A Circular Patch Microstrip Antenna with Partial Ground Plane for WiMAX and WLAN Applications

R Fernandez¹, T Putra¹, H Andre¹, Firdaus².  
¹Electrical Department, Universitas Andalas, UNAND, Indonesia  
²Electrical Department, Politeknik Negeri Padang, PNP, Indonesia

Corresponding author: rfernandez@eng.unand.ac.id

Abstract. Narrow bandwidth is the main problem of a microstrip antenna. Enhanced bandwidth is done by applying a partial ground plane. The antenna patch layer is a circular formed based on the formula to obtain its initial dimension. The dimension is used as a base for the antenna design with ground plane reduction. The antenna is designed using FR4, which has a thickness of 1.6 mm with a dielectric constant of 4.3. Simulation results from the design of partial ground plane antennas on WiMAX and WLAN band frequencies showed an increase in bandwidth of 3.14 GHz with minimum return loss values of -17.01 dB, gain antenna of 1.32 dB and a directional radiation pattern.

1. Introduction

Worldwide Interoperability for Microwave Acces (WiMAX) is a broadband wireless technology that has high access speeds with a wide range. WiMAX frequency allocation is 2.3 GHz, 2.5 GHz, 3.3 GHz, 3.5 GHz and 5.8 GHz according to IEEE 802.16[1]. Wireless Local Area Network (WLAN) is a network that uses radio waves as its data transmission media. WLAN using IEEE standard 802.11 has frequency allocation in 5 GHz area with a range of 5.12 GHz-5.25 GHz, 5.25 GHz-5.35 GHz and 5.725 GHz-5.825 GHz. For 2 GHz regions work in the frequency range of 2.4 GHz-2.4835 GHz.

This application at WLAN and WiMAX frequencies requires an antenna as its transmission medium. The antenna is an essential component in wireless telecommunications. The antenna can function as a receiver and a transmitter simultaneously. Without the antenna, wireless communication will not run.

A microstrip antenna is one of antenna type that can be used for WLAN and WIMAX applications. The microstrip antenna has the advantage of small, light, low cost, easy in the manufacturing process, and allows to be made dual or triple frequency. But this antenna also has some drawbacks which are small gain and narrow bandwidth[2].

Various methods have been proposed to increase bandwidth. The selection of the feeding method is important in the antenna design, such as coupled stripline fed, resulting in an impedance bandwidth of about 13%[3]. However, it is not so easy to create because it requires proper alignment at the time of fabrication. Another method is the use of electromagnetic band-gap (EBG) structure [4]-[5]. The use of metamaterials with negative refractive index is also an option but takes complexity in analyzing [6]. The use of additional substrate leads to more thickness to get an increment in bandwidth[7].

In this study proposes a designed antenna that has a wide bandwidth by applying a partial ground plane (PGP). The patch used on this microstrip antenna is a circular patch that has the advantage of
being relatively easy to optimize compared to other forms. The optimized is reached by adjusting the size of the patch radius. The Antenna has a single band to cover WIMAX and WLAN frequencies.

2. Materials and methods

The patch of the microstrip antenna is circular to be designed according to the shape shown in Figure 1. In this figure shows the circular patch has the radius, which is a, t is the thickness of the patch, h is the thickness of the substrate, and $\varepsilon_r$ is the substrate dielectric constant.

![Figure 1. A circular patch [8].](image)

The antenna microstrip is designed using these following formulas as in equation (1) and (2).

$$a = \frac{F}{\left\{ 1 + \frac{2h}{\pi \varepsilon_r} F \left[ \ln \left( \frac{\pi F}{2h} \right) + 1.7726 \right] \right\}^{\frac{1}{2}}}$$

(1)

$F$ is the logarithmic function of the radiating element and is indicated by:

$$F = \frac{8.791 \times 10^9}{f_r \sqrt{\varepsilon_r}}$$

(2)

The substrate used for the antenna is FR4 Epoxy with a thickness (h) of 1.6 mm, a dielectric constant ($\varepsilon_r$) of 4.3 and a dielectric tangent loss of 0.02. Before applying the data from substrate, the value of $F$ is needed to get the radius as in the equation 1. $F$ is determined by the resonance frequency of the designed antenna. The designed antenna operates from 2.3 GHz to 5.35 GHz. Therefore, the resonance frequency ($f_r$) is 3.825 GHz.

The calculation results show that the radius is about 18.24 mm with $F = 1.906$. The feed point is set 18.24 mm from the midpoint of the patch. The antenna is fed by a line feed. The width of the line feed is 3 mm, and the length is 21.35 mm. The total dimension of the antenna is 40.48 x 59.73 mm$^2$ after taking into account the dimension of the ground plane as in figure 2(a).
On the ground plane in figure 2(b), the cooper part is etched. This part is reduced until giving a better impact on the bandwidth of the antenna. The area with the cooper part is becoming decreased as small as 19.35 x 40.48 mm<sup>2</sup).

