

Design Of Modified Microstrip Antenna And 4x1 Microstrip Array For Data Communication At 2.4 GHz Frequency

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Abstract—The use of wireless or wireless communication technology is currently growing rapidly. To establish a wireless communication device, an antenna is needed to send and receive electromagnetic waves or signals during the data transmission process. In this research we undertook simulation, fabrication, parameter and distance testing for data communication at 2.4 GHz frequency. To achieve the above objective, first we made an antenna. The antenna dimensions were designed based on antenna formulas and then simulating with the CST Studio Suite. Second, we fabricated Microstrip antennas senders that could work well in the 2.4 GHz frequency with return loss = -12.06 dB, VSWR = 1.692, impedance = 38.35Ω ohms. While the 4x1 fabricated microstrip array antenna was designed to operate at 2.4 GHz frequency with return loss = -19.41 dB, VSWR = 1.235, impedance = 54.77 ohms. That is, the two microstrip antennas are suitable for use at 2.4 GHz frequency and in accordance with the expected specifications. The test using module Xbee PRO S2C and Xbee S2C. Result showed that communication runs smoothly that is able to send and received data properly..

Keywords—antenna; return loss; impedance, distance

I. INTRODUCTION

The use of wireless or wireless communication technology is currently growing very rapidly. To do wireless communication, an antenna is needed because it functions to send and receive electromagnetic signal waves. In data communication between 2 antennas, an RF (Radio Frequency) module is needed. This data communication test is to determine the distance of the antenna range that is fabricated as a signal amplifier and analyze the telemetry performance system.

Telemetry is a communication system for the transfer of remote measurement data that uses transmission media as a data carrier. In other words, it can be said that telemetry is an automatic communication process that is used to measure and retrieve data at a location that is far away to be transmitted to the data processing center [1]. Telemetry sistem influence by antenna wehere proper antenna selection, good design and correct installation will guarantee the performance of the system. The problem that often occurs is that the transceiver antenna cannot work optimally for a considerable distance.

In this study is designed, simulation, fabrication, antenna parameter testing using VNA (Vector Network Analyzer) and

antenna range test. Single patch microstrip antennas that are modified to obtain omnidirectional radiation patterns are recommended as sending antennas because they are easy to manufacture, inexpensive, small and light dimensions so that they are suitable to be applied on a moving device [2]. While yagi antennas and 4x1 microstrip array antennas (have more patches) are chosen as the receiving antenna for comparison because they are equally directional, which means the direction of the beam is focused in one direction and tends to have a large gain compared to omnidirectional so that it can receive signals with a sufficient distance range in a loss condition (without obstruction) if it is focused on the sending antenna.

In the previous research conducted by Alam, et al [3], in his journal entitled "Rancang Bangun Antenna Mikrostrip Peripheral Slits Linear Array Untuk Aplikasi Wi-Fi (Building Design of Peripheral Microstrip Antenna Linear Array for Wi-Fi Applications)". The measurement results of the composition of the four elements of peripheral slits obtained a bandwidth of 150 MHz (2.424 GHz-2.574 GHz) with a percentage of bandwidth of 6.12%. Measurement results at the middle frequency of 2.448 GHz obtained a return loss of -16.88 dB with a VSWR of 1.304.

Pasaribu, et al [4] on his journal entitled "Rancang Bangun Antena Mikrostrip Patch Segiempat Pada Frekuensi 2, 4 Ghz Dengan Metode Pencatutan Inset (Design of Patch Rectangular Microstrip Antenna at Frequency of 2, 4 Ghz with the Inset Imaging Method)". Based on the results of the antenna bandwidth obtained at 112 MHz (2.388 - 2.5 GHz) in VSWR ≤ 2. At the middle frequency of the antenna (2.45 GHz) obtained return loss of -14.77 dB, VSWR of 1.45, radiation pattern unidirectional, and gain 6 dBi .

Joni, et al [5] entitled "Pengujian Jarak dan Waktu Gabung Protokol IEEE 802.15. 4 / ZigBee di Lingkungan Indoor (Protocol IEEE 802.15. 4 / ZigBee Distance Test and Join Time in the Indoor Environmen)." The results showed that the pairing method can be done long distances to the outside of the building with a distance of about 65 meters, while the distance using the On / Off method can reach several rooms in the indoor area. The longest time to join takes about 1 minute 15 seconds .

