# A Novel Design of Miniaturaized Patch Antenna Using Different Substrates for S-Band and C-Band Applications

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***Abstract*—In advance communication technology, patch antennas are widely exploit due to their inexpensive and light weighted structure. This paper presents a novel design of miniaturized multiband patch antenna using different substrates frequently used in patch antennas. Various substrates such as Teflon, Roger 5880, Bakelite and Air are in use to achieve better gain and directivity. The proposed miniaturized multiband patch antenna contains 2 substrates where one substrate is FR4 (fixed and lossy) and the other substrates are changed to observe gain, directivity and return loss. Coaxial probe serving mode is presented in this paper. This serving mode is a contacting arrangement for patch, in which the outer conductor is linked to ground plane and the inner conductor of the coaxial connector spreads through dielectric and is bonded to the radiating patch. The proposed antenna can be used for various S-band and C-band applications.**

***Keywords—substrates; microstrip; return loss; directivity; miniaturized; Impdence bandwidth***

## I. Introduction

Micro strip antennas are widely used in communication devices for various applications such as radars, satellites and mobile phones etc. They are low cost, small structured and easily fabricated. Considerable amount of approaches have been develop for reducing the size of antenna but the central concern with the reduced area of an antenna is its minor gain. Some methods here are discussed below.

With the use of synthetic magnetic conductor area of antenna was reduced but with the result of lowered gain [1]. As gain was significantly improved as compared to magnetic conductor using split ring resonators but the reverse outcome was that reduce size was approximately equal to 10% [2]. The size reduction was achieved above 20% by way of Koch Fractal shape but with few repetitions gain starts diminishing [3].

In this paper we have analyzed a fractal pi shaped dual substrate patch antenna where one substrate is FR4 (fixed and lossy) and second is a variable one as a double substrate antenna shows good return loss [4]. Stage of substrate material is an considerable job in designing a patch antenna, as the restrictions regarding micro strip antenna such as negligible gain, poor efficiency and directivity can be mitigated by deciding on proper substrate materials, because performance factors of patch antenna like bandwidth, gain ,radiation pattern are linked up to permittivity of substrate material .[5][6].

To the best of our knowledge, no literature review on miniaturized double substrate selection is available so we are proposing a novel design of miniaturized patch antenna substrate selection for S-Band and C-Band applications.

This paper is organized as follows:

Section I deals with introductions, section II deals with antenna design and methodology whereas section III deals with results and discussion. Concluding remarks are given in section IV.

## II. Antenna Design

The designing of antenna is done stage by stage in a convenient way. The basic shape is shown in figure 1(a and b) [5-6].

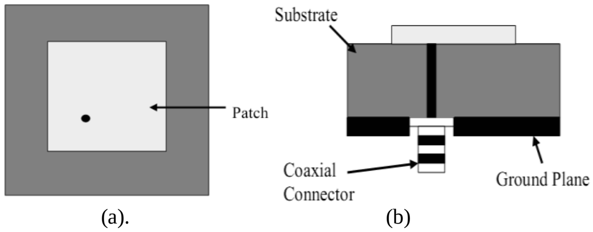


Fig. 1. (a) Top view of Micro strip patch antenna (b) Side view of patch antenna (Coaxial Cable Feed)

### A. Substrate Selectivity

Parameters of patch antenna like bandwidth, radiation efficiency are linked up with substrate material used for patch so setting up substrate material is prime assignment in designing patch. Thickness of substrate significantly impacts upon parameters.

According to Coulomb's la w:

$$E = \frac{q1\, q2}{4\Pi\, \varepsilon r\, r^2} \tag{1}$$

Where q1 and q2 are the charge bodies and **εr** is the permittivity of free space and r is the distance.

Electric field (E) is inversely proportional to the relative permittivity $\varepsilon r$ by increasing or decreasing relative permittivity of the various substrates change in electric field can be observed [4].The substrates used in this paper have the following dielectric constants.

TABLE I. DIFFERENT TYPES OF SUBSTRATES

| Substrate | Dielectric Constant |
|---|---|
| RO5880 | 2.2 |
| Air | 1.00 |
| Bakelite | 4.78 |
| Teflon | 2.1 |

### B. Width of the Patch

With the help of following equation, width of the patch is calculated. [4].

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

Where c = $3\text{x}10^8$ m/s.

$f_0$ =Resonant Frequency

$\varepsilon r$ is the permittivity of a substrate.

