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Design and Simulation of Microstrip Patch Antenna for Wireless Applications

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Abstract: ***In this paper two rectangular microstrip patch antennas are designed to operate in 2.4 GHz and 5.2 GHz bands, using Computer Simulation Technology (CST) Microwave Studio. The designed antenna can be used for industrial, scientific and medical (ISM) band applications. The RO4350B hydrocarbon ceramic laminates from ROGRES corporation substrate is chosen in the design of the dielectric substrate of the antennas. The designed antenna has low profile, low cost, easy fabrication and good isolation.***
The parameters such as return loss, voltage standing wave ratio (VSWR), antenna gain, radiation pattern has been simulated and analyzed.

Keywords: Microstrip patch antenna, dielectric substrate, Computer Simulation Technology (CST), Industrial Scientific and Medical (ISM) bands, voltage standing wave ratio (VSWR), antenna gain.

1. INTRODUCTION

An antenna plays a very important role in wireless communication systems. Microstrip patch antennas are attractive for low-profile wireless applications at frequencies above 100 MHz because of their low weight, cheap, and portability. As shown in Figure-1, a microstrip antenna in its simplest configuration consists of three layers; a radiating patch on the top, a dielectric substrate that underlies the patch, and a ground plane at the bottom [1] [2].

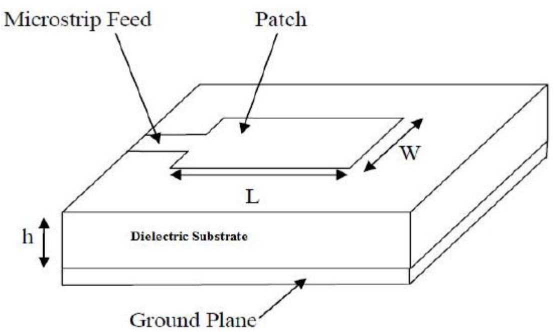

Figure-1: Microstrip patch antenna

The metallic patch normally made of conductors such as copper or gold. Although it can take different configurations, rectangular and circular patches are the most popular in practice, due to their attractive radiation characteristics. The dimensions of the patch are smaller compared to the substrate and ground [3] [4].

2. LITERATURE REVIEW

In this section a review of relevant works is studied. The approaching maturity of microstrip antenna technology coupled with the increasing demand and applications for such devices has resulted in a huge volume of research work in the field of microstrip antennas.

An array of Rectangular Microstrip Antenna (RMSA) with comparison to a single patch RMSA is designed in [5] using IE3D simulator for wireless local area network (WLAN) applications, at 2.4 GHz. In this work the FR4 substrate is chosen in the design process. The substrate has a dielectric constant of $\varepsilon_r = 4.4$ with a thikness of 1.6 mm. Maximum gain of 13.058 dBi is achieved by using four by two (4x2) array of eight patches as compared to 6.74 dBi for single patch. The dimensions of the designed path were $W = 38.3934\ mm$, and $L = 29.89\ mm$.

In [6] the substrate FR4, which has a dielectric constant of $\varepsilon_r = 4.4$ with a thikness of 1.6 mm, is proposed to be used to design a microstrip patch antenna, with the dimensions of $W = 39.4\ mm$, and $L = 28.9\ mm$. The antenna is designed and simulated in Ansoft-HFSSV13 for WLAN and ISM applications. The designed antenna provides 80 MHz of bandwidth at 2.4 GHz with a gain of 3.97 dBi. A review on the design and development of microstrip patch antennas at 5 GHz were studied in [7].

Mostly the FR4 substrate were used in the previous works with a thickness of 1.6 mm as in [5], [6], and [7]. In this paper the RO4350B hydrocarbon ceramic laminates from ROGRES corporation substrate is chosen in the design of two different single-microstrip patch antennas to operate in the 2.4 GHz and 5.2 GHz unlicensed instrument, scientific, and medical (ISM) bands. The proposed RO4350B substrate has the dielectric constant $\varepsilon_r = 3.66$ with a thickness of 0.762mm. Therefore, the thickness or height of the chosen dielectric substrate is much thinner, and is about two-times less than compared to the related works, which has the advantage of the reduction in the weight, size, and dielectric loss of the antenna. Beside this interesting point, the proposed antenna performance in terms of bandwidth, gain and VSWR is almost the same or better than the previous works

