Right Hand Circularly Polarized Microstrip Antenna with Two Resonance Elements at 1.5 GHz

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***Abstract*—This article presents a right hand circularly polarized (RHCP) microstrip antenna with two resonance elements at GPS frequency. The design process and measurement results are discussed. Measurement results provide frequency shift for both resonance elements in opposite direction, causing a dual band antenna. And, both simulation and measurement results cannot satisfy polarization requirements at any center frequency.**

***Keywords*—rhcp, microstrip antenna, trimmed patch**

I. INTRODUCTION

Microstrip patch antennas are very useful in various applications of wireless communication systems, as their parameters can be smoothly designed according to the choice of implementation. Their fabrication is greatly cost-effective and they can easily be implemented to a network after performing some basic operations on impedance matching. With these features, microstrip patch antennas have become widely popular, thus inspiring academies to reserve more place for the study of this field. Therefore, this project has shown up to be a powerful exercise on this mentioned area.

The selected antenna is specified as a right hand circularly polarized microstrip patch having an operating frequency of 1.5 GHz. As there are plenty of methods to obtain circular polarization, we tried to produce it with the cooperation of two different techniques: slotting and truncating. Having a sufficient -20 to -40 dB S11 bandwidth of 30-40 MHz around 1.5 GHz was important. Presenting the design topology and software simulation outcomes of the antenna are presented with required calculations and measurement results, this paper is divided into three sections after this brief introduction: the design, simulation and measurement results, and the conclusion. For design and simulation, CST was used.

II. DESIGN OF ANTENNA

A. Linear Antenna Design

First, step of our design process was designing a linear antenna at desired frequency. We use FR-4 with following specifications for our antenna; $\varepsilon_r = 4.6$, thickness = 35 µm and height = 1.6 mm.

Design of the linear patch antenna starts with calculating length of the square patch using (1).

$$L = 0.49 \frac{\lambda}{\sqrt{\varepsilon_r}} \quad (1)$$

where

L = length of the patch

λ = wavelength in free space

ε_r = relative dielectric constant

At GPS frequency, 1.5 GHz, L is found as 45.66 mm. Impedance matching is designed using brute force method. Initially length of feed set to 23.3 mm, which is quarter wavelength of guided wave, and feed width is set to 1 mm. Later optimal feed length found to be 36 mm and optimal feed width found to be 2 mm. After the feed line is optimized, patch dimensions were also optimized for better s_{11} parameter. Final length of patch is 46.8 mm and width of patch is 46 mm.

Fig 1. Microstrip patch antenna with slot

B. *Right Hand Circularly Polarized Antenna Design*

After completing linear antenna design, a slot is introduced to the patch as shown as at fig 1. Initial sizes of slot were 2 mm x 30 mm. The slot was adjusted to get right hand circular polarization (RHCP). However, adjustments were unsuccessful, thus corners of antenna were truncated as well.

All dimensions were optimized to obtain good s_{11} parameter with lowest axial ratio at Phi = 0 and Theta = 0. Final dimensions of antenna are illustrated at fig 2. Final length of one side of square patch is 48 mm.

III. Simulation Results

A. *Linear Antenna Design*

Linear antenna was simulated for s_{11} parameter. Simulation results provide s_{11} of -30.27 dB near center frequency, 1.5 GHz and 34.9 MHz bandwidth where s_{11} is lower than -10 dB. Linear antenna simulation results were provided at fig. 3.

B. *Right Hand Circularly Polarized Antenna Design*

S parameter simulation of RHCP antenna provided better results than linear. Fig 4 provides s_{11} result of simulation. At center frequency s_{11} is -36.37 dB. Moreover, bandwidth is increased especially for lower frequencies than center. RHCP

