PARAMETRIC STUDY OF A NOVEL STACKED PATCH ANTENNA

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ABSTRACT

An inverted stacked microstrip patch antenna with single-fed at 1.30 GHz for GPS applications is designed at L band using electromagnetic simulator WIPL-D. The radiation patterns of microstrip antennas depend upon parameters like width, length, resonant frequency and dielectric constant. In view of this, by varying the height of the air gap, feed position and dielectric constant of the patch, corresponding radiation pattern, near field and return loss are observed.

KEYWORDS: *Stacked microstrip patch antenna, Return loss, Radiation pattern, WIPL-D*

I. INTRODUCTION

Microstrip antennas often called patch antennas [1-5] are widely used in the microwave frequency region [6-7]. The advantages of the microstrip antennas are small size, low profile, and lightweight, conformable to planar and non planar surfaces. It demands a very little volume of the structure when mounting. They are simple and cheap to manufacture using modern printed circuit technology. There are many configurations that can be used to feed microstrip antennas. The four most popular are microstrip line, coaxial probe, aperture coupling and proximity coupling [8].

A wide range of substrate materials is available, clad with copper, aluminum or gold. Low cladding thickness simplify fabrication of the antenna to required tolerances, whereas thicker clads ease soldering [9]. For high power applications of microstrip antennas, a thick cladding is desirable. The large range of substrates are available, viz., PTFE, Polystyrene, Polyphenylene, Ceramic, etc., permits considerable flexibility in the choice of a substrate for particular applications [10].

In this paper, an inverted stacked microstrip patch antenna is designed with microstrip line feed using WIPL-D at frequency 1.30 GHz for GPS applications.GPS is global positioning system based on satellite technology [11-19]. In microstrip line type of feed technique, a conducting strip is connected directly to the edge of the microstrip patch. The conducting strip is smaller in width as compared to 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. Hence this is an easy feeding scheme, as it provides ease of fabrication and simplicity in modeling. In order to simplify analysis and performance prediction, the patch is generally square, rectangular, circular, triangular, and elliptical or some other common shape. The effect of various parameters such as relative permittivity (ε_r), the distance of feed position from center, and height of the air gap (h) on the performance of the antenna has been studied.

II. STACKED MICROSTRIP PATCH ANTENNAS

Coupled patch antennas can be made of two or multiple patches. The case of two stacked coupled patches can be viewed as a single wideband microstrip patch antenna that can be used alone or in an array [20-22]. Its gain will be slightly larger than that of a single-layered patch, due to its increased height above the ground plane, and controlled by its value in wavelength; that is, the larger the height of the stacked configuration, the larger its gain. This is the secondary benefit from the stacked structure, in addition to its broadband impedance bandwidth. The case of multiple coupled patch antennas can increase significantly both the input impedance bandwidth and the gain.

The coupled patch antennas have fundamentally two different configurations, the planar structures and stacked configurations. Both these configurations were investigated concurrently. In the planar configuration the coupling is from the edges of the adjacent patches. Since the geometry represents two coupled resonators, the coupling coefficient is the most important parameter for broad banding of the input impedance [23-24]. However, the coupling in this case is normally weak and below the coupling level necessary for optimum broad banding. Thus the degree of bandwidth broadening is limited to around 10 percent, unless multiple planar patches are used. Nevertheless, this type of impedance bandwidth increase becomes attractive in the design of planar arrays, like microstrip Yagi arrays, where the planar structure makes this type of impedance broadening very natural. In other cases this configuration becomes appealing only if there is a limitation on the antenna height and adequate planar surface is available for the coupled patches.

The stacked coupled patch structures have been favored in most applications because of the ease with which the coupling coefficient can be controlled by adjusting their separation height. Their other parameters such as the size of the patches and substrate parameters can also be modified independently to facilitate the designs [25-26]. Consequently, much research has been done on these antennas, and impedance bandwidths of 10–30 percent for (voltage standing wave ratio) VSWR < 2 have been achieved. From broadband network theory, if the coupling between the two patches is too strong, i.e., above the required critical coupling, there are two resonance frequencies that increasingly separate by increasing the coupling coefficient. Since in stack patches their spacing controls the coupling, the antenna becomes dual band when patches are too close to each other. As the spacing is increased, the coupling reduces and the two resonances merge at the critical coupling to provide a broadband antenna. Further increase of the spacing reduces the bandwidth gradually.

