Design and Implementation of 2x4 Truncated Corner Patch Microstrip Antenna with U-Slot at 2.4 GHz Frequency for Wi-Fi Applications

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***Abstract* — Antennas are an important component in wireless communication systems that continue to grow in the use of the 2.4 GHz frequency for 4G/LTE applications. Technology in the field of telecommunications has developed very rapidly wireless communication or called wireless. Microstrip antenna is one type of antenna that has a narrow bandwidth, small gain. The design and manufacture of a truncated corner microstrip patch antenna with a 2x4 array at a frequency of 2.4 GHz with a U-slot aims to be able to widen the bandwidth by using a U-slot with an expected bandwidth value of 94 MHz. The truncated corner method is used to obtain circular polarization. The truncated corner microstrip antenna is designed by cutting corners. The array method is used to obtain the maximum gain value, while the addition of the U-slot aims to reduce the return loss and Voltage Standing Wave Ratio (VSWR) values. The results of this study are an external device, namely a microstrip antenna that functions as a signal amplifier and the working frequency used is a microstrip antenna in the frequency range of 2401-2495 MHz for a Wi-Fi communication system with a working frequency of 2448 MHz. This study is in accordance with the antenna test parameters, the results of the antenna testing bandwidth with a U-slot of 31 MHz with a VSWR value of 1.5 The conclusion of this research is the testing and implementation of microstrip patch antenna truncated corner array 2x4 elements with U-slot capable of widening the bandwidth.**

***Keywords* — Microstrip Antenna, truncated corner, U-slot, Wi-Fi.**

I. INTRODUCTION

Antenna is an important part that plays a role in optimizing the performance of communication systems on Wi-Fi. The implementation of this research uses a microstrip antenna which has the advantages of being thin and small, light in weight, easy to fabricate, easy to integrate with other electronic devices and relatively cheap price. Microstrip antenna basically has several disadvantages such as low gain and narrow bandwidth [1].

Wireless communication systems require a device that can function as a transmitter and receiver (transmitter and receiver). To be able to facilitate the need for telecommunications technology that is currently developing, antenna devices are capable of receiving signals at several different working frequencies. Microstrip antennas have advantages, including being small, compact, and simple. However, this type of antenna has several drawbacks, including low gain, poor directivity, low efficiency, resistance losses on the feed line, and narrow bandwidth [2].

This study uses the truncated corner method which is applied to a Wi-Fi. This truncated corner method with the top edge and bottom antenna. To increase the gain value of the microstrip antenna, it can be done using the array method. The array method is done by arranging the microstrip antenna into several patches with a feed line (microstrip line) with the aim of producing a larger gain. And to overcome the small bandwidth, the patch is given a slot in the form of a U-slot [3].

The author's design process will use the CST Studio Suite 2018 software to be used in the design and testing process based on simulations. The author realized it using an FR-4 epoxy substrate with a dielectric constant of 4.3 and a thickness of 1.6 mm. The tests carried out will be based on the parameter values of return loss, VSWR (Voltage Standing Wave Ratio), bandwidth, gain and radiation pattern. The author does the implementation by using the access point TD -W8951ND

This thesis designs and implements a microstrip antenna with a patch in the form of a truncated corner array 2x4 element with a U-shaped slot for 2.4 GHz Wi-Fi frequency applications.

II. RESEARCH METHODS

A. System Design

System design in system planning is shown in Figure 1 as follows:

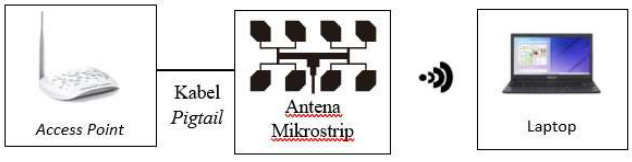

Figure 1. System block diagram

B. Research Design

Flowchart of the research design that will be made shown in Figure 2 as below:

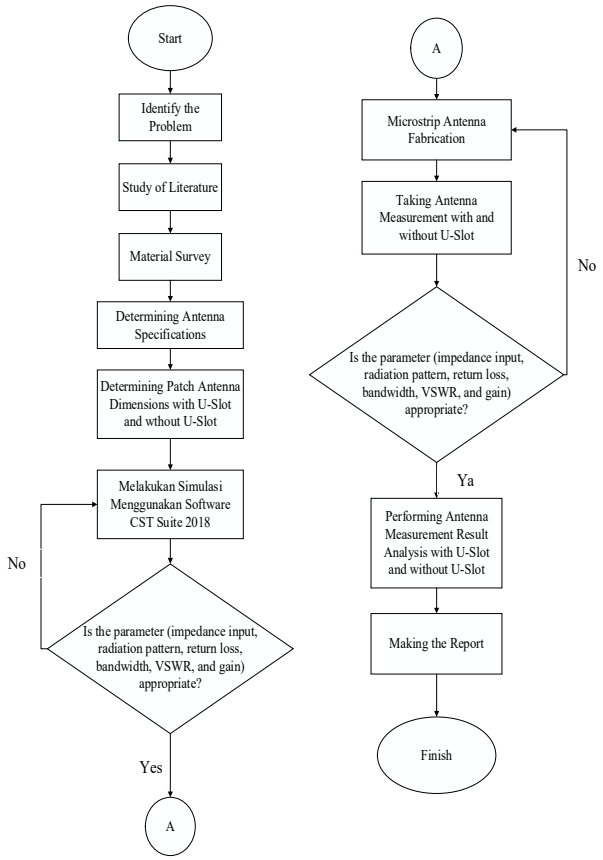

Figure 2. Research design flowchart

C. *Determination of Material Specifications*

The following is a specification of the materials to be used.

TABLE I
SPECIFICATION OF PCB FR-4

Details	Specification
Layer	2 (double)
Copper Thickness	0.015 mm
Thickness	1.57 mm
Size	312.42 x 147 mm
Made in	Shenzhen, China

D. *2x4 Element Truncated Corner Patch Microstrip Antenna Design with U-Slot*

The design of a microstrip antenna with a 2x4 truncated corner patch element with a U-Sloy is shown in Figure 3 and Figure 4 as follows:

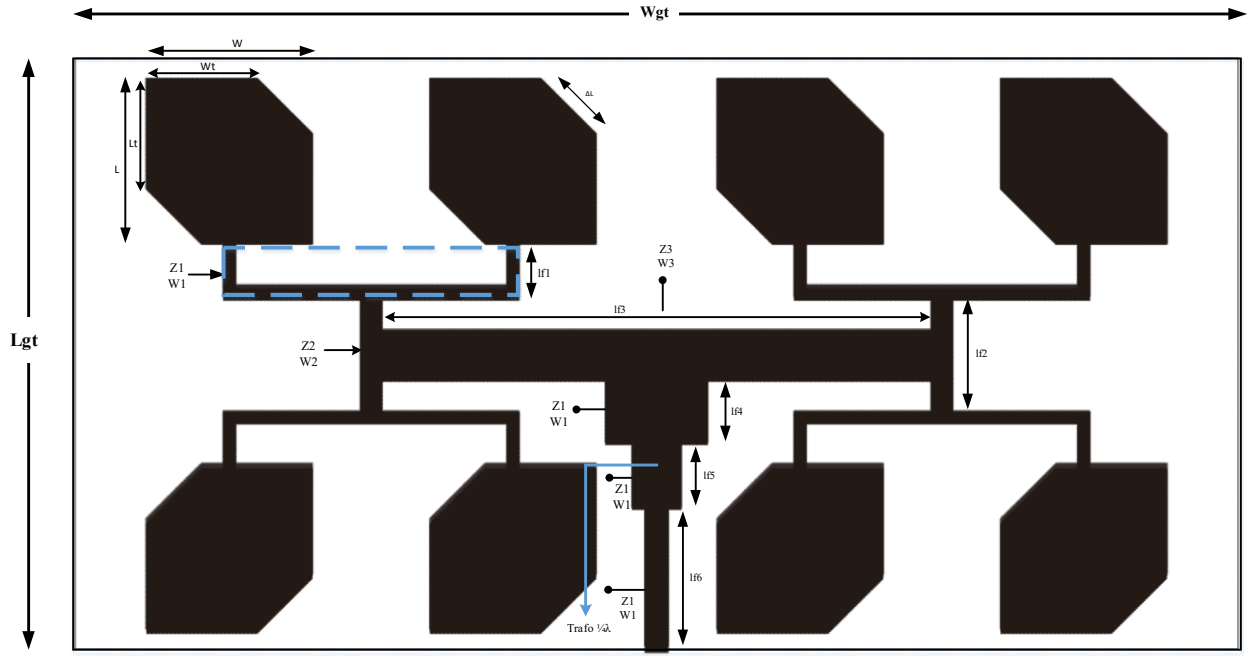

Figure 3. Design of a 2x4 element truncated corner microstrip patch antenna front view

Figure 4. Design of a 2x4 element truncated corner microstrip patch antenna with a U-Slot back view

E. Determination of Wavelength and Dimensions of Radiating Elements

1) Truncated Corner Patch Calculation

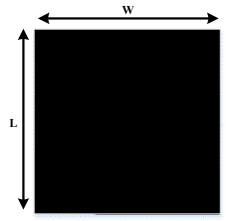

Figure 5. Square Patch

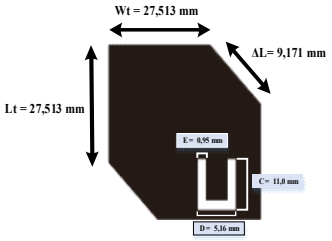

Figure 6. Truncated Patch Patch

- Patch width (Wt)
  Wh = 36.684 mm
- Patch length (Lt)
  Lh = 36.684 mm
- εreff (effective dielectric constant)
  εreff = 3.92 F/mm
- Δ*L*(patch side pieces)
  Δ*L* = 9.171 mm
- Truncated Corner input impedance
  Z3 = 93.654 Ω

2) Determination of Supply Line Impedance

- Supply Line Impedance
  Z6 = 50 Ω (ohm)

3) Calculation of Transmission Line Width

- Lebar Saluran Transmisi 1
  Wf1 = 2.95 mm
- Transmission Line Width 2
  Wf2 = 5.90 mm
- Transmissoin Line Width 3
  Wf3 = 11.81 mm
- Transmission Line Width 4
  Wf4 = 23.62 mm
- Transmission Line Width 5
  Wf5 = 11.43 mm
- Transmission Line Width 6
  Wf6 = 5.53 mm

4) Calculation of Transmission Line Length

- Transformer Length
  LT = 14.3 mm
- Length of Transmission Line-n (Lfn)
  Lf1 = 12.03 mm
  Lf2 = 25.13 mm
  Lf3 = 125.98 mm
  Lf4 = 14.8 mm
  Lf5 = 14.3 mm
  Lf6 = 13 mm

5) Determination of Groundplane Length and Width

- Groundplane length
  Wg = 267.04 mm
- Groundplane width
  Lg = 136.04 mm

6) Determining dimensions of U-Slot

- Width of circle head dumbbell radius
  E = 0.95 mm
- Dumbbell circle head channel width
  C = 11 mm
- Dumbbell circle head channel length
  D = 5.16 mm

III. RESULTS AND DISCUSSION

A. Return Loss (RL Simulation Results)

Figure 7 is the result of a simulation of the return loss of a 2x4 truncated corner patch microstrip antenna using a U-Slot.

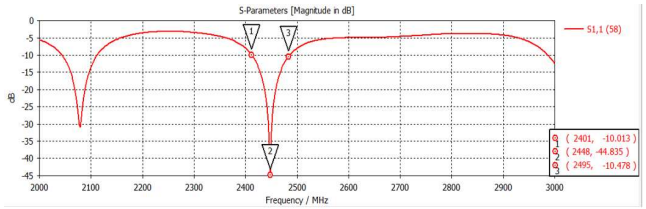

Figure 7. Return loss simulation of 2x4 truncated corner patch microstrip antenna using a u-slot

The return loss value is -10.01 dB for the frequency of 2401 MHz and -10.47 dB for the frequency of 2495 MHz. The frequency of 2448 MHz has the lowest return loss value, which is -44.835 dB.