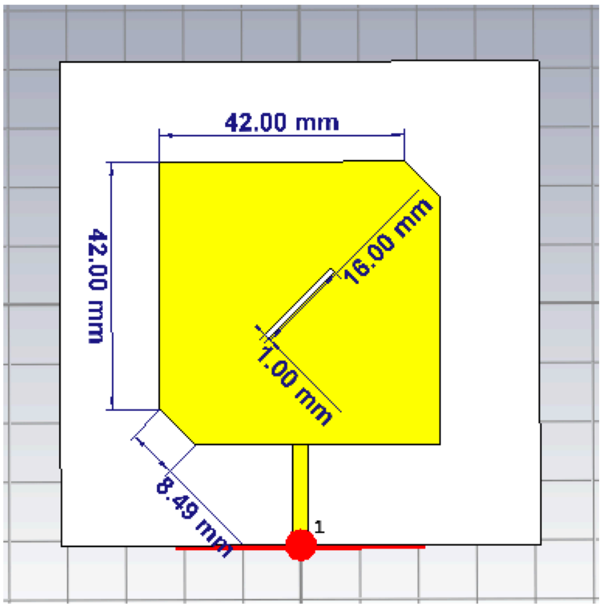

Fig 2. Final design

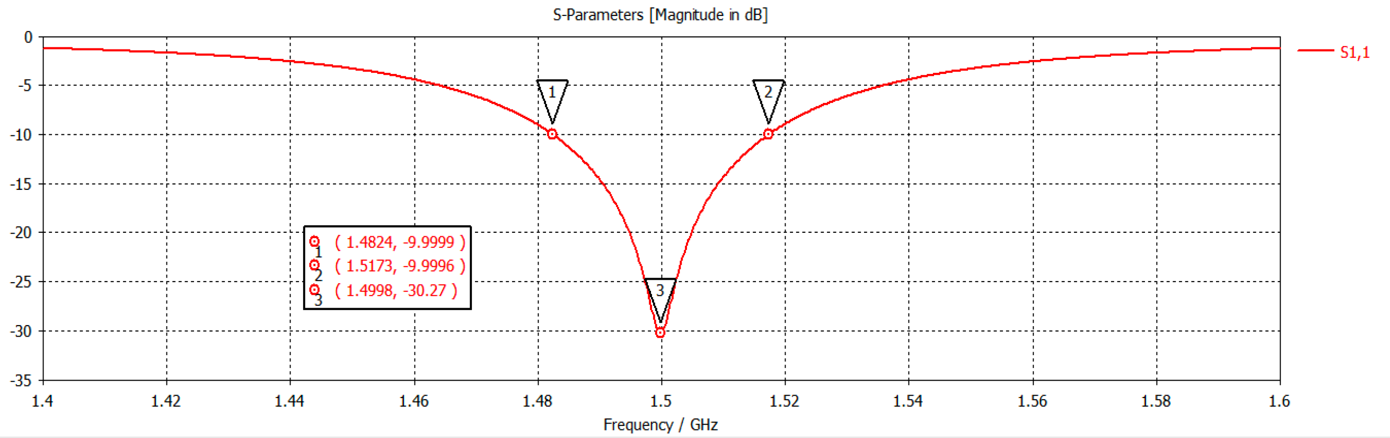

Fig. 3. s_{11} parameter results for linear antenna design

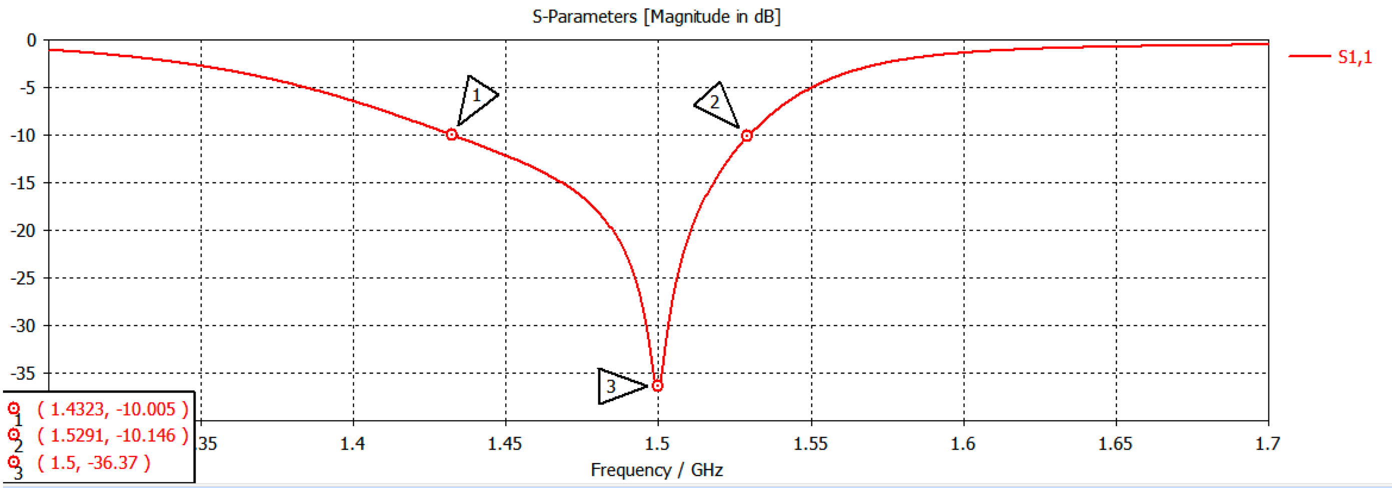

Fig. 4. s_{11} parameter results for RHCP antenna design

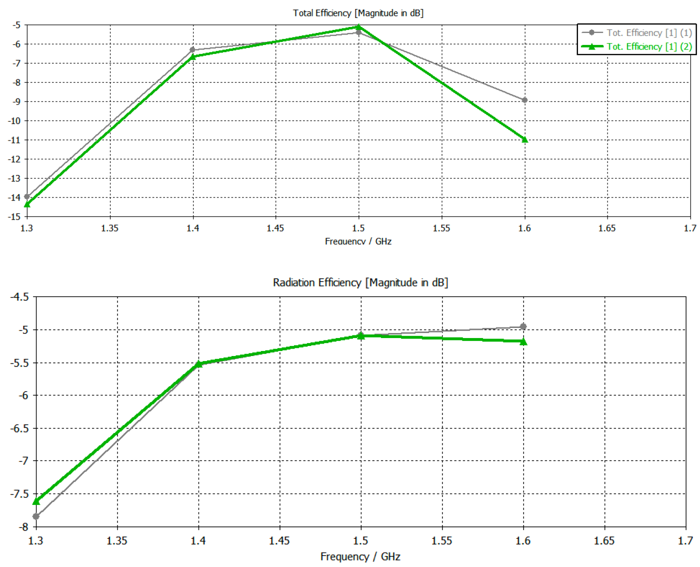

Fig. 5. Efficiency results for RHCP antenna design

bandwidth is 96.8 MHz. Fig 5 provides efficiency results of simulation. Axial ratio results were included at fig 6. Designed antenna failed to satisfy RHCP. Directivity of designed antenna is 6.183 dBi. Figure 7 provides far field results.

IV. Measurement Results

Manufactured and measured square patch antenna shown at fig 8. Measurement results provide quite different S-Parameters than simulation results. S parameters of measured antenna provided at fig. 9. Its observed that resonance frequency of slot and trim shifted opposite sides during manufacturing. Thus, antenna provides good, higher than simulated result put still much lower than -10dB, s_{11} parameter for two center

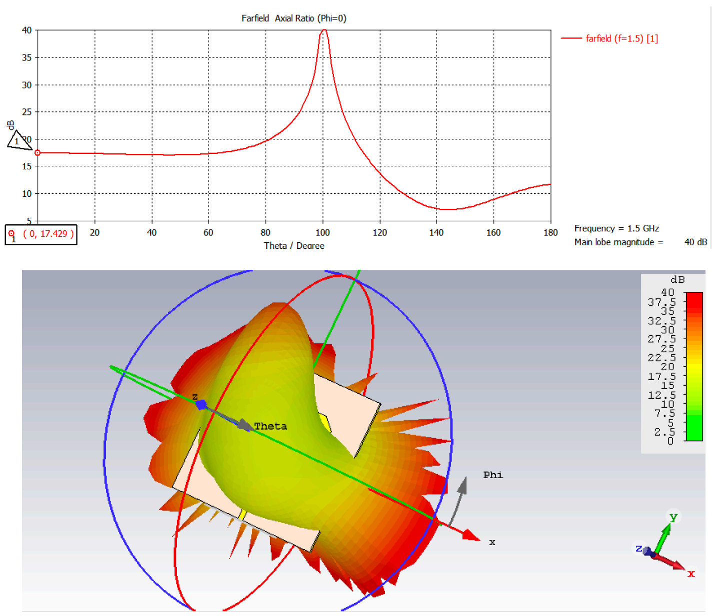

Fig. 6. Axial ratio results for RHCP antenna design

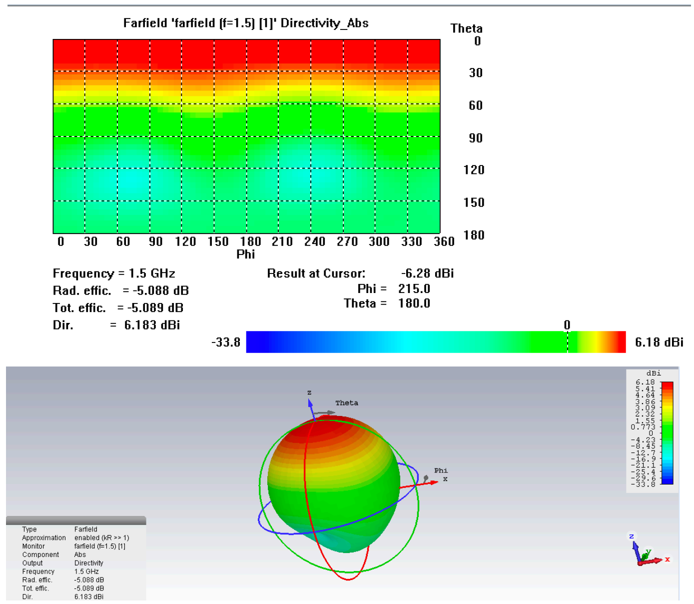

Fig. 7. Farfield results for RHCP antenna design

frequencies. Those are -25 dB for 1.44 GHz and -18 dB for 1.55 GHz. Thus, designed antenna can work like dual band antenna, and measurement results will be discussed separately for both center frequencies.

