Design and Implementation of 2x4 Element Hexagonal Array Microstrip Antenna with DGS Method in the Shape of Dumbbell Circle Head for 2.4 GHz Frequency Wi-Fi Applications

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Abstract— **Antenna is an important component in a wireless communication system that continues to develop on Wi-Fi technology with a working frequency of 2.4 GHz in accordance with the IEEE 802.11 standard. This study discusses the design and manufacture of microstrip antennas that aim to widen the bandwidth in Wi-Fi applications in the form of a hexagonal patch composed of 2x4 array elements. Microstrip antenna has a weakness that is narrow bandwidth, therefore it is necessary to modify it using the DGS (Defected Ground Structure) method in the form of a dumbbell circle head. This study discusses the results and performance effects of 2x4 element microstrip array antennas using DGS when it applicate on Wi-Fi. This DGS is placed on a ground plane and uses a PCB with an epoxy fiberglass substrate material which has a constant 4.58 dielectric and done by etching process. The result of this research is an external device, namely a microstrip antenna that can increase data transfer capacity and work at a Wi-Fi frequency of 2.4 GHz. This study is in accordance with the antenna testing parameters which have a return loss value of -22.7 dB and a VSWR of 1.15. The results of testing the bandwidth of a 2x4 hexagonal microstrip patch antenna with a DGS is 34 MHz. The results of the implementation of the power level of the hexagonal microstrip patch antenna arranged in a 2x4 array using DGS dBm can increase the power level by 7 dBm.**

Keywords— **Microstrip Antena, Hexagonal, Wi-Fi, Defected Ground Structure.**

I. INTRODUCTION

Wi-Fi (Wireless Fidelity) network is one of the developments of wireless networks that is needed today. This is because Wi-Fi can transfer data wirelessly and is very easily accessible by various devices. The allocation of the Wi-Fi working frequency used is 2.4 GHz in accordance with the IEEE 802.11 protocol standard issued by ITU (The International Telecommunication Union) [1].

Wireless communication and mobile communication are mandatory in communication for modern people who do not want to be limited in their movements in exchanging information. The era of globalization where people cannot be separated from the online world and social media makes the internet the main means to communicate with each other. The technology currently used and an alternative to access the internet is Wi-Fi. This online activity results in communication needs that require a large enough data transfer capacity to carry out the process of sending and receiving data. The drawback of Wi-Fi is that it is difficult to use to transfer large amounts of data [2].

Wi-Fi technology requires a transmitting antenna with a wide enough bandwidth to support the service capacity requirements of Wi-Fi technology. Antenna is an important part that plays a role in optimizing the performance of communication systems on Wi-Fi. The antenna serves as a transmitter (transmitting the signal of antenna) and a receiver (receiving the signal of antenna) radio waves. The implementation of this research uses a microstrip antenna which has the advantages of being thin and small, has a light weight, easy to fabricate, easy to integrate with other electronic devices and a relatively cheap price. Microstrip antennas basically have some disadvantages such as low gain and narrow bandwidth [3].

The problem of Wi-Fi performance can be done to improve the performance of the microstrip antenna to widen the bandwidth [4]. The method used to achieve the desired antenna performance in this study is the DGS (Defected Ground Structure) method which can widen the bandwidth of the microstrip antenna [5]. Improving signal quality is done by using the array method, which is arranging the microstrip antenna into several elements that are connected to the transmission line (feedline) [3].

To improve the bandwidth and signal strength of Wi-Fi technology so that it can be used by many users, it was made this final project is designed and implemented a microstrip antenna with a patch in the form of a hexagonal array of 2x4 elements using the DGS (Defected Ground Structure) method in the form of a dumbbell circle head for Wi-Fi applications with a frequency of 2.4 GHz.

II. RESEARCH METHODS

A. *Research Design*

Fig. 1 is a flowchart of the research design that will be made.

