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Design and Implementation of a Microstrip Patch Antenna Using ADS Software

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تصميم وتنفيذ هوائي تصحيح الشريط الدقيق باستخدام برنامج ADS

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Abstract:

In this paper, the design of a microstrip patch antenna using EMPro simulation is curried out to obtain a specific coefficient reflection at 3.6 GHz and to observe the gain and radiation pattern in 2D and 3D for both infinite ground plane and finite ground plane is investigated. A microstrip antenna consists of conducting patch on a ground plane separated by dielectric substrate. The micro strip antennas are the present-day antenna designer's choice. Low dielectric constant substrates are generally preferred for maximum radiation. In this paper, we will study the rectangular microstrip patch antenna in terms of coefficient reflection, gain and radiation for the infinite ground plane and the finite ground plane. An explanation of each step will be made with the support of the theoretical concept. The results show the radiation pattern major lobe in the z-direction with no minor lobes for the infinite ground plane, whereas for the finite ground plane shows the major lobe in the z-direction with minor lobes in other directions.

Keywords: Antenna Design, Microstrip, Power Gain, Directivity, ADS

الملخص

في هذا البحث، تم تصميم هوائي رقعة الشريط الدقيق (microstrip) باستخدام محاكاة EMPro للحصول على انعكاس معامل محدد عند 3.6 جيجا هرتز ومراقبة نمط الكسب والإشعاع في ثنائي البعد وثلاثي البعد لكل من المستوى الأرضي اللانهائي والمستوى الأرضي المحدود. يتكون هوائي الشريط الدقيق من إجراء رقعة على مستوى أرضي مفصولة بركيزة عازلة. هوائيات الشريط الصغير هي اختيار مصمم الهوائي الحالي. يفضل عموما استخدام ركائز ثابتة منخفضة العزل الكهربائي لأقصى قدر من الإشعاع. في هذا البحث، سوف ندرس هوائي رقعة الشريط الدقيق المستطيل من حيث انعكاس المعامل والكسب والإشعاع للمستوى الأرضي اللانهائي والمستوى الأرضي المحدود. سيتم تقديم شرح لكل خطوة بدعم من المفهوم النظري. أظهرت النتائج نمط الإشعاع الفص الرئيسي في الاتجاه z مع عدم وجود فصوص ثانوية للمستوى الأرضي اللانهائي، بينما يظهر المستوى الأرضي المحدود الفص الرئيسي في الاتجاه z مع فصوص صغيرة في اتجاهات أخرى.

الكلمات المفتاحية: تصميم الهوائي، الشريط الصغير، كسب القدرة، الاتجاهية، ADS.

Introduction

A microstrip antenna consists of conducting patch on a ground plane separated by dielectric substrate. The microstrip antennas are the present-day antenna designer's choice. Low dielectric constant substrates are generally preferred for maximum radiation. The conducting patch can take any shape, but rectangular and circular configurations are the most commonly used configuration. A microstrip antenna is characterized by its Length, Width, Input impedance, and Gain and radiation patterns. The length of the antenna is nearly half wavelength in the dielectric; it is a very critical parameter, which governs the resonant frequency of the antenna [1]. An antenna is a device that is made to efficiently radiate and receive radiated electromagnetic waves. There are several important antenna characteristics such as antenna radiation patterns, power gain, directivity and polarization. The Microstrip Antennas has a Low profile (can even be “conformal,” i.e., flexible to conform to a surface). It is easy to fabricate (use etching and photolithography). It is easy to feed (coaxial cable, microstrip line, etc.). It can easily incorporate with other microstrip circuit elements and integrate into systems. Its Patterns are somewhat hemispherical, with a moderate directivity (about 6-8 dB is typical). It is easy to use in an array to increase the directivity [2]. However, microstrip antennas has Low bandwidth (but can be improved by a variety of techniques). Bandwidths of a few percent are typical. Bandwidth is roughly proportional to the substrate thickness and inversely proportional to the substrate permittivity. Efficiency may be lower than with other antennas. Efficiency is limited by conductor and dielectric losses where it become more severe for thinner substrates., and by surface-wave losses where it become more severe for thicker substrates. It is only used at microwave frequencies and above (the substrate becomes too large at lower frequencies). It cannot handle extremely large amounts of power (dielectric breakdown). Microstrip Patch Antenna in its most fundamental form, consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side as shown in Figure 1. The patch is generally made of conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate [3]. Figure 2 shows the Common shapes of Microstrip Patch elements.

