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Impact of Feeding Methods on Patch Antenna Radiation Properties: Design and Analysis

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ABSTRACT

Microstrip rectangular patch antennas are gaining popularity among antenna designers due to their appealing features, which include minimal size, small weight, and ease of manufacturing. But they additionally have certain disadvantages, such as low bandwidth and poor gain. With careful antenna design, these disadvantages can be somewhat mitigated. Numerous factors affect an antenna's radiating capabilities, but for this project, we are focusing on the electricity feeding the antenna because it is crucial. Three distinct feed techniques are being examined here, and their impact on radiating properties was investigated by contrasting all of the antenna parameters to one another.FR4's dielectric constant material is 4.4, its thickness is 1.6 mm, which is used to make the 2.4 GHz antenna. Ansoff HFSS version 13 was utilized in the design. Results are shown for return loss, gain, VSWR, and impedance.

Keywords: Microstrip patch antenna, probe feeding, microstrip line feeding, impedance matching, S-parameters, VSWR, radiation pattern.

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تأثير طرق التغذية على خصائص الاشعاع لهوائي الرقعة: التصميم والتحليل

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الملخص

تزداد شـــعبية هوائيات الرقعة المســـتطيلة بين مصـــممي الهوائيات لما تتميز به من خصائص جذابة، من بينها صِغر الحجم، وخفة الوزن، وسهولة التصنيع. إلا أنها تعاني أيضًا من بعض العيوب مثل ضيق عرض الحزمة وضعف الكسب. ومن خلال التصميم الدقيق للهوائي يمكن التخفيف من هذه العيوب إلى حدٍّ ما. تؤثر عوامل عديدة في الخصـــائص الإشـــعاعية للهوائي، ولكن في هذا المشـــروع تم التركيز على طريقة تغذية الهوائي نظرًا لأهميتها الكبيرة. تم هنا دراســـة ثلاث تقنيات مختلفة للتغذية، كما تم تحليل تأثير كل منها على الخصـــائص الإشـــعاعية من خلال مقارنة جميع معاملات الهوائي فيما بينها. استُخدمت مادة مقاومة للهب ذات ثابت عزل كهربائي مقداره 4.4 وبسماكة 1.6 مم لتصـــنيع هوائي يعمل عند تردد 2.4 جيجا هرتز. وقد تم اســـتخدام برنامج المحاكاة HFSS الإصـدار 13 في عملية التصـميم. وتم عرض النتائج الخاصـة بفقد الإرجاع والكسب، ونسبة الموجة الواقفة للجهد، والممانعة.

الكلمات المفتاحية: هوائي الرقعة، تغذية المجس، تغذية خط النقل، مطابقة المعاوقة، معاملات S، نسبة الموجة الواقفة للجهد، نمط الاشعاع.

Introduction

Researchers have been interested in microstrip antennas because of their numerous appealing qualities. The patch structures for

http://www.doi.org/10.62341/gapa3187

microstrips are compared. Microstrip analysis has become a complex research challenge due to its ease of manufacturing. The 21st-century goals of microstrip antenna research were system-level integration, wide bandwidth, multiple functionalities, gain enhancement, and size reduction. [1],[2]. In light of wireless communication technology's recent widespread adoption, there is a growing need for small, low-cost. Profiles and broadband antennas have increased significantly. An antenna made of microstrip patches has been proposed as a remedy due to its diminutive size, portability, and reasonable price [3]. Executing a rectangular patch that is "W" broad and "L" long on a single dielectric side makes up the antenna with a microstrip patch. Thickness "h" and the substrate's dielectric coefficient. Although any continuous design can be used, the most prevalent forms for microstrip antennas are rectangular, elliptical, circular, and square.

This paper's goal is to design and analyze feeding methods, coaxial, inset cut, and transmission line, on patch antenna radiation characteristics by comparing their parameters. Such that antenna designers have the chance to select the best feed for their needs. A software HFSS v13 was used for this design.

II. DESIGN OF ANTENNA MICROSTRIP PATCH.

The full-wave, cavity, and transmission line models are more accurate to analyze microstrip patch antennas, which typically employ the Moment Method and integral equation. With its practical physical insight, the transmission line's model is the most basic prototype. Consequently, the transmission line's model is used within this work to illustrate our suggestion.

- Line of transmission

The representation of the microstrip antenna is given by a model using a pair of spaces with widths of W and elevations of h, separated by a transmission line that is L-long, as illustrated in Figure 1. A non-homogeneous line composed of two dielectrics is referred to as a microstrip. Usually, air and the substrate.[3].

