



Design and Realization of Wideband Printed Monopole Antenna with Tel-U Logo Patch

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ABSTRACT

One of the challenges of antenna development for wireless communication systems is to create an antenna that can be operated in wide frequency so that a single antenna can be used in various wireless communication technologies. This paper discussed the wideband antenna with Telkom University Logo-shaped patch, using Fr-4 ($\epsilon_r = 4.3$) substrate with 1.6 mm thickness. The antenna can be operated in the frequency range of 760 MHz – 13.75 GHz. The gain performance at the working frequency is still above 0 dBi. Hence, the antenna design to work properly for wireless communication systems which require relatively long distances. The Defected Ground Substrate (DGS) method is applied to achieve that bandwidth. Measurement shows the logo-shaped patch antenna achieves 12.994 GHz bandwidth with 1.33 VSWR and gain 2.85 at 921.5 MHz frequency.

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1. Introduction

Wireless communication developed rapidly in recent years. Many new wireless standards and technologies have been developed that work on different frequency bands. An antenna is an important part of wireless communication systems. It is the structure that transmits and receives electromagnetic waves that contain information so that two or more devices can communicate with each other in a particular frequency band. Wideband antennas are used to accommodate many operating frequencies. This type of antenna has better VSWR and gain in a relatively wide frequency range. The use of this wideband antenna will also reduce costs because it only uses one antenna for various purposes.

Planar antennas can be used as wideband antennas. Research and development of wideband antennas are carried out by various methods, such as wideband antennas with 2.3 - 6.0 GHz working frequency, which have been made using the CPW technique on the feedline [1]. The antenna's wide working frequency can also be achieved by using a slotted circular on the circular patch antenna. The slot impact antenna has 200% bandwidth at 3.5 GHz working frequency [2]. Another method is U-slot's use on the patch antenna array that produces 13 GHz bandwidth at 28 GHz [3].

The patch antenna's slot is shaped so that it looks like the logo of an institution or company. Antenna in [4] using the UTM campus logo, which is surrounded by a circular ring as a patch. By using this method, 106.16% bandwidth is obtained with 1.98 - 6.46 GHz working frequency. Wideband antennas with logo-shaped patches can be optimized using the Taguchi method and Particle Swarm Optimization (PSO) [5], where the Taguchi method is found as a better method than PSO.

In this paper, the Telkom University logo is made into a wideband patch antenna. This antenna has the advantage, such as very wide bandwidth with gain more than 0 dBi. Hence, it is possible to be used in communication systems that have a wide operating frequency and relatively long distances.

2. Antenna Design

Telkom University logo patch antenna is created from conventional microstrip rectangular patch antenna. Figure 1 shows the process of creating a logo-shaped patch. Figure 1(a) shows a conventional rectangular antenna that has been optimized. The rectangular patch uses a Fr-4 substrate with 1.6 mm thickness and 0.035 mm conductor thickness. Fr-4 has 4.3 relative conductivity (ϵ_r).

The rectangular patch antenna is designed for UHF-RFID frequencies. Based on Indonesia's regulation [6] UHF-RFID working at 921.5 MHz. To determine the dimension of the conventional rectangular antenna operating on UHF-RFID can be calculated based on Equation 1 until Equation 12 [7] [12] .

$$Wp = \frac{c}{2f_0 \sqrt{\frac{\epsilon_r + 1}{2}}} \quad \text{Equation 1}$$

The width of the patch can be calculated using Equation 1. Where c means the velocity of light in space (3 x 10⁸ meters per second), fo means resonance frequency (921.5 MHz). The effective dielectric (ϵ_{eff}), effective length (L_{eff}), and extended length (ΔL) must be calculated the first o to determine the length of Patch (L_p) because all of these variables have been bound to each other. Effective dielectric (ϵ_{eff}) compute by Equation 2, effective length (L_{eff}) calculated by

Equation 3 and Equation 4 is used for calculating extended length (ΔL). After all of these variables obtained, length of patch can be computed by Equation 5.

