# Design and Implementation of Microstrip Antenna Hexagonal – Rectangular Patch 2x4 Array with H - Slot at 2.4 GHz Frequency

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*Abstract*— **Antenna microstrip is one of the lots of antennas used in system telecommunication specifically for microwave frequency. Antenna microstrip own a number of applications as in communication cellular and satellite, GPS, RFID, WiMax, radar, rectenna to use in the medical world. Antenna microstrip has weaknesses such as narrow bandwidth, small gain, and low efficient. In this article an antenna microstrip with hexagonal - rectangular patches 2x4 array will be designed without and with "H" slot. Antenna will be designed and simulated using CST 2019 software. Printing antenna using PCB with substrate made from epoxy fiberglass which has constant dielectric 4.58. Antenna's parameters that will be measured are return loss, VSWR, gain, radiation pattern, and bandwidth. Measured parameter value then compared between antennas without slots and antennas that use slots with hope antenna microstrip with slots capable of expands bandwidth from antenna without slots. The testing result show that return loss of antenna microstrip without slot is -10.1 dB with bandwidth of 9.45 MHz and return loss of antenna microstrip with a slot is -11.73 dB with bandwidth of 55.59 MHz so can concluded that bandwidth of antenna slots is 46.14 MHz bigger than antenna microstrip without slots.**

***Keywords— Bandwidth, Hexagonal, Microstrip Antenna, Rectangular , Slot , Wi-Fi.***

## I. INTRODUCTION

Antenna is a very important component in a communications system, especially for wireless needs. Antenna quality can influence the working quality of wireless technology such as Wi-Fi in a telecommunications system. One of the antennas that is widely used in microwave frequency telecommunications systems is the microstrip antenna. Microstrip antennas have a simple basic form consisting of a substrate with a radiating patch on one side and a ground plane on the other side. Microstrip antennas have several applications such as in cellular and satellite communications, GPS, RFID, WiMax, radar, rectenna and even use in the medical world. [1].

Microstrip antennas have several advantages and disadvantages that need to be considered. The advantages of microstrip antennas are that they are practical, have simple sizes and dimensions, are easy to fabricate, and are easy to integrate with other technologies, making them suiTable for small-scale use such as IoT. The disadvantages of microstrip antennas include narrow bandwidth, small gain and low efficiency. There are many ways to overcome the weaknesses of microstrip antennas, from changing the substrate, changing the patch shape design, adding patches so that they form an array and adding slots to the patch antenna.

The disadvantages of microstrip antennas, especially narrow bandwidth, can be overcome by using slots in the patch as was done in research [2] which has proven that slots can increase bandwidth. And a small gain can be increased by using a patch array as was done in research [3].

Based on the explanation, in this research a microstrip antenna [4][5][6] will be created which will be designed with a hexagonal [7] - rectangular shaped patch [8] with an "H" slot to increase bandwidth and an array of 2x4 elements to increase gain. This research will implement a microstrip antenna design on Wi-Fi with the hope of improving Wi-Fi network performance.

## II. METHOD

This research was carried out by first determining the substrate to be used and the design of the microstrip patch antenna used.

### A. Specification Materials Used

The substrate that will be used is epoxy FR-4 with a thickness of 1.53 mm and a dielectric constant of 4.58. This substrate is used because it is widely available on the market and relatively cheap, as shown in Table I.

TABLE I
FR-4 PCB SPECIFICATIONS

| Details | Specification |
|---|---|
| Layers | 2 (double) |
| Copper Thickness | 0.04mm |
| Substrate Thickness | 1.53mm |
| Size length x width | 260.5mm x 122mm |
| Made in | China |

*Corresponding Author

## *B. Patch Antenna Design*

The microstrip patch antenna [9] design is determined by calculating the dimensions of the patch antenna shape. In this research, patches used hexagonal and rectangular with slots.

1. Rectangular Patch Dimensions

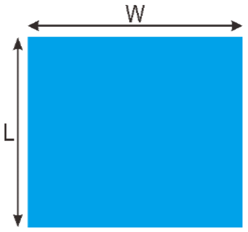


Figure 1. Rectangular Patch Antenna Microstrip

The width of the rectangular patch can be determined using the equation 1 [10]:

$$W = \frac{c}{2xf_r x\sqrt{\frac{\varepsilon_r + 1}{2}}} \tag{1}$$

Information:
W = Patch width (mm)
c = Speed light (299792458 m/s)
r = frequency resonant
ε r = Substrate Constant Dielectric

The length of the rectangular patch can be determined using the equation 2, 3, and 4 [11].

$$L = \frac{c}{2f\sqrt{\varepsilon_{reff}}} - 2\Delta L \tag{2}$$

Where

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(\frac{1}{\sqrt{1 + 12(\frac{h}{W})}}\right) \tag{3}$$

And

$$\Delta L = 0.421h\frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.246\right)}{(\varepsilon_{reff} - 0.285)\left(\frac{W}{h} + 0.8\right)} \tag{4}$$

$\varepsilon_{reff}$ is the effective dielectric constant [12] and h is the height of the substrate or what can be called the thickness of the substrate.

