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Performance Analysis between Single and Dual Substrate Patches for Wireless Communication and Applications

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Abstract: This paper presents software based analysis on single and dual substrate patch antenna. Using defected ground structure as basic technique, antenna is build up using fractal shape mounted with PI shape on its center. FR4 with relative permittivity of 4.3 is the first and basic substrate in single substrate patch. Air with relative permittivity of 1.00 is used as second substrate in dual patched antenna using stack configuration. In stacked configuration additional shortening pin technique is implemented between patches to enhance gain and directivity. Both in single and stacked feed patches antenna, good return loss, and gain and directivity results are achieved with multi band response. The proposed antennas' can be used for GSM, GPRS and other communication systems.

Keywords: Miniaturization, Gain, Return Loss, Radiating Patch.

1. INTRODUCTION

With the rapid advancement of technology now a days, patch antennas' have been placed with an important importance through their economic structure as compared to traditional antennas. Multiple band antennas' have got researchers and companies attraction as a major interest as patch abilities to resonate at different frequencies at one time has made it more suitable for communication systems.

This paper presents an analysis of Pi shaped fractal patch antenna with single and dual substrate structure. The pi shaped antenna was miniaturized up to quite satisfactory level as compared to other techniques such as synthetic magnetic conductor in which resonant frequencies resulted with lowered gain or split ring resonator as miniaturization was only up to 10%. .With Koch fractal shape gain weakens after few repetitions (Costa, *et al.,* 2009) (Ermutlu, 2005) (Dong, *et al.,* 2012) With high and Reactive impedance surfaces, (HIS) and (RIS) and meta materials the miniaturization of patches are achieved up to good stage but with the adverse effect of cost and complexity level in manufacturing process (Cohen, 1997). (Hu, *et al.,* 2006). In effort of reducing patch structures in (Li, *et al.,* 2010), wherever arrays of SRRs encumbered upon ground levels, (creating complementary SRRs or CSRRs). Nearly 35% of size reduction is accomplished.

In this paper, an inserted ground and slotted scorching patch of paired and lone substrate practice is cast to reach two principal intentions, size drop multiple response. Size compression is accomplished mainly by introducing ground irregularities plus patch cutting. The geometry of slots is optimized order to introduce features at lower frequencies. As basic base substrate of FR4 it has characteristics' of low aquatic preoccupation, enhance bandwidth, healthier efficiency, exceedingly directive and is easily availability.

This paper is organized as this. Section-1 introduction, after that mathematical and building structure of Patch Section. Section 3 and 4 deals with single and double patch patches and in last section conclusion is covered. (Lai, *et al.,* 2004)

2. ANTENNA DESIGN

While designing an antenna length, width and other terminologies are required to be proved accurately stage by stage. The basic patch antenna with coaxial cable is as follows.

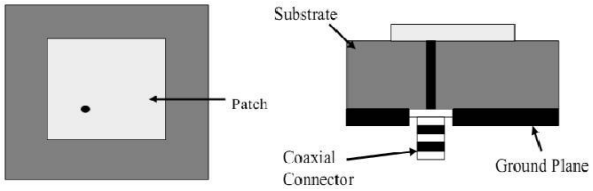

Fig. 1. Overall View of Patch Antenna

Substrate selection is quite concern and difficult task as in antenna manufacturing it covers cost and other structural parameters. For proposed antenna FR4 (Lossy) is chosen because of its good weather and moisture withstanding capabilities. Furthermore its cost effectiveness allows it to be more economical and suitable for our design.

The feeding method is chosen to be contacting method as it is easy to fabricate and also coaxial cable satisfies and fits upon Maxwell's equation very well.
Now after substrate selection next steps includes the derivation of physical dimensions i-e length and width of patch antenna.

2.1. Width of the Patch

Width of the patch derived through formula as follow:

The width of an antenna can be calculated by using equation (1).

$$W = \frac{c}{2 f_0 \sqrt{\frac{(\varepsilon r+1)}{2}}} \quad (1)$$

Where c is the rapidity of light at free space.$f_0$is the resonant rate and **εr**is the relative substrate permittivity.

