Comparison of Microstrip Patch Antenna Feeding Techniques

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Abstract—**This paper compares the proximity-feed, coaxial feed, inset feed, and microstrip-line feeding methods of a rectangular microstrip patch antenna. Performance metrics like return loss, VSWR, gain, bandwidth, and radiation pattern are used to compare the feeding techniques. Antenna with different feed is designed for the same dimensions of patch, ground, and substrate. The antenna with distinct feed is resonating at 2.9 GHz, which is ideal for satellite, radar, and wireless applications. Antenna performance for various feeds is analyzed using the Ansys HFSS V.13 software.**

Index Terms—**High frequency structure simulator (HFSS), Voltage standing wave ratio (VSWR), Microstrip patch antenna (MPA), fractional bandwidth (FBW), Defective ground structures (DGS)**

I. INTRODUCTION

Microstrip patch antennas are essential components of many current active and passive wireless communication systems. They are used to connect everything, from cellphones to satellite communications. They can operate in a variety of frequency bands, notably C, S, X, and Ku bands of wireless communication. The fundamental reason for their widespread use is that they have several benefits, like compact size, low weight, and ease of fabrication utilizing advanced printed circuit technology.

Microstrip patch antennas can be stimulated using a variety of techniques. Such techniques can be divided into two categories: contacting and non-contacting techniques. The contact method feeds RF power directly to the radiating patch via a connecting element, whereas the non-contacting feed method feeds RF power indirectly to the antenna patch via an electromagnetic coupling. The most common contacting feed techniques are micro strip line feed and coaxial feed. The most common non-contacting feeding methods involve aperture-coupled feed and proximity-coupled feed [1-3]. Table 1 illustrates their comparison based on many parameters. The feeding mechanism for a micro strip patch antenna is a crucial decision because it has a direct impact on the bandwidth, returns loss, and antenna efficiency [4]. Surface waves and spurious feed radiation rise as the substrate thickness increases, reducing the antenna's bandwidth [5].

The paper [6] presents the design of a rectangular microstrip patch antenna using microstrip line feeding. The recommended antenna has a return loss of -23.06 dB, VSWR of 1.155, impedance bandwidth of 22.4 MHz (2.42%), and gain of 5.76 dB. The present study [7] analyses the performance of a micro strip rectangular patch antenna utilizing both coaxial and micro strip line feeding techniques. The proposed antenna is based on a FR-4 dielectric substrate with a dielectric constant of 4.4 and a loss tangent of 0.02 with dimensions of 46.70 x 38.60 x1.6mm3. The performance of feeds is compared at 2.4GHz. The study concludes that coaxial feeding provides better results for all antenna characteristics than micro strip line feeding, barring gain.

A comparison of proximity-linked feed and coaxial probe feed rectangular microstrip patch antenna is presented in this research [8]. Both devices operate at

Table 1: Comparison of feeding techniques

Characteristics	Microstrip line Feed	Coaxial Feed	Proximity Coupling	Aperture Coupling
Spurious feed radiation	More	More	Minimum	Less
Reliability	Better	Poor	Good	Good
Ease of fabrication	Easy	Soldering and drilling	Alignment required	Alignment required
Bandwidth	2-5%	2-5%	13%	21%

2.4GHz, making them appropriate for short-range wireless applications. A rectangular microstrip patch antenna with a coaxial probe feed is designed using an FR4 substrate having height 1.6 mm and dielectric constant 4.3. On the other hand, the Rogers R03003 and substrate FR-4 are intended to have a proximity-connected feed rectangular patch antenna with a height of 1.6 mm and dielectric constants of 3.0 and 4.3, respectively. For proximity-linked feed and coaxial probe feed antennas, have shown return losses of -25 dB and -29 dB, respectively. For coaxial probe feed antennas, the obtained bandwidth at -10 dB is 30.4%, whereas for proximity coupled feed rectangular patch antennas, the value is 33.2%.

This paper [9] compares aperture-coupled patch antenna with inset line-feeding antenna in terms of return loss, gain, efficiency, directivity, and power factors. Antennas are designed at a 1.5 GHz center frequency. The aperture coupled design offers 5 dB gain, 4.5 dB directivity, 30% efficiency, and an impedance bandwidth that is more than 15% greater than the inset feed line. Using aperture feed impedance matching leads to a maximum return loss of -40 dB as compared to inset feed -19 dB.