2. Hexagonal Patch Dimensions

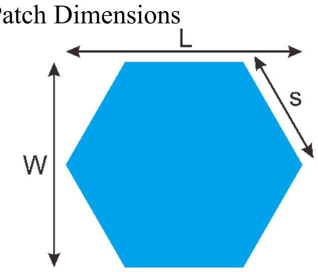


Figure 2. Hexagonal Patch Antenna Microstrip

The width of the hexagonal patch can be determined using the equation 5 [13].

$$W = \frac{c}{2xf_r x\sqrt{\frac{\varepsilon_r + 1}{2}}} \tag{5}$$

The length of the hexagonal patch can be determined using the equation 6 [14].

$$L = \frac{c}{2f\sqrt{\varepsilon_{reff}}} - 2\Delta L \tag{6}$$

The side lengths of a hexagonal patch [15] can be determined using the equation 7.

$$s = \frac{c}{3.1033xfr\sqrt{\varepsilon_r}} \tag{7}$$

3. H Slot Dimensions

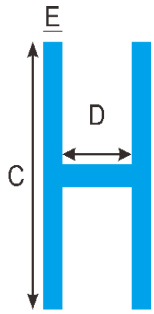


Figure 3. Slot "H"

The vertical length in H slot can be determined using the equation 8 [16].

$$\frac{C}{W} \geq 0.3 \tag{8}$$

The horizontal length of the H slot can be determined using the equation 9. [17]

$$D = \frac{c}{f\sqrt{\varepsilon_{reff}}} - \left(2L - (2\Delta L - E)\right) \tag{9}$$

The H slot width can be determined using the equation 10 and 11 [18].

$$E = \frac{\lambda}{60} \tag{10}$$

where

$$\lambda = \frac{c}{f\sqrt{\varepsilon_r}} \tag{11}$$

## *C. Antenna Transmission Line Design*

Determining the transmission line design requires knowing the impedance of each patch so that the channel width up to the 50 Ω supply can be determined.

*1) Hexagonal Input Impedance*

$$Z_{in} = 60\frac{\lambda_d}{L_h} \tag{12}$$

*2) Rectangular Input Impedance*

$$Z_{in} = 90.\frac{\varepsilon_r}{\varepsilon_r - 1}\left(\frac{L}{W}\right) \tag{13}$$

After knowing the input impedance value for each patch, proceed to determine the impedance on each branch of the transmission line.

*3) Transmission Line Impedance*

$$\frac{1}{Z_p} = \frac{1}{Z_1} + \frac{1}{Z_2} \tag{14}$$

Information:

$Z_p$ = Parallel impedance (Ω)
$Z_1$ = Transmission line branch 1 impedance(Ω)
$Z_2$ = Transmission line branch 2 impedance (Ω)

At every transition between unequal impedances [19], an impedance matching is required which is able to make the two channels match using a transformer ¼ λ with the equation15.

$$Z_t = \sqrt{Z_0 . Z_{in}} \tag{15}$$

Information:

$Z_t$ = Impedance transformation (Ω)
$Z_0$ = Impedance channel output transmission (Ω)
$Z_{in}$ = Impedance channel input transmission (Ω)

After knowing the impedance of each transmission line, you can continue by determining the channel width using the equation 16.

$$W_f = \frac{120\pi h}{Z_p\sqrt{\varepsilon_r}} \tag{16}$$

Information:

$W_f$ = Transmission line width (mm)

$Z_p$ = Transmission line impedance (Ω)

The equation will be used to determine the dimensions of the microstrip antenna as shown in Table II.

TABLE II
DIMENSIONS ANTENNA MICROSTRIP

| Dimensions | Size (mm) |
|---|---|
| Ground plane width | 260.5 |
| Ground plane length | 122 |
| Feed line 50 Ω | 5.39 |
| Line of 50 Ω supply transformer | 10,781 |
| Transmission line 12.5 Ω | 21,562 |
| Transmission line 25 Ω | 10,781 |
| Transmission line 50 Ω | 5.39 |
| Transmission line 100 Ω | 2,695 |
| Transmission line hexa transformer | 2,445 |
| Hexa transmission line | 2,223 |
| Recta transformer transmission line | 1,337 |
| Recta transmission line | 0.663 |
| Patch width | 36,659 |
| Patch length | 28,252 |
| Hexa side length | 18.45 |
| Vertical length of slots | 11 |
| Horizontal length of slots | 3.4 |
| Slots width | 2 |

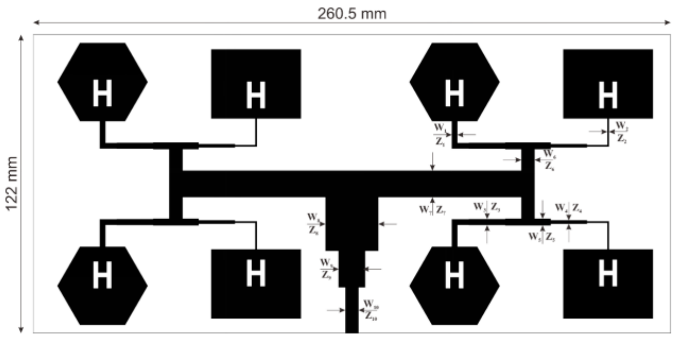


Figure 4. Antenna Hexagonal Microstrip - Rectangular Array 2x4 With "H" Slots

## III. RESULTS AND DISCUSSION

### *A. Return Loss Simulation Results*

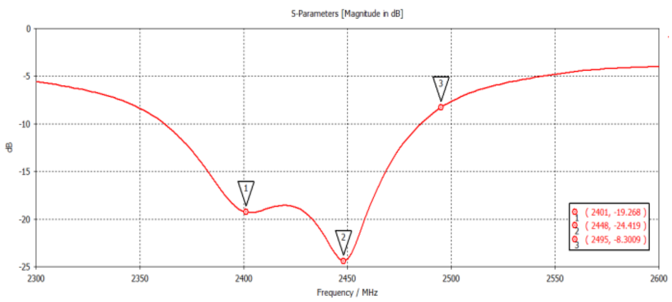


Figure 5. Return Loss Simulation Of 2x4 Hexagonal – Rectangular Array Microstrip Antenna With "H" Slot

