Pattern Analysis of Rectangular Microstrip Antenna for 3G Frequency

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Abstract - In high performance aircraft, spacecraft & missile applications, where size, weight, performance, ease of installation & aerodynamic profile are constraints, low profile antenna are required. Commercial applications such as wireless & mobile radio communication also have same specifications. To meet these requirements, MSA is used. These antennas are low profile, simple, inexpensive to manufacture using printed circuit board.
This paper provides a detailed study of how to design and fabricate a Rectangular Microstrip Patch Antenna using IE3D software operating at 2.5 GHz. For the calculation of Length (L) & Width (W) of Antenna, Transmission Line model analysis is used. For the excitation of antenna, Probe type fed arrangement is used. Considerable emphases are placed on the designing of RMSA and compare the simulated results with design hardware results. In this paper, particular attention is paid to the pattern analysis of antenna (Current distribution pattern & Radiation pattern) along with the measurement of Return losses, Input impedance, Band Width of the RMSA etc.

I. INTRODUCTION

Deschamps first proposed the concept of the MSA in 1953. However, practical antennas were developed by Munson and Howell in the1970s. The numerous advantages of MSA, such as its low weight, small volume, and ease of fabrication using printed-circuit technology, led to the design of several configurations for various applications. With increasing requirements for personal and mobile communications, the demand for smaller and low-profile antennas has brought the MSA to the forefront.
A Microstrip Antenna consists of a radiating patch on one side of a dielectric substrate and a ground plane on the other side. Radiation from the MSA can occur from the fringing fields between the periphery of the patch and the ground plane.

II. TRANSMISSION LINE MODEL ANALYSIS

The transmission line model is very simple and helpful in understanding the basic performance of a MSA & used for calculating the dimension of antenna (Length & Width). The Microstrip radiator element is viewed as a transmission line resonator with no transverse field variations (the field only varies along the length), and the radiation occurs mainly from the fringing fields at the open circuited ends. The patch is represented by two slots that are spaced by the length of the resonator. This model was originally developed for rectangular patches but has been extended for generalized patch shapes. Many variations of this method have been used to analyze the MSA. General equations for transmission line model analysis are-

1. Width of the patch

$$W = \frac{1}{2f_r\sqrt{\mu_0\ \epsilon_0}}\sqrt{\frac{2}{\epsilon_r + 1}} = \frac{v_0}{2f_r}\sqrt{\frac{2}{\epsilon_r + 1}} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

2. Effective dielectric constant of MSA

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2} \quad \ldots\ldots\ldots\ldots\ldots (2)$$

3. Extension of length from fringing field is determined by

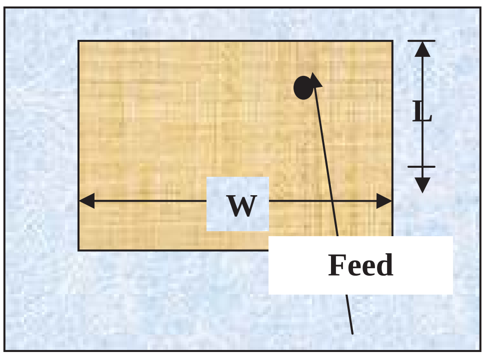
$$\frac{\Delta L}{h} = 0.412\frac{(\epsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\epsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad \ldots\ldots\ldots (3)$$

4. Actual length of the Patch is determined by

$$L = \frac{1}{2f_r\sqrt{\epsilon_{reff}}\sqrt{\epsilon_o\ \mu_o}} - 2\Delta L \quad \ldots\ldots\ldots\ldots\ldots (4)$$

III. Coaxial Probe feeding technique

Coaxial-probe feeds, where the inner conductor of the probe is attached to radiation patch while the outer conductor is connected to ground. The main advantage of this feed is that it can be placed at any desired location inside the patch. The top and side views of a rectangular MSA (RMSA) using probe feed is shown in Fig 1 (a & b).



