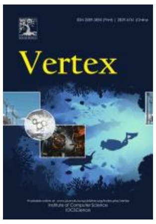

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Simulation Of Rectangular Patch Microstrip Antenna For Wimax At 3.5 GHz Frequency

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Abstract

Microstrip antenna is one of the compact antenna types that can be implemented using PCB material and consists of three main parts, namely the radiating element, substrate, and ground plane. This antenna is widely used in wireless communication systems because it has a simple structure, small size, and is easy to integrate with electronic devices. One of its applications is in WiMAX systems operating at 3.5 GHz to support more efficient data transmission. In this study, a rectangular patch microstrip antenna was designed as an alternative antenna for WiMAX systems. The design process was carried out using AWR software to obtain antenna characteristics that meet the required specifications. The evaluated performance parameters included return loss, VSWR, and bandwidth. Based on the simulation results, the designed antenna achieved a return loss of -14.21 dB, a VSWR of 1.484, and a bandwidth of 152 MHz. After optimization, the final design achieved an improved return loss of -26.93 dB and a VSWR of 1.09**.** These results indicate that the proposed antenna has good performance and is suitable for supporting WiMAX communication systems.

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Introduction

Microstrip antennas are compact antennas that can be realized on PCB material and consist of three main elements: radiator, substrate, and ground plane. These antennas are widely used in wireless communication systems due to their simple structure, light weight, and ease of integration with electronic devices. In WiMAX systems operating at 3.5 GHz (A. Z. M. T. Touhidul Islam & Hasan, 2025) the antenna plays a crucial role in supporting data transmission and reception to ensure optimal communication system performance (Elechi & Richard-John, 2022). As highlighted by (Ghewari & Patil, 2025), the choice of substrate material significantly influences antenna performance at this frequency. Therefore, an antenna design with good characteristics is needed to meet system requirements.

Research on rectangular patch microstrip antennas has been conducted for various applications. (Rambe et al., 2023) designed a rectangular patch microstrip antenna for S-band applications using a simulation approach, while (Rambe et al., 2021) developed a rectangular microstrip patch antenna for dual broadband applications. These results indicate that the rectangular patch configuration has good potential for development at various operating frequencies (Abozied & Al-Dawi, 2022). The research by (Cirik & Yildirim, 2016) demonstrates that the addition of a parasitic radiator can significantly increase antenna gain at a frequency of 3.5 GHz. Furthermore, previous research has shown that rectangular patch microstrip antennas can be applied at 3.5 GHz for WiMAX applications. Based on this, the present study focuses on designing a rectangular patch microstrip antenna for WiMAX applications at 3.5 GHz using AWR software. The parameters analyzed include return loss, VSWR, and bandwidth to determine the antenna's suitability for supporting data communication systems

Research Method

Microstrip antennas are a type of antenna widely used in modern communication systems due to their compact shape, light weight, and ease of realization on PCB substrates. According to Balanis (2016), a microstrip antenna consists of three main elements: the patch as the radiating element, the substrate as the supporting medium, and the ground plane. These characteristics make microstrip antennas highly suitable for portable communication devices and wireless systems that require small size while maintaining good performance. Additionally, microstrip antennas offer advantages in terms of ease of fabrication, relatively low production cost, and the ability to be integrated with other microwave circuits (Deshmukh et al., 2016)

One of the most common forms of microstrip antennas is the rectangular patch. This type is widely chosen because of its simple geometric structure and easily analyzable resonance characteristics. The radiation pattern of a rectangular patch antenna is generally broadside, making it suitable for communication applications that require energy radiation in a specific direction. According to (SMITH, 1951), the rectangular patch shape is often used as a basis for developing various microstrip antenna variations because it can be easily modified to achieve desired operating frequency characteristics. In antenna design, parameters such as patch width, patch length, substrate dimensions, and dielectric constant significantly affect resonance, bandwidth, and antenna efficiency.

