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Realization of Rectangular Patch 2x4 Microstrip Array Antennas at Frequency 2.7 GHZ- 2.9 GHZ for Weather Radar Applications

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Abstract
Microstrip antennas are used in various applications including weather radar applications. The antenna is widely used because it has a light mass, low price, and small dimension. On the other hand, microstrip antennas have the disadvantage in gain and the resulting bandwidth isrelatively small and array techniques are needed to overcome them. In this final project, writer has been designed, simulated,and realized a 2x4 microstrip patch antenna which is arranged planar which worksat the frequency of 2.7 GHz-2.9 GHz. This antenna has a type of microstrip antenna with FR-4 substrate material made of copper. The realized antenna produces a working frequency band 2.7 GHz – 2.9 GHz with center frequency 2.8 GHz, Bandwidth 200 MHz, VSWR ≤ 2, Gain ≥ 10 dBi, Return loss ≥ 10 dB, and the unidirectional radiation pattern.
Keywords: *Array , Bandwidth, Gain, Microstrip Antenna, Weather Radar*

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I. Introduction

Antenna is a very important component in the communication process. Antennas have many types including microstrip antennas, yagi, horn, and dipole antennas. Microstrip antennas are widely used for integration in many applications such as WiMAX, LTE and weather radar applications. This antenna has a variety of patch shapes, such as circular (round) and rectangular (rectangular), There is a study from the International Journal of Computer Applications that compares the performance results of circular and rectangular patch microstrip antennas. The results of this study indicate that the shape of the rectangular antenna has a better performance compared to the shape of the circular patch antenna [1]. In addition, microstrip antennas with rectangular patch shapes are easy to design and easy to calculate antenna dimensions.

Many microstrip antennas have been designed and realized, including the Design and Realization of FMCW Radar Antenna Patch Array at 9.4 GHz Frequency with Coaxial Probe Kit [2], Microstrip Circular Antenna Array Design For Radar Applications [3] and Making Microstrip Patch Antenna using Inset Raising Technique Feed for Weather Radar Applications at S-Band Frequencies [4].

In these three studies, there are drawbacks, namely the resulting antenna gain is not in accordance with the amount of gain that should be obtained based on the number of antenna elements, complex feeding techniques, the antenna is still in design, and the shape of the circular patch antenna is difficult in the design and performance of the antenna produced by the antenna. with a rectangular patch shape better than a circular patch [1].

This research proposes the realization of an antenna with a type of microstrip antenna that has a rectangular patch design with a 2x4 array using a microstrip line rationing technique that works at frequencies from 2.7 GHz to 2.9 GHz for weather radar applications. The antenna has a base material of FR-4 substrate with copper type patch material. Illustration of a weather radar system integrated into the proposed microstrip antenna is shown in Figure I.1.

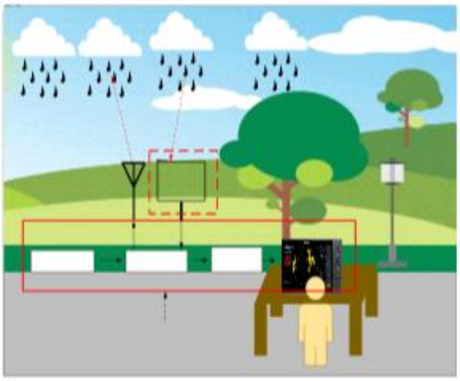


Figure I.1 Illustration of Radar Systems

The working principle of the radar system shown in Figure I.1 in general is by emitting electromagnetic waves through the sending antenna. When the wave hits the target, for example in the form of raindrops, the wave will be reflected back and received a 2x4 microstrip antenna. The reflected waves that the antenna receives are called echo signals. Furthermore the signal will be processed so as to produce an image or image on the weather radar monitor screen [5].

and the performance of the antenna produced by the rectangular patch is better than circular patch [1].
weather radar application. The antenna has a base material of FR-4 substrate with copper type patch material.

The objectives of this study are:
1.Designing a 2x4 rectangular patch microstrip antenna and simulating the antenna in the CST Studio Suite 2018 software to determine the specifications of the antenna produced;
2. Comparing the measurement results of the realization of the 2x4 rectangular patch microstrip antenna with the desired specifications.

The output to be achieved is the realization of a 2x4 array microstrip antenna which has:
- Working frequency 2.7 GHz - 2.9 GHz with a center frequency of 2.8 GHz
- 200 MHz bandwidth
- VSWR ≤ 2
- Gain ≥ 10 dBi
- Return loss ≥ 10 dB
- Unidirectional Radiation Pattern

II. Microstrip Antenna

The microstrip antenna [7] is a metal conductor attached to the groundplane in which there is a dielectric material. The microstrip antenna consists of three layers. These layers are counducting patch, dielectric substrate and groundplane. The shape of the patch can vary according to design needs and the intended specifications can be rectangular, square, circular, tringular, circular ring or other shapes. One form of patch that is widely used in the design of microstrip antennas is the rectangular shape. The structure of the microstrip antenna is shown in Figure II.1 below:

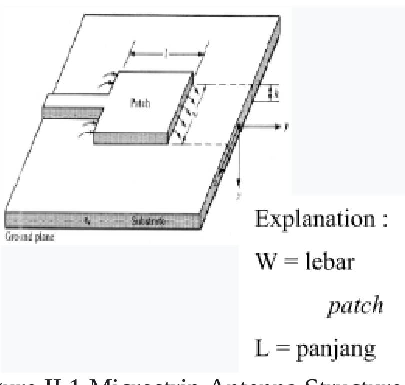


Figure II.1 Microstrip Antenna Structure

Microstrip antenna has advantages and disadvantages including:
- The advantages of microstrip antennas:
  a. Light weight and thin cross section.
  b. Cheap fabrication costs.
  c.Can produce circular or linear polarization.
  d. Can have two or more working frequencies.
- Disadvantages of microstrip antennas:
  a. Narrow bandwidth (1-5%)
  b. Low gain
  c. The smallness of the tools resulted in the need for high accuracy in design.