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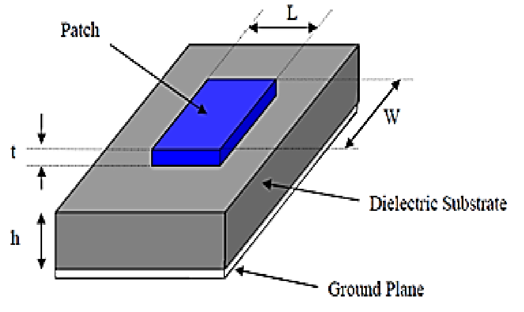

Figure 1. An antenna with a microstrip patch.

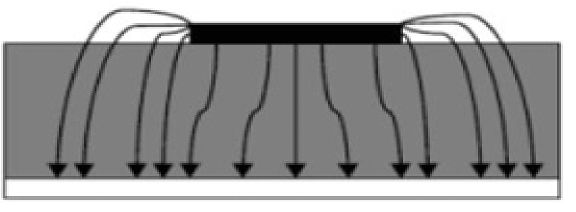

Figure 2. ground and plane electrical field lines. [4],[8]-[12]

By looking at Figure 2, the field distribution diagram, this demonstrates that while some Lines of electric field are partially within the air, most of the lines are seen on the substrate. Consequently, this line of transmission is not capable of supporting pure transverse transmission. The substrate and the air would have separate magnetic-electric (TEM) modes of transmission because of the different velocities of the phases. Instead, the mode of quasi-TEM would be the most common mode of propagation. Thus, it is necessary to calculate an effective dielectric constant to take the line's fringing and wave propagation into consideration. Due to the fields on the edge that encircle the edges of the patch being scattered within the atmosphere instead of inside the substrate for the dielectric, as seen in figure 2, the dielectric constant of the substrate is greater than the effective dielectric constant. The dielectric constant's effective value can be written as follows:[4],[8]-[12]

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

http://www.doi.org/10.62341/gapa3187

Where: ϵ_{reff} is the Effective dielectric constant, εr is the Dielectric constant of the substrate, h is the Height of the dielectric substrate, and W is the Width of the patch.

The two slots that comprise the microstrip patch's antenna are divided by an L-length transmission wire that is both ends open-circuited. Throughout the patch's breadth, the open ends cause the voltage to be at its highest and the current to be at its lowest .The domains located during the margins may be split up into the normal and tangential elements in relation to the plane on the ground. The width's two edges of the patches are of the patch out of phase and pointing in opposite ways, which cancel with one another in the broadside direction due to the patch's λ/2 length. The strongest domain that is radiated and normal to the structure's surface is produced by the combination of the in-phase tangential components. As a result, two radiating slots, each half of the area above the ground plane, can be used to depict the width's edges, separated by λ/2, and energized during the phase. The electrical microstrip antenna patch appears larger compared to its actual measurements, and the fields that border the breadth might be represented as radiating slots. and electronically, it appears that the microstrip antenna patch is larger compared to what it is. The size within the patch has now been expanded by ΔL on both ends, which is:[4],[8]-[12]

$$\Delta L = h0.412\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{W}{h}+0.8)} \qquad (2)$$

Here is the effective length: [4],[8]-[12]

$$L_{eff} = L + 2\Delta L \qquad (3)$$

The microstrip antenna's resonance frequency for the dominant TM mode depends on its length. It is typically provided by:[4],[8]-[12]

$$f_r = \frac{1}{2L\sqrt{\varepsilon_r}\sqrt{\mu_0\varepsilon_0}} = \frac{\vartheta_0}{2L\sqrt{\varepsilon_r}} \qquad (4)$$

Where: ϑ_0 is the open-space speed of light.

http://www.doi.org/10.62341/gapa3187

The width of the patch is established by:[4], [8]-[12]

$$w = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}} = \frac{\vartheta_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (5)$$

The patch's true length is provided by:[4],[8]-[12]

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{reff}}\sqrt{\mu_0\varepsilon_0}} - 2\Delta L \quad (6)$$

Ground plane dimensions is : [8],[10]

$$L_{g=}6h + L \quad (7)$$

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

The transmission line microstrip, featuring $z_0 = 50\Omega$ as the characteristic impedance, was employed in this paper. This value allowed for determining the transmission line's width.

