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Optimizing Rectangular Patch Antenna with Microstrip Line Feed Using Single Stub

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Abstract

Antenna microstrip is one of the antenna types that have been chosen to support small and lightweight equipments. However, its performance is poor in conventional form. This paper discussed the optimization of a single stub rectangular patch antenna with a microstrip feed line. The simulation results showed an increase in return loss up to 139 %, a 14% increment in bandwidth and a 2% gain improvement. The measurement obtained a return loss of -45.61 dB, 106 MHz bandwidth at VSWR ≤ 2 with about 5.6 dB gain.

1. Introduction

Microstrip antenna consists of a radiating patch, dielectric substrate, a feed line and a ground plane. Figure 1 shows microstrip antenna configuration.

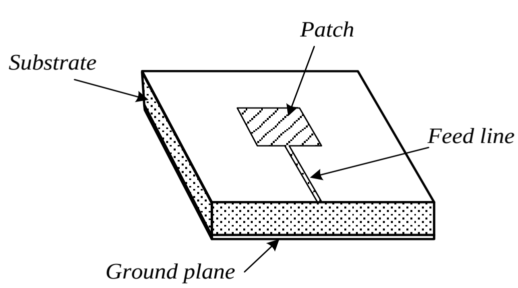

Figure 1. The microstrip Antenna

Microstrip antenna concept was first proposed by Deschamps in 1953 and got a patent in 1955 for the names of Gutton and Baissinot. The rapid development of microstrip antenna started in 1970s, 20 years later as the dielectric substrates with a low loss tangent, supportive thermal and mechanical properties were available [1].

Various development and modifications have been made to the microstrip antenna to improve the performance, such as array [2], aperture coupled [3], metamaterial [4], defected ground Structure (DGS) [5], photonic bandgap structures (PBG) [6], and electromagnetic bandgap (EBG) [7]. This paper employed a stub on the microstrip feed line for a rectangular patch antenna. By applying a stub on feed line, the performance of the rectangular patch antenna can be optimized.

2. Antenna Design

The width (W) and length (L) properties of the rectangular patch antenna are given by [1][8][9]:

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

$$L = L_{eff} - 2\Delta L \tag{2}$$

$$L_{eff} = \frac{c}{2 f_r \sqrt{\varepsilon_{reff}}} \tag{3}$$

$$\Delta L = 0.412h \frac{\left(\varepsilon_{reff} + 0.3\right)\left(\frac{W}{h} + 0.264\right)}{\left(\varepsilon_{reff} - 0.258\right)\left(\frac{W}{h} + 0.8\right)} \tag{4}$$

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(\frac{1}{\sqrt{1 + 12h/W}}\right) \tag{5}$$

Constant c is velocity of light (3x10^8 m/s), ε_r is the dielectric constant of the substrate, f_r is resonant frequency, h is thickness of the substrate, L_{eff} is the effective patch length, ΔL is the length extension and ε_{reff} is the effective dielectric constant of the substrate.

The characteristic impedance of the narrow microstrip line for $w/h \leq 2$ is given by [10]:

$$Z_0 = \frac{119{,}9}{\sqrt{2(\varepsilon_r + 1)}}\left[\ln\left\{\frac{4h}{w} + \left\{\left(\frac{4h}{w}\right)^2 + 2\right\}^{1/2}\right\} - \frac{(\varepsilon_r - 1)}{2(\varepsilon_r + 1)}\left(0{,}4516 + \frac{0{,}2416}{\varepsilon_r}\right)\right] \tag{6}$$

and for $w/h \geq 2$:

$$Z_0 = \frac{376{,}7}{\sqrt{\varepsilon_r}}\left[\frac{w}{h} + 0{,}8825 + 0{,}1645\left(\frac{\varepsilon_r - 1}{\varepsilon_r^2}\right) + \frac{\varepsilon_r + 1}{\pi\varepsilon_r}\left\{1{,}4516 + \ln\left(\frac{w}{2h} + 0{,}94\right)\right\}\right]^{-1} \tag{7}$$

Where Z_0 = characteristic impedance

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h = thickness of the substrate
w = width of microstrip line
ε_r = dielectric constant of the substrate

The selected dielectric material for antenna design in this paper is FR4 (ε_r = 4.4 and h = 1.6 mm) and the patch was designed to operate at a resonant frequency of 2.4 GHz. The length and width were calculated to be L = 38.04 mm and W = 28.44 mm. The width of Z_0 = 50 Ω line is 3 mm.

