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Analysis of Miniaturized Compact Stacked Patch Antennas for Future Short Range Communication

[1]S.Sreenath Kashyap, [2]Ved Vyas Dwivedi
[1]Research Scholar, C.U.Shah University, [2]Pro-Vice chancellor, C.U.Shah Univeristy

Abstract— This paper presents the design and analysis of miniaturized nano size planar radiators resonating at Terahertz frequency using substrates which differ in dielectric permittivity. These structures are analyzed by varying the electromagnetic gap (mechanical distance) between the patches along with the rotation of the upper patch. Electrical performance is studied and found improved with help of antenna parameters namely S11, Gain and Bandwidth. Comparative study of the results is envisaged for these antenna structures using Arlon and Polymide as general purpose substrate materials. Researches speak that these radiating structures are useful for applications such as high frequency sensing and short range communication systems. Major features of these antennas include zero losses, negligibly small volume and weight, and extremely miniaturized surface making perfect electromagnetically conducting body. In addition, it contributes beautiful solution for global issues of environmental dangers due to material extraction from earth's crust and heat loss, significant decrease in fuel consumption while launching the space vehicle and least power consumption for during its entire life in space.

Index Terms— Microstrip patch Antennas, Terahertz Communication, Terahertz Antennas,Stacked Patch Antennas,Furture short range communication, Terahertz band, Terahertz frequency.

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1 INTRODUCTION

The development in wireless communications plays a key role in the advancements of science and technology [1]. Planar antennas are attracting most of the researchers due to its advantages – compactness, less volume, resistant to shocked and many more [2]. The high bandwidth and gain are important features required for an antenna at terahertz frequency for avoiding path loss [3]. The enhancement in bandwidth and gain can be done by using multiple reflectors. Another best method is by placing a second patch at height in front of the first one which is called as stacked patch antenna [4].

In this present contribution the structures are designed on two substrates namely Arlon and Polymide which differ in dielectric permittivity. The electromagnetic coupling is used for feeding the second patch whereas the first patch is fed through a coaxial probe. The analysis of the radiating structures is done by varying the distance between the patches along with the rotation of patches.

2 ANTENNA STRUCTURE

The figure 1 shows the proposed design of conventional patch antenna and figure 2 shows the proposed design of the stacked patch model. In proposed model of antennas patch is printed on a ground plane with Arlon and polymide as a substrate of thickness't'. The upper patch is placed at a distance'd' above the lower patch.

- *S.Sreenath Kashyap is currently pursuing Ph.D in Electronics and Communications at Faculty of Technology & Engineering, C.U.Shah University, Wadhwan city, Gujarat, India. E-mail:kashyap.foru3@gmail.com.*
- *Dr. Ved Vyas Dwivedi is currently Pro- Vice Chancellor at C.U. Shah university, Wadhwan City Gujarat, India.*
- *Corresponding Author: S.Sreenath Kashyap – Research Scholar, C.U.Shah University, Wadhwan City, Gujarat, India. Email: kashyap.foru3@gmail.com*

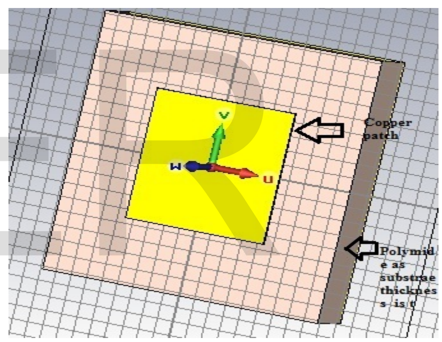

Fig.1. Conventional Patch Antenna

The width [5] of the patch can be calculated using the equation (1).

$$W = \frac{C}{2 f_0}\sqrt{\frac{\varepsilon_r + 1}{2}} \quad (1)$$

Due to the fringing effect, the effective dielectric permittivity is to be considered.[5] The effective dielectric permittivity can be calculated using equation (2)

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[\frac{1}{\sqrt{1 + 12(h/W)}}\right] \quad (2)$$

The length [5] of the patch can be calculated using the equation (3).

$$L = \frac{C}{2 f_0 \sqrt{\varepsilon_{eff}}} - 0.824h\left(\frac{(\varepsilon_{eff} + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{eff} - 0.258)(\frac{W}{h} + 0.8)}\right) \quad (3)$$