According to Qun, Deng Et al [9]. “Design and simulation of the microstrip antenna for 2,4 Ghz HM remote control system”, showed that antenna model simulated in ADS and obtained the requirement parameter through optimizing and matching.

II. THEORY

A. Microstrip Antenna

Based on the origin of the word, microstrip consists of two words, namely micro (very thin / small) and strip (slats / pieces). Microstrip antennas can be defined as one type of antenna that has a shape like a blade or a piece that has a very thin or small size[2].

B. Dimensions of the Microrip antenna

In designing a microstrip antenna using CST Studio Suite 2016 software, the antenna dimensions are determined in advance based on the calculation of the antenna formula. The frequency and specifications of the material to be used are the main factors in the calculation of antenna dimensions.

The basic structure of a microstrip antenna consists of a radiating element or commonly called an conducting patch, substrate element (dielectric substrate), and grounding element. The size of the irradiation or patch element is obtained from the following equation [2]:

Patch width (W) can be calculated by the equation [2] :

$$W = \frac{C}{2f_0 \sqrt{\frac{\epsilon_r + 1}{2}}} \tag{1}$$

W= patch wide (mm)

c = Light speed (3 x [10] ^8 m/s)

f_0 = Resonance Frekuensi (Hz)

ε_r = permittivity / constant dielectric

Whereas Patch Length (L) can be calculated by the equation [2] :

$$L = \frac{C}{2f_0 \sqrt{\frac{\epsilon_r + 1}{2}}} \tag{2}$$

Where is the effective length obtained from the equation:

$$L_{eff} = \frac{c}{2f_0 \sqrt{\epsilon_{r_{eff}}}} \tag{3}$$

In calculating L_{eff} it must be known $\epsilon_{r_{eff}}$ For $\epsilon_{r_{eff}}$ can be calculated by the equation[2] :

$$\epsilon_{r_{eff}} = \frac{\epsilon_r + 1}{2} + \left(\frac{\epsilon_r - 1}{2} \times \frac{1}{\sqrt{1 + \left(\frac{12h}{W}\right)^2}} \right) \tag{4}$$

And for increasing length (ΔL) can be calculated by the equation [2] :

$$\Delta L = 0,412 \cdot h \cdot \frac{\left(\frac{\epsilon_{r_{eff}} + 0,3}{\epsilon_{r_{eff}} - 0,258}\right) \left(\frac{W}{h} + 0,264\right)}{\left(\frac{W}{h} + 0,8\right)} \tag{5}$$

Next look for the dimensions of the feeder (transmission line). Feeder width (Wf) can be calculated by the equation [6]:

$$B = \frac{60\pi Z_0}{Z \sqrt{\epsilon_r}} \tag{6}$$

$$Wf = \frac{2h}{\pi} \left\{ (B - 1 - \ln(2B - 1)) \right\} + \frac{\epsilon_r - 1}{2\epsilon_r} \left\{ (\ln B - 1) + 0,39 - \frac{0,61}{\epsilon_r} \right\} \tag{7}$$

While the length of the feeder (Lf) can be written with the equation [6]:

$$\Delta g = \frac{\lambda}{\sqrt{\epsilon_{r_{eff}}}} \tag{8}$$

$$Ls = \frac{1}{4} \lambda \tag{9}$$

Next look for groundplane dimensions. The groundplane on the microstrip antenna serves to separate the dielectric substrate from other objects that can interfere with signal radiation.

Groundplane Width Dimensions (Wg) can be calculated by the equation [7] :

$$Wg = 6h + W \tag{10}$$

As for the groundplane length (Lg) can be calculated by the equation:

$$Lg = 6h + L \tag{11}$$

The distance between the elements on this antenna is $\lambda / 2$ with a constan [2]

$$\lambda = \frac{c}{f} \tag{12}$$

Required specifications

TABLE I. MATERIAL ANTENNA SPECIFICATION

Copper	Spesification	
	Relative Permittivity (ϵ_r)	Thickness
Copper	1	0,035 mm
FR4 Epoxy (substrate)	4,3	1,6 mm

TABLE II. ANTENNA SPECIFICATION PARAMETER

Parameter	Value
Frequenzy	2,4 GHz
Strenght	< -10 db
Return Loss	< 2
VSWR	50 Ohm

Table II Material that used to make antenna with required parameter at Table II.