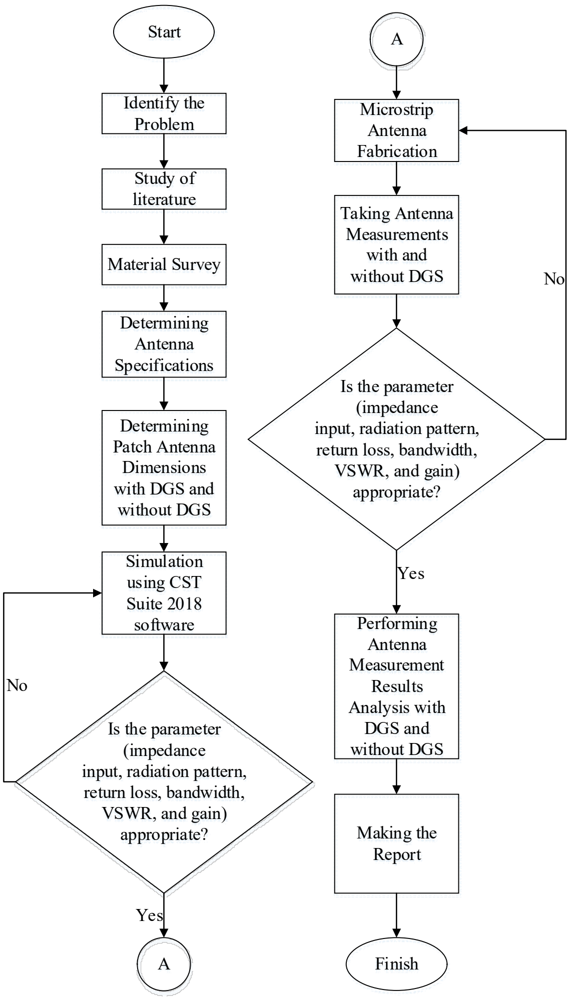


Figure. 1 Research design flowchart

B. *System Design*

System design in system planning is shown in Fig. 2 as follows.

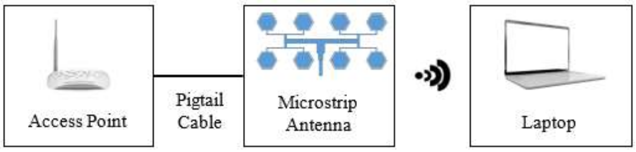


Figure. 2 System block diagram

C. *Deteremination 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 Hexagonal Patch Microstrip Antenna Design with Defected Ground Structure*

The design of a microstrip antenna with a 2x4 hexagonal patch element with a defected ground structure.

E. *Determination of Wavelength and Dimensions of Radiating Elements*

1. Hexagonal Patch Calculation
   - Side lenght (s)
     s = 18.45 mm [7]
   - Patch width (Wh)
     Wh = 36.68 mm
   - εreff (effective dielectric constant)
     εreff = 3.92 F/mm
   - ΔL(length difference)
     ΔL = 0.74 mm
   - Patch length (Lh)
     Lh = 29.47 mm
   - Hexagonal input impedance
     Z3 = 116.567 Ω [8]
2. Determination of Supply Line Impedance
   - Supply Line Impedance
     Z6 = 50 Ω (ohm).
3. Calculation of Transmission Line Width [9]
   - Lebar Saluran Transmisi 1
     Wf1 = 2.37 mm
   - Transmission Line Width 2
     Wf2 = 4.74 mm
   - Transmissoin Line Width 3
     Wf3 = 9.48 mm
   - Transmission Line Width 4
     Wf4 = 18.97 mm
   - Transmission Line Width 5
     Wf5 = 10.24 mm
   - Transmission Line Width 6
     Wf6 = 5.52 mm
4. Calculation of Transmission Line Length
   - Transformer Length
     LT = 14.3 mm
   - Length of Transmission Line-n (Lfn)
     Lf1 = 8.18 mm
     Lf2 = 26 mm
     Lf3 = 136.4 mm
     Lf4 = 23 mm
     Lf5 = 14.3 mm
     Lf6 = 31 mm
5. Determination of Ground plane Length and Width
   - Ground plane length
     Wg = 312.42 mm
   - Groundplane width
     Lg = 147 mm
6. Determining dimensions of defected ground structure
   - Width of circle head dumbbell radius [10]
     rdgs = 7.5 mm
   - Dumbbell circle head channel width
     g = 1.38 mm
   - Dumbbell circle head channel length
     L_{dgs} = 19.93 mm

