Analysis of Parasitic Patch for Axial Ratio Bandwidth Enhancement in Circularly-polarized-slotted Microstrip Antenna

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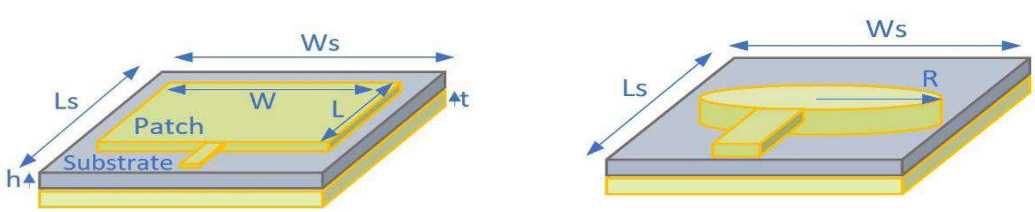
Abstract— Analysis of the circularly-polarized slotted microstrip antenna in L-Band in 2–3 GHz is analyzed and discussed in this paper. The analyzed antenna is proposed for nanosatellite for electron density and scintillation measurement of ionosphere research. The requirements for nanosatellite antenna have physical specifications, such as lightweight, thin layer and small size with length and width smaller than or equal to 100 mm × 100 mm and electrical specification, such as the axial ratio (AR) lower than 3-dB, reflection coefficient (S_{11}) lower than −10 dB. The proposed antenna is simulated based on computer simulation technology (CST) simulator with single proximity-coupled feeding, single patch. The proposed antenna consists of the ground with a circular and rectangular slotted patch on the upper side and the shifted feed line at the bottom side. Between the ground patch and the feeding line have a substrate which has a dielectric constant of 2.17, the dissipation factor of 0.0005 and dielectric thickness of 1.6 mm. The analysis is performed by varying the length (l), width (w) and form (F) such as rectangular, circular and elliptical of the parasitic patch on upper side. The effect of that antenna parameters l, w and F to impedance bandwidth (IBW), the 3-dB axial ratio bandwidth ($ARBW$) will be analyzed and presented. The characteristic of the analyzed antenna has a good agreement between simulation and measurement result. The length, width and form of the parasitic patch has dominant effects to the 3-dB axial ratio bandwidth and position of the feed line has the dominant effect to the reflection coefficient. The simulated result shows that a parasitic with rectangular form can generate the 3-dB axial ratio bandwidth more than 1 GHz from 2.1–3.2 GHz.

1. INTRODUCTION

Microstrip antennas became very popular in many applications such as radar, satellite [1–4]. These antennas consist of a metallic patch on the upper side, a substrate and metallic patch on the lower side. The metallic patch can take many different patterns. However, the rectangular and circular patches, are the most popular because of ease of fabrication and analysis. The microstrip antennas are low profile, simple and inexpensive to fabricate using modern printed-circuit technology. These antennas can be mounted on the surface of satellites, aircraft, and even mobile devices. Figures 1(a), 1(b) show the rectangular and circular/ellipse microstrip patches antennas, respectively.



(a) (b)

Figure 1: Rectangular and circular/ellipse microstrip patch. (a) Rectangular. (b) Circular/Ellipse.

For reference, the size of the analyzed rectangular patch microstrip was calculated as the transmission line model [5] for the following parameters: resonance frequency (f_r) of 2 GHz and resonance frequency (f_r) of 3 GHz, relative permittivity (ε_r) = 2.17, and substrate height (h) = 1.6 mm. The calculated patch size based on Figure 1, the patch width (W) is then

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} = 59.57\,\text{mm}, \text{ and for } 3\,\text{GHz} = 39.7\,\text{mm}$$

with $\frac{W}{h} > 1$, the effective permittivity is calculated by

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12\frac{h}{W}\right)^{1/2} = 2.09, \text{ and for } 3\,\text{GHz} = 2.06$$

The extension length (ΔL) due to the fringing field is calculated by

$$\Delta L = 0.412 \times h \frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8\right)} = 8.47\,\text{mm, and for } 3\,\text{GHz} = 8.4\,\text{mm}$$

moreover, the patch length L is therefore

$$L = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}} - 2\Delta L = 50.13\,\text{mm, and for } 3\,\text{GHz} = 33.1\,\text{mm}$$

For practical, the size of the substrate and the ground plane is around $6h$ larger than patch sizes,

$$\begin{aligned} L_s &= L + 6h = 59.73\,\text{mm}, \text{ and for } 3\,\text{GHz} = 42.7\,\text{mm} \\ W_s &= W + 6h = 69.17\,\text{mm}, \text{ and for } 3\,\text{GHz} = 49.3\,\text{mm} \end{aligned}$$

However, these basic designs and formulas generate a narrow impedance bandwidth and a narrow 3 dB axial ratio bandwidth. One method for generating the wideband microstrip antenna is realized by cutting slots inside the patch with appropriate patterns, which is fabricated on a thicker and lower dielectric constant substrate. Analysis of the effect of the slots on rectangular microstrip already discussed in [6, 7]. However, analysis for the combination of the circularly and rectangular slots patch antenna is unfound yet in the literature. In this paper, a study of the impact of parasitic patch parameters with 3 types (circular, ellipse and rectangular) to resonant frequencies, impedance bandwidth and 3 dB axial ratio bandwidth for a rectangular microstrip antenna was presented here.

