Microstrip rectangular with bended-slots antenna design for radar remote sensing application

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Abstract. The development of radar remote sensing applications in Indonesia is increasingly being used for environmental monitoring, rainfall estimation, earth, and coast observation, or even for disaster mitigation. The study in this paper is to carry out a compact and low profile design of a microstrip slot antenna for radar remote sensing applications, in the X-band frequency range. The proposed design is a rectangular microstrip antenna with bended-slots on the feed line sides. From the simulation, the result showed that the antenna has wide bandwidth 605 MHz. Thus, the antenna can be used for radar applications.

1. Introduction
The excesses of the radar in detecting and tracking has made radar image data widely used and developed for various applications, such as disaster monitoring and mitigation, earth and sea observation, weather (rainfall) estimation, land mapping, and so forth. Moreover, radar image data on remote sensing satellite can be used as a complement to optical image data of remote sensing satellite, this is because radar image data is not affected by cloud cover [1, 2]. Radar in the electromagnetic spectrum is located in the microwave range in the X-band frequency. According to IEEE, the X-band frequency in radar is at 8 to 12 GHz, whereas in communication techniques, the X-band frequency range from 7 to 11.2 GHz [3, 4].

Antenna is the most important component in a radar system. The need for a compact, easily fabricated, integrated, and with good performance antenna is very desirable in modern communication systems [4]. Microstrip patch antennas can be an option to meet those needs. Not only its small-sized, lightweight, low profile, and easy to integrate, but the antenna that can also operate over a wide frequency range.

Among many advantages, one drawback of the microstrip antennas that is quite a concern is its narrow bandwidth. Lots of studies and techniques that have been conducted in order to broaden the bandwidth. The use of a substrate with low dielectric constant provides the antenna with better efficiency and wider bandwidth, but it will make the size of the antenna becomes larger [3, 6]. Proximity-coupled feeding can be choose to improve the bandwidth [6]. Arranging antennas with array systems can also broaden the bandwidth [7]. The addition of slots as additional resonant elements, on the radiation surface, can increase the bandwidth [5 – 9]. Hence, this study proposes a rectangular microstrip antenna with bended-slots on both sides of the feed line, which operate in X-band frequency.
2. Antenna Design

The structure of the proposed antenna is shown in figure 1. The antenna is designed on an FR-4 substrate with dielectric constant ($\varepsilon_r$) 4.3, loss tangent dielectric (tan $\delta$) 0.02, and substrate thickness (h) 1.6 mm. The overall dimension of the antenna is 64 x 50 x 1.6 mm$^3$.

![Figure 1. The proposed antenna](image)

In designing the conventional microstrip rectangular antennas, there are equations for calculating the width (W), the effective dielectric constant ($\varepsilon_{reff}$), the extension of length ($\Delta L$) and the antenna length (L), which can be used to determine the dimensions of the antenna [10].

First, the equation for determining the antenna width is given by

$$W = \frac{c}{2f_r}\left(\frac{2\varepsilon_r+1}{\varepsilon_r^{1/2}}\right)^{1/2}$$  \hspace{1cm} (1)

Next, the equation for calculating the effective dielectric constant by using

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

From the equation (1) and (2), the extension of the length can be found by

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff}+0.3)(W/\pi+0.264)}{(\varepsilon_{reff}−0.258)(W/\pi+0.8)}$$ \hspace{1cm} (3)

The last is the equation for determining the length of the antenna

$$L = \frac{c}{2f_r(\varepsilon_{reff})^{1/2}} - 2\Delta L$$ \hspace{1cm} (4)

where c is the speed of light, $f_r$ is the resonant frequency, $\varepsilon_r$ is the dielectric constant of the substrate and h is the thickness of the substrate.

After doing the calculations and some optimizations, the dimensions of the proposed antenna are acquired and shown in table 1.
Table 1. The Optimized dimension of the proposed antenna

| Parameters | Size (mm) |
|------------|-----------|
| SW         | 30        |
| SL         | 34        |
| IW         | 4         |
| IL         | 7         |
| FW         | 1.5       |
| FL         | 25        |

3. Result and Simulation

Several simulations and optimizations have been carried out on the proposed antenna using CST Studio Suite software with range frequency 7 – 9 GHz. The S11 parameter value resulted from the simulation is shown in figure 2. The S11 value of the resonating frequency 8 GHz is -10.62 dB and the bandwidth is around 605 MHz.

![S-parameters](image)

**Figure 2. S-parameter of the proposed antenna**

The simulations are also carried out to see the radiation pattern of the proposed antenna, which represent in figure 3. From the plot, it can be observed not only the radiation pattern but the beamwidth and maximum amplitude as well. At the resonant frequency, on the y-z plane and phi (Φ) is 90, the antenna has a directional radiation pattern. The beamwidth of the antenna is 31.5° and the maximum amplitude is 2.46 dB at 21°.
4. Conclusion
The proposed antenna has a compact design and worked in X-band frequency 7 – 9 GHz. With dimensions of 64 x 50 x 1.6 mm³, the antenna has a rectangular shape with bended-slots on both side of the feedline. The simulation results showed that the proposed antenna has S11 parameter value at the resonant frequency is -10.62 dB and gain 2.46 dB. The antenna has a wide bandwidth of around 605 MHz. Therefore, the antenna can be used for radar applications. By adjusting the slot and parameter design properly, a multiband antenna can be made. This will lead to the use of antennas for MIMO radar applications.

Acknowledgment
This research was supported partly by PIT-9 grant from Universitas Indonesia, under contract No. NKB-0054/UN2.R3.1/HKP.05.00/2019.

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