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Miniaturization of rectangular patch microstrip antenna by using complementary split ring resonator

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Abstract. The mobile device miniaturization requires the applied antenna microstrip size be much smaller to reduce the radio front-end load. This paper discusses the rectangular patch microstrip antenna miniaturization by using complementary split ring resonator (CSRR) structure for 3G mobile communication system on 2.1 GHz. The structure is implemented on the microstrip ground plane. Simulation evaluation by using the AWR simulator shows that the CSRR structure is able to reduce antenna dimension about 62.71% from 3192 mm^2 (56mm×57mm) to 1190 mm^2 (34mm×35mm). Beside miniaturization, VSWR and return loss also experience improvements about 1.05 and -33.83 dB subsequently. Bandwidth increment about 70.37% is also achieved.

1. Introduction

Generally, antenna dimension is inversely proportional to the working frequency. The lower the working frequency, the greater the antenna the antenna size. This problem emerges on mobile wireless applications on ultra-high frequency (UHF) band of 300 MHz – 3 GHz. The smaller size antenna dimension is preferred to support miniaturized devices such as handphones and tablets.

Some existing methods in miniaturizing the antenna dimension such as defected ground structure (DGS) [1],[2], fractal [3] [4] and metamaterial [5] [6] have been proposed. This paper focuses on the use the complementary split ring resonator (CSRR) for reducing the rectangular patch microstrip antenna (RPMA) working on wide band code division multiple access (WCDMA) frequency band of 2.1 GHz. The CSRR method has been implemented in [7] to reduce the 50% antenna dimension. The evaluated antenna is realized by using FR4 substrate with dielectric constant of 4.4 and 1.6 mm thickness.

2. The RPMA design equations

The RPMA design is initiated by defining the antenna dimension that works on the expected frequency: patch width and length. These sizes are correlated with the effective substrate dielectric constant (ε_{reff}) which is determined by the Equation 1 [8], [9]):

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{-\frac{1}{2}} \quad (1)$$

So that the antenna length (L) is calculated by using Equation 2:

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{reff}\mu_0\varepsilon_0}} - 2\Delta L \quad (2)$$

With the ΔL (additional patch length) is defined as:

$$L_{eff} = L + \Delta L \tag{3}$$

$$\frac{\Delta L}{h} = 0{,}412\frac{(\varepsilon_{reff}+0{,}3)(\frac{W}{h}+0{,}264)}{(\varepsilon_{reff}-0{,}258)(\frac{W}{h}+0{,}8)} \tag{4}$$

In order to obtain microstrip patch width (*W*), Equation 5 is employed [8], [9]:

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_{r+1}}} = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \tag{5}$$

where c is light speed 3×10^8 m/s, ε_r is substrate dielectric constant, f_r is resonant frequency, h is substrate thickness and L_{eff} is effective patch length.

3. The CSRR design

Figure 1 illustrates the CSRR design implemented throughout this paper. The CSRR appears like a rectangular ring with the thickness *R* separated by a gap (*G*) placed on the antenna ground plane. The CSRR implementation is initiated by etching the inner ring with size of W1 and L1. Afterwards, the outer ring is added (W2 and L2). Both rings are separated by distance of *D*. To realize the expected design, the structure dimension are selected by using W2=9mm, L2=18mm, W1=3mm, L1=13mm, R=1mm, D=2mm and G=2mm.