2.2 Length of the Patch

The length of the patch is calculated using equation (2).

$$L = L(eff) - 2\Delta L \quad (2)$$

$$\text{Where } L(eff) = \frac{c}{2 f_0 \sqrt{\varepsilon_{(reff)}}} \quad (3)$$

$$\text{And} \varepsilon_{(reff)} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{4}\left(1 + \frac{12h}{W}\right)^{-1/2} \quad (4)$$

4.4 GHz antenna is calculated with coaxial serving method after derivation of physical dimensions. Regarding patch and ground structural dimensions with all slots information is covered in **(Table 1).**

Table 1. Simulation Results of Miniaturized Antenna

Parameters	Values in MM
Patch Length, PL	16.89
Patch Width, PW	22.36
Ground Length, GL	29.89
Ground Width, GW	33.51
Slot Length, SL	5.10
Slot Width, SW	2.30
Pi Slot Length, PPL	4.10
Pi Slot Width, PPW	1.10
Height of Patch, HP	0.045
Height of Ground, HG	0.8
Height of Substrate, HS	2.05
Horizontal U and L Slot Length, HUL&HLL	8.05
Horizontal U and L Slot Width, HUW &HLW	2.05
Vertical U and L Slot Length, VUL&VLL	8.05
Vertical U and L Slot Width, VUW &VLL	2.05

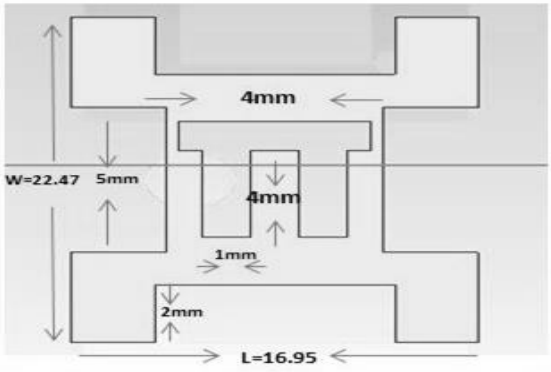

Fig. 2. Front View of Patch Antenna

Clearly from figure dimensions of patch can be seen. 5mm fractal patch length with 4mm slots of PI on patch reduces antenna size up to great extent.

2.3 Ground Plane.

Fig. 2(a) illustrates back assessment of patch showing ground plane. The Ground dimensions are 29mm length and 33mm width. On ground level U and L irregularities reduces antenna dimensions. The flat length of U-shape is 8.05mm and breadth is 2.05mm. The perpendicular extent of U-shape is 8.05mm and breadth is 2.05mm .same goes for L shape structure as goes for U.

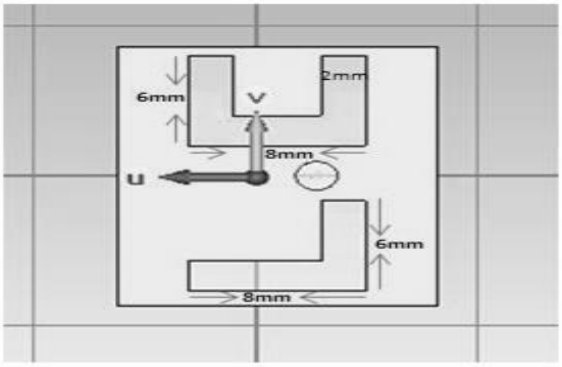

Fig. 2 (a): Slotted Ground Plane

From proposed design it is cleared that announcing openings escalates current scattering lane, accumulating electrical extent and causing in echoing frequencies flowing in downward course hence illuminating several band response at once.

2.4 RESULTS OF SINGLE PATCH

In this section, results are discussed along the performance of pi shaped patch antenna. First comes the return loss.

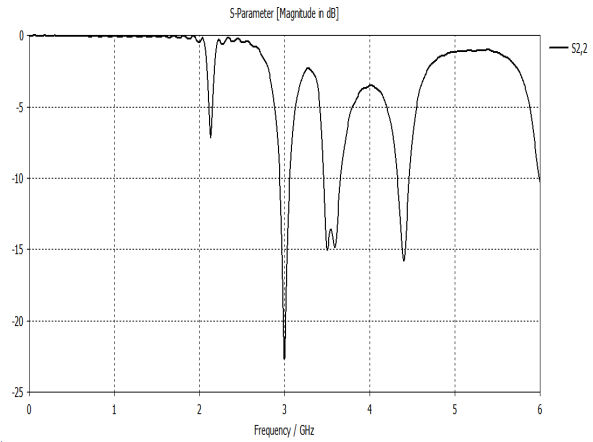

Fig. 2(b) Return loss plot of antenna

The antenna resonated at 3 different frequencies as -10db criteria. Return loss values are as follow in **(Table-2)** along with gain and directivity.