C. Techniques For Microstrip Antenna Recording

The feed technique used is the Microstrip line feed technique. This technique is one popular, simple and easily fabricated technique is a line feed technique, but this technique results in a bandwidth that is not wide and the gain is not so large [8].

III. RESEARCH METHODS

A. Flowchart

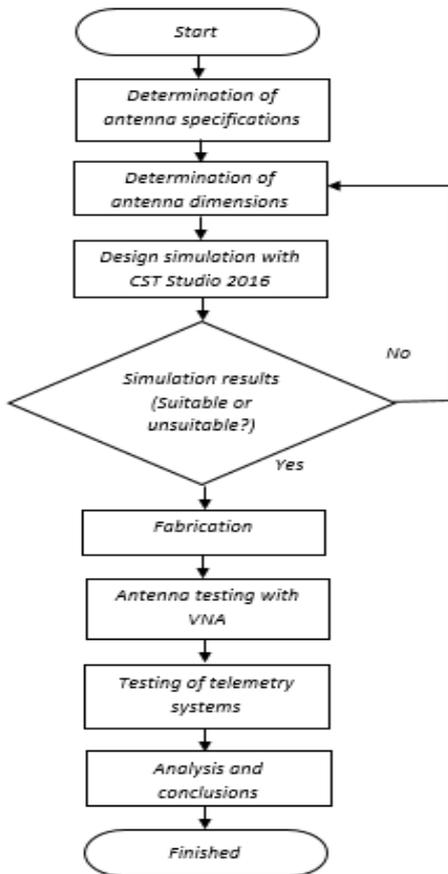


Fig. 1. Flowchart

The initial stage of the research is to study literature about the antenna to be made. Determine the required material specifications and antenna parameters and the dimensions of the antenna based on the antenna formula. Then design by entering the dimensions and simulating the CST Studio Suite 2016.

software simulation results in the form of antenna parameters that affect the performance of the antenna (Fig 1). The parameters taken as a reference here are the matching parameters, namely VSWR, Return Loss and impedance. If the simulation results are not in accordance with the expected antenna specifications, it is necessary to optimize the simulation by changing the antenna dimensions slightly and modifying the shape. If the simulation results are appropriate, then fabricated and tested for feasibility with a VNA device. After this stage, direct distance testing or telemetry system implementation is carried out.

B. Telemetry System Block Systems

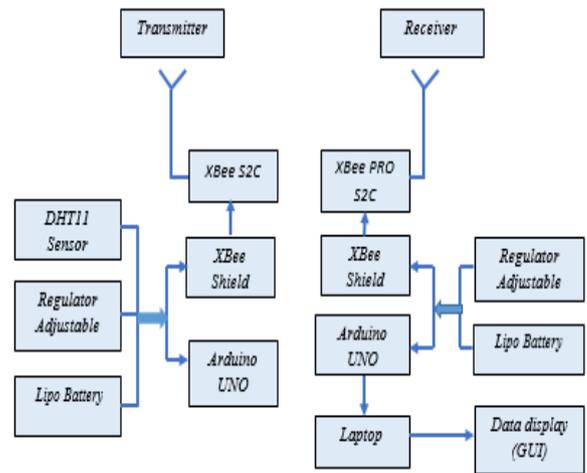


Fig. 2. Telemetry System Block Diagram

The working principle of this telemetry system is sending data in the form of temperature using a DHT11 sensor, then processing the data by Arduino. In this telemetry system lipo batteries are used as a voltage source and adjustable regulator as a voltage regulator / stabilizer. The transmitter and receiver modules used are Xbee modules that work on the 2.4 GHz frequency. Modified microstrip antennas are used as sending antennas, while receiver antennas are used microstrip array antennas installed in GCS (Ground Control Station) and connected to laptops. The test can determine the maximum range of the antenna can send or receive signals

IV. RESULT AND DISCUSSION

A. Sender Microstrip Antenna

The designed sender microstrip antenna is expected to have an omnidirectional radiation pattern. Therefore, at least 2 substrates must be needed, namely FR4 Epoxy double layer and single layer. The patch model that is designed is rectangular then modified by adding parasitic and adjusting the antenna dimensions.