II.1. Microstrip Array Antenna [8]

Typically single element antennas have a very wide radiation pattern, and each of these elements results in poor directionality and gain. In many applications an antenna with good alignment and high gain is required. Examples of applications that require these characteristics include radar. These characteristic requirements can be met by arranging antennas with several configurations. This array antenna is often referred to as an array antenna.

An antenna array is an array of identical antennas. In the microstrip patch antenna, which is arranged in an array is the patch part. The total field of the antenna array is determined by the vector sum of the fields radiated by a single element. In order to form a pattern that has a certain direction, it is necessary that the fields of each array element interfere constructively in the desired direction and interfere destructively in other directions. In an antenna array with identical elements, there are five controls that can be used to form an antenna pattern, namely:
a. geometric configuration (linear, circular, rectangular, spherical, etc.)
b. relative displacement between elements
c. the excitation amplitude of each element
d. the excitation phase of each element
e. relative pattern of each element
There are several kinds of antenna array configurations, including linear, planar, and circular.

II.2. Channel Strip [9]

The electric and magnetic field configurations for the strip line are shown in Figure II.2a. The electric field emerges from the strip and ends in both ground planes, while the rotating magnetic field forms a loop around the strip. This magnetic field is always perpendicular to the electric field. The fundamental mode that propagates on the stripe channel is the TEM mode. Figure II.2b is the capacitance model of the strip line. An example of an implementation of a strip channel is a filter.

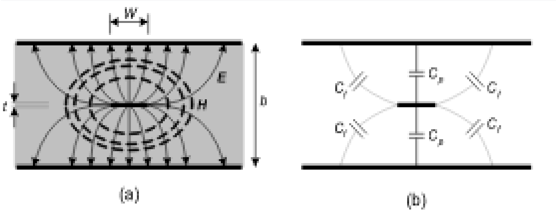


Figure II.2 Field Configuration and Capacitance Model on Strip Channel

II.3.. Microstrip Line [9]

Figure II.3 shows the electric field pattern on the microstrip line. Unlike the strip channel, the microstrip channel consists of a strip conductor (line) and a ground plane conductor separated by a dielectric medium with a dielectric constant r. Above the strip is air so that if without shieding, some of the electromagnetic field will radiate to the air and some of it will re-enter the dielectric substrate or what is called the fringing effect.

There are two dielectrics that cover the microstrip channel, namely the dielectric with air material (εr = 1) and the substrate that has a dielectric εr> 1.Thus, this microstrip channel as a whole can be seen as a channel with a homogeneous dielectric of 1 <εeff <εr. This dielectric constant is called the effective dielectric constant. An example of an implementation of a strip line is an antenna.

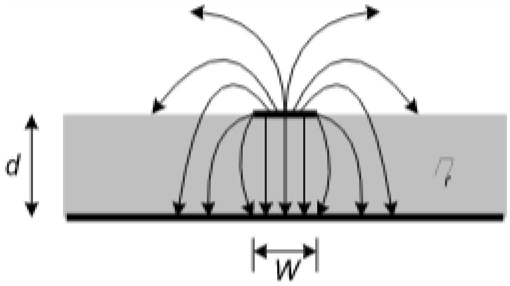


Figure II.3 Electric Field Pattern in Microstrip Line

The εeff equation is as follows:

ε_{reff} = + W/h≤1 ……………………………………..(2.1)
ε_{reff} = + W/h ≥ 1...(2.2)

II.4. Antenna General Parameters [7]

To describe the performance of an antenna, it is very important to understand the general parameters of the antenna, namely:

a.Bandwidth

Bandwidth is the working range of the frequency which is limited by a certain VSWR.

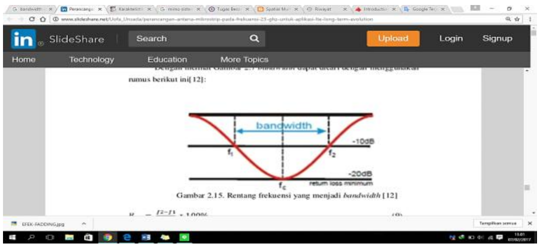


Figure 2.4 Bandwidth

b. VSWR (Voltage Standing Wave Ratio)

It is the ratio between the maximum standing wave amplitude (| Vmax |) and the minimum (| Vmin |). On the transmission line there are two components of the voltage wave, namely the transmitted voltage (V0 +) and the reflected voltage (V0-).
The formula for finding VSWR is:

VSWR = = ...(2.3)

The best condition is when the VSWR is 1 (S = 1) which means there is no reflection when the channels are perfectly matched. However, in reality this value is difficult to obtain, so the basic VSWR value used in antennas is generally ≤ 2.

c. Return loss

Is a parameter that shows how much power is lost to free space. This return loss can occur due to discontinuity of the transmission line with the load input impedance (antenna). The return loss equation is:

Return loss = 20 log | Γ | ....(2.4)

d. Gain (Gain)

The gain (G) on a microstrip antenna is the ratio of the radiation intensity in a certain direction to the received radiation intensity if the power received comes from an isotropic antenna. Gain is formulated:
Gain =
= 4π .... (2.5)
Or:
Gain = Gain 1 antenna element + 10 log (n) .... (2.6)

Information:
n = Number of antenna elements

e. Directivity

Is the ratio between the maximum power density in the main beam to the average power density radiated.

f. Radiation Pattern

The radiation pattern can be defined as a description of the emission or reception of an antenna's signal in a function of angle. This can be likened to when we see a street lamp from a distance, the light will form a certain pattern.