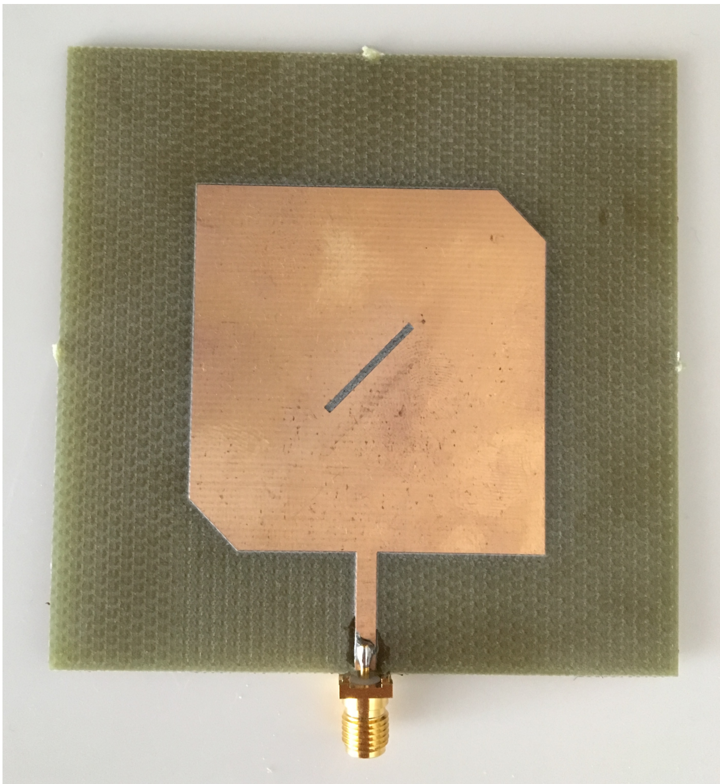

Fig. 8. Slotted and edge trimmed square patch antenna

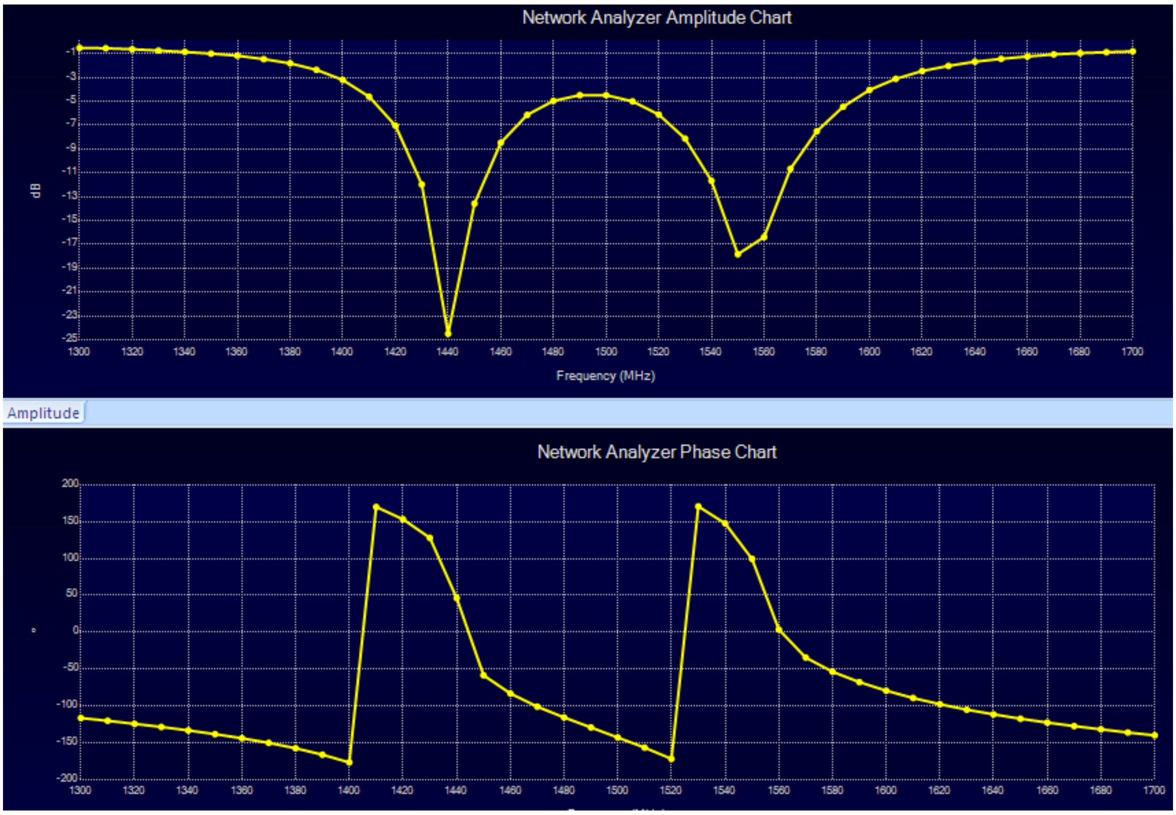

Fig. 9. Measured s_{11} parameter

A. Results at 1.44 GHz:

1) Position Phi

Efficiency of antenna measured to be 3.69% and gain of antenna measured to be -8.25dB at 1.44 GHz. Fig. 10 provides measured far field results and bi-section cuts at 1.44 GHz, position Phi. Fig 11 provides near field results for 1.44 GHz, position Phi.

At center point:

$$H_x = 0.00788 \angle 150.54^o$$

$$H_y = 0.0041 \angle 67.7^o$$

X and y components has phase difference close to 90^o, however magnitudes are not same. Thus, it is not circularly polarized.

2) Position Theta

Efficiency of antenna measured to be 22.57% and gain of antenna measured to be -0.75dB at 1.44 GHz. Fig. 12 provides measured far field results and bi-section cuts at 1.44 GHz, position Theta. Fig 13 provides near field results for 1.44 GHz, position Theta.