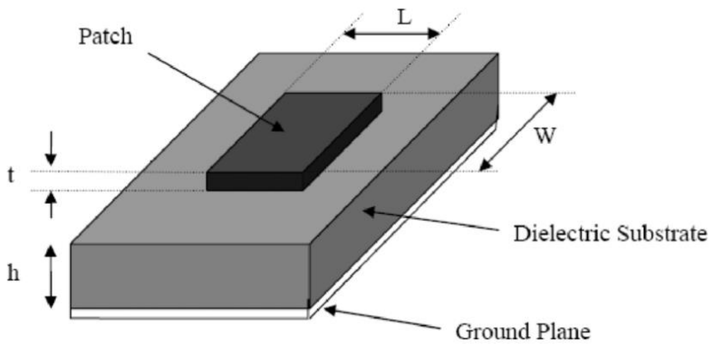


Figure 1: Structure of Microstrip Patch Antenna.

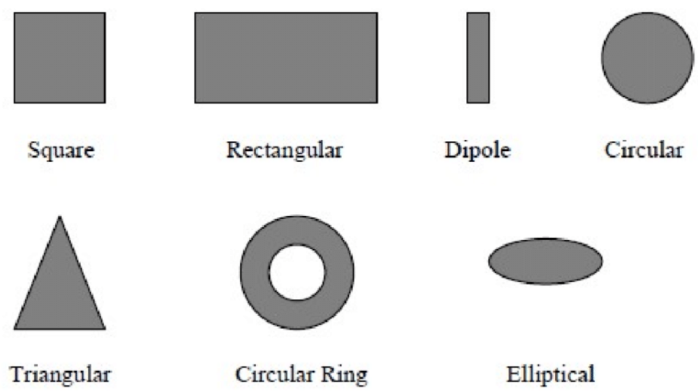


Figure 2: Common shapes of Microstrip Patch elements.

The study and the design of rectangular patch antenna is presented in this research paper. It begins first with electromagnetic model of the rectangular patch antenna. Then, the different simulations result of circuit conceived are studied and presented.

Microstrip Patch Antenna Feeding Techniques

Microstrip Patch Antenna can be fed through variety of techniques. These techniques can be classified into two categories: contacting and non-contacting. In the contacting methods, the RF power is fed directly to the radiating patch using connecting elements such as a microstrip line [4]. Meanwhile, in a non-contacting scheme, the power is transferred to the path from the feed line through electromagnetic coupling. The most commonly used non-contacting feed methods are aperture and proximity coupled feed.

Microstrip Line Feed

In this type of feed technique, a conducting strip is connected directly to the microstrip patch's edge, as shown in Figure 3. The conducting strip is smaller in width than 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 [5,6]. The purpose of the inset cut in the patch is to match the feed line's impedance to the patch without the need for any additional matching element, as in Figure 3.

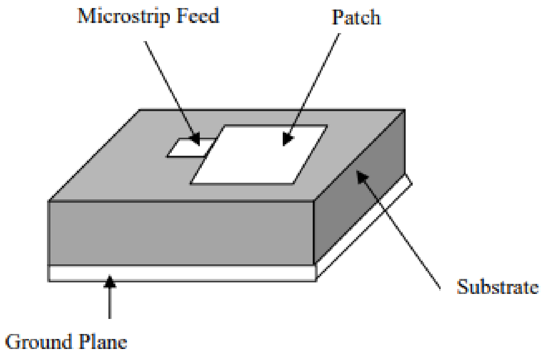


Figure 3: Microstrip Line Feed.

Microstrip Prob Feed

The prob feed is a non-planar feeding technique in which z co-axial cable is used to feed the patch. The inner conductor of the prob connector extends through the dielectric, making a metal contact with the patch, and the outer conductor of the cable is connected to the ground plane, as shown in Figure 4. The probe is in direct contact with the antenna, and it is located at the point where the antenna input is 50 ohms. Figure 10: Co-axial feed line This feed method is easy to fabricate and has low spurious radiation. However, its major disadvantage is that it connected to Ground Plane Connector, as shown in Figure 4.