3. Simulations and Experimental Result

The software used to simulate antenna design is the AWR Design Environment. After several trials and errors, the best results were achieved for return loss -11.56 dB and VSWR 1.7187. A single stub was designed to optimize this outcome. Figure 2 and Figure 3 show the variations of the single stub design.

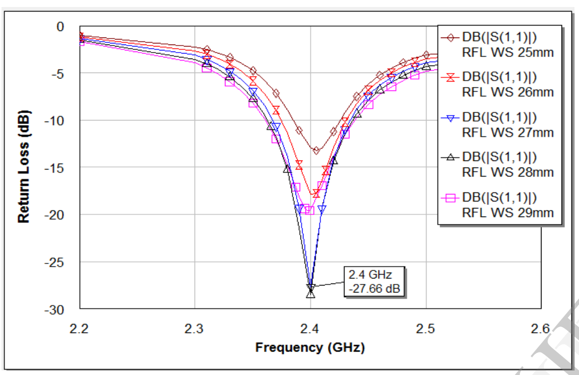

Figure 2. The variations of stub length

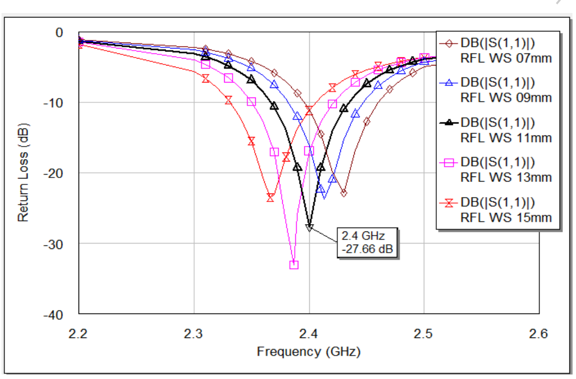

Figure 3. The variations of stub position

After simulating the single stub design, the optimum of return loss is found to be -27.66 dB and VSWR is to be 1.0864. Figure 3 and Figure 4 show the comparisons of return loss and VSWR respectively for the antenna design without stub (Rect Feed Line) and with single stub (Rect Feed Line With Stub).

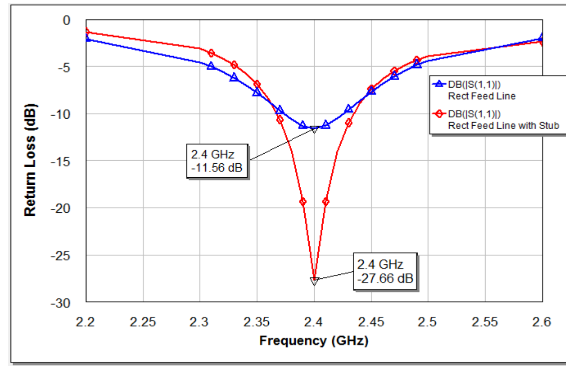

Figure 4. The comparison of return loss

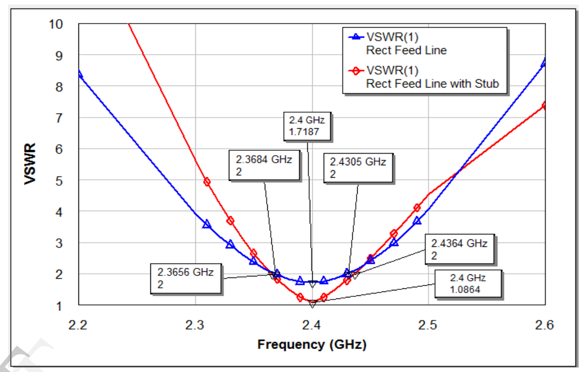

Figure 5. The comparison of VSWR

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Based on simulation result, the return loss increases about 139 %. Bandwidth increases from 62.1 MHz (2.4305 GHz – 2.3684 GHz) to 70.8 MHz (2.4364 GHz – 2.3656 GHz) at VSWR ≤ 2.

