The Comparison Analysis of Beam Reconfigurable 4G Microstrip Antenna Using Array Shifting Structure Method

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ABSTRACT

This research proposes four antenna designs. There are microstrip array patch rectangular (1x2 and 1x4) and microstrip array patch triangular (1x2 and 1x4). The most optimal antenna for use at a working frequency of 2,3 GHz is the antenna microstrip array patch rectangular 1x4 using the array shifting structure method. This antenna has success in forming two-beam (reconfigurable beam) arrangements in one antenna, each beam showing a graphical representation of the antenna alignment in the space plane including the propagation of the electric field (E) and the propagation of the magnetic field (H). The antenna parameter values for the left beam are: VSWR 1.27, return loss -18.36 dB, bandwidth 50 MHz, gain 3.47 dB, beamwidth azimuth (theta 90° = 115°, theta 170° = 145° and theta 270° = 115°) and a directional radiation pattern. While the antenna parameter values for the right beam are: VSWR 1.23, return loss -19.46 dB, bandwidth 60 MHz, gain 3.64 dB, beamwidth azimuth (theta 90° = 100°, theta 170° = 150° and theta 270° = 100°) and a directional radiation pattern. Antenna design and simulation using Ansoft HFSS software version 15.

Keywords: Reconfigurable Beam; Microstrip Array; Rectangular Antenna; Triangular Antenna; 4G (fourth generation).

Introduction

The development of telecommunications systems in the modern era is very rapid, especially in the field of mobile telecommunications on 4G applications. In everyday life, the need for information is very important and the information is very easy to access on the internet. The application of the 4G/LTE communication system demands very high speed in the process of transferring or sending data and connectivity, besides that, the sending and receiving devices are also getting smaller and more compact (Alam & Wijaya, 2018). In a wireless communication system, the process of exchanging information requires a sending and receiving device, one of which is an antenna.

One type of antenna currently widely used for wireless communication is a microstrip antenna. Microstrip antennas have advantages such as being simple, small, and compact (Imran et al, 2020). This antenna also has several drawbacks including poor directionality, low gain, low efficiency, resistance losses on the feed line, and narrow bandwidth. To overcome the shortcomings of the micro strip antenna can be done using the array method. The antenna array design method is done by arranging the microstrip antenna into several patches that are connected to the feed line or microstrip line (Alam & Nugroho, 2018).

The microstrip antenna designed in this study uses a rectangular patch consisting of two patch elements arranged in a linear array. The antenna parameters tested are return loss value -10 dB, VSWR 2, and gain value. The simulation results of the two-element array design with a substrate size of 134 mm x 91 mm obtained a return loss value of -35.08 dB, VSWR 1.035 for a frequency of 2.3 GHz. The single element simulation results based on the calculation, the VSWR value at a frequency of 2.4 GHz is 2.025, return loss is -10.296 dB and gain is -0.057 dBi. From the experimental results, it is found that the value of W = 2.76 mm and L = 26 mm which is smaller than the calculation results produces a better value with a VSWR value of 1.543, a return loss of -12.941 dB, and a gain of -0.025 dBi. Currently, 4G-LTE technology has been implemented in Indonesia.

The bandwidth speed of 4G-LTE technology Internet connections is said to be able to reach 10 times the speed of 3G access, encouraging the application of media convergence in Indonesia (Desi, 2021). The emergence of 4G-LTE technology opens up opportunities for the emergence of the latest media in Indonesia and poses a challenge to converge (merge) existing media. It is enough for people to have one device with 4G-LTE technology to access all forms of wireless communication and all forms of mass media that exist today (Gemiharto, 2015).

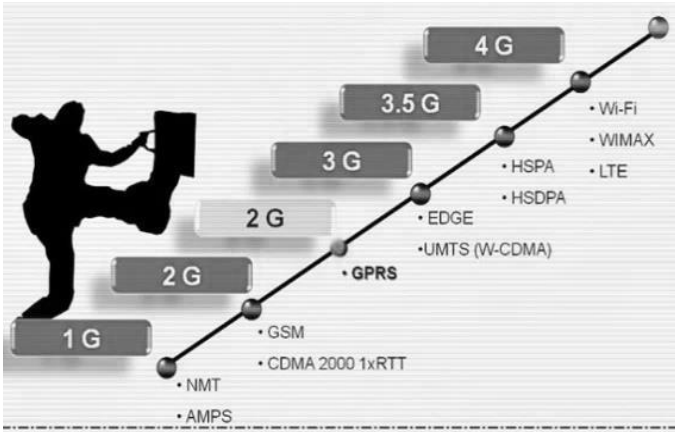

Figure 1. Mobile Technology Development in Indonesia

Literature Review

Bandwidth is defined as the working frequency range of the antenna, with several characteristics, as defined by the standard. Bandwidth can also be defined as the maximum capacity of the communication line to process sending and receiving data in seconds. Like a highway, bandwidth is the width of the road, the wider it is, and the more riders can pass at the same time (Hassan et al, 2021). Bandwidth can be defined as the frequency range, from the lowest frequency to the highest frequency the antenna can work well, antenna characteristics such as input impedance, beamwidth, polarization, and gain are within values that can be accepted by those at the center frequency. For broadband antennas, bandwidth is usually defined as the ratio of the upper frequency to the lower frequency (Buwardah, 2014). Meanwhile, for narrowband antennas and antenna width, it is defined as the percentage of the difference in frequency above the center frequency of the width of the field (Azis et al, 2021).

Long-term Evolution (LTE) is a long-term evolution radio access network from the 3rd Generation Partnership Project (GPP). LTE or Long term Evolution is a continuation of the third-generation technology (3G) WCDMA-UMTS. This technology has been commercially tested since 2009 and is expected to become the standard for the evolution of mobile broadband data communications for the next decade. Since December 2007, 3GGP has conducted a feasibility study for LTE (Long term Evolution) by issuing the 7th release. Finally, the LTE concept was formed in 2008 with the release of the 8th release (Ulfah & Irtawaty, 2018).