The following is an optimized table of antenna dimension calculation.

TABLE III. OPTIMIZED SENDER MICROSTRIP DIMENSIONS

Antenna Dimension	Value (mm)
Patch Width (W)	40
Patch Length (L)	34
Gpf	0,2
patch feeder width (Wf)	1,404
patch feeder length(Lf)	15
Patch radius	8
Substrate width (Ws)	47
substrat length (Ls)	80
ground width (Wg)	22
ground length (Lg)	40
feeder ground width (Wfg)	3,038
feeder ground length (Lfg)	40
Slot radius	12

1) Simulation Test

Antenna works well at a frequency of 2.4 GHz with return loss = -33.45 dB, VSWR = 1.043, impedance = 50 ohm, gain = 2.207 dB. This antenna is expected to have an omnidirectional radiation pattern (emission in all directions) because it will be applied as a sending antenna, but the simulation results of this antenna are still bidirectional radiation pattern (two-way beam). The parameter simulation results are shown in Fig 3,4,5,6.

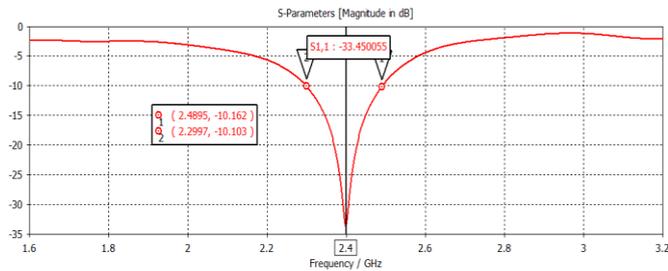


Fig. 3. Return Loss Simulation Results of Sender Microstrip Antenna

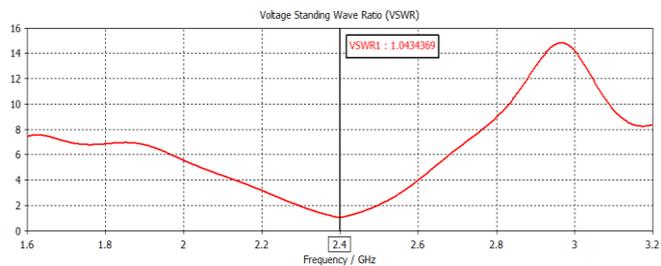


Fig. 4. VSWR Simulation Results of Sender Microstrip Antenna

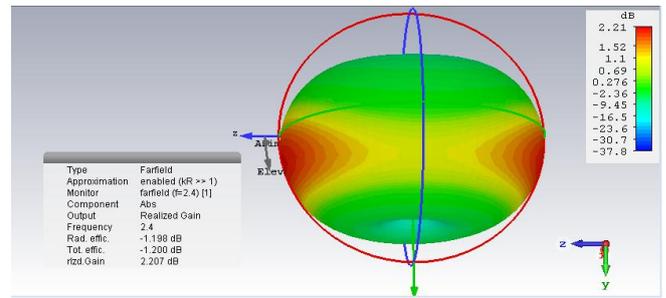


Fig. 5. Gain Simulation Results of Sender Microstrip Antenna

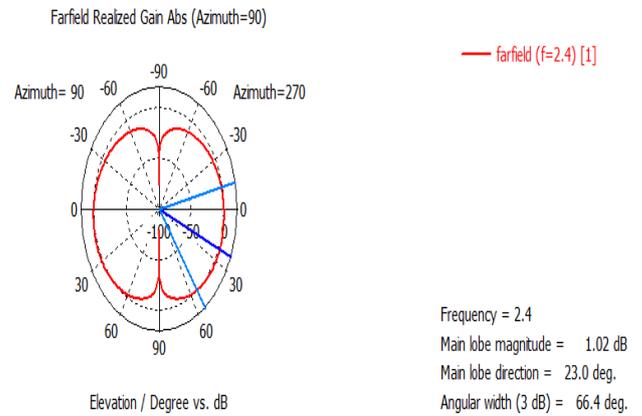


Fig. 6. Results of Simulation of Sender Microstrip Antenna Radiation Pattern