### C. Length of the Patch

With the help of following equation, length of the patch is calculated [4].

$$L = L(eff) - 2\Delta L \tag{3}$$

Where

$$L(eff) = \frac{c}{2 f_0 \sqrt{E(reff)}} \tag{4}$$

And

$$\varepsilon_{(reff)} = \frac{\varepsilon r + 1}{2} + \frac{\varepsilon r - 1}{4}\left(1 + \frac{12h}{W}\right)^{-1/2} \tag{5}$$

By calculating the length and width of the patch and ground, in this paper a 4 GHz antenna is designed with coaxial feeding technique. After miniaturizing and reducing its size up to 79.12%.This was achieved by using combination of U-shaped and L-shaped slots on the ground plane and pi-shaped slot on the double fractal patch of antenna with shorting pin between patch and ground [7] As a result antenna produced multiband response with a high gain and sufficient impedance bandwidth for each band [9]. We have considered thickness of the first and second substrate constant (2mm) but we have changed permittivity of second substrate one by one by changing various material like, RogerRT5880, Bakelite, and Teflon and Air.

For these substrates relative permittivity is **εr** < 5.

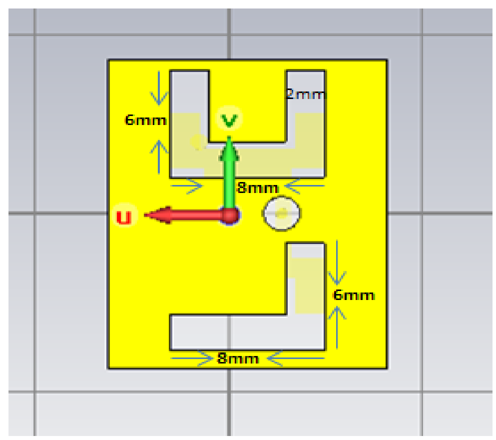


Fig. 2. Back view of Dual Fractal Patched Pi Antenna

TABLE II. DIMENSIONS OF PI SHAPED ANTENNA

| Parameters | Values in MM |
|---|---|
| Length of Patch, LP | 16.95 |
| Width of Patch, WG | 22.47 |
| Length of Ground, LP | 28.95 |
| Width of Ground, WP | 34.47 |
| Slot Length, SL | 5.00 |
| Slot Width, SW | 2.00 |
| Pi Slot Length, PL | 4.00 |
| Pi Slot Width, PW | 1.00 |
| Height of Patch | 0.035 |
| Height of Ground, HG | 0.8 |
| Height of Substrate, HS | 2.00 |
| Horizontal U and L Slot Length, HUL&HLL | 8.00 |
| Horizontal U and L Slot Width, HUW &HLW | 2.00 |
| Vertical U and L Slot Length, VUL&VLL | 8.00 |
| Vertical U and L Slot Width, VUW &VLL | 2.00 |

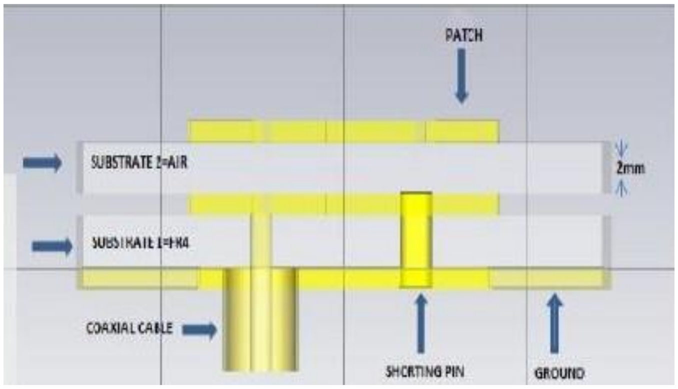


Fig. 3. Front View of Dual Fractal Patched Pi Antenna

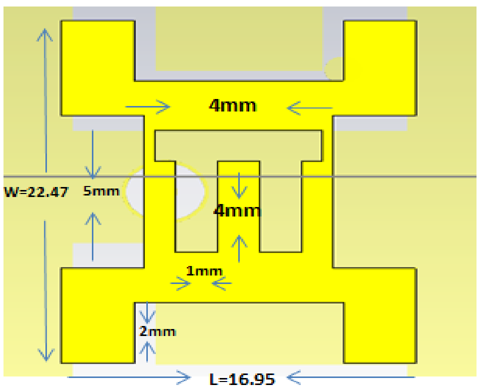


Fig. 4. Bottom View of Dual Fractal Patched Pi Antenna

The ground plane is shown in Fig II or in other terms back view of antenna. Approximately 35mm and 29mm are antenna width and length dimensions. 8mm U-shape and 2mm L-shape holes on ground plane reduced antenna size up to quite satisfactory level. In Fig III we clearly see the overall structure of proposed patch comprising of 2 substrates where lower substrate is FR4 and upper substrate is Air and feeding coaxial probe with shortening pin connecting 2 patches. AIR has a dielectric constant of 1.00 and its thickness is taken to be 2mm.