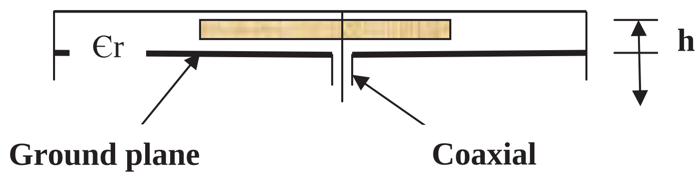


Fig 1(a & b)

IV. Parameters & simulated results on IE3D

Operating Frequency (fr) = 2.5Ghz
Dielectric constant of PCB (Ɛr) = 4.2
Thickness of PCB (h) =1.6 mm

By putting these parameters into equations 1, 2, 3 & 4, After We get,

W=37.21mm & L=28.49mm

Putting these parameters into IE3D software, we get the structure shown in fig 2(a) & feed point at the location (9, 18) from left corner of the RMSA shown in fig 2(b).

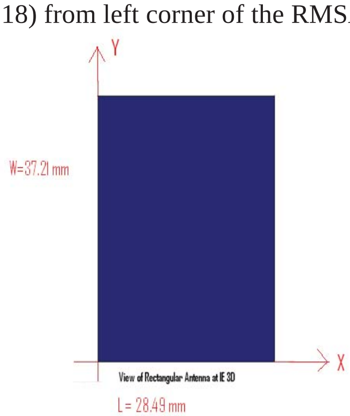


Fig 2(a)-Geometry on IE3D

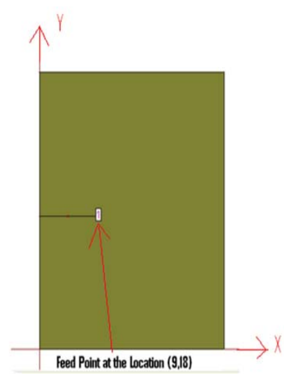


Fig 2(a)-Feed point on IE3D (9, 18)

Return losses at the feed point is shown in fig-3 which is -26.1992dB at the operating frequency 2.5 GHz & Table-1 shows the different parameters of RMSA at IE3D.

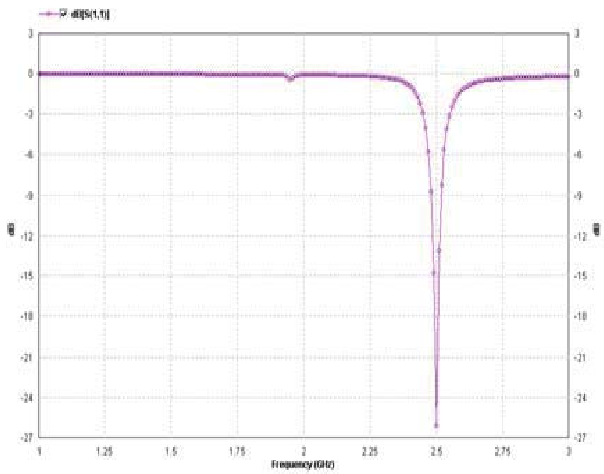


Fig-3 Return losses versus Frequency curve

Parameters	Value
VSWR	1.10388
BW	34.4MHz
Gain	5.7322dB
Directivity	6.53201dB
Antenna η%	83.353%
I/P Impedance	51.13Ω
Radiation η%	83.5567%

Table-1 Parameters of RNSA

V. CURRENT DISTRIBUTION OF RMSA

For the fundamental TM10 mode, voltage is maximum and current is minimum at the edges, the input impedance of the RMSA varies from a zero value at center to the maximum value at the radiating edges. So feed point at that location, where the input impedance of the antenna matches the characteristics impedance of the feed (50Ω). On top & bottom edges, current is null and on at the feed, it is maximum, It decrease towards the edges. This is opposite for the voltage (null at feed point & maximum at the edges). Current distribution is shown in fig-4. Red point shows the magnitude of current at the patch.

