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Yagi Antenna With Three Reflector Elements To Amplify 4G Signal In Suburban Area

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***Abstract*—Along with the increasing number of cellular telephone users and the high cost of 4G network infrastructure, the investment required to build 4G infrastructure is IDR 278 trillion so that many suburban cellular telephone users (suburban areas) get 4G access with poor network quality. So it requires repeaters as an effective solution with small capital to increase coverage areas in weak signal areas. The Yagi antenna is a suitable antenna for long-distance communication with three reflector elements to strengthen the 4G signal in the suburban area at frequencies of 1710-1880 MHz. The material for making the antenna consists of aluminum pipes as reflector elements and director elements with a diameter of 8.4 mm and wire as a driven element with a diameter of 4 mm. In the manufacture, there is the addition of balun and three reflector elements that can improve the performance of the Yagi antenna parameters. The testing of the Yagi antenna was carried out in two ways, namely the Anechoic Chamber room and the Telecommunication Electronics Lab. For the transmission cable using a sma female connector cable to operate the Anechoic Chamber device appointed female students who have been trained in measurements using Network Analyzer software from the results of manual measurements and Network Analyzer obtained the results of unidirectional radiation patterns, maximum power level of -23.24 dBm, resonant frequency 1809 MHz, Bandwidth 52 MHz, HPBW 250, FBR 12.97 dB, Gain 8.572 dB, VSWR 1.09, and Return loss -26.6 dB design using MMANA-GAL software simulations show that the antenna works at a frequency of 1.800 MHz, antenna impedance 42.84 + j2.906 Ω, VSWR 1.18, Gain 20.66 dB, and FBR 23.77 dB and has a unidirectional radiation pattern.**

Keywords*: *4G, Reflector, Yagi Antenna, Network Analyzer

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I. INTRODUCTION

The increasing number of cellular telephone users and the high cost of 4G network infrastructure are based on the required investment of Rp 278 trillion until 2019). [According to the Ministry of Communication and Information (2017), until July 2017, 4G infrastructure has reached 55,701 eNodeBs in Indonesia, the area of Indonesia is not comparable to the ideal needs that should be met resulting in the need for a repeater.

According to Lee et all (2010), repeaters are used as an effective solution with little capital to increase coverage area in weak signal areas. Yagi antenna is an antenna suitable for long-distance communication. [2] According to Lim and Ling (2006), the yagi antenna is used to obtain high gain with a simple design. [In the study of Radiation Patterns Using Modified Design of Yagi-Uda Antenna by using three reflector elements at a frequency of 157 MHz, Thakur, et all [4] (2016) obtained an increase in gain from 6 dB to 8 dB and a narrower HPBW when compared to using one reflector element.[5] The addition of the number of reflector elements makes the unidirectional radiation beam from the Yagi antenna more focused. Based on this, the author raises the title "Yagi Antenna with Three Reflector Elements to Amplify 4G Signals in Suburban Areas".

Previous research conducted by the son titled about the 1.8 GHz Yagi antenna to strengthen 4G signal reception in 2017 This antenna produces less than optimal unidirectional polarisation, antenna gain of 18.86 dB, and HPBW 500[6]. repeaters are used as an effective solution with small capital to increase coverage area in weak signal areas. The Yagi antenna is an antenna that is suitable for long-distance communication in previous studies the Yagi antenna is less than optimal for strengthening 4G networks in suburban areas because there is no addition of reflector elements This antenna produces unidirectional polarization, antenna gain 18.86 dB, and HPBW 500 so it is narrower than the addition of the number of reflector elements on the yagi antenna Further development of additions made by Thakur, et all (2016) improves the performance of the yagi antenna. The study of Radiation Patterns Using the Modified Design of the Yagi-Uda Antenna added three reflector elements at a frequency of 157 MHz and experienced an increase in gain from 6 dB to 8 dB and HPBW The addition of reflector elements makes the unidirectional radiation beam from the yagi antenna more focused [7].