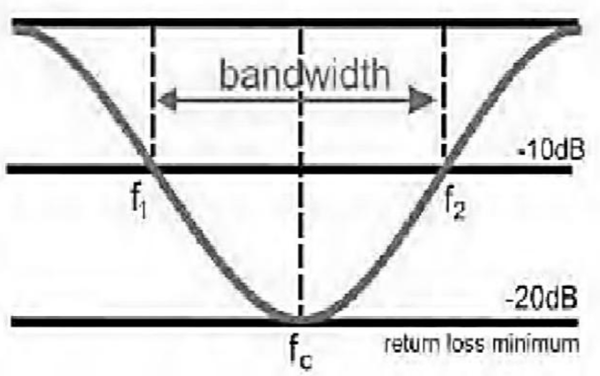

Figure 2. Bandwidth Frequency Range

Transmission speed is influenced by the amount of bandwidth. Large amounts of data when passing through a narrow bandwidth take a long time; therefore the bandwidth of the microstrip antenna needs to be increased. The application of an antenna in the sending and receiving system is always limited by the working frequency area. In a certain working frequency range, the antenna is required to be able to work effectively or maximally to receive or transmit waves in a certain frequency range (Wairooy & Haswin, 2018).

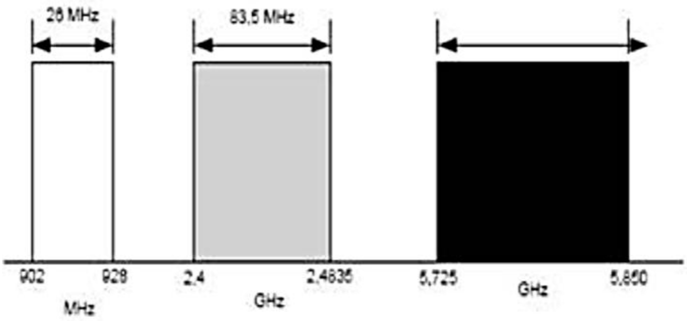

Figure 3. Antenna Bandwidth

An antenna works at a center frequency of f_C, but this antenna can still work well at frequencies f_1 (below f_C) to f_2 (above f_C), then the bandwidth of the antenna is ($f_2 - f_1$). However, when expressed in percent, the antenna bandwidth can be calculated using equation (2.1):

$$BW = \frac{f_2 - f_1}{f_c} x\ 100$$

Description:
BW : *Bandwidth*
f_2 : highest frequency
f_1 : lowest frequency
f_c : middle frequency

The bandwidth value can also be calculated using equation (2.2) as follows:
$BW = F_H - F_L$
Description:
BW = *Bandwidth* (MHz)
F_H = Highest frequency
F_L = Lowest frequency

The benchmark used to obtain f_2 and f1 is determined by the value of VSWR = 1. Here are some types of bandwidth associated with micros trip antennas (Sailaja & Naik, 2021). Impedance bandwidth is the frequency range where the patch antenna is in a state of matching with the feed line. This happens because the impedance value of the antenna element varies depending on the frequency value. The matching value or the suitability of this antenna can be seen from the return loss and VSWR. In general, the return loss and VSWR values are still considered good, return loss is below -10 dB and VSWR is below 2.

a) The bandwidth pattern is the frequency range in which the bandwidth, side lobe, and gain, which vary according to frequency, meet certain values. The frequency value must be determined at the beginning of the antenna design so that the bandwidth value can be found.
b) Polarization or axial ratio bandwidth is the frequency range where linear polarization or circular polarization still occurs. The axial ratio value for circular polarization is less than 3 dB.

The antenna array is an arrangement of several identical antennas. The signal from the micro strip array antenna is combined or processed to improve the performance obtained from one antenna (Donelli, 2017). The purpose of the antenna array design is to increase the antenna gain, increase the directivity of the antenna, direct the transmit power to the desired angle sector and determine the direction of the signal arrival (Alam & Nugroho, 2018). The radiation pattern produced by an antenna is closely related to the arrangement of the antenna. The method of arranging the antenna is related to the magnitude of the amplitude distribution that is supplied to each antenna (Koutinus et al, 2020). By adjusting the amplitude and phase distribution pattern, the desired radiation pattern and antenna gain are obtained. Uniform arrangement of antennas is supplied by feeding each antenna with a uniform amplitude distribution (same phase and amplitude) for the same distance between antennas; the result obtained is a narrow beamwidth (related to maximum directivity) but has side lobes large ones (Dase, 2017).

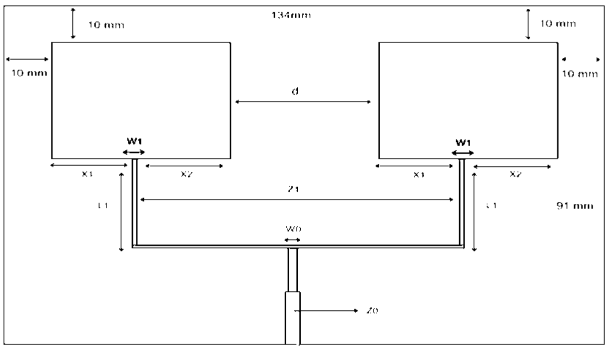

Figure 4. Rectangular Array Microstrip Antenna Model

The shifting structure antenna system works by switching the beam to the desired direction. The use of switched beams further increases the capacity of the system when the signal arrives. The base station determines the potential beam that leads to the incoming signal and then activates the beam so that the user can communicate (Donelli, 2016). The selection of the potential beam is usually based on the maximum received power level received by the user. The shifting structure antenna system is shown in figure 5 below:

