Analysis of Multilayered Microstrip Patch Antenna

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Abstract

In this paper analysis of multilayered antenna is done by considering two approaches in which stacked patch is realized with common dielectric and in other approach stacked patch is realized with different dielectric substrates. Both the approaches are analyzed commonly with 10% reduction in dimensions of the patch. The antenna is designed at 2.4 GHz which is commonly applied frequency band for wireless applications. Here the antenna shows good directivity in both approaches. The gain of the antennas is found to be 8.5dBi. This gain and the size reduction both play a vital role which helps the designed multilayered antenna to be utilized in wireless communication efficiently.

Keywords: Dielectrics, Multilayer Patch, Patch Antenna, Stacked Patch, Directivity, Gain

1. Introduction

Microstrip Patch Antenna finds applications in radar systems, missiles, telemetry systems, aircraft communication systems, satellite communication and mobile handsets. Microstrip patch antenna (MSPAs) is widely used because of small size, less weight, low cost. The limitation of microstrip antennas is narrow bandwidth, low gain and poor efficiency [1]. These can overcome by using multilayered structures. Multilayered Microstrip patch is also useful to provide protection to patch from heat, rain and physical damage [2-4], wide band width and high gain. There are many methods available in the literature to design the multilayered patch based on numerical technique [5]. These methods require rigorous, complex analysis which are time consuming and cannot be easily included in CAD system.

In the present paper, an attempt has been made to improve the directivity by increasing the multiple layers of the patch. Various antenna parameters such as directivity, return loss, radiation efficiency, total efficiency and radiation pattern are compared as the layers of the microstrip patch antenna gets increased. In this paper two approaches of multilayered patch is described. The first approach deals with stacked patch with common dielectric with 10% reduction in dimensions as well as 10% reduction of height of the substrate as the spacing between the two consecutive layers of the patch. In the second approach, stacked patch with different dielectric substrates with 10% size reduction. Then both the approaches are being compared for the characteristics of an antenna and checks the best suited for wireless communication.

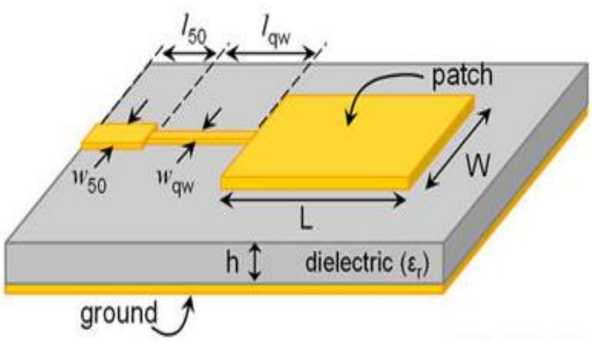

Fig.1. Square Microstrip patch

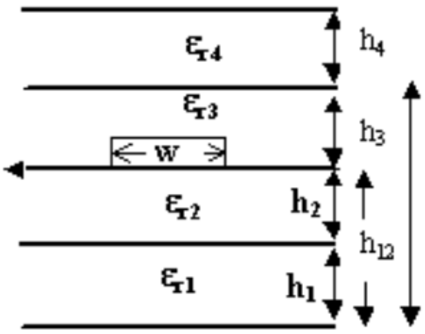

Fig. 2. Multilayered Microstrip patch

First the simple patch was designed at 2.4 GHz using RT Duriod 5880. Microstrip (50Ω line) is used as feeder. To improve the efficiency, Quarter wave line is incorporated between the patch and feeder.The design layout and the simulation result is shown in Fig 2.

2. Design Procedure

Fig.1and 2 shows the multilayered square microstrip patch antenna, which consists of square patch of dimension W[6], dielectric constant ε_{r1}, ε_{r2}, ε_{r3}, ε_{r4} and the thickness of the substrate h_1,h_2 and superstrate of h_3 and h_4.The resonant frequency of the multilayered square microstrip patch antenna of Fig.2 can be calculated by the expression given below:

$$f_r = \frac{C}{2(L+2\Delta L)\sqrt{\varepsilon_{eff}(f)}} \qquad (1)$$

where the L is the length of the patch antenna, C is the velocity of light in free space, ΔL is the length extension due to the end effect and $\varepsilon_{eff}(f)$ is the frequency dependent effective dielectric constant of multilayered microstrip structure.

