

Design and simulation of rectangular patch microstrip antenna with inset feed for S-band application

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Abstract. Microstrip antenna is one of the most applied antennas for various radio applications as its low profile and high performances. This paper discusses design and simulation of the rectangular patch microstrip antenna (RPMA) for S-band radio by using inset feeding. Initially, theoretical calculation was performed, followed by performance evaluation by using AWR simulator. Inset deep iterations were conducted through repeated simulation adjustment to obtain optimal design. Based on the concluded simulation adjustment, the minimum achieved VSWR is 1.056 to get bandwidth of 104.5 MHz (3.1636 – 3.2681 GHz). The minimum return loss that can be achieved is -31.33 dB with gain of 5.777 dB.

1. Introduction

The rectangular patch micro strip antennas (RPMAs) have several feeding techniques, such as inset feed (Barman et al. 2017), microstrip line feed (Rambe et al. 2013), probe-coax (Rambe 2012), aperture coupled (Civerolo 2011) and electromagnetically coupled feed (Abraham and Mathew 2015).

Inset feed is a simple and general feeding for patch antennas. Inset feed uses substrate efficiently as it requires small patch intervention. Many antenna applications use this feeding techniques such as for wireless LAN application (Shankar and Chaurasiya 2015), Bluetooth (Barman et al. 2017), GPS and Radar (Putranto et al. 2017). Inset feed performances are not homogenous for all applications depending upon the working frequency, patch shape, patch materials and others.

This paper reports RPMA design by using inset feed. The FR4 substrate for the designed antenna has parameter ϵ_r of 4.4 with thickness of 1.6 mm and work at S-Band frequency of 3.2 GHz.

2. Antenna design

A rectangular patch micro strip antenna (RPMA) with inset feed is shown in Figure 1. Its fed dimension slightly changes the RPMA shape. The dimension is width (W_i) and length (L_i). Even the RPMA shape is adjusted; the approximated equation can use the original RPMA model, which is expressed in the following equations.

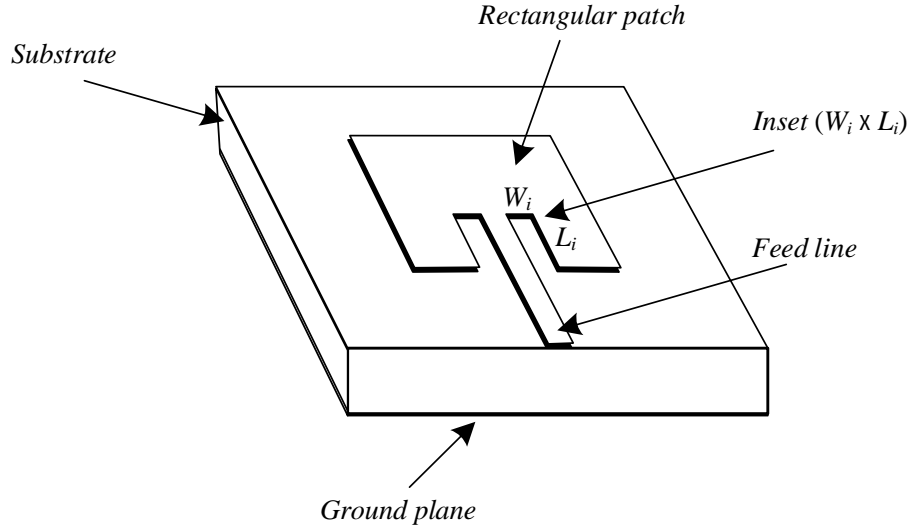


Figure 1. RPMA with inset feed

a. Rectangular patch

Dimension of wide (W) and length (L) of the RPMA patch are determined by Equation 1 and Equation 2 (Balanis, 2005)(Rambe and Abdillah, 2018).

$$W = \frac{c}{2f_r \sqrt{\frac{(\epsilon_r + 1)}{2}}} \quad (1)$$

$$L = L_{eff} - 2\Delta L \quad (2)$$

where,

$$L_{eff} = \frac{c}{2f_r \sqrt{\epsilon_{reff}}}$$

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

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left(\frac{1}{\sqrt{1 + 12h/W}} \right)$$

Constant c is free-space velocity of electromagnetic wave (3×10^8 m/s), ϵ_r and h are dielectric constant and thickness of the substrate, and f_r is resonant frequency. In this paper, $\epsilon_r = 4.4$, $h = 1.6$ mm and $f_r = 3.2$ GHz.