The general shape of the antenna radiation pattern can be seen in Figure II.5, where Figure (a) shows the shape of the antenna radiation pattern in polar coordinates (angle). Whereas in figure (b) it shows the shape of the radiation pattern in Cartesian Coordinates. From Figure II.5a it can be seen that the radiation pattern consists of the Main Lobe or Main Beam in the area perpendicular to the antenna. This perpendicular to the antenna (00) shows the beam direction or maximum reception direction of the antenna. While Minor Lobe is another lobe besides Main Lobe. The beam width from the antenna is called the Beam Width or Half Power Beam Width (HPBW), which is the width of the angle at half the maximum power that the antenna can transmit or receive.

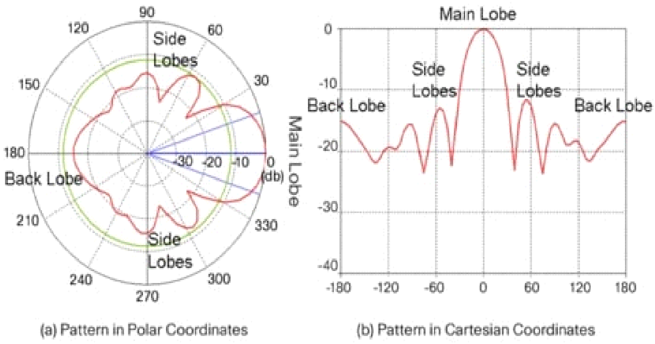


Figure II.5 Antenna Radiation Pattern

II.5. Patch Dimensions [7]

The Fringing Effect causes the dimensions of the microstrip antenna's electromagnetic field to appear larger than its physical appearance.

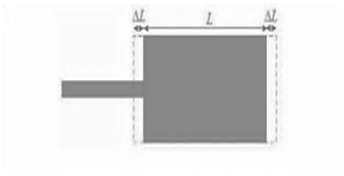


Figure II.6 Effective Length of Antenna

It can be seen from Figure II.6, the length of the microstrip antenna increases by 2 L [7]:
With:
=0.412.....(2.7)
The patch length is determined by the equation:

L = - 2ΔL..................(2.8)

The patch width is determined by the equation:

W = ...(2.9)

The groundplane size is the same as the substart, namely:

Lg ≥ 6h + L............................(2.10)
Wg ≥ 6h + W.......................... (2.11

II.6.Microstrip Line Feeding Technique [7]

There are 2 kinds of feeding techniques, namely the contact method and the non-contact method. In the contact method, the RF power is applied directly to the radiator patch using a connecting element. In the non-contact method, electromagnetic field coupling is carried out to distribute power to the microstrip channel antenna with a patch. Some feeding techniques that are often used are microstrip line, coaxial probe, aperture coupling and proximity coupling.

The microstrip line technique is a feed which is done by connecting the antenna port and the patch using the supply line, where the patch and supply line use the same material. The use of this technique must pay attention to the match between the load line impedances in an effort to maximize power transfer. This Microstrip Line feeding technique was chosen in the final project design because of the ease in fabrication and design.

For design purposes, if the characteristic impedance Z0 and the dielectric constant are known, the strip width can be found by equation [7]:

= ……………………………………………(2.12)
With
A = + ...(2.13)
B = ...(2.14)
Here is the equation for channel length (Lf)

...............................(2.15)

The value of ε_reff, follows equations 2.1 and 2.2.

II.7. Distance Between Elements

The distance between elements in the design of the microstrip array antenna needs to be adjusted so that the elements that are close together do not overlap each other. If the distance between elements is too close or smaller than twice the thickness of the substrate, there is a concern that electromagnetically coupled will occur. Conversely, if the distance between elements is too far, there will be a lot of losses and the use of substrate dimensions will be less efficient. For this reason, the optimum distance between elements is regulated so as not to reduce antenna performance. The distance between elements is measured from the point of one element to another adjacent element. The following is the distance between the elements used:

d = λ / 4 .... (2.16)

III. Implementation Methodology

III.1. Antenna Dimensions Calculation

1. Dimensions of Patch Antenna

In designing this antenna, prior to the simulation, first calculate the dimensions of the patch, microstrip line and groundplane using mathematical equations.

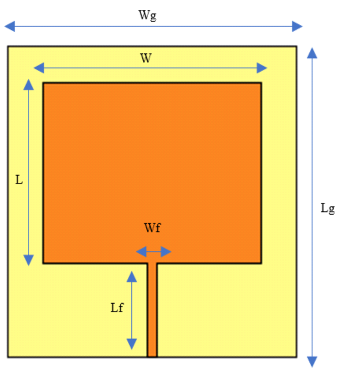


Figure III.1 Dimensions of Microstrip Antenna

Calculation of the patch width (W) with equation 2.9
W =
W =
W = 32,602 mm

Patch length calculation (L)
Before calculating the length of the patch (L), the increment of patch length (ΔL) must be calculated first using equation 2.7.

