Available *online* at : http://jnte.ft.unand.ac.id/

Jurnal Nasional Teknik Elektro

| ISSN (Print) 2302-2949 | ISSN (Online) 2407-7267 |

Microstrip Rectangular Patch Array Antenna for Tsunami Radar

Fitrilina [1], Junas Haidi [1], Alex Surapati [1], Hendy Santosa [1], Firdaus[2], Rudy Fernandez[3]

[1] *Electrical Engineering Department, Faculty of Engineering, University of Bengkulu, Indonesia*
[2] *Electrical Engineering Department, Politeknik Negeri Padang, Indonesia*
[3]*Electrical Engineering Department, Faculty of Engineering, University of Andalas, Indonesia*

ARTICLE INFORMATION

Received: April 28, 22
Revised: July 30, 22
Available online: July 31, 22

KEYWORDS

Microstrip Antenna, Rectangular Patch, Tsunami Radar

CORRESPONDENCE

Phone: +62 85263777076

E-mail: fitrilina@unib.ac.id

ABSTRACT

Tsunami radar is one of the detection tools used in the tsunami early warning system. The most commonly used is high-frequency radar with a long-range but high power and low resolution. However, in order to improve the reliability of the tsunami warning system in detecting signs of a tsunami and monitoring with a high speed of updating information, a radar system with a high resolution is needed. High resolution can only be obtained by a radar that has a large bandwidth in the radio spectrum. Increasing the bandwidth can be done by increasing radar operating frequency. An antenna is one of the essential components that can determine the performance of the radar system. Therefore, in this study, an antenna was designed at Super High Frequency to be applied to a radar system. The designed antenna is a microstrip antenna with a rectangular patch using array method. The desired specifications at a frequency of 5.8 GHz are return loss ≤-10 dB, VSWR ≤2, bandwidth >150 Mhz, beamwidth $>20^0$. After the simulated design met the specifications, the fabrication and measurements were later carried out. The measurement results show a frequency shift to 5,71 GHz with a return loss of -21,346, VSWR of 1,186, bandwidth of 200 MHz, a beamwidth of 40^o and gain 11.65 dB. Thus, the proposed antenna, the 8-rectangular patch microstrip array antenna, can be applied in tsunami radar systems.

INTRODUCTION

A tsunami is a series of giant ocean waves caused by an earthquake, submarine, landslide, volcanic eruption under the sea, meteorite impact, or combination [1]. Indonesia is one of the countries prone to this natural disaster. There were 106 tsunamis between 1900 and 1999 and 28 tsunamis between 2000 and 2018 [2]. Based on the casualties, there were seven tsunamis in Indonesia that resulted in more than 1000 fatalities, including the one in Aceh in 2004 with 227,898 fatalities, the Banten tsunami in 1883 with 36,000 fatalities, the Flores tsunami in 1992 with 2,500 fatalities, and the Banda Islands tsunami in 1883 with 2,460 victims people, the Banda Islands tsunami in 1664 with 2,243 fatalities, the Palu-Sigi-Donggala tsunami in 2018 with 2,037 fatalities, and the Bali Island tsunami in 1815 with 1,200 fatalities. [2] When and where a tsunami takes place is still unpredictable. Thus, the development of technology for tsunami detection continues to be developed. The development of tsunami technology includes measuring current velocity, pressure, surface differences, satellites and radar.

Radar, an acronym for radio detection and ranging, detects objects of interest by transmitting radio signals in known directions from a narrow-beam antenna or scanner which scans the horizon, then timing the instants of reception of returned echoes from these 'targets"[3]. Radar detect objects by firing pulses or waves, and the radar antenna will transmit a signal. If the signal is blocked by an object, the signal will be reflected back to the receiver radar. The signal received by the radar receiving antenna will be processed by the radar system to get information regarding the obstacle object.