III. ANTENNA DESIGN

The basic design considerations for a rectangular patch were considered for the design. The length L of the patch is usually $0.3333\lambda o < L < 0.5\lambda_o$, where λ_o is the free-space wavelength. The patch is selected to be very thin such that $t << \lambda_o$ (where t is the patch thickness). The height h of the dielectric substrate is usually $0.003\lambda o \leq h \leq 0.05\ \lambda_o$. The dielectric constant of the substrate (ε_r) is typically in the range $2.2 \leq \varepsilon_r \leq 12$. Formulas used for the patch design is given below [27-32].

$$\text{Patch width} = w = \frac{c}{2f\sqrt{\frac{(\epsilon_r+1}{2}}} \quad (1)$$

$$\text{Patch length} = L = L_{eff} - 2dL \quad (2)$$

$$\text{Where} \quad L_{eff} = \frac{C}{2f\sqrt{\varepsilon_{reff}}} \quad (3)$$

$$dL = 0.412h\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{W}{h}+0.8)} \quad (4)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}(1+12\frac{h}{W})^{-\frac{1}{2}} \quad (5)$$

$$\text{Ground length, } L_g = 6h + L \quad (6)$$

$$\text{Ground Width, } W_g = 6h + W \quad (7)$$

The proposed antenna structure is shown in Fig 1. The top patch (length *p2*) is printed on substrate with thickness *t2* and dielectric constant ε_{r2}, and the bottom patch (length *p1*) printed on substrate with thickness *t1* and dielectric constant ε_{r1}, while a air gap with thickness *h* separate the two layers of substrates, *L* is length of the ground plane. Polyflon–Norclad (ε_{r2} =2.55, tanδ=0.0011) with t2=1.5mm as superstrate [33]. FR4-epoxy (ε_{r1} =4.4, tanδ=0.02) with t1=1mm is used as substrate. In this paper, corner truncated approach is used with a pair of opposite corners (side length *q1*, *q2*). In stacked patch antenna, *h* is the other freedom parameter affecting return loss performance, which controls the coupling between patches [34-35].

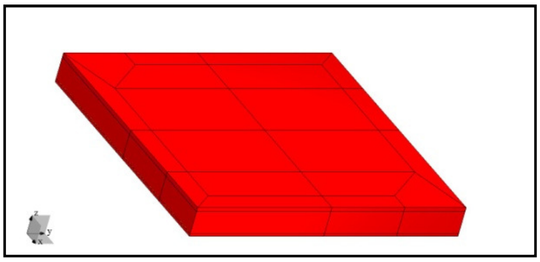


Fig 1: Geometry of the proposed stacked microstrip antenna

Fig 2: shows the cross sectional view of the microstrip patch antenna deigned in WIPL-D with line feeding and table 1: Shows the designed parameters of patch antenna using line feeding.

Table 1: Parameters of the patch antenna using line feeding (mm)

L	p1	p2	q1	q2	t1	t2	h
97.6	52.6	82.6	7.2	14.8	1	1.5	8

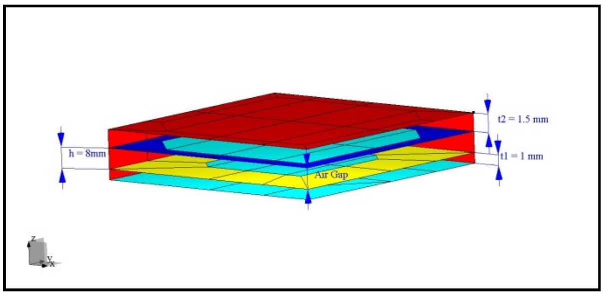
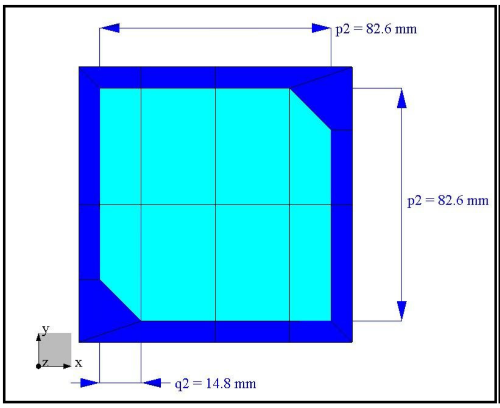


