Design of reflector microstrip patch antenna for LAPAN Surveillance UAV (LSU) application

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Abstract. In the modern days, the development of UAV’s communication encourages modified antenna design to fulfill its optimum requirement in aerodynamic system. PUSTEKBANG as aeronautic institution also develop this field through designing the antenna in compact model using microstrip patch design. This paper explains simulation result of microstrip patch antenna using reflecting layer in 5.8 GHz. The result shows that antenna gain increased more than twice at 5 dBi and return loss is getting lower in -20 dB by this proposed model than its previous conventional microstrip antenna design.

1. Introduction
Unmanned aircrafts are fixed-wing, rotor-wing, or lighter-than-air vehicles that fly without a human on board. It has been the subject of concerted research over the past few years [1][2][3][4][5], owing to their autonomy, flexibility, and broad range of application domains. Recently, the use of unmanned aerial vehicles (UAVs) as an alternative in certain activities such as monitoring large areas, delivery medical supplies, collecting images, surveillance of large territories and others, has significantly increased [6]. Also, UAV could have a number of advantages, such as, providing reliable and cost-effective wireless communication solutions for a variety of real-world scenarios. On the one hand, UAV can be used as aerial base stations (BSs) that can deliver reliable, cost-effective, and on-demand wireless communications to desired areas [7]. Besides that, the development of the UAV drives us to afford huge amounts of data in transmitting and receiving through wireless networking and communication scheme [8]. The UAV-based networking approach has become especially attractive in the recent years due to the availability of low-cost Commercial Off-The-Shelf (COTS) wireless equipment, such as IEEE 802.11 wireless LAN (“WiFi”) [9]. For example, by integrating compact, 802.11 wireless equipment into a small 94-inch wing-span UAV, we can readily create a powerful networking node in the air [10].

PUSTEKBANG as an aeronautics institution in Indonesia also develops UAV called LAPAN Surveillance UAV (LSU). Many series has been produced and developed such as LSU01, LSU 02, LSU03, and LSU05. For these series, the research of communication system still plays in coding and decoding between autopilot, communication module, and payload. Meanwhile, the design of antenna in UAV has not been intensively investigated yet, whereas position and antenna’s form play important role as aerodynamic system can work properly. From this issue, we configure design of LSU’s antenna that works in 5.8 GHz in thin design to reduce losses in dynamic movement during operation.
2. Antenna design

Considering the requirement of antenna in compact design, microstrip patch is chosen due to its thin shape and easy to configure. The design uses FR4 substrate with $\varepsilon_r = 4.3$ and loss tangent $= 0.025$. In addition, reflecting layer is used to increase gain in frequency 5725 – 5875 MHz while microstrip line feed is applied as basic feeding technique. In terms of patch’s dimension, the formula is given in [11].

2.1. Path section formula

Length of patch ($L_p$):

$$L = \frac{1}{2\sqrt{\varepsilon_r \varepsilon_{eff}}/\mu_0} = -2\Delta L$$  \hspace{1cm} (1)

Where $h$ is substrate tickness

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2} \left[1 + 12 \frac{h}{W}\right]^{-1/2}$$  \hspace{1cm} (2)

$$\frac{\Delta L}{h} = 0.412 \left(\frac{\varepsilon_{eff}+0.3}{\varepsilon_{eff}-0.258}\right) \left(\frac{W}{h}+0.264\right)$$  \hspace{1cm} (3)

Wide of patch ($W_p$):

$$W = \frac{1}{2\sqrt{\varepsilon_r \varepsilon_{eff}}/\mu_0} \sqrt{\frac{2}{\varepsilon_r+1}} = \frac{V_0}{2\sqrt{\varepsilon_r+1}}$$  \hspace{1cm} (4)

where

$\varepsilon_r$ = dielectric constant of substrate

$\varepsilon_{eff}$ = Effective dielectric constant

$W_p$ = Width of the patch

2.2. Ground plane section formula

Length of ground plane ($L_g$):

$$L_g = 6h + L$$  \hspace{1cm} (5)

Wide of ground plane ($W_g$):

$$W_g = 6h + W$$  \hspace{1cm} (6)

Figure 1. Basic design of microstrip patch antenna.

The result calculation from the equations above is shown in the table 1 below.
Table 1. Dimension of the antenna design based on formula [11].

| Parameter                        | Dimension (in mm) |
|----------------------------------|-------------------|
| Width of patch (Wp)              | 15.8869           |
| Length of patch (Lp)             | 11.8848           |
| Width of ground plane (Wg)       | 25.4869           |
| Length of ground plane (Lg)      | 21.4848           |
| Width of feed line (Wf)          | 3.0389            |
| Length of feed line (Lf)         | 4.8               |
| Inset of feed line point (Fi)    | 4.3859            |
| Gap of feed line (Gpf)           | 0.087704          |
| Radius inner spacer              | 2.4               |
| Radius outer spacer              | 1.2               |
| Air gap                          | 4.5               |
| Radius slot                      | 5.5               |

2.3. Reflecting layer

In [12], a reflecting layer is presented with dual-layer microstrip patch antenna design by taking the design of conventional square patch antenna, then changing it by removing symmetrical parts from the left and right sides, changing the right angles to curves, and finally introducing a circular slot in the ground plane. Following its model, the proposed design was developed in different resonant frequency which is at 5.8 GHz. The geometry and design reflector antenna is shown in figure 2. Gain enhancement will be optimized by changing four parameters in antenna, such as inner spacer radius, outer spacer radius, circular slot radius, and air gap/distance of reflector.