$$\boldsymbol{z_0} = \begin{cases} \frac{60}{\sqrt{\varepsilon_r}} \ln\left(\frac{8d}{w} + \frac{w}{4d}\right) & \boldsymbol{for\ w/d \le 1} \\ \frac{120\pi}{\sqrt{\varepsilon_e}\,[\frac{w}{d}+1.393+0.667\ \ln(\frac{w}{d}+1.444)]} & \boldsymbol{for\ w/d \ge 1} \end{cases} \quad (9)$$

$$\frac{w}{d} = \begin{cases} \frac{8e^A}{e^{2A}-2} & \boldsymbol{for\ w/d < 2} \\ \frac{2}{\pi}[B - 1 - \ln(2B-1) + \frac{\varepsilon_r - 1}{2\varepsilon_r}\{\ln(B-1) + 0.39 - \frac{0.61}{\varepsilon_r}\}] & \boldsymbol{for\ w/d > 2} \end{cases} \quad (10)$$

After we calculate some parameters, $\Delta L, L_{eff}$ *and* f_r the microstrip antenna's width is 38mm, and its length is 29.4 mm

III. Methods of Feeding.

It is possible to feed microstrip patch antennas in a number of ways. These techniques are split into two clusters: touching and not touching. The mode of contact uses an element that connects, like a microstrip line, to directly deliver RF energy to the patch that is

http://www.doi.org/10.62341/gapa3187

emitting. Both the microstrip and the radiating patch exchange power at the non-contacting scheme. In order to guarantee efficient operation and optimize the matching of the input impedance of the antenna, nourishment is essential.[6] The many kinds of feeding methods include:

A. Coaxial Feed

Coaxial feeding of probes, as shown in figure 3 and 4, is a typical technique of supplying antennas with microstrip patches. The coaxial cable's inner conductor is soldered to the emitting metal patch after passing through the dielectric, whereas the ground plane and the outer conductor are joined. The input should be positioned wherever within the patch that corresponds to the antenna's input cable impedance. [4] The primary goals of probe feeding are impedance matching, narrow bandwidth, and increased gain. [5]

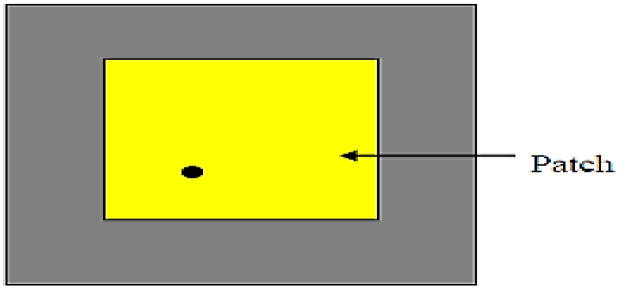

Figure 3. The upper view of the coaxial feed.[8]

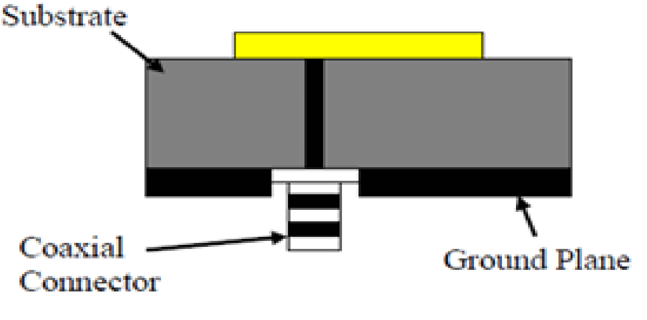

Figure 4. A side view of coaxial feed.[8]

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The design of a microstrip antenna with probe feeding, as simulated using HFSS, is shown in Figure 5.

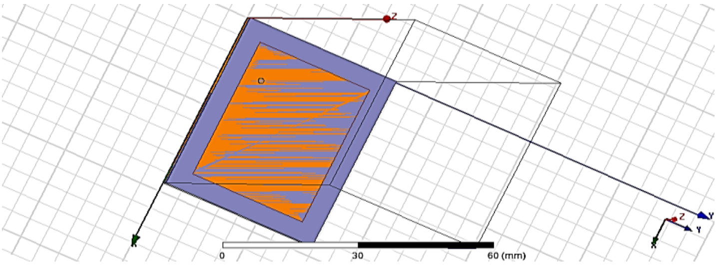

Figure 5. The proposal microstrip antenna with probe feeding in HFSS

B. Microstrip line Feed

As seen in Figure 6, A strip of conductivity is attached straight near the microstrip patch's edge in this type of feeding technique. The advantage of such an arrangement for a feed setup is that the input line is possibly engraved on the same substrate to create a flat structure, and the strip of conductivity is narrower compared to the patch.[7]