3. DESIGN CONSIDERATIONS

The resonant frequency is a key parameter for the design of microstrip patch antennas and must be selected properly to fit the application requirements. Dimensions (width and length) of a microstrip patch antenna depend on the resonant frequency f_o and value of the dielectric constant ε_r of the substrate. The width W and length L of a rectangular patch are calculated as follows [4] [5]:

$$W = \frac{c}{2 f_o \sqrt{\frac{\varepsilon_r+1}{2}}} \quad (1)$$

$$\varepsilon_{r_{eff}} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\sqrt{1+12\frac{h}{W}} \quad (2)$$

$$L = \frac{c}{2 f_o \sqrt{\varepsilon_{r_{eff}}}} - 0.824\, h\, \frac{(\varepsilon_{r_{eff}}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{r_{eff}}-0.258)(\frac{W}{h}+0.8)} \quad (3)$$

Where,
c: is the seed of light
$\varepsilon_{r_{eff}}$: is the effective dielectric constant
h: is the height of the substrate

The dimension of a substrate is equal to that of the ground plane. Typically, the dimension of the ground plane is assumed to be infinite during the analysis and design of microstrip patch antennas. In an actual application only a finite size ground plane can be implemented, which makes diffraction of radiation from the edges of the ground plane, and resulting in a change in radiation pattern, radiation conductance, and resonant frequency of the antenna. Therefore, the size of the ground plane is to be greater than the patch dimensions by approximately six times the substrate thickness. The length of a ground plane (L_g) and the width of a ground plane (W_g) are calculated using the following equations [4]:

$$W_g = W + 6h \quad (4)$$

$$L_g = L + 6h \quad (5)$$

There are different methods for feeding the microstrip patch antennas, such as feed line method, coaxial probe feeding method, etc. In this work the feed line method is used.

4. RESULTS

In this work two single-microstrip patch antennas are designed to operate at 2.4 GHz and 5.2 GHz respectively. The initial or approximate dimensions of each antenna are determined based on the design equations given from (1) through (5). The RO4350B dielectric is used to design the substrate which has the dielectric constant $\varepsilon_r = 3.66$ with a thickness of 0.762mm. The design parameters of the antennas are shown in Figure-2.

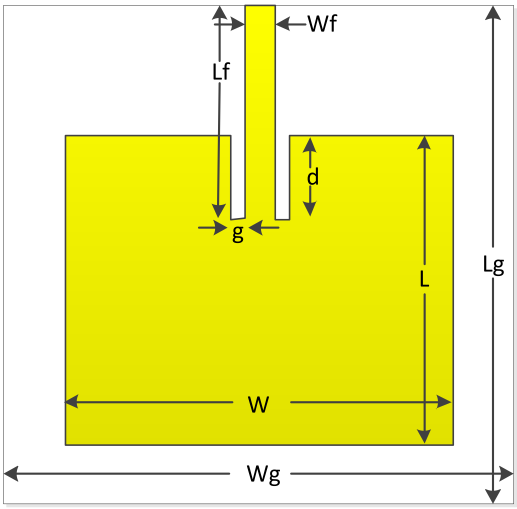

Figure-2: Design parameters of the proposed antenna

The designed antennas were simulated using the CST microwave studio. The dimensions of the proposed antennas are changed and optimized during the simulation process to get better performance of the antenna, i.e. radiation patterns, standing wave ration, bandwidth, and antenna gain.

Table-1 depicts the material specifications and design parameters of the designed antenna at 2.4 GHz.

Table-1: Design parameters of the designed antenna at 2.4 GHz.

Center frequency, f_o	2.4 GHz
Substrate	RO4350B
Substrate height, h	0.762 mm
dielectric constant, ε_r	3.66
Length of the patch, L	32 mm
Width of the patch, W	40.94 mm
Length of the substrate, L_g	41.6 mm
Width of the substrate, W_g	50.54 mm
Length of microstrip feed, L_f	16.497 mm
Width of microstrip feed, W_f	3 mm
Distance of inset feed, d	11.6966 mm
Gap between microstrip feed and patch, g	0.6 mm
Thickness of the patch, t	0.07 mm

Figures-3 shows the simulated far-field directivity or the radiation pattern for the designed antenna at 2.4 GHz. The results show that the designed microstrip patch antenna mainly radiates in the vertical direction. This is in agreement with the theoretical radiation pattern for these structures. The antenna has a gain of 6.08 dBi.