Current circulation on patch of antenna is shown on Fig IV. As marked from figure, it is clear that on ends of Pi-shape slot, current concentration is supplementary as compared to rest of the patch. Introducing slots increases current distribution path, increasing electrical length and resulting in resonating frequencies shifting downward direction hence revealing several band response. As compared to traditional antenna with familiarized resonance frequency, the overall surface of antenna is reduced to excessive level.

## D. Substrate Varying

In this section, we have used second substrate of fractal pi shape antenna and observed the gain and directivity. The First substrate to replace air is RO5880 having permittivity of 2.2.

After R05880 substrate was changed from R05880 to Bakelite having permittivity of 4.78.similarly Bakelite substrate was changed from Bakelite to Teflon having permittivity of 2.1. Various changes were seen in gain and directivity as well as return loss.

# III. RESULTS AND DISSCUSSIONS

Satisfactory results were achieved as individual factors like radiation pattern, gain, and return loss were examined for several regularities of interest. The obtained results achieved are discussed below.

## A. Air

With Air substrate, antenna showed very good results as shown in table III, by showing multi-level response at different resonant frequencies.

TABLE III. AIR SUBSTRATES RESULTS

| Resonant Frequency | Return Loss | Gain | Directivity |
|---|---|---|---|
| 2.603 | -31.74dB | 3.08dB | 4.32dBi |
| 3.119 | -26.84dB | 4.03dB | 5.25dBi |
| 3.5 | -15.91dB | 2.26 | 4.2dBi |
| 4.21 | -18.945dB | 5.47dB | 6.71dBi |
| 6.16 | -12.89dB | 0.145dB | 3.72dBi |

The minimum return loss occurred at resonant frequency of 3.00 GHz which was -31.74dB having gain of 3.08dB and directivity of 4.32dBi.