2) Fabrication results of Sender Microstrip Antenna

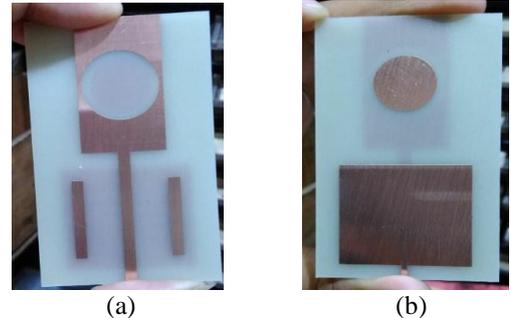


Fig. 7. (a) Sending Microstrip antenna front and rear with 2 substrates(b) Sending Microstrip Antenna patch parts

3) Sending Microstrip Antenna patch parts

The fabricated sender microstrip antenna is able to work at 2.4 GHz frequency with return loss = -12.06 dB, VSWR = 1.692, impedance = 38.35 Ω □ 24.70. This means that the antenna that is fabricated is in accordance with the expected specifications. But for impedance does not match the cable impedance used is the RG58 50 Ω coaxial cable. Bandwidth or working area of this antenna is 282 MHz between the frequency of 2,298 GHz - 2,580 GHz. Test results with VNA are shown in Fig 8,9,10.

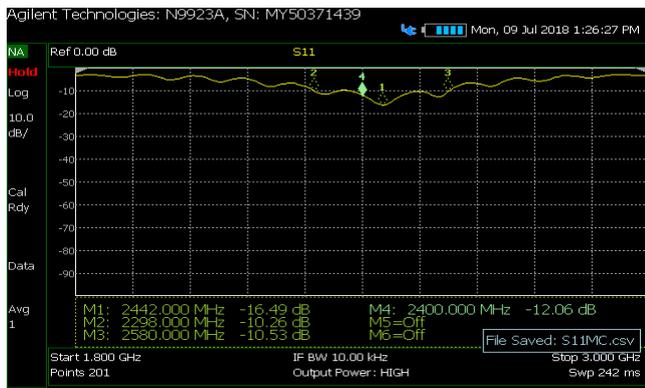


Fig. 8. Results of Return Loss Testing with VNA in Sender Microstrip Antenna



Fig. 9. Results of VSWR Testing with VNA in Sender Microstrip Antenna

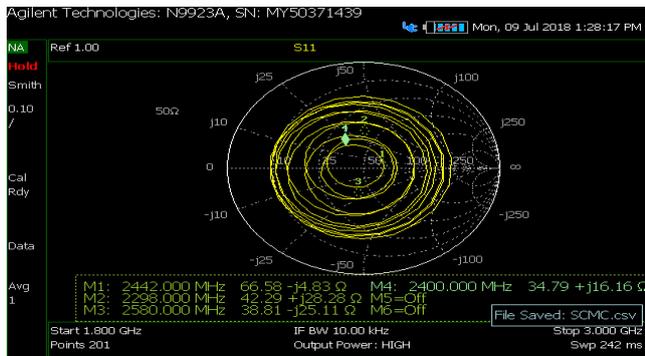


Fig. 10. Results of Impedance Testing with VNA in Sender Microstrip Antenna

B. 4x1 Array Microstrip Antenna

The designed 4x1 microstrip array antenna is applied to the receiver side in GCS (Ground Control Station) and is expected to have unidirectional radiation patterns.

The following is a table resulting from the calculation of the antenna dimensions that have been optimized.