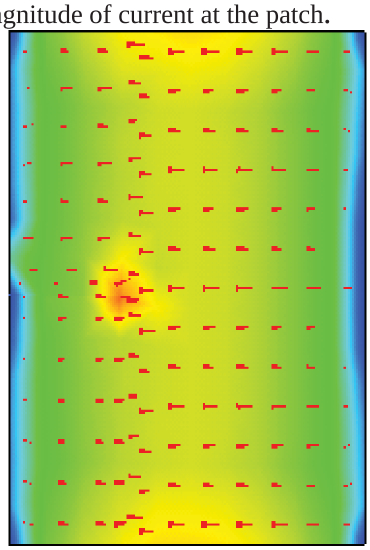


Fig-4 current distribution

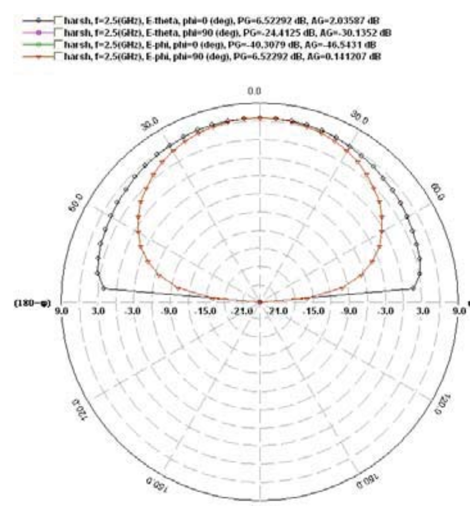
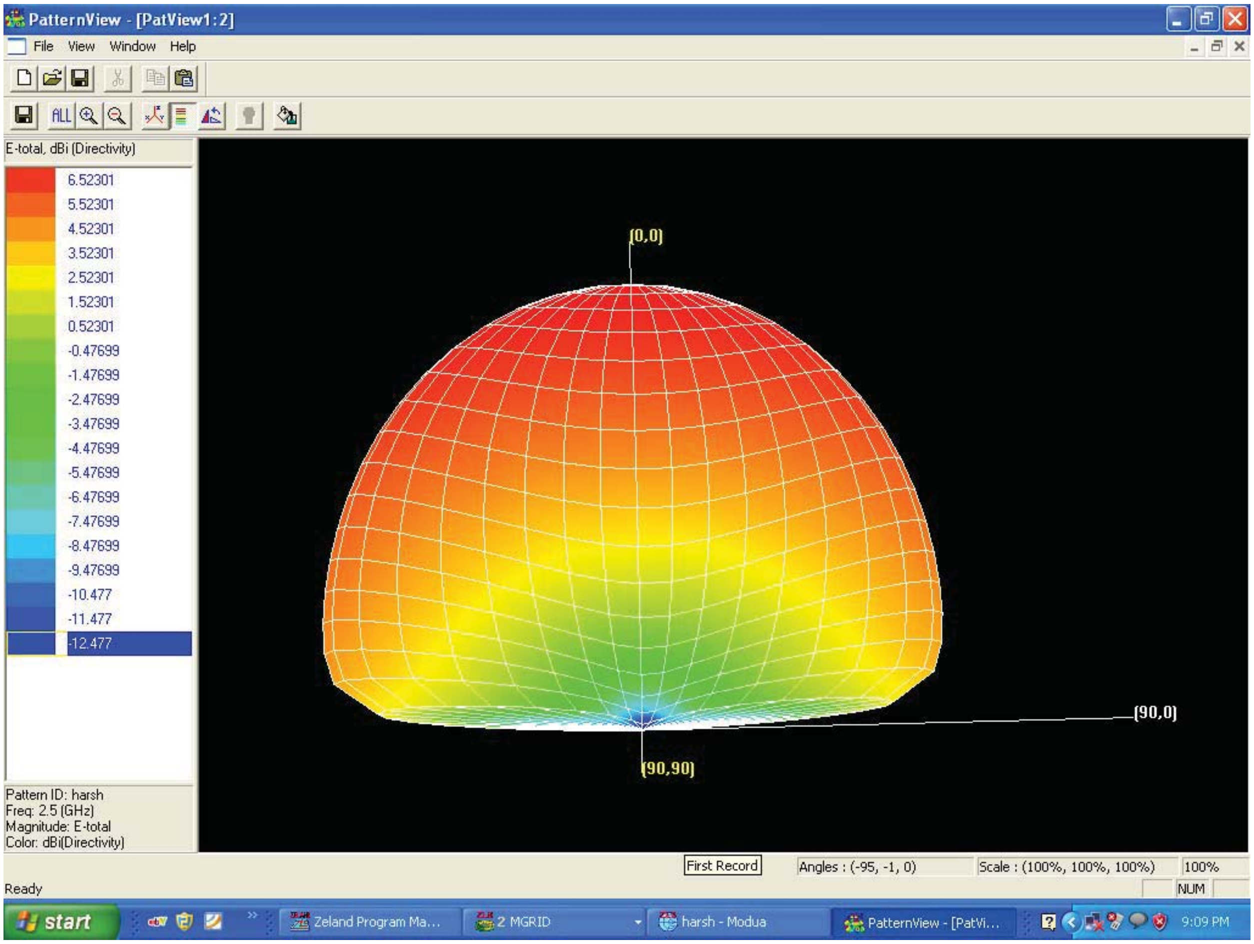