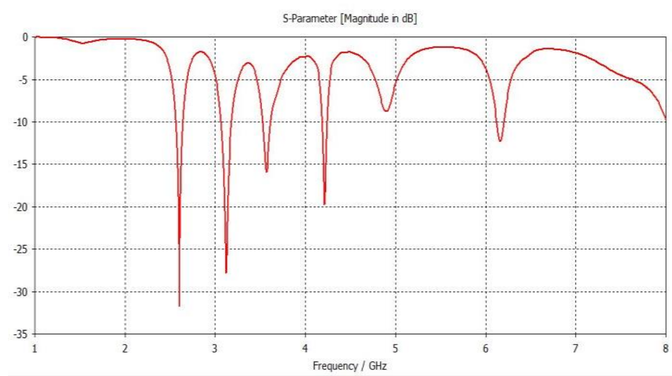


Fig. 5. Return Loss of Air

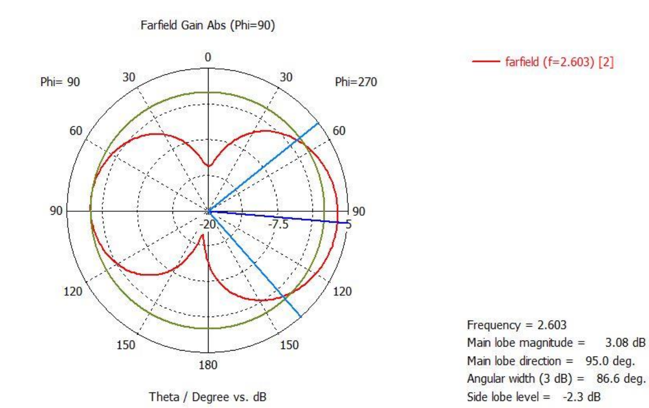


Fig. 6. 1D plot of Gain at Resonant Frequency 0f 2.603 GHz

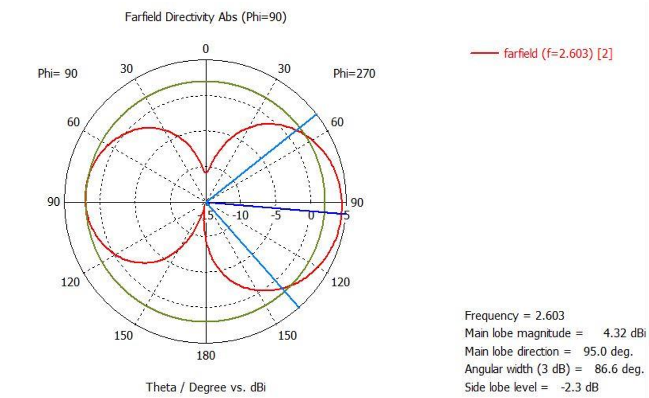


Fig. 7. 1D plot of Directivity at Resonant Frequency 0f 3.00 GHz

In 2.603GHz the level of main lobe is 3.08dB, direction is 95 degrees and angular width is 86.2 degrees with side lobe level of -2.3dB.

## *B. Teflon*

With Teflon antenna showed good and satisfactory results showing multi-level response at different resonant frequencies.

TABLE IV. TEFLON SUBSTRATE RESULTS

| Resonant Frequency | Return Loss | Gain | Directivity |
|---|---|---|---|
| 2.50 | -25.3dB | 2.97dB | 4.23dBi |
| 3.00 | -35.7dB | 4.11dB | 5.39dBi |
| 3.70 | -11.48dB | 4.49dB | 6.49dBi |
| 5.89 | -13.32dB | 0.0078dB | 3.26dBi |

The minimum return loss occurred at resonant frequency of 3.00 GHz which was -35.7dB having gain of 4.11dB and directivity of 5.39dBi.

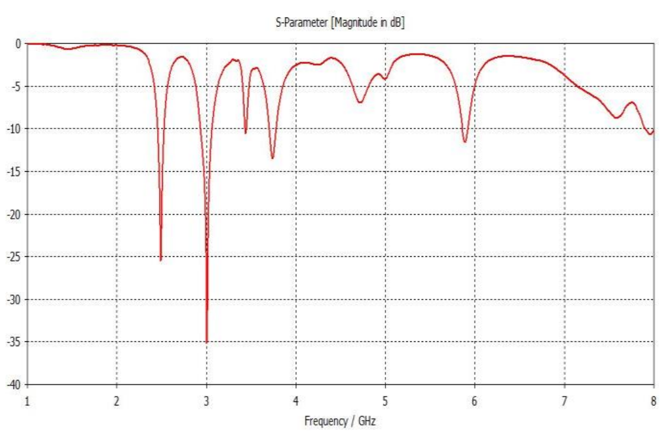


Fig. 8. Return Loss Plot of Teflon

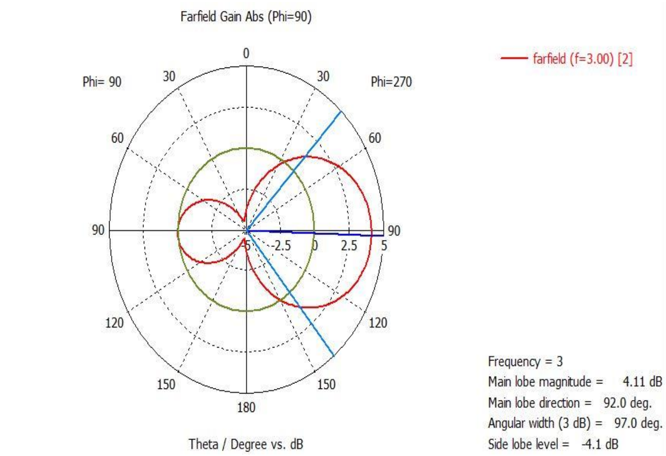


Fig. 9. 1D plot of Gain at Resonant Frequency 0f 3.00 GHz

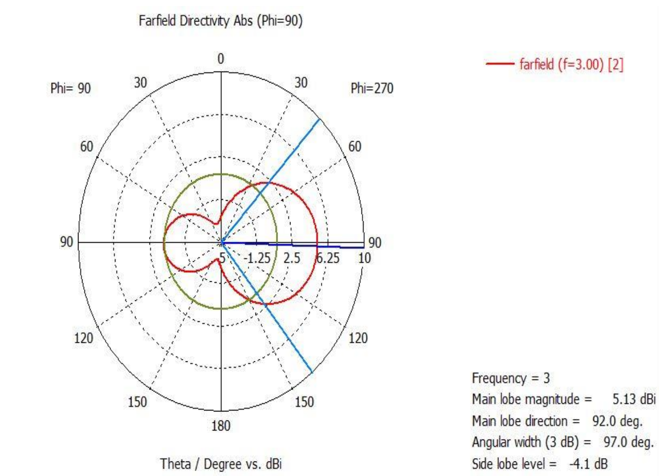


Fig. 10. 1D plot of Directivity at Resonant Frequency of 3.00 GHZ

In 3.00GHz the level of main lobe is 5.13dB, direction is 92 degrees and angular width is 97 degrees with side lobe level of -4.1dB.