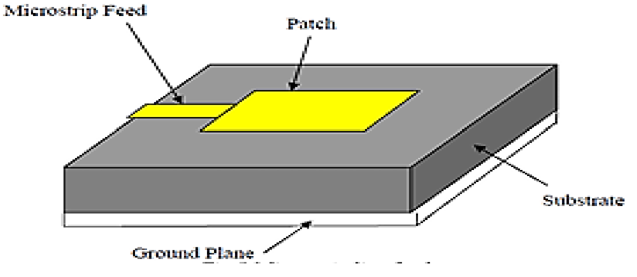

Figure 6. Feed for microstrip lines.[8]

We simulated the microstrip antenna with a line feed by using HFSS, as shown in Figure 7.

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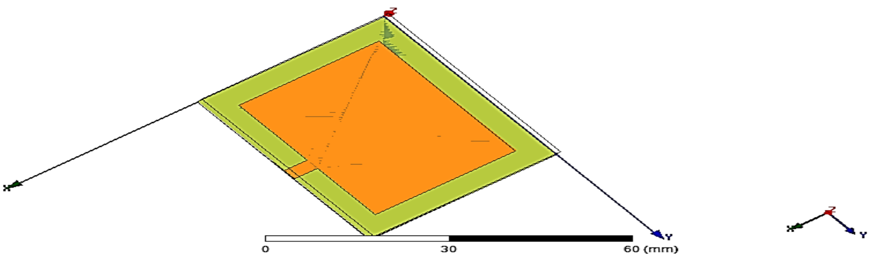

Figure 7. The proposed microstrip antenna with line feed in HFSS

C. Cut Feed

Without the need for an additional matching component, the patch's inset cut matches the line of feed impedance to the patch, as shown in Figure 7. That's accomplished through appropriately managing the inset location.[5]. Consequently, this creates a simple feeding plan because it offers impedance matching, simplified modeling, and ease of fabrication. The antenna's bandwidth is hampered by surface waves and erroneous radiation from the feeds, which are further exacerbated by the dielectric substrate thickness. Additionally, the feed radiation produces undesired cross- polarized radiation.

We simulated the microstrip antenna with inset cut feeding by using HFSS, as shown in Figure 8

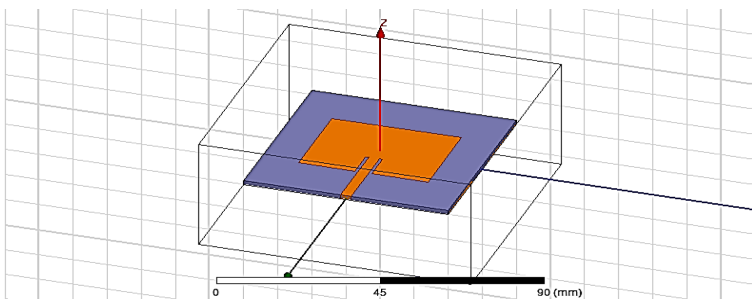

Figure 8. The proposed microstrip antenna with an inset cut feeding in HFSS.[13]

International Science and Technology Journal
المجلة الدولية للعلوم والتقنية
Volume 38 العدد
Part 1 المجلد
المجلة الدولية للعلوم والتقنية
International Science and Technology Journal
ISTJ
http://www.doi.org/10.62341/gapa3187

IV. Outcomes and discussion

A. Loss of Return

Loss of return is a metric that explains the amount of power that is effectively delivered to the radiating element's feed point. When functioning at a 2.4GHz frequency, the amount of return loss of the microstriped patch antenna with coaxial feed is-13.536 dB as figure 9, while that of a microstrip cut feed is -24.019dB as figure 10, and for feed is -11.49 dB as figure 11 at 2.4GHz. Thus, based on the information above, we can conclude that cut feed is producing better results than the other two.

