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DESIGN OF RECTANGLE PATCH SLOT-U MICROSTRIP ANTENNA ELECTROMAGNETICALLY COUPLED FILING FOR BROADBAND WIRELESS ACCESS TECHNOLOGY

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Abstract - Microstrip antenna design with millimeter-wave frequency has become a necessity for broadband devices, where wireless access networks are becoming increasingly important and the economic factor supports the use of the network so it is necessary to design an antenna that can be applied to Broadband Wireless Access (BWA) technology. Broadband technology requires the transfer of large data packets and fast data rate, to meet these needs, the antenna is designed Microstrip with U-slot rectangle patch with electromagnetically coupled feeding, the method used in this study is the research method, where for the design of the antenna microstrip through several stages. The design that has been done has resulted in the design of a u-slot rectangle patch microstrip antenna with electromagnetically coupled feeding and can be applied to broadband wireless access technology. Furthermore, the design results have a Substrate Antenna size of 27 mm × 21 mm. The results obtained that the antenna can work at a frequency of 2.368 GHz has a return loss value = -12.66 dB and 3.38 GHz has a return loss value of 15.22 dB, a VSWR value of 1.34, and has an antenna gain of 3.7 dB and has a frequency center at 2.3 GHz and 3.38 GHz and input impedance of 50 and vertical radiation polarization so that the antenna can be applied to Wireless Access networks.

Keywords: *Microstrip Antenna*, U-Slot Rectangle Patch, Electromagnetically Coupled Broadband Wireless Access

1. Introduction

Technology development Wireless communication technology is currently running faster and more diverse, [1], so that many new and increasingly sophisticated technology standards appear, [2]. In addition, in the future, communication will not only use voice services but has begun to enter service. data, [3], where data services, of course, require fairly wide bandwidth, practical and compatible in the use of devices, [4], The needs of the world telecommunications market on a global and national scale lead to the distribution of information in large data capacities,[5], So we need a communication device that works with a very wide bandwidth or wideband,[5]. Currently developing Broadband Wireless Access (BWA) technology, [6], where Wireless technology is allocated in the 2.3 GHz to 5.8 GHz frequency band with the respective frequencies of 2.3 GHz, 2.5 GHz, 3.3 GHz, 3.5 GHz, 5.5 GHz, and 5.8 GHz. On the other hand, there is a very rapid increase in demand for internet services in Indonesia[5], characterized by several things: first, the increase in the number of sales of telecommunication equipment that leads to more complex functions (voice, video, and data with high speed up to 80 Mbps), secondly, internet service providers must be able to prepare an adequate amount of bandwidth capacity due to technology BWA works at high speed and provides ease of access and wider coverage, [5], Therefore, the Indonesian government has launched and deployed internet services using millimeter-wave frequencies, (must work at above 1 GHz) where the technology applied must offer telecommunications services with wide bandwidth and large bit rates.

BWA technology can provide a variety of applications including voice, video, and data at high speeds up to 80 Mbps. In Indonesia, Wireless technology has begun to be implemented and has the potential to increase high-speed broadband services (Digital TV, Telephone, Internet together),[7], To meet these needs, it is necessary to develop research from within the country to support the development of BWA technology. BWA technology requires a device to receive and transmit signals, namely Antenna. An antenna is a transformer or transmission structure between guided waves (transmission channel) and free space waves[8], [9],. Microstrip antenna is one type of antenna that consists of two conductors (patch and ground plane) separated by a dielectric substrate. For BWA (Broadband Wireless Access) service needs, an antenna has been developed which has a compact design and has good performance and low profile, small size, and low production cost.

In principle, microstrip antennas have several advantages, namely: compact shape, small dimensions, easy to fabricate, can be connected and integrated with other electronic devices (ICs, active circuits, passive circuits), and Microwave integrated circuits (MICs) and side radiation. which is low, but the microstrip antenna has the disadvantage of having a narrow bandwidth characteristic. The use of two layers (double layer) with a microstrip channel as the feeder of the feeding element located at a different layer with the radiating element (patch antenna) can produce a high coupling effect, wide bandwidth, and multi-frequency (multiband). The feeding technique uses electromagnetic coupling, the channel and the radiating element are physically unrelated (electromagnetically related,[10], Microstrip antenna is defined as one type of antenna that has a blade-like shape with a very thin size,[11], [12], The basic structure of a microstrip antenna consists of a radiating patch, a substrate dielectric, and a ground plane. The structure of a microstrip antenna Radiating element (patch) is made of metal and has a certain thickness and functions to radiate electromagnetic waves[13], Microstrip antennas can provide a solution because of their small size, lightweight, low cost, can be fabricated by modern printed board technology and easy to integrate with microwave integrated circuits (MICs).[14],One form of microstrip antenna that is widely used and easy to analyze is the rectangular patch.

