern of the antenna having maximum gain of 6.49 dB, and Figure 6b shows the beamwidth of 92.1 deg. Shown in Figure 7 is the Smith chart with an impedance of 46.6Ω

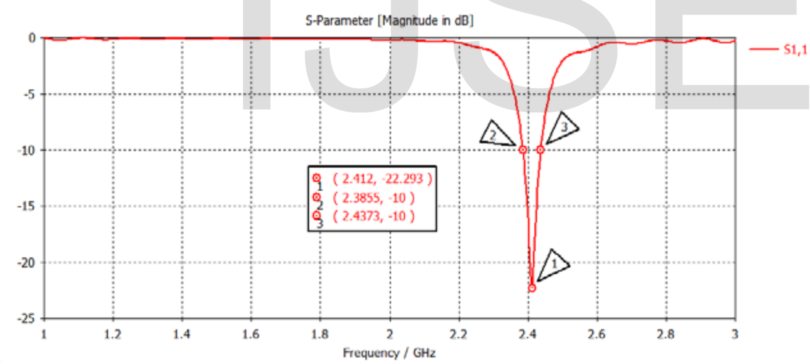


Figure 4: Reflection Coefficient of the designed antenna using coaxial feed method

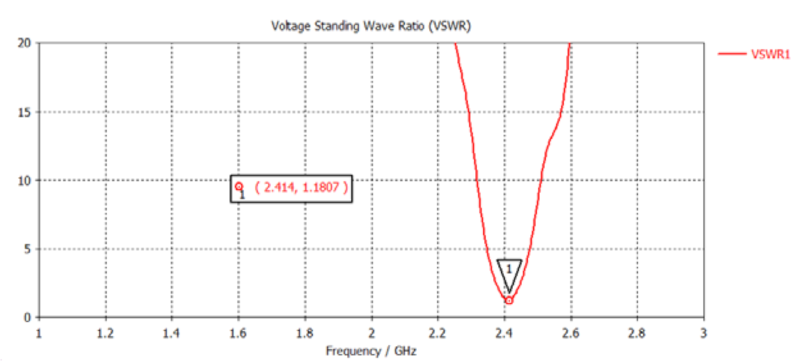
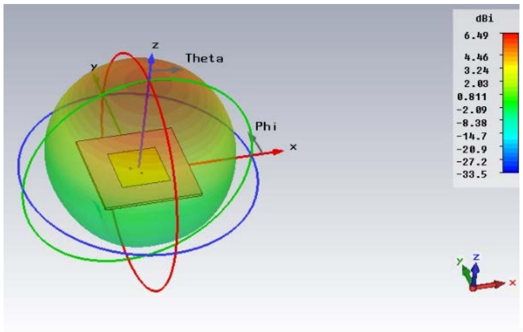


Figure 5: VSWR of the designed antenna using coaxial feed method



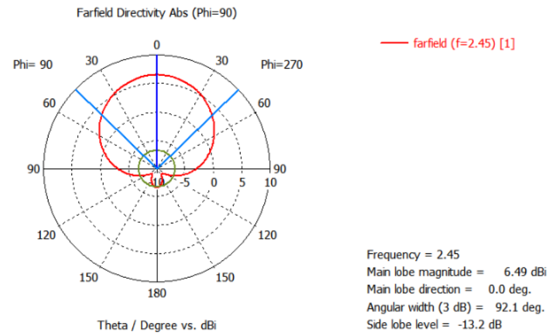


Figure 6a: Radiation pattern in 3D 6b: Radiation pattern in polar form.

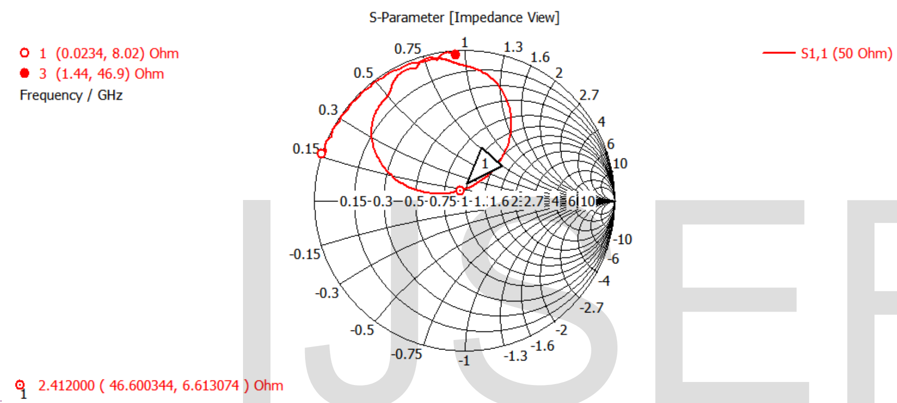


Figure 7: Smith Chart of antenna using coaxial feed method.