In this study [10], a concise description of microstrip antennas and their feed types is provided. Beyond that, a comparison of several feeding methods was presented along with a discussion of their design diagram and benefits and drawbacks. It has been found that, out of all the feeding methods, microstrip feed is the most straightforward. Substantial bandwidth is provided via coaxial feed. Proximity coupling with a tougher approach offers both significant bandwidth and the least amount of spurious radiation. In this study, we tried to develop and compare the performance of all four feeding approaches, as the majority of literature articles compare the performance of just two feeding methods.

II. DESIGN OF PROPOSED ANTENNA

The key objective of the work suggested is to design a standard patch antenna that uses different feeding mechanisms. Here, antennas with coaxial, proximity, microstrip line, and inset feed are designed, and their performance comparisons are carried out. The FR4-epoxy substrate material, which has a relative permittivity of 4.4, a thickness of 1.6 mm, and a loss tangent of 0.02, is used for making the proposed structure with a different feed type. For the design of the antenna chosen is a 3 GHz frequency. Different feed antennas are simulated for the same patch, substrate, thickness, and ground dimensions. Antennas typically measure 31 mm × 24.25 mm² dimensions. The suggested design is simulated using HFSS software. Numerous antenna characteristics, like return loss, gain, directivity, and VSWR, have been studied for comparison. Table 2 gives over all dimensions of the proposed antenna with different feeds.

II.DESIGN OF CO-AXIAL FEED ANTENNA

Figure 1(a) depicts the coaxial feed patch antenna configuration. The outer conductor of the coaxial connector is connected to the ground plane during antenna design, while the inner conductor is drawn through the dielectric and soldered on the radiating patch at a position where the printed substrate's resistance is about 50 Ohms. The feed's measurements are 0.7 mm for the probe's radius and 1.6 mm for its height.

Table 2: Antenna dimensions for various feeding method

Feeding Type	Patch Width (W_p)	Patch Length (L_p)	Feed line width (Wf)	Feed line length (Lf)
Microstrip feed line	31 mm	24.25 mm	1.58 mm	6.52 mm
Inset feed	31 mm	24.25 mm	1.58 mm	6.52 mm
Proximity feed	31 mm	24.25 mm	1.58 mm	6.52 mm
Coaxial feed	31 mm	24.25 mm	0.7 (Radius of pipe)	1.6 (height of pipe)
Substrate permittivity – 4.2 mm	Substrate height – 1.6 mm	Proximity substrate height – 0.8 mm		