The pulse radar at high frequency (HF) is a widely used tsunami radar today due to its long range, up to 200 km. However, the weakness is that it uses a large amount of power and a low resolution[4]. The ability to recognize signs of a tsunami from a long distance is needed to get sufficient time to give a warning. An HF tsunami radar capable of observing surface sea current velocity at a distance of 50 to 200km will be able to provide a warning time of 30 minutes to 2 hours [5]. The use of HF radar technology is always a trade-off between accuracy in measuring surface sea current velocity and coverage, which simultaneously depends on the working frequency, transmit power, antenna gain, water salinity and sea conditions [5]. Some of the requirements needed for marine radar in providing information to improve the reliability of a tsunami warning system are: the spatial and temporal resolution of tsunami mapping must be sufficiently high so that it is able to detect signs of a tsunami and the rapid changes in the surface sea current, areas that are potentially affected by a tsunami must be monitored in a fast acquisition mode with a high

https://doi.org/10.25077/jnte.v11n2.1020.2022

speed of updating surface sea current information every 30 seconds [5].

In order to obtain radar resolution and monitoring capability with high information update speed, a large bandwidth is required. Increasing the bandwidth can be done by increasing the working frequency of the radar. Expanding the working frequency of tsunami radar from HF to UHF has been conducted in research [6][7]. Research on radar working at the SHF frequency has also been carried out to obtain high resolution, for example, coastal surveillance radar (CSR) [8]. The frequencies commonly used in radar systems are S band (2-4 GHz), C band (4-8 GHz), X band (8-12 GHz) and Ku band (12-18 GHz) [9]

An antenna is one of the essential devices that will determine the performance of the radar system. if analogous to the human body, the antenna systems as an eye which is very vital [10] . Due to the high price of imported of a radar set, Indonesia is required to develop radar. Tsunami radar generally uses a yagi type of antenna. NJRC HF radar works at a frequency of 24.5 MHz, full bandwidth of 100 Khz, a resolution of 1.5 km, the beamwidth of $\pm 45^{o}$ with the transmitter using 3 yagi elements and the receiver using 9 yagi elements [5]. The Rumena radar uses 8 receiving antenna elements, a frequency of 24.5 Mhz, a full bandwidth of 500 Khz, a resolution of about 300 m and beamforming up to $\pm 43^{o}$ [5]. This research focuses on microstrip antennas to support the development of tsunami radar technology at the SHF frequency. This type of antenna has many advantages over other microwave antennas, including small dimensions, lightweight, relatively inexpensive and often used for antenna applications covering a wide frequency range from 100 MHz to 100 GHz [11]. They can be designed in a variety of shapes in order to obtain enhanced gain and bandwidth. Microstrip Patch Antenna implementations is a mile stone in wireless communication system designs [12]. Most HF radars have a bandwidth of 50 kHz to 150 kHz with a resolution (pixel length) of 3 to 1 km [13]. In this study, a microstrip array antenna was designed for tsunami radar by increasing the working frequency at 5.8 GHz to get a minimum bandwidth of 150 Mhz to be able to provide 1 m resolution and beamwidth that meets the needs of tsunami radar.

METHOD

The spatial resolution of HF radars in the radial dimension depends on the bandwidth of the radar in the radio spectrum, The required bandwidth (Δf) can be calculated using equation 1, [10]

$$\Delta f = \frac{c}{2\Delta r} \tag{1}$$

The antenna in this study is a microstrip array antenna with FR-4 material at a frequency of 5.8 GHz, voltage standing wave ratio (VSWR) 2, bandwidth > 150 Mhz, beamwidth > 20^{o}. The FR4 material was used due to its ability to operate at a frequency of 2-10 GHz [14]; besides that, it is cheap and easy to obtain. There are also specifications for the substrate, namely the relative dielectric constant (ε_r) 4.4, the dielectric loss tangent (tan δ) 0.02 and the thickness of the material (h) 1.6 mm. Some formulas are used to obtain the initial design based on these specifications. A simulation was later carried out using an electromagnetic field simulator to get the optimal design. Furthermore, the fabrication and measurements of the manufactured antennas are carried out. All stages of the microstrip array antenna design can be seen in Figure 1