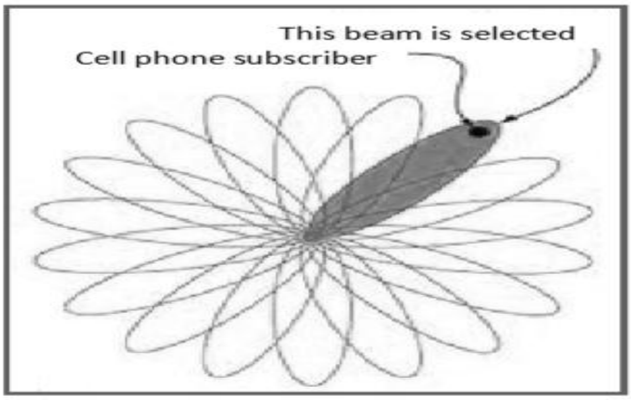

Figure 5. The Working Principle of the Switched Beam of the Antenna

The switched beam system consists of several antenna arrays, each array covering a specific area. This system is equipped with a phase shifter that functions to form beams in a certain direction and an RF switch that functions to activate the selected beam in the desired direction (Ali et al, 2020). Beam selection is controlled by a certain algorithm. This algorithm searches all beams and decides one beam based on the strongest signal received and measured at the detector (Dase, 2017). Several methods that can be used as a series of phase shifters include buttler matrix array, blass array, wullenweber array, and rotman lens.

Methods

Researched the theoretical basis from the basic concepts of Microstrip Array Antennas, especially rectangular patch array microstrip antennas (1x2 and 1x4) and triangular patch array microstrips (1x2 and 1x4) as well as Ansoft HFSS software version 15. Antenna design using Ansoft HFSS software version 15. Which will be designed in this final project are rectangular patch array microstrip antennas (1x2 and 1x4) and triangular patch array microstrip antennas (1x2 and 1x4). The working frequency of the antenna to be designed is 2.3 GHz for 4G/LTE applications and the type of substrate is FR-4, Microstrip Line Feeding technique. Antenna simulation using Ansoft HFSS software version 15. Before doing the simulation, first determine the dimensions of the antenna, namely the length and width of the antenna, determine the antenna beam configuration (beam reconfigurable) with the array shifting structure method (Amaelia & Hugeng, 2013).

The data obtained from the simulation results of the comparison of rectangular patch microstrip array antennas (1x2 and 1x4) and triangular patch microstrip array antennas (1x2 and 1x4). The data that has been obtained is then analyzed by referring to the comparison of the beam reconfigurable rectangular patch array antenna (1x2 and 1x4) and the triangular patch microstrip array (1x2 and 1x4) using the array shifting structure method.

In this antenna design, we want an antenna that can work on the following specifications:

- Antenna design : rectangular patch array microstrip antenna (1x2 and 1x4) and triangular patch array microstrip antenna (1x2 and 1x4).
- Frequency of work : 2.3 GHz = 23 x 10^8 Hz
- Impedance : 50 Ω
- VSWR : $1 \leq$ VSWR ≤ 2
- Return Loss : $\leq$ -10 dB
- Substrate Type : FR-4 Epoxy

Table 1. Specifications of the Substrate Used

Substrate type	FR-4 Epoxy
Relative dielectric constant (ε_r)	4.4
Substrate thickness (h)	1.6 mm

The following is the design of rectangular patch array microstrip antenna and triangular patch microstrip array antenna:

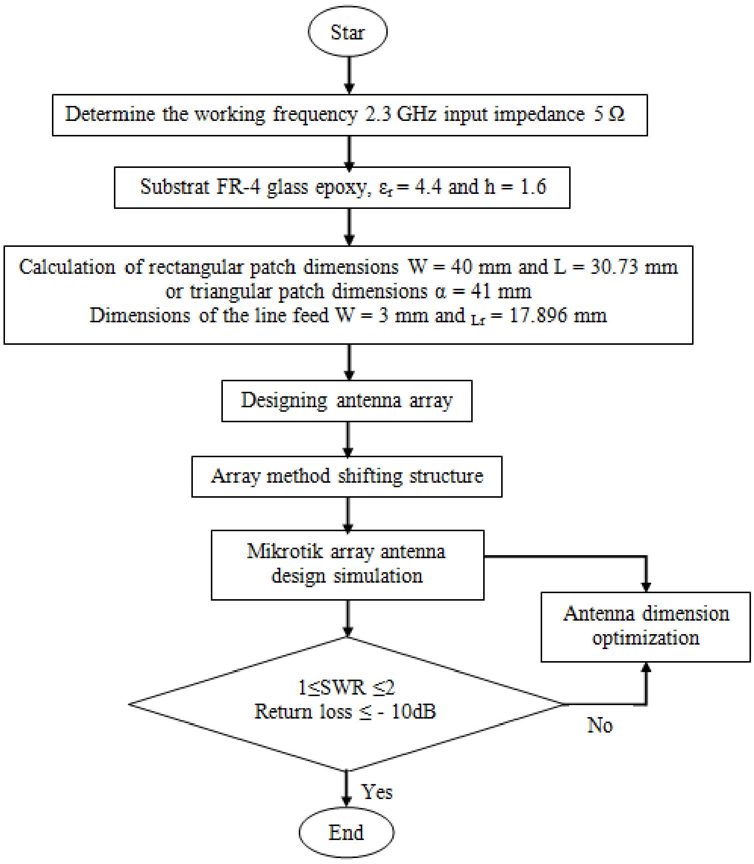

Figure 6. Simulation Stage Design Process Flow

Result

1. Feed Line Design

a) Specifies the width of the feed channel (*w*)

Is known:

h: Substrate thickness = 1.6 mm

π = 3.14

Z_0: Input impedance = 50 Ω

ε_r: Substrate dielectric constant = 4.4

Before looking for the value of w (width of the supply line) you must first know the value of B (Inductance) to get the impedance matching value Z_0 equal to the value of the SMA connector, using equation (2.7).