B. Voltage Standing Wave Ratio (VSWR) Simulation Results

Figure 8 is the results of a VSWR simulation of a 2x4 truncated corner patch microstrip antenna using a U-Slot.

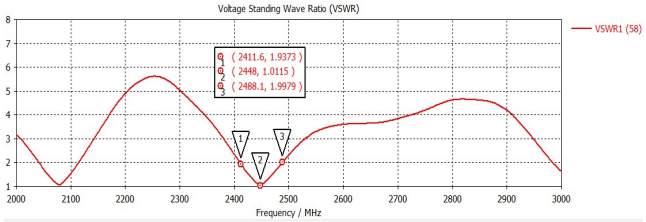

Figure 8. VSWR simulation of 2x4 truncated corner patch microstrip antenna using a u-slot

VSWR values obtained are 1.9373 for the frequency of 2401 MHz and 1.9979 for the frequency of 2495 MHz. The frequency of 2448 MHz has the lowest VSWR value, which is 1.0115.

C. Bandwidth Simulation Results

Figure 9 is the results of a bandwidth simulation of a 2x4 truncated corner patch microstrip antenna using a U-Slot.

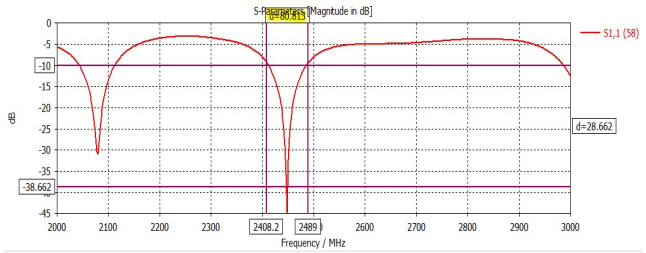

Figure 9. Bandwidth simulation of 2x4 truncated corner patch microstrip antenna using a u-slot

Bandwidth value of 85.506 MHz where the lower frequency is 2408.1 MHz and the upper frequency is 2499 MHz.

D. Return Loss (RL) and Voltage Standing Wave Ratio (VSWR) Testing Results

Figure 10 is the result of measuring the return loss reference level of a 2x4 truncated corner patch antenna using a U-Slot.

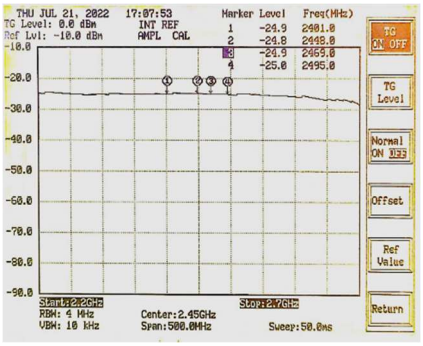

Figure 10. The results of measuring the return loss reference level of the 2x4 trunacated corner patch microstrip antenna using a u-slot

Figure 11 is the result of measuring the return loss reading level of the 2x4 truncated corner patch antenna using a U-Slot.

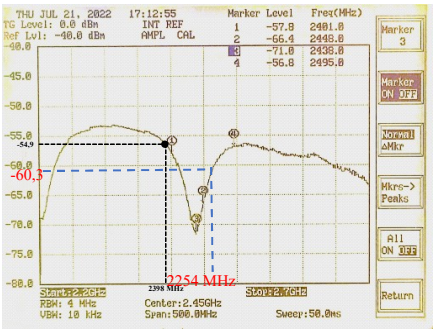

Figure 11. The results of the level measurement read the return loss of the truncated corner patch microstrip antenna using a u-slot

Figure 11 The return loss value is -21.6 dB with a VSWR value of 1.18 at a frequency of 2448 MHz, while the lowest return loss value is -26.1 with a VSWR value of 1.08 at a frequency of 2438 MHz.

TABLE II
RL AND VSWR TESTING OF TRUNCATED CORNER PATCH MICROSTRIP ANTENNA 2X4 ELEMENT WITH U-SLOT

Frequency (MHz)	Level (dBm)			RL (dB)	VSWR
	Read	Reference	Attenuation DC		
2401	-57.8	-24.9	-20	-12.9	1.56
2478	-66.4	-24.8	-20	-21.6	1.18
2448	-71.5	-24.9	-20	-26.1	1.08
2495	-56.8	-25.0	-20	-11.8	1.66

E. Gain and Bandwidth Testing Results

Table III is the result of testing the gain of a 2x4 truncated corner patch microstrip antenna using a u-slot.