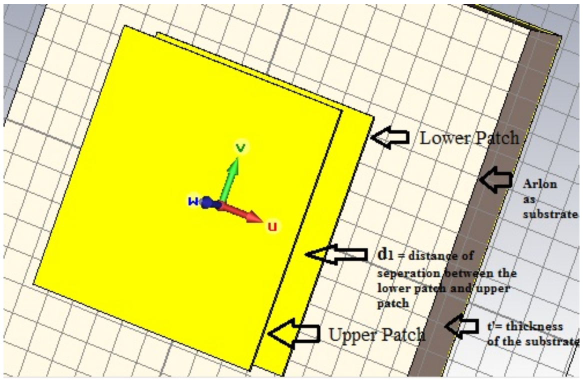

Figure2. Proposed model of Stacked Patch Antenna

Table I. Design parameters of the proposed model

Sr.No	Parameter	Arlon	Polymide
1.	Dielectric Permittivity of Substrate (Ɛr)	6.0	3.5
2.	Thickness of the lower patch	1 µm	1 µm
3.	Thickness of the upper patch	1 µm	1 µm
4	Distance of separation between the patches	d µm	d µm
5.	Length of the patch	120 µm	130 µm
6.	Width of the patch	135µm	146 µm
7.	Resonant frequency	0.6THz	0.6THz

3. Result and Analysis

The design and analysis is carried out in CST Microwave studio which uses the finest integral technique.
Design 1 – Arlon as substrate

Case 1: Conventional Patch model

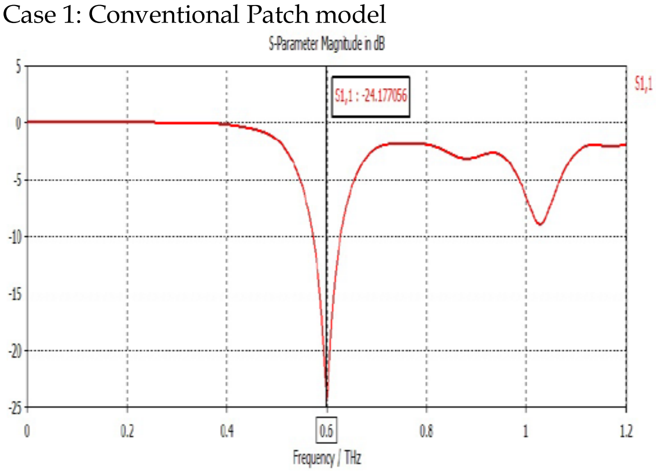

Figure3. Return loss plot of Case 1 conventional patch model using Arlon as substrate

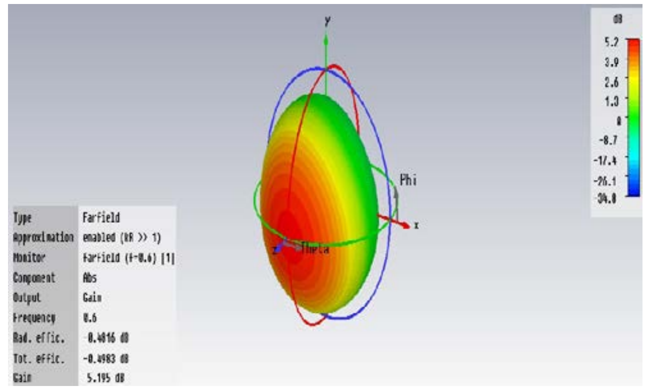

Figure4. Gain plot of Case 1 conventional patch model using Arlon as substrate

Case 2: d = t (only patches are separated by distance)

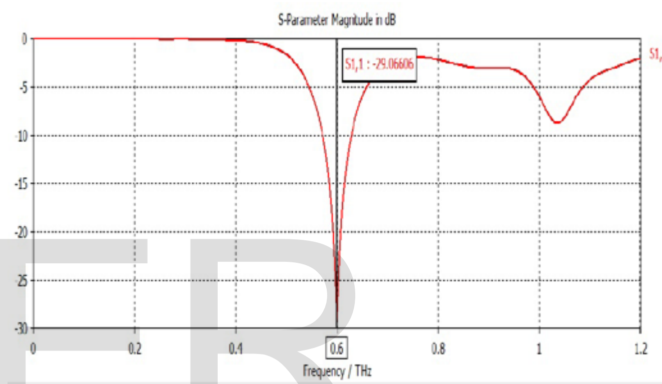

Figure5. Return loss plot of Case 2 d = t without rotation of proposed model using Arlon as substrate

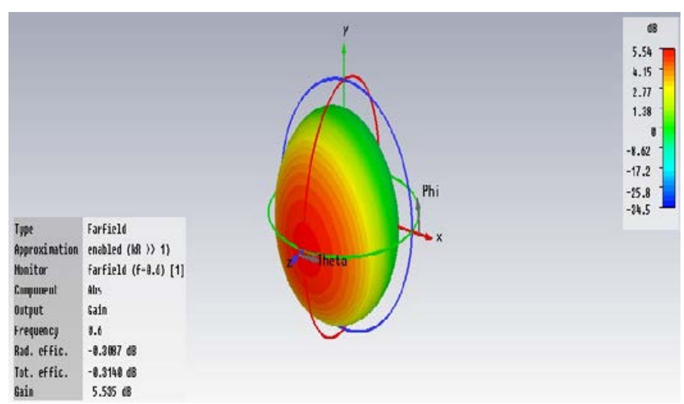

Figure6. Gain plot of Case 2 d= t without rotation of proposed model using Arlon as substrate