Figure 5 is the return loss simulation result of a microstrip antenna with an "H" slot at a working frequency of 2401 - 2495 MHz with a center frequency of 2448 MHz. The markers in the image have the following explanation:

1. Marker 1 is the minimum frequency located at 2401 MHz with a return loss of -19,268 dB.
2. Marker 2 is a resonant frequency located at 2448 MHz with a return loss of -24,419 dB.
3. Marker 3 is the maximum frequency located at 2495 MHz with a return loss of -8.3009 dB.

*B. VSWR Simulation Results*

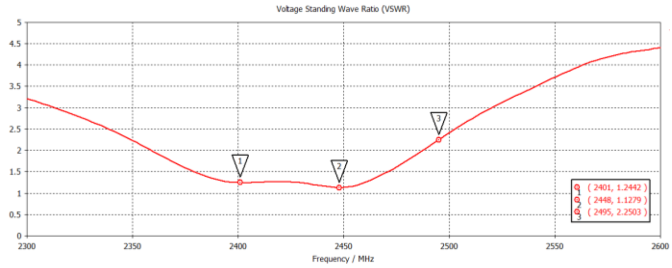


Figure 6. VSWR Simulation Of 2x4 Hexagonal – Rectangular Array Microstrip Antenna With "H" Slot

Figure 6 shows the VSWR results from a microstrip antenna simulation with a slot designed at a working frequency of 2401 – 2495 MHz with a resonant frequency of 2448 MHz. The markers in the image have the following explanation:

1. Marker 1 is the minimum frequency located at 2401 MHz with a VSWR of 1.2442
2. Marker 2 is the resonant frequency located at 2448 MHz with a VSWR of 1.1279
3. Marker 3 is the maximum frequency located at 2495 MHz with VSWR 2.2503

Simulations using CST Studio 2019 show that the microstrip antenna without the "H" slot produces a VSWR of 1.1426 and the microstrip antenna with the "H" slot produces a VSWR of 1.1436 at a frequency of 2448 MHz. Because the VSWR simulation result of the microstrip antenna is ≤ 2, the simulated antenna meets the minimum specification standards.

*C. Bandwidth Simulation Results*

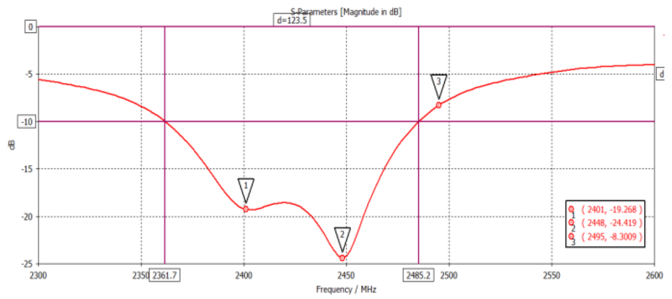


Figure 7. Simulation Results Of 2x4 Hexagonal – Rectangular Array Microstrip Antenna Bandwidth With "H" Slot

Figure 7 shows the bandwidth results from simulating a microstrip antenna with an "H" slot which is shown by the intersection of the horizontal measure line at a value of -10 dB with the vertical measure line at the first frequency of 2361.7 MHz and the second frequency of 2485.2 MHz. From the frequency value obtained from the two intersections, the bandwidth value can be determined using the equation 17 and 18.

$$Bandwidth = f_h - f_l \quad (17)$$

$$Bandwidth = 2485.2 - 2361.7 = 123.45\ MHz \quad (18)$$

When compared with the planned antenna bandwidth specifications, namely >94 MHz, the microstrip antenna meets the planned bandwidth specifications.

*D. Return Loss Test Results*

1. Return loss results of 2x4 hexagonal - rectangular array microstrip antenna without "H" slot

Tests that have been carried out on hexagonal – rectangular microstrip antennas to measure the return loss value have obtained the results shown in Figure 8.

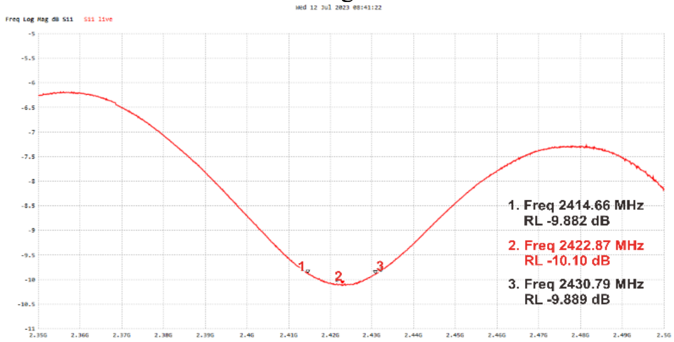


Figure 8. Antenna Return Loss Hexagonal – Rectangular Microstrip Without "H" Slot

Figure 8 shows that the resonant response frequency of the microstrip antenna without the "H" slot is at a frequency of 2422.87 MHz with a return loss of -10.10 dB.