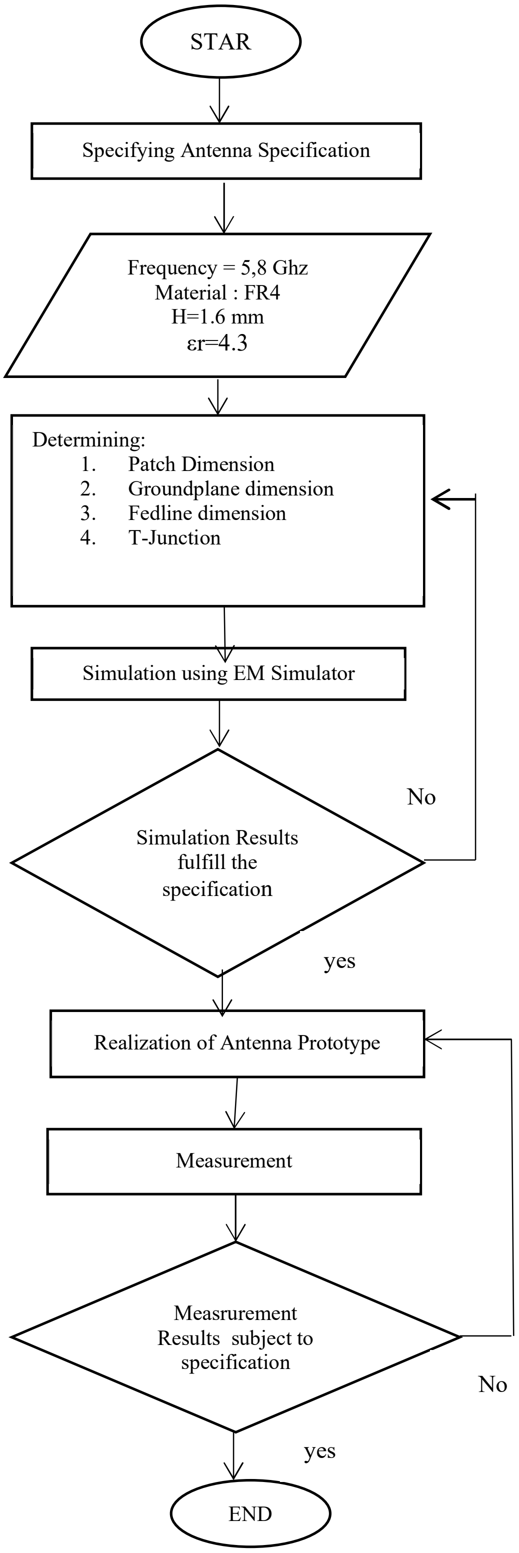


Figure 1. Microstrip Antenna Design Flow Diagram

The patch width dimension (Wp) of the antenna at a frequency of 5.8 GHz can be calculated using Equation 2 [15][16].

$$W = \frac{c}{2f_o\sqrt{\frac{(\epsilon_r+1)}{2}}} \tag{2}$$

https://doi.org/10.25077/jnte.v11n2.1020.2022

Determining the patch length (L) requires ΔL, which is the increase in length L due to fringing effects. The increase in length L (ΔL) can be calculated using Equation 3 [15][17]

$$\Delta L = 0.412h \left[\frac{(\epsilon_{reff}+0.3)\left(\frac{h}{W}+0.264\right)}{(\epsilon_{reff}-0.258)\left(\frac{h}{W}+0.8\right)} \right] \tag{3}$$

$\epsilon_{r\,eff}$ is the effective dielectric constant, which can be calculated using equation 4 [15][17][18]

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

The patch length (L) can be obtained by using equation 5 [15][17]

$$L = L_{eff} - 2\Delta L \tag{5}$$

while L_{eff} is an effective patch length as in equation 6 [17].

$$L_{eff} = \frac{c}{2f_o\sqrt{\epsilon_{reff}}} \tag{6}$$

Ground dimension is also needed to be determined. The width and the length of the ground are calculated using equation 7 and equation 8, respectively.

$$W_g = 6h + W_p \tag{7}$$

$$L_g = 6h + L_p \tag{8}$$

All the result from the calculation above is presented as follow $\epsilon_{reff} = 3{,}84$, $\Delta L = 0{,}309$ mm, $L_{eff} = 13{,}19\ mm$, L =12,57 mm, $W_g = 25{,}33$ mm, and $L_g = 22{,}17$ mm.