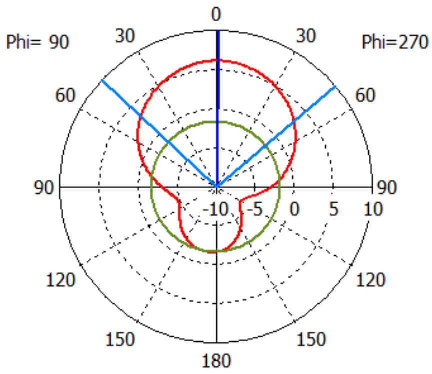

Figure-3: Far-field directivity of the 2.4 GHz antenna

The simulated S-parameter versus frequency for the designed antenna at 2.4GHz is presented in Figure-4. It can be seen that the simulated center frequency is slightly shifted from the 2.4 GHz. The antenna has a return loss of $-28.1579\ dB$ at 2.409 GHz. The bandwidth of the antenna is about 23.19 MHz, as shown in Figure-5.

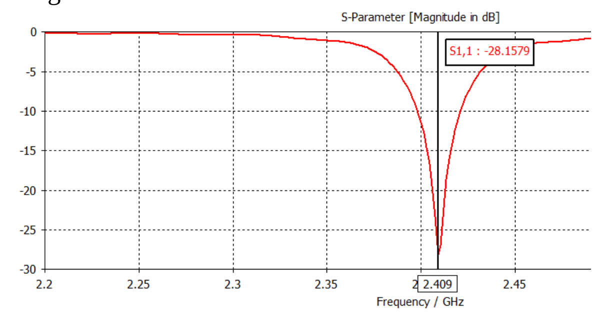

Figure-4: Return loss (S11) of the designed 2.4 GHz antenna

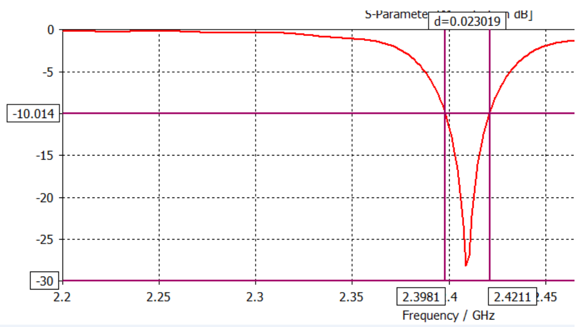

Figure-5: Bandwidth of the designed 2.4 GHz antenna

The voltage standing wave ratio (VSWR) of the antenna at the resonant frequency is about 1.081, as shown in Figure-6.

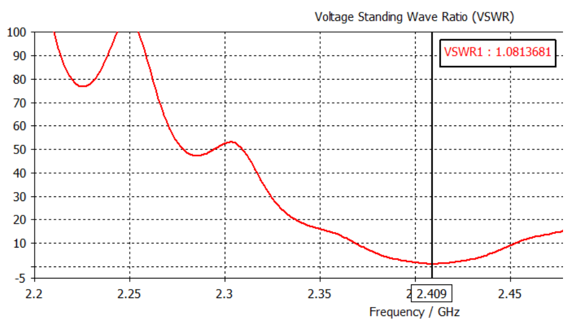

Figure-6: VSWR for the designed antenna at 2.4 GHz

Table-2 illustrates the material specifications and design parameters of the designed antenna at 5.2 GHz.

Table-2: Design parameters of the designed antenna at 5.2 GHz.	
Center frequency, f_o	5.2 GHz
Substrate	RO4350B
Substrate height, h	0.762 mm
dielectric constant, ε_r	3.66
Length of the patch, L	14.8 mm
Width of the patch, W	15.8 mm
Length of the substrate, L_g	24.4 mm
Width of the substrate, W_g	25.4 mm
Length of microstrip feed, L_f	10.13 mm
Width of microstrip feed, W_f	3 mm
Distance of inset feed, d	5.33 mm
Gap between microstrip feed and patch, g	0.8 mm
Thickness of the patch, t	0.07 mm

Figures-7 shows the Far-field directivity radiation pattern for the designed antenna at 5.2 GHz. Similarly, as the previous design, the antenna mainly radiates in the vertical direction. The antenna has a gain of 6.35 dBi.