Case 2 (a): d = t Upper Patch Rotated 25^0

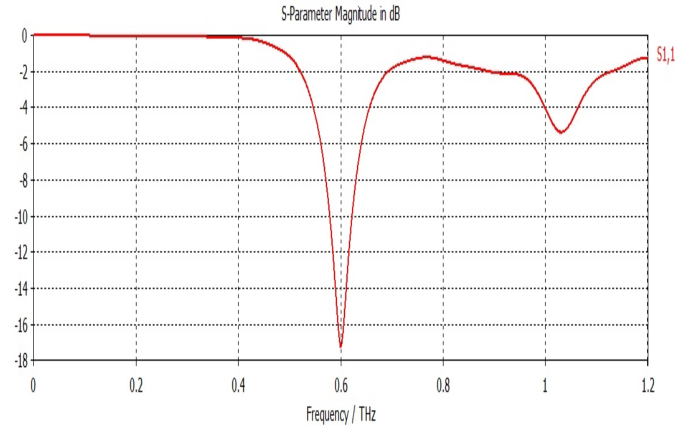

Figure7. Return loss plot of Case 2 (a) d = t upper patch rotated 25^0 of proposed model using Arlon as substrate

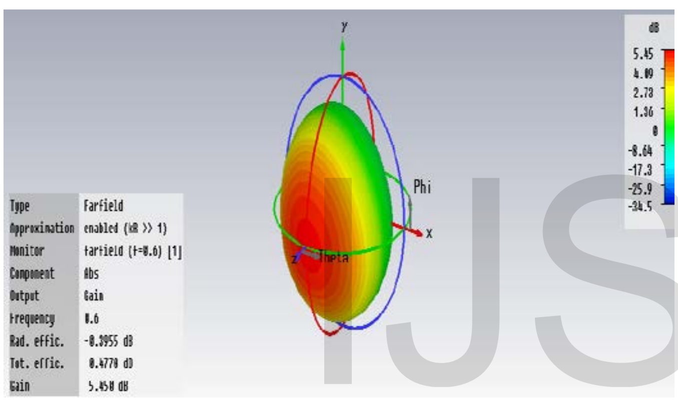

Figure8. Gain plot of Case 2 (a) d = t upper patch rotated 25^0 of proposed model using Arlon as substrate

Case 2 (b): d = t Upper Patch Rotated 50^0

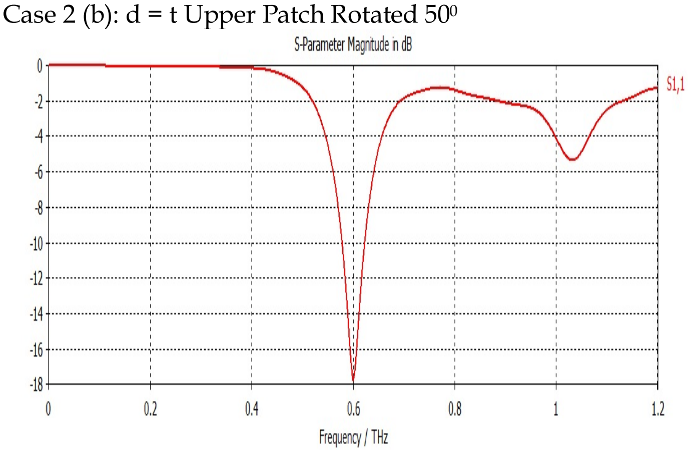

Figure9. Return loss plot of Case 2(b) d = t upper patch rotated 500 of proposed model using Arlon as substrate

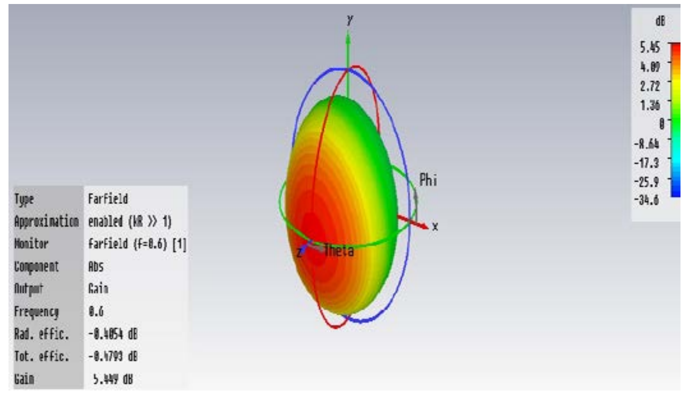

Figure10. Gain plot of Case 2 (b) d = t upper patch rotated 50^0 of proposed model using Arlon as substrate