## *C. Bakelite*

With Bakelite antenna showed quite good and satisfactory results by showing multi-level response at different resonant frequencies.

TABLE V. BAKELITE SUBSTRATE RESULTS

| Resonant Frequency | Return Loss | Gain | Directivity |
|---|---|---|---|
| 2.30 | -12dB | 2.45dB | 4.22dBi |
| 2.73 | -13dB | 3.16dB | 4.88dBi |
| 3.45 | -12.42dB | 4.09dB | 5.62dBi |
| 6.58 | -16dB | 0.736dBi | 3.81dBi |
| 7.74 | -15dB | 5.39dB | 6.44dBi |

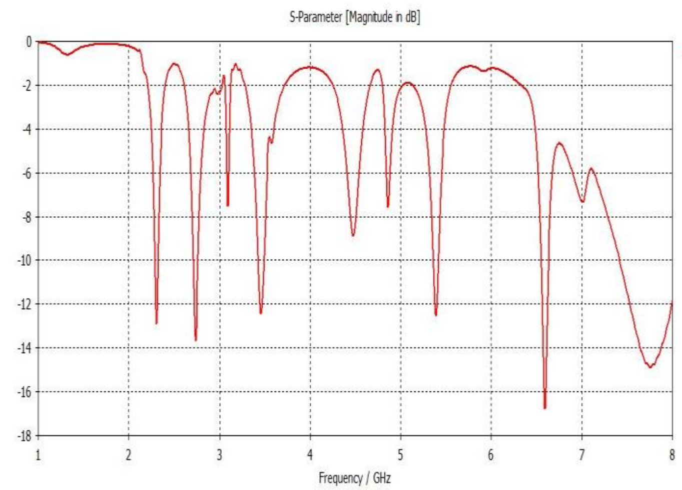


Fig. 11. Return loss of Bakelite

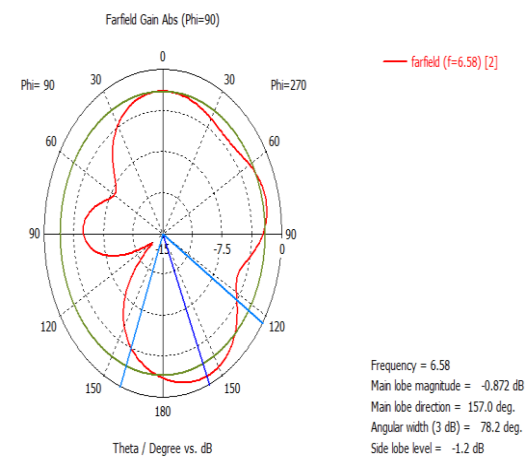


Fig. 12. 1D plot of Gain at Resonant Frequency of 6.58 GHZ

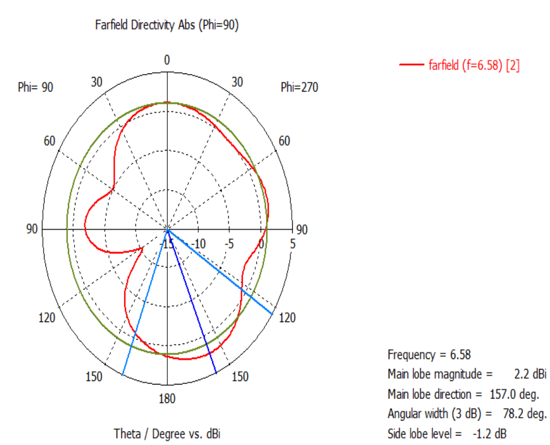


Fig. 13. 1D plot of Directivity at Resonant Frequency of 6.58 GHZ

In 6.58GHz the level of main lobe is 0.872dB, direction 157 deg, angular width is 78.2 deg with Side lobe level of -1.2dB.

## *D. Roggers5880*

With R05880 antenna showed quite good and satisfactory results by showing multi-level response at different resonant frequencies.

