Effect of Patch Plating on Rectangular Microstrip Antenna Parameters

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Abstract

This research paper reports effect of plating variation on rectangular micro strip patch antenna (RMSA) parameters at 2.4GHz frequency. The results reported here were obtained using a computer simulation of the antenna with Ansoft HFSS software. The antenna uses a stacked dielectric layer structure and has rectangular shape. Platting material is coated on patch of conducting material where the patch was on substrate material. For this design the platting materials are used as Gold, Hal and Nickel with substrate thickness 1.6 mm. basically, these platting materials are coated on copper patch FR4 Glass Epoxy.

Key Words – *Patch Plating, Rectangular patch antenna, FR4*

I. INTRODUCTION

Micro strip patch antennas have various system applications. Some of the applications are Bluetooth, mobile access, radar systems, missiles telemetry systems, aircraft communications systems, free broadcasting, wireless radio, W-LAND broadcasting, satellite communication and mobiles handsets. Micro strip Patch Antennas (MSPAs) have the advantage of small size and low profile allowing them to be easily integrated in the body of aircrafts, missiles or computers. Micro strip patches can be fabricated easily at low cost. The disadvantage of a MSPA is its small bandwidth of 1 to 2% around the resonant frequency. Analysis and design of wideband low profile antennas are currently an important research area. The Rectangular geometry of the micro strip patch (Fig. 1) drew the attention of their searchers in investigating the structure as planar circuit components and as radiating elements in conventional and multi layered configurations Compared to other patch geometries, the Rectangular micro strip is physically smaller having better radiation but has a lower radiation loss. In recent years, the RMSA has found several new applications as broad band radiators [1].

The rectangular patch antenna is the most used Configuration because this shape requires a simple theoretical analysis. We are going to approach on this part the plating method used to improve the antenna parameters. The results of Gold plated, HAL plated & nickel plated micro strip patch antennas are compared here [6].

II. RECTANGULAR PATCH AS MICROSTRIP CIRCUIT

The first study on RMSA dates back to 1977 [4]. Initial reports show that the RMSA was considered as a narrow band structure owing to its high Q value. Hence, the early studies show potential applications of the RMSA as oscillators, filters and circulators [4]. Almost simultaneously, Helsza jn and James [5] reported theoretical and experimental gain on RMSA as disk resonator, filter and circulator. They used the cavity resonator model to determine the resonant frequencies for the TMn,m,l modes and also showed their respective field patterns.

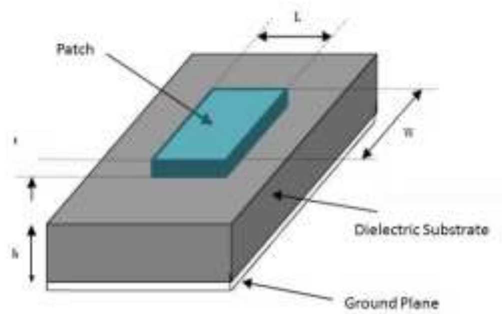

Fig. 1 Rectangular patch antenna

III. RMSA DESIGN

The stacked patches analyzed in this project are made of a driven and a parasitic Rectangular patch FR4. The sides of the patches are basically half wavelength of the operating Frequency 2.4 GHz used for ICM (Industrial Scientific Medical) band license free band, dimensions emanates from basic equations for micro strip patch antenna design shown below. Antenna is simulated on an FR4 substrate with a dielectric constant of 4.4. The bandwidth of the microstrip antennas is directly proportional to the substrate thickness h and inversely proportional to the square root of its dielectric constant. As a result, a thicker substrate with a low dielectric constant is generally used to obtain broad bandwidth. The bandwidth could be defined in terms of its VSWR or input impedance variation with frequency or in terms of radiation parameters. It can be defined by the variation of the input impedance, of radiation pattern and the polarization [6, 7]