TABLE III
GAIN TEST RESULTS OF TRUNCATED CORNER PATCH MICROSTRIP ANTENNA 2X4 ELEMENT WITH U-SLOT

Frequency (MHz)	Level (dBm)		Gain (dBi)	Normalization
	Reference Antenna	Antenna Under Test		
2320	-56,6	-59,3	-0,55	-13,8
2330	-57,3	-58,4	1,05	-12,2
2340	-59,4	-58,4	3,15	-10,1
2350	-62,2	-58,7	5,65	-7,6
2360	-64,6	-59,5	7,25	-6
2370	-58	-61,6	-1,45	-14,7
2380	-56,9	-66,4	-7,35	-20,6
2390	-57,4	-64,4	-4,85	-18,1
2400	-60,3	-59,7	2,75	-10,5
2410	-55,2	-61,6	-4,25	-17,5
2420	-56,6	-57,8	0,95	-12,3
2430	-58,4	-56,8	3,75	-9,5
2440	-55,4	-56,4	1,15	-12,1
2450	-68,5	-59,3	11,35	-1,9
2460	-70,4	-59,3	13,25	0
2470	-68,9	-58,6	12,45	-0,8
2480	-65,7	-60,8	7,05	-6,2
2490	-66,2	-61,8	6,55	-6,7
2500	-55	-61,1	-3,95	-17,2
2510	-57	-60	-0,85	-14,1
2520	-58	-62,6	-2,45	-15,7
			Highest Gain = 13.25 dBi	

The following is a graph of the bandwidth of a 2x4 truncated corner patch microstrip antenna using a u-slot based on Table III.

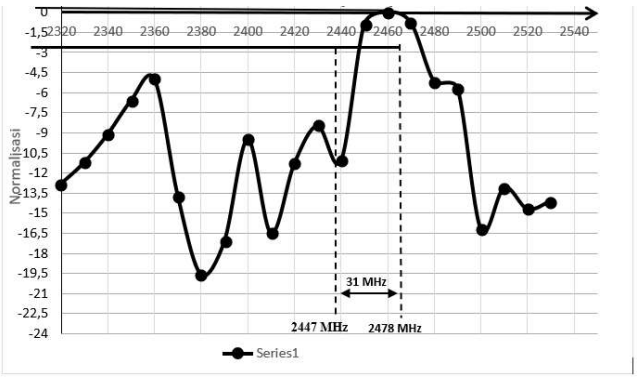

Figure 12. Bandwidth of 2x4 truncated corner patch microstrip antenna using a u-slot

The bandwidth results for the truncated corner 2x4 element microstrip patch antenna using a u-slot can be shown through the intersection of the normalization points with a value of -3 dBi. The graph above shows the bandwidth value of 34 MHz obtained from a frequency of 2451 MHz - 2485 MHz. The gain obtained is close to the working frequency of the truncated corner 2x4 element microstrip patch antenna with a DGS of 2462 MHz with a value of 4.75 dBi.

F. Radiation Pattern Testing Results

Table IV is the result of testing the radiation pattern of the 2x4 truncated corner patch microstrip antenna using a u-slot.

TABLE IV
TESTING RADIATION PATTERN OF TRUNCATED CORNER MICROSTRIP PATCH ANTENNA 2X4 ELEMENT WITH U-SLOT

Corner(°)	Frequency 2448 MHz	
	Radiation Pattern (dB)	Normalization
0	-55,8	0
10	-60,7	-4,9
20	-63,5	-7,7
30	-63	-7,2
40	-66,2	-10,4
50	-68	-12,2
60	-67,5	-11,7
70	-68,4	-12,6
80	-71,8	-16
90	-77,5	-21,7
100	-76	-20,2
110	-72	-16,2
120	-72,4	-16,6
130	-70,1	-14,3
140	-72,9	-17,1
150	-69,6	-13,8
160	-68,2	-12,4
170	-67,5	-11,7
180	-67,9	-12,1
190	-70,9	-15,1
200	-68	-12,2
210	-67,8	-12
220	-67,6	-11,8
230	-66,6	-10,8
240	-66,7	-10,9
250	-67,9	-12,1
260	-69,2	-13,4
270	-70	-14,2
280	-71,7	-15,9
290	-72	-16,2
300	-71,2	-15,4
310	-69	-13,2
320	-67,2	-11,4
330	-64,9	-9,1
340	-60,6	-4,8
350	-60	-4,2