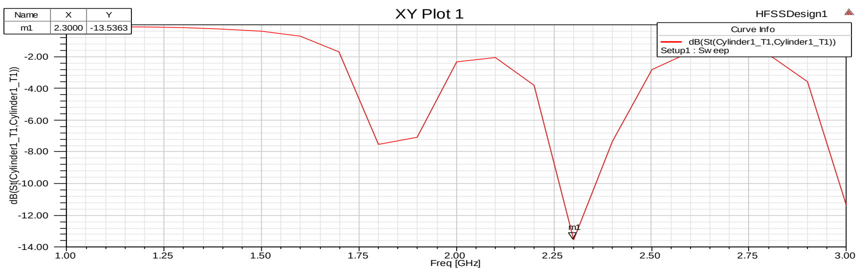

Figure 9. S11 of the probe feeding method

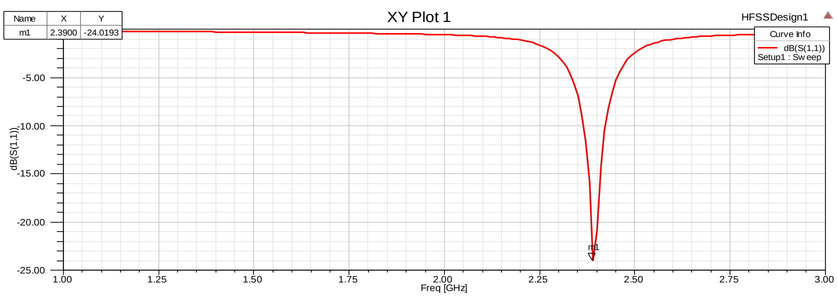

Figure 10. S11 of the inset feeding method

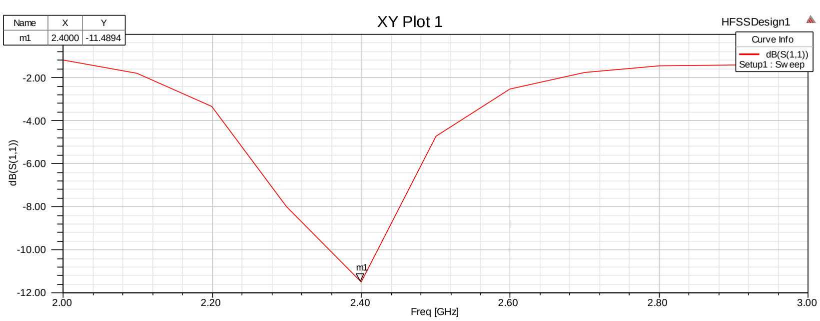

Figure 11. S11 of the microstrip feeding method

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B. Gain_3D

One of the most important challenges faced by antenna designers is gain; in this paper, we can see how the type of feeding affects it, in Figures 12, 13, and 14. As we found, the inset cut feeding is the best type of feeding to achieve more gain.

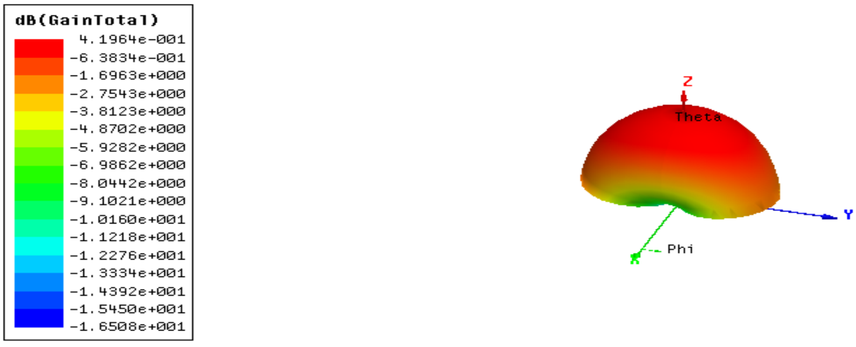

Figure 12. Gain of probe feeding

Figure 13. Gain of inset cut feeding

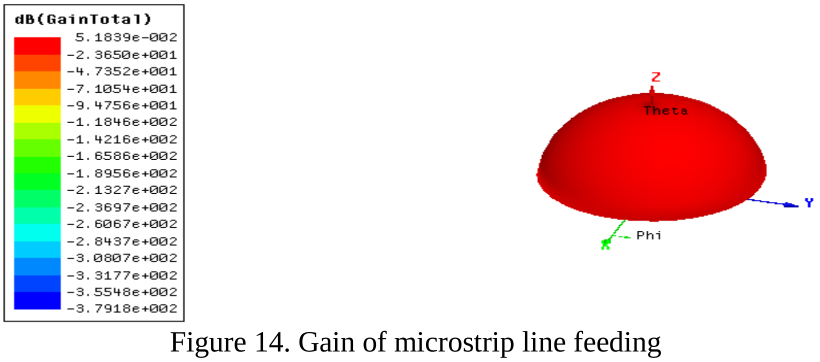

Figure 14. Gain of microstrip line feeding

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C. Impedance

As seen from figures 15, 17, and 19, the best impedance matching is achieved in the cut feeding method, and the results in 2D are illustrated in figures 15,17,19, and by using the Smith chart in figures 16, 18 and 20.