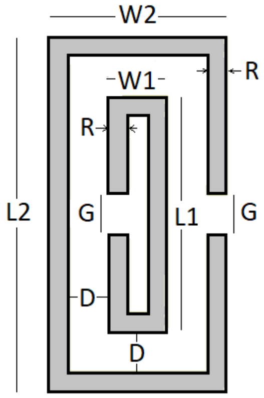
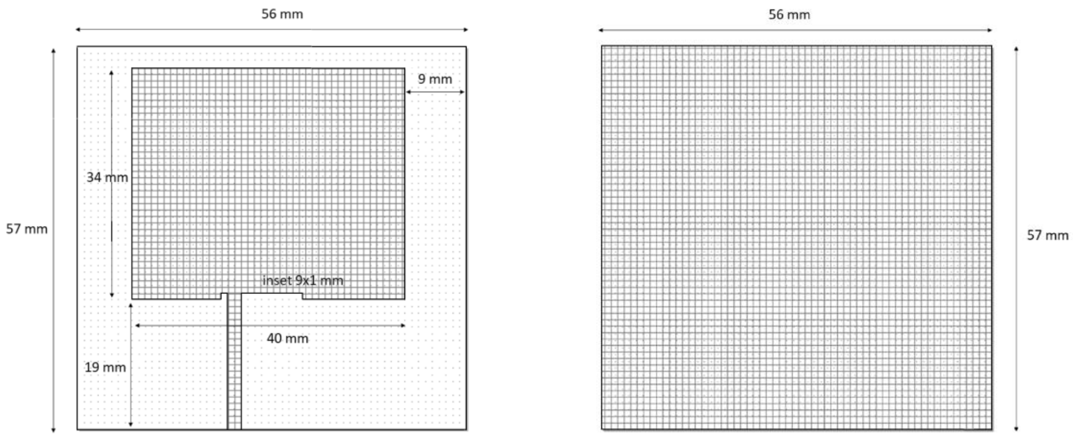


Figure 1. The CSRR structure

4. Simulation Results

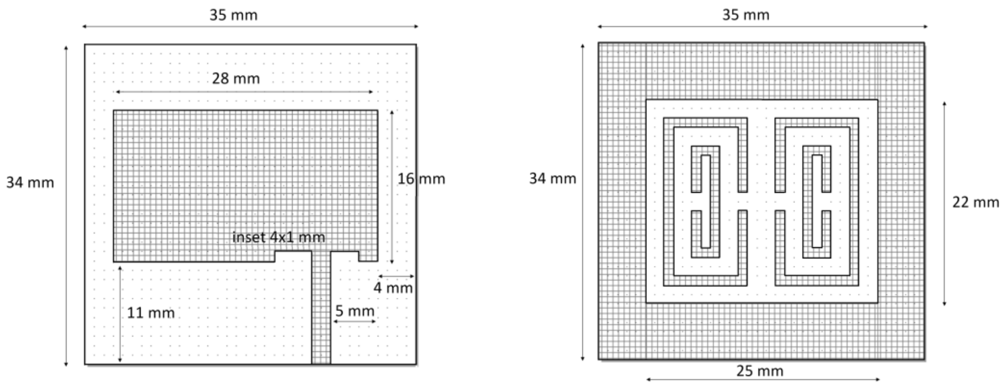
Figure 2 shows the conventional RPMA design for wireless applications on 2.1 GHz. The optimum result is achieved with conventional RPMA dimension of 57×56 mm^2 and rectangular patch of 40×34 mm^2.

Figure 3 shows the RPMA design with CSRR structure. Based on the optimal result given by simulation, the RPMA with CSRR structure has dimension of 35×34 mm^2 and rectangular patch of 28×16 mm^2. By using this size, the expected design is achieve, this means the CSRR is successfully minimizing the RPMA dimension as 35×34 mm^2 is lower than 57×56 mm^2. The dimension comparison of both conventional RPMA and the minimized one is shown in Table 1. Further, the return loss and VSWR generated by both antennas are presented in figure 4 and figure 5.