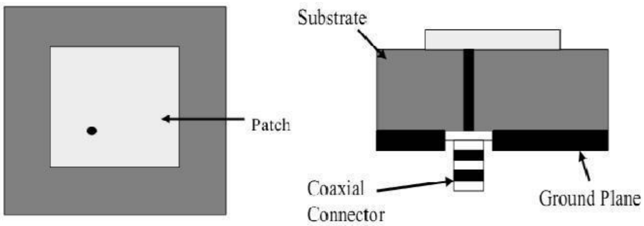


Figure 4: Microstrip Line Feed.

Aperture-coupled Feed

The aperture feed technique consists of two dielectric substrates, namely antenna dielectric substrate, and feed dielectric substrate. These dielectric substrates are separated by a ground plane, which has a slot at its center. The metal patch is placed on top of the antenna substrate is shown in Figure 5. The ground plane is placed on the other side of the antenna dielectric. The feed dielectric and feed line are placed on the other side of the ground plane to provide isolation. Aperture feed provides excellent polarization purity, which is something unattainable with other feed techniques [9].

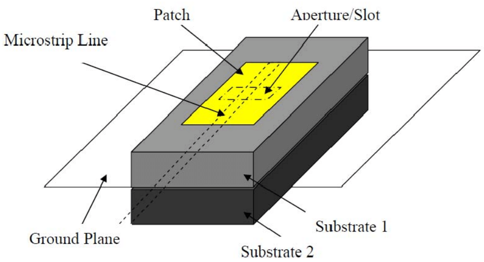


Figure 5: Aperture coupling feed.

Proximity-coupled Feed

In proximity feed, the feed line is placed between two dielectric substrates as depicted in Figure 6. In the edge-fed technique, it is impossible to choose a 50 ohms feed point since the impedance at the edges will be very high. To overcome this, the feed line is moved to a lower level below the patch. The edge of the feed line is located at a point where the antenna input impedance is 50 ohms. Here the power transfer from the feed to the patch takes place through electromagnetic field coupling. Since the feed line has been moved to a lower level, feed line radiation has been reduced to a great extent, and also, this technique allows planar feeding [7].

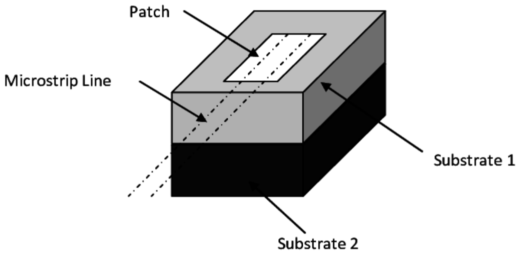


Figure 6: Proximity-coupled Feed.

Design a rectangular patch antenna

In this paper, a rectangular microstrip antenna is designed and investigated to operate at a frequency of 3.6 GHz. The proposed rectangular patch antenna has been conceived utilizing the substrate The proposed rectangular patch antenna has been conceived utilizing the substrate Fr4 with relative permitivity equal to ε_r = 2.2, the length (L) and width (W) of the patch are equal and the height of substrate (h) = 1.6 mm. This microstrip antenna is working at a frequency of 3 GHz to 5 GHz. The basic procedures for the design of a rectangular patch antenna (RPA) are presented.

Stage 1: Microstrip Patch Antenna with infinite ground plane as shown in Figure 7. In this stage, the task is to match the antenna at 3.6 GHz where the input reflection coefficient S_{11} should be lower than -12dB.

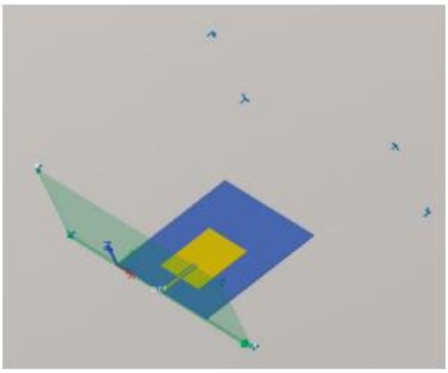


Figure 7: Microstrip Patch Antenna design in EMPro for the infinite ground plane.