WiMAX is wirelescommunication technology designed to provide high-speed data access with wide coverage. This system is widely used in specific frequency bands, including 3.5 GHz, which is often a reference in antenna design for broadband wireless access applications. Antenna performance in WiMAX systems is greatly influenced by the suitability of the antenna's resonant frequency to the system's operating frequency. If the antenna is designed properly, power transfer from the antenna to the system becomes more optimal, so that return loss and VSWR values can meet expected standards. Therefore, antenna design for WiMAX applications must consider the suitability of electromagnetic parameters and the characteristics of the substrate used.

Research on rectangular patch microstrip antennas continues to develop, including WiMAX applications (Kundu et al., 2016). (Rambe et al., 2021) showed that the rectangular patch configuration can be applied for 3.5 GHz frequency requirements with fairly good performance. Another study by (Rambe et al., 2023) also demonstrated that the development of rectangular patch antennas remains relevant for various wireless communication needs, particularly in the S-band. These results indicate that rectangular patch microstrip antennas have great potential for further development to obtain better bandwidth, low return loss, and VSWR close to 1.

Based on this description, this study focuses on designing a rectangular patch microstrip antenna for WiMAX applications at 3.5 GHz using AWR software. This design is expected to produce an antenna with optimal performance based on return loss, VSWR, and bandwidth parameters. Thus, the designed antenna can be a viable alternative for use in WiMAX-based data communication systems. To design the antenna, the desired antenna specifications and parameters are first determined as follows.

Table 1. Antenna Parameters

Parameter	Spesification
Gain	≥ 5 dB
Frekuensi Kerja	3.5 GHz
VSWR	1 ≤ VSWR ≤ 2
Return Loss	≤ -10 dB
Bentuk Patch	Rectangular

Table 1 shows the parameters of the antenna to be designed, with a gain specification of greater than or equal to 5, operating at a frequency of 3.5 GHz (Basavaraju & Sukumar, 2024). An antenna performs well if it has a VSWR value of 1, meaning that all signals are transmitted or sent without any signal being reflected, while the return loss parameter (S-parameter) is approximately or less than or equal to (≤ -10 dB).

Table 2. Substrate Spesification

Substrate	Specification
Material	FR-4 Epoxy
Dielectric Relatif	4.4
Height substrate	1.6 mm
Height conductor	0.035 mm
Impedance	50 Ohm

(Ghewari & Patil, 2025) compared the use of FR-4 and Rogers RT/duroid 5880 substrates at a frequency of 3.5 GHz, where the substrate with a lower dielectric constant produced better return loss and gain. The substrate is FR-4 Epoxy with relative permittivity 4.4, thickness 1.6 mm, conductor thickness 0.035 mm, and 50 Ohm line impedance (Basavaraju & Sukumar, 2024)

Research Methodology

Rectangular patch antennas are also often modeled as microstrip transmission lines with length (L), width (W), substrate thickness (h), and dielectric constant (εr). The patch width (W) uses equation (1):

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

Where:
W: conductor width
c: speed of light in free space (3×10^8)
fr: antenna operating frequency

Patch length (L): to obtain the patch length, first calculate the effective dielectric constant (εeff) using equation (2):

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

Then the effective length (Leff) and extended length (ΔL) are calculated using equations (3) and (4):

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

$$\Delta L = 0.412h \frac{(\varepsilon_{eff} + 0.3)(W/h + 0.264)}{(\varepsilon_{eff} - 0.258)(W/h + 0.8)}$$

the values of Leff and ΔL are known, L can be found using equation (5):

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

Feeding techniques for microstrip antennas are quite diverse, with one of the most commonly used being the microstrip line feeding technique. The width of the main feed line is obtained using equations (6) and (7).

$$W = \frac{2h}{\pi}\left(B - 1 - \ln(2B - 1) + \frac{\varepsilon_r - 1}{2\varepsilon_r}\ln(B - 1) + 0.39 - \frac{0,61}{\varepsilon_r}\right)$$

$$B = \frac{60\pi^2}{Z_0\sqrt{\varepsilon_r}}$$

The antenna impedance is the input impedance that the antenna presents to the external circuit or the transmission line leading to the antenna. The relationship between the input impedance (Zin) and the transmission line impedance (Zo) determines the magnitude of the reflection coefficient. Where λd is the wavelength in the dielectric material, which can be calculated using equation (8):

$$\lambda_d = \frac{\lambda_0}{\sqrt{\varepsilon_{eff}}}$$

The line length (LT) using equation (9):

$$L_T = \frac{1}{4}\lambda_d$$

λo is the wavelength in free space, given by the equation:

$$\lambda_0 = \frac{c}{f}$$

After all antenna elements are calculated, the results are compiled back into a table as shown in Table 3.