![Proposed design of antenna with reflecting layer.](image)

3. Result and analysis

The proposed design was simulated using CST-MW studio; the design was done which contained a single layer antenna with a full ground plane. Then, the antenna were enhanced by introducing a circular slot of 5.5 mm radius in the ground layer. The slot radius was chosen through sweeping the radius in the simulation from zero to 6 mm. Next, the simulation results were obtained for the antenna with proposed design operating around 5.8 Ghz and will be discussed in this section. Figure 3 shows the graph of return loss profile for reflector antenna and conventional antenna. From this graph, it can
be analyzed that return loss at 5.8 GHz for both antenna design are below -10 dB which comply with criterias.

![Graph showing return loss](image1)

**Figure 3.** Return loss characteristic microstrip patch antenna without reflector.

Furthermore, it can be investigated that antenna without reflector shows better performance in return loss than antenna with reflector. Meanwhile, the gain of conventional antenna is low at 2 dBi. Comparing the bandwidth result from the antenna without reflector of 343 MHz to the reflector patch antenna of 420 MHz, therefore, the reflector patch antenna has improved the bandwidth up to 22%.

The simulated gain of both antennas are shown in figure 4. The results shows that the antenna gain is 5.11 dBi at the center frequency 5.8 GHz. From this figure, we can observe that gain of the antenna increased two times by adding reflector. Moreover, the effect of the air gap distance on the gain of the dual layer microstrip patch antenna at the desired frequency is shown in figure 5. The values of air gap, in figure 5, represent the distance in mm between the two-substrate layers. In comparison with the conventional microstrip patch antenna, it is clear that there is an increment in the gain along the distance range from air = 1 mm to air = 5 mm. The curve reaches the maximum value at the desired frequency with an air gap distance of 5 mm. Nonetheless, along with increasing gain, the return loss is getting worst. So it’s truly important to establish the value of air gap in proper state in order to reach optimum design to meet satisfying results, including return loss and gain.

![Graph showing gain comparison](image2)

**Figure 4.** Gain comparison between reflector antenna and no reflector antenna.
Figure 5. Effect of air gap distance on the gain at desired of frequency.

From figure 6, it is noticed that beamwidth of reflector antenna is about 70° in phi=90, while it is slightly bigger at 74° in phi=0. The radiation pattern is directive in one direction, even though there is still small side lobe and back lobe produced by the antenna, see figure 6.

Figure 6. Beamwidth reflector antenna at 5.8 GHz.

In summarize, the result simulation of proposed reflector antenna is presented in Table 2. From this, it is revealed that bigger gain can be achieved through modification of the antenna, resulting 5.1 dBi for reflector antenna gain. By using parameter sweep, it can be known that if slot become bigger, the gain is also bigger. But it also shifts resonant frequency. So, to make it constant in 5.8 GHz, the dimension of slot has to be limited. Moreover, if distance of reflector is getting further, then gain gradually increases but also resulting return loss rises. By this point, it is important considering all of parameters to obtain optimum result.

Table 2. Comparison result between conventional microstrip antenna and reflector antenna.

| Design                      | Return-Loss (dB) | Gain (dB) | VSWR | Bandwidth (MHz) | Dimension (mm) (L x W x T) |
|-----------------------------|------------------|-----------|------|-----------------|---------------------------|
| Initial design (without reflector) | -29.603          | 2.471     | 1.068| 343             | 18.9 x 25.4 x 1.6         |
| Antenna reflector           | -20.149          | 5.111     | 1.218| 420             | 20 x 30 x 7.8            |

4. Conclusion
In this paper the design and simulation of a microstrip reflector antenna aiming its implementation on the UAV was presented. The objective or goal was to design an antenna in compact design with high gain that should work in target operating frequency 5.8 GHz. In order to achieve this goals, the method of reflecting layer which is placed near the conventional antenna has been introduced and gave satisfying gain in small design. The gain was increased more than twice, reaching 5 dBi in realized gain. The return loss in the operating frequency is also low, at -20 dB. The parameters that affect the
result are inner spacer radius, outer spacer radius, circular slot radius, and air gap/distance of reflector. Furthermore, the result simulation will be tested in anechoic chamber and will be evaluated and compared with simulation result.

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