By applying equation 1, and varying the patch dimensions and the offset length, the patch dimensions and offset length that provides S_{11} at least less than 12dB are the following:

- width of the patch: $30mm$.
- length of the patch: $27mm$.
- length of the offset: $9.2m$.

$$L = W = \frac{c}{(2f\sqrt{\varepsilon_r})} \qquad (1)$$

Where,

c: velocity of light, 3*108 m/s,
ε_r: dielectric constant of the substrate.
f: resonant frequency of antenna

The parameters of the proposed Microstrip Patch Antenna for the infinite ground plane are shown in Table 1. The S_{11} in dB for the Microstrip Patch Antenna from 3 GHz to 4 GHz for the infinite ground plane is obtained as shown in Figure 8 and the S_{11} in dB for the Microstrip Patch Antenna at 3.6 GHz which is -13.248 dB for the infinite ground plane.

Name	Formula	Value	Description
HSUB	508um	0.508 mm	Substrate height
timestep	1.41634e-11	1.41633846290...	Simulation timestep in seconds
WPATCH	30 mm	30 mm	Patch Width
LPATCH	27mm	27 mm	Patch Length
minFreq	3 GHz	3 GHz	Minimum frequency of interest for the project.
TMET	35um	0.035 mm	Metal Thickness
maxFreq	4 GHz	4 GHz	Maximum frequency of interest for the project.
LOFFSET	9.2mm	9.2 mm	Length of the inset
LB	60mm	60 mm	Length of the board
L50	10mm	10 mm	Length of the 50 Ohm access line
WGAP	1mm	1 mm	Gap between line and patch in the inset
WB	70mm	70 mm	Board width
W50	1540um	1.54 mm	50 Ohm line width

Table 1: Microstrip Patch Antenna parameters for the infinite ground plane.

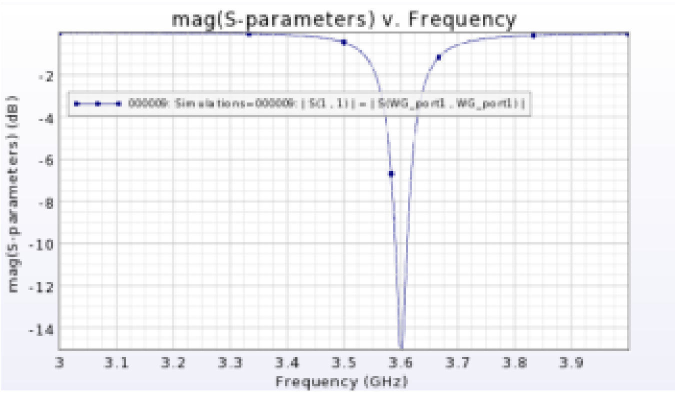


Figure 8: S_{11} in dB for the Microstrip Patch Antenna from 3 GHz to 4 GHz for the infinite ground plane.

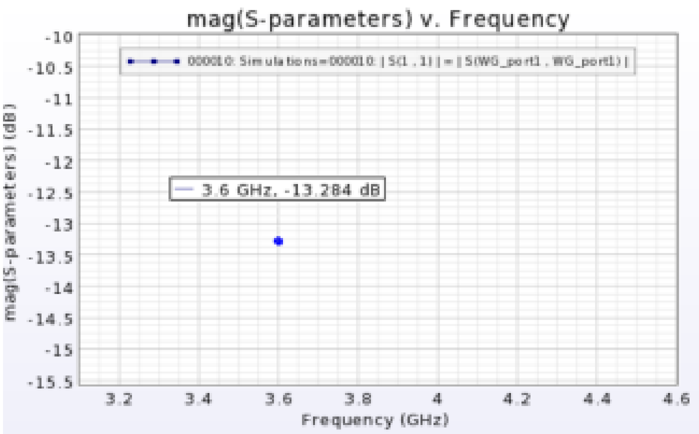
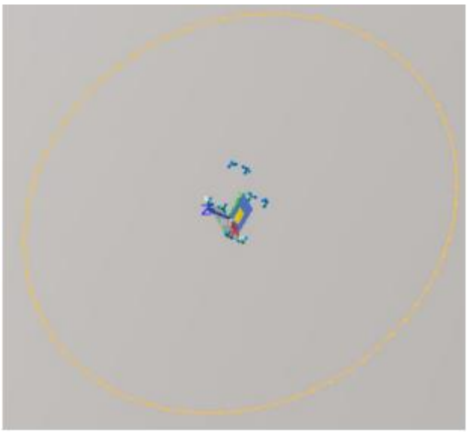
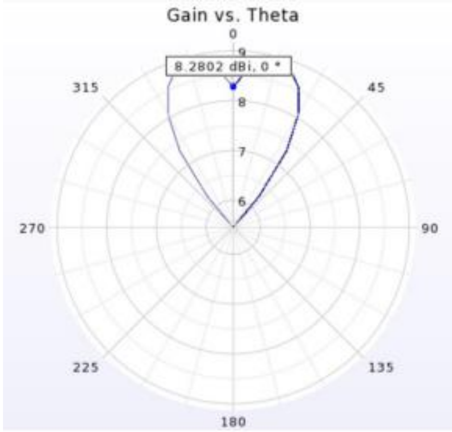