b. Feed line:

The size of W_0 is obtained by adjusting the expecting characteristic impedance (Z_c)(Balanis 2005) by using Equations 3. The expected characteristic impedance within this paper is 50 Ohm.

$$Z_c = \begin{cases} \frac{60}{\sqrt{\epsilon_{\text{reff}}}} \ln \left[\frac{8h}{W_0} + \frac{W_0}{4h} \right], & \frac{W_0}{h} \leq 1 \\ \frac{120\pi}{\sqrt{\epsilon_{\text{reff}}} \left[\frac{W_0}{h} + 1.393 + 0.667 \ln \left(\frac{W_0}{h} + 1.444 \right) \right]}, & \frac{W_0}{h} > 1 \end{cases} \quad (3.a)$$

$$(3.b)$$

The feed line size (L_0) can be calculated by using Equation 4.

$$L_0 = \frac{1}{4} \lambda_g \quad (4)$$

Where: $\lambda_g = \frac{c}{f_T \sqrt{\epsilon_T}}$

c. Ground plane:

The dimensions of the RPMA ground plane is approximated by using Equation 5 and 6 (Gupta et al. 2014):

$$Lg = 6h + L \quad (5)$$

$$Wg = 6h + W \quad (6)$$

d. Inset:

The inset deep or length, denoted by L_i , is determined by the available feed line and the dimension of the designed ground plane. Meanwhile, the inset width (W_i) should be carefully chosen based on the results of AWR simulations.

3. Simulation results

The theoretical calculation is actually an initial step in order to achieve the intended RPMA performances. Approximation in design should be performed as irregularity of realized dimension, simplification of material constant and variables as well as non-ideal components always exist. Figure 2 shows the characteristics of the theoretical designed RPMA with inset feed. This graph is an initial pattern of return loss and should be considered as an initial characteristic.

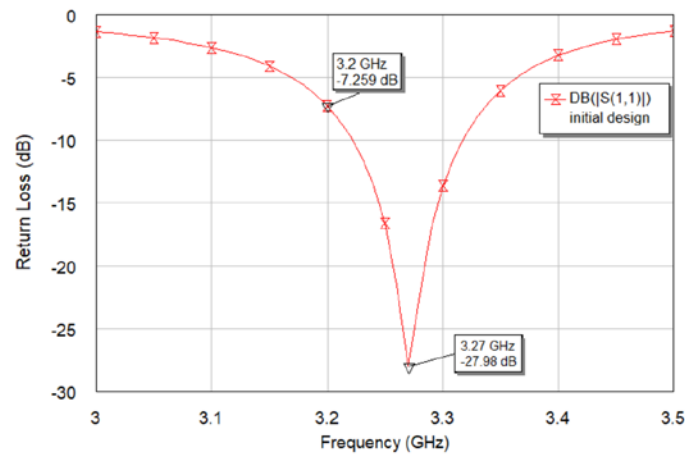


Figure 2. Return loss of the initial design

Initial design obtained return loss of -7.259 for the expected working frequency of 3.2 GHz. The minimum return loss achieves -27.98 dB but the frequency is shifted to 3.27 GHz.

Adjustment should be performed so that lower return loss as expected can be achieved. Inset length adjustment can be performed by using the AWR simulations as depicted in Figure 3.