At center point:

$$H_x = 0.0245 \angle -164.5^o$$

$$H_y = 0.0218 \angle 155.7^o$$

X and y components has close magnitudes, however phase difference much more than 90^o. Thus, it is not circularly polarized.

B. Results at 1.55 GHz

1) Position Phi

Efficiency of antenna measured to be 3.54% and gain of antenna measured to be -8dB at 1.55 GHz. Fig. 14 provides measured far field results and bi-section cuts at 1.55 GHz, position Phi. Fig 15 provides near field results for 1.55 GHz, position Phi.

At center point:

$$H_x = 0.006714 \angle 7^o$$

$$H_y = 0.004182 \angle -164.5^o$$

X and y components has close magnitudes, however phase difference much more than 90^o. Thus, it is not circularly polarized.

2) Position Theta

Efficiency of antenna measured to be 23.4% and gain of antenna measured to be 0.2dB at 1.55 GHz. Fig. 16 provides measured far field results and bi-section cuts at 1.55 GHz, position Theta. Fig 17 provides near field results for 1.55 GHz, position Theta.

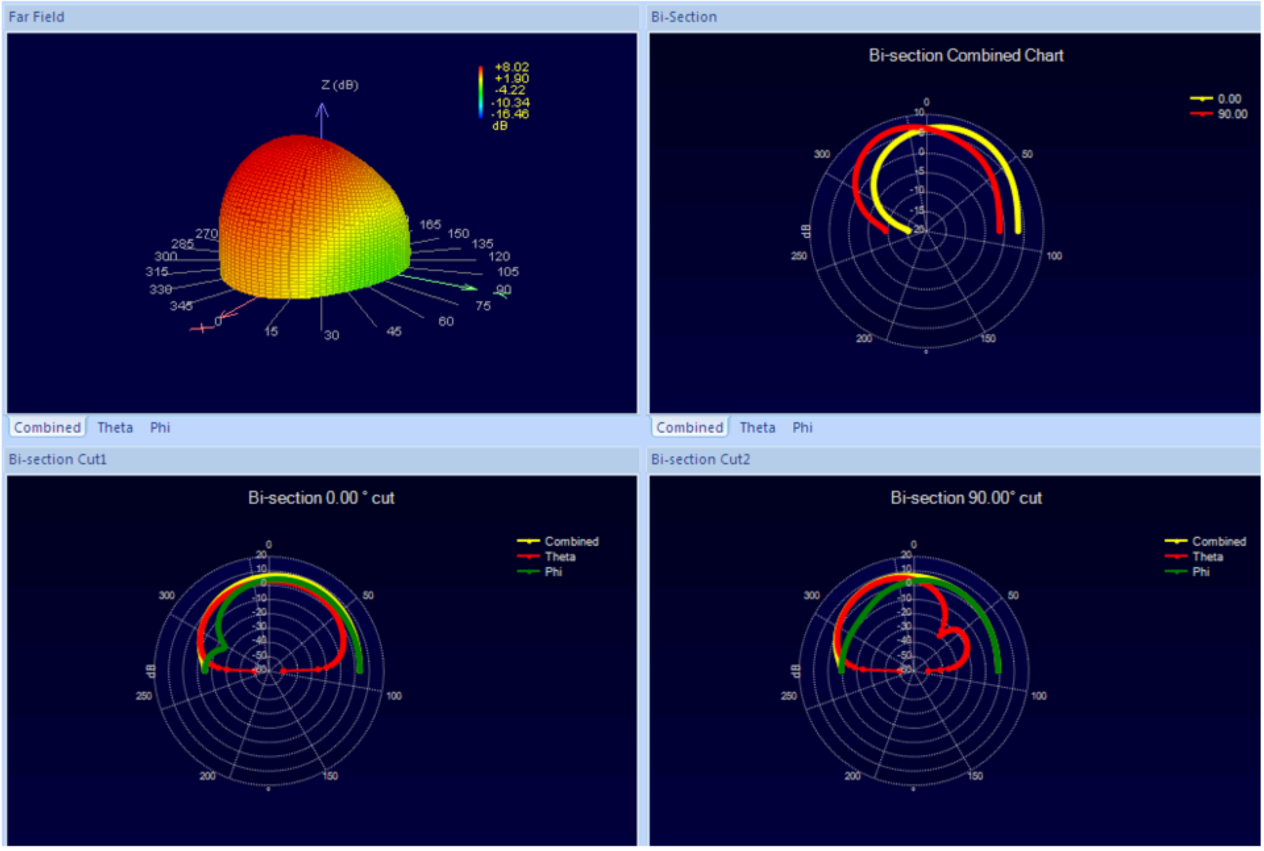

Fig. 10. Far field at 1.44 GHz, Position Phi