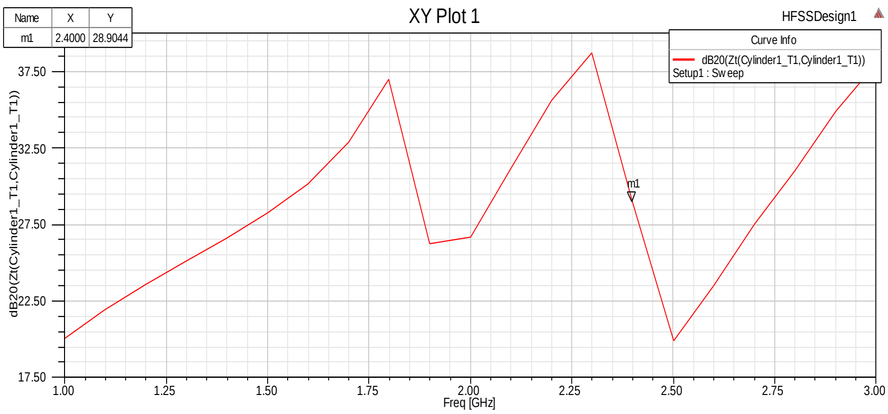

Figure 15. Impedance of Probe feeding method

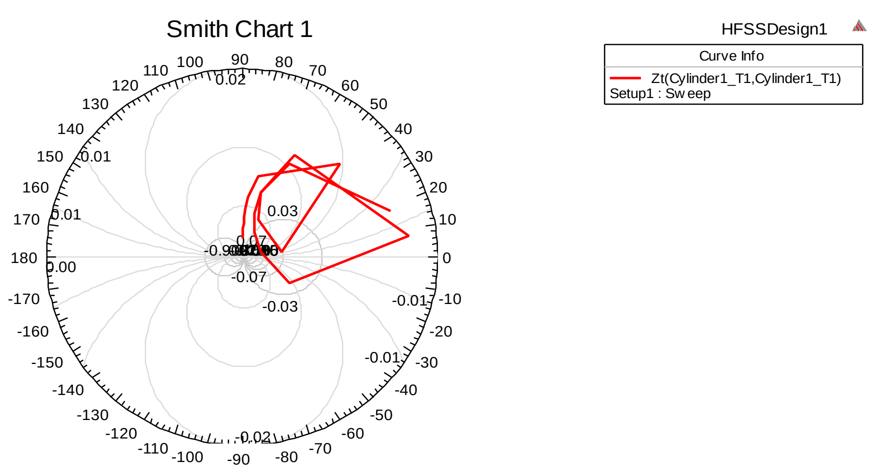

Figure 16. Smith chart of impedance of the probe feeding method

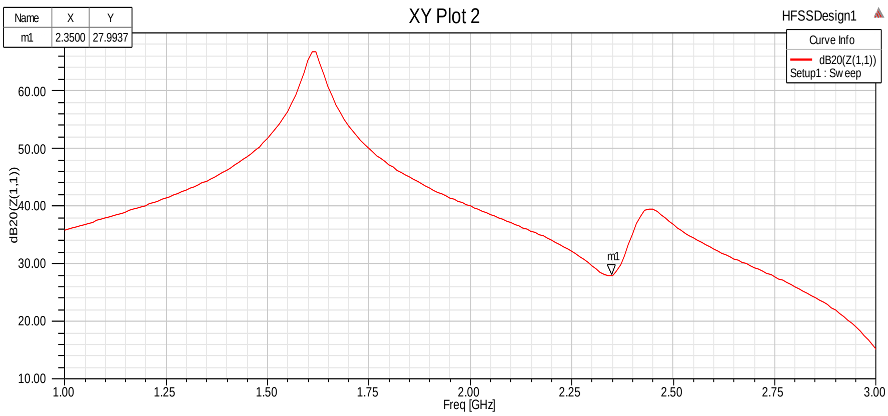

Figure 17: Impedance of the Cut feeding method

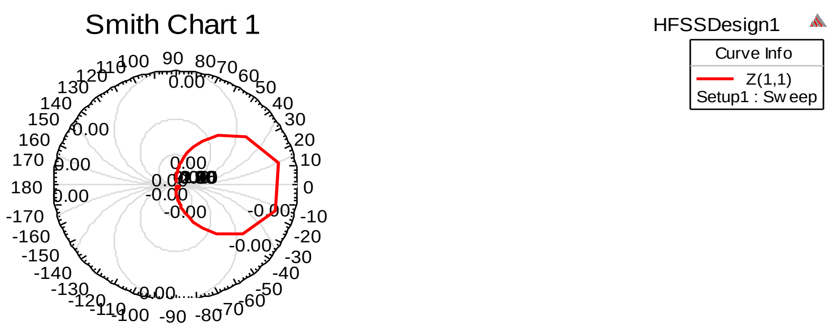

Figure 18. Smith chart of impedance of Cut feeding method

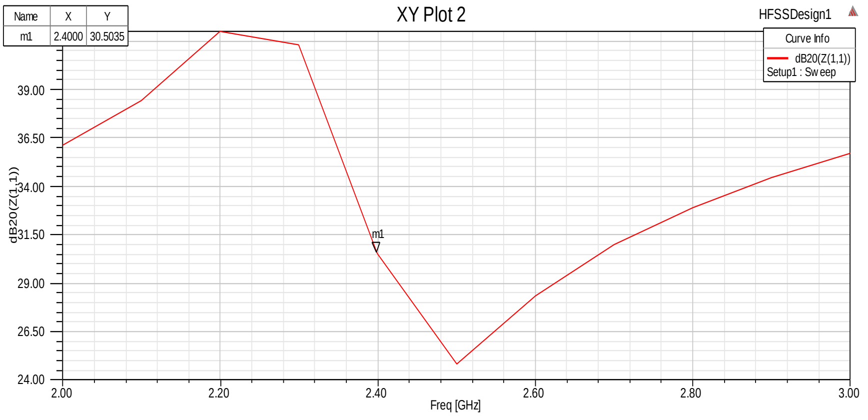

Figure 19. The Microstrip line feeding method's impedance