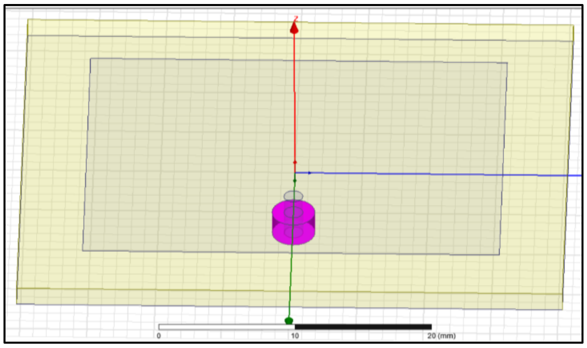

Figure 1a. Design of antenna

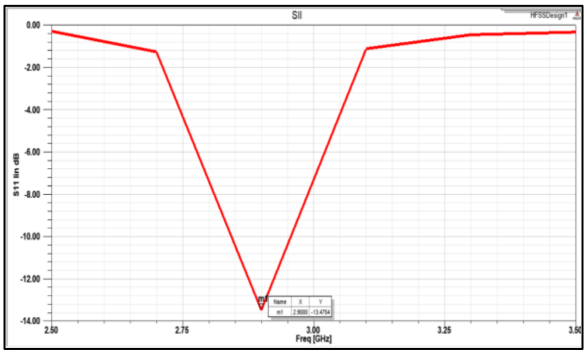

Figure 1b. Return loss in dB

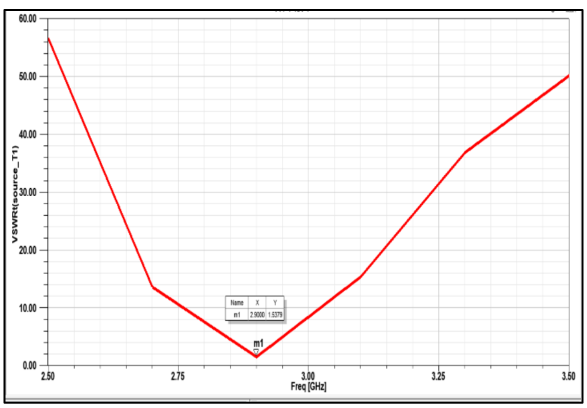

Figure 1c. VSWR

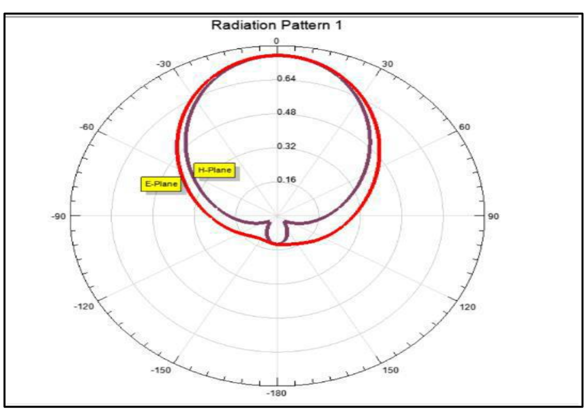

Figure 1d. Radiation Pattern in E-plane and H-plane

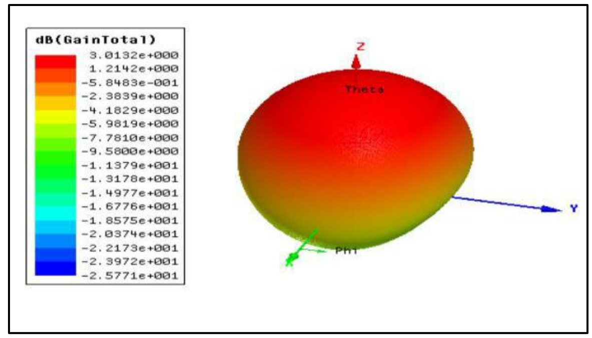

Figure 1e. Gain

As illustrated in Figure 1(b), an early simulation of a coaxial feed patch antenna on HFSS resulted in a −10 dB bandwidth of 100 MHz (2.85GHz-2.95GHz) and S11 of −13.47 dB at operational frequency 2.9GHz. According to Figure 1(c), the suggested antenna's simulated VSWR as a function of frequency is 1.5. The coaxial feed antenna radiation pattern for the azimuth plane and elevation plane is displayed in Figure 1(d). It explains how the energy emitted by an antenna is directed [11]. Coaxial feed patch antenna with directional radiation pattern can strengthen 4G and 5G signals propagation in the desired direction. Figure 1(e) shows the simulated 3D gain to provide more insight into the antenna performance. It can be seen that the achieved gain is 3.013 dB at the frequency 2.9 GHz.

III.MICROSTRIP FEED LINE ANTENNA

Figure 2(a) depicts the proposed patch antenna design with a 50Ω microstrip line feed. Based on calculations conducted at a 3 GHz frequency, feed is simulated with a length of 6.52 mm, a width of 1.58 mm, and a height of 1.6 mm. During the simulation, the feed strip is directly attached to the microstrip patch in order for the microstrip feeding technique to work. This sort of feed has the advantage of being etched on the same substrate to produce a planar surface, and the strip is smaller in both width and length than the patch.