Table 2. Results of proposed antenna

Resonant Frequency	Return Loss	Gain	Directivity
3.00	-22.70dB	3.61dB	4.63dBi
3.59	-14.8dB	2.61dB	4.04dBi
4.40	-15.91dB	2.77dB	4.30dBi

The tri band patch showed following radiation patterns allowing multiple applications to be processed at one time.

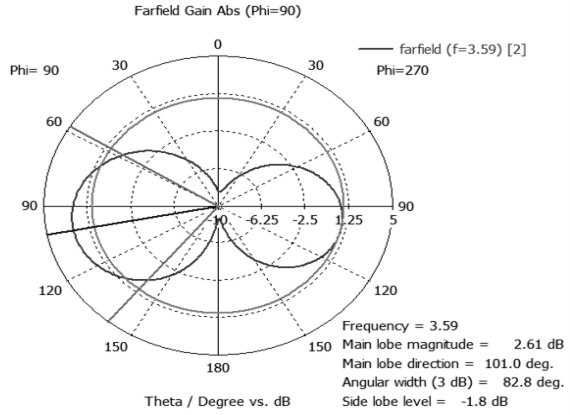

Fig 3:1D plot of gain at 3.59GHz Frequency

Clearly from figure we can see that main lobe direction or level is 101 deg while side lobe level is 82 degrees with angular width of -1.8dB.

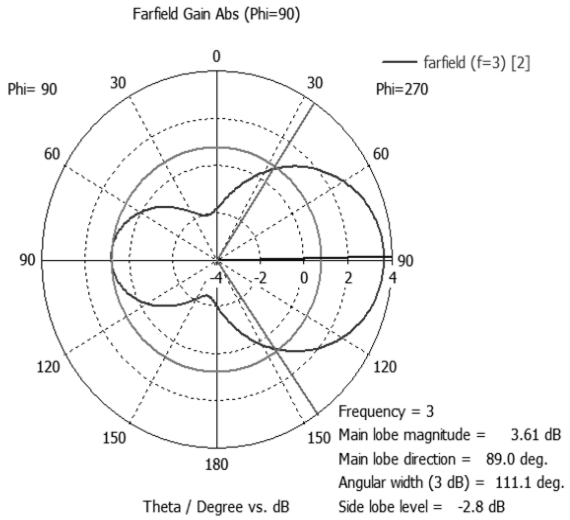

Fig 4:1D plot of gain at 3.00GHz frequency

Clearly from figure we can see that main lobe direction or level is 89 deg while side lobe level is 111.1 degrees with angular width of -2.8dB.

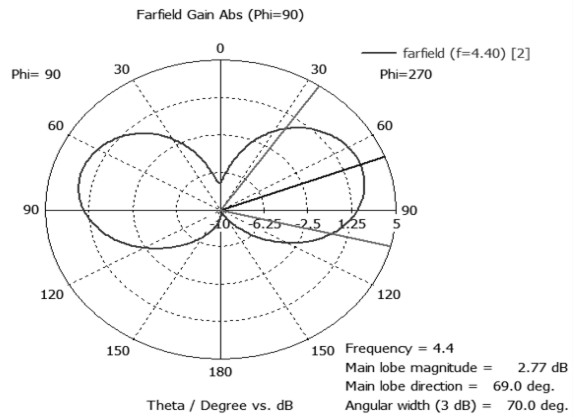

Fig 5: 1D plot of gain at 4.40GHz Frequency

Clearly from figure we can see that main lobe direction or level is 69deg while side lobe level is 70degrees with angular width of -3.1dB. With more good radiation patterns as (Luukkonen, 2008). (Wu, 2008), (Lee, 2007). antenna showed good response as side lobe levels were minimum making it capable of communication system applications.