$$B = \frac{60\pi^2}{Z_0\sqrt{\varepsilon_r}} = \frac{60 \cdot 3.14^2}{50\sqrt{4.4}} = 5.6$$

Determine the width of the feed line using equation (2.8).

$$w = \frac{2h}{\pi}\left\{B - 1 - In(2B-1) + \frac{\varepsilon_r - 1}{2\varepsilon_r}\left[In(B-1) + 0.39 - \frac{0.61}{\varepsilon_r}\right]\right\}$$

$$= \frac{2 \cdot 1{,}6}{3.14}\left\{5.6 - 1 - \text{In}(2 \cdot 5.6 - 1) + \frac{4.4-1}{2 \cdot 4.4}\left[\text{In}(5.6-1)0.39 - \frac{0.61}{4.4}\right]\right\}$$

$$= \frac{3.2}{3.14}\left\{4.6 - \text{In}(10.2) + \frac{3.4}{8.8}\left[\text{In}(4.6) + 0.39 - 0.13863\right]\right\}$$

$$= \frac{3.2}{3.14}\{4.6 - 2.322 + \frac{3.4}{8.8}[1.526 + 0{,}39 - 0.13863]\}$$
$$= \frac{3.2}{3.14}\{4.6 - 2.322 + 0.3863[1.78]\}$$
$$= \frac{3.2}{3.14}\{2.278 + 0.688\}$$
$$= \frac{3.2}{3.14} \cdot 2.966$$
$$= \frac{9.4912}{3.14}$$
$$= 3.022 \text{ mm}$$
$$= 3 \text{ mm}$$

b) Determine length

Determine the length of the supply line $_f$ from the wavelength λ_o using equation (2.9); it is known that the speed of light (3x108 m/s) and the working frequency is 2.3 GHz = 23 x 108 Hz.

$$\lambda_0 = \frac{c}{f} = \frac{3\text{x}10^8}{23\text{x}10^8} = 0.130434 \text{ m} = 130.434 \text{ mm}$$

The equation to find the effective dielectric constant of the feeder uses equation (2.10), where the dielectric constant of the substrate ε_r= 4.4, the thickness of the substrate h = 1.6 mm, and the width of the feed channel w = 3 mm

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1 + 12 \cdot \frac{h}{w}\right]^{-\frac{1}{2}}$$
$$= \frac{4.4+1}{2} + \frac{4.4-1}{2}\left[1 + 12 \cdot \frac{1.6}{3}\right]^{-\frac{1}{2}}$$
$$= \frac{5.4}{2} + \frac{3.4}{2}[1 + 12 \cdot 0.533]^{-\frac{1}{2}}$$
$$= \frac{5.4}{2} + \frac{3.4}{2}[1 + 6.4]^{-\frac{1}{2}}$$
$$= \frac{5.4}{2} + \frac{3.4}{2}[7.4]^{-\frac{1}{2}}$$
$$= \frac{5.4}{2} + \frac{3.4}{2}\left[\frac{1}{\sqrt{7.4}}\right]$$
$$= 3.32 \text{ mm}$$

Where λo is the wavelength in free space, and λo is the wavelength in the material, using the equation (2.11):

$$\lambda_g = \frac{\lambda_0}{\sqrt{\varepsilon_{eff}}} = \frac{130.434}{\sqrt{3.32}} = \frac{130.434}{1.822086} = 71.584 \text{ mm}$$

Then the length of the supply line L can be calculated by Equation (2.12) as follows:

$$L_f = \frac{\lambda_g}{4} = \frac{71.584}{4} = 17.896 \text{ mm}$$

b) Determine the patch length (L)

f : frequency of work = 2.3 GHz = 23x10^8 Hz
h: material thickness (mm) = 1.6 mm
ε_r: dielectric constant = 4.4

2. Rectangular Patch Array Microstrip Antenna Design

a) Specifies the patch width (w)

Determining the width of the patch using equation (2.13), it is known that:

ε_r: substrate dielectric constant = 4.4
c: speed of light in free space = 3x10^8 m/s
f: antenna working frequency = 2.3 GHz = 23x10^8 Hz.

$$W = \frac{C}{2f\sqrt{\frac{\varepsilon_r + 1}{2}}}$$
$$= \frac{3\text{x}10^8}{2 \cdot 23\text{x}10^8\sqrt{\frac{4.4+1}{2}}}$$
$$= \frac{3}{46\sqrt{\frac{5.4}{2}}}$$
$$= \frac{3}{46 \cdot 1.64317}$$
$$= \frac{3}{75.5857}$$
$$= 0.040 \text{ m}$$
$$= 40 \text{ mm}$$

c: speed of light = 3×10^8 m/s
W: antenna patch width = 40 mm
To determine the length of the antenna, you must first know the effective length of the antenna (L_{eff}), antenna effective dielectric constant (ε_{eff}), and delta L (ΔL). The formula to find the effective dielectric constant uses equation (2.14), as follows:

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\cdot\frac{h}{W}\right]^{-\frac{1}{2}}$$

$$= \frac{4.4+1}{2} + \frac{4.4-1}{2}\left[1+12\cdot\frac{1.6}{40}\right]^{-\frac{1}{2}}$$

$$= \frac{5.4}{2} + \frac{3.4}{2}\left[1+12\cdot\ 0.04\right]^{-\frac{1}{2}}$$

$$= \frac{5.4}{2} + \frac{3.4}{2}\left[1+0.48\right]^{-\frac{1}{2}}$$

$$= \frac{5.4}{2} + \frac{3.4}{2}\left[\frac{1}{\sqrt{1.48}}\right]$$

$$= 4.097$$

Determining the value of the effective length of the antenna L_{eff} using equation (2.15):

$$L_{eff} = \frac{c}{2f\sqrt{\varepsilon_{eff}}}$$

$$= \frac{3x10^8}{2\cdot 23x10^8\sqrt{4.097}}$$

$$= 0.03222 \text{ m}$$

$$= 32.22 \text{ mm}$$

The formula for determining delta *L* using equation (2.16):