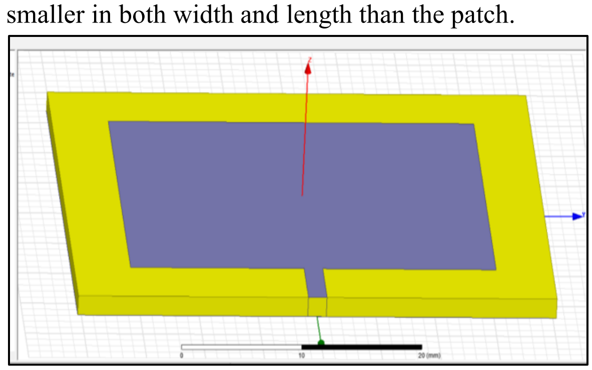

Figure 2a. Design of antenna, microstrip feed

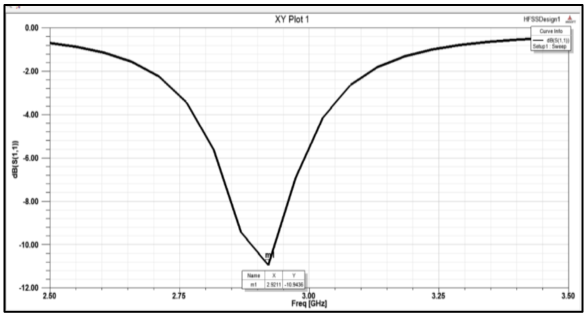

Figure 2b. Return loss in dB

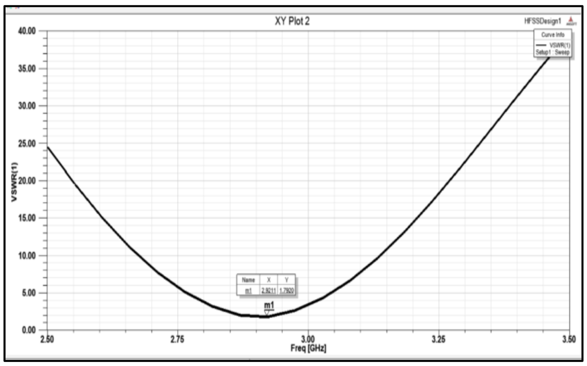

Figure 2c. VSWR

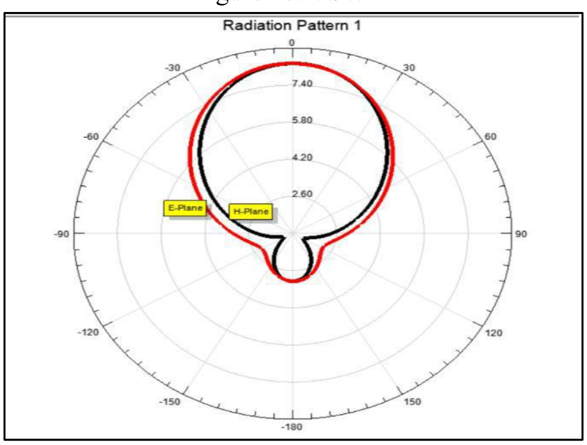

Figure 2d. Radiation Pattern

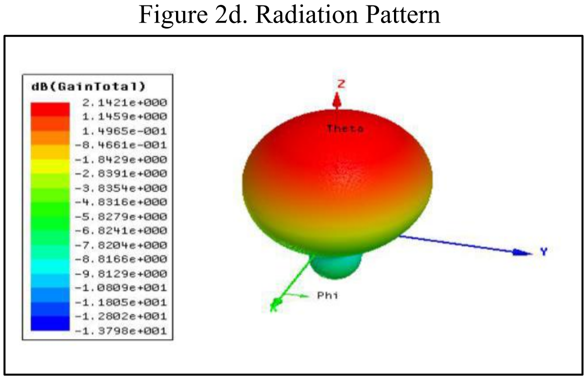

Figure 2e. Three-dimensional gain

Figure 2(b). Shows performance of microstrip feed patch antenna operating at 2.9GHz with the reflection coefficient ≤ -10dB. In figure at 2.9 GHz │S11│is up to -11 dB indicates satisfactory performance of antenna. Impedance bandwidth of 50MHz is observed. At 2.9 GHz, the VSWR value is 1.7, as shown in Figure 2(c). Poor transmission-line efficiency and reflected energy are indicated by this VSWR value. The radiation pattern for the azimuth plane (H-plane = 0) and elevation plane (E-plane = 90) at f = 2.9 GHz for microstrip line feed is displayed in Figure 2(d). Radiation Pattern of patch antenna with microstrip feed line is directional that limits radio waves propagation in undesired direction, Unidirectional radiation patterns allow antennas to send powerful signals in a specific direction. Unidirectional radiation patterns are used in many wireless communication systems; including radar, medical imaging, and 5G base stations. Figure 2(e). Shows the Gain vs. frequency plot. It is observed that gain is 2.142 dBi at 2.9 GHz.