The performance of a microstrip antenna is based on the value of return loss and Voltage Standing Wave Ratio (VSWR) parameters. The antenna has a good performance when the return loss is < -10 dB and VSWR ≤ 2 at the expected working frequency, and the radiation pattern is set adirectional [8].

3. Results and discussion
The proposed antenna is simulated using an EM Simulator to evaluate the antenna in figure 1. The evaluation is measured based on RL (figure 3), Voltage Standing Wave Ratio (VSWR) (figure 4), and radiation pattern of the antenna (figure 5).

![Figure 3. The RL of the proposed antenna](image-url)
After applying the partial ground plane, parasitic capacitance is introduced by increment of fringing field due to defected ground structure. The coupling between the ground plane and the patch is increased by this parasitic capacitance which leads to enhancement of the bandwidth.

In Figure 3 above, the bandwidth has achieved the desired result with a return loss below -10 dB from WiMAX frequency (2.3 GHz) to WLAN (5.35 GHz). The achieved bandwidth is measured from the minimum frequency of 1.53 GHz to the maximum frequency of 5.57 GHz (4.04 GHz). The bandwidth is wider than the bandwidth target. The bandwidth for covering WiMAX and WLAN frequencies is about 3.05 GHz.

Similarly, with Figure 4, VSWR has reached the target, which is below 2 from WiMAX frequency (2.3 GHz) to WLAN (5.35 GHz). So, the result of simulated VSWR also confirms the achieved bandwidth. It shows that the value of VSWR is below 2 as needed, along with the range of the achieved bandwidth. The value of simulated RL and VSWR parameters affirm that the antenna has a good impedance matching in target bandwidth.

The radiation pattern of the proposed antenna is also simulated to see its directivity. It is a directional, as shown in Figure 5. The gain of the simulated antenna is 1.32 dB.
All of the parameters of the proposed antenna is presented in table 1. The table shows the comparison of the parameters between the antenna without PGP and with PGP. The value of RL and VSWR in the table is the minimum value that each antenna can get.

**Table 1.** The comparison between antenna without and with PGP

| Antenna Parameter       | Without PGP | With PGP |
|-------------------------|-------------|----------|
| Return Loss (dB)        | -11.16      | -17.01   |
| Gain (dB)               | 0.39        | 1.32     |
| Bandwidth (GHz)         | 0.9         | 4.04     |
| (Frequency Range)       | (3.78 – 3.87)| (1.53 – 5.57) |

The parameters in the table show that the partial ground plane has an impact on broadening the bandwidth of the antenna. Therefore, the antenna can operate in WiMAX and WLAN frequencies.

4. Conclusions
The partial ground plane on circular microstrip antenna that works on WiMAX and WLAN frequencies has managed to increase bandwidth by 3.14 GHz from its original bandwidth. The results of the simulation show the following parameters, minimum return loss -17.01 dB with the antenna gain of 1.32 dB. The antenna has a directional radiation pattern.

Acknowledgements
This research is supported by a research grant for DosenJurusanTeknikElektro from Dana DIPA UniversitasAndalasTahunAnggaran 2018No. 086/UN.16.09.D/PL/2018

References
[1] S. Y. Tang, *WiMAX SECURITY AND QUALITY OF SERVICE: An End-to-End Perspective*, vol. 66. West Sussex, United Kingdom: John Wiley and Sons, Inc., Publication, 2010.
[2] R. Garg, *MICROSTRIP ANTENNA DESIGN HANDBOOK.pdf*. Norwood, United Kingdom: Artech House, Inc., 2001.
[3] S. He, P. Tang, B. Chen, and P. Wang, “Design of an X-band Stripline-fed Co-aperture Microstrip Multilayer Transceiver Array Antenna,” *2016 Prog. Electromagn. Res. Symp. PIERS 2016 - Proc.*, pp. 4676–4681, 2016.
[4] N. Llombart, A. Neto, G. Gerini, and P. de Maagt, “Planar Circularly Symmetric EBG Structures for Reducing Surface Waves in Printed Antennas,” *IEEE Trans. Antennas Propag.*, vol. 53, no. 10, pp. 3210–3218, 2005.
[5] N. Rao and K. V. Dinesh, “Performance enhancement of a microstrip antenna by suppression of surface waves using EBG structure in multiple layer substrate,” in *Proceedings - 2011 IEEE-APS Topical Conference on Antennas and Propagation in Wireless Communications, APWC’11*, 2011, pp. 935–939.
[6] P. Y. Chen and A. Alù, “Sub-wavelength elliptical patch antenna loaded with μ-negative metamaterials,” *IEEE Trans. Antennas Propag.*, vol. 58, no. 9, pp. 2909–2919, 2010.
[7] R. Fernandez and F. A. Pratama, “Penggunaan Dual-Layer Substrate untuk Meningkatkan Bandwidth Antena Mikrostrip pada Frekuensi LTE,” *J. Nas. Tek. Elektro*, vol. 7, no. 2, pp. 117–121, 2018.
[8] C. A. Balanis, *ANTENNA THEORY*, 3rd ed. New Jersey: John Wiley and Sons, Inc., Publication, 2005.