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

$$= 0.412\cdot 1.6\,\frac{(4.097\ +0.3)(\frac{40}{1.6}+0.264)}{(4.097\ -\ 0.258)(\frac{40}{1.6}+0.8)}$$

$$= 0.6592\,\frac{(4.397)(25.264)}{(3.839)(25.8)}$$

$$= 0.6592\,\frac{111.085}{99.0462}$$

$$= 0.6592\ \cdot 1.1215$$

$$= 0.7416 \text{ mm}$$

The formula for determining the length of the antenna (*L*) using equation (2.17), as follows:

$$L = L_{eff} - 2\Delta L$$

$$= 32.22 - 2\cdot 0.7416$$

$$= 32.22 - 1.4832$$

$$= 30.73 \text{ mm}$$

3. Triangular Patch Array Microstrip Antenna Design

Is known:
f_r: frequency of work = 2.3 GHz = 23×10^8 Hz
ε_r: dielectric constant = 4.4
c: speed of light = 3×10^8 m/s

Determine the side of the triangle antenna using equation (2.18)

$$a = \frac{2c}{3f_r\sqrt{\varepsilon_r}}$$

$$= \frac{2\cdot 3x10^8}{3\cdot 23x10^8\sqrt{4.4}}$$

$$= \frac{6}{69\cdot 2.09761769634}$$

$$= \frac{6}{144.735621047}$$

$$= 0.041 \text{ m}$$

$$= 41 \text{ mm}$$

a) Slot design

$$\lambda_0 = \frac{c}{f} = \frac{3x10^8}{23x10^8} = 0.130434 \text{ m} = 130.434 \text{ mm}$$

Description:
λ_o = wavelength in free space
W' = slot width
L' = slot length

Rectangular patch array microstrip antenna 1x2
w' = 0.015333 x $\lambda_0 = 0.015333\ x\ 130.434 = 2$ mm
Determine the slot length (*L*')
L' = 0.095834 x $\lambda_0 = 0.095834\ x\ 130.343 = 12.5$ mm
Rectangular patch array microstrip antenna 1x4
Determine the slot width (*w*')
w' = 0.015333 x $\lambda_0 = 0.015333\ x\ 130.434 = 2$ mm
Determine the slot length (*L*')
L' = 0.130334 x $\lambda_0 = 0.130334\ x\ 130.343 = 17$ mm

1x2 triangular patch array microstrip antenna
Determine the slot width (w')
$w' = 0.007666 \text{ x } \lambda_0 = 0.007666 \; x \; 130.434 = 1$ mm
Determine the slot length (L')
$L' = 0.046 \text{ x } \lambda_0 = 0.046 \; x \; 130.343 = 6$ mm
1x4 triangular patch array microstrip antenna
Determine the slot width (w')
$w' = 0.007666 \text{ x } \lambda_0 = 0.007666 \; x \; 130.434 = 1$ mm
Determine the slot length (L')
$L' = 0.092 \text{ x } \lambda_0 = 0.092 \; x \; 130.343 = 12$ mm

Antenna design using Ansoft HFSS version 15 application was analyzed based on antenna parameters, namely Voltage Standing Wave Ratio (VSWR), S11/ return loss, radiation pattern, gain, beamwidth, and bandwidth. The antenna parameters determine the results of the comparison of the beam reconfigurable 4G microstrip antenna using the array shifting structure method. The results of the analysis produce the most ideal type of antenna for use at a working frequency of 2.3 GHz (4G applications).

Table 2. Dimensions of Rectangular Patch Array Antenna

Structure	Material	Relative Permittivity	Antenna dimension (mm)					
			Thickness (h) according to the formula	**Thickness (h) after optimization**	**Width (w) According to the formula**	**Width (w) after optimization**	**Long (L) according to the formula**	**Long (L) after optimization**
Dielectrics substrates	FR-4 Epoxy	4.4	1.6	1.6	94	94	75	75
Patch Right	Perfect Electric Conductor (PEC)		0.05	0.05	40	40	30.73	30.73
Patch Left			0.05	0.05	40	40	30.73	30.73
Feeding line Right			0.05	0.05	3	3	17.896	17.896
Feeding line Left			0.05	0.05	3	3	17.896	17.896
Ground Plane			0.05	0.05	94	94	75	75
Slot			-	0.05	-	2	-	12.5
Excitation (feeder)			0.05	0.05	3	3	1.6	1.6
Boundary	Air		100	100	100	100	100	100

(a) (b)

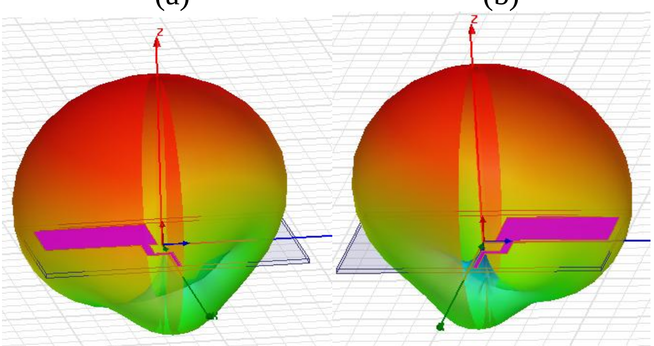

Figure 7. Antenna Comparison Simulation

Figure 7 is a simulation result of a 1x2 rectangular patch array microstrip antenna design based on calculations and overall antenna design before the shifting structure method is applied. The simulation results for the design of a rectangular 1x2 microstrip patch array microstrip antenna based on the following calculations: (a) left switched patch; (b) right switched patch. In this condition, the shifting structure method has been applied for the reconfigurable beam design; the shifting structure method is carried out in a united way (combination of patch and feed line). The form of electromagnetic wave propagation in the 3D radiation pattern, where the antenna has succeeded in realizing a reconfigurable beam, namely the left beam and right beam, both beams form a directional pattern.