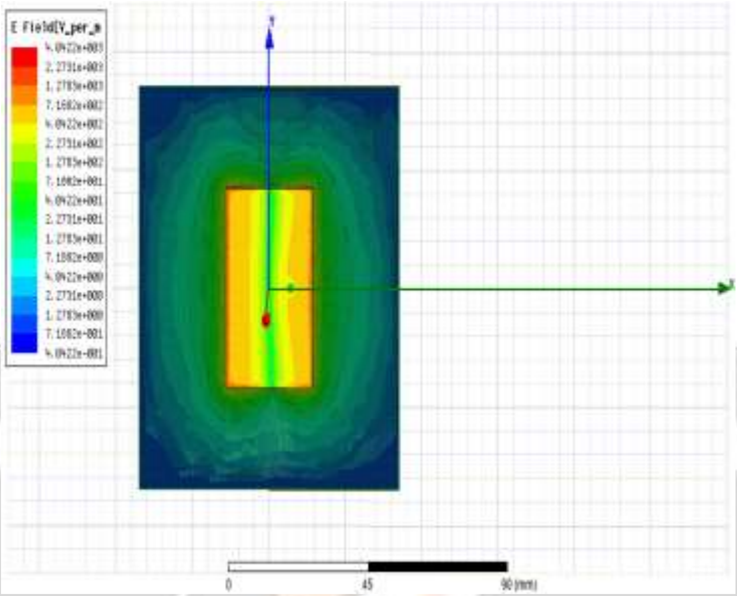

Fig.2. Geometrical Layout of Rectangular antenna.

IV. Design parameters of micro strip antenna

Patch shape	Rectangular
Frequency	2.4 GHz
Feeding method	Coaxial probe
Dielectric material	FR4(glass epoxy)
Plating Materials	Gold, HAL & Nickel
Dielectric constant of substrate	4:4

V. Design Formula for RMSA-

Numerical computer calculations were made with Ansoft HFSS (fig.3) to find an optimum position of the coaxial probe on the primary patch feed and the length of the Rectangular patch elements. The results are shown in fig.4. The values of L and Xp that give the best return loss and bandwidth[2].

1. Calculation of Width (w)

By the formula:

$$W = \frac{c}{2f_0\sqrt{\frac{(\varepsilon_r + 1)}{2}}}$$

2. Calculation of effective Dielectric constant (ε_{reff})

By the formula:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}[1 + 12\frac{h}{W}]^{\frac{1}{2}}$$

3. Calculation extension Length (ΔL)

ΔL Is used for calculating resonant frequency of Micostrip antenna

By the formula:

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

4. Calculation of Length (L)

By the formula:

$$L = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} - (2 \times \Delta L)$$

5. Calculation of inset depth

By the formula:

$$G_{12} = \frac{1}{120\pi^2}\int_0^{\pi}\left[\frac{\sin\left(\frac{K_0 \omega}{2}\cos\theta\right)}{\cos\theta}\right]^2 J_0(K_0 L \sin\theta) Sin^3\theta$$

6. Input resistance for the inset-feed is given approximately by:

$$R_{in}(y = y_0) = \frac{1}{2(G_1 + G_2)}cos^2\left(\frac{\pi}{L}y_0\right)$$

$$= R_{in}(y_0 = 0)cos^2\left(\frac{\pi}{L}y_0\right)$$

7. Calculation of *Return loss*

By the formula:

Return loss= $-10 \times log_{10}(1 - \Gamma^2)$

8. Calculation of V.S.W.R

By the formula:

$$VSWR = \frac{(1 + abs(\Gamma))}{(1 - abs(\Gamma))}$$

9. Calculation of directivity

By the formula

$$directivity = 4 \times \pi\frac{U_{max}}{P_{rad}}$$

VI. RESOURCES

a) Software requirements Ansoft HFSS
b) Hardware requirements FR4, photolithography film, SMA connectors or N type connectors
c) Testing & measurements VSWR, return loss measurement

VII. SOFTAWARE ANALYSIS

In order to achieve the goal of best performance of MSA designer uses simulation tools during different steps of the designing process. There is variety of simulation software available in last decade [7] to help the designer in deciding the material, plating and dimensions along with the thickness before actually fabricating the same.
Ansoft HFSS 13 is an interactive software package for calculating the electromagnetic behavior of structure. Generalized s-parameters renormalized to specific port impedance can solve a wide range of electromagnetic problem.