On *Patch* rectangular patch is one of the easiest and most widely used in the design of patch microstrip antennas is the rectangular patch,[15], The following are some of the calculations used to design a rectangular microstrip antenna[16], To determine the characteristic impedance (Z0), the microstrip line width is adjusted. This is related to the impedance matching between the microstrip line and the supply line[17], Proximity Coupled Channel Technique as an electromagnetic coupling scheme. using two dielectric substrates and a channel line between the two substrates and the radiation patch is at the top of the top substrate. The main advantages of this technique are that the channel can eliminate spurious radiation and can provide very high bandwidth (about 13%), due to the increase in the overall microstrip thickness of the patch antenna. This scheme also provides a choice between two different dielectric media materials, one for the patch and one for the channel to optimize individual performance[18],

Techniques using narrow slots or wide slots are termed microstrip slot antennas (MSA) [19]. So that the electromagnetic feeding technique using slots is more efficient in using the substrate for the antenna. In microstrip slot antennas it has a coupling mechanism, where the microstrip channel gives an effect. electromagnetic waves to the radiating element (slot) through a substrate. The coupling effect is given between the microstrip line and the radiating element as a transformer deal. In this study, the focus is on designing a microstrip antenna using the proximity coupling technique.[20].[21]

2. Methodology

The antenna design process is carried out through several stages, namely, determining the working frequency, calculating the patch dimensions (Wand and ΔL), running simulation (running program HFSS v.13), determining substrate characteristics, fabrication, and implementation.

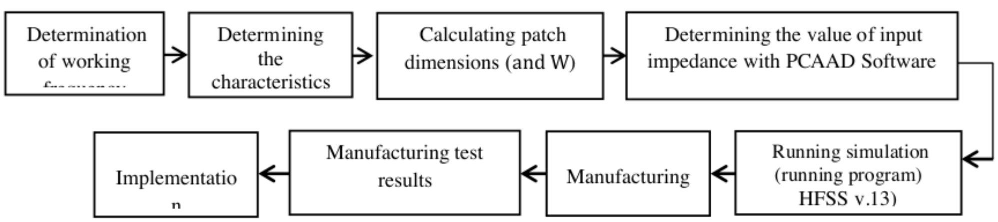


Figure 2. Antenna design flow chart

Figure 2 is a flow diagram of the steps in the process of designing a U-slot range microstrip patch antenna with the following explanation:

a) Determination of the working frequency is done by using the Wifi standard, Simulation with HFSS v13 software.
   This antenna is designed to work at a working frequency of 2.3 GHz -2.46 GHz with a working frequency range from 1 GHz to 5 GHz. The results of this antenna design have VSWR 2 and return loss -10 dB.
b) Determine the characteristics of the substrate, Substrate is the basic material used for antenna design. Each substrate has different characteristics and parameter values. Therefore, in designing an antenna, the determination of the characteristics must be done at the beginning.

Table 1. The substrate parameters used

No	Substrate Type FR4	(Epoxy)
1	Relative Dielectric Constant(ξr)	4.4
2	Dielectric Loss Tangent (tan)	0.02
3	Substrate Thickness (h)	1.6 mm

Table 1 is a Microstrip Antenna material using a substrate type of Epoxy FR4 and has a valueThe Relative Dielectric Constant(ξr) is equal to 4.4, Dielectric Loss Tangent (tan) is 0.02, and substrate thickness (h) is 1.6 mm.

c) Calculating patch dimensions (Δand W) using the following mathematical calculations:

$$W = \frac{c}{2fo\sqrt{\frac{\varepsilon_{f+2}}{2}}}$$

$$W = \frac{3 \times 10^8}{2.3{,}3\sqrt{\frac{4.4+1}{2}}}$$

$$W = \frac{3 \times 10^8}{6.6\sqrt{\frac{4.4+1}{2}}}$$

$$= \mathbf{3 \times 10^8 / 6.6 \times 10^9 \sqrt{5.4/2}}$$

$$= \mathbf{3 \times 10^8 / 6.6 \times 10^9 \times 1.64}$$

$$= \mathbf{3 \times 10^8 / 10.8 \times 10^9}$$

= 0,027 m =27 mm= 2.7 cm

Where W is the width of the patch, c is the speed of light in free space, which is 3x108 m/s, f_0 is the working frequency of the antenna, and $_r$ is the dielectric constant of the substrate material. Meanwhile, to determine the patch length (L), the parameter L is needed which is the increase in length from L due to the fringing effect. The increase in length of L (ΔL) is formulated by:

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

$$\Delta \boldsymbol{L} = 0.412h\frac{(3.36+0.3)(\frac{27}{1.6}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{27}{1.6}+0.8)}$$

$$= \mathbf{0.6592}\ \frac{\mathbf{(3.66)(17.134)}}{\mathbf{(3.102)(17.67)}}$$

$$= \mathbf{0.6592 \times 1.144 = 0.754}$$

where h is the height of the substrate and $_{reff}$ is the relative dielectric constant which is defined as:

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

$$\sqrt{\boldsymbol{\epsilon reff}} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2} \times \left(1 + \frac{12h}{w}\right)^{-\frac{1}{2}}$$

$$= \frac{5.4}{2} + \frac{3.4}{2} \times \left(1 + 12\ \frac{16}{27}\right)^{-\frac{1}{2}}$$

$$= \mathbf{2.7 + 1.7} \times \left(1 + \frac{19.2}{27}\right)^{-\frac{1}{2}}$$

$$= \mathbf{4.4 \times 0.764}$$

$$\boldsymbol{\varepsilon_{r\,eff}} = \mathbf{3.36}$$

Thus the patch length is given by:

$$\boldsymbol{L} = \boldsymbol{L\epsilon ff} - \mathbf{2}\Delta\boldsymbol{L} = \mathbf{23 - 2 \times 0.754}$$

$$= \mathbf{23 - 1.508}$$

$$= \mathbf{21.4\ mm = 2.1\ cm}$$

Where L_{eff} is the effective patch length which can be formulated by:

$$L\epsilon ff = \frac{c}{2fo\sqrt{\epsilon reff}}$$

$$= \frac{3 \times 10^8}{2 \times 3.3\sqrt{3.36}}$$

$$= \frac{3 \times 10^8}{6.6 \times 10^9 \times 1.83}$$

$$= \frac{3 \times 10^8}{12.07 \times 10^9} = 0.0238\, m = 23cm$$

d) Determine the input impedance value with PCAAD software, the impedance value can be obtained by setting the width of the supply line and simulating it into PCAAD software, the supply line used in this design has an impedance of 50 ohms. Z0 value = 50 , $\mathcal{E}$ r = 4.4 (FR 4 Epoxy) and h = 0.16 cm, then the feeder width is 0.3 cm.The distance between the antenna elements designed in this study is about half of the wavelength (d = λ /2).

$$d = \frac{c}{2f} = \frac{3\ 10\text{^}8}{2x2\ .33\ x10\text{^}9} = 6{,}43\ mm$$

Feeding value of substrate characteristics with PCAAD software this design has an input impedance of 50 ohms. The width of the feeder that produces an impedance of 50 ohms can be calculated mathematically, namely:

$$B = \frac{60x4.4\text{^}2}{50x\sqrt{4.4}} = 3.98$$

$$W = \frac{2\,x\,1{,}6}{3{,}14}\,x\left\{\begin{matrix} 3{,}98 - 1 - In((2\,x\,3{,}98) - 1) \\ + \dfrac{4{,}4 - 1}{2\,x\,4{,}4}\,x \\ \left[In\left(3{,}98 - 1 + 0{,}39 - \dfrac{0{,}61}{4{,}4}\right)\right] \end{matrix}\right\} = 1{,}6\ mm$$

e) Running a simulation (running program HFSS v.13), in designing this microstrip antenna, researchers have designed a Patch Dual U–Slot Double Layer microstrip antenna with Proximity Coupled feeding technique, in this feeding technique two substrates are used on different layers. The stages of designing a microstrip antenna using HFSS software, starting with determining the type of substrate to be used, then measuring the dimensions of the substrate, patch, and slot, then determining the characteristics of the material/substrate. Step by step the design is simulated to get the desired parameters. If the parameters do not match, then redesign is done to get the antenna parameters that match the characteristics of the Access wireless network. The simulation results with the HFSS v.13 programs are, *First,* Rectangular Antenna Patch model with a U-shaped slot, second, the ideal antenna has a value of parameter Return loss -10 dB, small reflection coefficient, so that it will produce a smooth transmission process, third, the value of VSWR > 1 and VSWR < 2 concerning the resonance frequency, fourth, the resulting radiation pattern is vertical.

f) Manufacturing
simulation is a virtual image as reference material, for that we need a comparison process that expresses a real picture. After the simulation is carried out using HFSS v.13 software, then the production stage of the design that has been determined to be fabricated is carried out. This stage is carried out to obtain a real form of a microstrip antenna that has been designed and simulated in software. So it can be measured and analyzed in real.
The following are the stages of the production of microstrip antennas:
   1) Creating layouts in the Corel Draw X6 software application
   2) Print the layout in the form of a film. The following shows an image created with Corel Draw X6 and printed in the form of a film
   3) Print film to a printed circuit board; In this design, the FR4_epoxy type is used
   4) The process of etching the printed circuit board that already has a layout.
   5) the printed circuit board is ready to be measured and used.