C. Microstrip Line Feed Method

Table 2: Patch Antenna Dimensions using the microstrip line feed. Fig. 8 is the simulation set up in CST.

Parameters	**Value**
Patch width (Wp)	28.45 mm
Patch length (Lp)	28.45 mm
Substrate height (h)	1.6 mm
Dielectric Permittivity (ε_r)	4.4
Substrate	FR-4
Width of Ground plane (Wg)	56.9 mm
Length of Ground plane (Lg)	56.9 mm
Feed inset (fi)	5 mm
Feed gap (Gpf)	3 mm

Feedline Width (Wf)	1.125 mm

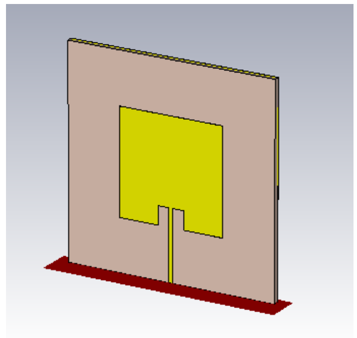


Figure 8: Microstrip line feed simulation set up.

Figure 9 shows the graph of reflection coefficient in dB verses frequency of the antenna. At 2.45 GHz frequency simulated the patch antenna with a coaxial feed exhibits a reflection coefficient of -36.392 dB with a bandwidth of 54.6 MHz. Figure 10 shows the VSWR verses frequency. At 2.45 GHz frequency simulated shows the VSWR of 1.04. Figure 11a shows the radiation pattern of the antenna having maximum gain of 6.31 dB, and Figure 11b shows a beamwidth of 95.4 deg. In addition Figure 12 is the Smith chart showing an impedance of 48.5Ω.

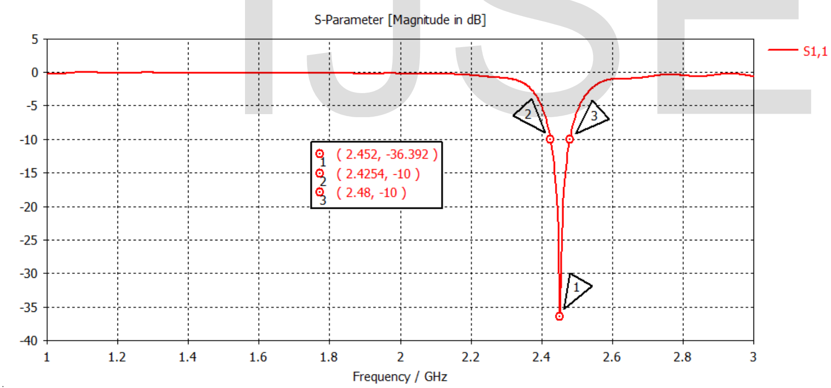


Figure 8: Reflection coefficient of the antenna using microstrip line feed method

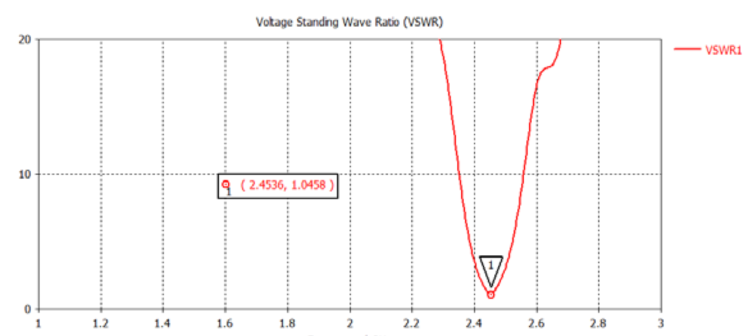


Figure 10: VSWR of the antenna using the microstrip line feed method.