Fig 2: Cross sectional view of microstrip patch antenna

Figs 3 and 4 indicate the upper (parasitic) and lower (radiating) patches of proposed stacked patch antenna.



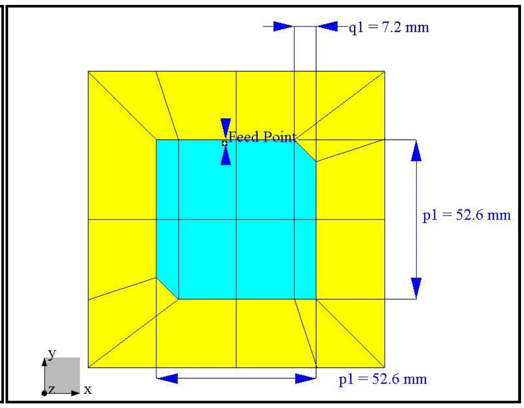


Fig 3: Parasitic patch

Fig 4: Radiating patch

Antenna consists of ground plane, square patch and dielectric parts. Cyan color indicates the metallic surfaces, Yellow, dark blue and Red indicate dielectric surfaces of first and second layers respectively [36].

IV. MODELING AND SIMULATION

The software used to model and simulate the microstrip patch antenna is WIPL-D. It is a 3D frequency domain EM solver based on method of moments [37-38]. It enables to model the structures of arbitrary shape using wires and plates as basic building blocks. The basic steps when using the 3D EM solver are defining the problem, editing and checking the input data, saving the project and running the analysis, listing and plotting the computed results [39-40].

V. RESULTS

Fig. 5 represents the overlaid Return Loss at different dielectric constants, maximum Return Loss observed at ε_{r2}=2.55 Fig. 6 shows the overlaid Return Loss at corresponding heights, maximum Return Loss observed at h=8mm. Fig. 7 shows the overlaid Return Loss of corresponding feed positions, maximum Return Loss observed at feed=(-4,25). Figs. 8-10 represent the overlaid Radiation pattern at phi=180^0 at different dielectric constants, heights and feed positions respectively. Fig. 11 shows the Radiation pattern in 3D at optimum feed = (-4, 25), h=8mm, ε_{r2}=2.55. Tables 2-4 represent the Return Loss observed at different values of $\varepsilon_{r2,}$ feed position and height respectively.