TABLE VI. RO5880 SUBSTRATE RESULTS

| **Resonant Frequency** | **Return Loss** | **Gain** | **Directivity** |
|---|---|---|---|
| 2.48 | -22.7dB | 2.95dB | 4.21dBi |
| 2.98 | -27.7dB | 4.05dB | 5.11dBi |

The minimum Return Loss occurred at resonant frequency of 2.98 GHz which was -27.7dB having gain of 2.95dB and directivity of 4.21dBi.

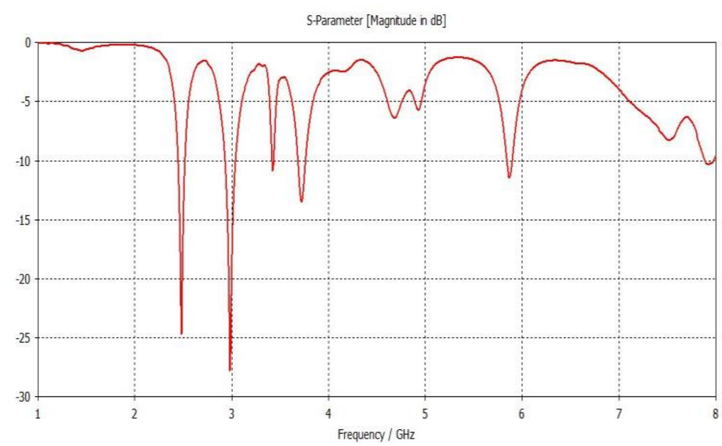


Fig. 14. Return loss of RO5880

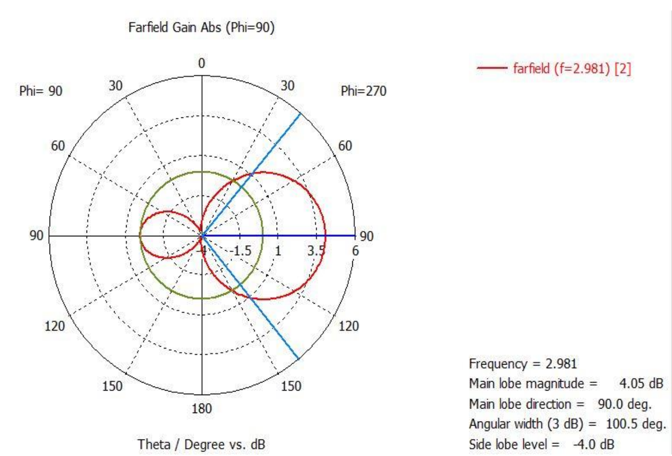


Fig. 15. 1D plot of Gain at Resonant Frequency of 2.98 GHZ

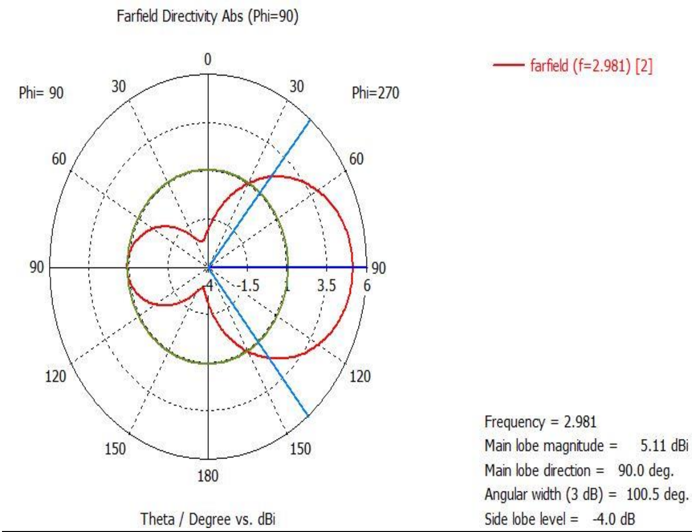


Fig. 16. 1D plot of Directivity at Resonant Frequency of 2.98GHz

In 2.981GHz the level of main lobe is 5.11dB, direction 90 deg with angular width of 100.5 deg and Side lobe level of -4.0dB.

## IV. Conclusion

This paper presents a novel design of miniaturized multiband patch antenna using different substrates frequently used in patch antennas. The proposed miniaturized multiband patch antenna contains 2 substrates where one substrate is FR4 (fixed and lossy) and the other substrates are changed to observe gain, directivity and return loss. In this paper coaxial probe feeding technique is also used. The proposed antenna can be used for various S-band and C-band applications such as mobile communication, WIMAX, WLAN and Vehicular communication etc.

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