Case 3: d = t / 2 (only patches are separated by distance)

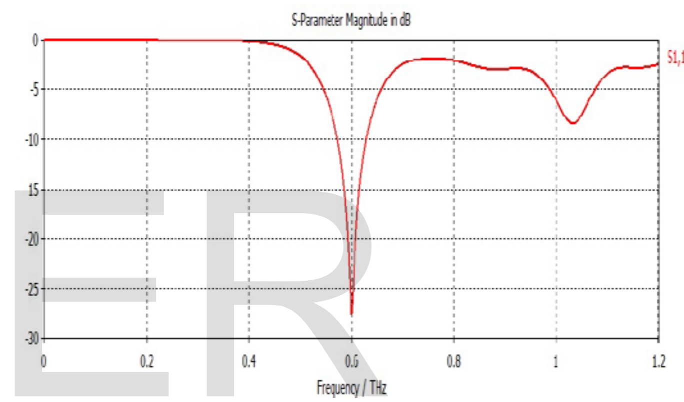

Figure11. Return loss plot of Case 3 d = t / 2 without rotation of proposed model using Arlon as substrate

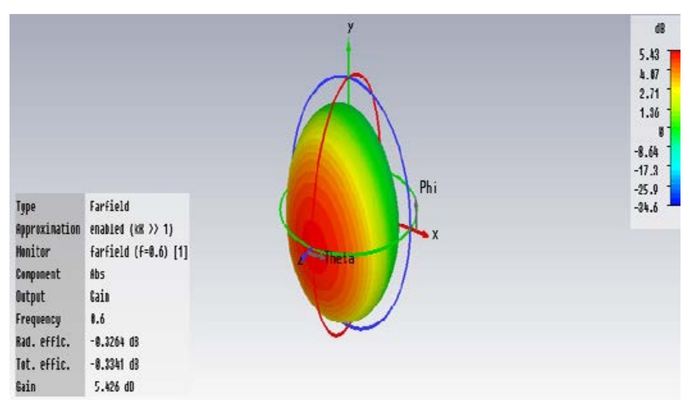

Figure12. Gain plot of Case 3 d = t / 2 without rotation of proposed model using Arlon as substrate

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Case 3 (a): d= t / 2 Upper Patch Rotated 25^0

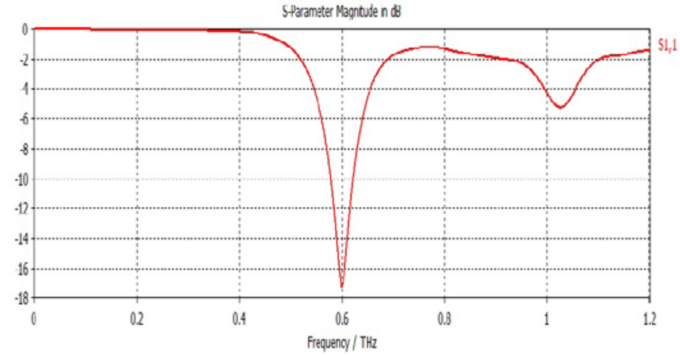

Figure13. Return loss plot of Case 3(a) d = t / 2 upper patch rotated 25^0 of proposed model using Arlon as substrate

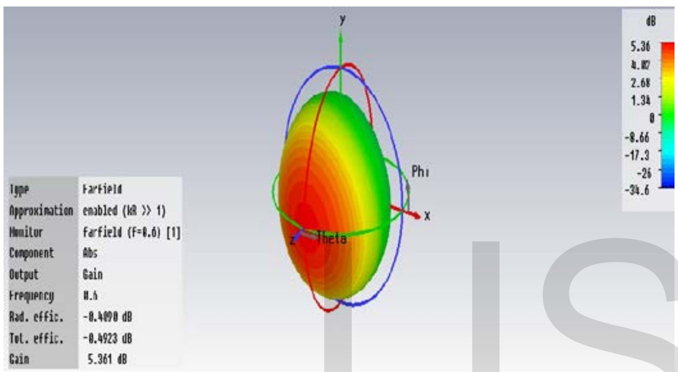

Figure14. Gain plot of Case 3(a) d = t / 2 upper patch rotated 25^0 of proposed model using Arlon as substrate