= 0.412

εreff is the effective dielectric constant calculated using equation 2.2.
ε_{reff} = +

ε_{reff} = +
ε_{reff} = ,048
Substitute equations for 2.2 and 2.7, to get the value ΔL.
=0.412
ΔL = 0.7952 mm
The patch length (L) is calculated by equation 2.8.
L = - 2ΔL
L = – 2 x 0.7952
L = 25,035 mm

2. Microstrip Line Channel Dimensions
The dimensions of the microstrip line can be determined by equation 2.12 as follows: 50 Ω Microstrip Feed Line Calculation;
Z0: 50 Ohm (load impedance)
Wf1 =
Where A = + ; Z0 : 50 Ohm (load impedansi)
= +
A = 1,529, so that
Wf1 =
Wf 1= 3,06 mm
The length of the main supply line can be determined using a λg / 4 transformer. With the following equation:

1.The wavelength in the dielectric medium

ε_{reff} = +
= +
ε_{reff} = 3,33
λg =
λg =
λg = 58,713 mm

where = wave length
=
=
λo = 107,142 mm
2.Transformer Channel Length λg/4
Lf 1= λg
Lf1 = 14,678 mm
• 100 Ω Microstrip Feed Line
. Calculation of Micro-stripping Supply
100 Ω

To design a 2-element linear array, a channel that can provide a characteristic impedance of 50 Ω is required. Thus, a T-Junction channel with a value of 100 Ω is given. In designing 2 antenna elements, 2 microstrip channels are used which have an impedance of 50 Ω and 100 Ω. Calculation of the length and feed line uses the same method as before. Based on the calculations, the channel width (Wf2) is 100 Ω with a value of 0.7088 mm and length (Lf2) with a value of 15.34 mm.

• 70.7 Ω Microstrip Feed Line Calculation

In designing a 2-element linear array, a channel is needed for the T-shaped array, called a parallel feed, with 2 50 Ω and 100 Ω microstrip channels. To calculate the channel width and length, it is done in the same way as the 50 Ω supply line, referring to equations 2.12 to 2.15. The Zo value is adjusted to the desired impedance, which is 70.7 Ω. Based on the calculation, the channel width (Wf3) is 70.7 Ω with 1.6224 mm and the length (Lf3) is 15.034 mm.

3. Groundplane calculation

The width and length of the ground plane are calculated through the following calculations:

1 element groundplane length:

Lg1 = 3h + L + Lf
= 3 (1,6) + 25,035 + 14,678
Lg1 = 44,513 mm

1 element groundplane width:

Wg1 = 6h + W
= 6 (1,6) + 32,602
Wg1 = 42,202 mm

8 element groundplane length:

L2 = Lo + Wf2 + Lo + Wf
= 5 + 0.7088 + 5 + 3.06
= 13.7688 mm
Lg2 = 6h + 2L + d + L2
= 6 (1.6) + 2 (25,035) + 26.7855 + 13.7688
= 100.22 mm

8 element groundplane width:

Wg2 = 6h + 4W + 3d
= 6 (1,6) + 4 (32,602) + 3 (26,7855)
= 220.36 mm

4. Distance Between Elements

The calculation of the distance between elements is calculated using equation 2.16.

d = 107,142 / 4
= 26.7855 mm

III.2. Antenna Packaging Design

The size of this antenna packaging design follows the length and width of the antenna designed from the CST Studio Suite 2018 simulation. The packaging material for this antenna is acrylic with a thickness of 2 mm. This acrylic design is shown in Figure III.2.

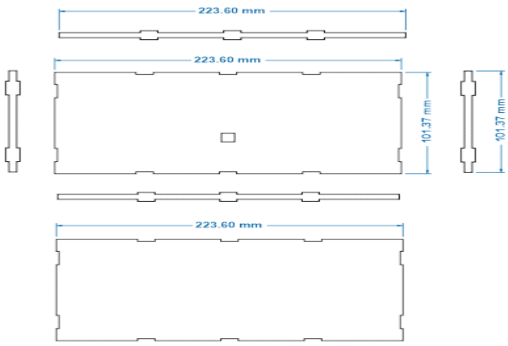


Figure III.2 Antenna Packaging Design

III.2. Antenna Simulation

The software used for this antenna simulation is CST Studio Suite 2018 software. The simulated antenna aims to test the antenna dimensions from the calculation results to produce an antenna that matches the desired specifications. If it is not suitable, then the next step is to optimize the dimensions of the antenna.

III.2.1. One Element Microstrip Antenna Design

1. Design One Element Microstrip Antenna Before Optimization

At this stage a one-element antenna is made to make it easier to design an eight-element antenna. Antenna designed based on table III.1, then the shape of the antenna after being simulated with CST Studio Suite 2018 as in Figure III.3 below.

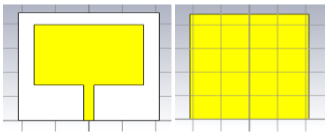


Figure III.3 Antenna Design one elements match the results calculations (before optimization)
(a) front view; (b) rear view

The graph of the design of the one-element antenna according to the calculation results or before optimization:

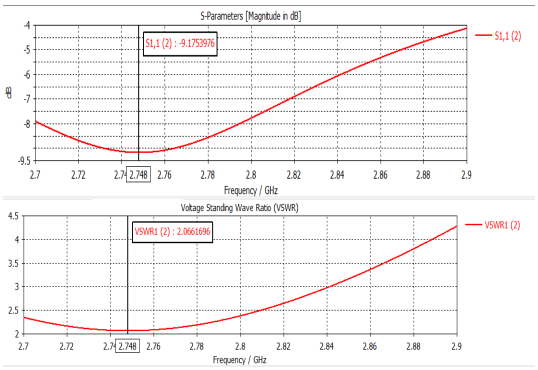


Figure III.4 Graph of Return loss and VSWR of One Element Antenna Design Results Before Optimization

a. Return loss

The return loss of one element antenna is found to be 9.175 dB.
This result is still below the desired limit, namely return loss ≥ 10 dB. So it is necessary to do optimization by changing the dimensions of the antenna.

b. Middle Frequency

The center frequency of this single element antenna is obtained at 2.748 GHz.
This frequency has shifted and it is necessary to optimize it so that the center frequency obtained is in accordance with the specifications, which is 2.8 GHz.