The next step is to determine the dimensions of the feed line that will be used in the initial design. The width of the feed line (Wf) at the input impedance of 50 was calculated using equation 9 [15][19]

$$W_f = \frac{2h}{\pi}\left\{B - 1 - \ln(2B-1) + \frac{\varepsilon_r}{2\epsilon_r}\left[\ln(B-1) + 0.39\frac{0.61}{\epsilon_r}\right]\right\} \tag{9}$$

where the value of B can be calculated using equation 10 [12].

$$B = \frac{60\ ^2}{Z_o\sqrt{\varepsilon_r}} = \frac{60\pi^2}{50\sqrt{4.4}} = 5.64 \tag{10}$$

$$W_f = \frac{2(1.6)}{\pi}\left\{5.64 - 1 - \ln(2(5.64)-1) + \frac{4.4}{2(4.4)}\left[\ln(5.64-1) + 0.39\frac{0.61}{4.4}\right]\right\} = 3.06\ mm$$

Based on the calculation results, the width of the feed line (Wf) is 3.06 mm.

After all dimension values were obtained using mathematical calculations, the design of a single rectangular patch antenna with a frequency of 5.8 GHz can be seen in Figure 2.

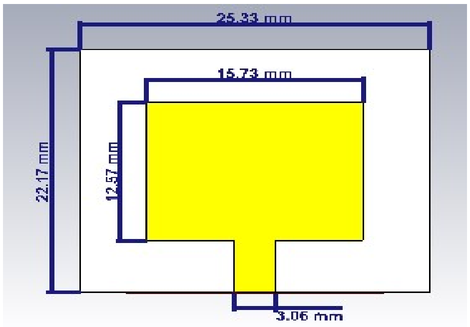


Figure 2. The Initial design of the rectangular patch antenna

This study employs a line impedance of 50 with 2 arrays (n = 2). Thus, to find the impedance matching on the 50 line impedance with 2 arrays, Equation 11 was used.

$$Z = 50\sqrt{n} = 70.71\ \Omega \tag{11}$$

After the calculation, the impedance values to be used are 50 and 70.71 ohms. The width of the feed line can be calculated using equations 8 and equation 9, hence that the width of the feed line is 3.06 mm for the 50 impedance and 1.06 mm for the 70.71 impedance. The design of the T-Junction can be seen in figure 3.

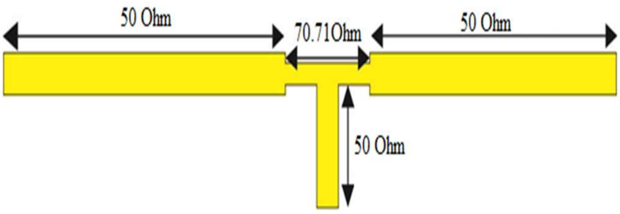


Figure 3. *T-Junction*

In designing the microstrip antenna with the array method, it is necessary to pay attention to the distance between the patch elements. The distance between patch elements (d) can be calculated using Equation 12 [19]

$$d = \frac{c}{2fo} \tag{12}$$

The distance between the patch elements obtained is 25.86 mm.

RESULTS AND DISCUSSION

Antenna Design And Simulation

The microstrip antenna is designed for the SHF frequency tsunami radar. The antenna is expected to have a large bandwidth to be able to provide high resolution in the radar system. High bandwidth and resolution can provide more precise and faster information and data updates. Because the tsunami radar detects the movement of the water surface, an antenna with a reasonably wide beamwidth was used, which is greater than 10° [20]. Some tsunami radars at HF frequencies, such as the Rumena radar, have a beamwidth of ± 43° radar, and the NJRC HF radar has a beamwidth of ± 45° [5].

- Single antenna

This research began with designing a single antenna using the provided formulas to get the initial dimensions. Furthermore, simulations were carried out using an electromagnetic simulator to obtain optimal antenna dimensions to meet the requirements for return loss < -10 dB, VSWR < 2 at a frequency of 5.8 GHz. The design of the single antenna in the simulator can be seen in Figure 4

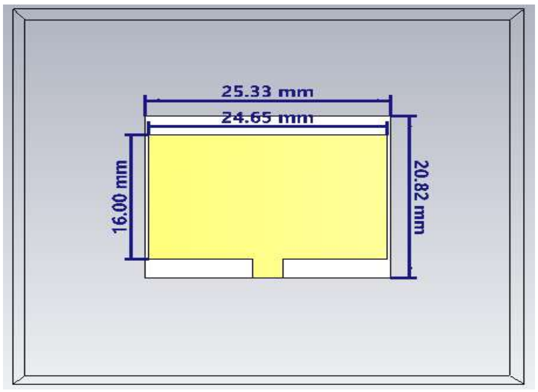


Figure 4. The single microstrip antenna

The simulation results on a single microstrip rectangular antenna show the return loss of -34.46 dB with a bandwidth of 216 MHz, impedance of 48.42 ohms and VSWR of 1.039. For more details about the simulation results, the return loss graph can be seen in Figure 5, the Smith chart of antenna impedance can be seen in Figure 6, and the VSWR graph can be seen in Figure 7.