IV.PROXIMITY FEED ANTENNA

Two dielectric substrates measuring 33.85 × 40.6 × 0.8 mm^3 are employed in the design of this antenna. As seen in Figure 3(a), this technique places the radiating patch on top of the upper substrate and a feed line between the two substrates.

As seen in Figure 3(b), the suggested proximity feed patch antenna exhibits a satisfactory return loss of -13.82 dB at the resonance frequency 2.85 GHz. It provides a bandwidth of 50 MHz (2.95-2.9 GHz) at this resonant frequency. The suggested PFA's VSWR plot can be seen in Figure 3(c). The VSWR at the resonant frequency is 1.5, indicating improved impedance matching. The radiation pattern and polar plot of the total gain at the resonance frequency 2.85GHz are displayed in Figures 3(d-e). A gain of 3.28 dBi is observed.

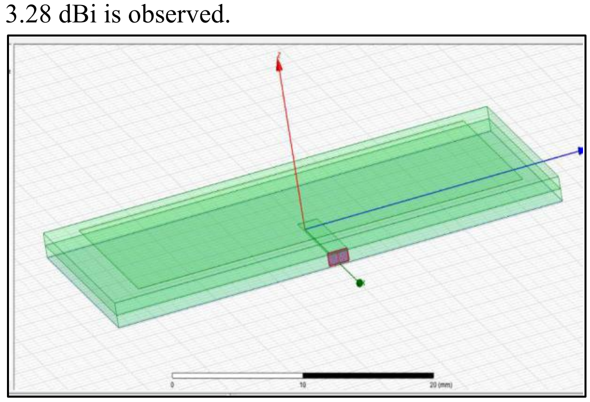
Figure 3a. Antenna design

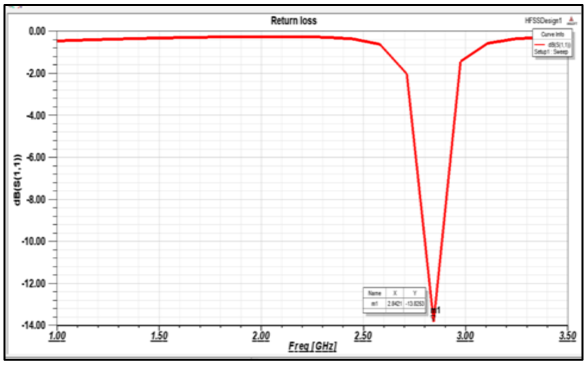

Figure 3b. Return loss in dB

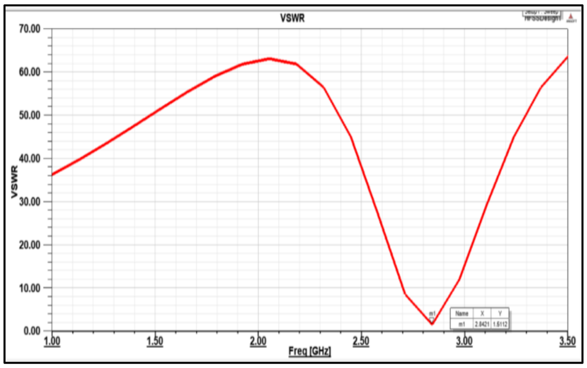

Figure 3c. VSWR

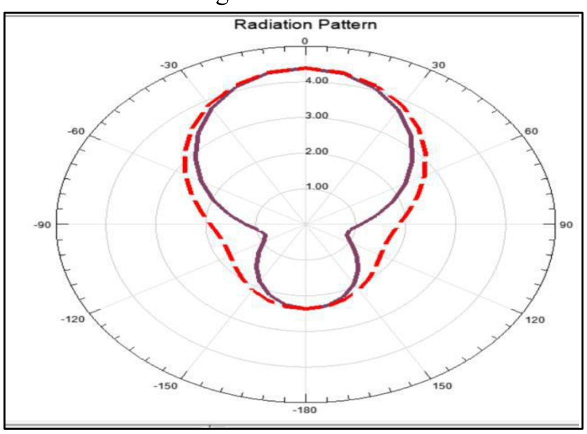

Figure 3d. Radiation Pattern

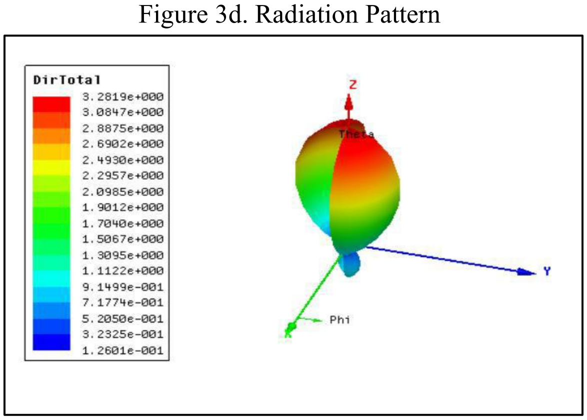

Figure 3e. Gain in dB

V.INSET FEED ANTENNA

Microstrip inset feed is the advancement of the previously introduced microstrip feed line. During the simulation, the feeding point is located on the rectangular patch's surface where the patch's impedance and the 50-ohm microstrip feed line impedance match. After that, the feed line is connected to that specific antenna position. In normal circumstances, the feed point where the rectangular patch's impedance is 50 ohms is located in the middle of the length and at one-third of the width. Figure 4(a) shows the proposed design.