4. Voltage Standing Wave Ratio (VSWR)

VSWR patch left

	Freq [GHz]	VSWRt(GND_T1) Setup1 : Sweep
22	2.210000	4.338900
23	2.220000	3.833552
24	2.230000	3.354471
25	2.240000	2.908063
26	2.250000	2.499972
27	2.260000	2.135174
28	2.270000	1.818677
29	2.280000	1.558211
30	2.290000	1.373823
31	2.300000	1.317303
32	2.310000	1.422545
33	2.320000	1.638919
34	2.330000	1.927055
35	2.340000	2.274112
36	2.350000	2.675358
37	2.360000	3.127566
38	2.370000	3.627164
39	2.380000	4.169753
40	2.390000	4.750079
41	2.400000	5.362162
42	2.410000	5.999482

VSWR patch right

	Freq [GHz]	VSWRt(GND_T1) Setup1 : Sweep
22	2.210000	4.058154
23	2.220000	3.599867
24	2.230000	3.165061
25	2.240000	2.759103
26	2.250000	2.386691
27	2.260000	2.051938
28	2.270000	1.758952
29	2.280000	1.514087
30	2.290000	1.334597
31	2.300000	1.271177
32	2.310000	1.365331
33	2.320000	1.564774
34	2.330000	1.828352
35	2.340000	2.143774
36	2.350000	2.506962
37	2.360000	2.915386
38	2.370000	3.366279
39	2.380000	3.856169
40	2.390000	4.380819
41	2.400000	4.935314
42	2.410000	5.514209

Figure 8. VSWR Table Data Comparison Simulation

From the simulation results of the comparison of the beam reconfigurable rectangular 1x2 patch array microstrip antenna based on the calculation, it can be noted that at a working frequency of 2.3 GHz, the VSWR value for the left patch is 1.39 and the right patch is 1.27. This value has met the optimal antenna requirements.

a) Bandwidth

Based on the VSWR value generated from the simulation. Comparison of beam reconfigurable rectangular 1x2 patch array microstrip antennas, bandwidth values can be calculated using equation (2.2) in the literature review, here is the bandwidth calculation:

Left patch bandwidth (left beam):

BW = FH - FL

= 2.33 GHz – 2.27 GHz

= 0.06 GHz. = 60 MHz

The bandwidth of the right patch (right beam):

BW = FH - FL

= 2.33 GHz – 2.27 GHz

= 0.06 GHz. = 60 MHz

Based on the calculation results, the bandwidth generated from the simulation results is 60 MHz, the ratio of the bandwidth values between the left beam and the right beam does not shift. The results of the design of a 1x2 rectangular microstrip array antenna based on calculations, besides being able to work at FC frequency or working frequency of 2.3 GHz, can also work well at a frequency of 2.27 to 2.33 GHz.

b) Return Loss

RL patch left

	Freq [GHz]	dB(St(GND_T1,GN... Setup1 : Sweep
22	2.210000	-4.076968
23	2.220000	-4.638704
24	2.230000	-5.340841
25	2.240000	-6.227376
26	2.250000	-7.359627
27	2.260000	-8.823985
28	2.270000	-10.738654
29	2.280000	-13.222763
30	2.290000	-16.055645
31	2.300000	-17.270170
32	2.310000	-15.168017
33	2.320000	-12.319607
34	2.330000	-9.986510
35	2.340000	-8.197721
36	2.350000	-6.823842
37	2.360000	-5.756220
38	2.370000	-4.916554
39	2.380000	-4.248888
40	2.390000	-3.712668
41	2.400000	-3.278058
42	2.410000	-2.922818

RL patch right

	Freq [GHz]	dB(St(GND_T1,... Setup1 : Sweep
22	2.210000	-4.370654
23	2.220000	-4.955883
24	2.230000	-5.683024
25	2.240000	-6.595859
26	2.250000	-7.755918
27	2.260000	-9.251712
28	2.270000	-11.210594
29	2.280000	-13.786880
30	2.290000	-16.873790
31	2.300000	-18.459975
32	2.310000	-16.224107
33	2.320000	-13.143489
34	2.330000	-10.666367
35	2.340000	-8.782223
36	2.350000	-7.336574
37	2.360000	-6.210366
38	2.370000	-5.320911
39	2.380000	-4.610198
40	2.390000	-4.036529
41	2.400000	-3.569286
42	2.410000	-3.185601

Figure 9. RL Table Data Comparison Simulation

Based on Figure 9, the simulation results of the comparison of the table data return loss beam reconfigurable rectangular 1x2 microstrip array patch antenna based on calculations, at a working frequency of 2.3 GHz, the return loss value for the left patch (left beam) is -17.27 dB and the right patch return loss (right beam) of -18.45 dB. The resulting return loss value between the left beam and right beam does not have a big difference and the resulting return loss has met the requirements as an optimal antenna to work at a frequency of 2.3 GHz.

c) 3D Radiation Pattern

(a) (b)