2. ANTENNA GEOMETRY AND DESIGN

The microstrip antenna with a slot and parasitic patch was discussed on paper [8–10], and in this study be the basic design for analysis. For analysis the effect of the parasitic patch to 3 dB axial ratio bandwidth, there are three types of the parasitic patch: circular shape, an ellipse shape, and rectangular shape. Detail geometry and parameter of the analyzed antenna was showed in Figure 2 and tabulated on Table 1. For analysis, the parasitic patch placed on the same position x_p, y_p and the same area size.

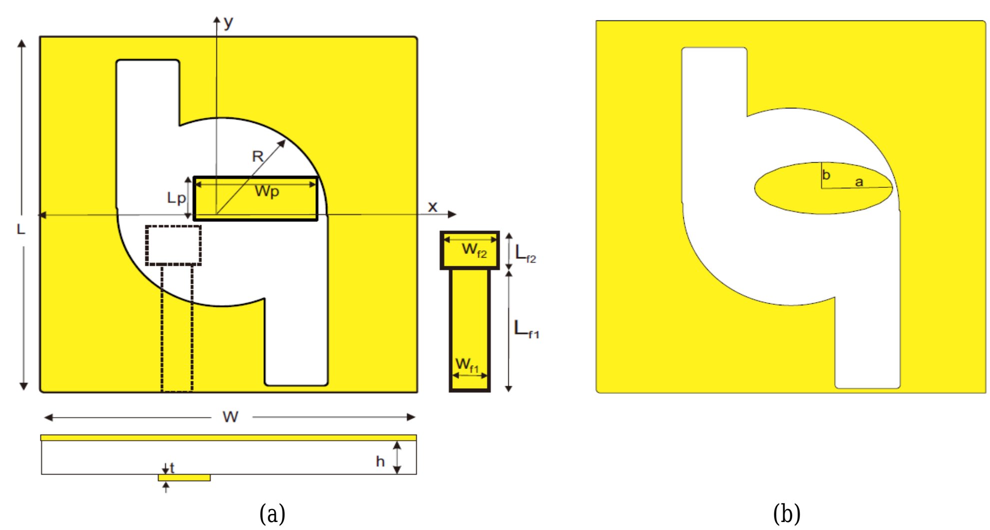


Figure 2: The geometry of the microstrip antenna, with three types of the parasitic patch. (a) Rectangular shape. (b) Circular/ellipse shape.

Microstrip feedline is described on the right side, and the edge profile of the antenna is drawn on the bottom side.

Table 1: Dimensions of the antenna models.

Parasitic Models	R (mm)	L_{s1} (mm)	L_{s2} (mm)	W_{f1} (mm)	W_{f2} (mm)	X_{f1} (mm)	X_p (mm)	Y_p (mm)	a (mm)	b (mm)	L_p (mm)	W_p (mm)
Circular	26.5	48	40	4	10	−9	8	5	10.88	-		
Ellipse	26.5	48	40	4	10	−9	8	5	7	16.9		
Rectangular	26.5	48	40	4	10	−9	8	5			12	30

The x_p, y_p for parasitic patch is $(8, 5)$, and the area size of circular is πa^2, ellipse is πab and rectangular is $L_p W_p$. So, for the same area of the parasitic size, the a is 10.88 mm for circular, the a is 7 mm and b is 16.9 mm for ellipse shape, and the L_p is 12 mm and W_p is 30 mm for rectangular shape.

3. RESULTS AND DISCUSSION

Figure 3 shows the reflection coefficient of the analyzed antenna for three types of parasitic shape. While the antenna uses the parasitic patch with circular and ellipse shape, they generate the reflection coefficient in frequency of 2.47 and 2.43 GHz, with impedance bandwidth of 1.39 and 1.16 GHz from 2.01–3.4 GHz and 2.01–3.17 GHz, respectively. While the parasitic patch uses rectangular shape, it generates the reflection coefficient in frequency of 2.19 GHz, with impedance bandwidth of 0.84 GHz in frequency 1.86–2.7 GHz. The center of the impedance frequency shift from higher to lower frequency, while the parasitic patch circular, ellipse and rectangular, respectively.