II. THE MATERIALS AND METHOD

The study used a 3-element Yagi antenna in the antenna design and simulation process using MMANA-GAL software and the measurement process was carried out in the Anechoic Chamber room and in the Telecommunication Electronics Lab in the Anechoic Chamber room using Network Analyzer software. The antenna transmission cable connector used is an SMA female connector. in this room also uses the Anechoic Chamber device, measurements of antenna parameters carried out in the Anechoic Chamber room obtained from these measurements are the resonant frequency, bandwidth, return loss, and VSWR. In the Anechoic Chamber room using a frequency of 1800 MHz in the manufacture of yagi antennas, There are two frequency bands in the 4G network, namely the uplink frequency and the downlink frequency. The uplink frequency bandwidth is 75 MHz, namely 1710 MHz - 1785 MHz. The downlink frequency bandwidth is 75 MHz, namely 1805 MHz - 1880 MHz.

In the Telecommunication Electronics Lab room using a dipole antenna as a transmitter with a distance of 1 meter and as a meter spectrum analyzer Yagi antenna measurements in the Telecommunication Electronics Lab. The parameters to be carried out in the room in the communication electronics lab obtained are radiation patterns, antenna gain, HPBW, and FBR in testing radiation patterns in the communication electronics lab room carried out by changing the position of the receiving antenna using a motor control.

A. Antenna Design

In the antenna design process, the antenna design specification process of working frequency, VSWR, Return Loss, and Bandwidth is carried out. Calculating the length of the antenna element and the distance between elements to be simulated using MMANA-GAL software after the antenna design process specifications have been obtained in the next step.

The steps taken in designing and manufacturing the antenna can be described as follows

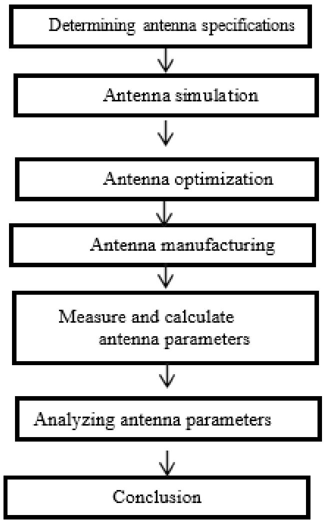


Figure 1. System Block Diagram

B. Antenna Parameters

Before designing the antenna there must be the following predetermined parameters

Table 1 Antenna parameters

No.	Antenna parameters	1710-1880 MHz
1	Resonant Frequency	1800 MHz
2	*Bandwidth*	170 MHz
3	*Return Loss*	≤ -10 dB
4	VSWR	1≤VSWR≤2
5	Impedance of the antenna	50 Ω

In the antenna design process, calculate the size of each antenna element. The first thing to do before calculating the size of the yagi antenna is to know the resonant frequency of the antenna to be made.

$$\lambda = \frac{c}{f} = \frac{3x^{108} m/s}{1800x^{106} Hz} = 0.167m \qquad (1)$$

so,

a. Reflector length
The length of the reflector element is obtained based on equation 2.3. L reflector= 0.482 x λ
Reflector L= 0.482 x 0.167 = 0.08049 m

b. Driven length
The length of the driven element is obtained based on equation 2.1. Ldriven= 0.47 x λ
Ldriven = 0.47 x 0.167 = 0.07849 m

c. Length of the element director
The length of the director element is obtained based on equation 2.4. Ldirektor = 0.42 x λ

Ldirector = 0.42 x 0.167 = 0.07014 m

d. Spacing between elements

The width of the space between elements is obtained based on equation 2.5. Space between elements = 0.2 x λ.

Space between elements = 0.2 x 0.167 = 0.0334 m

In the antenna there is a calculation of elements in the yagi antenna there is 1 driven element, 9 director elements of the same size 3 reflector elements of the same size the following table is the result of calculating each element.