TABLE III
ANTENNA RETURN LOSS HEXAGONAL - RECTANGULAR MICROSTRIP WITHOUT "H" SLOT

| Markers | Frequency | *Return loss* |
|---|---|---|
| 1 | 2414.66 MHz | -9,882 dB |
| 2 | 2422.87 MHz | -10.10 dB |
| 3 | 2430.79 MHz | -9,889 dB |

2. Return loss results of 2x4 hexagonal - rectangular array microstrip antenna with "H" slot

The results of microstrip antenna testing that have been carried out on hexagonal - rectangular with "H" slots for measuring return loss values are shown in Figure 9.

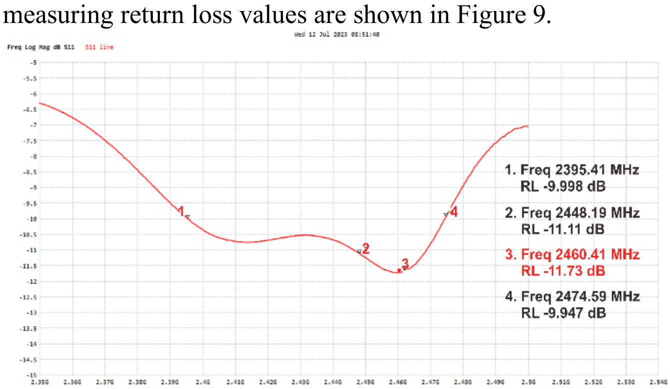


Figure 9. Return Loss Of Hexagonal - Rectangular Microstrip Antenna With "H" Slot

Figure 9 shows that the resonant response frequency of the microstrip antenna without the "H" slot is at a frequency of 2460.41 MHz with a return loss of -11.73 dB.

TABLE IV
RETURN LOSS HEXAGONAL - RECTANGULAR MICROSTRIP ANTENNA WITH "H" SLOT

| Markers | Frequency | *Return loss* |
|---|---|---|
| 1 | 2395.40 MHz | -9,998 dB |
| 2 | 2448.19 MHz | -11.11 dB |
| 3 | 2460.41 MHz | -11.73 dB |
| 4 | 2474.59 MHz | -9,947 dB |

### *E. VSWR Test Results*

1. VSWR results of 2x4 hexagonal – rectangular array microstrip antenna without "H" slot

Tests that have been carried out on hexagonal - rectangular microstrip antennas without "H" slots obtained VSWR results as in Figure 10.

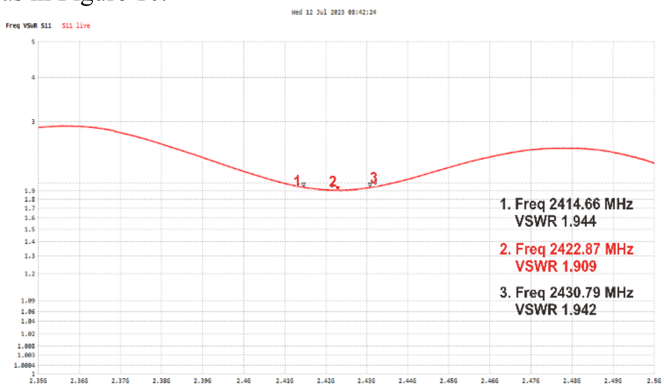


Figure 10. Antenna VSWR Hexagonal - Rectangular Microstrip Without "H" Slot

Figure 10 shows the VSWR results where at the resonant frequency, namely 2422.87 MHz, the VSWR value is 1,909.

The VSWR value can also be obtained by calculating the return loss value by determining the reflection coefficient value first:

$$RL = 20 \log|\Gamma| \tag{19}$$
$$|\Gamma| = 10^{\frac{RL}{20}}$$
$$|\Gamma| = 10^{\frac{-10.1}{20}}$$
$$|\Gamma| = 0.313$$

After the reflection coefficient value has been determined, proceed with calculating the VSWR in the following way:

$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|} \tag{20}$$
$$VSWR = \frac{1+0.313}{1-0.313}$$
$$VSWR = 1.909$$

TABLE V
VSWR RESULTS OF HEXAGONAL - RECTANGULAR MICROSTRIP ANTENNA WITHOUT "H" SLOT

| Markers | Frequency | Coefficient Reflection | VSWR |
|---|---|---|---|
| 1 | 2414.66 MHz | 0.321 | 1,944 |
| 2 | 2422.87 MHz | 0.313 | 1,909 |
| 3 | 2430.79 MHz | 0.320 | 1,942 |

2. VSWR Results Of 2x4 Hexagonal - Rectangular Array Microstrip Antenna With "H" Slot

Tests that have been carried out on hexagonal - rectangular microstrip antennas with "H" slots have obtained VSWR results as in Figure 11.

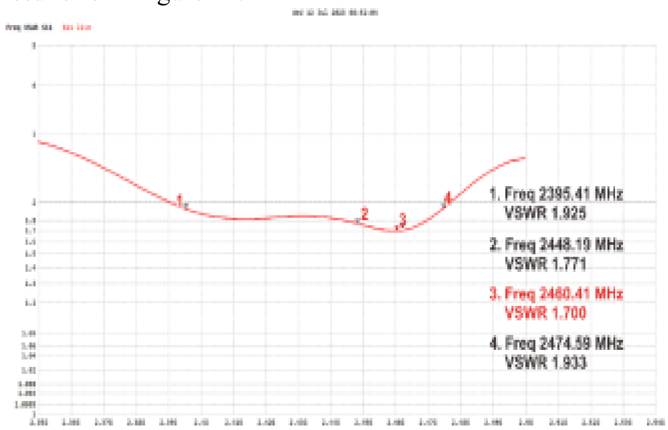


Figure 11. VSWR Hexagonal - Rectangular Microstrip Antenna With "H" Slot

Figure 11 shows the VSWR results where at the resonant frequency, namely 2460.41 MHz, the VSWR value is 1.7.