TABLE IV. DIMENSIONS OF ARRAY ANTENNAS THAT HAVE BEEN OPTIMIZED

Antenna Dimension	Value (mm)
Patch Length (L)	38
Lebar Width (W)	29
Inset Length (Li)	8,85

Antenna Dimension	Value (mm)
Inset Width (Gpf)	1
Feeder Width (Wf) 50 Ω	3,137
Feeder Width (Wf) 70 Ω	1,677
Substrat Length & Ground (Lsg)	315
Substrat Width & Ground (Wsg)	80,51
Distance Patch 1&2	35
Distance Patch 2&3	62,5
Distance Patch 3&4	35

1) Simulation Testing

Antenna works at 2.4 GHz frequency with return loss of -50.44 dB, VSWR of 1.035, impedance of 49 ohms, and gain of 6.362 dB and has a directional radiation pattern. The parameter simulation results are shown in Fig 11,12,13,14.

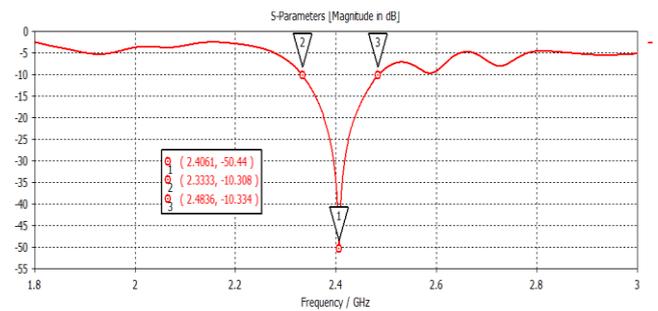


Fig. 11. Return Loss Simulation Results of 4x1 Array Microstrip Antenna

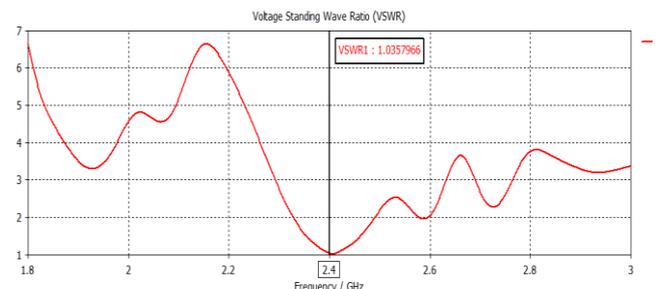


Fig. 12. VSWR Simulation Results of 4x1 Array Microstrip Antenna

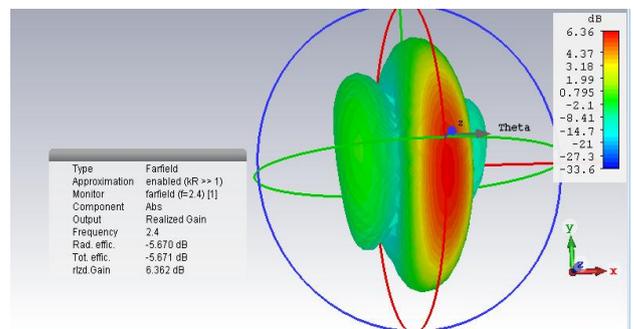


Fig. 13. Gain Simulation Results of 4x1 Array Microstrip Antenna

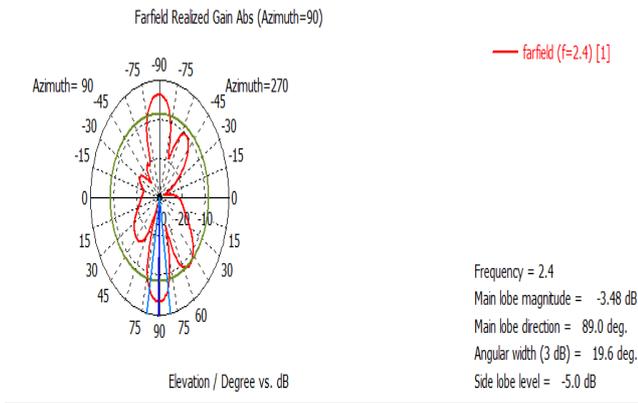


Fig. 14. . Results of Simulation of 4x1 Array Microstrip Antenna Radiation Patterns