Table 2 Calculation results of Yagi antenna elements

No.	Element type	Element length (m)
1	Reflector 1	0.08049
2	Reflector 2	0.08049
3	Reflector 3	0.08049
4	Driven	0,07849
5	Director 1	0,07014
6	Director 2	0,07014
7	Director 3	0,07014
8	Director 4	0,07014
9	Director 5	0,07014
10	Director 6	0,07014
11	Director 7	0,07014
12	Director 8	0,07014
13	Director 9	0,07014
14	Horizontal position (θ) between reflector and R1, Reflector and R3	30^0 and 30^0

C. Tools and Materials

In the process of making antennas, you must pay attention to accuracy and neatness during the fabrication process to get the desired results The materials used in the manufacture of antennas are aluminum pipes for reflector and director elements which have a diameter of 8.4 mm and wire for driven elements has a diameter of 4mm.

The components or materials needed are:

1. Aluminum pipe (8.4 mm diameter) to taste
2. Copper cable (4 mm diameter) special for driven elements to taste
3. Aluminum 0.9 x 1.6 cm to taste
4. 50 Ω coaxial cable to taste
5. BNC *male* connector 1 piece
6. Bolt with 3.5 mm insulator to taste
7. PCB board to taste
8. One telephone rosette
9. Insulation to taste
10. Tin to taste
11. Copper cable (4 mm diameter)

For induction to the *cellphone* to taste the equipment needed to support the process of making this antenna is:

1. Mistar
2. Pencil
3. Markers
4. Hacksaw
5. Drilling machine
6. 3.5 mm drill bit
7. Fine sandpaper
8. Scissors
9. Cutter Knife
10. Glue
11. Solder

III. RESULTS AND DISCUSSION

After carrying out the process of designing and simulating the antenna in Software the fabrication process and the measurement process in the telecommunications lab and the Anechoic Chamber room and the measurement process using Network Analyzer software for the Anechoic Chamber device carried out by *female* students who have been trained. The antenna transmission cable connector is an SMA *female* connector.

A. Yagi Antenna Measurement

Measurements of the yagi antenna were carried out in the Anechoic Chamber room and in the Telecommunication Electronics Lab with the following parameters and using Network Analyzer software. and Anechoic Chamber devices for Anechoic Chamber devices that run students who have been trained

a. Resonant frequency
b. Bandwidth
c. VSWR (Voltage Standing Wave Ratio)
d. Return loss

Measurement in the communication electronics lab. The parameters to be obtained are radiation pattern, antenna gain, HPBW, and FBR. When doing this test, the transmitter used is a dipole antenna.

a. Radiation pattern
b. Antenna gain
c. HPBW (Half Power Beamwidth)
d. FBR (Front to Back Ratio)

B. Yagi Antenna Measurement Results

After the measurement is complete, the parameters determined are Return Loss, Resonant Frequency, VSWR, Bandwidth, Bandwidth, and Gain of the yagi antenna.

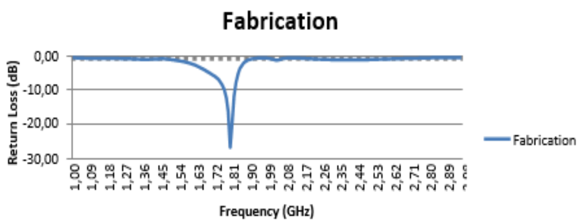
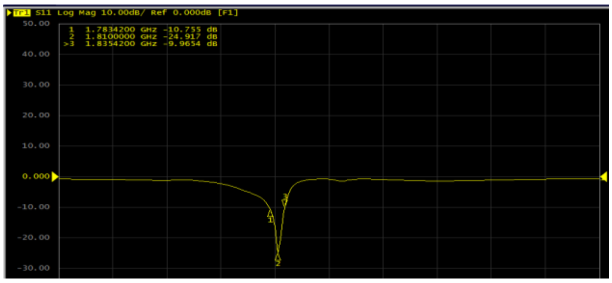


Figure 2 Yagi Antenna Measurement Results

From Figure 2, it is known that the value of the resonation frequency of the yagi antenna is 1.81GHz with a return loss of -26.6 db.

C. Antenna Bandwidth

Lower frequency = 1783 MHz, in the image shown by marker no. 1 Upper frequency = 1835 MHz, in the image shown by marker no.3 Based on equation 2.10, Bandwidth = 1835 MHz - 1783 MHz Bandwidth = 52 Mhz.