2. Designing One Element Microstrip Antenna After Optimization

Optimization of the antenna design is carried out in order to obtain the expected antenna specifications.

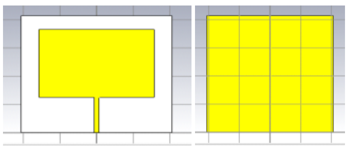


Figure III.5 Microstrip Antenna Design One Element after Optimization
(a) front view; (b) rear view

Table III.1 Dimension Antenna Calculation Results

Parameter	Nilai (mm)	Keterangan
W	32,602	Patch width
L	25,035	Patch length
Wg1	42,202	Element ground plane width
Wg2	220,36	Width 8 plane ground plane
Lg1	44,513	Length 1 element ground plane
Lg2	100,22	Length 8 plane ground plane
Wf1	3,06	Line width (50 Ω)
Lf1	14,678	Long supply line (50 Ω)
Wf2	0,7088	Line width of the feed(100Ω)
Lf2	15,34	Length of feed line (100 Ω)
Wf3	1,6224	Length of feed line (70.7 Ω)
Lf3	15,034	Length of the feeding line (70.7 Ω)
d	26,7855	Distance between elements

Table III.2 Comparison of Dimensions of One Element Microstrip Antennas

Parameters	Before Optimization (mm)	After Optimization (mm)
W	32,602	31,6
L	25,035	24,06
Lf1	14,678	12,5
Wf1	3,06	1,4
Wg1	42,202	41,2
Lg1	44,513	41,36

2. Designing One Element Microstrip Antenna After Optimization
Graph of the results of the design of one element antenna after optimization.

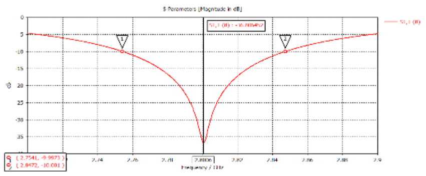


Figure III.6 Graph of Results of Antenna Design Optimization one Element

a. Return loss
The return loss obtained in Figure III.16 after optimization is 36.806 dB. These results are in accordance with the desired specifications, namely return loss ≥ 10 dB.
b. Bandwidth
Bandwidth has not reached the desired and only produces 93.1 Mhz or bandwidth = (2.8472-2.7451) GHz = 93.1 MHz while the desired one is 200 MHz.

c. Middle Frequency
The middle frequency that is obtained after optimization is 2,8006 GHz. These results are in accordance with the desired specifications, namely the 2.8 GHz center frequency. Antenna patch width reduction affects the shift in frequency where the smaller the patch width, the resulting frequency is getting bigger, and vice versa.

d. Voltage Standing Wave Ratio (VSWR)

VWSR obtained after optimization of 1,029. These results are in accordance with the desired specifications, namely VSWR ≤ 2. The VSWR results obtained are shown in Figure III.7.

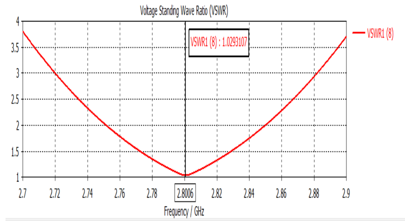


Figure III.7 VSWR Antennas for One Element Optimization

e. Gain

One element microstrip antenna gain with a center frequency of 2,8006 GHz is 2,315 dB. These results have not reached the desired specifications, namely gain ≥ 10 dB. One element antenna gain can be seen in Figure III.8.

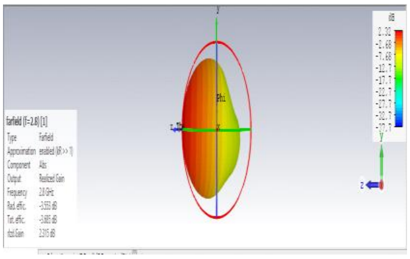


Figure III.8 Gain of One Element Antennas Optimization

f. Radiation Pattern

One antenna element that results from the simulation does not yet have a radiation pattern Graph of the results of the design of one element antenna after optimization.

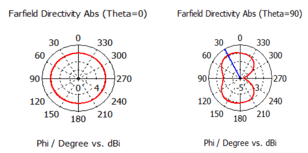


Figure III.9 Antenna radiation pattern 1 Element

(a) E-Plane (b) H-Plane

III.2.2. Design of the Eight Element Microstrip Antenna

After getting one element antenna with retun loss, and the frequency of work in accordance with specifications, the next step is to make an 8 element antenna. It should be noted in the preparation of the 8 element antenna is the distance between elements (d) is very influential on the simulation results.