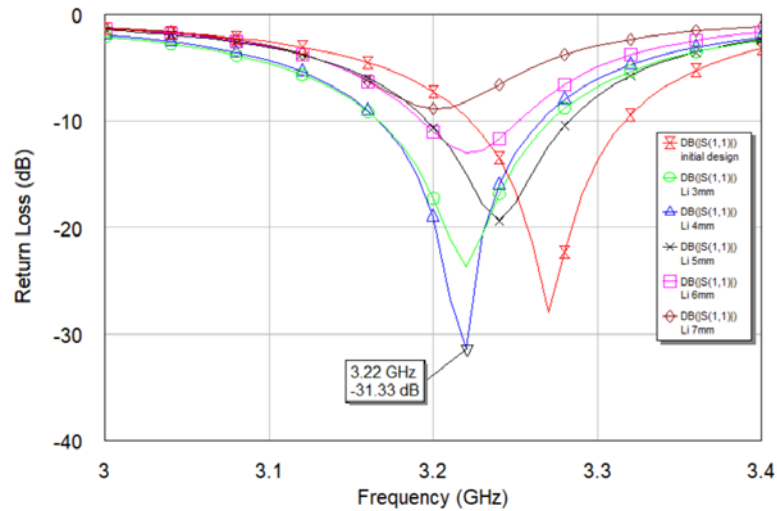


Figure 3. Return loss pattern as result inset length adjustment

By considering the return loss pattern variations, the optimal characteristic for the expected design can be observed. The best position is figured up when inset length is 4 mm (Figure 3 with Li 4 mm). The optimal return loss value is -31.33 dB on frequency of 3.22 GHz. At this condition, the achieved VSWR pattern is as plotted in Figure 4.

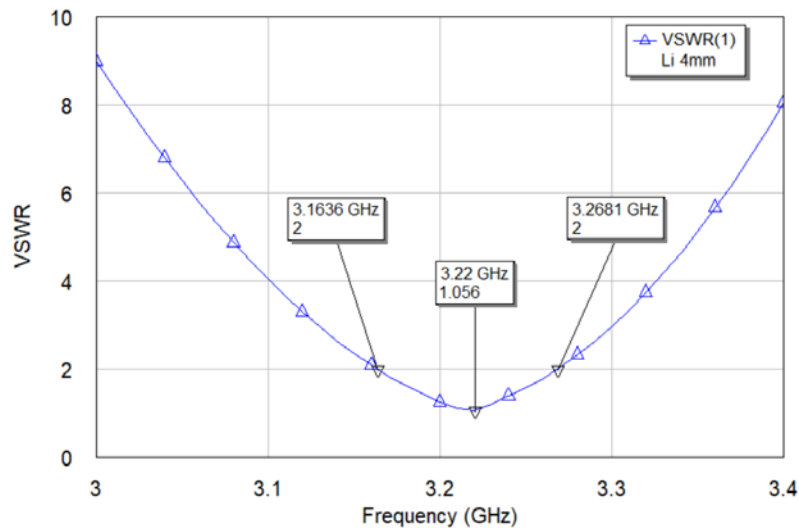


Figure 4. VSWR pattern of the optimal design

Based on this figure, the minimum achieved VSWR is 1.056 when working pada on frequency of 3.22 GHz. The working bandwidth at this position can be calculated as (3.2681 – 3.1636) GHz or 104.5 MHz

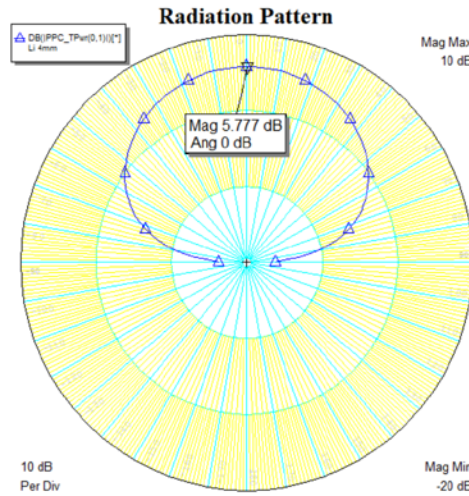


Figure 5. Radiation Pattern

Figure 5 shows the optimal directional radiation pattern with gain achieving 5.777 dB. The geometry of the designed RPMA with inset feed is illustrated in Figure 6.

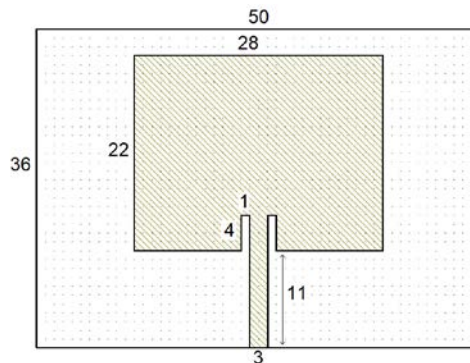


Figure 6. Designed RPMA with inset feed geometry (in mm)

4. Conclusion

This paper has presented design and simulation of the RPMA with inset feed. The expected design has been found that works in S-Band frequency of 3.2 GHz. The optimal design is achieved when inset length is 4 mm. This optimal design occurs in frequency of 3.22 GHz, producing minimum return loss of -31.33 dB and minimum VSWR of 1.056. The antenna has bandwidth of 104.5 MHz with gain achieves 5.777 dB.

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