The VSWR value can also be obtained by calculating the return loss value by determining the reflection coefficient value first:

$$RL = 20 \log|\Gamma| \tag{21}$$
$$|\Gamma| = 10^{\frac{RL}{20}}$$
$$|\Gamma| = 10^{\frac{-1.7}{20}}$$
$$|\Gamma| = 0.259$$

After the reflection coefficient value has been determined, proceed with calculating the VSWR in the following way:

$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|} \tag{22}$$
$$VSWR = \frac{1+0.259}{1-0.259}$$
$$VSWR = 1.7$$

TABLE VI
VSWR RESULTS OF HEXAGONAL - RECTANGULAR MICROSTRIP ANTENNA WITHOUT "H" SLOT

| Markers | Frequency | Coefficient Reflection | VSWR |
|---|---|---|---|
| 1 | 2395.41 MHz | 0.316 | 1,925 |
| 2 | 2448.19 MHz | 0.278 | 1,771 |
| 3 | 2460.41 MHz | 0.259 | 1,700 |
| 4 | 2474.59 MHz | 0.318 | 1,933 |

### *F. Gain Test Result*

1. Gain results of 2x4 hexagonal - rectangular array microstrip antenna without "H" slot

The results of tests carried out on hexagonal - rectangular microstrip antennas without "H" slots for measuring gain values are shown in Table 7.

TABLE VII
GAIN OF HEXAGONAL - RECTANGULAR MICROSTRIP ANTENNA WITHOUT "H" SLOT

| Frequency (MHz) | Ref level. (dB) | Test Level (dB) | *Gains* (dB) |
|---|---|---|---|
| 2400 | -59.9 | -60.9 | 1.15 |
| 2410 | -61.9 | -60.7 | 3.35 |
| 2420 | -62 | -62.4 | 1.75 |
| 2430 | -60.6 | -61.7 | 1.05 |
| 2440 | -65.3 | -59.9 | 7.55 |
| 2450 | -67 | -62.4 | 6.75 |
| 2460 | -65.7 | -61.8 | 6.05 |
| 2470 | -67.8 | -61 | 8.95 |
| 2480 | -68.4 | -59 | 11.55 |
| 2490 | -76.2 | -61.4 | 16.95 |
| 2500 | -64.6 | -64.5 | 2.25 |
| 2510 | -68.5 | -70.1 | 0.55 |
| 2520 | -69.2 | -65.6 | 5.75 |

Based on the gain test results Table VII, a graph was created that visually illustrates the gain results shown in Figure 12.

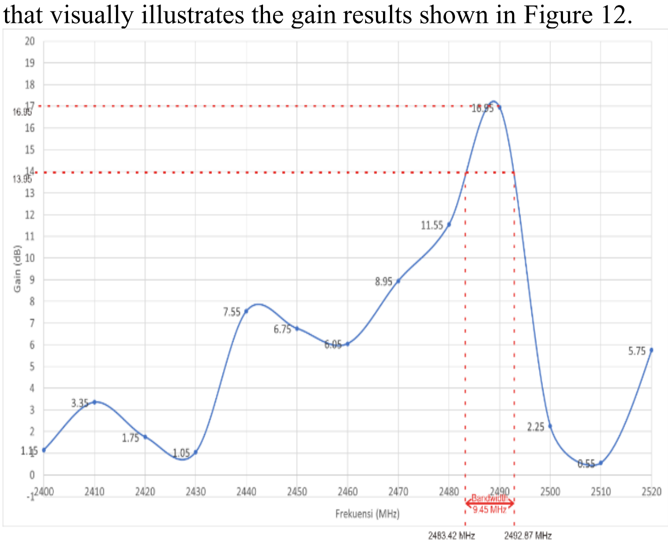


Figure 12. Gain Graph Of Hexagonal - Rectangular Microstrip Antenna Without "H" Slot

Figure 12 shows that the highest gain is at a frequency of 2490 MHz with a gain value of 16.95 dB. From the highest graph value drawn -3 dB down, namely 13.95 dB, we will get an intersection at the frequencies 2483.42 MHz and 2492.87 MHz where this frequency will be used to determine the bandwidth.

$$BW = f_h - f_l \quad (23)$$
$$BW = 2492.87\ MHz - 2483.42\ MHz$$
$$BW = 9.45\ MHz$$

The bandwidth of the hexagonal – rectangular microstrip antenna without slots is 9.45 MHz.

2. Gain results of 2x4 hexagonal - rectangular array microstrip antenna with "H" slot

The results of tests carried out on hexagonal - rectangular microstrip antennas with "H" slots for measuring gain values are shown in Table 8.