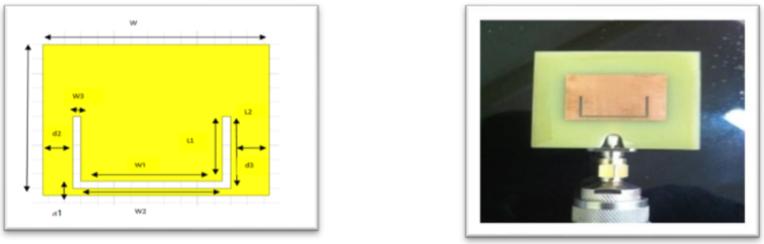
g) implementation,

The implementation of the antenna on the network is done by replacing the antenna on the modem or router where the WIFI modem specifications are set on the 4G network. As a result, the antenna attached to the wifi modem can still be connected and can be used to access the internet. Antenna testing by installing a microstrip antenna on a wifi modem has a comparison that is not too far from the comparison antenna. The comparison antenna used is made for WIFI networks with a frequency of 2.4 GHz-5 GHz. While the microstrip antenna that is made is in mm-Wave with a frequency of 2.3 GHZ-3.5 GHZ which is designed for BWA technology.

3. Results and Discussion

3.1 Patch Geometry

Figure 5 (a) shows the results of the microstrip antenna design with HFSS v13 simulation with a rectangle patch model and on the patch, there is a U-shaped slot. Figure 5 (b) is a manufactured microstrip antenna.



(a) b

Figure 5. The geometry of Patch Antenna`

Table 2. Patch geometry

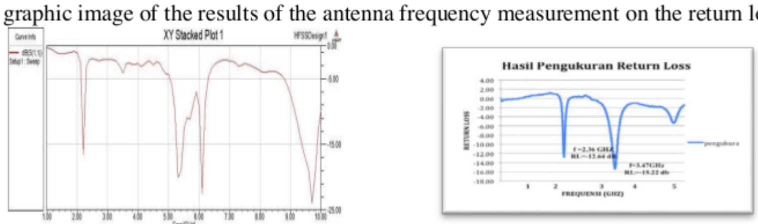
No	Dimension	Size (cm)
1	w	2.7
2	w1	1.7
3	w2	1.9
4	w3	0.1
5	L	2.1
6	L1	0.9
7	L2	1
8	D1	0.1
9	D2	0.36
10	D3	0.46

Table 2 shows the overall patch geometry dimensions of a design with HFSS v13 simulation and is a definite measure of the microstrip antenna manufacturing process in Figure 5 (b).

3.2 Parameters of the resulting Antenna

a) Return loss measurement results

Below is a graphic image of the results of the antenna frequency measurement on the return loss value



(a) (b)

Figure 6. The return loss of simulation results (a) and Measurement (b)

Figure 6(a) shows the return loss value of the simulation result of -16 dB at a frequency of 2.3 GHz and Figure 6(b) shows the return loss value of the measurement results, the return loss value generated at the resonant frequency at 2.3 GHz is -12, 66 dB and at 3.47 GHz the Return loss value is 15.22. This shows the antenna can work well on wireless access networks.

Table 3. Comparison of simulation and measurement return loss

No	Simulation frequency (GHz)	Measurement Frequency (GHz)	Simulation Center Frequency (GHz)	Measurement Center Frequency (GHz)	Simulation Bandwidth (MHz)	Bandwidth Measurement (MHz)
1	2,3-2, 4	2,3-2.4	2.3	2.36	72	84
2	3.3 -3.4	3.4 -3.5	2.38	3.48	114	122

Table 3 shows the value of the Return loss comparison from the simulation results with the antenna measurement results. Where the difference between the results of the center frequency measurement with the simulation is almost not much different. At the center frequency of 2.3, the difference is only 0.06 GHz and at the center frequency of 3.38, the difference is 0.1.