Based on the data obtained in Table IV, a radiation pattern diagram can be described as shown in Figure 12.

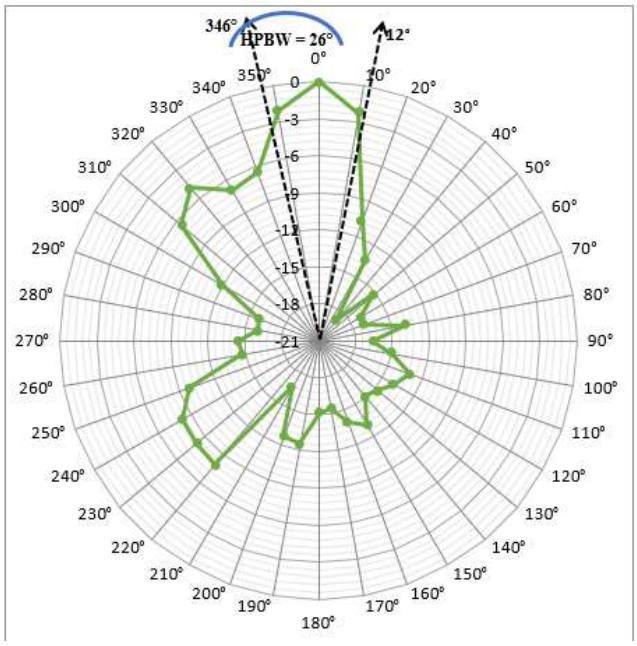

Figure 13. Radiation pattern of 2x4 truncated corner patch microstrip antenna using a u-slot

Figure 13 obtained a directional radiation pattern because it has an effective radiation direction at an angle of 0º compared to other angles.

G. Results of Implementation of Bulit in Antenna and Microstrip Patch Truncated Corner 2x4 Elements Using U-Slot

Table VI is the result of implementing the built-in antenna and microstrip patch truncated corner 2x4 elements using a u-slot.

TABLE V
RESULTS OF IMPLEMENTATION OF BUILT IN ANTENNA AND TRUNCATED CORNER PATCH MICROSTRIP 2X4 ELEMENT WITH U-SLOT

Antenna	Receive Signal Strength Indicator (RSSI)
Built-in	-52 dBm
Microstrip patch truncated corner 2x4 element	-48 dBm

From Table V, there are RSSI values between the built-in antenna and 2x4 truncated corner patch microstrip antenna using a u-slot. So the difference in power can be calculated using the following equation:

$$\text{Power difference} = RSSI_{mikrostrip} - RSSI_{built\text{-}in}$$

$$= -48 - (-52)$$

$$= 4 \text{ dBm}$$

The power received by the TD-W8951ND access point when using an external 2x4 truncated corner patch microstrip antenna using a u-slot is 4 dBm stronger when compared to the built-in antenna.

IV. CONCLUSION

Based on the research and testing that has been done, several conclusions can be drawn, namely:

1. The results of testing the truncated corner 2x4 element microstrip patch antenna using a u-slot, the return loss value for the frequency of 2448 is -21.6 dB with a VSWR of 1.18.
2. The results of testing the bandwidth of the truncated corner 2x4 element microstrip patch antenna with a u-slot of 31 MHz.
3. The results of testing the radiation pattern of the truncated corner 2x4 element microstrip patch antenna using a u-slot obtained an HPBW value of 26º. The resulting radiation pattern is directional.
4. The results of the RSSI implementation show an increase in the power level for the microstrip antenna, which is 4 dBm.
5. For the next research, the microstrip antenna fabrication process is recommended to use the printing method in order to get precise results.

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