X. RESULTS OPTIMIZATION

Figure 3 shows return loss for Gold, Hal and Nickel as Patch Plating materials for RMSA. It is found that return loss for Gold plating is better i.e.-49.78 as that of HAL plating i.e. -42.15 while return loss of Nickel plating material i.e. -39.12 is acceptable. The standard antenna performance Return Loss ≥ −10 dB.

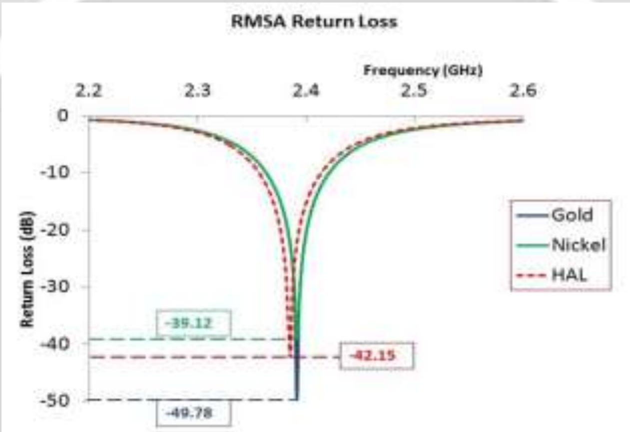

Fig.3 Return loss curve

Figure 5.19 shows VSWR for Gold, HAL and Nickel as Patch Plating materials for RMSA. It is found that VSWR for Gold plating is better i.e.1.00 as that of HAL plating i.e.1.01 while VSWR of Nickel plating material i.e. 1.09 is acceptable.
The standard antenna performance VSWR is between 1 and 2.

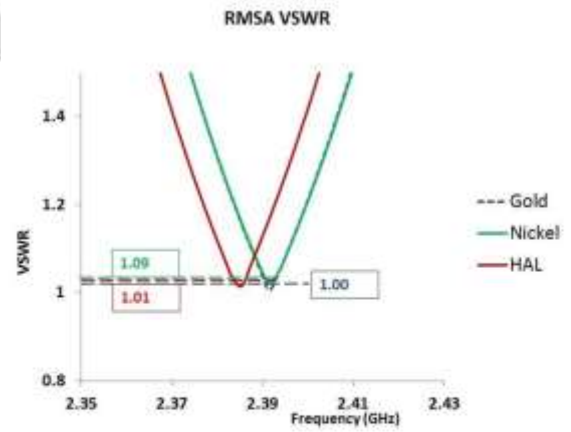

Fig. 4 VSWR Curve

Following are the results of RMSA antenna design

Plating Material	**Bandwidth**	**VSWR**	**Return Loss**	**Rin (Ω)**
Gold	58.0	1.00	-49.78	48.13
HAL	57.3	1.01	-42.15	49.24
Nickel	58.1	1.09	-39.12	49.72

Table shows HFSS results for RMSA with 1.6 mm substrate material with plating variations. Using HFSS parameters F_{max} , F_{min} , F_C , RL, V SW R are measured using graph. From the above results one can calculate the bandwidth and percentage bandwidth.

Calculation of Bandwidth:

$BW_{Gold} = F_{max} - F_{min} = 2.4214 - 2.3634 = 58.00$ M Hz

Calculation of % Bandwidth:

$\%BW_{Gold} = [F_{max} - F_{min}] / F_C = [2.4214 - 2.3634] / 2.3914 = 2.42$

Similarly bandwidth and % bandwidths with Hal and Nickel as patch plating materials are calculated. The calculated bandwidth with Hal and Nickel as patch plating materials materials are 57.3 and 58.1 respectively. The calculated % bandwidth with Hal and Nickel as patch plating materials are 2.40 and 2.42 respectively.

Smith charts are reflecting the input impedances for three different patch plating materials considered for HFSS design. Figure 5.20, Figure 5.21 and Figure 5.22 shows smith chart of FR4 with Gold, Hal and Nickel as patch plating materials for RMSA.