b) Comparison of simulated and measured VSWR

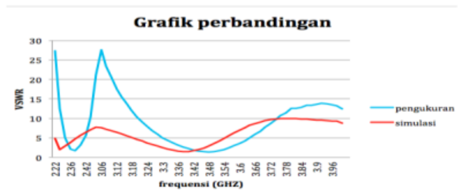


Figure 7. Comparison of simulated and measured VSWR

Figure 7 shows a comparison graph where the difference between the results of the center frequency measurement and the VSWR value with the simulation is almost the same. At the center frequency of 2.3 GHz the value of VSWR is 1.3 and at the center frequency of 3.38 GHz, the value of VSWR is 1.4.

c. Radiation Pattern Simulation

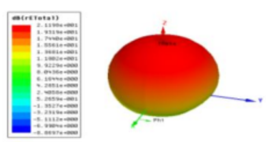


Figure 8. Antenna Radiation Pattern simulation results

figure 8 is the result of the radiation pattern of the microstrip antenna which shows a vertical transmission pattern because it is a directional antenna type, so at frequencies of 2.3 GHz and 3.5 GHz, it has a vertical radiation pattern and has a large bandwidth on the main lobe in the front of the patch. Where the radiation pattern is by the characteristics of wireless Access.

4. Conclusion

The antenna design has been designed as a rectangular patch with slots and an electromagnetically coupled feeding method. Simulation and measurement results show that the VSWR value at the center frequency of 2.3 GHz is 1.3 and at a frequency of 3.38 GHz it is 1.4 GHz. So the value of the two VSWR according to the standard is <2. The Return Loss value for the 2.3 GHz frequency is -12.66 dB while at the 3.38 GHz frequency the Return Loss value is -15.22 dB. From the results obtained, the antenna is by the characteristics of the antenna for wireless Access networks.

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FINAL GRADE

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GENERAL COMMENTS

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FOCUS

State a clear claim/topic sentence and stay focused on supporting it.

MEETS EXPECTATIONS	A precise claim/topic sentence based on the historical topic and/or source(s) is present. The response maintains a strong focus on developing the claim/topic sentence, thoroughly addressing the demands of the task.
APPROACHES EXPECTATIONS	A claim/topic sentence based on the historical topic and/or source(s) is present, but it may not completely address the demands of the task, or the response does not maintain focus on developing it.
DOESN'T MEET EXPECTATIONS	The claim/topic sentence is vague, unclear, or missing, and the response does not address the demands of the task.

EVIDENCE

Represent relevant historical information accurately.

MEETS EXPECTATIONS	The most appropriate evidence is presented to support the topic sentence, and all information is historically accurate.
APPROACHES EXPECTATIONS	Appropriate evidence may be presented to support the topic sentence, but it may be inadequate or contain some historical inaccuracies.
DOESN'T MEET EXPECTATIONS	Evidence is general, inappropriate, or inadequate in support of the topic sentence, or is largely inaccurate.

DEVELOPMENT

Explain how evidence supports the topic sentence.

MEETS EXPECTATIONS	The response demonstrates reasoning and understanding of the historical topic and/or source(s), and sufficiently explains the relationship between claims and support.
APPROACHES EXPECTATIONS	Some reasoning and understanding of the historical topic and/or source(s) are demonstrated. The response attempts to explain the relationship between claims and support.
DOESN'T MEET EXPECTATIONS	The response does not demonstrate reasoning and understanding of the historical topic and/or source(s), and explanation of the relationship between claims and support is minimal.

ORGANIZATION

Present ideas in a logical structure that shows the relationships between ideas.

MEETS EXPECTATIONS	An effective organizational structure enhances the reader's understanding of the information. The relationships between ideas are made clear with effective transitional phrases.
APPROACHES EXPECTATIONS	An organizational structure is evident, but may not be fully developed or appropriate. Transitional phrases may be used but the relationships between

	ideas are somewhat unclear.
DOESN'T MEET EXPECTATIONS	An organizational structure is largely absent and the relationships between ideas are unclear.

LANGUAGE

Communicate ideas clearly using vocabulary specific to the historical topic.

MEETS EXPECTATIONS	Ideas are presented clearly, using vocabulary specific to the historical topic. If errors in conventions are present, they do not interfere with meaning.
APPROACHES EXPECTATIONS	Ideas are mostly clear, using some vocabulary specific to the historical topic. Some errors in conventions are present that may interfere with meaning.
DOESN'T MEET EXPECTATIONS	Ideas are not clear, using little to no vocabulary specific to the historical topic. Several errors in conventions interfere with meaning.