3.1 Dual Patched Antenna Design

Now as compared to single feed patch antenna, stack configuration was used and second patch copy along with new substrate was mounted on top of it. The only difference was that this time the second substrate was let to be Air instead of FR4 (lossy).
The bottom view of antenna is as following.

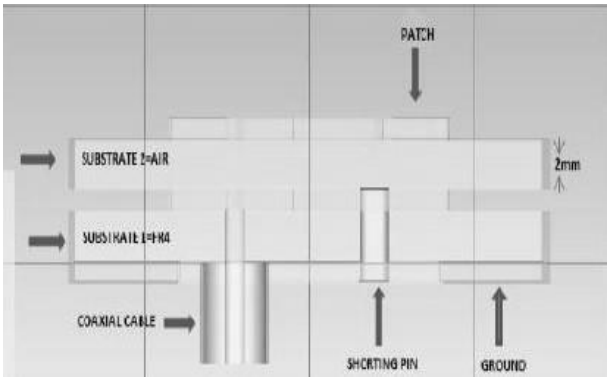

Fig 6: Bottom view of proposed stacked Patch Antenna

In stacked patch configuration one thing that was included additionally was shortening pin technique. The purpose of this technique was to enhance current distribution path alongside patch between ground and patches.

Same dimensions were used as previous one. The results obtained are as follow.

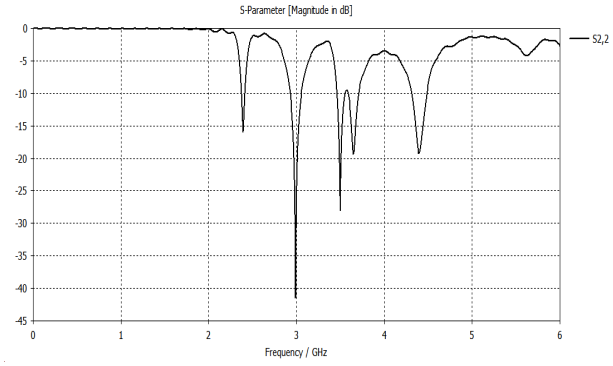

Fig 7: Return loss plot

As from return loss plot shown in fig 7, following results were obtained mentioned in table 3.

Table 3: Results of dual patched proposed antenna

Resonant Frequency	Return Loss	Gain	Directivity
2.38	-13.40dB	1.33dB	2.96dBi
2.988	-41.50dB	3.78dB	4.76dBi
3.49	-27.79dB	1.57dB	4.30dBi
3.64	-19.30dB	2.83dB	3.44dBi
4.40	-18.90dB	3.77dB	5.06dBi

As obtained results from table 2 following are the radiation patterns. The patterns are better than single structured patch antenna.

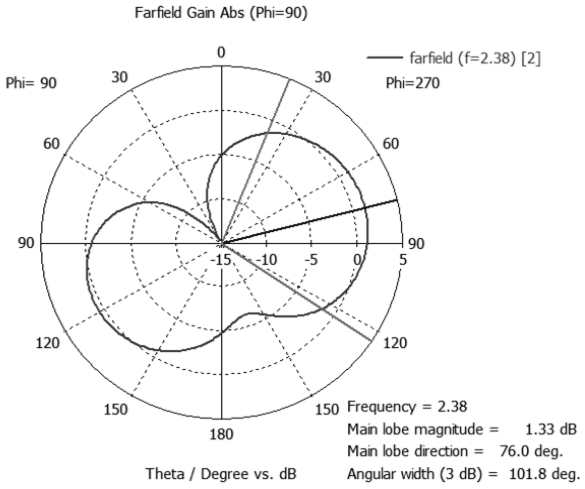

Fig 8: 1D plot gain at 2.38GHz frequency

Clearly from figure we can see that main lobe direction or level is 76deg while side lobe level is 101degrees with angular width of -2.8dB.