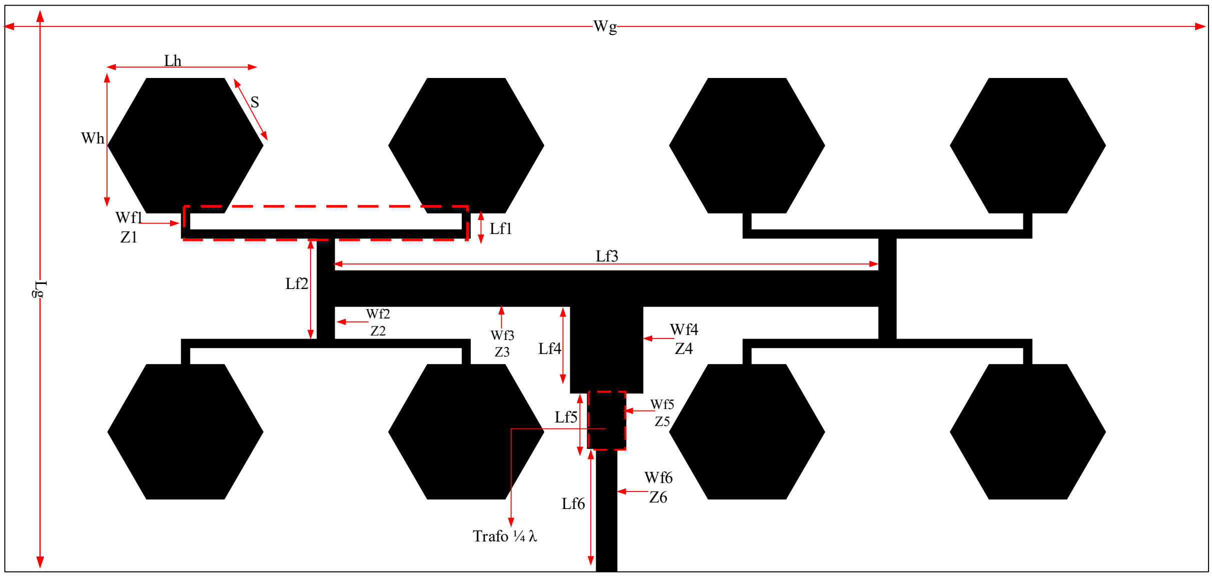


Figure. 3 Design of a 2x4 element hexagonal microstrip patch antenna with a defected ground structure front view

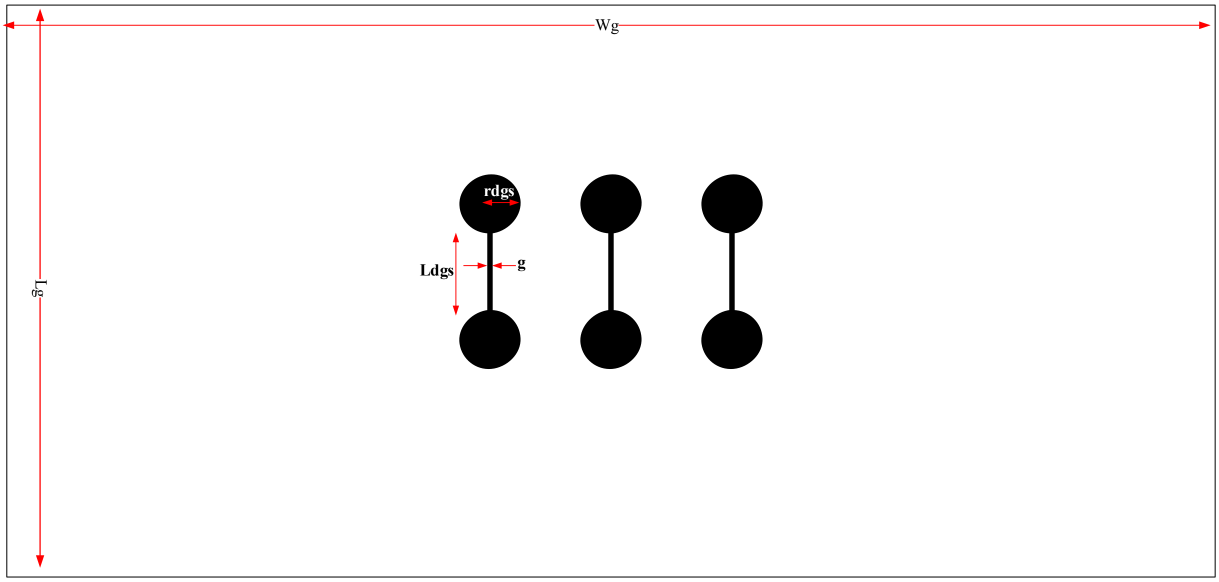


Figure. 4 Design of a 2x4 element hexagonal microstrip patch antenna with a defected ground structure back view