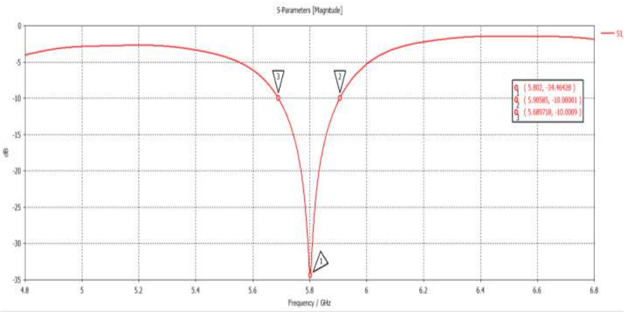


Figure 5. The return loss of single antenna microstrip

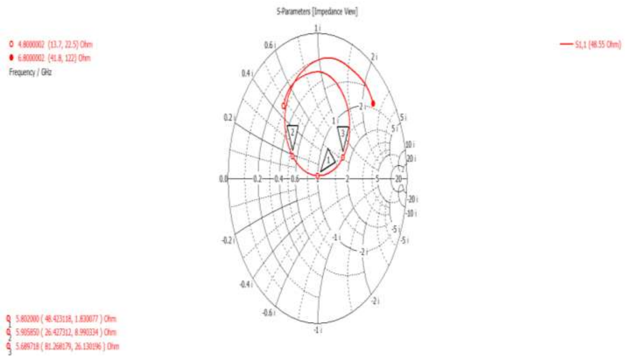


Figure 6. The impedance of single antenna microstrip

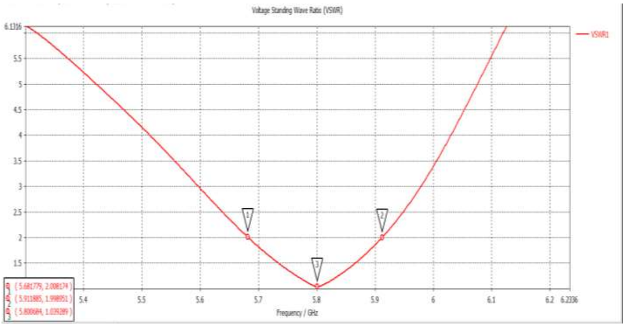


Figure 7. VSWR of single antenna microstrip

The simulated radiation pattern of the antenna is omnidirectional, with an HPBW value of 179° and a gain of 3.51 dBi. The radiation pattern of a single antenna can be seen in Figure 8.

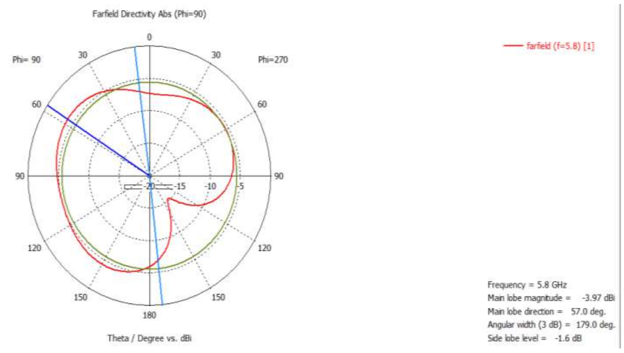


Figure 8. Radiation Pattern of single antenna microstrip

- Array Antenna

However, the gain of the single antenna is still not as expected, and the beamwidth is too wide. So, it is not suitable for radar applications. Antenna array is a configuration of multiple antennas (elements) arranged to achieve a given radiation pattern[3]. Linear Antenna arrays are used commonly in satellite,mobile and radar communications systems to have improved performance in terms of directivity, signal-to-noise ratio (SNR), spectrum efficiency, etc[21]. There are several ways to increase the antenna gain, one of which is by adding the 2nd antenna element. The next designed antenna is to add a number of antennas (microstrip array). The microstrip array antenna using 8 patches is designed and optimized by the simulator can be seen in Figure 9.