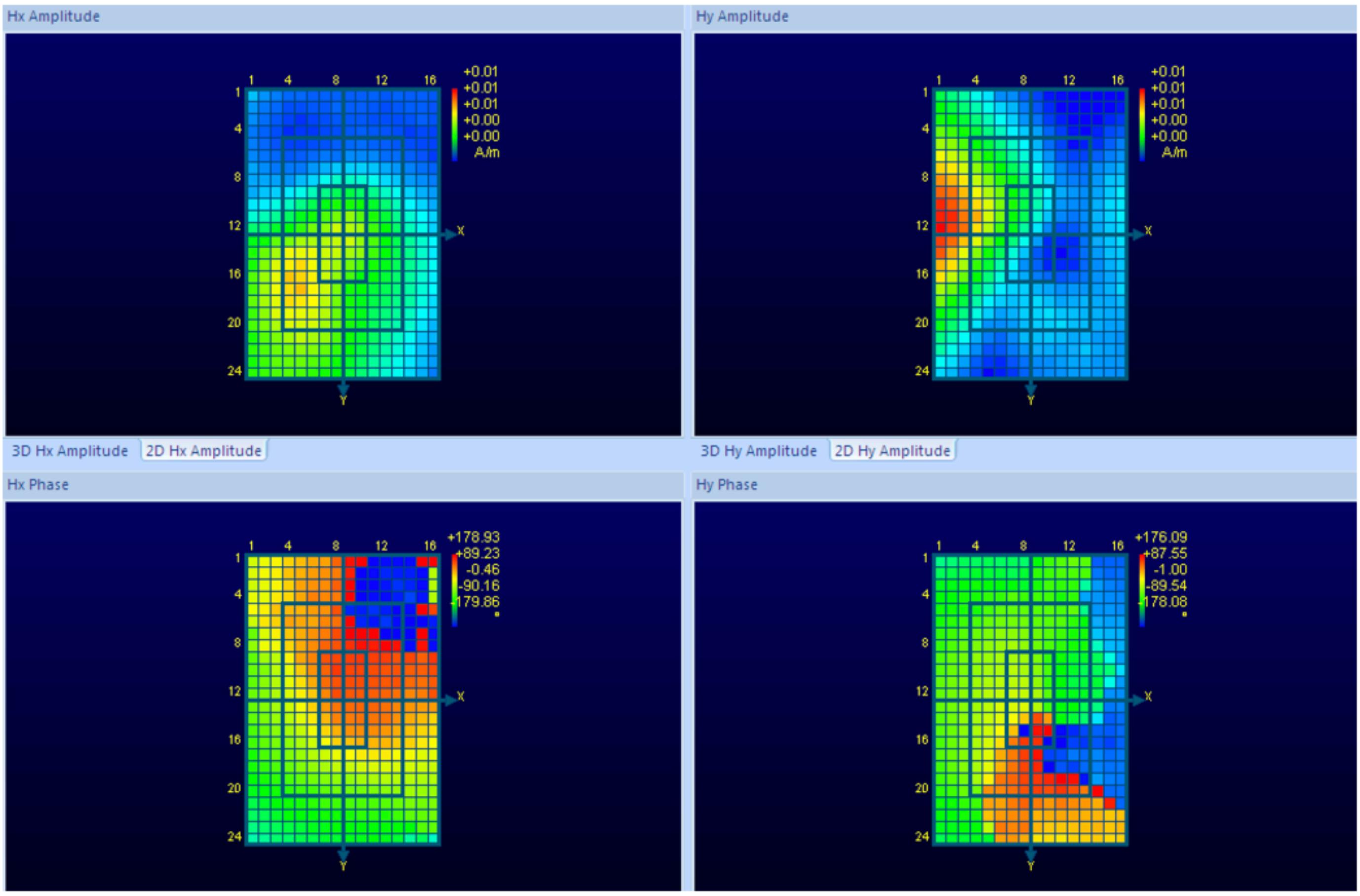

Fig. 11. Near field at 1.44 GHz, Position Phi

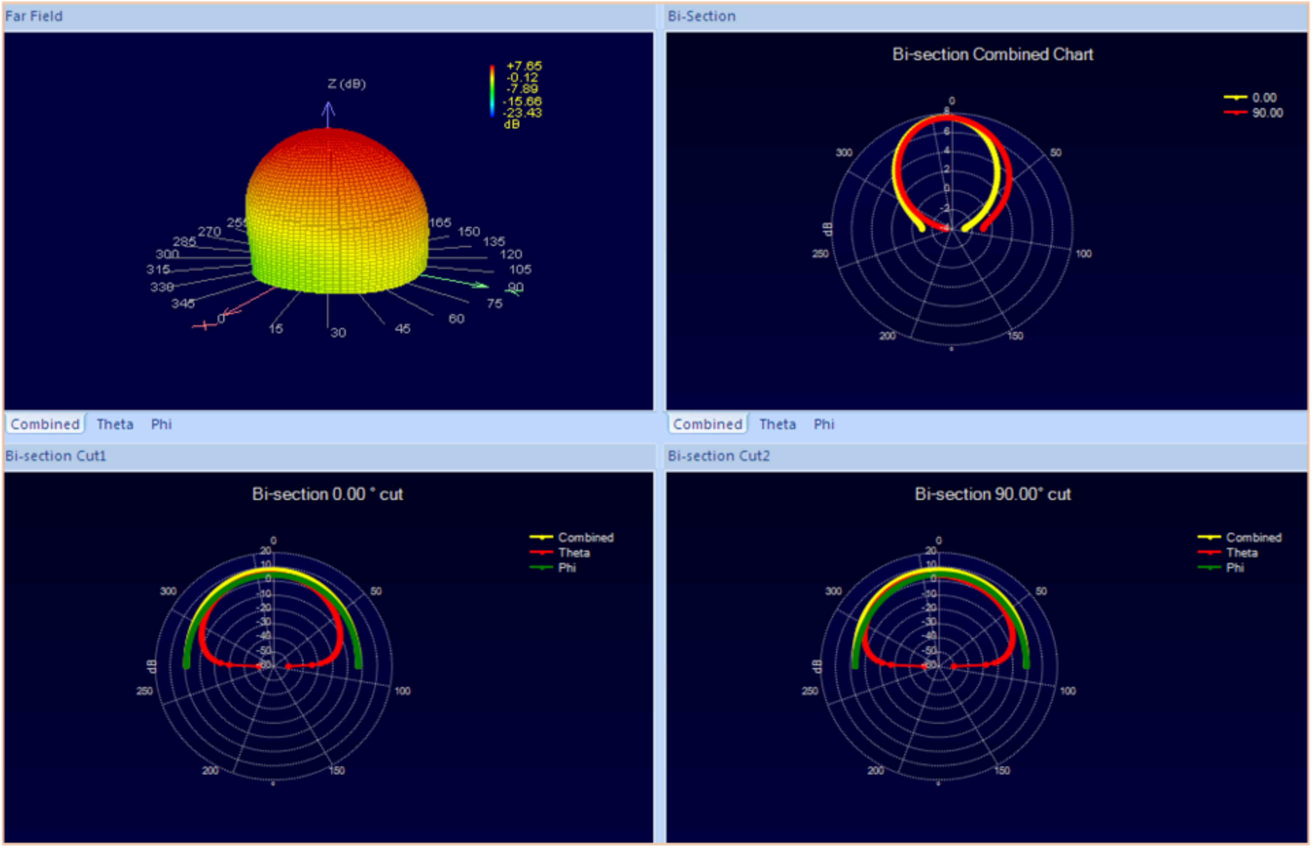

Fig. 10. Far field at 1.44 GHz Position Theta

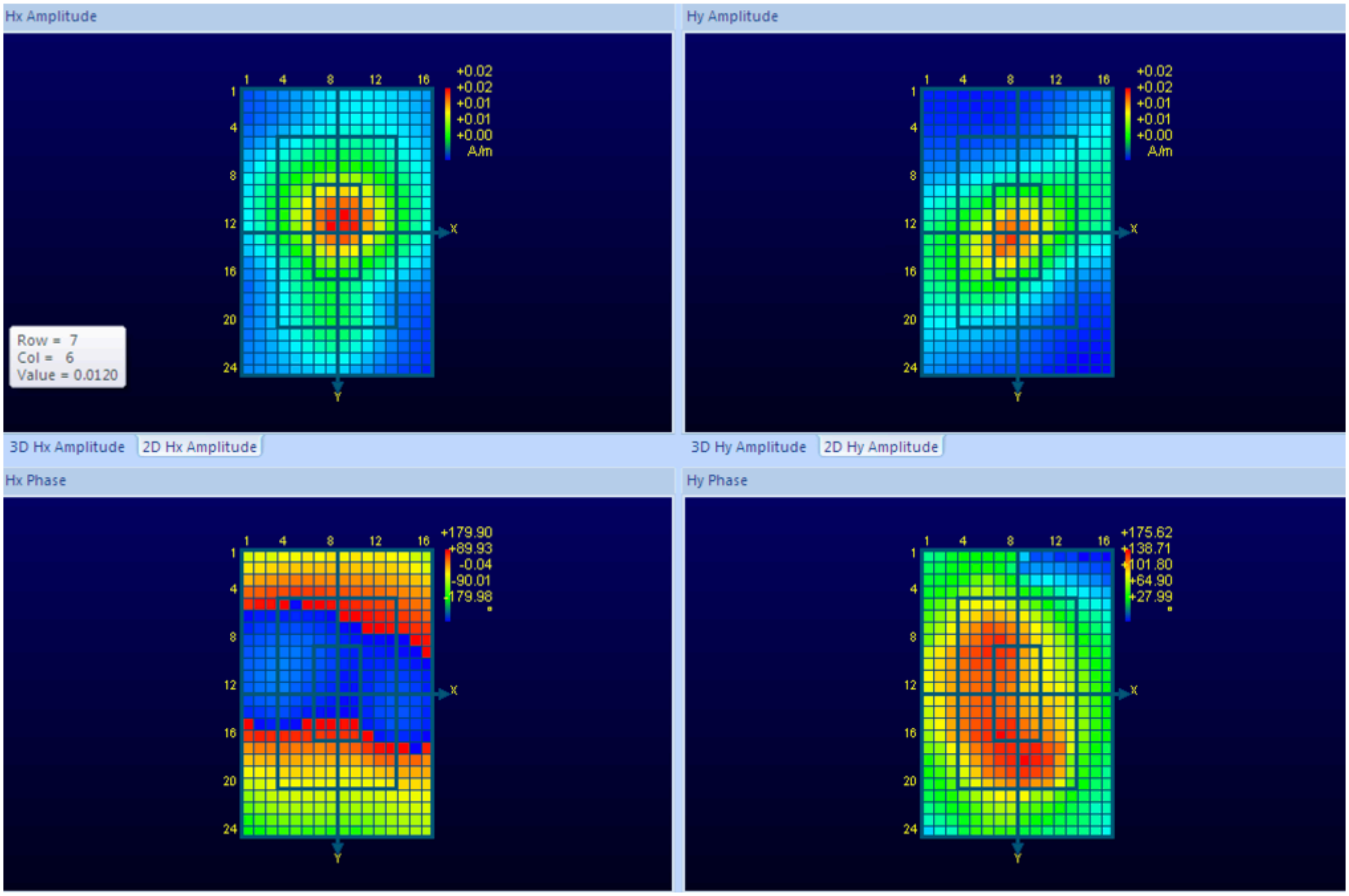

Fig. 11. Near field at 1.44 GHz Position Theta

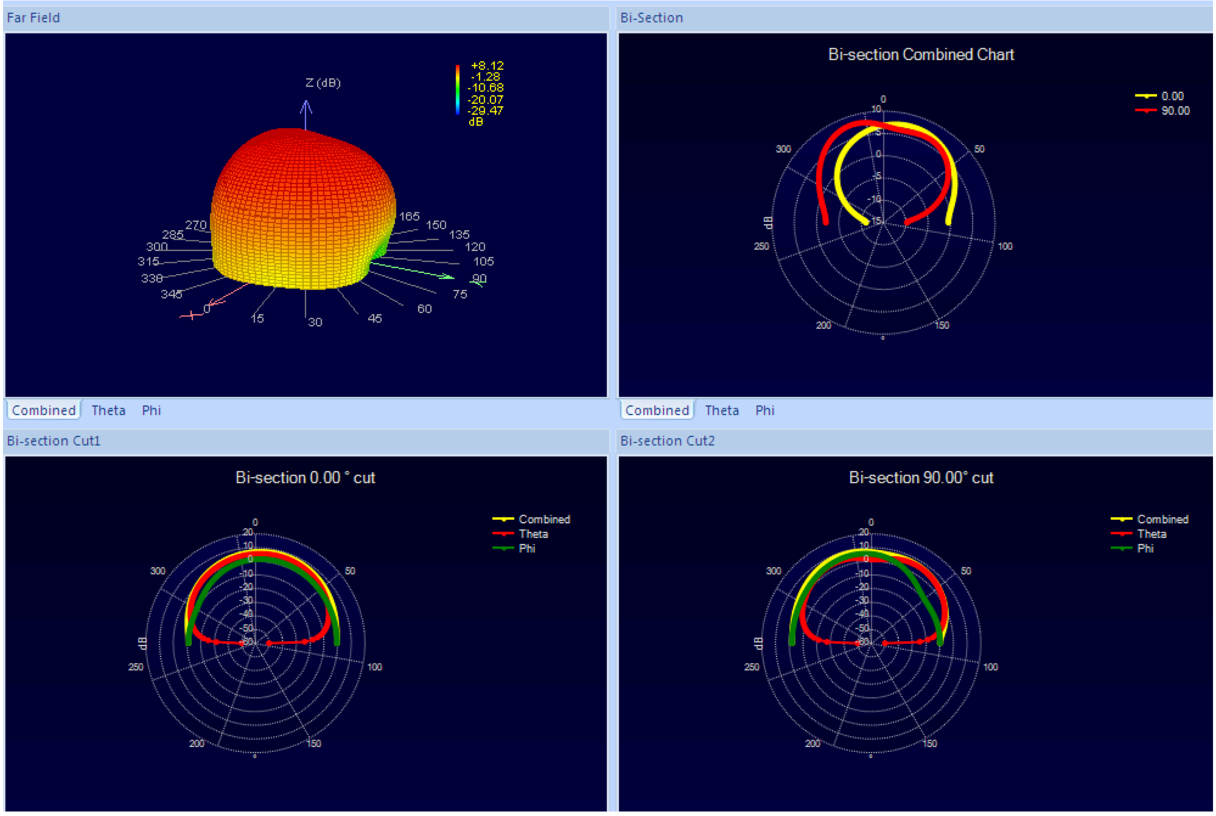

Fig. 12. Far Field at 1.55 GHz Position Phi

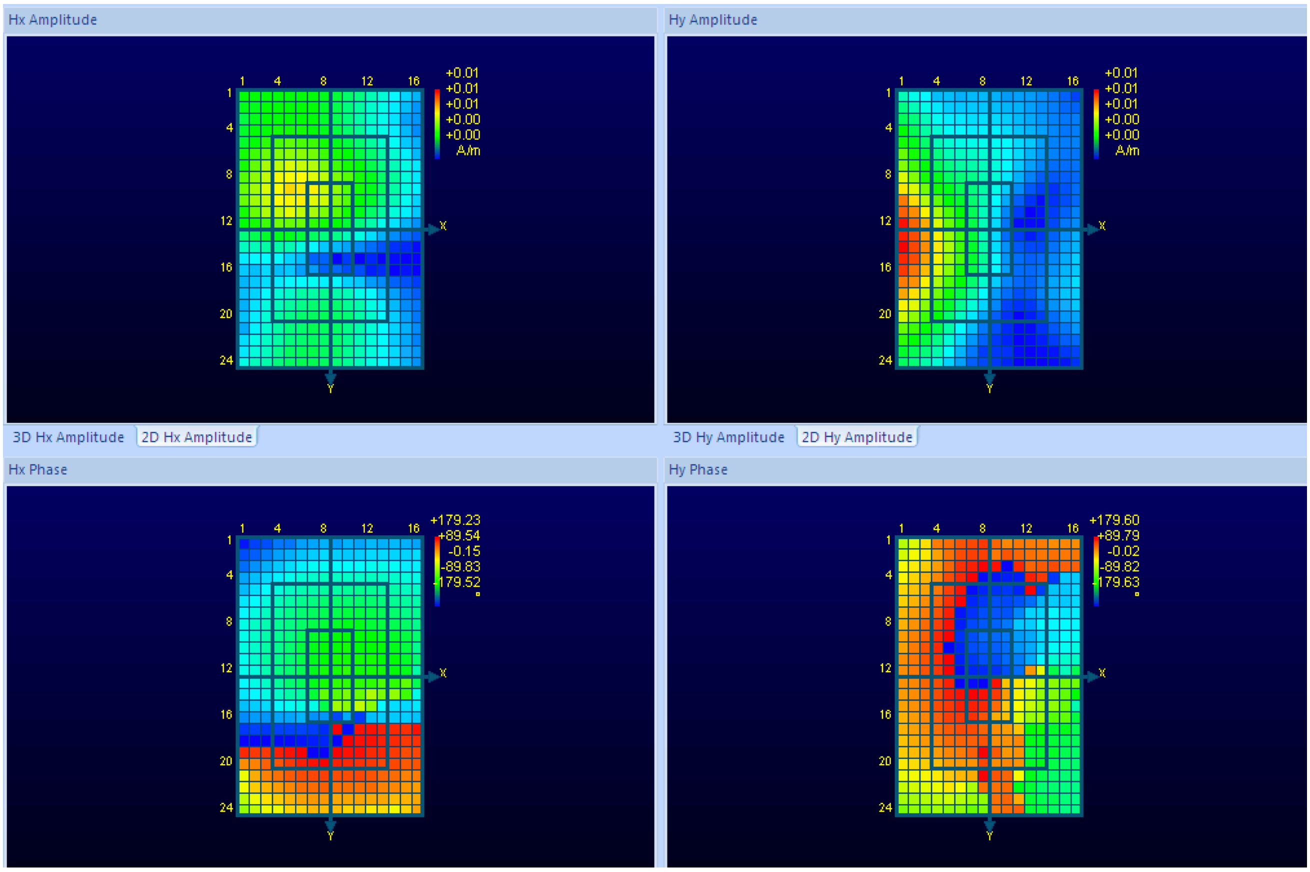

Fig. 13. Near Field at 1.55 GHz Position Phi

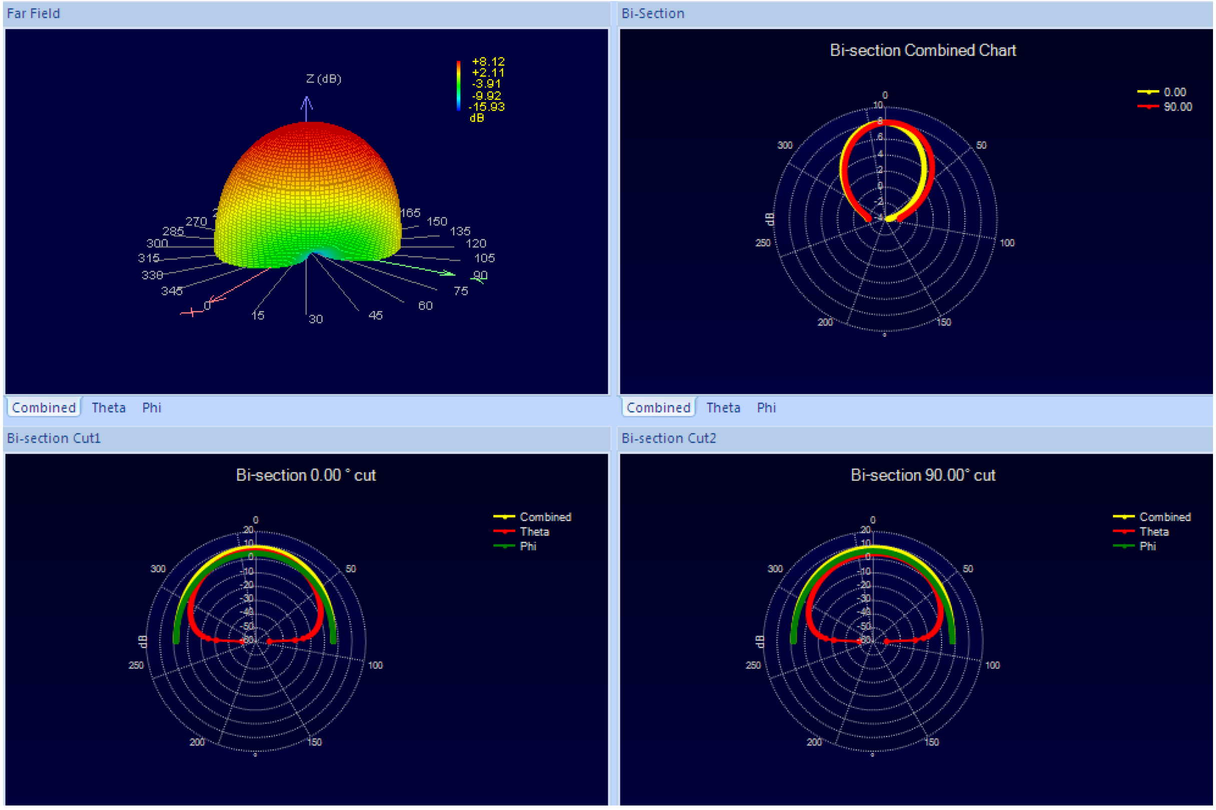

Fig. 14. Far Field at 1.55 GHz Position Theta