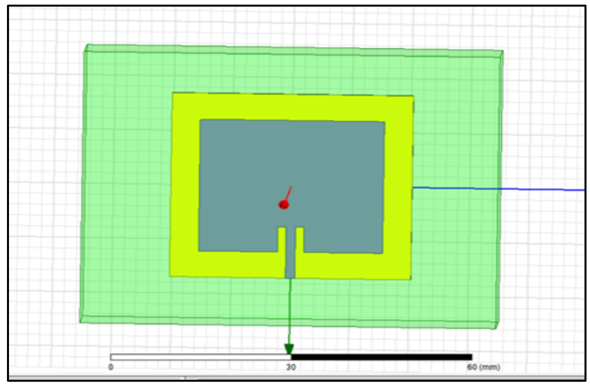

Figure 4a. Antenna Design

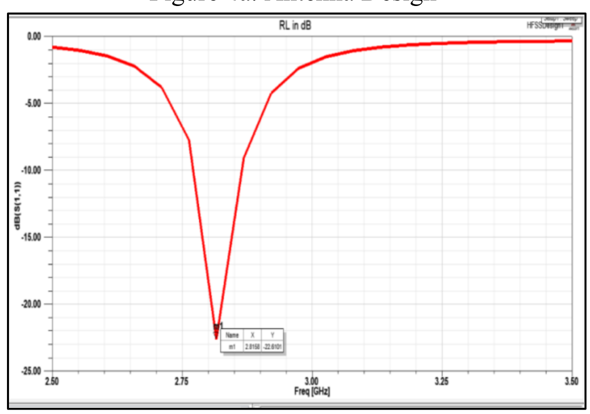

Figure 4b. Return loss in dB

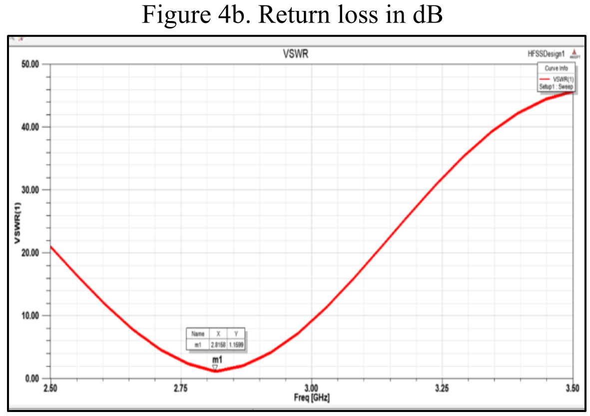

Figure 4c. VSWR

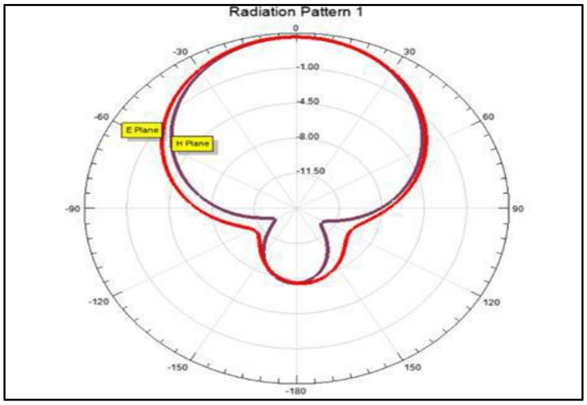

Figure 4d. Radiation Pattern

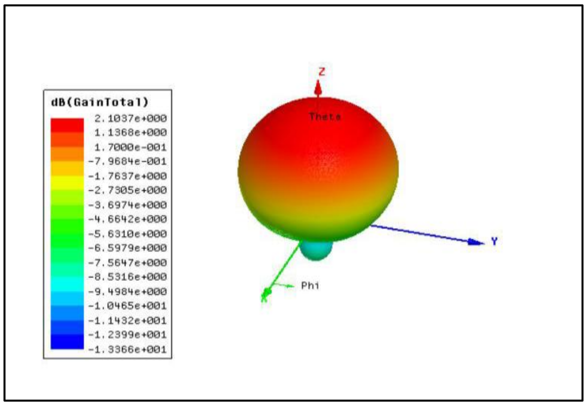

Figure 4e. Gain in dB

Figure 4(b) Shows performance in terms of S11 of antenna in presence of inset feed. From figure it can be seen that antenna is operating at 2.9 GHz with │S11│ -22.61 dB. -10dB bandwidth obtained from return loss plot 100MHz (2.76-2.88GHz). Figure 4(c) gives the value of VSWR that is 1.15 at 2.9GHz frequency. This value of VSWR indicates better performance of inset feed antenna. Figure 4(d) shows the radiation pattern for E-plane and H-plane at f = 2.9 GHz. Radiation Pattern of patch antenna is uni-directional. This makes antenna suitable for various wireless devices applications. Figure 4(e) shows the Gain 2.10 dB at resonant frequency.

Table 3 gives comparison of four feeding techniques. The shifting in resonance frequency from 3GHz to 2.9 GHz in four cases may be of the fringing fields. From the results observed in Table3 it can be clearly state that out of four feed techniques i.e coaxial feed, Microstrip feed, proximity feed, and inset feed, the inset feed is giving efficient results. Inset feed antennas have better impedance matching, lower VSWR and return loss than other feed methods for the same patch dimensions, substrate permittivity and the substrate height. Such an Inset feed antenna with satisfactory performance can be used in wireless communication systems such as satellite communication, MIMO systems, cognitive radio, and 5G communication.