(a) top view (b) button view

Figure 2. Conventional RPMA



(a) top view (b) button view

Figure 3. RPMA with CSRR structure

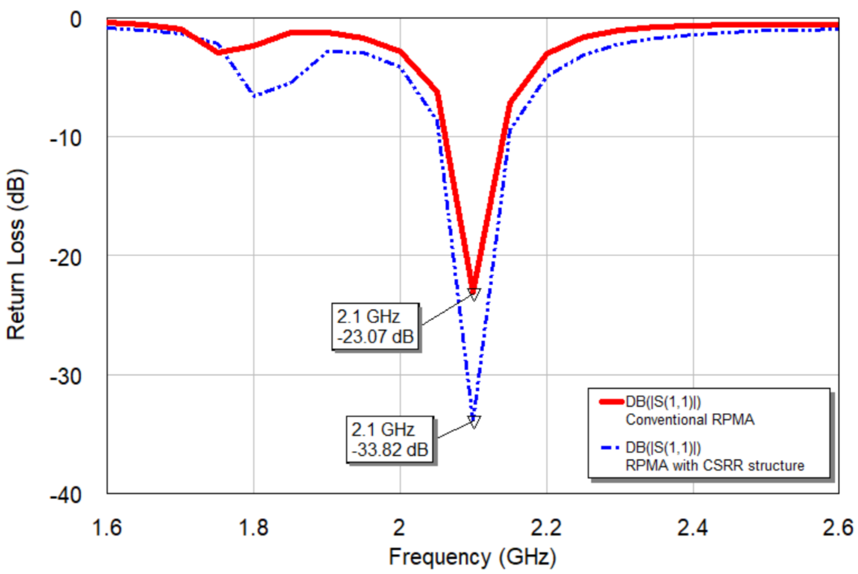


Figure 4. Return loss (S11)

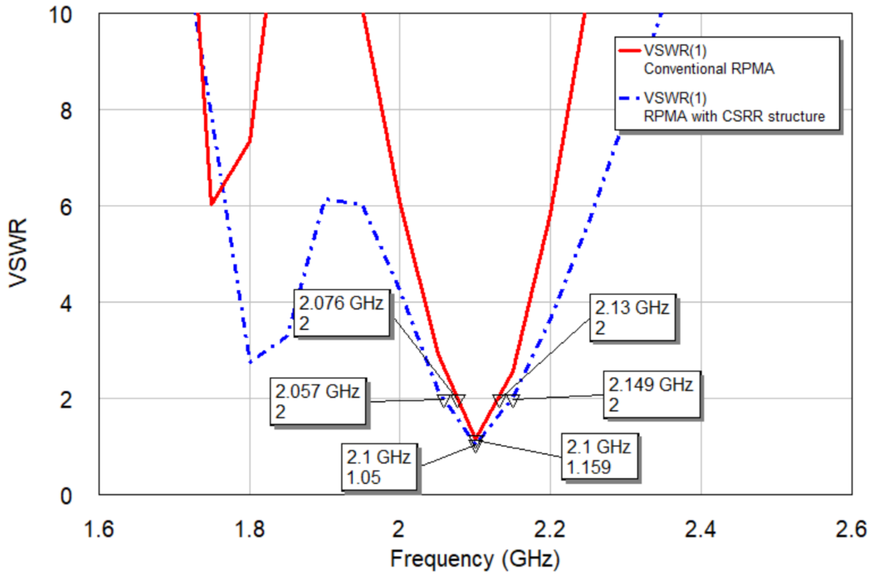


Figure 5. VSWR

The return loss value on resonant frequency of 2.1 GHz of the conventional RPMA is -23.07dB. The CSRR structure implementation on the ground plane causes the return loss value decreases to -33.82dB. Meanwhile, the bandwidth of the conventional RPMA on VSWR ≤ 2 is 54 MHz (2.13 GHz – 2.076 GHz) and the minimum VSWR is 1.159. These values are improved by CSRR structure addition, where the bandwidth of VSWR ≤ 2 becomes 92 MHz (2.149 GHz – 2.057 GHz) with minimum VSWR is 1.05.

Table 1. Antenna dimension comparison

	Conventional RPMA	RPMA with CSRR structure	Annotation
Antenna dimension	57×56 mm (3192 mm^2)	35×34 mm (1190 mm^2)	Reduction=62.17%
Patch Dimension	40×34 mm (1360 mm^2)	28×16 mm (448 mm^2)	Reduction=67.06%
Bandwidth	54 MHz	92 MHz	Enhancement=70.37%

5. Conclusion
This paper has evaluated the RPMA miniaturization by using the CSRR structure implemented on the RPMA ground plane. Based on simulation results, the CSRR structure is able to reduce the RPMA dimension up to 62.17% compared to the conventional one when working on 2.1 GHz. The rectangular patch dimension is also experiencing reduction by 67.06%. Furthermore, the obtained bandwidth is also greater, achieving 92 MHz, compared to only 54 MHz in conventional RPMA. These facts prove that the CSRR structure is able to minimize the RPMA dimension on the assessed WCDMA frequency of 2.1 GHz.

6. Acknowledgment
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7. References

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