2.1. *First Approach*

In the first approach, seven layers of patch is designed and simulated using RT Duriod 5880 (common dielectric). But stacked patch is realized through 10% reduction in the dimensions of the patch and also the distance between the two consecutive layers is also subsequently reduced by 10%. The design and the simulation results are given in Fig 3 to Fig12 respectively.

2.2. *Second Approach*

The second approach deals with the above specified resonant frequency but here the stacked patch

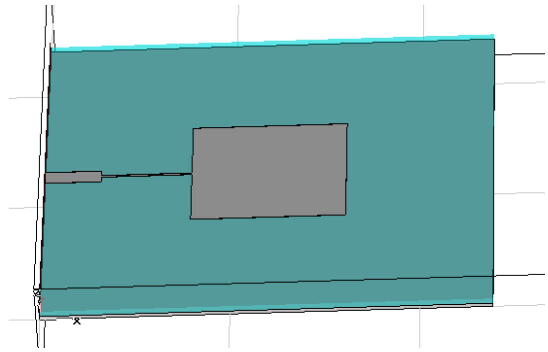

Fig. 3. Layout of the simple Microstrip patch antenna

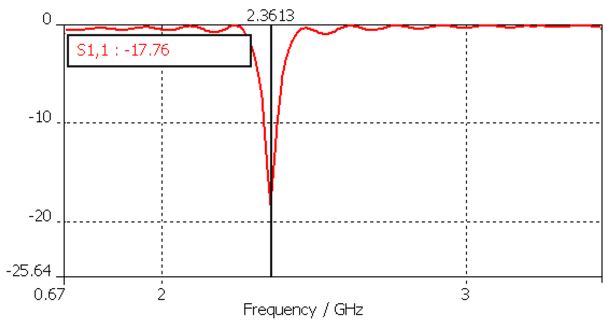

Fig.4. S parameter of the simple Microstrip patch antenna

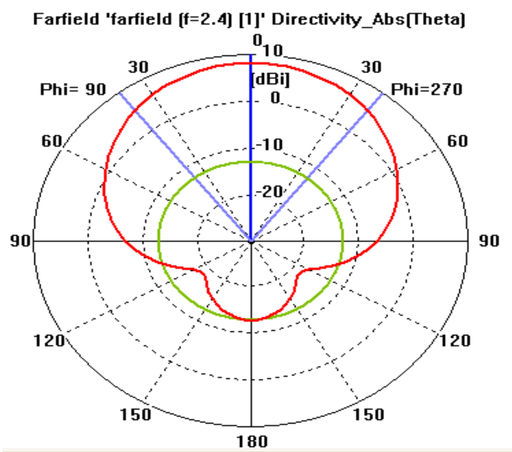

Fig.5. Radiation Pattern of the simple Microstrip patch antenna