Feed Type	Frequency(GHz)	S11	VSWR	Gain	Bandwidth (MHz)
Coaxial Feed	2.9	-13.47	1.5	3.013	2.85-2.95
Microstrip Feed	2.9	-11	1.7	2.142	2.22-2.93
Proximity Feed	2.85	-13.82	1.5	3.28	2.9-2.95
Inset Feed	2.9	-22.61	1.1	2.10	2.76-2.88

Table 3: Shows Comparison of MSA for different feeding techniques

In Table 3, the proximity feed technique is able to achieve a prominent high realized gain at 3.28 dBi as compared to inset feed antenna 2.10dBi. The gain of inset feed antenna can be improved using methods like defective ground structure and slots on the patch [12]-[15].

VI.CONCLUSION

Planar directional antennas are known as microstrip patch antennas. Patch antennas can be fed via a variety of methods. This study compares the inset feed, co-axial feed, proximity feed, and inset feed of a rectangular microstrip patch antenna based on the radiation pattern, gain, bandwidth, S11 parameter, and VSWR. The HFSS13.0 software is used to simulate and analyse the design of each feeding approach. All four of the antennas examined in this research have a resonance frequency of 2.9 GHz. From the results observed it can be concluded that out of four feed techniques Inset feed antennas have better impedance matching, lower 1.1 VSWR and return loss of -22Db and 110MHz bandwidth than other feed methods for the same patch dimensions, substrate permittivity and the substrate height. Such an Inset feed antenna with satisfactory performance can be used in wireless communication systems such as satellite communication, MIMO systems, cognitive radio, and 5G communication.

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