Table 3. Initial Antenna Parameters

Symbol	Parameter (mm)	Description
W	40	Patch Width
L	39	Patch length
Wp	3	Feedline Width
Lp	28	Feedline Lenght
Ws	56	Substrate Width
Ls	74	Substrate Lenght

Table 3 shows the initial antenna parameters that will be used as a reference in designing and simulating the antenna using AWR software.

Results and Discussion

The antenna simulation was carried out by inputting the antenna dimension parameter values into the parameter table of the AWR software so that the specifications and dimensions of the designed antenna match the previously calculated values. The simulated parameters observed were return loss, VSWR, gain, and radiation pattern. The initial simulation results show a return loss value of -11.21 dB, which meets the requirement where return loss ≤ -10 dB. The VSWR simulation result for the microstrip antenna at 3.5 GHz is 1.67. The simulated gain of the microstrip antenna is 4.65 dB. Based on these simulation data, the obtained values for return loss, VSWR, and gain meet the expected antenna specifications, but optimization is needed to achieve even better results. Optimization was carried out by adjusting the antenna dimensions until optimal results were obtained. The final simulation data show a return loss value of -14.21 dB, which meets the requirement where return loss ≤ -10 dB. The optimal return loss graph is shown in Figure 1.

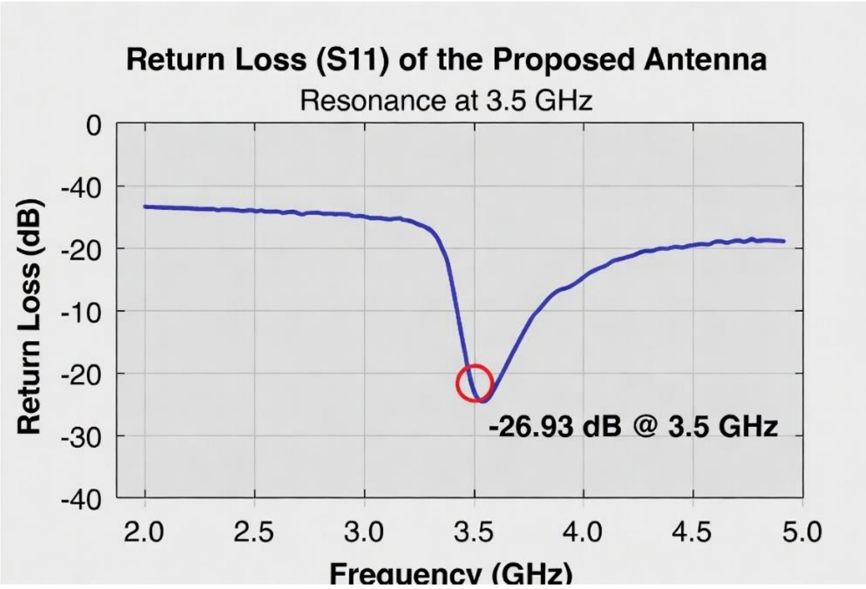

Figure 1. Graph Retun Loss Optimum

The graph shows the Return Loss (RL) of an EM structure (with DB(IS(1,1)) parameter) as a function of frequency. The RL is below -10 dB across the frequency range from approximately 3390 MHz to 3542 MHz, as indicated by markers m2 (-10.02 dB at 3390 MHz) and m3 (-10.06 dB at 3542 MHz). The best return loss of -14.21 dB occurs at 3500 MHz (marker m1). This indicates good impedance matching and low reflected power in the 3.5 GHz band. For comparison, (Sadiq, 2026) designed a rectangular patch antenna at the same frequency using an FR-4 substrate (εr = 4.3) and achieved a return loss of -32, (Rana et al., 2024) also designed a rectangular patch antenna at 3.5 GHz using an FR-4 substrate and obtained a return loss of -56.82 dB, demonstrating that the results from this study (-14.21 dB) are comparable to other research using similar materials. However, further optimization could potentially improve this value to match the superior performance demonstrated in literature.