Using HFSS smith charts are observed and input impedance of antenna is measured for proper impedance matching theoretical input impedance is around 50 Ω.
Here coaxial feeding technique is used to get good results of transmission and reception and vice versa.
From Smith chart input impedances for microstrip antenna with Gold, Hal and Nickel as patch plating materials are 48.13 Ω, 49.24 Ω and 49.72 Ω respectively.
Figure 5 shows Smith Chart for RMSA with Gold Patch Plating. This Smith chart is analyzed for calculation of Input Impedance of RMSA with Gold patch plating. The observed simulation result through Smith chart shows that the R_{in} = 48.13 Ω.

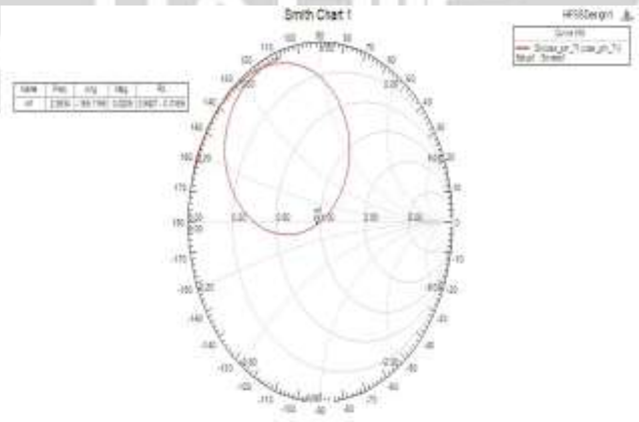

Figure 5: RMSA Smith Chart with Gold Patch Plating Material

Figure 6 shows Smith Chart for RMSA with Hal Patch Plating. This Smith chart is analyzed for calculation of Input Impedance of RMSA with Hal patch plating. The observed simulation result through Smith chart shows that the R_{in} = 49.24 Ω.

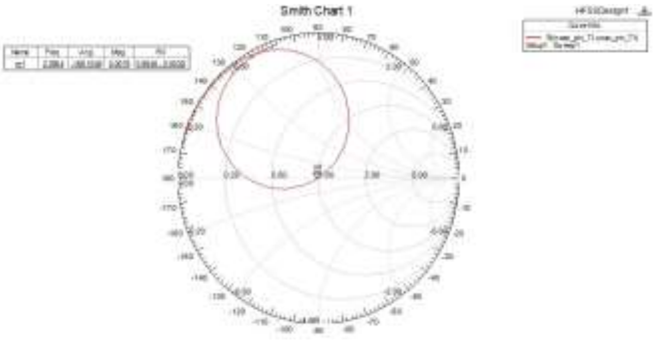

Figure 6: RMSA Smith Chart with Hal Patch Plating Material

Figure 7 shows Smith Chart for RMSA with Nickel Patch Plating. This Smith chart is analyzed for calculation of Input Impedance of RMSA with Nickel patch.

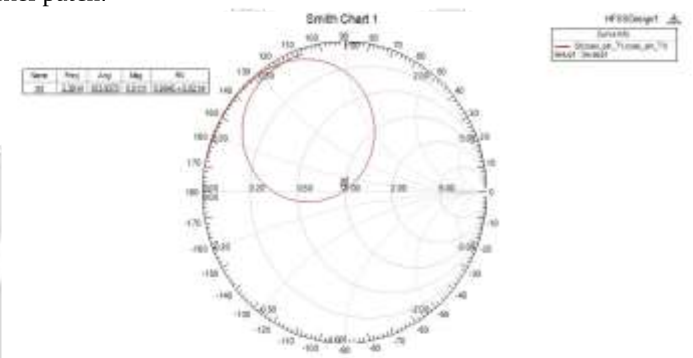

Figure 7: RMSA Smith Chart with Nickel Patch Plating Material

CONCLUSION

From simulation result, it is found that return loss for Gold plating is better i.e.-49.78 as that of HAL plating i.e. -42.15 while return loss of Nickel plating material i.e. -39.12 is acceptable.

VSWR for Gold plating is better i.e.1.00 as that of HAL plating i.e.1.01 while VSWR of Nickel plating material i.e. 1.09 is acceptable.

Properties of gold plated microstrip patch antennas are better as compared to HAL & Nickel plating.

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