Design and Analysis of Multilayer Substrate Structure Microstrip Patch Antenna

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Abstract

A rectangular microstrip patch antenna with multilayer substrate structure is designed in this paper. The designed antenna is analysed for the multilayer substrate structure. The height of the one dielectric substrate is taken as 1.6mm. Hence different antenna characteristics such as gain, bandwidth, return loss, directivity and VSWR are analysed four layer structureof the dielectric substrate. The resonant frequency of the designed antenna is 2.4 GHz. The dielectric substrate material used to design the antenna is FR4-epoxy having a dielectric constant of 4.4. The designed antenna has a bandwidth which covers the frequency band of WLAN applications. It is observed that the return loss of the antenna changes significantly with the layered structure of dielectric substrate. A return loss of -28.28 dB is achieved for the four layer substrate structure of the designed antenna which is much greater than the single layer structure. Microstrip line feeding method for energizing the antenna. Voltage standing wave ratio for the designed antenna is less than 2.The antenna is designed and simulated with Software High Frequency Structure Simulator (HFSS 13.0).

Keywords —*Multi-layer structure, Directivity, HFSS, WLAN.*

I. INTRODUCTION

A large number of microstrip patches are used in wireless communication.Microstrip patch antenna is a narrow band wide beam antenna having dielectric substrate, ground plane and a metallic patch. Radiation in microstrip antenna occurs from the fringing fields existing at the open circuited end or edges of the patch. Maximum radiation in the microstrip patch is in the broadside direction. It can be mounted on a flat surface. Microstrip antennas are used in various applications such as radar and altimeters, high speed space vehicles, biomedical applicators, remote sensing and navigation. Various techniques are used to energize the microstrip antenna feeding techniques such as coaxial feeding, microstrip feeding, aperture coupled feed and proximity coupled feed. From these feeding techniques microstrip feeding technique is easy [1-3].Here the antenna is observed for the different characteristics such as return loss, gain, bandwidth, directivity etc.

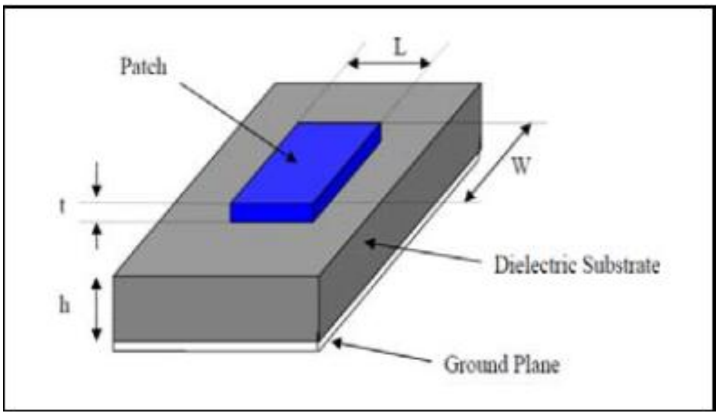

Fig.1 Structure of a Microstrip Patch Antenna

For an efficient radiator, practical width that leads to good radiation efficiencies is

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}}$$

The effective dielectric constant of the microstrip patch antenna is calculated using the formula given below-

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-\frac{1}{2}}$$

The effective length is given by-

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}}$$

Length extension **(**ΔL) is calculated using the given formula -

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

Actual length of the patch is given by-

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

So by using the above formulas the length and width of the rectangular microstrip patch is calculated.

II. ANTENNA DEISGN

The antenna is designed at a frequency of 2.4 GHz using FR4-epoxy as a dielectric substrate material having a dielectric constant of 4.4.The designed antenna has a substrate of size 61mm×76 mm. The length and the width of the microstrip patch calculated by the above formulas are 27mm and 38mm respectively. The designed is energized using the microstrip line feeding method. As the designed antenna is multilayer substrate structure antenna, so it is analysed for the four layer substrate structure. The height of each layer is 1.6mm. The different characteristics of the antenna such as gain, bandwidth, and voltage standing wave ratio are analysed for the different layered structured of the antenna.