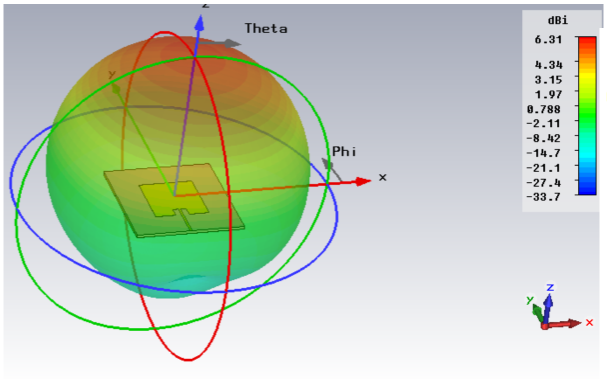


Figure 11a: Radiation pattern in 3D

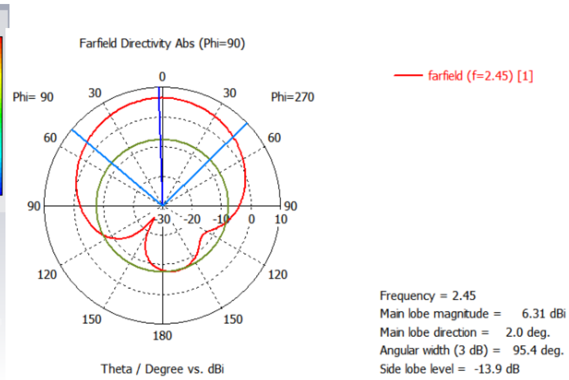


Figure 11b: Radiation pattern in polar form

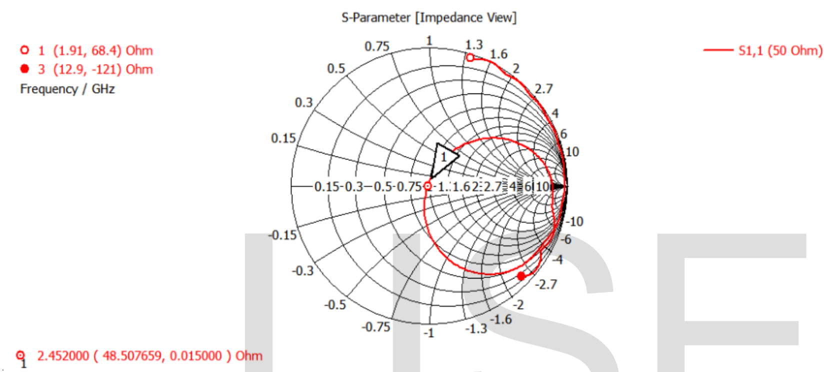


Figure 12: Smith Chart of the simulated antenna with microstrip line feed.

V. MEASUREMENT

The antennas are fabricated with the coaxial and microstrip line feeding methods at a resonant frequency of 2.4 GHz and tested using a Vector Network Analyzer (VNA). Measurements were found to be satisfactory compare to the simulated results. The fabricated antennas are shown in figure 13 (a) and 13 (b) respectively.

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Figure 13a: Fabricated Patch with Coaxial feed method, 13b: Patch antenna with microstrip line feed method.

Figure 14 shows measurement of reflection coefficient of the microstrip patch antenna with coaxial feed method using the network analyzer to be -11.34 dB, also in Figure 15 the value of VSWR is 1.7556, and as shown in Figure 16 value of the impedance is 37.67Ω at frequency of 2.4 GHz from the Smith chart.

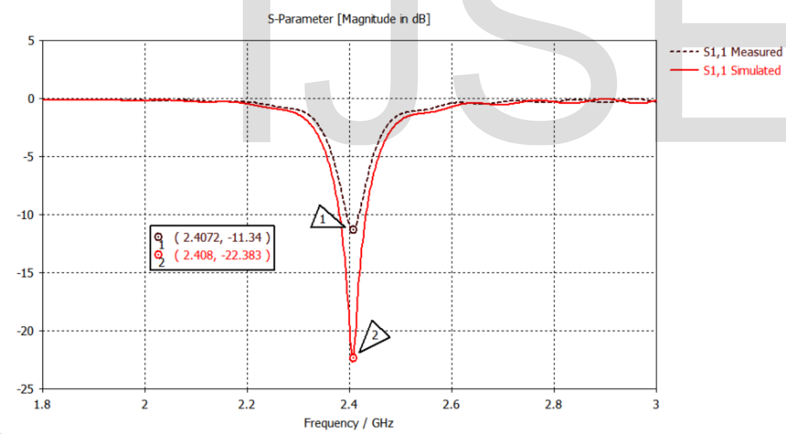

Figure 14: Reflection coefficient of Measured result vs Simulated result of coaxial feed method.