Case 3 (b) : d = t / 2 Upper Patch Rotated 50^0

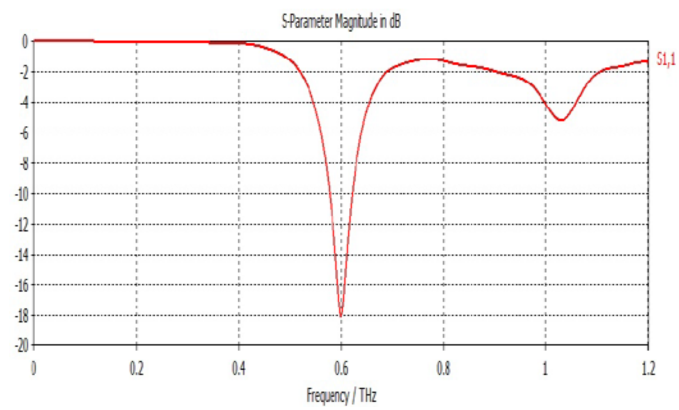

Figure15. Return loss plot of Case 3(b) d = t / 2 upper patch rotated 50^0 of proposed model using Arlon as substrate

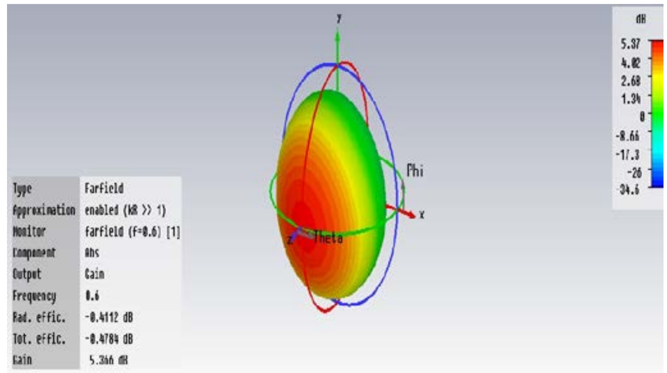

Figure16. Gain plot of Case 3(b) d = t / 2 upper patch rotated 50^0 of proposed model using Arlon as substrate

Design 2 – Polymide as substrate

Case 1: Conventional Patch model

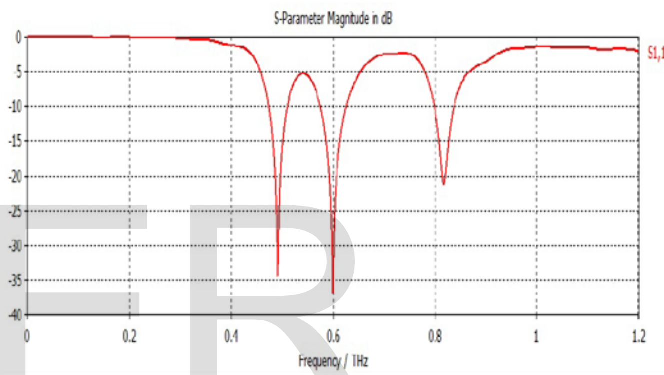

Figure17. Return loss plot of Case 1 conventional patch of proposed model using Polymide as substrate

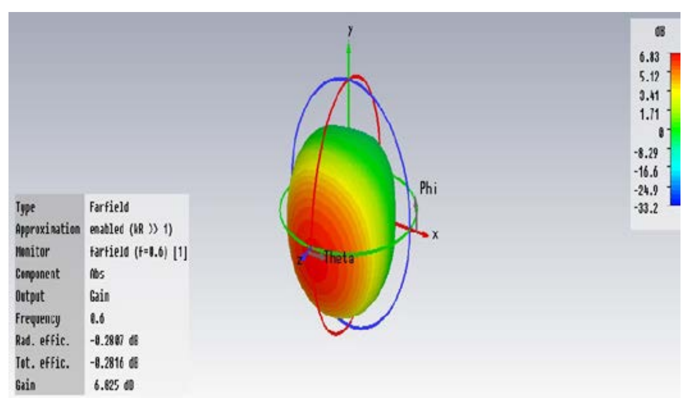

Figure18. Gain plot of Case 1 conventional patch of proposed model using Polymide as substrate

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Case 2: d = t (only patches are separated by distance)

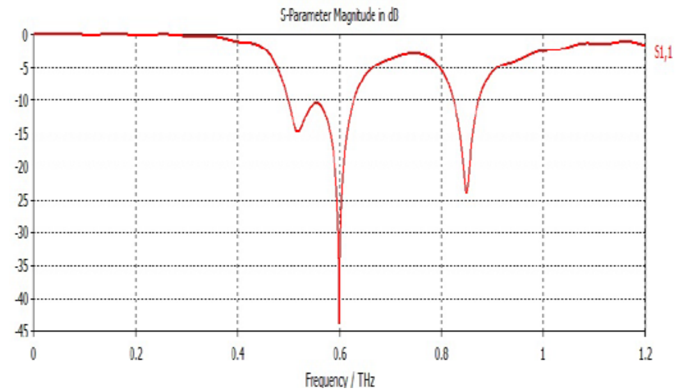

Figure19. Return loss plot of Case 2 d = t of proposed model using Arlon as substrate