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[\frac{1}{\sqrt{1 + \frac{12h}{W_p}}} \right] \quad \text{Equation 2}$$

$$L_{eff} = \frac{c}{2f_0 \sqrt{\epsilon_{reff}}} \quad \text{Equation 3}$$

$$\Delta L = 0.412h \frac{(\epsilon_{reff} + 0.3) \left(\frac{W_p}{h} + 0.264 \right)}{(\epsilon_{reff} - 0.259) \left(\frac{W_p}{h} + 0.8 \right)} \quad \text{Equation 4}$$

$$L_p = L_{eff} - 2\Delta L \quad \text{Equation 5}$$

This study uses a microstrip transmission line as a feeding technique. This feeding method was chosen because it is simpler and easier to make. Equation 7 is used to determine the width of the feed (W_f). The relative dielectric const uses Equation 8 to calculate the length of the feed (L_f), the wavelength of the dielectric material (λ_g) is calculated using Equation 9. Width of the ground plane (W_g) and length of the ground plane can be calculated by using Equation 11 and Equation 12.

$$B = \frac{60\pi^2}{Z_0 \sqrt{\epsilon_r}} \quad \text{Equation 6}$$

$$W_f = \frac{2h}{\pi} \left\{ B - 1 - \ln(2B - 1) + \frac{\epsilon_r - 1}{2\epsilon_r} \left[\ln(B - 1) + 0.39 - \frac{0.61}{\epsilon_r} \right] \right\} \quad \text{Equation 7}$$

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left(\frac{1}{\sqrt{1 + 12 \frac{h}{W_f}}} \right) \quad \text{Equation 8}$$

$$\lambda_g = \frac{c}{f_0 \sqrt{\epsilon_{reff}}} \quad \text{Equation 9}$$

$$L_f = \frac{\lambda_g}{4} \quad \text{Equation 10}$$

$$W_g = 6h + W_p \quad \text{Equation 11}$$

$$L_g = 6h + L_p + L_f \quad \text{Equation 12}$$

The dimension of a conventional rectangular patch that resulted in Equation 1 until Equation 12 is optimized by changing some geometry until achieving the best performance. The optimized geometry showed in Table 1. The optimum dimension will be the reference geometry for the Telkom University logo patch shaped.

In a related study, a technique to reducing patch conductor by slot method at the conventional shape of patch to made logo patch look-like had been implemented [4] [8]. From these researches, forming the Telkom University logo by adding some slots into a conventional rectangular patch antenna is possible.

Rectangular patch antenna has given slot, so it becomes Telkom University logo look like as shown in Figure 1(b). The unused conductor patch is removed and smoothed, so it becomes the Telkom University logo shown in Figure 1(c).

The logo patch antenna is optimized until it achieves optimum performance. Logo's width and length are fixed ratio $12:17.5 = w_p:l_p$. When one of the geometry parameters is changed, all the other antenna dimensions are changed—the optimization process by trial-and-error by changing one parameter. Then follow the trend of the optimization results to get the geometry that produces an acceptable antenna performance. Figure 1(d) shows the backside of the logo antenna, which using the DGS method. The use of DGS will be explained in the next part.

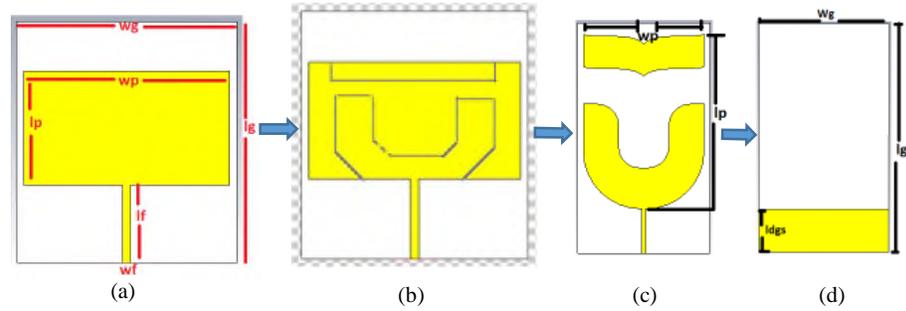


Figure 1 Optimized Conventional Rectangular Patch (a), Slot Gives into Rectangular Patch (b), Telkom University Logo-Shaped Patch (c), Back Side of Logo Patch Antenna (d)