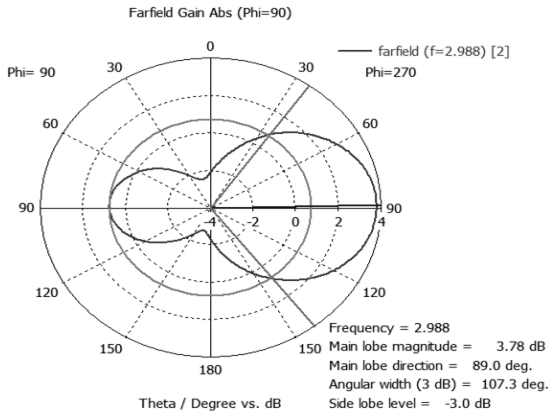

Fig 9:1D plot of gain at 2.988GHz Frequency

Clearly from figure we can see that main lobe direction or level is 89deg while side lobe level is 107 degrees with angular width of -1dB.

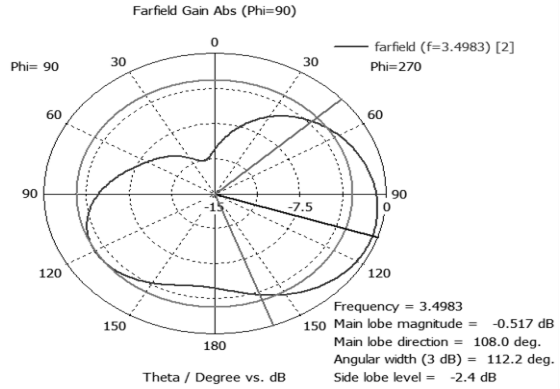

Fig 10: 1D plot of gain at 3.49GHz frequency

Clearly from figure we can see that main lobe direction or level is 108 deg while side lobe level is 112 degrees with angular width of -2.4dB.

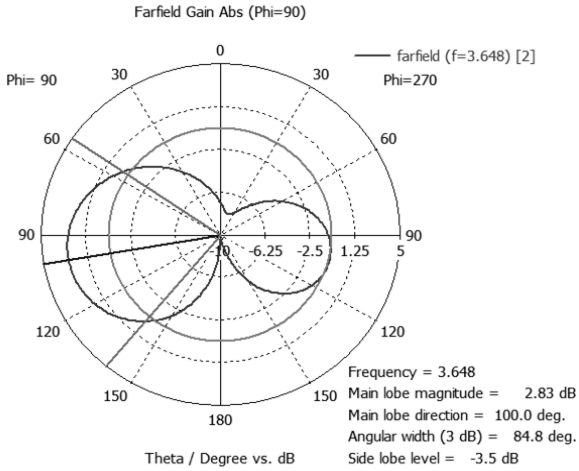

Fig 11:1D plot of gain at 3.64GHz frequency

Clearly from figure we can see that main lobe direction or level is 100 deg while side lobe level is 84 degrees with angular width of -3.5dB.

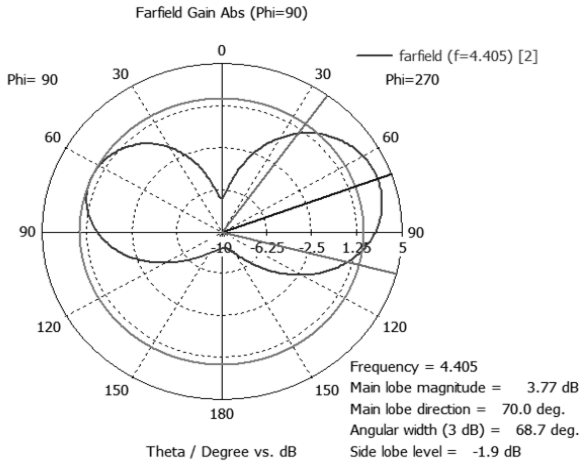

Fig 12:1D plot of gain at 4.40GHz of frequency

Clearly from figure we can see that main lobe direction or level is 70deg while side lobe level is 68 degrees with angular width of -1.9dB.

3. CONCLUSION

In case of single patched antenna the fundamental frequency was moved downward to 3GHz**.** Now for 3GHz antenna, the area required for patch is 23.44×30.28=690.80 mm² as in this case its only 381mm² resulting in condensing size up to nearly 60%.So it means that our proposed proposal has condensed size up to 60.60%. Clear from radiation patterns stacked patch antenna performance outclass single patched antenna. Even at the miniaturization level the fundamental frequency was shifted further downward to 2.8GHz.Thus reducing antenna size further 12%.

The propose antenna can be used for GSM, GPRS, Fixed satellite services and other S-band and C-band communication applications systems.

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