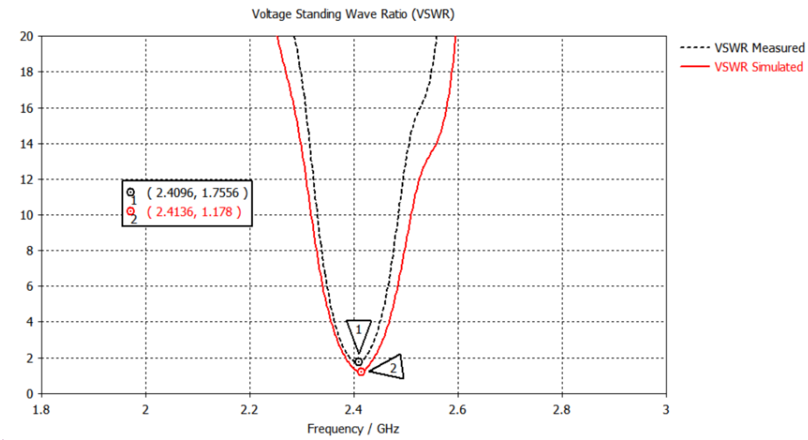

Figure 15: VSWR of Measured result vs Simulated result of coaxial feed method.

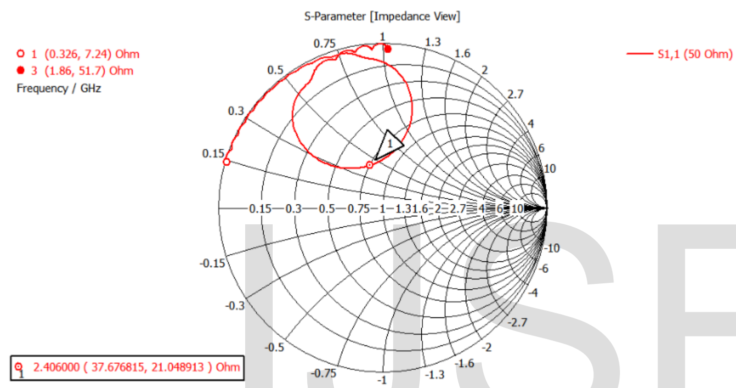

Figure 16: Smith Chart of the measured antenna with coaxial feed method

Figure 17 shows measurement of reflection coefficient of the microstrip patch antenna with microstrip line feed method using the network analyzer to be -28.758 dB, also Figure 18 indicates the value of VSWR to be 1.0781, and as shown in Figure 19 the value of the impedance is 46.48Ωat frequency of 2.45 GHz.

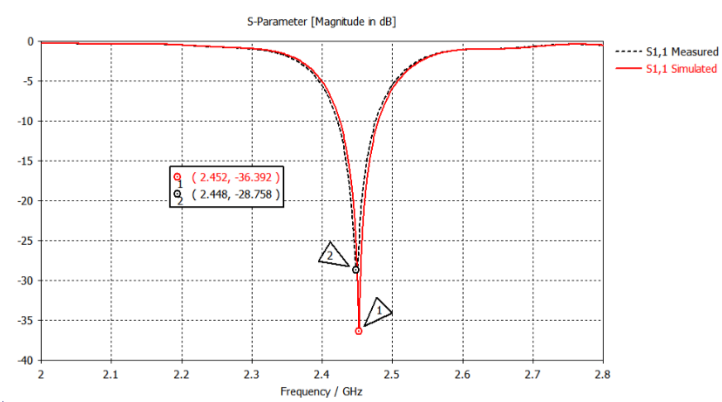

Figure 17: Reflection coefficient of Measured result vs Simulated result of microstrip line feed method.