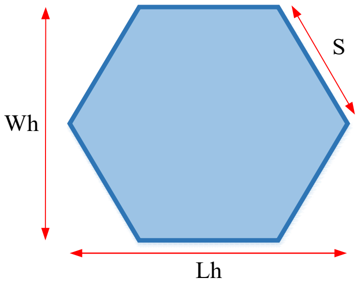


Figure. 5 Hexagonal Patch [6]

III. RESULTS AND DISCUSSION

A. Return Loss (RL) Simulation Results

Fig. 6 is the result of a simulation of the return loss of a 2x4 hexagonal patch microstrip antenna using a defected ground structure.

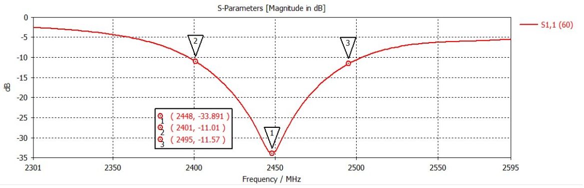


Figure. 6 Return loss simulation of 2x4 hexagonal patch microstrip antenna using a defected ground structure

The return loss value is -11.01 dB for the frequency of 2401 MHz and -11.57 dB for the frequency of 2495 MHz. The frequency of 2448 MHz has the lowest return loss value, which is -33.891 dB. Return loss at frequencies of 2401 MHz and 2495 MHz is greater than 2448 MHz, this is because 2448 MHz is the resonant frequency and working frequency of the 2x4 hexagonal patch microstrip antenna using a defected ground structure.

The return loss value is less than -10 dB indicating that the microstrip antenna is matched with the load impedance to be applied.

B. Voltage Standing Wave Ratio (VSWR) Simulation Results

Fig. 7 is the results of a VSWR simulation of a 2x4 hexagonal patch microstrip antenna using a defected ground structure.

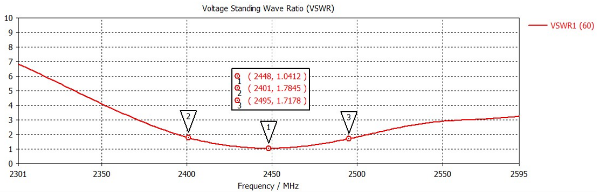


Figure. 7 VSWR simulation of 2x4 hexagonal patch microstrip antenna using a defected ground structure

VSWR values obtained are 1.7845 for the frequency of 2401 MHz and 1.7178 for the frequency of 2495 MHz. The frequency of 2448 MHz has the lowest VSWR value, which is 1.0412. The known VSWR value aims to determine how big the standing wave is caused by the reflected signal. The most expected value for VSWR is 1 but VSWR has a maximum tolerable value of 2, this is based on the minimum return loss value if the value is -10 then the VSWR is 2. The VSWR value at a frequency of 2448 MHz is smaller and better than the frequency 2401 MHz and 2495 MHz, this is because 2448 MHz is the resonant frequency and the working frequency.

C. Bandwidth Simulation Results

Fig. 8 is the results of a bandwidth simulation of a 2x4 hexagonal patch microstrip antenna using a defected ground structure.

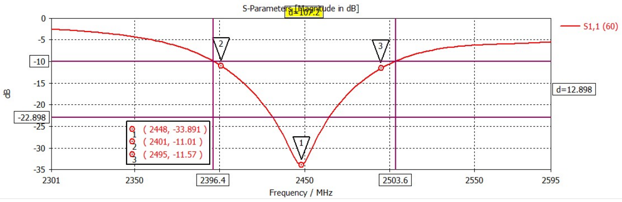


Figure. 8 Bandwidth simulation of 2x4 hexagonal patch microstrip antenna using a defected ground structure

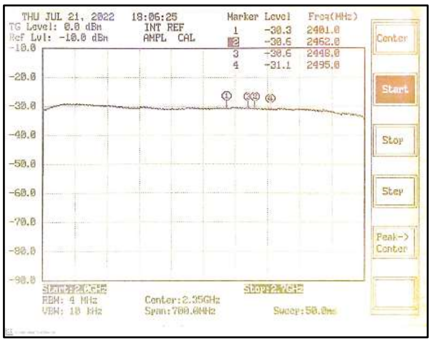
Bandwidth testing aims to determine the bandwidth (working frequency range) of the hexagonal 2x4 element microstrip patch antenna that has been designed [11]. Bandwidth can be determined by subtracting the upper and lower frequencies [12].