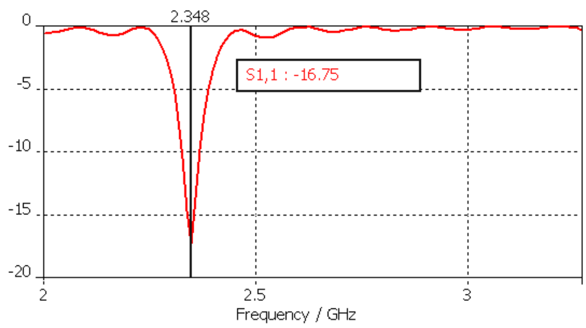

Fig.6. S parameter of the stacked Microstrip patch antenna with 2 layer

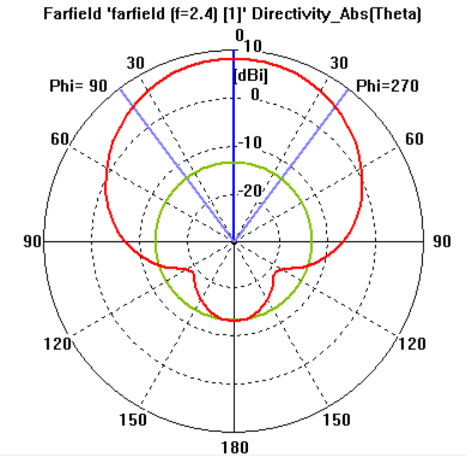

Fig.7. Radiation Pattern of the stacked Microstrip patch antenna with 2 layer

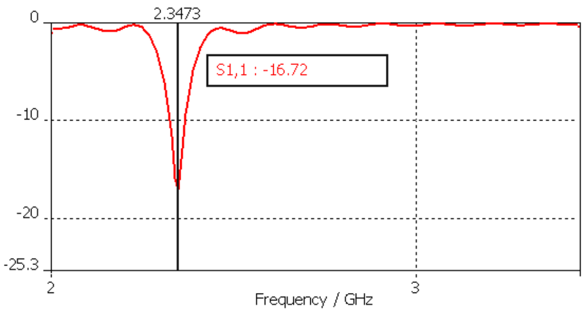

Fig.8. S parameter of the stacked Microstrip patch antenna with 4 layer

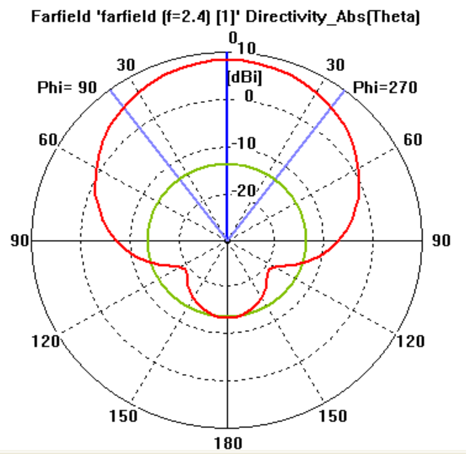

Fig.9. Radiation Pattern of the stacked Microstrip patch antenna with 4 layer

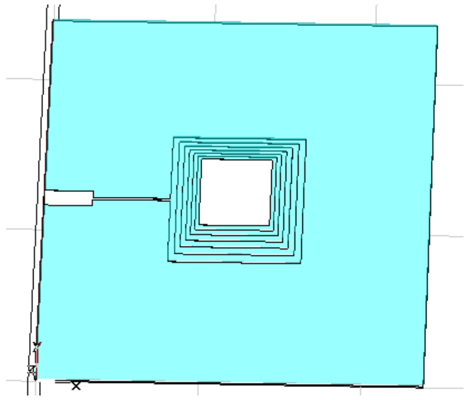

Fig.10. Layout of the stacked Microstrip patch antenna with 7 layers of same dielectric

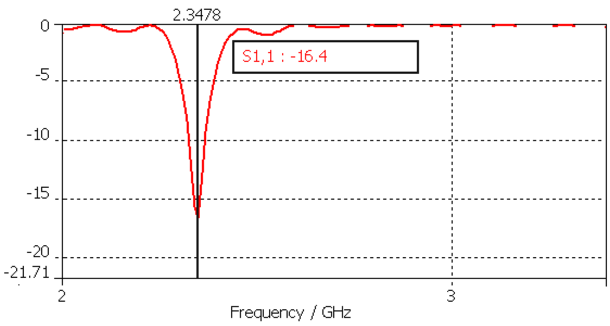

Fig.11. S parameter of the stacked Microstrip patch antenna with 7 layer

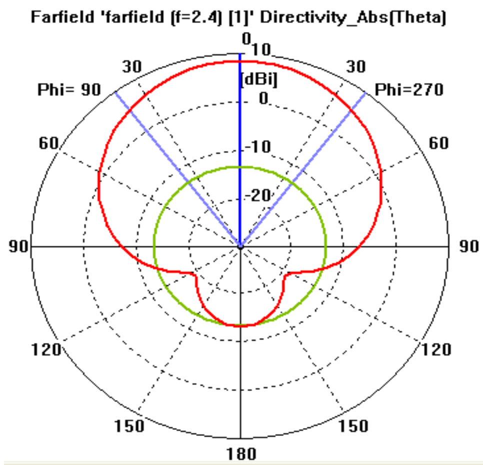

Fig.12. Radiation Pattern of the stacked Microstrip patch antenna with 7 layer.