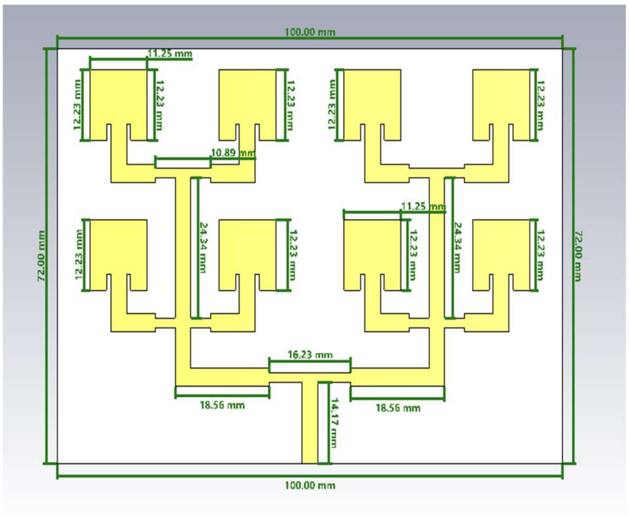


Figure 9. The microstrip rectangular patch Array antenna

The simulation result shows that the 8-patch microstrip array antenna has a return loss value of -44.44 dB, a bandwidth of 303 MHz, an impedance of 50.52 ohms, and VSWR of 1,012. For more details, the return loss graph can be seen in Figure 10, the antenna impedance in Figure 11 and the VSWR graph can be seen in Figure 12

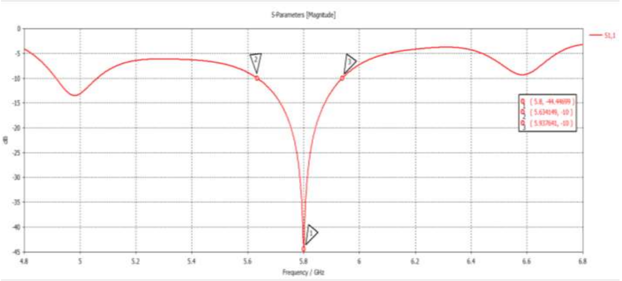


Figure 10. Simulation Results for Return loss

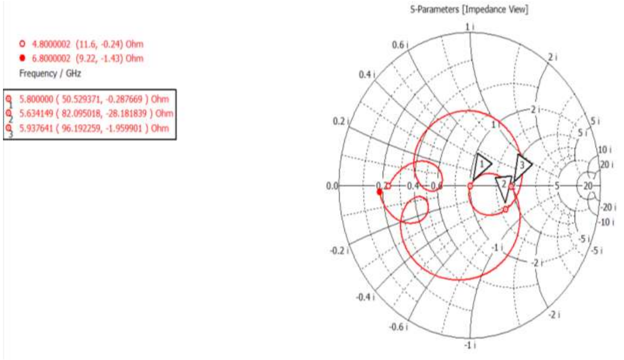


Figure 11. Smith chart impedance array antenna

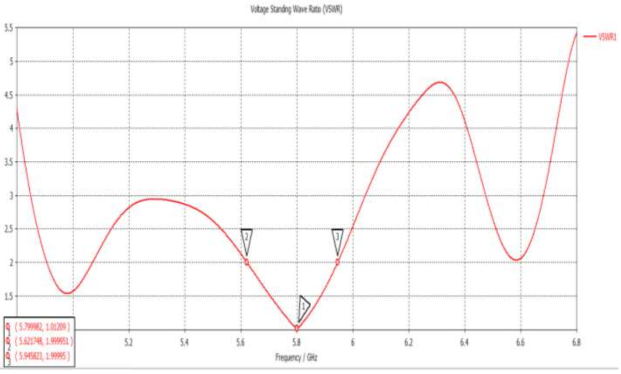


Figure 12. Simulation Results for VSWR of array antenna

The 8-patch antenna array has a directional radiation pattern with a gain of 9.42 dBi and an HPBW of 27.2°. The radiation pattern of the array antenna can be seen in Figure 13. The comparison between a single antenna and an 8-patch array can be seen in Table 1.