The bandwidth of the 2x4 element hexagonal microstrip patch antenna uses a defected ground structure which is designed at a resonant frequency of 2448 MHz. Bandwidth value of 107.2 MHz where the lower frequency is 2396.4 MHz and the upper frequency is 2503 MHz.

The bandwidth results obtained in the simulation are already more than the bandwidth of wireless fidelity (Wi-Fi), which is 94 MHz. Thus, the 2x4 element hexagonal patch microstrip antenna signal using the Defected Ground Structure bandwidth already covers the wireless fidelity (Wi-Fi) frequency range, which is 2401 MHz – 2495 MHz.

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

Fig. 9 is the result of measuring the return loss reference level of a 2x4 hexagonal patch antenna using a defected ground structure.



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THU JUL 21, 2022    18:06:25     Marker Level   Freq(MHz)
TG Level: 0.0 dBm    INT REF       1    -30.3    2401.0
Ref Lvl: -10.0 dBm   AMPL  CAL     2    -30.6    2462.0
                                   3    -30.6    2448.0
                                   4    -31.1    2495.0
Start:2.0GHz                         Stop:2.7GHz
RBW: 4 MHz        Center:2.35GHz
VBW: 10 kHz       Span:700.0MHz       Sweep:50.0ms
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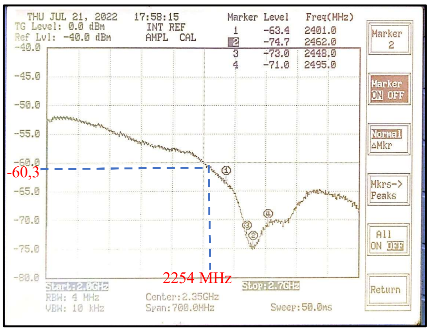
Figure. 9 The results of measuring the return loss reference level of the 2x4 hexagonal patch microstrip antenna using a defected ground structure

Fig. 10 is the result of measuring the return loss reading level of the 2x4 hexagonal patch microstrip antenna using a defected ground structure.