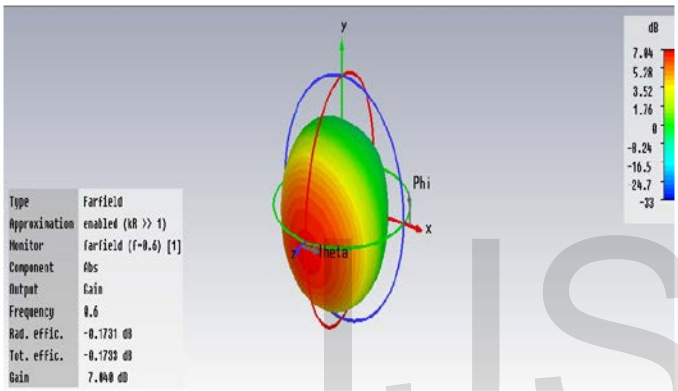

Figure20. Gain plot of Case 2 d = t of proposed model using Polymide as substrate

Case 2 (a): d = t Upper Patch Rotated 25^0

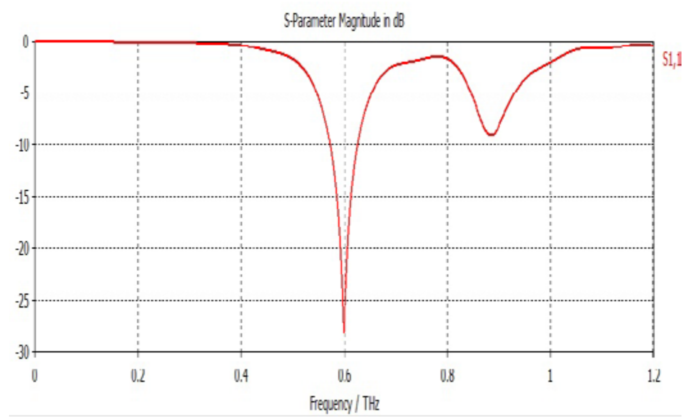

Figure21. Return loss plot of Case 2(a) d = t upper patch rotated 25^0 of proposed model using polymide as substrate

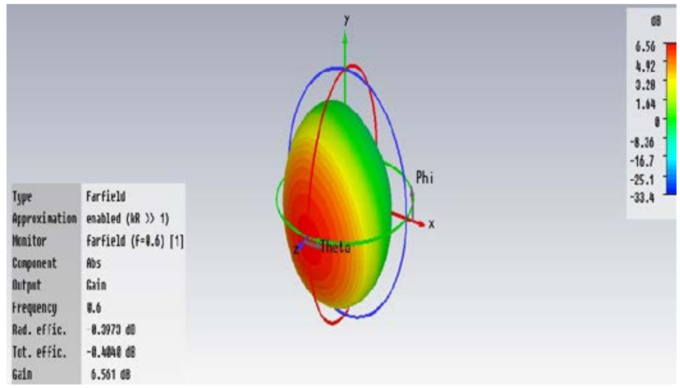

Figure22. Gain plot of Case 2 (a) d = t upper patch rotated of proposed model using polymide as substrate

Case 2 (b):d = t Upper Patch Rotated 50^0

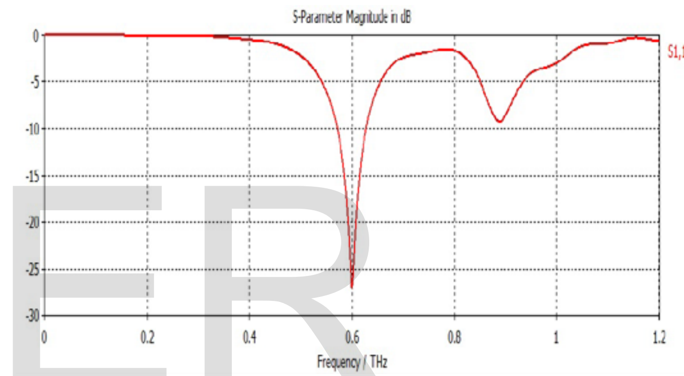

Figure23. Return loss plot of Case 2 (b) d = t upper patch rotated 50^0 of proposed model using Arlon as substrate