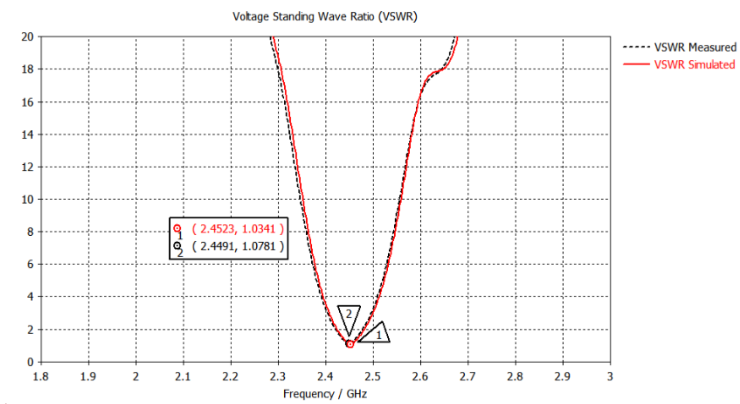

Figure 18: VSWR of Measured result vs Simulated result of microstrip line feed method.

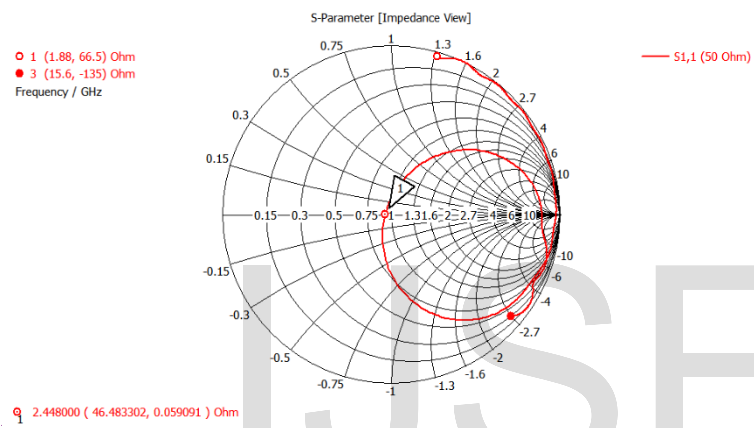

Figure 19: Smithchart of the measured antenna with microstrip line feed method

VI. RESULTS

The simulation and measurement results of the microstrip patch antenna using different feed methods are analyzed and compared. The simulation and measurement are done by applying CST Microwave Studio and measurement carried out using Vector Network Analyzer (VNA) respectively to obtain the antenna parameters as shown in Table 3. The antenna parameters compared are reflection coefficient, VSWR, impedance, frequency, bandwidth, beamwidth and gain.

Table 3:Comparison of both the simulated and measured parameters of the contacting-type feed methods

S/No.	Parameters	Simulated		Measured	
		Coaxial Feed	**Inset Feed**	**Coaxial Feed**	**Inset Feed**
1.	Reflection Coefficient	-22.293 dB	-36.392 dB	-11.340 dB	-28.758 dB
2.	VSWR	1.1671	1.0341	1.7556	1.0781
3.	Bandwidth	51.8 MHz	54.6 MHz	24.3 MHz	54.6 MHz
4.	Impedance	46.6Ω	48.5Ω	37.67Ω	46.48Ω

5.	Resonant Frequency	2.412 GHz	2.452 GHz	2.407 GHz	2.448 GHz
6.	Beamwidth	92.1 deg.	95.4 deg.	-	-
7.	Gain	6.49 dBi	6.31 dBi	6.5dBi	6.3 dBi

VII. CONCLUSION

A comparative survey on microstrip patch antenna using coaxial feed and microstrip line (both contacting-types feed)is presented in this paper. The microstrip antenna is designed and operates at a frequency of 2.45 GHz. The patch antenna with two different feed methods is successfully designed and implemented on FR4. The performance of the simulated and fabricated antenna agreed well. Selection of feeding technique for patch antenna is importance because it affects various parameters of antenna. In coaxial feed method, the impedance matching is quite difficult compared with that of microstrip line feed. Overall microstrip line feed gives less return losses, reliable, easy to fabricate, and VSWR is less. The fabricated antenna works well at the required WLAN frequency band.

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