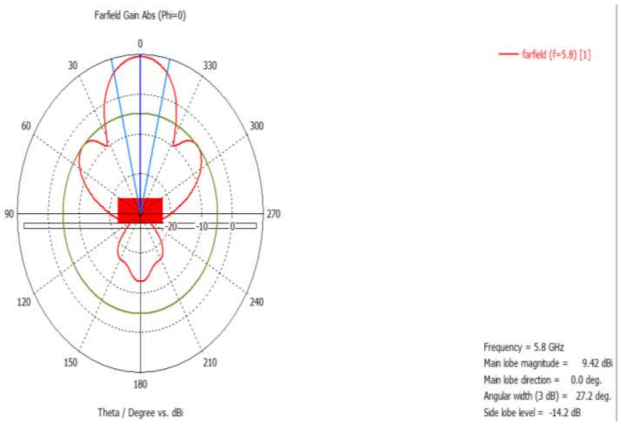


Figure 13. Simulation results for radiation pattern of array antenna

Table 1. Simulation results for single dan array antenna

Parameter	Microstrip Antenna	
	Single	Array 8 Patch
Return Loss (dB)	-34,46	-44,44
VSWR	1,039	1,012
Impedansi (ohm)	48,42	50,52
Gain (dB)	3,51	9,42
HPBW (°)	179	27,2
Bandwidth (MHz)	216	303

Based on Table 1, it can be seen that there is an improvement in the output quality of the antenna array compared to a single antenna. By using an 8-patch array, there was an improvement of 9.98 dB in return loss, a decrease in the value of VSWR by 0.027, and the antenna impedance increased to 50.52 ohms, approaching the reference impedance of 50 ohms. Hence, the designed antenna is said to be matching because the back wave is relatively very small. The gain is increased from 3.15 dBi to 9.42 dBi or an increase of 6.27 dBi. The antenna radiation is changed from omnidirectional to directional with HPBW changed from 179° to 27°. Since the simulation results show that the designed antenna's parameter values have met the desired specifications, the next process is manufacturing and measuring.

Realization And Measurement

The image of antenna fabrication results can be seen in figure 14. The fabricated antenna was tested by the E5063A Network Analyzer, measuring the value of return loss, impedance and VSWR. The measurement results of the return loss, the impedance, and the VSWR can be seen in Figure 15, Figure 16 and Figure 17, respectively.

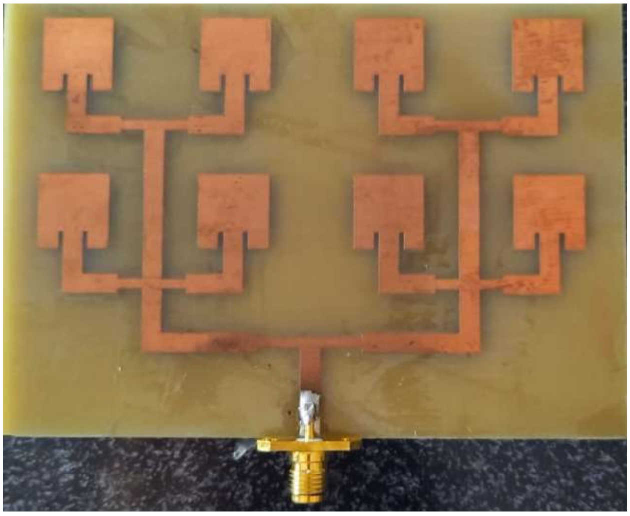
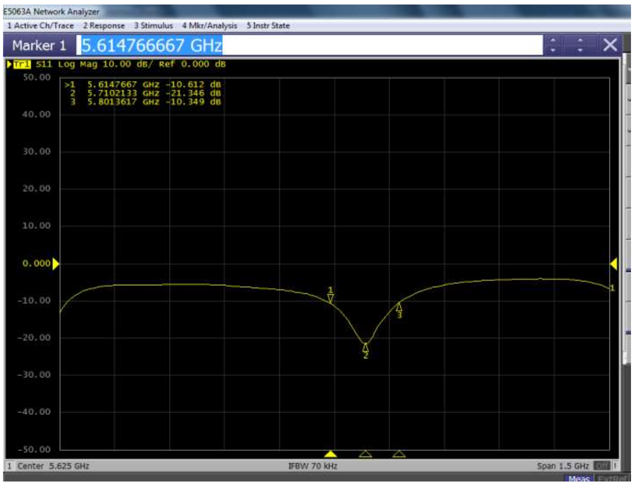
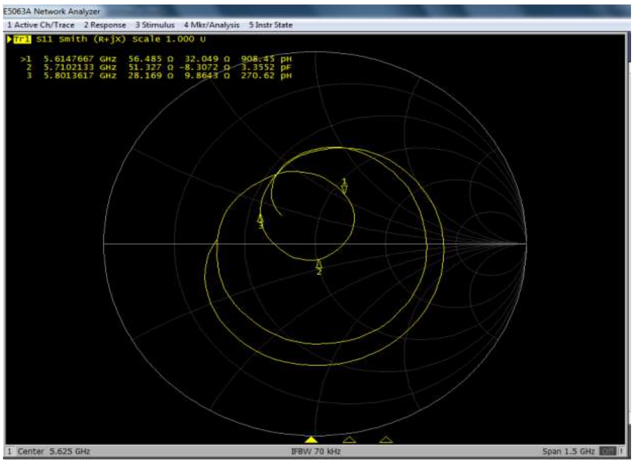