Table 1 Geometry of Conventional Rectangular Patch

Symbol	Dimension (mm)	Explanation
W_p	138	Width of Patch
L_p	74.9	Length of Patch
W_g	147.6	Width of Groundplane
L_g	140.9	Length of Groundplane
W_f	4.1	Width of Feed

The logo antenna is optimized based on the conventional rectangular patch geometry. The logo antenna optimization results tend to produce VSWR below two and gain below 0 dBi, with the directivity always above 0 dBi. It means antenna has low efficiency, and there is mismatch antenna impedance. The DGS method is implemented to achieve high efficiency and match the impedance [9]. The ground plane conductor is reduced step by step until the antenna achieves good performance. Figure 2(a) shows the most optimum ground plane conductor's length ($ldgs$) dimension. Groundplane conductor's length that the resulting best antenna performance is 37.02 mm. This dimension gives the most matched impedance and resulting in the lowest VSWR. Reducing the ground plane conductor also effects on antenna efficiency. The decrement of the ground plane conductor's dimension ($ldgs$) makes the antenna more efficient and implicating at an increasing gain, as shown in Figure 2(b).

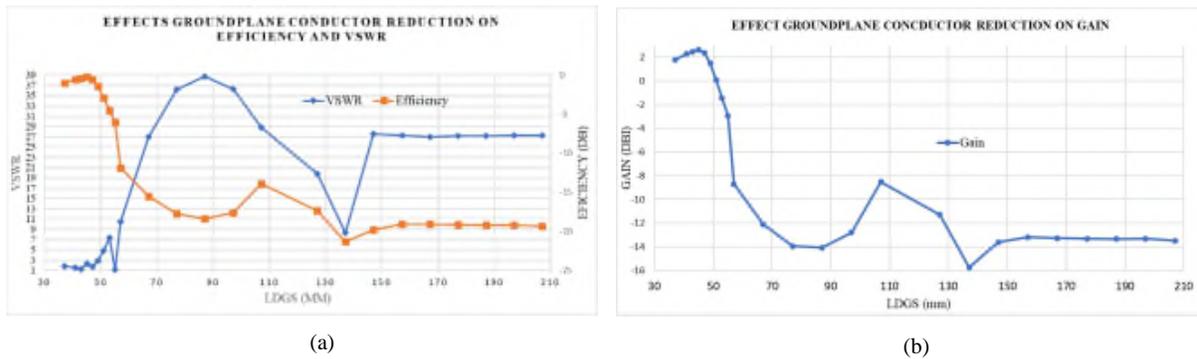


Figure 2 Effects Groundplane Conductor Reduction on (a) Efficiency, VSSWR and (b)Gain

Table 2 Geometry of Logo Patch

Symbol	Dimension (mm)	Explanation
Wp	138	Width of Patch
Wp	102.45	Width of Patch
Lp	149.416	Length of Patch
Wg	112.05	Width of Substrate
Lg	197.01	Length of Substrate
Wf	3.1	Width of Feed
Lf	38	Length of Feed
Ldgs	37.02	Length of Groundplae

3. Results and Discussion

The optimal geometrical antenna, as shown in Table 1 and Table 2, are fabricated and measured. Figure 3(a) shows the fabricated antenna of conventional rectangular patch, and Figure 3(b) shows the logo patch antenna. Fabrication of booth antenna was made as rigid as possible with the simulation dimension. The size of antenna dimensions is relatively large compare to the microstrip antenna in general. Big dimension antenna caused by convention rectangular antenna was designed to operate at 921.5 MHz frequencies, where that frequency conduces a relatively long wavelength. In accordance with Equation 1, the width of patch is inversely proportional to working frequency. The patch dimension's width is one variable to calculate length of Patch in Equation 2 until Equation 5. The geometry of patch will impact the ground plane size in Equation 11 and Equation 12. Because UHF-RFID has a relatively long wavelength size of antenna will relatively bigger than another conventional antenna.