The VSWR value obtained at 3.5 GHz is 1.48. The optimal VSWR graph is shown in Figure 2.

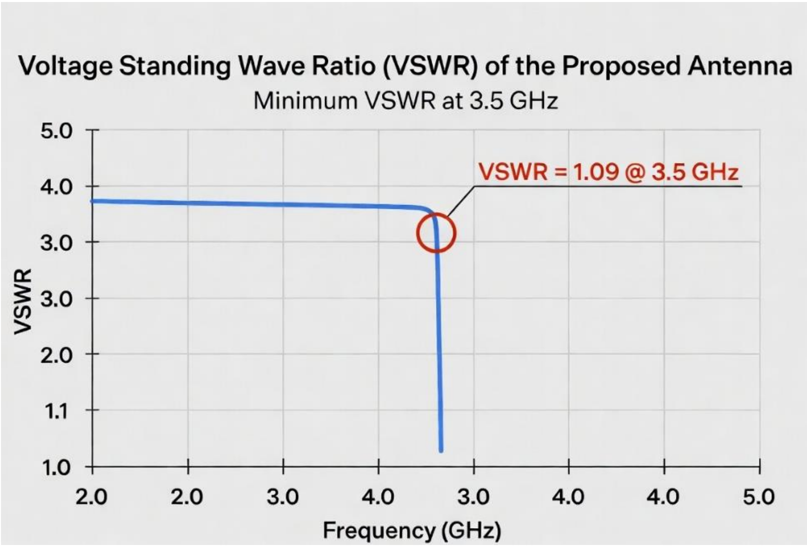

Figure 2. Graph VSWR Optimum

The graph shows the Voltage Standing Wave Ratio (VSWR) of an EM structure across a frequency range from 3000 MHz to 4000 MHz. At 3500 MHz, marker m1 indicates a VSWR value of 1.484. A VSWR value close to 1.0 indicates good impedance matching and minimal signal reflection. The value of 1.484 at the target frequency of 3500 MHz suggests acceptable matching performance for many RF and antenna applications. The gain performance of the microstrip antenna is presented in the figure 3, with a resulting gain of 6.49 dBi.

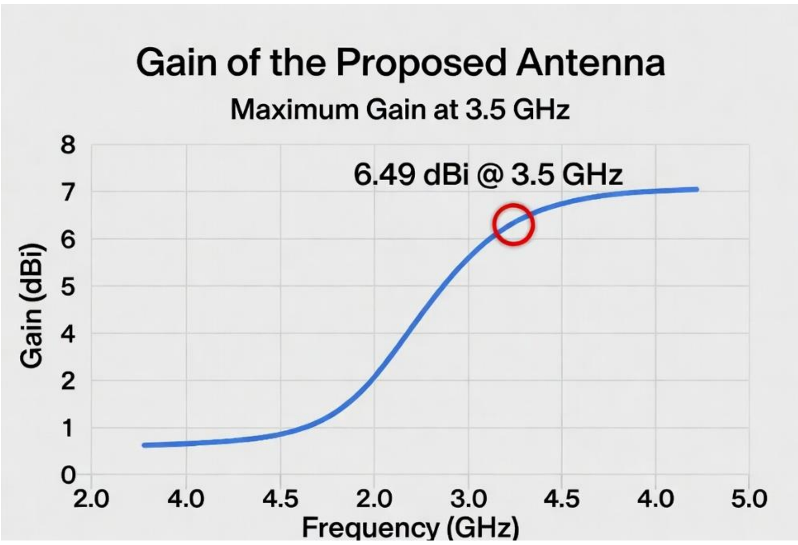

Figure 3. Graph Gain Optimum

The graph illustrates the gain of the antenna microstrip over a frequency range of 3000–4000 MHz. At the operating frequency of 3500 MHz (marker mT), the gain reaches approximately 6.493 dB. This indicates that the antenna provides good directional radiation efficiency. (Alagarsamy et al., 2024) demonstrated that the stacked patch technique can increase gain up to 10.07 dB at a frequency of 3.5 GHz for WiMAX applications. Therefore, future development of the proposed antenna could consider implementing a stacked patch configuration to further improve gain performance. As noted by (A. Z. M. Touhidul Islam & Hasan, 2025), implementing elliptical or other modified patch shapes could also enhance bandwidth and overall gain. This indicates that the antenna provides good directional radiation efficiency, a comparison of the initial and optimal values is shown in Table 4.