Figure 9: S_{11} in dB for the Microstrip Patch Antenna at 3.6 GHz which is -13.248 dB for the infinite ground plane.

After fixing the patch weight and patch length as shown in Table 1, the change of the offset length plays a big role in obtaining a specific reflection coefficient at a specific frequency as shown in Figure 9. To obtain a specific reflection coefficient at 3.6 GHz, several iterations have been made to achieve it. Figure 10(a) shows the 2D applied far zone sensor on the microstrip patch antenna. The yellow circle is the geometry coordinates in 2D to observe the gain and radiation pattern in the z-direction. Meanwhile, Figure 10 (b) shows the gain plot for the infinite ground plane. Figure 11 (a) shows the 3D applied far zone sensor on the microstrip patch antenna. The yellow sphere is the geometry coordinate in 3D to observe the gain and radiation pattern in x-y-z direction as shown in Figure 11 (b).

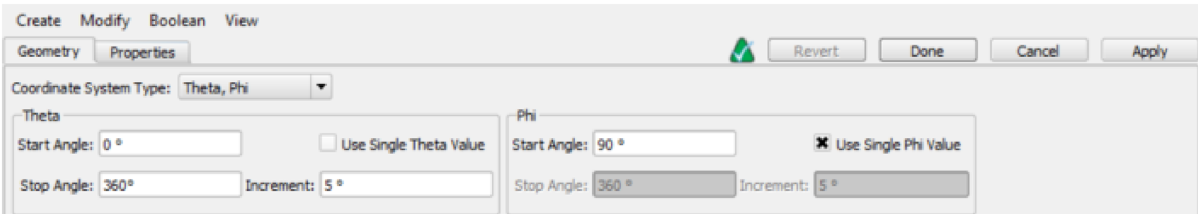




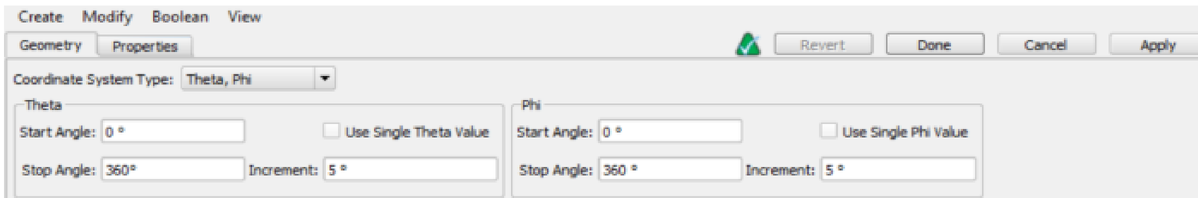
(a) (b)

Figure 10: Microstrip Patch Antenna 2D for the infinite ground plane
(a) Far Field Sensor (b)gain plot for the infinite ground plane.

The radiation pattern of an antenna is a plot of the far-field radiation properties of an antenna as a function of the spatial co-ordinates which are specified by the elevation angle (θ) and the azimuth angle (φ). The settings for the elevation angle (θ) and the azimuth angle (φ) for 2D and 3D gain plot for the infinite ground plane are shown in Figure 11. More specifically it is a plot of the power radiated from an antenna per unit solid angle which is nothing but the radiation intensity. It can be plotted as a 3D graph or as a 2D polar or Cartesian slice of this 3D graph [3].