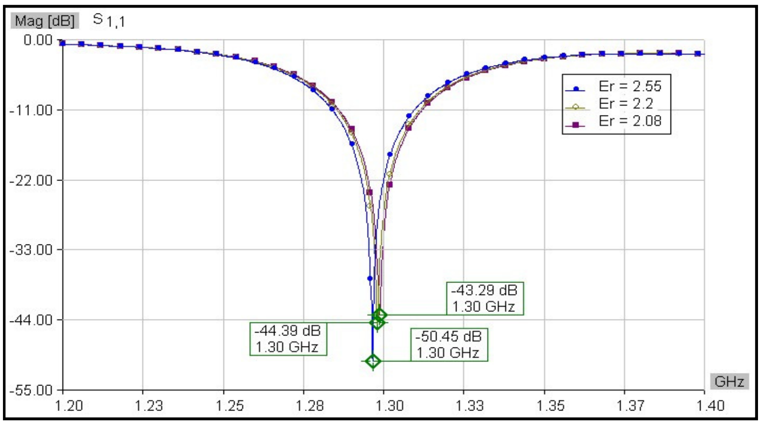


Fig 5: Return Loss at ε_{r2} = 2.55, 2.2, 2.08

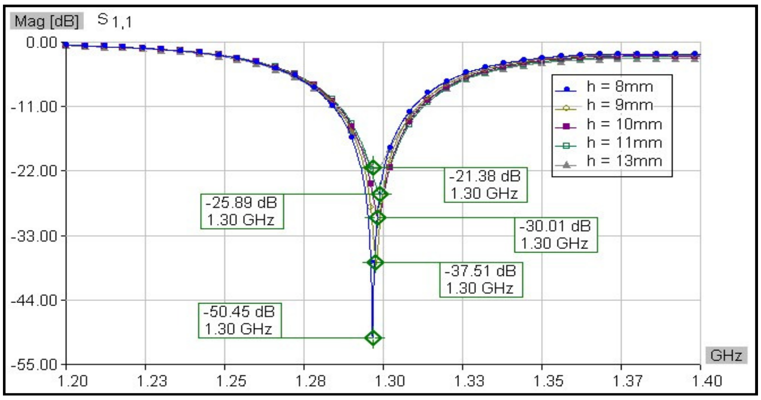


Fig 6: Return Loss at h=8mm, 9mm, 10mm, 11mm, 13mm.

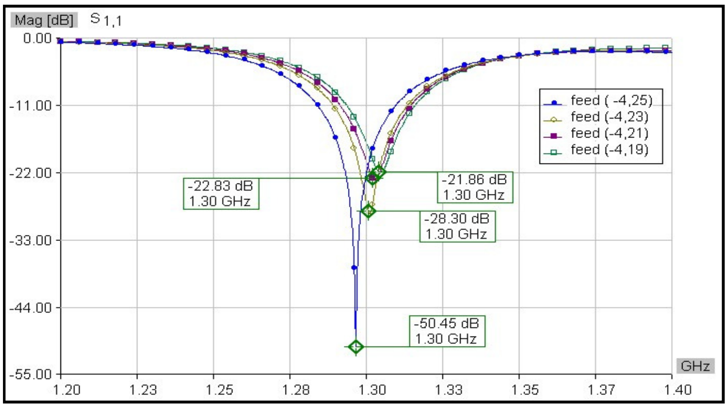


Fig 7: Return Loss at feed position = (-4, 25), (-4,23), (-4,21), (-4,19)