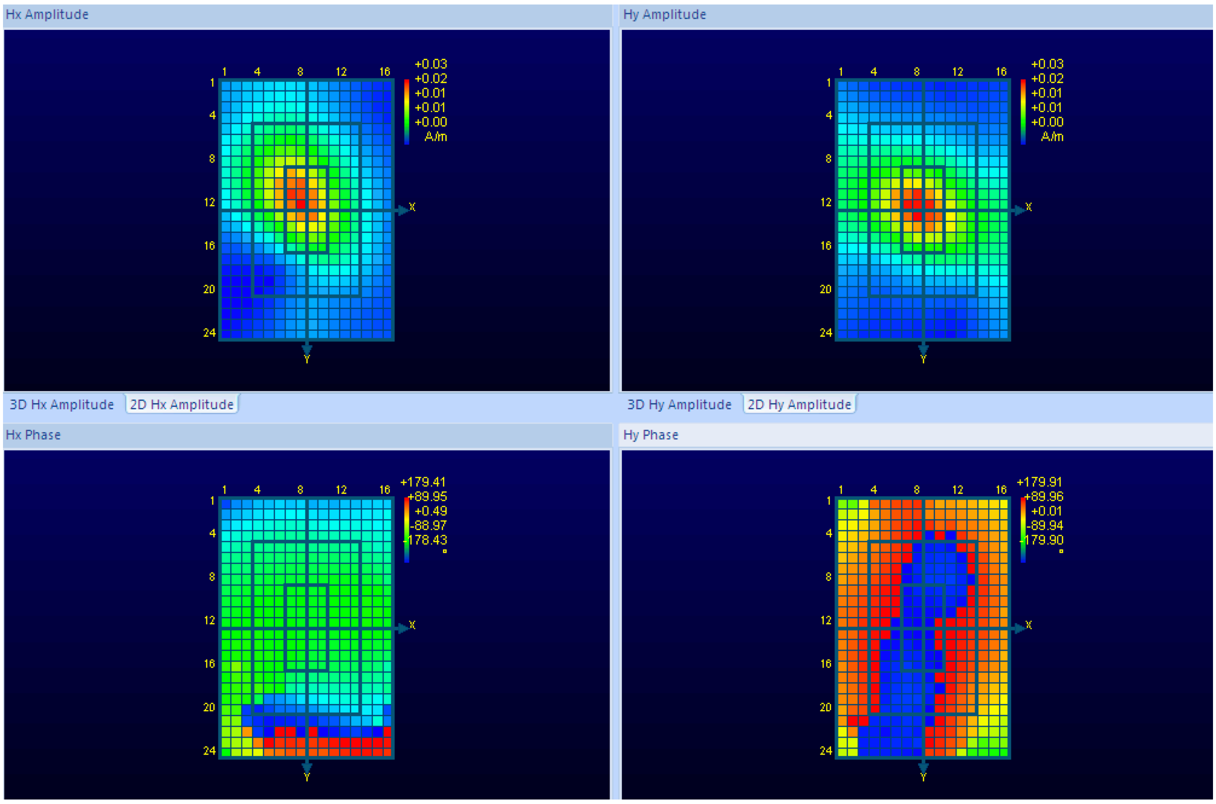

Fig. 14. Near Field at 1.55 GHz Position Theta

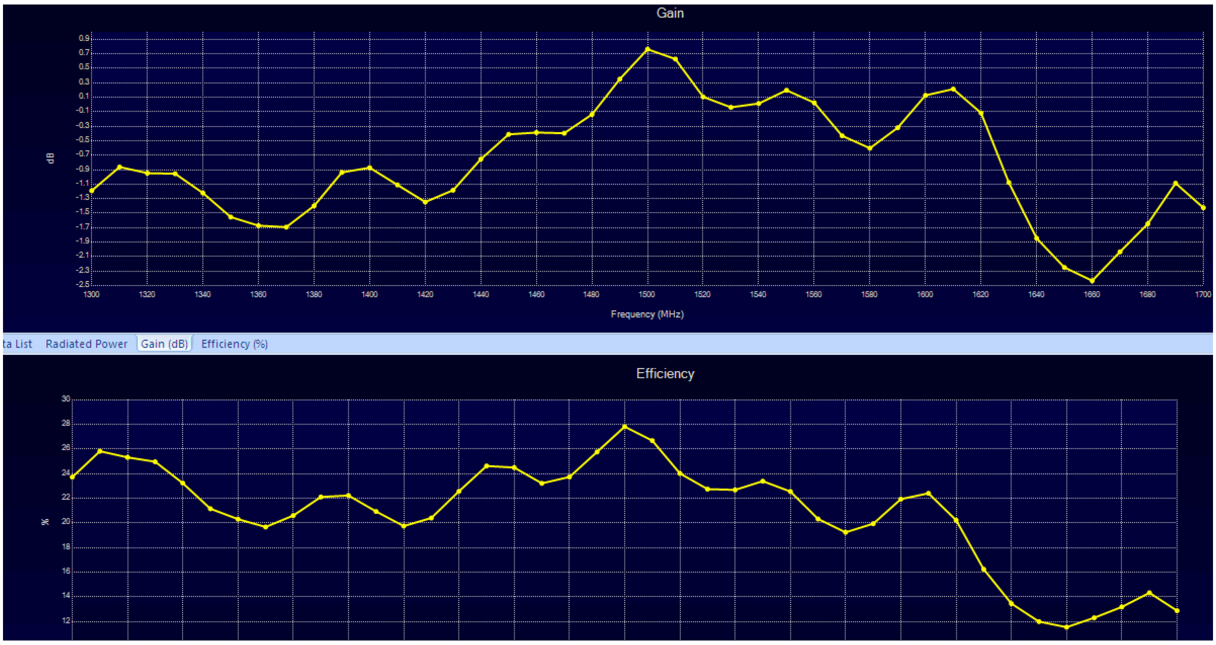

Fig. 15. Gain and efficency at Position Theta

At center point:

$$H_x = 0.0234 \angle -9.9^{o}$$

$$H_y = 0.0245 \angle -177.2^{o}$$

X and y components has close magnitudes, however phase difference much more than 90^{o}. Thus, it is not circularly polarized.

C. Gain and Efficiency

Since designed antenna has no gain at Phi direction, it is not presented. Designed antenna provides its highest gain at 1.5 GHz as 0.8 dB. Gain and efficiency graphs are presented at fig 15.

V. Conculution

In this paper, design process and measurement results of microstrip patch antenna with slot and trimmed edges is presented. Designed antenna failed to satisfy right hand circular polarization requirements and center frequency of 1.5GHz, GPS frequency. Instead designed antenna can work at applications that require center frequencies 1.44 GHz and 1.5 GHz, and where the polarization is not important.

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