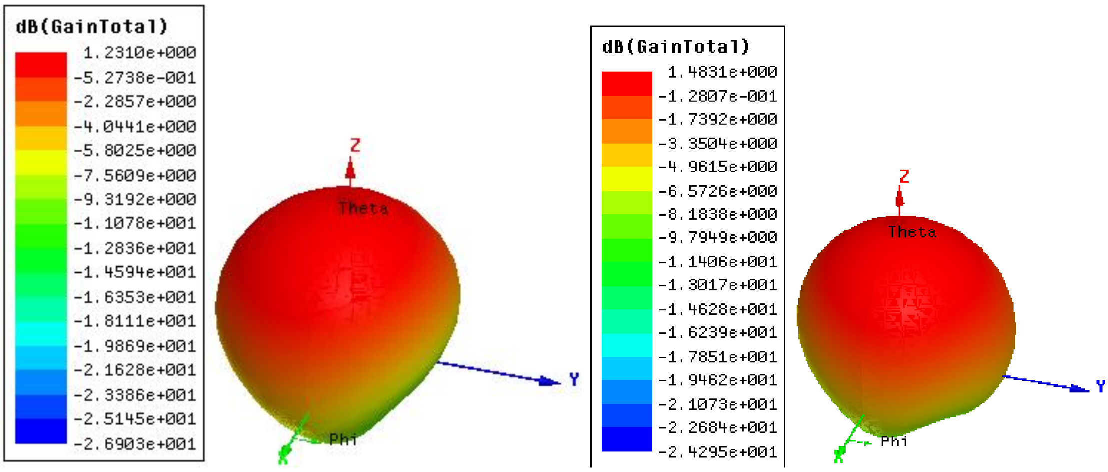

Figure 10. 3D Radiation Pattern Comparison Simulation

Based on Figure 10, shows a three-dimensional (3D) radiation pattern which shows a graphical representation of the antenna orientation in the space plane including the propagation of the electric field (E) and the propagation of the magnetic field (H). The propagation of the electromagnetic field from the comparison of the reconfigurable beam of a rectangular 1x2 patch array microstrip antenna based on the calculation results in two-beam arrangements, where the left beam and right beam have a directional radiation pattern. The radiation emission pattern generated between the left beam and the right beam has the main beam in a certain direction. The maximum gain for the left beam is 1.23 dB and for the right beam is 1.48 dB.

Table 3. Rectangular Antenna Parameter Results Based on Calculations

Antenna parameters		Left beam	Right beam
VSWR		1.31	1.27
Return Loss (dB)		-17.27	-18.45
Bandwidth (MHz)		60	60
Gain Maksimum (dB)		1.23	1.48
Beamwidth Azimuth	90°	222.5°	225°
	170°	180°	182°
	270°	225°	225°
Radiation pattern		Directional	Directional

VSWR value (left beam 1.31 and right beam 1.27), return loss value (left beam -17.27 dB and right beam -18.45 dB), bandwidth value (left beam 60 MHz and right beam 60 MHz), gain value (left beam 1.23 dB and right beam 1.48 dB), beamwidth azimuth value for theta angle 90° (left beam 225° and right beam 225°) beamwidth azimuth value for theta angle 170° (left beam 180° and right beam 182°) the beamwidth azimuth value for theta angle is 270° (left beam 225° and right beam 225°) and the resulting radiation pattern is directional.

Discussions

Recapitulation of parameter data from antenna simulation results after optimization. For rectangular patch array microstrip antenna 1x2 VSWR value (left beam 1.25 and right beam 1.28), return loss value (left beam -18.84 dB and right beam -18.05 dB), bandwidth value (left beam 60 MHz and right beam 60 MHz), gain value (left beam 1.23 dB and right beam 1.36 dB), beamwidth azimuth value for 90° theta angle (left beam 222.5 ° and right beam 215°) beamwidth azimuth value for theta angle 170° (left beam 233° and right beam 195°) the beamwidth azimuth value for theta angle is 270° (left beam 222.5° and right beam 215°) and the resulting radiation pattern is directional.

Rectangular patch array microstrip antenna 1x4 VSWR value (left beam 1.27 and right beam 1.23), return loss value (left beam -18.36 dB and right beam -19.46 dB), bandwidth value (left beam 50 MHz and right beam 60 MHz), gain value (left beam 3.47 dB and right beam 3.64 dB), beamwidth azimuth value for 90° theta angle (left beam 115° and right beam 100°) beamwidth azimuth value for 170 theta angle ° (left beam 145° and right beam 150°) the beamwidth azimuth value for theta angle of 270° (left beam 115° and right beam 100°) and the resulting radiation pattern is directional.

1x2 triangular patch array microstrip antenna VSWR value (left beam 1.5 and right beam 1.43), return loss value (left beam -13.95 dB and right beam -15.02 dB), bandwidth value (left beam 40 MHz and right beam 50 MHz), gain value (left beam 3.37 dB and right beam 1.04 dB), beamwidth azimuth value for 90° theta angle (left beam 115° and right beam 120°) beamwidth azimuth value for theta angle 170° (left beam 190° and right beam 270°) beamwidth azimuth value for theta angle of 270° (left beam 115° and right beam 120°) and the resulting radiation pattern is directional.

Triangular 1x4 patch array microstrip antenna VSWR value (1.26 left beam and 1.33 right beam), return loss value (left beam -18.50 dB and right beam -16.96dB), bandwidth value (left beam 40 MHz and right beam 40 MHz), gain value (left beam 7.50 dB and right beam 4.91 dB), beamwidth azimuth value for 90° theta angle (left beam 68° and right beam 68°) beamwidth azimuth value for 170° theta angle (left beam 150° and right beam 135°) beamwidth azimuth value for theta angle of 270° (left beam 68° and right beam 68°) and the resulting radiation pattern is directional.

The VSWR value determines the good or bad performance of the antenna. The greater the VSWR value, the greater the reflected power due to channel mismatch. The most ideal condition is that the VSWR value is 1 and the VSWR value that can be tolerated is below 2. The four types of antennas produce an optimal VSWR value for the 2.3 GHz frequency. Of the four antennas, the smallest VSWR value is the VSWR generated by a rectangular 1x4 which is 1.27 on the left beam and 1.23 on the right beam. Return Loss occurs because the load impedance is not by the transmission line impedance, resulting in not all the power entering the load can be received, there is some reflected power. The return loss value of the four types of antennas has met the requirements namely; the return loss is below -10 dB. This means that the transmission lines for the four types of antennas have been matched. The most optimal return loss value for a working frequency of 2.3 GHz is produced by a 1x4 rectangular antenna, namely the left beam -18.36 dB and the right beam -19.46.