D. VSWR (Voltage Standing Wave Ratio)

The ideal VSWR value is 1, the antenna impedance value is the same as the transmission line impedance. The maximum VSWR value that can still be tolerated is 2 because when VSWR is 2, the return loss is -10 dB. An explanation of this return loss value will be explained in the next point.

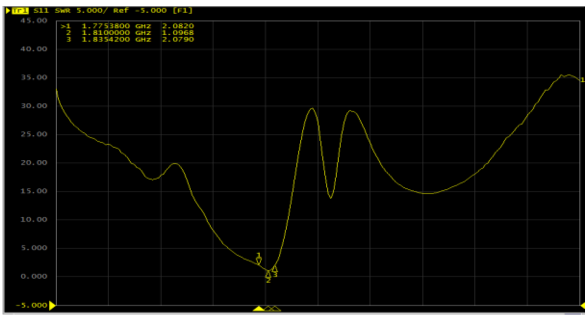


Figure 4 VSWR rounding result

E. Antenna Radiation Pattern

Measurement of radiation patterns in the communication electronics laboratory using a spectrum analyzer measuring device and also using transmitting and receiving antennas with a distance of 1m using a dipole antenna as a transmitter and a yagi antenna as a receiver every antenna position changes the receiving antenna using a motor control.

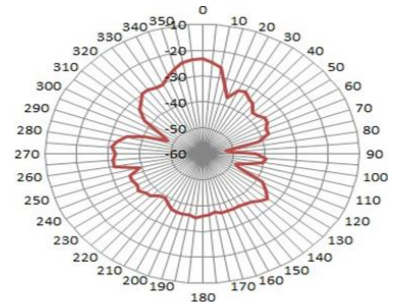


Figure 5. Horizontal polarization of the antenna

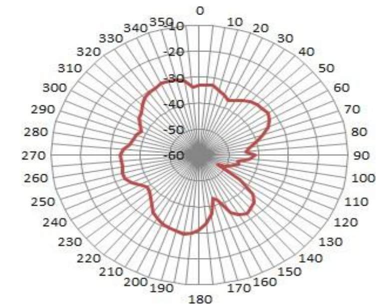


Figure 6. Vertical antenna polarization

F. Antenna Gain

Antenna gain is an antenna parameter that is utilized to amplify 4G signals. The gain of the yagi antenna is done by comparing the power level of the yagi antenna with the dipole antenna as the receiving antenna. The dipole antenna is used as a reference antenna in calculating the gain of the yagi antenna.

Table 3 Antenna gain measurement

No.	Antenna type	Transmitting power (dBm)	Received power (dBm)
1	1800 MHz *dipole* antenna	+0	-47,52
2	1800 MHz yagi antenna	+0	-38,95

G. HPBW (Half Power Beamwidth)

HPBW is the coverage area of an antenna expressed in degrees. HPBW is closely related to antenna gain. HPBW is especially important if the antenna is used for long-distance point-to-point communication. The angular width of the HPBW is the width of the angle formed in the

when the radiation intensity1 of its maximum value or drops 3 dB.

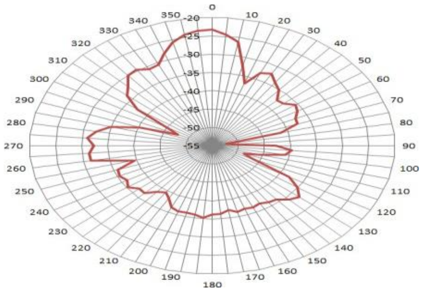


Figure 7 HPBW manufacturing result

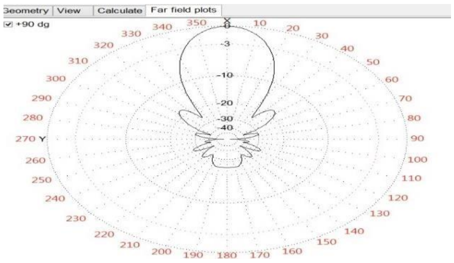


Figure 8 HPBW simulation results

H. Yagi Antenna Parameter Analysis

The resonation frequency is designed at a frequency of 1800 resonation frequency is where the antenna works or gains maximum power after the confirmation process to see its resonation in the Anechoic Chamber. The process of measuring and testing return loss using a Network Analyzer device. To see the resignation using the return loss graph because the smaller the return loss of the antenna, the greater the power emitted or received the test results prove that this yagi antenna has a resonant frequency close to 1810 MHz and the results of the equation obtained that the resonant frequency of the yagi antenna is at a frequency of 1809 MHz. This frequency is slightly different from the initial design of 1800 MHz. This is due to the less neat manual fabrication process.