The dimension of the optimum conventional rectangular patch antenna is the reference of the Telkom University logo patch-shape. Due to the conventional rectangular antenna size is relatively large than other, the microstrip antenna inflict dimension of logo shape antenna relational has big size.

The prototype of antenna measured in Antenna and Wireless Communication Telkom University Laboratory. Because of the limited facility, antenna measurement is not using the anechoic chamber as a requirement for ideal measurement.

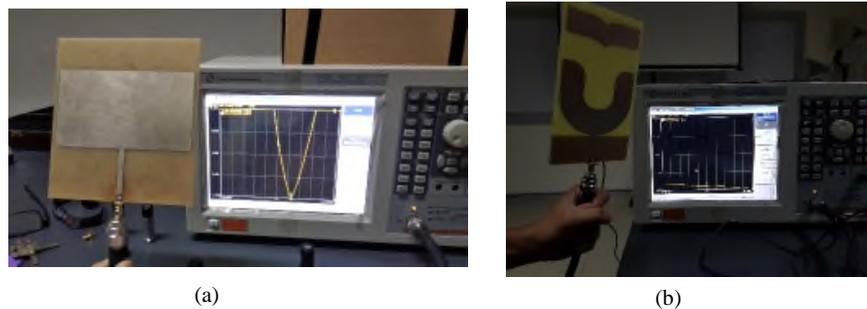
**Figure 3** Near Field Antenna Measurement (a) Rectangular Patch (b) Logo Patch

Table 3 shows the result of the antenna simulation and measurement. The results of simulation and measurement are different because the antenna's measurement is not in an ideal condition. However, the dimension of the fabricated antenna is as similar as possible to the dimension of simulation. Measurement and simulation do not differ too far, so the results obtained are still be accepted.

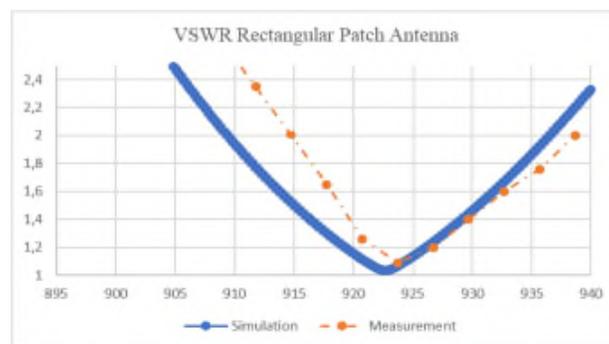
Table 3 Antenna Performance.

Parameter	Conventional Rectangular Antenna		Logo Antenna	
	Simulation	Measurement	Simulation	Measurement
VSWR at 921.5 MHz	1.07	1.26	1.13	1.33
Bandwidth	27.17 MHz	23.67 MHz	12.994 GHz	1679.3 MHz
Gain at 921.5 MHz	1.54 dBi	0.85 dBi	2.7	2.85
Beamwidth at 921.5 MHz	90.3° Azimuth; 91.7° Elevation	65° Azimuth; 45° Elevation	108° Azimuth; 77.1° Elevation	100° Azimuth 80° Elevation

As mentioned before, the conventional rectangular patch antenna is the dimension reference of the logo antenna. The rectangular antenna is designed for UHF-RFID. It makes the observation frequency in Table 3 is 921.5. VSWR at rectangular patch is better compared to the logo antenna. One of the factors that cause the difference in performance is the shape of the patch antenna.

Patch at logo antenna contains two-part. The first part is u-shape connected into the feedline, and the other one is the book symbol above the u-shape. The book symbol becomes a parasitic element. The parasitic element influences the antenna impedance and implicates on VSWR changes. The parasitic element in this antenna increasing VSWR but enhanced bandwidth [9] [10].