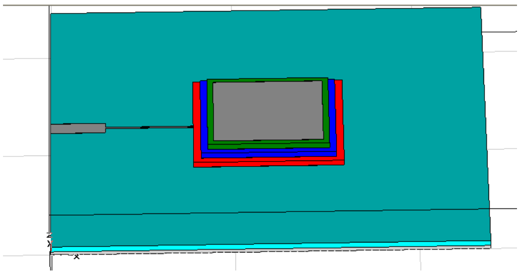

Fig.13. Layout of the stacked Microstrip patch antenna with different dielectric constants with 4 layer.

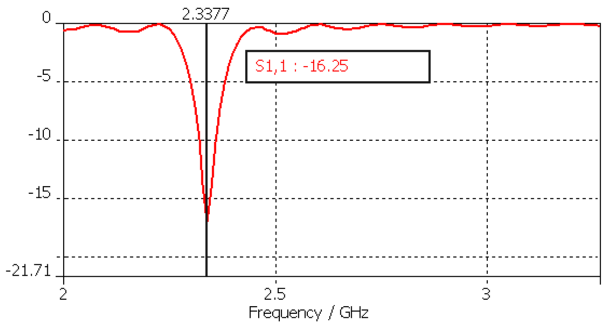

Fig.14. S parameter of the stacked Microstrip patch antenna with dielectric ε_{r2}

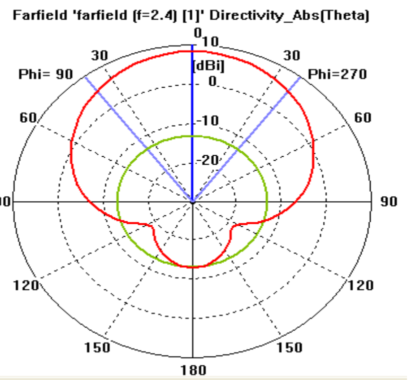

Fig.15. Radiation Pattern of the stacked Microstrip patch antenna with dielectric ε_{r2}.

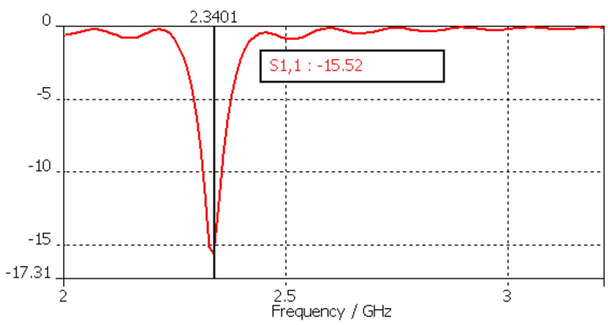

Fig.16. S parameter of the stacked Microstrip patch antenna with dielectric ε_{r3}

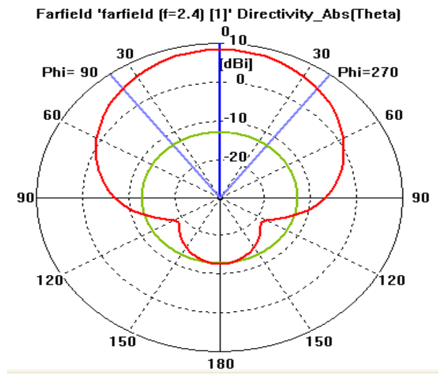

Fig.17. Radiation Pattern of the stacked Microstrip patch antenna with dielectric ε_{r3}.

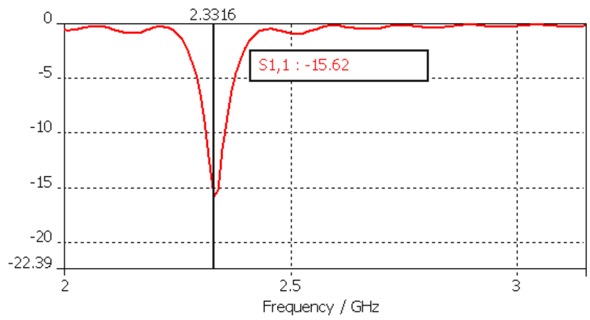

Fig.18. S parameter of stacked Microstrip patch antenna with dielectric ε_{r4}.