Fig-5 2D pattern

2D Pattern:- Fig-5 shows the radiation pattern (2D) of RMSA , from which we observe that there is no back or side lobes which represent the waste of energy during the transmission is minimum. This antenna has the efficiency of 83.35%.

3D Pattern:- Fig-6 shows the “True 3D” as the “Pattern Style” and dB (Directivity) as the Scale Style. 3D pattern shows the general shape of the pattern but you cannot easily see the co-pol and cross-pol components. That is why we will also plot the 2D patterns in the E- and H-planes as shown in fig-5. Antenna is radiating only in the upper hemisphere as seen from its 3D radiation pattern. This is caused as a result of the presence of the infinite ground plane underneath the patch that isolates the lower half space.



VI. TESTING OF ANTENNA USING SPECTRUM ANALYZER

After the designing of antenna using PCB lab [fig 5(a)], we get the results using spectrum analyzer as shown in fig (5- b).

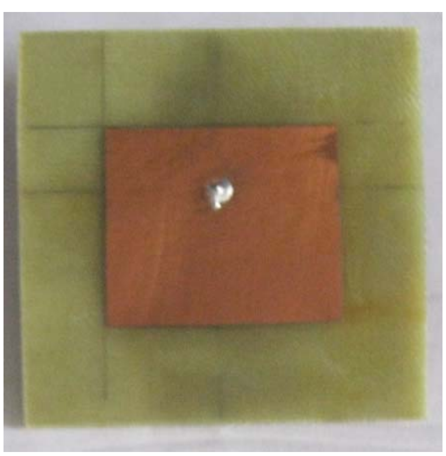


Fig 5(a) Designed hardware

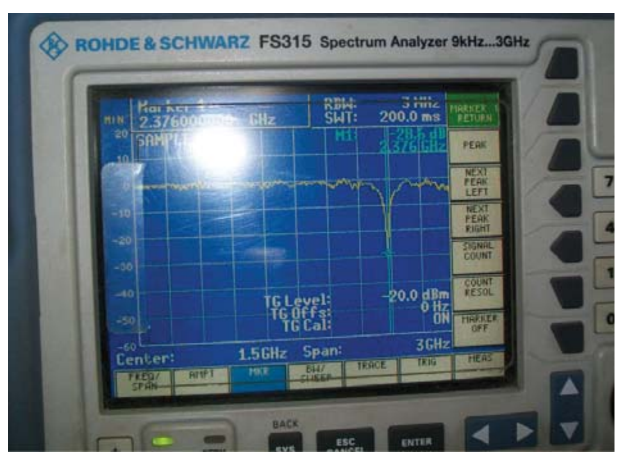


Fig 5(b) Tested results on spectrum analyzer

From testing of antenna, we get the following results shown in table-2.

Return losses	14.01 dB
VSWR	1.494
BW	30 MHz

Table-2 Tested Results

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