TABLE VIII
GAIN OF HEXAGONAL - RECTANGULAR MICROSTRIP ANTENNA WITHOUT "H" SLOT

| Frequency (MHz) | Ref level. (dB) | Test Level (dB) | *Gains* (dB) |
|---|---|---|---|
| 2400 | -59.9 | -62.5 | -0.45 |
| 2410 | -61.9 | -61.5 | 2.55 |
| 2420 | -62 | -62.2 | 1.95 |
| 2430 | -60.6 | -62.7 | 0.05 |
| 2440 | -65.3 | -59.6 | 7.85 |
| 2450 | -67 | -61.2 | 7.95 |
| 2460 | -65.7 | -61.5 | 6.35 |
| 2470 | -67.8 | -63.5 | 6.45 |
| 2480 | -68.4 | -65.1 | 5.45 |
| 2490 | -76.2 | -69.8 | 8.55 |
| 2500 | -64.6 | -75 | -8.25 |
| 2510 | -68.5 | -73.5 | -2.85 |
| 2520 | -69.2 | -65.7 | 5.65 |

Based on the gain test results Table VIII, a graph was created that visually illustrates the gain results shown in Figure 13.

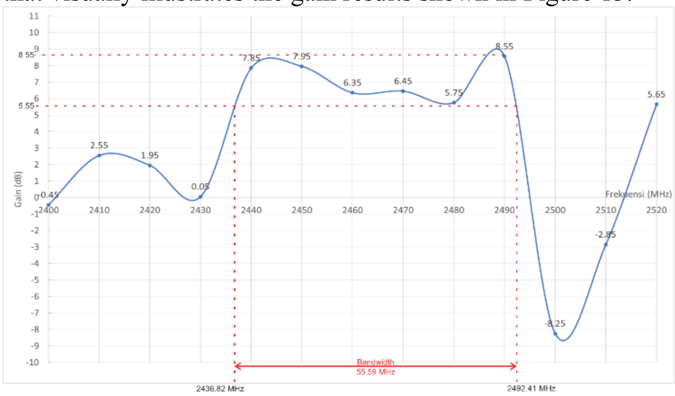


Figure 13. Gain Graph Of Hexagonal - Rectangular Microstrip Antenna With "H" Slot

Figure 13 shows that the highest gain is at a frequency of 2490 MHz with a gain value of 8.55 dB. From the highest graph value drawn -3 dB down, namely 5.55 dB, we will get the intersection at frequencies 2436.82 MHz and 2492.41 MHz where this frequency will be used to determine the bandwidth.

$$BW = f_h - f_l \quad (24)$$
$$BW = 2492.41\ MHz - 2436.82\ MHz$$
$$BW = 55.59\ MHz$$

## *G. Radiation Pattern Test Results*

1. Result of radiation pattern of 2x4 hexagonal - rectangular array microstrip antenna without "H" slot

The results of tests carried out on hexagonal - rectangular microstrip antennas without "H" slots for measuring radiation patterns are shown in Table IX.

TABLE IX
RESULTS OF MEASURING THE RADIATION PATTERN OF A HEXAGONAL - RECTANGULAR MICROSTRIP ANTENNA WITHOUT "H" SLOT

| (°) | Receive level (dB) | Normalization | (°) | Receive level (dB) | Normalization |
|---|---|---|---|---|---|
| 0 | -60.1 | 0 | 180° | -70.8 | -10.7 |
| 10° | -61.3 | -1.2 | 190° | -74 | -13.9 |
| 20° | -64.3 | -4.2 | 200° | -73.9 | -13.8 |
| 30° | -67 | -6.9 | 210° | -74.9 | -14.8 |
| 40° | -69.7 | -9.6 | 220° | -78 | -17.9 |

| (°) | Receive level (dB) | Normalization | (°) | Receive level (dB) | Normalization |
|---|---|---|---|---|---|
| 50° | -70.6 | -10.5 | 230° | -76 | -15.9 |
| 60° | -73.4 | -13.3 | 240° | -74.5 | -14.4 |
| 70° | -73.2 | -13.1 | 250° | -71.5 | -11.4 |
| 80° | -73.5 | -13.4 | 260° | -68.8 | -8.7 |
| 90° | -76.4 | -16.3 | 270° | -67.3 | -7.2 |
| 100° | -72.5 | -12.4 | 280° | -65.9 | -5.8 |
| 110° | -72 | -11.9 | 290° | -65.2 | -5.1 |
| 120° | -77.4 | -17.3 | 300° | -66 | -5.9 |
| 130° | -77.5 | -17.4 | 310° | -65.9 | -5.8 |
| 140° | -77.6 | -17.5 | 320° | -65.3 | -5.2 |
| 150° | -78.1 | -18 | 330° | -62.5 | -2.4 |
| 160° | -71.7 | -11.6 | 340° | -61.2 | -1.1 |
| 170° | -70.2 | -10.1 | 350° | -60.2 | -0.1 |

From the results of the received power levels in Table IX, a graph was created that visually depicts the radiation pattern of the hexagonal - rectangular microstrip antenna without the "H" slot as in Figure 11.