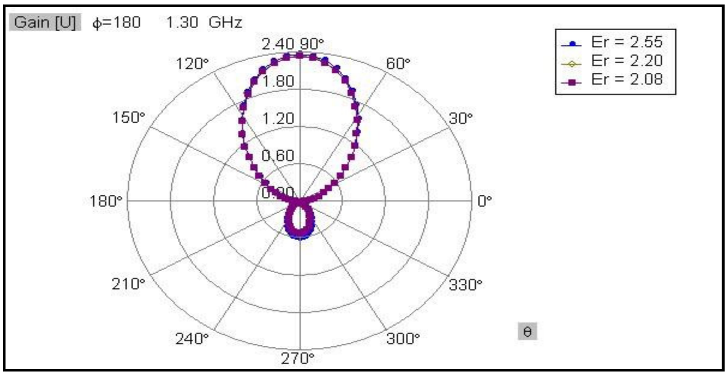


Fig 8: Radiation pattern at ε_{r2} = 2.55, 2.2, 2.08

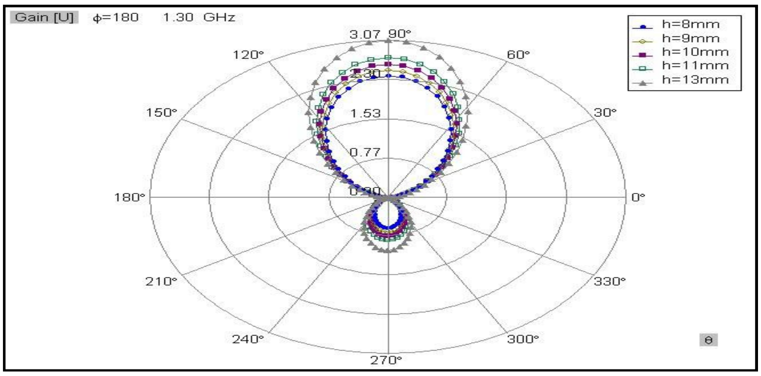


Fig 9: Radiation pattern, at h=8mm, 9mm, 10mm, 11mm, 13mm

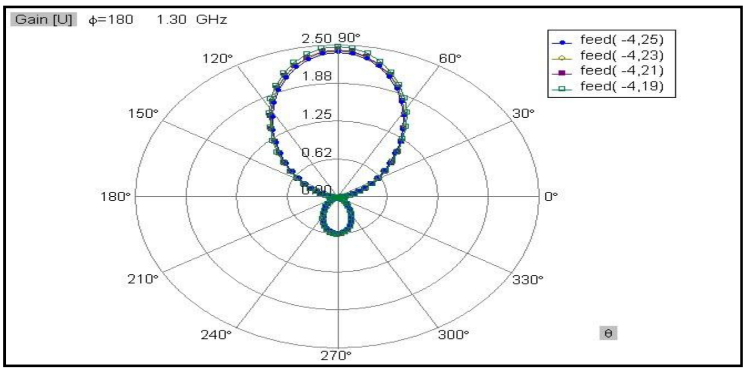


Fig 10: Radiation pattern, at feed position = (-4, 25), (-4, 23), (-4, 21), (-4, 19)

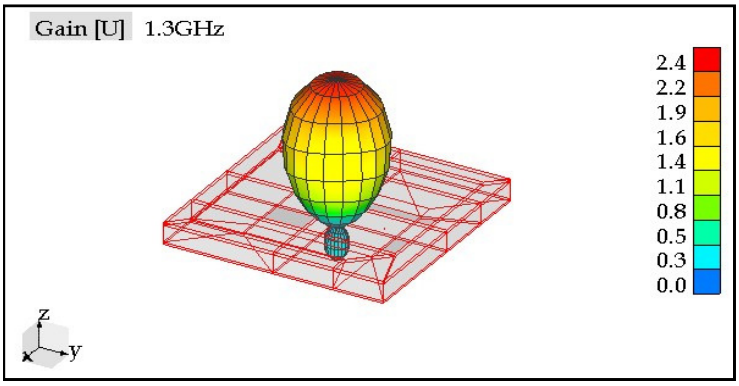


Fig 11: Radiation pattern observed in 3D at feed = (-4, 25), h=8mm, ε_{r2}=2.55

Table: 2 Return Loss at different values of ε_{r2}
ε_{r1}=4.4, h=8mm, feed position (-4, 25)

ε_{r2}	Return Loss (dB)	Frequency (GHz)
11.9	-19.07	1.30
4.882	-32.38	1.30
9.5	-21.48	1.30
2.08	-43.29	1.30
2.2	-44.39	1.30
2.55	**-50.45**	**1.30**
6	-27.53	1.30
10.8	-19.99	1.30

Table: 3 Return Loss observed at different values of feed position
At ε_{r1}=4.4, ε_{r2}=2.55, h=8

Feed position	Return Loss in dB	Frequency (GHz)
-4,19	-21.82	1.30
-4,21	-22.83	1.30
-4,23	-28.30	1.30
-4,25	**-50.45**	**1.30**

Table: 4 Return Loss observed at different values of height
At ε_{r1}=4.4, ε_{r2}=2.55, feed position (-4, 25)

Height (mm)	S11(RL) in dB	Frequency (GHz)
7	-33.26	1.30
8	**-50.45**	**1.30**
9	-37.51	1.30
10	-30.03	1.30
11	-25.88	1.30
12	-24.01	1.30
13	-21.38	1.30
14	-19.37	1.30

VI. CONCLUSION

An inverted patch antenna is designed with double layers of truncated square patches using line feeding to operate at L-band for GPS applications using WIPL-D. By varying the feed position, dielectric constant and height of the air gap (h) corresponding radiation pattern and return loss are observed. The optimum feed position, dielectric constant and height of the air gap (h) are found to be

(-4, 25), ε_{r2} = 2.55 and h = 8mm respectively. The return loss of -50.45 dB is observed at designed frequency 1.30GHz.

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