(a) 2D

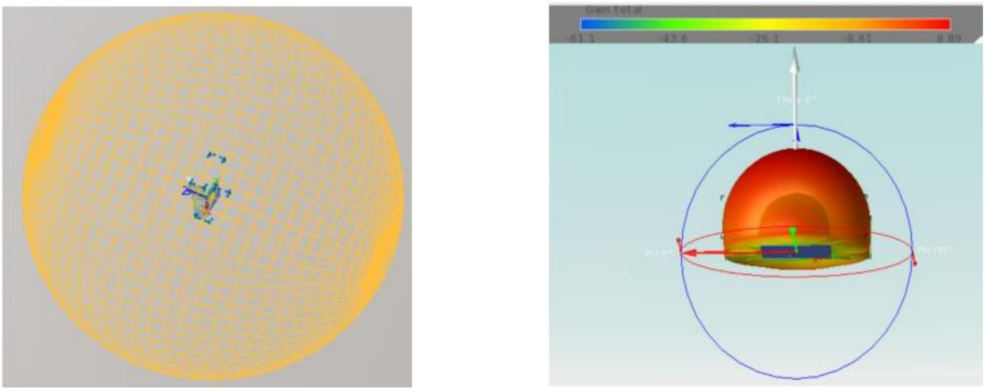


(b) 3D

Figure 11: Far Zone Sensor settings for gain plot for the infinite ground plane.

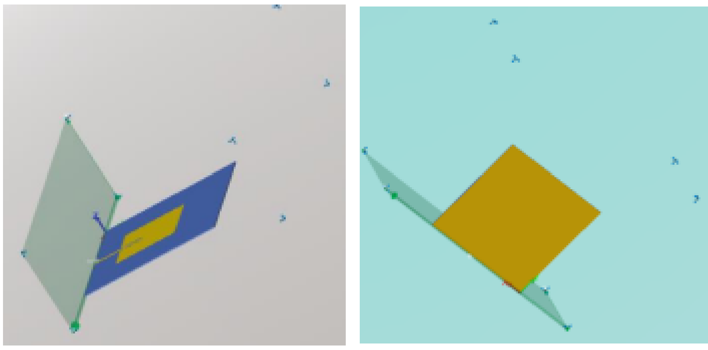
Figure 10 (b) shows the 2D radiation pattern gain plot for the Microstrip Patch Antenna for the infinite ground plane which is 8.2808 dB at 0° while Figure 12 (a) shows the 3D radiation pattern gain plot which is 8.89dB. The gain results for both plots are very close. Because it's an infinite ground plane, there is no reflection, so the radiation pattern is in the zdirection which is the major lobe. There are no minor lobes as shown in Figure 12 (b) where the radiation pattern is a semi spherical shape in the z-direction.

Stage 2: Microstrip Patch Antenna with finite ground plane as shown in Figure 13. In this stage, we will remove the infinite ground plane and create a ground plane of the same size of the board at the back of the board and apply what has been made in stage 1.



(b) (b)

Figure 12: Microstrip Patch Antenna 3D for the infinite ground plane (a) far Field Sensor (b) radiation pattern and gain plot.



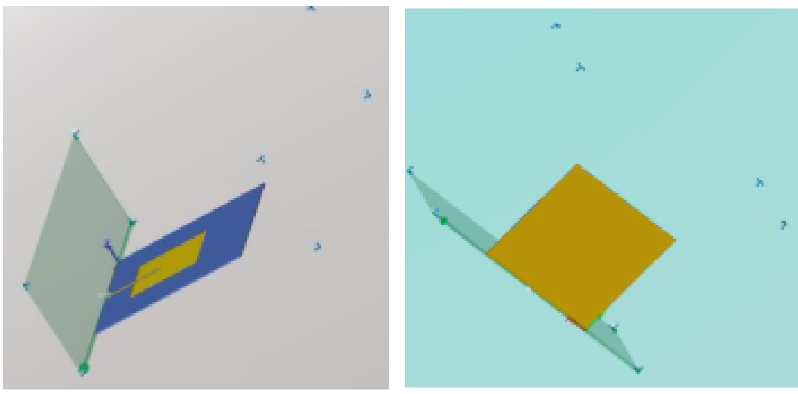
(a) (b)

Figure 13: Microstrip Patch Antenna (a) from the top angle, (b) from the bottom angle after adding the ground plane.

By changing the boundary condition in the Z lower boundary from PEC to absorbing and varying the offset length to provide S_{11} less than -12dB at frequency 3.6 GHz as shown in Figure 14, the patch dimensions are the following:

- width of the patch: $30mm$.
- length of the patch: $27mm$.
- length of the offset: $9.9032mm$.