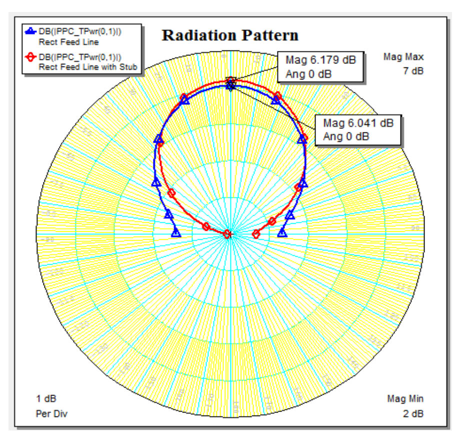
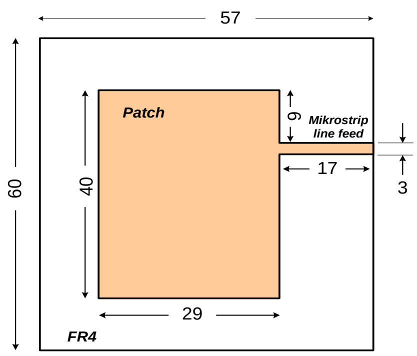
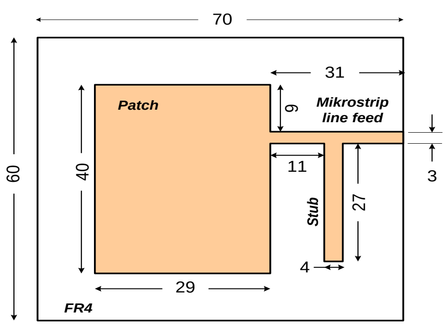


Figure 6. The comparison of radiation pattern

The comparison of the radiation pattern is shown in Figure 6. The gain increases about 2 %. The geometry (in mm) of the designed antenna is shown in Figure 7.



(a)



(b)

Figure 7. Geometry of the designed antenna: (a) without stub (b) with single stub

Based on the design given in Figure 7 (b), the antenna was fabricated and measured. Figure 8 and 9 show the comparison simulated and measured return loss and VSWR from antenna.

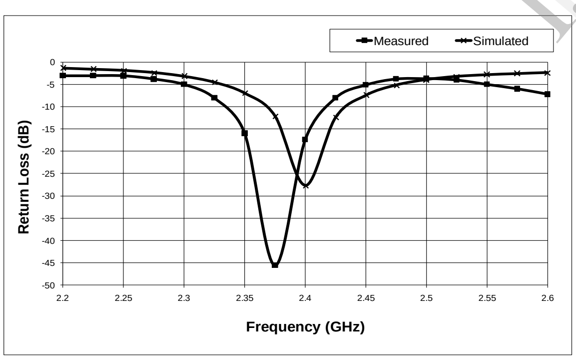


Figure 8. The simulated and measured return loss

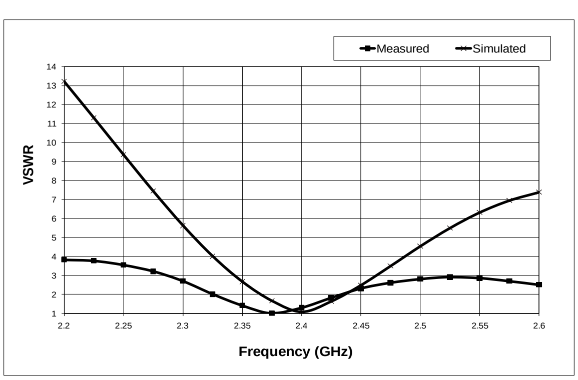


Figure 9. The simulated and measured VSWR

From Figure 8, the minimum return loss is -45,61 dB at frequency 2.380 GHz. Figure 9 shows that the frequency is 2.326 GHz and 2.432 GHz at VSWR ≤ 2,. Therefore the bandwidth is :

bandwidth = 2.432 GHz – 2.326 GHz = 106 MHz

or :

$$\text{bandwidth} = \frac{2.432\ GHz - 2.326\ GHz}{2.380\ GHz} \times 100\% = 4.45\ \%$$

Figure 10 shows the pattern radiation of the measured antenna. The achieved gain is about 5.6 dB.

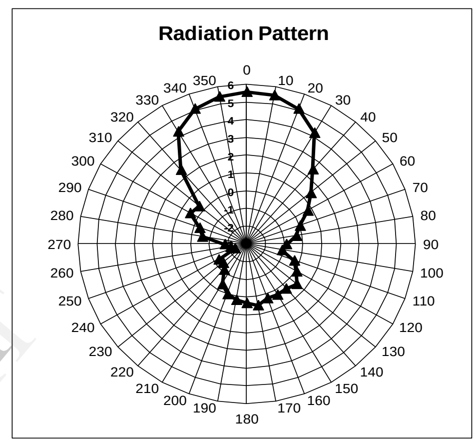


Figure 8. The measured radiation pattern

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4. Conclusion

The rectangular patch antenna with microstrip feed line has been analyzed. The performance of the microstrip antenna can be optimized by using a single stub. The proposed optimization successfully increases the return loss, VSWR, bandwidth, and gain. The measurement demonstrates that the antenna has 106 MHz bandwidth (at VSWR ≤ 2) and 5,6 dB gain.

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