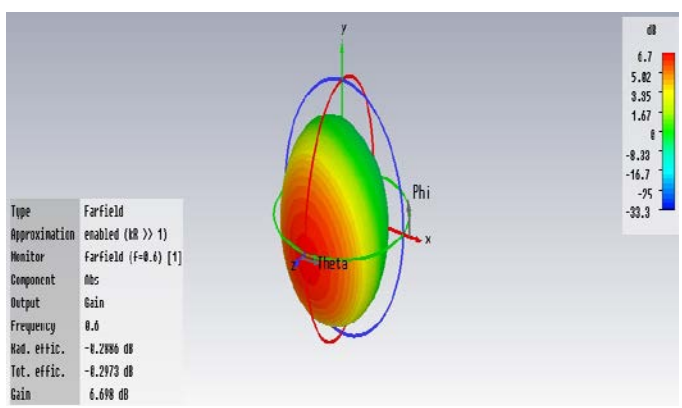

Figure24. Gain plot of Case 2 (b) d = t upper patch rotated 50^0 of proposed model using polymide as substrate

Case 3: d = t / 2 (only patches are separated by distance)

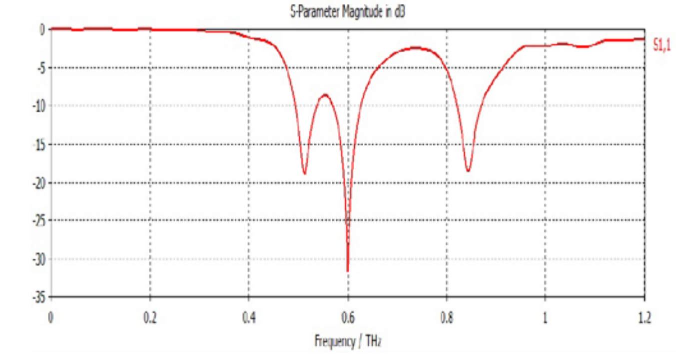

Figure25. Return loss plot of Case 3 d = t/2 of proposed model using Polymide as substrate

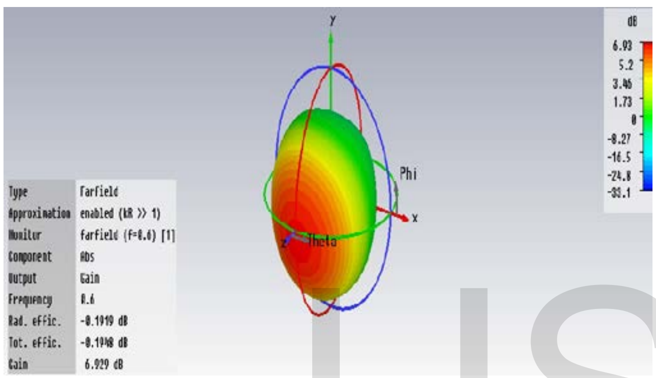

Figure26. Return loss plot of Case 3 d = t/2 of proposed model using polymide as substrate

Case 3 (a) : d= t / 2 upper patch rotation 25^0

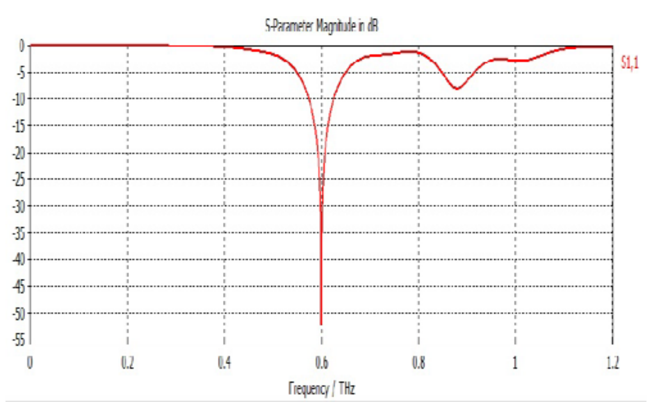

Figure27. Return loss plot of Case 3 (a) d = t / 2 of proposed model using Polymide as substrate

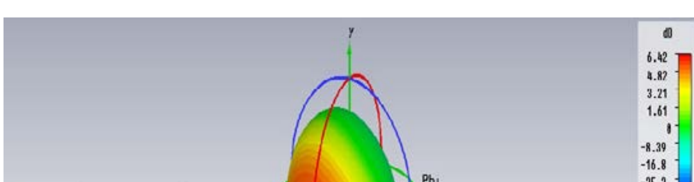

Figure28. Gain plot of Case 3 (a) d = t / 2 upper patch rotated 25^0 of proposed model using polymide as substrate