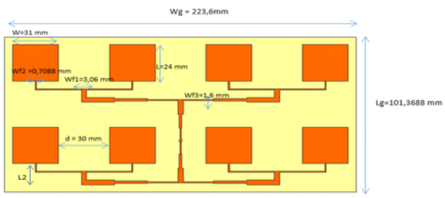


Figure III.10 Antenna Design Eight elements

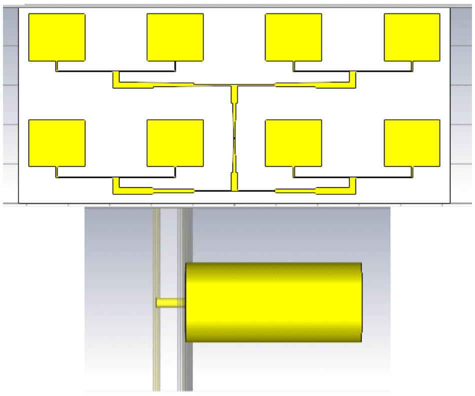


Figure III.11 Microstrip Antenna Designing of Eight elements and SMA connectors with CST Suite Studio 2018 Simulation

III.2.3. Results of Simulation of Eight Elements Microstrip Antenna

1. Return loss

Based on Figure III.12, the return loss value generated at the antenna is 46.333509 dB, where the resulting value meets the specifications.

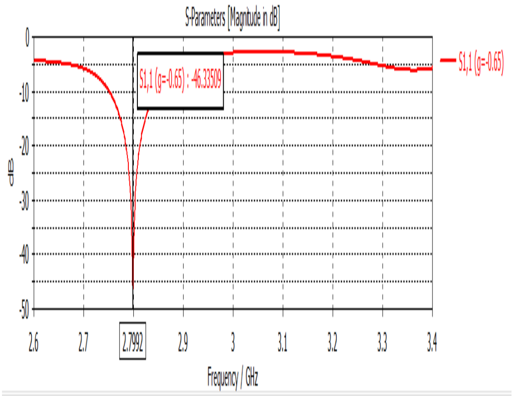


Figure III.12 Return loss Microstrip antenna 8 elements

2. Middle Frequency

The middle frequency obtained is 2.7992 GHz. These results are close to the desired specifications, namely the 2.8 GHz center frequency.

3. VSWR

VSWR of the eight antenna elements has VSWR ≤ 2 which is 1.00, where the resulting value meets the specifications.

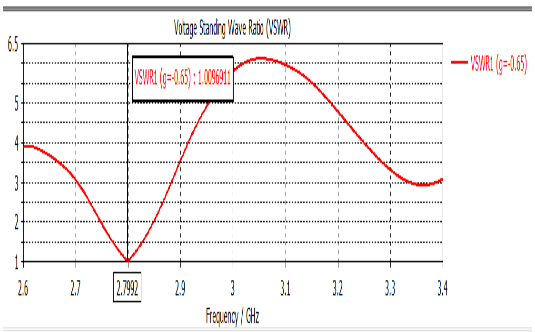


Figure III.13 VSWR Microstrip Antenna Eight elements

4. Bandwidth

Bandwidth has not reached the desired target and only produces 94.6 MHz or f2-f1 = 2845.3 MHz - 2750.7 MHz = 94.6 MHz

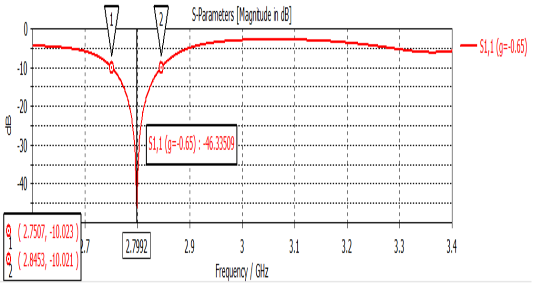


Figure III.14 Bandwidth Antennas of the Eight Elements Microstrip

5. Gain

An eight element microstrip antenna gain with a center frequency of 2.8 Ghz was 9,226 dB. Whereas the desired is ≥ 10 dB.

One element antenna gain can be seen in Figure III.15.

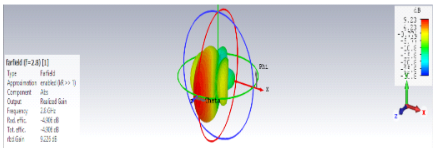
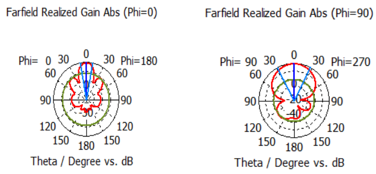


Figure III.15 Frequency Antenna Gain 2.8 GHz

6. Radiation Pattern

The eight simulated antenna elements have a unidirectional radiation pattern. The eight element antenna radiation pattern can be seen in the image below:



(a) E-Plane (b) H-Plane

Figure III.16. 8 Element Antenna Radiation Pattern

Table III.3 Comparison of the dimensions of the eight elements of the microstrip antenna omnidireksional

Parameters	Before Optimization (mm)	After Optimization (mm)
W	32,602	31
L	25,035	24
Lf1	14,678	14,678
Wf1	3,06	3,06
Lf2	15,34	15,34
Wf2	0,7088	0,7088
Lf3	15,034	15,034
Wf3	1,6224	1,6
Wg2	220,36	223,6
Lg2	100,22	101,3688
d	26,7855	30

Table III.4 Comparison of Design and Specification of Antenna 1 Element Design Results

	Specification	**Design Result**
Operating Frequency	2,7 GHz-2,9 GHz	2,7507 GHz – 2,8453 GHz
Middle Frequency	2,8 GHz	2,7992 GHz
Return loss	≥ 10 dB	46,33509 dB
Bandwidth	200 Mhz	94,6 Mhz
VSWR	≤ 2	1,0
Gain	≥ 10 dBi	9,226 dBi
Radiation Pattern	Unidireksional	Unidireksional