Bandwidth is the range in a working antenna bandwidth that serves to know the width of a frequency that can be received antenna bandwidth value of 52 MHz this value is different in the bandwich initial frequency of 1710 MHz to 1880 MHz. In general, bandtwich has a band with frequency LTE worth 75 MHz. In LTE use uplink and downlink On uplink has a frequency of 1710 MHz-1785 MHz and a downlink frequency of 1805 MHz - 1880 MHz so that the uplink and downlink frequencies have a frequency of 75 MHz and band gap frequency uplink and downlink (1785 MHz - 1805 MHz) has 20 MHz The antenna frequency range of 1783 MHz - 1835 MHz is still in the bandwidth of uplink and downlink frequencies in LTE technology. The value of vswr ideally is 1 transmission impedance and antenna impedance has the same value if the value of vswr diporeleh 2 can be tolerated when VSWR has a value of 2 then the value of return loss diporeleh by 10 db In the simulation results diporeleh value of 1.09 vswr value is good compared to the simulation results of 1.18.db In the experiment a unidirectional radiation pattern has a large back lobe.

The simulation results are different from the experimental results in the simulation in the form of a unidirectional radiation pattern. good (has a small back lobe). Due to lack of accuracy during the fabrication process.

Radiation patterns that are not in accordance with the simulation are also caused by noise when testing. This noise is caused because the test is carried out in the lab room so the antenna test is affected by reflected waves. This yagi antenna produces a narrow HPBW so that it is more focused to a point. This antenna has a high gain because the narrower the HPBW of an antenna, the higher the gain. HPBW and gain values are inversely proportional

Gain is an amplifier on the signal on the test antenna carried out in the communication electronics lab using a dipole antenna as the received power level of the yagi antenna is -38.95 dBm and the received power level of the dipole antenna is -47.52 dBm. From the measurement results, the gain value of this antenna is 8.572 dB. This result is smaller when compared to the simulation results, where the simulation results obtained are 20.66 dB.

HPBW is the large coverage area of the antenna expressed in degrees. HPBW is related to antenna gain The HPBW angle has a wide angle formed when the radiation intensity is ½ when the maximum value drops by 3db HPBW this rounding result has a better or more focused value compared to the simulation results. HPBW from simulation results is 300

FBR (Front to Back Ratio) Is the ratio between the main lob and back lobe FBR = power in the direction 00 - power in the direction 1800 = -23.24 dBm - (-36.21dBm) = -12.97 dB Return Lossb Is back attenuation. Return loss serves to check the loss of transmitter power and know the value of power received on the yagi antenna as a receiver. return loss measurement chart, a good antenna has a return loss value below -10 dB. The return loss value is known from the VSWR value. The return loss value of the simulation results is not displayed by the software but uses the formula.

IV. CONCLUSIONS

The antenna design and simulation process uses MMANA-GAL software and uses a frequency of 1800MHz from the simulation results obtained antenna impedance of 42.84 + j2.906 Ω, VSWR 1.18, Gain 20.66 dB, and FBR of 23,77 dB and has a unidirectional radiation pattern and in calculations carried out manually and using a Network Analyzer the radiation pattern is unidirectional, the maximum power level is -23.24 dBm, the resonant frequency is 1809 MHz, Bandwidth is 52 MHz, HPBW is 250, FBR is 12.97 dB, Gain is 8.572 dB, VSWR is 1.09, and Return loss is -26.6 dB. With the addition of the reflector element on the antenna, it results in an increase in resonation impedance.

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After completing this journal, a new chapter in life will begin that is not the end. Without the help of others, I as a writer would not have been able to complete my journal.

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