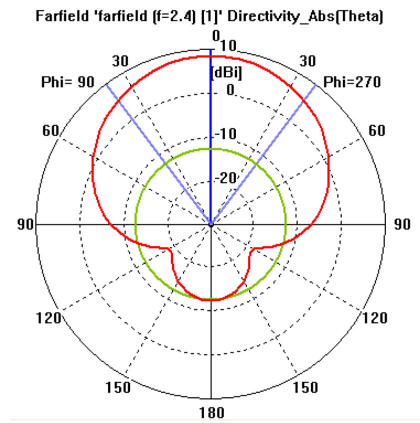

Fig. 19. Radiation Pattern of the stacked Microstrip patch antenna with dielectric ε_{r4}.

realization is through different dielectric materials with 10% reduction in the dimensions of the patch. The various dielectric constants used are ε_{r1} is RT Duroid5880, ε_{r2} is FR4, ε_{r3} is alumina with the dielectric constant 4.6, ε_{r4} is also alumina with the dielectric constant of 9.6. The structure and simulation results of the multilayered patch are given in Fig 13 to Fig 19. Through simulation, the S parameter and radiation pattern of ε_{r1} is same as that of simple Microstrip patch antenna as in Fig 4 and Fig 5.

3. Results and Discussion

Both the approaches of multilayered patch antenna with same dielectric constants and with different dielectric constants at 2.4 GHz are designed and there simulation results are shown in the above section. Simulation results of both approaches are summarized in Table I and II respectively. Table I shows the radiation characteristics when the layer gets increased from 2 to 7. It is clear that the return loss gets reduced upto 4^{th} layer (-17.02dB) but from 5^{th} layer onwards the return loss gets increased also with increase in gain & efficiency of (0.87). In the above table the directivity is increased upto 8.5 dBi, radiation efficiency is 0.87 and the total efficiency is configured to be 0.48.

Table 2 shows the stacked microstrip patch antenna with different dielectrics medium with 10% size reduction. The structure is analyzed 4 layers. It's clear from the table that the return loss gets reduced to -15.66, directivity is 8.59dBi, radiation efficiency 1.01 and total efficiency is 0.39 leading to reduction in total efficiency.

4. Conclusion

This paper presents the comparison between two approaches of multilayered stacked Microstrip Patch antenna keeping in view of its utilization in wireless communication. Both the approaches have good gain of 8.5 dBi and with 10% size reduction step wise. This gain and size reduction is needed for wireless communication and finds very good application in mobile handsets. It is clear, that the return loss in the first approach gets increased as the layers are getting increased i.e. after 4^{th} layer the S_{11} value gets increased to be -16.69 .But in the second approach as the different dielectric constants are used in 4 layer itself the return loss gets reduced to -15.66 .Though the return loss is less, but it is well applicable below the specified range for antennas, also found to yield good radiation efficiency, high gain & hence it can be adopted.

Table 1. Stacked microstrip patch antenna with same dielectric layers

No. of Patch	S11 (dB)	Directivity (dBi)	Rad. efficiency	Total efficiency
1	-17.76	8.327	0.7861	0.5431
2	-16.57	8.441	0.8603	0.4798
3	-16.95	8.478	0.8641	0.4747
4	**-17.02**	**8.510**	**0.8682**	**0.4775**
5	-16.69	8.526	0.8734	0.4779
6	-16.64	8.541	0.8737	0.4804
7	-16.6	8.554	0.8739	0.4830

Table 2. Stacked microstrip patch antenna with different dielectric medium

No. of Patch	S11 (dB)	Directivity (dBi)	Rad. efficiency	Total efficiency
1	-17.76	8.327	0.7861	0.5431
2	-16.97	8.489	0.9612	0.4258
3	-15.56	8.539	0.9864	0.4029
4	**-15.66**	**8.595**	**1.010**	**0.3990**

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