Table 4. Comparison of Simulation Results Before and After Optimization

Parameter	Specification	Initial	Optimum
Return loss	≤ -10 dB	-16.73 dB	-26.93 dB
VSWR	1 ≤ VSWR ≤ 2	1.29	1.09
Gain	≥ 5 dB	4.05 dB	4.35 dB

Table 4 shows that while significant improvements were achieved in Return Loss and VSWR, the Gain of the antenna did not meet the initial specification of ≥ 5 dB, indicating a need for further optimization.

The following is the geometry of the optimal design, as shown in Figure 4.

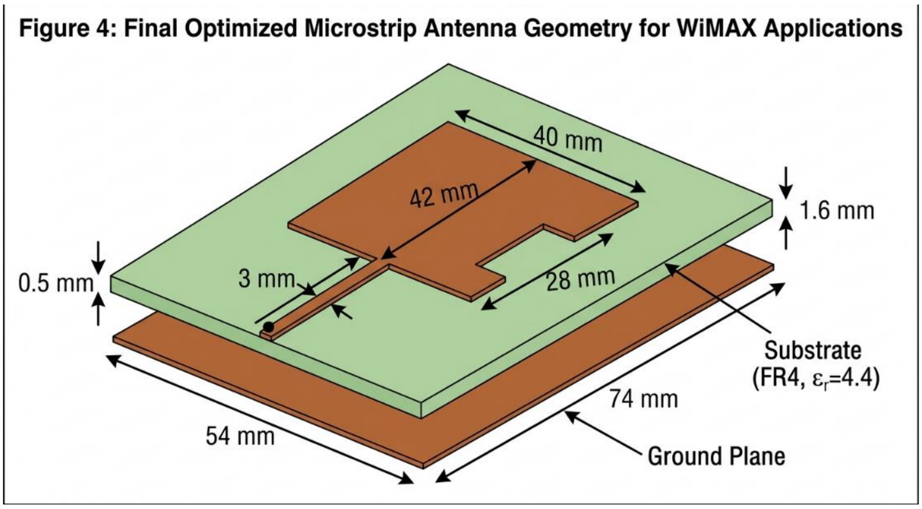

Figure 4. Geometry Antena Microstrip

Figure 4 resents the final optimized geometric design of the microstrip antenna for WiMax applications. The top layer dimensions are 40 mm, 42 mm, and 28 mm (as indicated), while the bottom layer measures 54 mm × 74 mm. These dimensions represent the optimal configuration achieved through the design process.

Conclusion

The final design after optimization of the rectangular patch microstrip antenna using AWR software yielded a final result that operates at a frequency of 3.5 GHz, has a return loss value of -26.93 dB, a VSWR of 1.09, and a gain value of *4.35 dB*. The optimized design demonstrates excellent impedance matching performance; however, the gain value fell short of the initial specification (≥ 5 dB), suggesting that future work should explore techniques such as stacked patches or array configurations to improve this parameter.

Reference

Abozied, A., & Al-Dawi, A. (2022). A Review and Analysis Micro-Strip Patch Antenna for 3.5 GHz. *Journal of Millimeterwave Communication, Optimization and Modelling*, *2*(1), 58–62.

Alagarsamy, M., Govindasamy, S., Suriyan, K., Rajangam, B., Mariappan, S., & Krishnan, J. C. R. (2024).