Table 3 shows the result of the antenna simulation and measurement. The results of simulation and measurement are different because the antenna's measurement is not in ideal condition, and the solder's lead at the join of the connector and the antenna also affects antenna impedance. Result of measurement and simulation do not differ too far, so the results obtained can still be accepted

**Figure 4** VSWR Result of Rectangular Patch

Antenna logo's bandwidth in simulation result is wider compared to conventional rectangular patch. The bandwidth of conventional antennas shown in Figure 4. The bandwidth of conventional rectangular is determined by the range of frequencies that below VSWR 2. According to [7], the term bandwidth not only limited by VSWR parameters. Range of operation frequencies can determine by some acceptable parameters, such as gain, polarization, sidelobe level, gain, etc. In this paper, the bandwidth of the logo patch antenna defined by $VSWR \leq 2$ and gain still above 0 dBi. Gain above 0 dBi makes antenna work properly for wireless technology that operating at relatively long distances.

Figure 5 shows the logo antenna's gain and VSWR plot on frequency. The bandwidth is calculated by upper frequency minus the lower frequency. $VSWR \leq 2$ and gain above 0, the dBi is starting from 756 MHz with 2.0 VSWR and 1.7 dBi gain. This point marked as to lower frequency. The upper frequency is spotted at

13.75 GHz with VSWR 1.69 and gains 0.01 dBi. From this result, the logo antenna's bandwidth is 12.994 GHz.

The width of bandwidth at the logo antenna is affected by several factors. The parasitic element in the logo antenna has an impact on impedance, and it increases bandwidth. Furthermore, the DGS method also affects the bandwidth. Reducing conductor at the ground plane also reduces antenna resistance. The antenna resistance also affects impedance that gives wider bandwidth [9].

In the logo patch, there is a U-character part which connected to the feeding line. This part looks like U-patch in previous studies [11]. U-Patch planar antenna is an antenna that has given some slots so that the remaining part is U-shaped look like. The slot that had been given into patch changing antenna impedance and make resonant bandwidth wider.

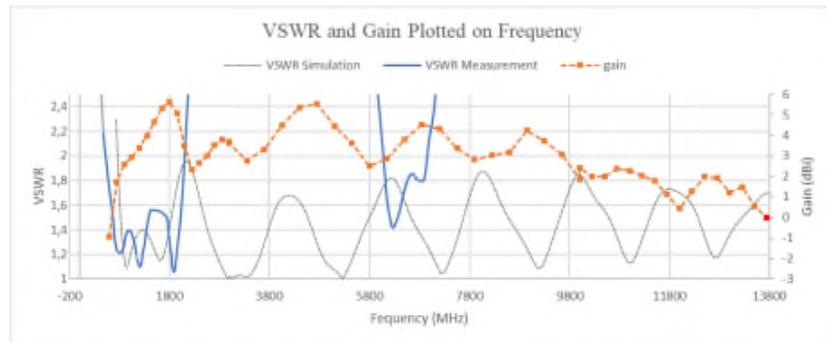


Figure 5 VSWR and Gain of Logo Patch Antenna

The measurement result of the logo patch's bandwidth is different compared to the simulation result. Antenna only achieves 1679.3 MHz bandwidth even though of fabrication has been done as accurately as possible. This is caused by measurement, not in ideal conditions. Items in the laboratory distracting the antenna performance when measured. Network Analyzer that used to measure antenna only has measurement capability until 8 GHz frequencies. That makes the graph of VSWR in Figure 4 limited until 8 GHz. Although the fabricated antenna has not wide bandwidth as a simulation result, the fabricated antenna has good performance at 921.5 MHz frequencies with VSWR 1.33.

The logo patch antenna has bidirectional radiation patterns. A conventional rectangular patch has unidirectional radiation patterns, as shown in Figure 6 and Figure 7. Logo patch antennas become bidirectional antennas because of the DGS method that was implemented before. Reducing the conductor at the ground plane makes electromagnetic waves radiate at the backside of the antenna [9]. Figure 6(b) and Figure 6(d) shows that DGS effects on radiation pattern become bidirectional in elevation plane and azimuth plane. Measurement result in Figure 6(a) and Figure 6(c) not similar to simulation result because far-field measurement not in ideal condition.