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Marker Level    Freq(MHz)
  1    -63.4    2401.0
  2    -74.7    2462.0
  3    -73.0    2448.0
  4    -71.0    2495.0
```

Figure. 10 The results of the level measurement read the return loss of the hexagonal 2x4 microstrip patch antenna using a defected ground structure

Fig. 10 The return loss value is -22.7 dB with a VSWR value of 1.15 at a frequency of 2448 MHz, while the lowest return loss value is -24.4 with a VSWR value of 1.12 at a frequency of 2462 MHz.

TABLE II
RL AND VSWR TESTING OF HEXAGONAL PATCH MICROSTRIP ANTENNA 2X4 ELEMENT WITH DEFECTED GROUND STRUCTURE

Frequency (MHz)	Level (dBm)			RL (dB)	VSWR
	Read	Reference	Attenuation DC		
2401	-63.4	-30.3	-20	-13.1	1.56
2478	-74.7	-30.3	-20	-24.4	1.12
2448	-73	-30.6	-20	-22.7	1.15
2495	-71	-31.1	-20	-20.7	1.19

Based on the table of return loss and VSWR above, the test results with the simulation results have not too much difference. The test results get a value that is in accordance with the standard microstrip antenna, namely the return loss is less than -10 dB and the VSWR is less than 2.

The resonant frequency or the center frequency of Wi-Fi has shifted. The frequency shifts at a frequency of 2462 MHz which means that the resonance frequency shifts by 14 MHz from the designed resonant frequency of 2448 MHz. This can be seen based on the hexagonal patch formula, where the frequency shift to the right is caused by the decrease in the dimensions of the hexagonal patch.

E. Gain and Bandwidth Testing Results

Table III is the result of testing the gain of a 2x4 hexagonal patch microstrip antenna using a defected ground structure.

TABLE III
GAIN TEST RESULTS OF HEXAGONAL PATCH MICROSTRIP ANTENNA 2X4 ELEMENT WITH DEFECTED GROUND STRUCTURE

Frequency (MHz)	Level (dBm)		Gain (dBi)	Normalitzation
	Reference Antenna	Antenna Under Test		
2320	-56.6	-69.9	-11.15	-15.9
2330	-57.3	-72.4	-12.95	-17.7
2340	-64,4	-70.9	-4.35	-9.1
2350	-62.2	-73.1	-8.75	-13.5
2360	-61.6	-75	-11.25	-16
2370	-60	-70.6	-8.45	-13.2
2380	-56.9	-74.4	-15.35	-20.1
2390	-57.4	-68.6	-9.05	-13.8
2400	-60.3	-61.2	1.25	-3.5
2410	-55.2	-66.3	-8.95	-13.7
2420	-56.6	-76.6	-17.85	-22.6
2430	-58.4	-73.2	-12.65	-17.4
2440	-53.4	-69.9	-14.35	-19.1
2450	-59.2	-60.7	0.65	-4.1
2460	-58.6	-56	4.75	0
2470	-61.5	-60	3.65	-1.1
2480	-59,8	-57.4	4.55	-0.2
2490	-56.6	-61.8	-3.05	-7.8
2500	-63.1	-66.1	-0.85	-5.6
2510	-64.7	-65.7	1.15	-3.6
2520	-67.6	-71.3	-1.55	-6.3

Highest Gain = 4.75 dBi

The following is a graph of the bandwidth of a 2x4 hexagonal patch microstrip antenna using a defected ground structure based on table III.

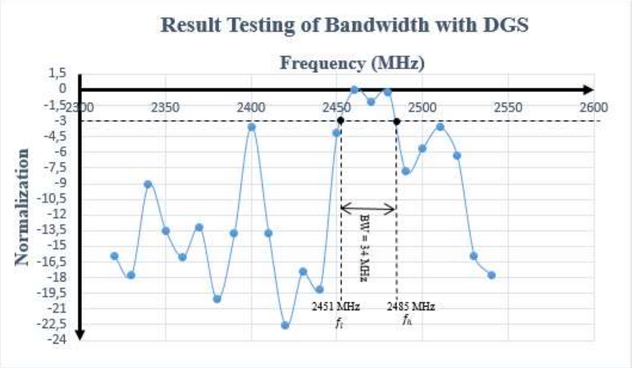

Figure. 11 Bandwidth of 2x4 hexagonal patch microstrip antenna using a defected ground structure

The bandwidth results for the hexagonal 2x4 element microstrip patch antenna using a defected ground structure can be shown through the intersection of the normalization points with a value of -3 dBi [13]. 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 hexagonal 2x4 element microstrip patch antenna with a defected ground structure of 2462 MHz with a value of 4.75 dBi.

Bandwidth test results with bandwidth simulation results have a significant difference. The simulation results are better than the test results, this is due to the interference process that occurs in the transmitter antenna around the test room, with interference and noise from the air this greatly affects the bandwidth results obtained.

This gain and bandwidth test requires a dipole antenna as a transmitter. The dipole antenna is the choice as a transmitter because the dipole antenna is close to a perfect antenna, which is an isotropic antenna [14].