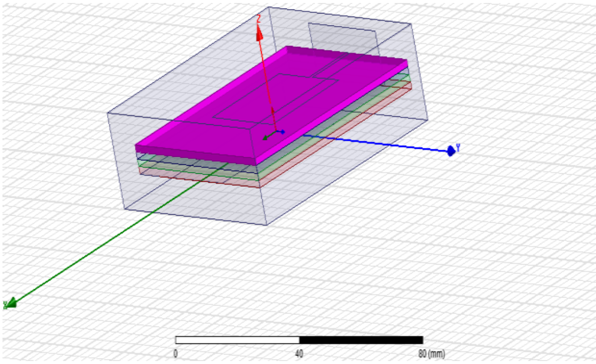

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Fig.2 Actual HFSS design

III. SIMULATION RESULTS

The designed antenna is simulated using software High Frequency Structure Simulator. The different characteristics of the antenna are observed here for the multilayered structure.

A. Single Layer Substrate Structure

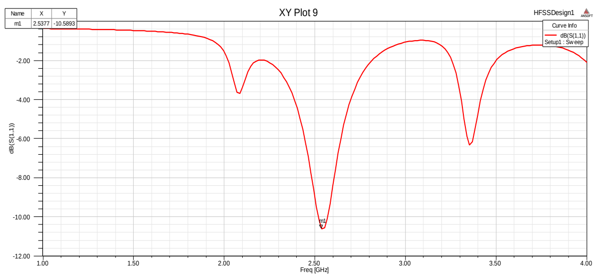

Fig.3 Return Loss of the Antenna

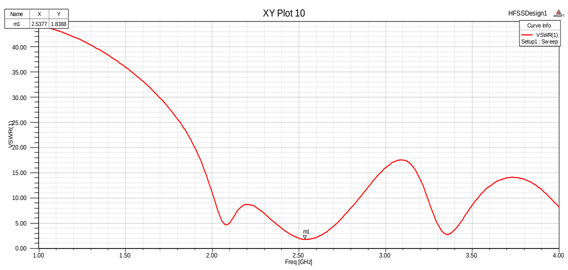

Fig.4 VSWR of the Antenna

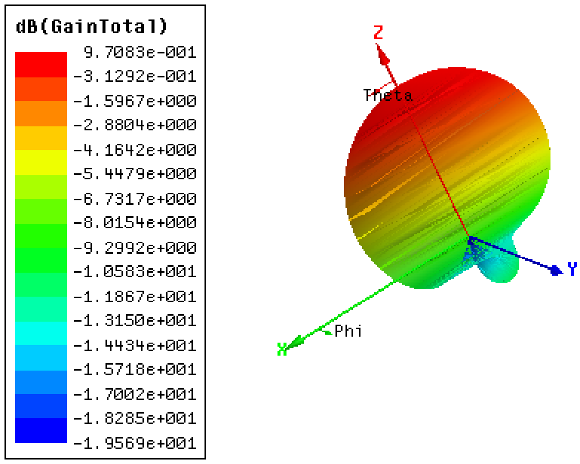

Fig.5 Gain of the Antenna

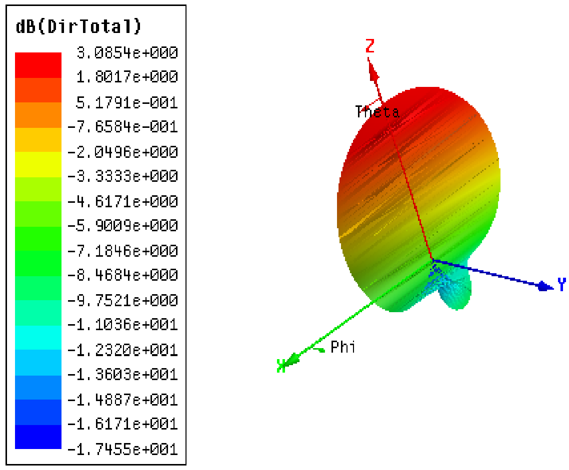

Fig.6 Directivity of the Antenna

B. Double Layer Substrate Structure:

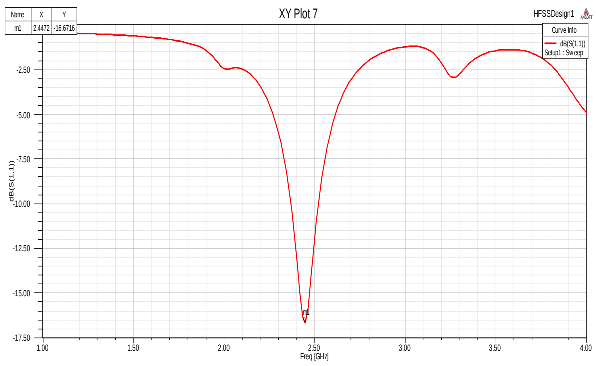

Fig.7 Return Loss of the Antenna