2) Fabrication Results Of 4x1 Array Microstrip

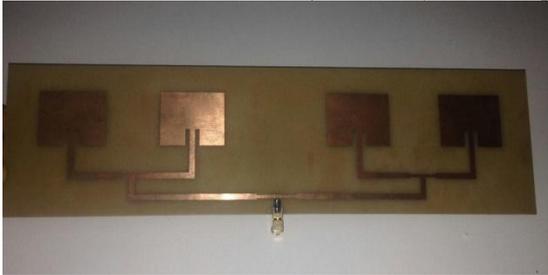


Fig. 15. 4x1 Array Microstrip Antenna Patch

Fig 15, showed result of 4x1 array microstrip antenna using two layers circuit board.

3) Testing with VNA

The 4x1 fabricated microstrip array antenna is able to work at 2.4 GHz with return loss = -19.41 dB, VSWR = 1.235, impedance = $54.77 \square \square 10,750$. This means that the antenna that is fabricated is in accordance with the expected specifications. For its impedance it almost matches the impedance of the RG58 50 \square coaxial cable.

Bandwidth of 90 MHz between the frequency of 2.328 GHz - 2.418 GHz. Test results with VNA are shown in the following Fig 16-18.



Fig. 16. . Results of Return Loss Testing with VNA in 4x1 Array Microstrip Antenna

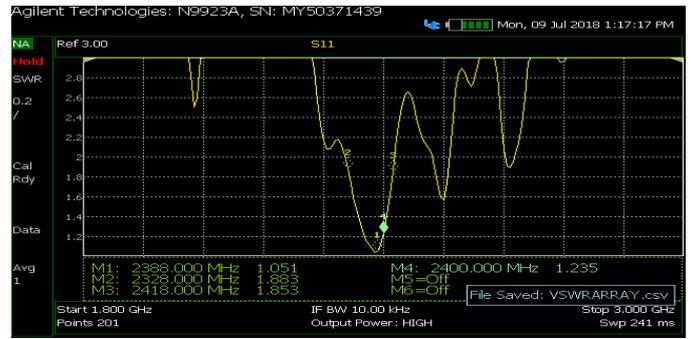


Fig. 17. Results of VSWR Testing with VNA in 4x1 Array Microstrip Antenna

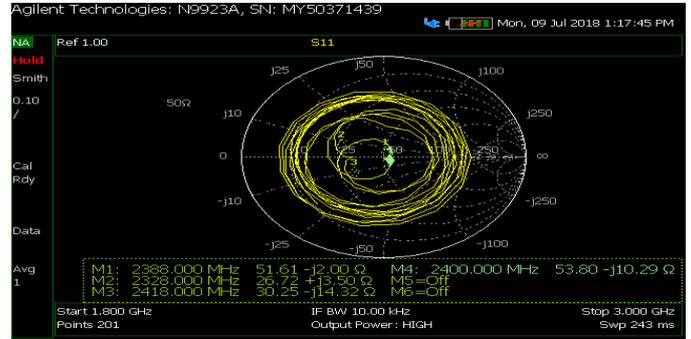


Fig. 18. Results of Impedance Testing with VNA in 4x1 Array Microstrip Antenna

V. CONCLUSION

This research obtained to designed, simulation, fabrication, antenna parameter testing using VNA (Vector Network Analyzer). The conclusions that can be taken from this research are:

1. From simulation showed the sending microstrip antenna that is manufactured according to the expected specifications. the antenna is able to work at a frequency of 2.4 GHz with return loss = -12.06 db, VSWR = 1.692, impedance = 38.35 ohms. It is as desired that antenna work at 2,4 GHz frequency.
2. Design of 4x1 array microstrip antenna fabricated is also in accordance with the expected specifications. From simulaton showed that antenna is able to work well at a frequency of 2.4 GHz with return loss = -19.41 db, VSWR = 1.235, impedance = 54.77 ohms.
3. Data communication testing in sending and receiving data has been successfully carried out on both antennas that have the same frequency of 2.4 GHz, where as sender was microstrip antenna and 4x1 array microstrip as received antenna.

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