Case 3 (b): d = t / 2 upper patch rotation 50^0

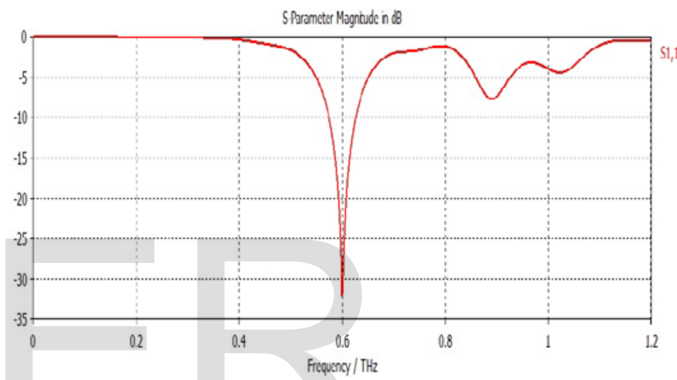

Figure29. Return loss plot of Case 3 (b) d = t/2 upper patch rotated 50^0 of proposed model using polymide as substrate

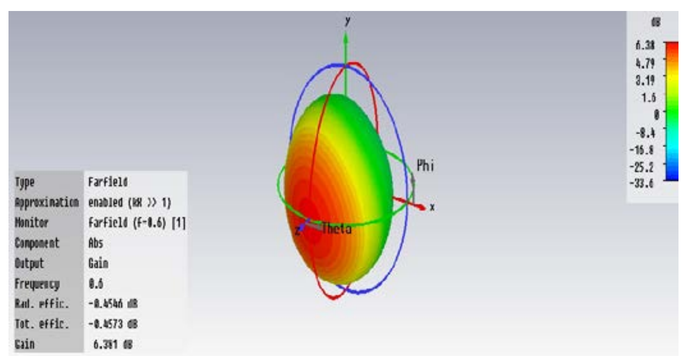

Figure30. Return loss plot of Case 3 (b) d = t/2 upper patch rotated 50^0 of proposed model using Polymide as substrate

The proposed model using arlon as substrate exhibits only one transmission valley with highest value of return loss of 29.06 dB for the case d=t without rotation of upper patch. Interestingly the bandwidth of 9.3 is observed which highly appreciable for the case d= t/2 when upper patch is rotated using arlon as the substrate material.This is due to the high loss tangent of Arlon, at terahertz frequencies the dielectric loss becomes quite high. It is observed that the model designed using Polymide as substrate is effective in enhancing the gain and bandwidth and realizing the dual and triple band resonance of 0.49 THz, 0.6 THz and 0.8 THz.

Table II. Comparison table of proposed model on two different substrates for proposed model

Condition	Geometric variation	Freq (THz)	S11 (dB)	Gain (dB)	B.W (%)
Arlon Single		0.6	-24.17	5.19	9.5
Arlon d = t	Without Rotation	0.6	-29.06	5.53	9.5
	25^0	0.6	-17.26	5.45	7.3
	50^0	0.6	-17.72	5.449	7.3
Arlon d = t/2	With out Rotation	0.6	-27.52	5.426	9.7
	25^0	0.6	-17.21	5.361	7.5
	50^0	0.6	-18.13	5.366	7.5
Polymide Single		0.49 0.6 0.8	-25.10 -36.39 -21.50	6.82	8.9
Polymide d = t	With Out Rotation	0.51 0.6 0.84	-14.68 -43.76 -23.86	7.04	10.1
	25^0	0.6	-28.13	6.561	8.7
	50^0	0.6	-26.97	6.698	8.9
Polymide d = t/2	With out Rotation	0.5 0.6 0.8	-18.95 -31.72 -18.58	6.929	9.7
	25^0	0.6	-34.19	6.424	9.1
	50^0	0.6	-31.96	6.381	8.5

The highest value of reflection -43.79 dB, gain of 7.04 dB and Bandwidth of 10.1 % occurs for condition stacked patch model d = t where as the gain is 6.871 dB and bandwidth is 11.5 % is observed for the case d = t /2 when upper patch is rotated 90 degrees. It is to be noted that the gain of 7.092 dB, return loss of -32.73 dB, and bandwidth of 10 % at 0.6 THz is obtained for the condition of d=t when upper patch is rotated 90 degrees which is also appreciable. Therefore such responses with good resonances open avenues for High frequency sensing and communication applications.

4. Conclusion

In this paper the conventional Microstrip patch antenna and stacked patch antenna is analyzed and simulated at Terahertz frequencies on substrates namely Arlon and Polymide. The mechanical distance of separation between patches along with the rotation of upper patch was varied to analyze this electromagnetic structure. These obtained electrical results after iterative simulations of the proposed model of antenna prove that the use of electromagnetic coupling enhances the value of reflection, gain and bandwidth when compared to those of a conventional patch antenna. The triple band resonance is obtained by carefully selecting the available substrate materials for the specified applications. At terahertz frequency the skin depth is also significant in determining the return loss, gain and bandwidth. The multiband multi frequency antennas and high gain antennas can be had by implementing the electromagnetic coupling technique. The proposed model has a wide scope in applications like high frequency radar sensing and wireless communications.

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