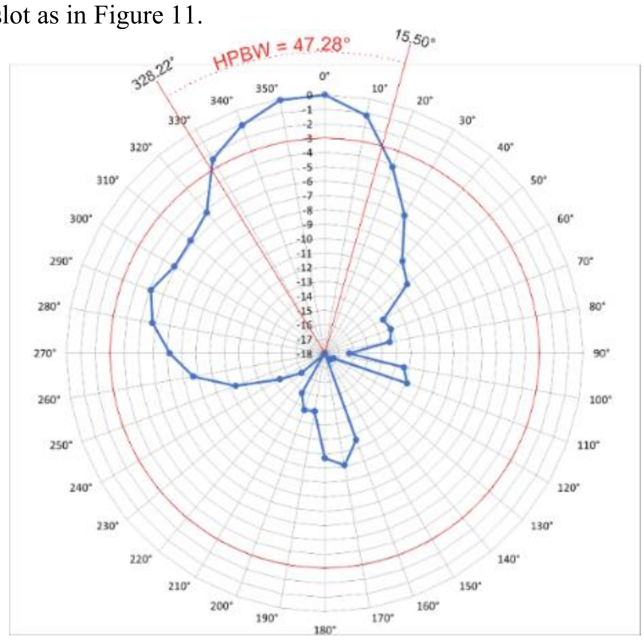


Figure 14. Directional Radiation Pattern Of Hexagonal - Rectangular Microstrip Antenna Without "H" Slot

$HPBW = HP(left) + HP(right)$
$HPBW = (360° - 328.22°) + (0° + 15.50°)$
$HPBW = 31.78° + 15.50°$
$HPBW = 47.28°$

Figure 14 shows that the radiation pattern of the hexagonal – rectangular microstrip antenna is directional with an HPBW of 47.28° with effective radiation in the direction between 328.22° and 15.50°.

2. Results of the radiation pattern of a 2x4 hexagonal - rectangular array microstrip antenna with "H" slot

The results of tests carried out on hexagonal - rectangular microstrip antennas with "H" slots for measuring radiation patterns are shown in Table X.

TABLE X
RESULTS OF MEASURING THE RADIATION PATTERN OF A HEXAGONAL - RECTANGULAR MICROSTRIP ANTENNA WITH "H" SLOT

| (°) | Receive level (dB) | Normalization | (°) | Receive level (dB) | Normalization |
|---|---|---|---|---|---|
| 0° | -59.5 | 0 | 180° | -74.2 | -14.7 |
| 10° | -59.7 | -0.2 | 190° | -76.9 | -17.4 |
| 20° | -60.5 | -1 | 200° | -76.7 | -17.2 |
| 30° | -62.4 | -2.9 | 210° | -77.1 | -17.6 |
| 40° | -65.8 | -6.3 | 220° | -76.7 | -17.2 |
| 50° | -68.7 | -9.2 | 230° | -74.9 | -15.4 |
| 60° | -69.7 | -10.2 | 240° | -77.4 | -17.9 |
| 70° | -72.4 | -12.9 | 250° | -76.7 | -17.2 |
| 80° | -73.5 | -14 | 260° | -72.1 | -12.6 |
| 90° | -71.3 | -11.8 | 270° | -68.1 | -8.6 |
| 100° | -75.1 | -15.6 | 280° | -66.2 | -6.7 |
| 110° | -71.7 | -12.2 | 290° | -66.1 | -6.6 |
| 120° | -74.4 | -14.9 | 300° | -69.6 | -10.1 |
| 130° | -78.2 | -18.7 | 310° | -77.4 | -17.9 |
| 140° | -78.2 | -18.7 | 320° | -69.5 | -10 |
| 150° | -76.3 | -16.8 | 330° | -63.1 | -3.6 |
| 160° | -74.1 | -14.6 | 340° | -60.2 | -0.7 |
| 170° | -68.5 | -9 | 350° | -60 | -0.5 |

From the results of the received power levels in Table X, a graph was created that visually depicts the radiation pattern of the hexagonal - rectangular microstrip antenna with "H" slot as in Figure 12.

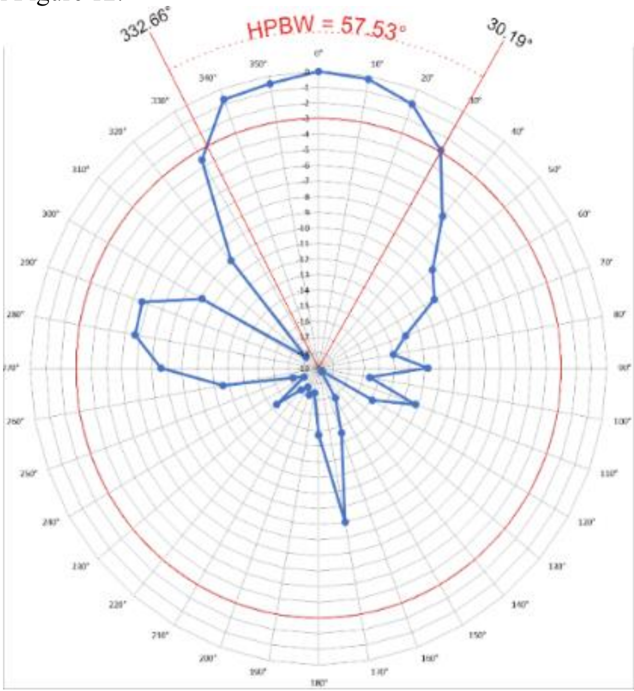


Figure 15. Directional Radiation Pattern Of Hexagonal - Rectangular Microstrip Antenna Without "H" Slot

$HPBW = HP(left) + HP(right)$
$HPBW = (360° - 332.66°) + (0° + 30.19°)$
$HPBW = 27.34° + 30.19°$
$HPBW = 57.53°$

Figure 15 shows that the radiation pattern of the hexagonal – rectangular microstrip antenna is directional with an HPBW of 57.53° with effective radiation in the direction between 332.66° and 30.19°.