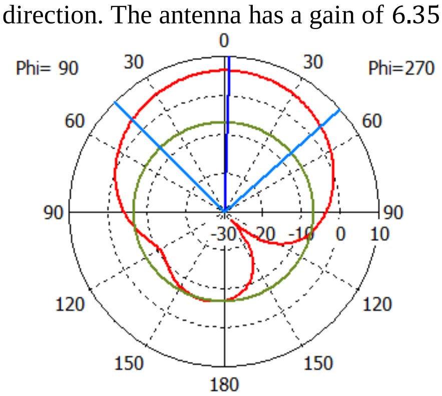

Figure-7: Far-field directivity of the 5.2 GHz antenna

The simulated S-parameter versus frequency for the designed antenna at 5.2 GHz is presented in Figure-8. It can be seen that the simulated center frequency is shifted from the designed target, but still very close to 5.2 GHz. The antenna has a return loss of $-32.103\ dB$ at 5.228 GHz. The bandwidth of the antenna is about 93.433 MHz, as shown in Figure-9.

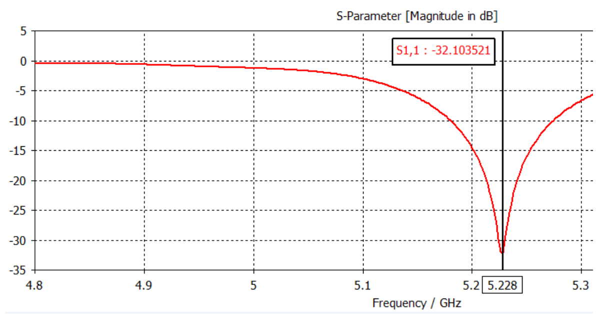

Figure-8: Return loss (S11) of the designed 5.2 GHz antenna

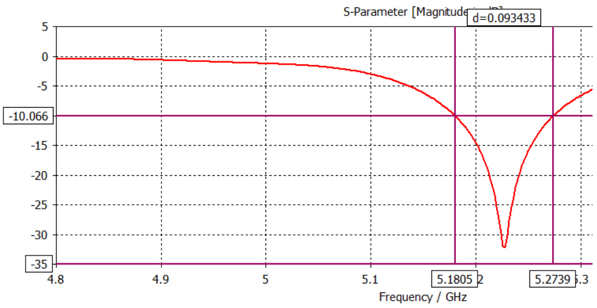

Figure-9: Bandwidth of the antenna

The VSWR of the patch antenna is about 1.051 at $5.228\ GHz$, which is practically strongly acceptable, as shown in Figure-10.

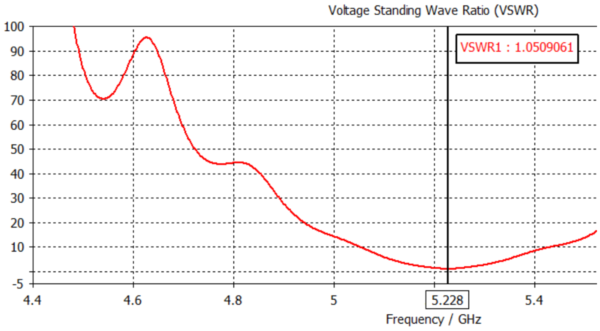

Figure-10: VSWR for the designed 5.2 GHz antenna

5. DISCUSSION

In this paper two different patch antennas were designed using a dialectic substrate with a thickness of 0.762 mm which is much narrower than the related works as done in [5], [6], and [7].

The designed 2.4 GHz antenna has comparable dimensions as given in the related works. The antenna has a maximum gain of 6.08 dBi with a main lobe in the direction of theta = 0 degrees and phi = 0 degrees was obtained. The simulated gain is a much higher compared to the results reported in [6] but comparable to that given in [5]. The return loss of the antenna is slightly less than the related works, and it has better and more desired value of VSWR. The dimensions of the designed 5.2 GHz are much less than in that of the 2.4 GHz antenna.

The bandwidth of the designed 2.4 GHz antenna is 23.19 MHz, while the bandwidth of the designed 5.2 GHz antenna is 93.433 MHz. These obtained values of bandwidth are less than compared the results reported in [5], [6], and [7]. Therefore, it can be depicted that the proposed designs can be much useful in the design of wireless systems that require narrow bandwidth such as sensor networks that lie in the ISM bands.

6. CONCLUSION

In this study the RO4350B substrate is proposed in the design of two different single microstrip patch antennas to operate at 2.4 GHz and 5.2 GHz ISM bands. The thickness or height of the chosen dielectric substrate is much thinner which has the advantage of the reduction in the weight of the proposed antenna with a good performance in gain, return loss, and VSWR is the important futures of the proposed antennas for various wireless applications including wireless sensor networks, wireless telemedicine devices, and WLANs.

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