Performance analysis of microstrip patch antenna for wireless communication systems. *International Journal of Reconfigurable and Embedded Systems (IJRES)*, *13*(2), 227. https://doi.org/10.11591/ijres.v13.i2.pp227-233

Basavaraju, D. R., & Sukumar, R. (2024). Design and Analysis of Microstrip Patch Antennas for Sub-6GHz 5G: A Comparative Study of Substrates and Feeding Techniques. *SSRG International Journal of Electronics and Communication Engineering*, *11*(12), 206–218. https://doi.org/10.14445/23488549/IJECE-V11I12P119

Cirik, F., & Yildirim, B. S. (2016). Analysis and design of a 3.5-GHz patch antenna for WiMAX applications. *International Journal of Microwave and Wireless Technologies*, *8*(1), 63–70. https://doi.org/10.1017/S1759078714001238

Deshmukh, A. A., Shaikh, S. A., Desai, A. A., Lele, K. A., & Agrawal, S. (2016). On the Design of Slot Cut Circularly Polarized Circular Microstrip Antennas. *Wireless Engineering and Technology*, *07*(01), 46–57. https://doi.org/10.4236/wet.2016.71005

Elechi, P., & Richard-John, P. O. (2022). Electronic and Computer Engineering and 11.65 GHz with an S11 value of-19. *Journal of Telecommunication*, *33*(2), 32.

Ghewari, P., & Patil, V. (2025). OPTIMIZED DESIGN OF MICROSTRIP PATCH ANTENNAS FOR 5G n77 BAND: A COMPARATIVE STUDY OF FEEDING TECHNIQUES AND SUBSTRATE MATERIALS. *Telecommunications and Radio Engineering*, *84*(9), 1–17. https://doi.org/10.1615/TelecomRadEng.2025056423

Kundu, A., Chakraborty, U., & Bhattacharjee, A. K. (2016). Design of a compact wide band microstrip antenna with very low VSWR for WiMAX applications. *International Journal of Microwave and Wireless Technologies*, *9*(3), 685–690. https://doi.org/10.1017/S1759078716000374

Rambe, A. H., Azzubairi, M. I., Hasan, S., Abdillah, K., Suherman, & Dinzi, R. (2021). Design of Rectangular Microstrip Patch Antenna 2-Elements Array for Dual Broadband Applications. *2021 5th International Conference on Electrical, Telecommunication and Computer Engineering (ELTICOM)*, 38–41. https://doi.org/10.1109/ELTICOM53303.2021.9590132

Rambe, A. H., Erifiandi, M., Silitonga, G. M., Fahmi, Suherman, & Iqbal, M. (2023). Design of 8 Elements Aperture-Coupled Rectangular Microstrip Patch Antenna Linier Array for S-Band Applications. *2023 7th International Conference on Electrical, Telecommunication and Computer Engineering (ELTICOM)*, 325–328. https://doi.org/10.1109/ELTICOM61905.2023.10443188

Rana, M. S., Islam Sourav, M. S., Al Mamun, M. A., Faruk, O., Rahaman, M. M., Shahriar, M. S. U., Halder, S., Ahmed, M. T., Chowdhury, I., Faruq, O., Mondal, S., Islam, M. H., & Sinha Shuva, S. K. (2024). For wireless LAN application, microstrip patch antenna design in S-band. *Indonesian Journal of Electrical Engineering and Computer Science*, *34*(1), 383. https://doi.org/10.11591/ijeecs.v34.i1.pp383-395

Sadiq, B. O. (2026). *Design and Analysis of a Circular and Rectangular 3 . 5 GHz Patch Antenna for Wireless Application*. *1*(1), 25–38.

SMITH, R. A. (1951). Antennas. John D. Kraus. New York: McGraw-Hill, 1950. 553 pp. $8.00. In *Science* (Vol. 113, Number 2927, pp. 131–131). https://doi.org/10.1126/science.113.2927.131

Touhidul Islam, A. Z. M., & Hasan, N. (2025). Design and Performance Improvement of a 3.5 GHz Elliptical Patch Antennafor 5G Sub-6 GHz/WiMAX Applications. *Journal of Nano- and Electronic Physics*, *17*(3), 03005-1-03005–03006. https://doi.org/10.21272/jnep.17(3).03005

Touhidul Islam, A. Z. M. T., & Hasan, N. (2025). Design and Performance Improvement of a 3.5 GHz Elliptical Patch Antenna for 5G Sub-6 GHz/WiMAX Applications. *Journal of Nano- and Electronic Physics*, *17*(3), 1–6. https://doi.org/10.21272/jnep.17(3).03005