By applying the same settings in Figure 11, there will be some changes in the results. Figure 15 shows the 2D gain plot for the microstrip patch antenna finite ground plane which is 8.4771 dB at 0° and -5.7912 dB at 90°. Figure 16 shows the 3D radiation pattern, and the gain is 8.71 dB. In both figures, there are minor lobes, unlike microstrip patch antenna with infinite ground plane, and the reason for that is the material absorbs the radiation and try to radiate it in other directions, and the major lobe radiates in the z-direction.



(a) (b)

Figure 13: Microstrip Patch Antenna (a) from the top angle, (b) from the bottom angle after adding the ground plane.

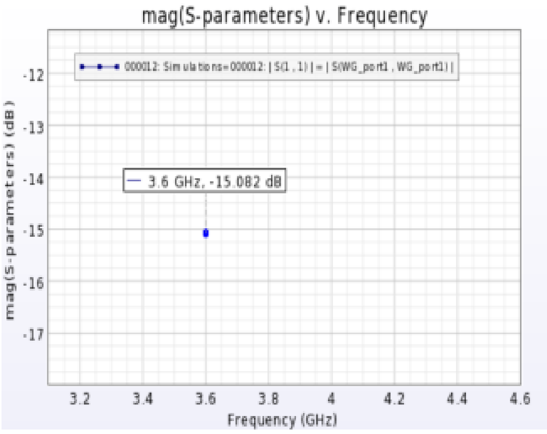


Figure 14: *S*11 in dB for the Microstrip Patch Antenna at 3.6 GHz which is -15.082 dB for the finite ground plane.

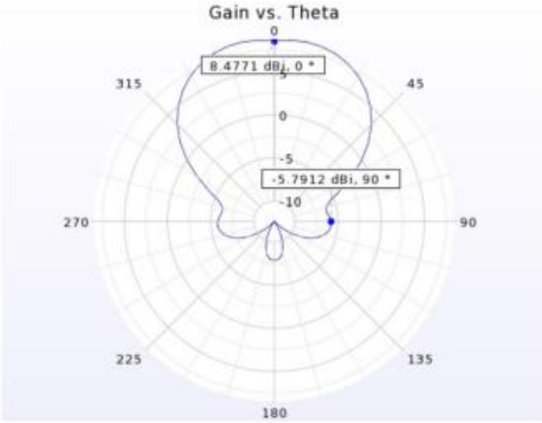


Figure 15: Microstrip Patch Antenna 2D gain plot for the finite ground plane.

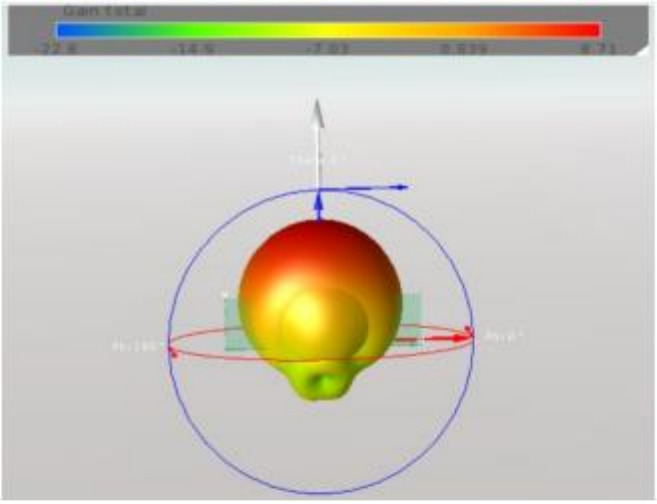


Figure 16: Microstrip Patch Antenna 3D radiation pattern and gain plot for the finite ground plane.

Conclusion

In this paper, the conception and simulation of rectangular microstrip patch antenna that operates at a frequency of 3.6 GHz was successfully designed using an advanced design system. By changing the value of the offset length in both infinite and finite ground planes, the characteristics of the microstrip patch antenna have been investigated to obtain a specific reflection coefficient at a certain frequency. The simulation results show that the antenna is perfectly operating at the designed frequency. The 2D and 3D radiation pattern and gain for both infinite and finite ground planes have been obtained. For the infinite ground plane, the major lobe is in the z-direction and there is no minor lobe as there is no reflection in the ground plane. For the finite ground plane, the major lobe is in the z-direction with minor lobes because the metal absorbs some radiation and radiates it to other directions.

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