Figure 4 shows the axial ratio of the analyzed antenna for three types of parasitic shape. While the antenna uses the parasitic patch with a circular shape, they generate the axial ratio in the frequency of 2.32 GHz, with an axial ratio bandwidth of 0.45 GHz in the frequency of 2.04–2.49 GHz. While the antenna uses the parasitic patch with an ellipse shape, they generate the axial ratio in the frequency of 2.34 GHz, with an axial ratio bandwidth of 0.56 GHz in the frequency of 2.08–2.64 GHz

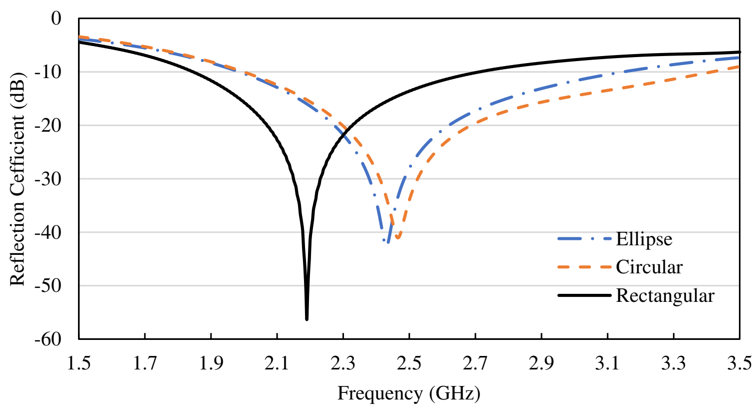


Figure 3: Reflection coefficient for parasitic patch with ellipse, circular and rectangular shape.

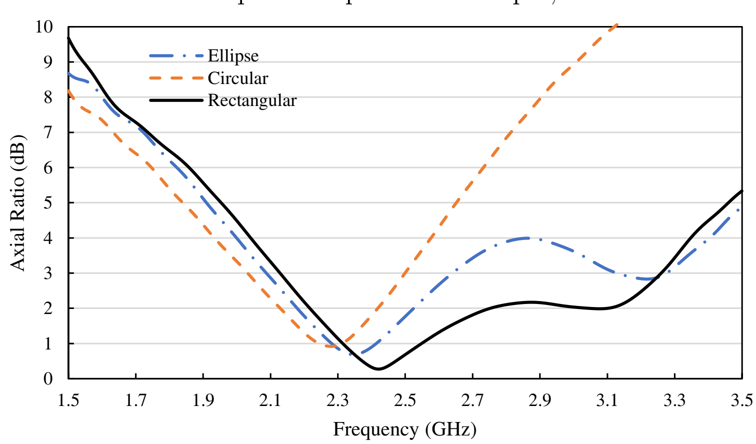


Figure 4: Axial ratio of the parasitic patch with ellipse, circular and rectangular shape.

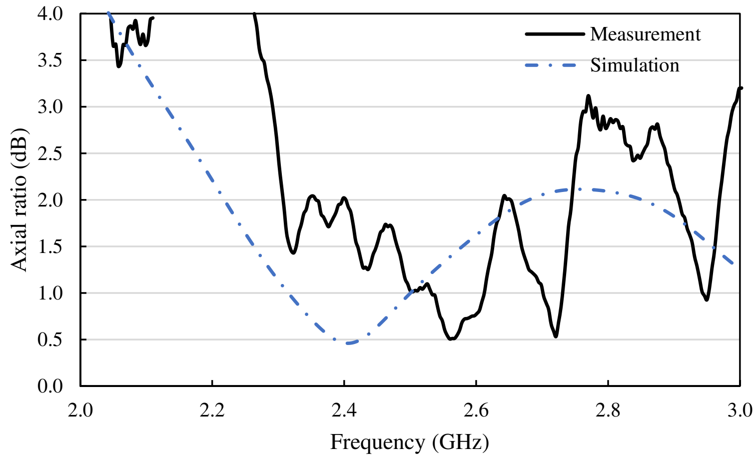


Figure 5: Comparison of the simulated and fabricated axial ratio for rectangular shape of the parasitic patch.

and in frequency 3.24 GHz, with axial ratio bandwidth of 0.14 GHz in frequency of 3.12–3.26 GHz. While the parasitic patch uses rectangular shape, it generates the axial ratio in the frequency of 2.19 GHz with the axial ratio bandwidth of 1.13 GHz in the frequency of 2.13–3.26 GHz. The circular parasitic patch generates narrower the 3 dB axial ratio bandwidth than ellipse shape. The rectangular shape can generate wider the 3 dB axial ratio bandwidth.

Fabrication and measurement were done to validate the simulation result. Figure 5 shows the comparison of the simulated and measurement result with a rectangular parasitic. It shows the axial ratio of the antenna has a good agreement, but the measured result has narrower axial ratio bandwidth compared to the simulated result.

4. CONCLUSION

For generating the wideband microstrip antenna is more commonly realized by cutting slots inside the patch with appropriate patterns. The simulated result shows that while the parasitic patch with circular and ellipse shape, it generates similar the reflection coefficient and the axial ratio. While the wide of the ellipse parasitic patch (a) is wider, the impedance center frequency shift to lower frequency. While the parasitic patch with a rectangular shape, it generates wider the axial ratio bandwidth. The simulated result and the measured result show a good agreement result, overthought the measured result narrower than simulated result.

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