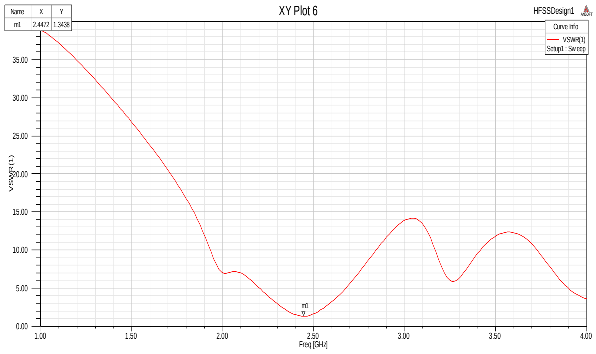

Fig.8 VSWR of the Antenna

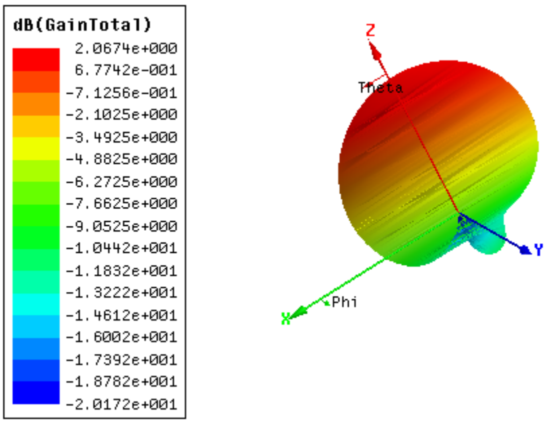

Fig.9 Gain of the Antenna

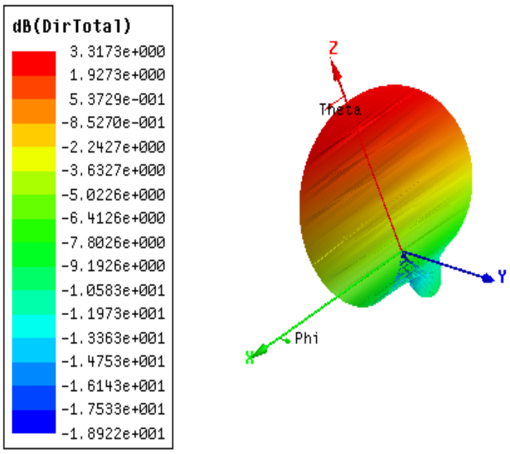

Fig.10 Directivity of the Antenna

C. *Triple Layer Substrate Structure*

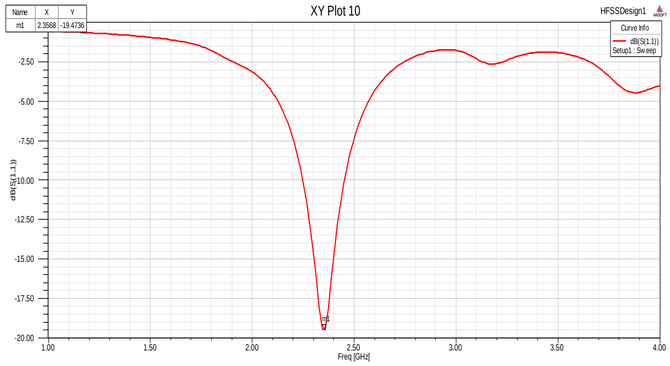

Fig.11 Return Loss of the Antenna

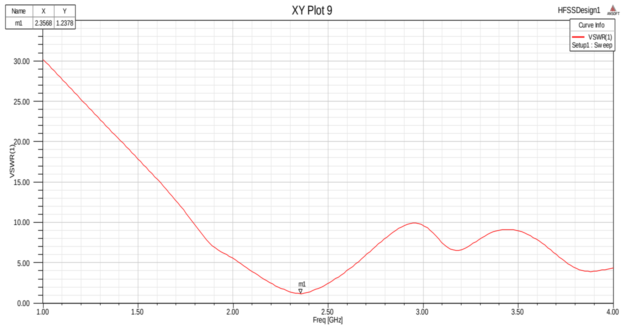

Fig.12 VSWR of the antenna

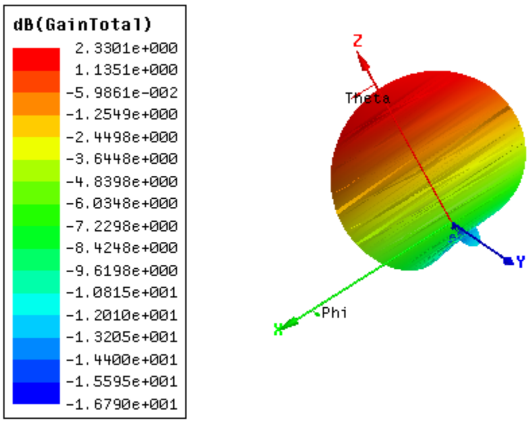

Fig.13 Gain of the Antenna

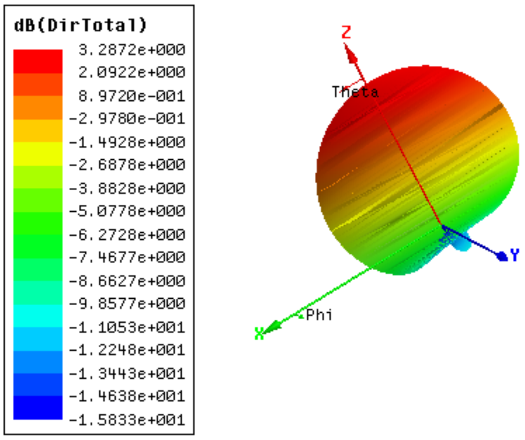

Fig.14 Directivity of the Antenna

D. *Four Layer Substrate Structure*

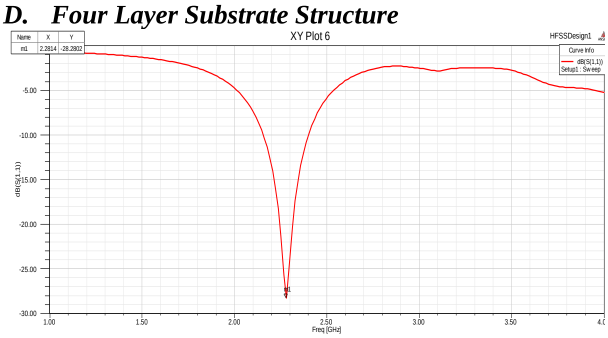

Fig.15 Return loss of the Antenna

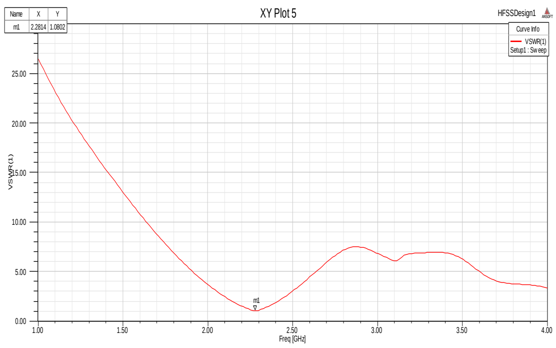

Fig.16 VSWR of the Antenna

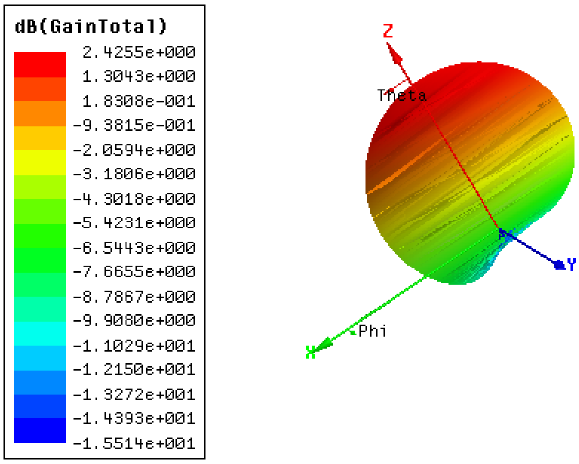

Fig.17 Gain of the Antenna