The highest gain results at a frequency of 2460 MHz with a value of 4.75 dBi when compared to a dipole antenna has a gain of 4 times greater than that of a dipole antenna.

F. Radiation Pattern Testing Results

Table IV is the result of testing the radiation pattern of the 2x4 hexagonal patch microstrip antenna using a defected ground structure.

TABLE IV
TESTING RADIATION PATTERN OF HEXAGONAL MICROSTRIP PATCH ANTENNA 2X4 ELEMENT WITH DEFECTED GROUND STRUCTURE

Corner (°)	**Frequency 2448 MHz**	
	Radiation Pattern (dB)	**Normalization**
0	-59.9	0
10	-60.7	-0.8
20	-63.5	-3.6
30	-63	-3.1
40	-66.2	-6.3
50	-68	-8.1
60	-65.5	-5.6
70	-65.4	-5.5
80	-70.8	-10.9
90	-70.5	-10.6
100	-76	-16.1
110	-65	-5.1
120	-72.4	-12.5
130	-70.1	-10.2
140	-72.9	-13
150	-69.6	-9.7
160	-67.2	-7.3
170	-67.5	-7.6
180	-67.9	-8
190	-70.9	-11
200	-68	-8.1
210	-67.8	-7.9
220	-66	-6.1
230	-67.6	-7.7
240	-64.7	-4.8
250	-67.9	-8
260	-67.2	-7.3
270	-72	-12.1
280	-70.7	-10.8
290	-73	-13.1
300	-71.2	-11.3
310	-69	-9.1
320	-67.2	-7.3
330	-62.9	-3
340	-62.6	-2.7
350	-62	-2.1

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

The value of half power beamwidth (HPBW) is obtained by knowing the angle that has a normalization of -3 dB, namely the angle of 330º as HP(right) and 19º as HP(left). Therefore, HPBW can be calculated using the following equation [15]:

$$\text{HPBW} = \text{HP(right)} - \text{HP(left)}$$

$$= (360^\circ - 330^\circ) + 19^\circ$$

$$= 49^\circ$$

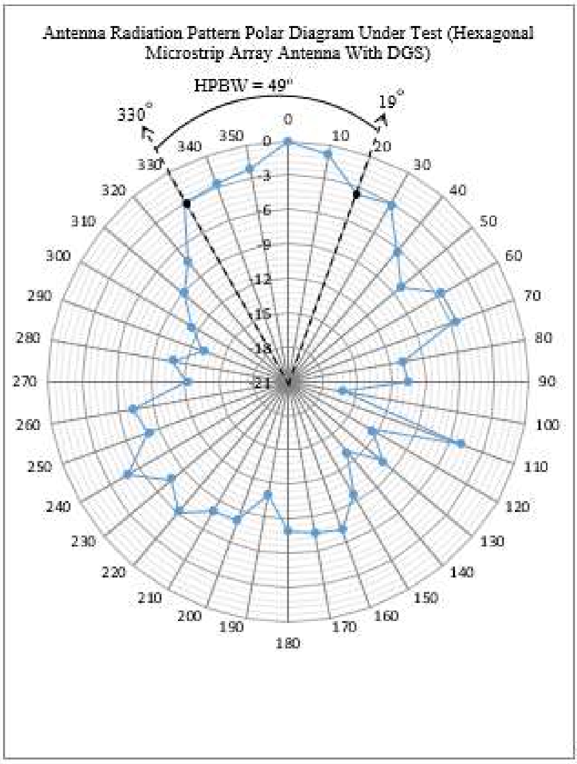

Figure. 12 Radiation pattern of 2x4 hexagonal patch microstrip antenna using a defected ground structure

Fig. 12 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 Hexagonal 2x4 Elements Using Defected Ground Structure

Table VI is the result of implementing the built-in antenna and microstrip patch hexagonal 2x4 elements using a defected ground structure.

TABLE V
RESULTS OF IMPLEMENTATION OF BUILT IN ANTENNA AND HEXAGONAL PATCH MICROSTRIP 2X4 ELEMENT WITH DEFECTED GROUND STRUCTURE

Antenna	**Receive Signal Strength Indicator (RSSI)**
Built-in	-44 dBm
Microstrip patch hexagonal 2x4 element	-37 dBm

From table VI, there are RSSI values between the built-in antenna and 2x4 hexagonal patch microstrip antenna using a defected ground structure. So the difference in power can be calculated using the following equation:

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

$$= -37 - (-44)$$

$$= 7 \text{ dBm}$$

The power received by the TD-W8951ND access point when using an external 2x4 hexagonal patch microstrip antenna using a defected ground structure is 7 dBm stronger when compared to the built-in antenna.

IV. CONCLUSION

The results of testing the hexagonal 2x4 element microstrip patch antenna using a defected ground structure, the return loss value for the frequency of 2448 is -22.7 dB with a VSWR of 1.15, the bandwidth is 34 MHz, the radiation pattern obtained an HPBW value of 49º so the result of radiation pattern is directional, the results of the RSSI implementation show an increase in the power level for the microstrip antenna, which is 7 dBm. The results of the hexagonal 2x4 element microstrip patch antenna in this final project have met the standards of the microstrip antenna. There is a shift in the resonant frequency or working frequency that occurs. This can be seen based on the hexagonal patch formula, where the frequency shift to the right is caused by the reduction in the dimensions of the hexagonal patch. This is influenced by factors during the etching process that are less precise so that the results of the microstrip antenna fabrication do not match the simulation results.

For the next research, the microstirp antenna fabrication process is recommended to use the printing method in order to get precise results.

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