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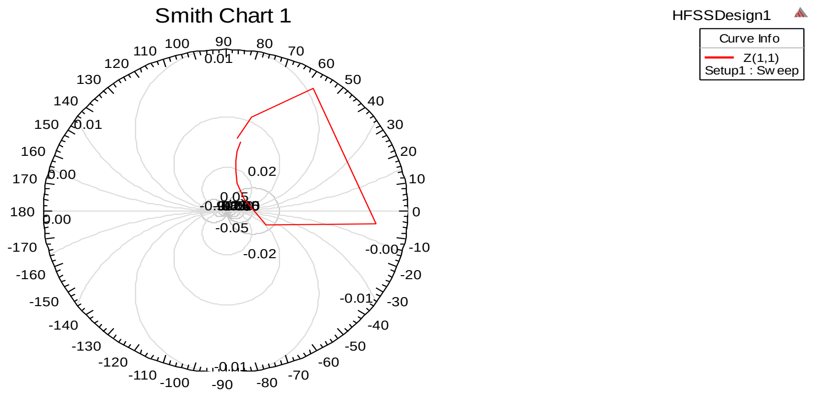

Figure 20. Smith chart impedance of the Microstrip line feeding method

D-Voltage standing wave ratio (VSWR):

As we know, this property is very important to see if there is any reflection of power. In figures 21, 22, and 23, we can see the result for VSWR of three types of feeding, where the cut feeding method is a very good result compared with the other two types.