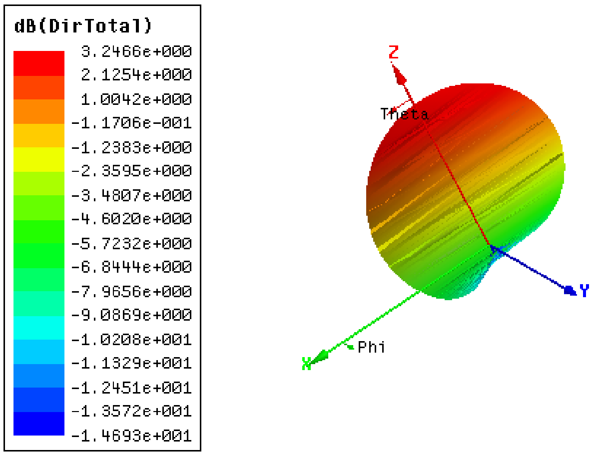

Fig.18 Directivity of the Antenna

IV. COMPARISON CHART USING MULTI-LAYER SUBSTRATE STRUCTURE

Layer Structure	Return loss (dB)	VSWR	Gain (dB)	Directivity (dB)	B.W (MHz)
Single	-10.58	1.84	9.70	3.08	50
Double	-16.68	1.34	2.06	3.31	150
Triple	-19.47	1.23	2.33	3.28	210
Four	-28.28	1.08	2.42	3.24	250

So from the above table it is clear that return loss of the antenna is minimized significantly when the multilayer substrate is used. A return loss of -28.28 dB is achieved for four layer substrate structure. The gain and bandwidth of the antenna is also increased. The voltage standing wave ratio of the designed antenna is less than 2.The bandwidth for the four layer structure is 250MHz.

REFERENCES

[1] Constantine A. Balanis, Antenna Theory, Analysis and Design,3rd edition, A John Wiley & Sons, Inc. , Publication, 2005.

[2] K. Jhamb L. Li K. Rambabu, "Frequency adjustable microstrip annular ring patch antenna with multi-band characteristics", IET Microwave. Antennas Propagation, 2011, Vol. 5, Issue 12, pp. 1471–1478 & the Institution of Engineering and Technology 2011

[3] Sudarshan Kumar Jain, "Comparative Analysis of Microstrip rectangular Patch antenna using different height substrates" International Journal of Advanced Research in Computer and Communication Engineering -2015

[4] Zhu Yongxiang, Chen Jianjun, SongXuerui, Cao Hongxi, "The Design Study of the Wide Bandwidth and High Gain RFID Microstrip Patch Antenna**",** Third IEEE International Conference on Intelligent System Design and Engineering Applications-2013.