Reducing the ground plane conductor affects the radiation pattern on azimuth on Beamwidth of the logo antenna is sharpen compared to conventional rectangular patch. It shows that the antenna logo has a good focus on radiating electromagnetic waves than conventional rectangular. This fact makes the gain of the logo antenna higher than the rectangular antenna.

The radiation pattern of the conventional rectangular patch antenna is unidirectional because using a full ground plane. Figure 7(b) and Figure (d) show the result of the radiation pattern is unidirectional at azimuth plane and elevation

plane. Figure 7(a) and Figure 7(c) are measurement results of the conventional rectangular radiation pattern. Measurement results at azimuth and elevation planes are not good as the simulation result because the antenna is not measured in an ideal condition. Instead, not in ideal condition, Figure 7(c) shows the radiation pattern at the azimuth plane is unidirectional.

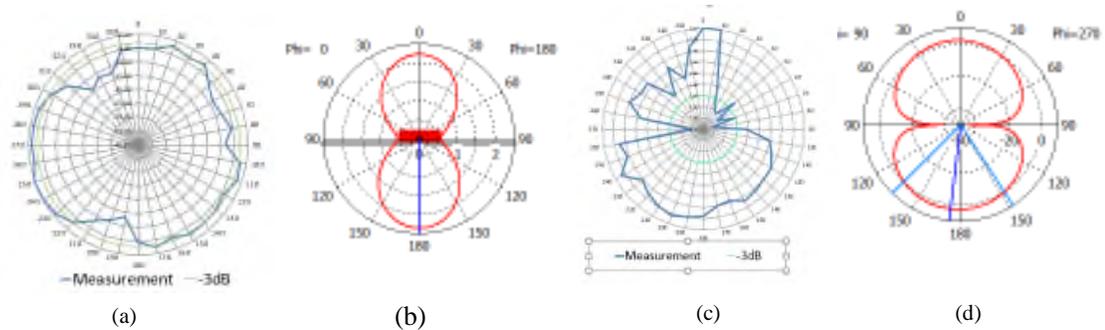


Figure 6 Radiation Pattern of Logo Patch Antenna (a) Elevation Measurement, (b) Elevation Simulation, (c) Azimuth Measurement, (d) Azimuth Simulation

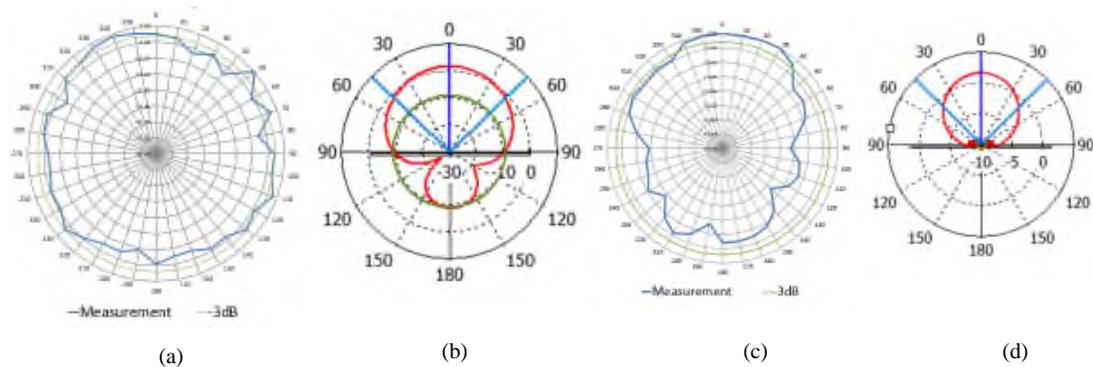


Figure 7 Radiation Pattern of Rectangular Patch Antenna (a) Elevation Measurement, (b) Elevation Simulation, (c) Azimuth Measurement, (d) Azimuth Simulation

4. Conclusions

Wideband printed monopole antenna with Telkom University logo-patch shaped is presented in this paper. With all the adjustment of antenna dimension, the antenna can be operated between 756 MHz until 13.75 GHz frequency bands for wideband applications. All antennas gain at operating frequencies above 0 dBi and make antennas compatible with wireless technology that needs a relative long-range distance.

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