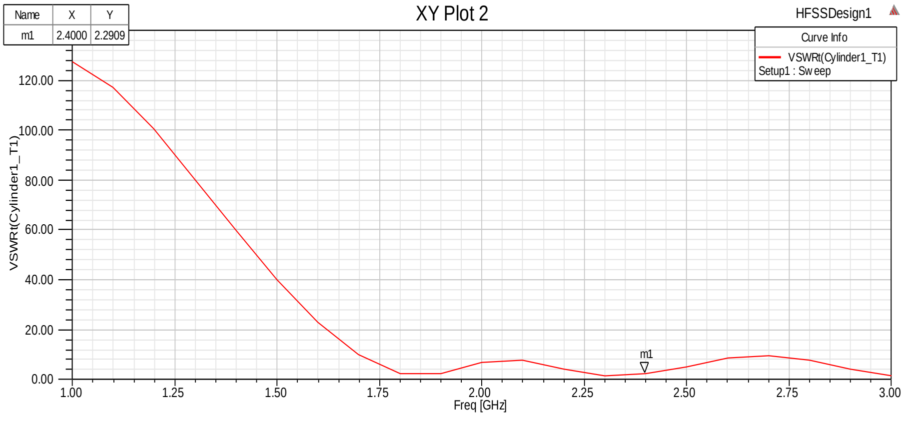

Figure 21. VSWR for the Probe feeding method

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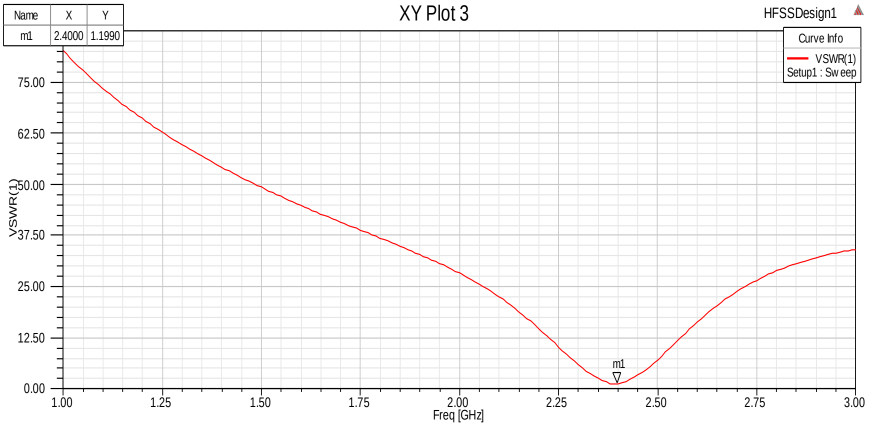

Figure 22. VSWR for the cut feeding method

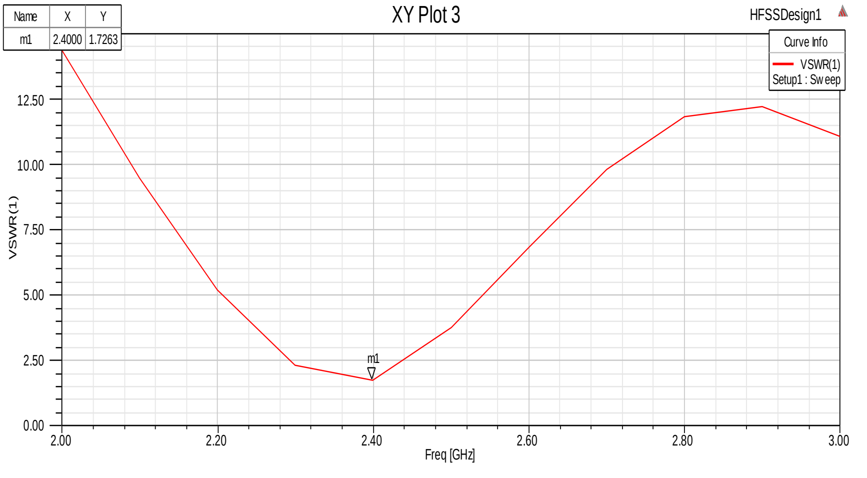

Figure 23. VSWR for the microstrip line feeding method

In table1, we can see a comparison between three types of feeding. This comparison shows the differences in four properties of the patch antenna. We note that the inset cut feeding achieves the best results of return loss and gain.

http://www.doi.org/10.62341/gapa3187

TABLE1: Comparison Of The Three Feeding Methods' Various Parameters.

Feeding Technique	S parameter (dB)	VSWR (dB)	Gain (dB)	Impedance (dB)
Transmission line feeding	-11.489	1.7263	0.025	30.5035
Inset cut feeding	-24.02	1.1990	2.91	27.9937
Coaxial probe feeding	-13.536	2.2909	0.42	28.9044

V. Conclusion

In this research, a comparison of several feeding methods for an antenna with a rectangular microstrip patch is conducted. feeding with coaxial probes, inset feeding, and microstrip line feeding are contrasted using S-parameters, Gain, radiation patterns, and VSWR.HFSS software is employed to simulate the Antenna Microstrip Patch for the three feeding techniques. When comparing consumption strategies. For the dielectric material FR4 with the inset feed, the Patch Antenna Microstrip in Rectangular Form offers the highest gain, the least amount of return loss, and the lowest VSWR at 2.4 GHz. As a result, it claims that the inset feed offers superior impedance matching in contrast to the Coaxial, moreover, the line of microstrip feed.
This study utilizes HFSS software to highlight the importance of feed selection in antenna design. By comparing different feeding types, we show how gain, loss, and impedance matching are affected. Based on these findings, the most effective feeding for our specific antenna design can be accurately identified.

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