Table II.5 Comparison of Design and 8 element antenna

	Specification	**Design Result**
Operating Frequency	2,7 GHz-2,9 GHz	2,7541GHz-2,8472 GHz
Middle Frequency	2,8 GHz	2,8006 GHz
Return loss	≥ 10 dB	36,806 dB
Bandwidth	200 Mhz	93,1 Mhz
VSWR	≤ 2	1,02
Gain	≥ 10 dBi	2,315 dBi
Radiation Pattern	Unidireksional	Omnidireksional

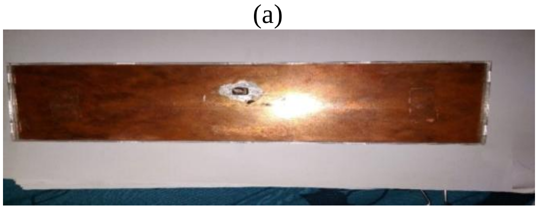
Based on the design data contained in tables II.4 and II.5, the addition of elements to the antenna patch from 1 element to 8 elements using array techniques can increase the gain, bandwidth, and other antenna parameters such as VSWR and return loss to better.

III.3 Realisasi

III.3.1. Realization of PCB

Antennas that have been designed and simulated with CST Suite Studio 2018 are then realized with a predetermined FR-4 material substrate.

(a)

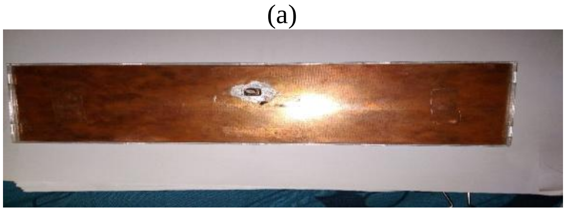


(b)

Figure III.17. Realization of the Eight
Elements Microstri Antenna
(a) Front View (b) Rear View

III.3.2 Antenna Package Realization
The antenna is realized by being equipped with a packaging that has acrylic material with a thickness of 2 mm.

(a)



(b)
Figure III.18. Realization of the Eight
Elements Microstrip Antenna with Casing
(a) Front View (b) Rear View

IV. Results And Discussion

IV.1. Testing
IV.1.1. Tested Parameters
The parameters tested refer to the antenna specifications to be achieved. These parameters include:
1. Middle frequency
2. Working frequency
3. Bandwidth
4. VSWR
5. Gain

IV.1.2. Overview of Testing Situations.
1. Tools Used
Measuring instruments used include the MS46322B Economy Vector Network

IV.2. Measurement Results and Discussion
1. Work Frequency, Return loss, VSWR, and Bandwidth Measurement Results
The following is the result of testing antenna parameters consisting of working frequency, return loss, VSWR, and antenna bandwidth without casing and casing that have been realized. The data file is based on attachment 2 which has been attached.

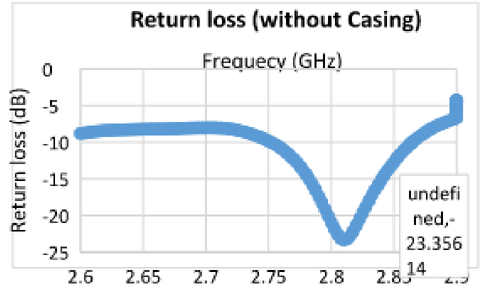


Figure IV.1 Measurement Results ofMicrostrip Antenna Return Loss without Casing

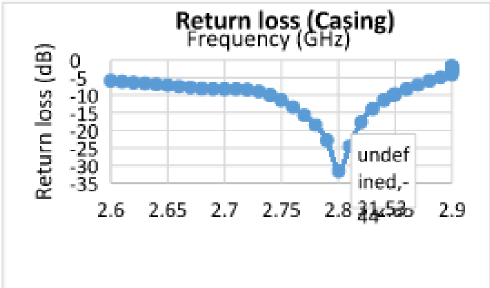


Figure IV.2 Measurement Results of Microstrip Antenna Return Loss with Casing

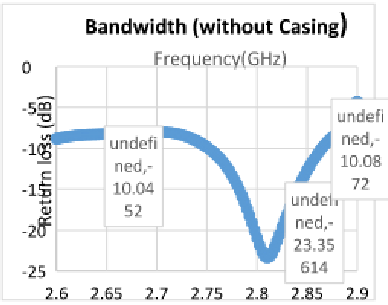


Figure IV.3 Measurement Results of Working Frequency Band and Bandwidth without Casing

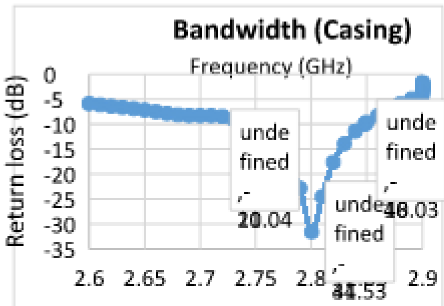


Figure IV.4 Measurement Results of Working Frequency Band and Bandwidth with Casing