### *H. Comparison Of Simulation And Test Results*

1. Comparison of return loss and VSWR values

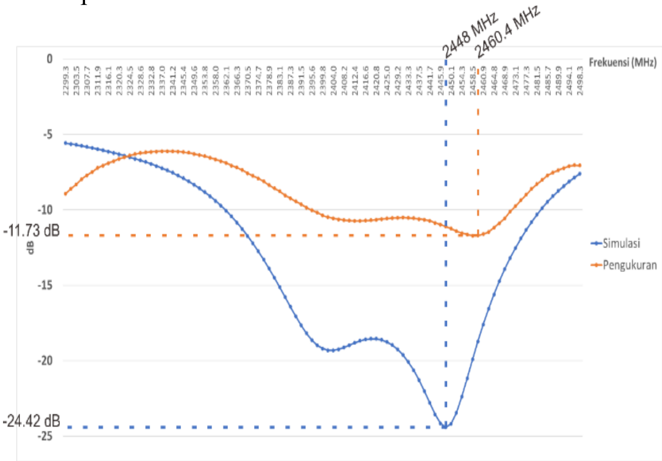


Figure 16. Comparison Of Simulated Return Loss and Measurement

In the simulation, the resonant frequency obtained was 2448 MHz, while in testing there was a shift in the resonant frequency, namely to 2460.41 MHz. The frequency shift causes a change in the return loss value from -24,419 dB in the simulation to -11.73 dB in the test.

The resonant frequency shift occurs due to influences during antenna fabrication. From the shift in the resonant frequency, it can be seen that the dimensions after fabrication become smaller so that the resonant frequency during testing is higher than in the simulation. The frequency shift can be considered not too much of a problem because it is still in the range between 2401 MHz to 2495 MHz.

TABLE XI
COMPARISON OF RETURN LOSS AND VSWR VALUES

| Frequency (MHz) | *Return Loss* (dB) | | Coefficient Reflection | | VSWR | |
|---|---|---|---|---|---|---|
| | Simulation | Test | Simulation | Test | Simulation | Test |
| 2448 | -24,419 | -11.11 | 0.06 | 0.278 | 1,128 | 1,771 |
| 2460.4 | -18,811 | -11.73 | 0.115 | 0.259 | 1.26 | 1.7 |

2. Comparison of gain and bandwidth

TABLE XII
COMPARISON OF GAIN AND BANDWIDTH BETWEEN SIMULATION AND TESTING

| Parameter | Simulation | Testing |
|---|---|---|
| *Gain* (dB) | 3.81 | 8.55 |
| *Bandwidth* (MHz) | 123.45 | 55.59 |

Table 12 shows a comparison of the gain and bandwidth values for a 2x4 hexagonal – rectangular array microstrip antenna with "H" slot. In the simulation the gain obtained was 3.81 dBi, while in the test the gain obtained was 8.55 dBi. The gain test value meets the minimum antenna standard, namely ≥ 5 dB. The bandwidth comparison in the simulation is 123.45 MHz while in testing it is 55.59 MHz.

### *I. Wi-Fi Implementation*

Figure 17. Wi - Fi Implementation

TABLE XIII
RESULTS OF COMPARISON OF RSSI VALUES BETWEEN THE BUILT-IN ANTENNA AND THE MICROSTRIP ANTENNA

| Wi-Fi Channel | Built-In antenna average RSSI value | Average RSSI value of hexagonal – rectangular microstrip patch antenna with "H" slot |
|---|---|---|
| 1 | -66 | -71 |
| 2 | -67 | -69 |
| 3 | -69 | -64 |
| 4 | -66 | -68 |
| 5 | -67 | -71 |
| 6 | -67 | -72 |
| 7 | -64 | -71 |
| 8 | -64 | -68 |
| 9 | -64 | -66 |
| 10 | -66 | -69 |
| 11 | -66 | -71 |
| 12 | -67 | -74 |
| 13 | -64 | -74 |

Table 13 shows the results of the implementation and RSSI reading of a 2x4 hexagonal - rectangular array microstrip antenna with "H" slot on each Wi - Fi channel where on channel 3 the RSSI reading was -64 dB with a distance of 22 m from the router to the laptop while the RSSI reading for the built-in antenna it is -69 dB so that the 2x4 hexagonal - rectangular array microstrip antenna with "H" slot is able to increase signal quality by 5 dB compared to the built-in antenna.

## IV. CONCLUSION

Testing of the 2x4 hexagonal - rectangular array microstrip antenna without the "H" slot resulted in a shift in the resonant frequency from 2448 MHz to 2422.87 MHz, thus affecting other parameters. The read return loss is 10.1 with a VSWR of 1,909. The microstrip antenna without the "H" slot has a maximum gain of 16.95 dB with a directional radiation pattern. Testing of the 2x4 hexagonal - rectangular array microstrip antenna with "H" slot occurred at a frequency of 2460.41 with a return loss of -11.73 dB. The microstrip antenna with the "H" slot has a maximum gain of 8.55 dB with a directional radiation pattern. Bandwidth testing showed that the microstrip antenna without the "H" slot had a bandwidth of 9.45 MHz, while the microstrip antenna with the "H" slot had a bandwidth of 55.59 MHz. The results of the comparison of the two known bandwidths show that the microstrip antenna with slots is able to widen the bandwidth. The antenna implementation shows the results that on channel 3 the RSSI value is better when using a hexagonal - rectangular microstrip antenna than when using a built - in antenna. The microstrip antenna gets an RSSI value of -64 dB while the built-in antenna gets an RSSI value of -69 dB.

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