Bandwidth indicates the working frequency range of the antenna. Bandwidth data, where the antenna that has the highest frequency range is a 1x2 and 1x4 rectangular antenna. The 1x2 rectangular antennas produces a bandwidth on the left beam and right beam of 60 MHz, while for rectangular 1x4 it produces a bandwidth of 50 MHz for the left beam and 60 MHz for the right beam. Antenna gain or the ability of the antenna to send and receive signals from a certain direction is influenced by the amount of transmit power, the number and arrangement of the antennas. Antennas that have a wide beamwidth make the antenna gain smaller because the power emitted by the antenna is widely distributed, and vice versa, an antenna that has a narrow beamwidth will make the antenna gain large. In addition, to transmitting power, the number of patch antenna

arrays also affects the gain, but the greater the gain, the greater the VSWR. So we need an antenna that has high gain and ideal VSWR.
The simulation results of the comparison of gain values after the antenna optimization process, the graph shows the largest gain is owned by a 1x4 triangular patch array microstrip antenna, which is 7.50 dB in the left beam and 4.91 dB in the right beam; this happens because this antenna has the highest beamwidth. Narrower than the other three antennas, so the power emitted by this 1x4 triangular antenna is not widely distributed, resulting in high gain. But these antennas have a higher VSWR and return less than a 1x4 rectangular antenna. So that the 1x4 rectangular antenna is more optimal for the 2.3 GHz working frequency than the 1x4 triangular antenna.

The width of the beamwidth on an antenna affects the coverage area or coverage area of the antenna performance, the wider the beam width, the wider the coverage area, and vice versa, the narrower the beam width, the narrower the coverage area. To determine the optimal antenna based on the beamwidth value, depending on the antenna specifications, whether to produce a wide coverage area or prioritize large gains (narrow beamwidth). For antennas that prioritize coverage area, the antenna must have a large beamwidth value and if the antenna only prioritizes the strength of the antenna to radiate the signal, then the selected antenna is an antenna that has a narrow beamwidth.

The simulation results compare the beam width azimuth values at an elevation angle of 90° from the four types of antennas. For rectangular antennas 1x2 produces a wide beamwidth (left beam 222.5° and right beam 215°), rectangular 1x4 produces a wide beamwidth (left beam 115° and right beam 100°), triangular 1x2 produces a wide beamwidth (left beam 115° and beam right 120°) and triangular 1x4 resulting in wide beamwidth (left beam 68° and right beam 68°). The simulation results compare the beamwidth azimuth values at an elevation angle of 170° from the four types of antennas.

For rectangular antennas 1x2 produces a wide beamwidth (233° left beam and 195° right beam), rectangular 1x4 produces a wide beamwidth (left beam 145° and right beam 150°), triangular 1x2 produces a wide beamwidth (left beam 190° and right beam 270 °) and triangular 1x4 resulting in a wide beamwidth (left beam 150° and right beam 135°). The simulation results compare the beamwidth azimuth values at an elevation angle of 270° from the four types of antennas. For rectangular antennas 1x2 produces a wide beamwidth (left beam 222.5° and right beam 215°), rectangular 1x4 produces a wide beamwidth (left beam 115° and right beam 100°), triangular 1x2 produces a wide beamwidth (left beam 115° and beam right 120°) and triangular 1x4 resulting in wide beamwidth (left beam 68° and right beam 68°).

Conclusion

The simulation results of the comparison of beam reconfigurable 4G microstrip antennas using the array shifting structure method can be drawn the following conclusions:

a) From the results of the design that has been carried out, it is obtained that the design of a rectangular 1x2 microstrip array antenna with antenna dimensions after optimization is patch width (W) 40 mm, patch length (L) 30.73 mm, and additional slots on the patch.
b) The design of a rectangular 1x4 microstrip patch array antenna with antenna dimensions after optimization, namely patch width (W) 40 mm, patch length (L) 31.5 mm, and additional slots.
c) Triangular 1x2 microstrip patch array antenna design with antenna dimensions after optimization, namely the antenna side (a) 41 mm and the addition of slots.
d) Triangular 1x4 microstrip patch array antenna design with antenna dimensions after optimization, namely the antenna side (a) 41 mm and the addition of slots.
e) The four antenna structure designs have met the standard antenna parameters, namely 1≤VSWR≤2 and Return Loss -10 dB so that all of them can be used at a working frequency of 2.3 GHz and have succeeded in forming a reconfigurable beam by using the shifting

structure method, meaning the right and switched patches. Left patch with unite, excitation, and boundaries settings in Ansoft High-Frequency Structural Simulator (HFSS) software version 15.

f) The type of antenna that has the most optimal performance for a working frequency of 2.3 GHz is a 1x4 rectangular patch array microstrip antenna using the array shifting structure method. This type of antenna has the most optimal VSWR and return loss values and is closer to the ideal antenna parameters compared to the other three types of antennas. VSWR value (left beam 1.27 and right beam 1.23), return loss value (left beam -18.36 dB and right beam -19.46 dB). Bandwidth value (left beam 50 MHz and right beam 60 MHz), gain value (left beam 3.47 dB and right beam 3.64 dB). Beamwidth azimuth value for 90° theta angle (left beam 115° and right beam 100°) beamwidth azimuth value for 170° theta angle (left beam 145° and right beam 150°) beamwidth azimuth value for 270° theta angle (left beam 115 ° and right beam 100°) and the resulting radiation pattern is directional.

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