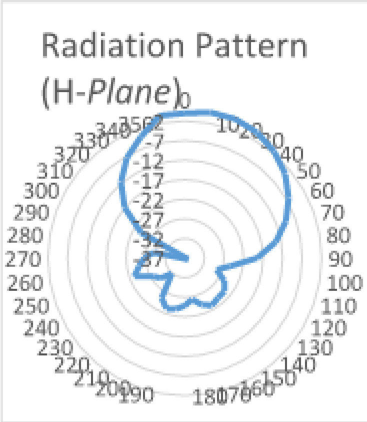


Figure IV.5 H-PlaneRadiation Pattern Without Cassing

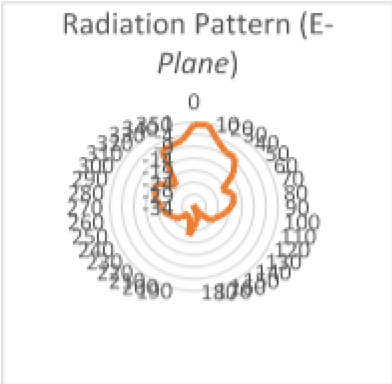


Figure IV.6. E-Plane Radiation Pattern without Casing

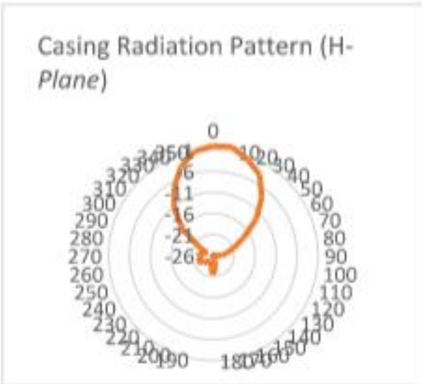


Figure IV.7. Horizontal Radiation Pattern with Casing

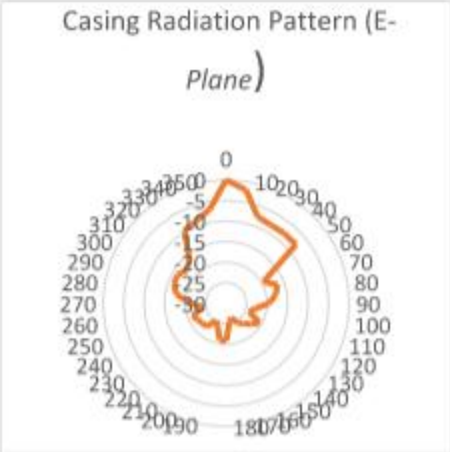


Figure IV. Radiation Pattern (E-Plane) with Casing

Table IV.1 Comparison of Specifications and Test Results

Antenna Parameters	Desired Specifications	Test Results (without Casing)	**Test Results (Casing)**
Working Frequency	2,7 GHz-2,9 GHz	2,7525 GHz – 2,8640 GHz	2,7404 GHz - 2,8483 GHz
Working Frequency	2,8 GHz	2,81 GHz	2,8005 GHz
Return loss	≥ 10 dB	23,35614 dB	31,5344 dB
Bandwidth	200 MHz	111,5 MHz	107,9 MHz
VSWR	≤ 2	1,14	1.055

Table IV.2 Comparison of Desired Specifications and Test Results

Antenna Parameters	**Desired Specifications**	**Test Results (*without Casing*)**	**Test Result (*With Casing*)**
Working Frequency	2,7 GHz-2,9 GHz	2,7525 GHz – 2,8640 GHz	2,7404 GHz - 2,8483 GHz
Center Frequency	2,8 GHz	2,81 GHz	2,8005 GHz
Return loss	≥ 10 dB	23,35614 dB	31,5344 dB
Bandwidth	200 Mhz	111,5 MHz	107,9 MHz
VSWR	≤ 2	1,14	1,055
Gain	≥ 10 dBi	10,49 dBi	10,19 dBi
Radiation Pattern	Unidireksional	Unidireksional	Unidireksional

V. Conclusion

V.1 Conclusion

Based on the measurement data of the realization of the 2x4 microstrip array antenna, it can be concluded:

1. Realization of 2x4 microstrip antenna has a working frequency of 2.7525 GHz - 2.8640 GHz with a middle frequency of 2.81 GHz. Despite the shift, the frequency has entered the desired specification frequency band of 2.7 GHz to 2.9 GHz.
2. The resulting bandwidth is 111.5 MHz of the desired specification that is 200 MHz.
3. Return loss obtained is 23,35614 dB which is in accordance with the desired specifications, namely return loss ≥ 10 dB and VSWR obtained is 1.14 which is in accordance with the specifications.
4. The resulting gain is 10.49 dBi which is included in the specifications that is gain ≥ 10 dBi. The radiation pattern produced is unidirectional which already meets the desired specifications.
5. The use of the casing on the antenna affects the middle frequency produced by using the casing produces 2,8005 GHz frequency. This value meets the desired specifications. While the gain yields a value of 10.19 dBi or down 0.3 dBi from the antenna gain without the casing. The radiation pattern produced is unidirectional which already meets the desired specifications.
6. Return loss and VSWR with the casing produce better values than without using the casing. The difference is the return loss is 8.1 dB with a difference of 0.09 VSWR.

7. Bandwidth on the casing antenna has a narrower frequency width than without the casing. The difference is 3.6 MHz.
8. The following are some of the factors that affect antenna specifications:
- The discrepancy between the dielectric constant and the size of the FR-4 PCB material in the market with the results of the calculation and antenna simulation.
- Uncluttered soldering when connecting the SMA connector with the antenna.

V.2 Suggestions

In subsequent studies, there are several things you can do to get better antenna performance, namely:
1. The soldering process on the antenna port must be neatly done and really connected to the antenna because it will affect the frequency shift.
2. Before doing the calculation process on the dimensions of the microstrip antenna, you should first make sure that the dielectric constant and FR-4 substrate thickness are available in the market so that the desired specifications can be maximized.

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