Figure 14. The image of fabricated antenna



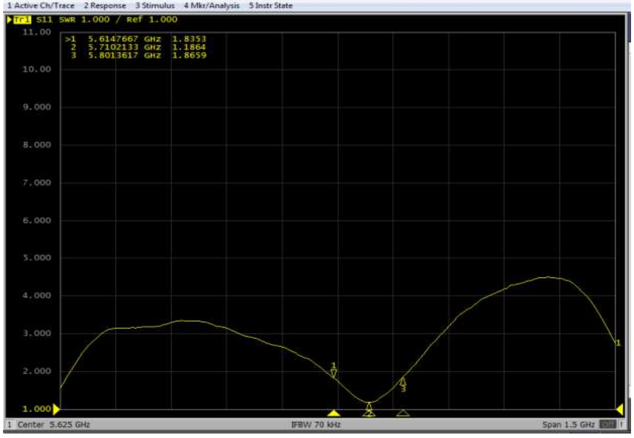
```
Tr1 S11 Log Mag 10.00 dB/ Ref 0.000 dB
>1  5.6147667 GHz -10.612 dB
 2  5.7102133 GHz -21.346 dB
 3  5.8013617 GHz -10.349 dB
1 Center 5.625 GHz                IFBW 70 kHz                Span 1.5 GHz
```

figure 15. The measurement result of Return Loss



```
Tr1 S11 Smith (R+jX) Scale 1.000 U
 >1  5.6147667 GHz  56.485 Ω  32.049 Ω  908.45 pH
  2  5.7102133 GHz  51.327 Ω -8.3072 Ω  3.3552 pF
  3  5.8013617 GHz  28.169 Ω  9.8643 Ω  270.62 pH
```

Figure 16. The measurement result of the Impedance



```
Tr1 S11 SWR 1.000 / Ref 1.000
 >1  5.6147667 GHz  1.8353
  2  5.7102133 GHz  1.1864
  3  5.8013617 GHz  1.8659
```

Figure 17. The measurement result of the VSWR

Based on the measurement results in Figures 14, 15 and 16, it can be seen that there is a frequency shift in the fabricated antenna. If the simulation uses a frequency of 5.8 GHz, but on the manufactured antenna, the smallest return loss value is obtained, the impedance is close to 50 ohms, and the lowest VSWR is at a frequency of 5.71 GHz. Therefore, it can be said that there is a frequency shift of 0.09 GHz. If the simulation shows the lowest return loss of -44.44 dB at 5.8 GHz, while the measurement results are -21.346 dB at 5.71 GHz, the return loss value increases by 23.094 dB. However, the return loss value obtained from the measurement results still meets the antenna design standards. The impedance value of the measurement results also experienced a shift compared to the simulation results. The simulated antenna has an impedance difference of 0.52 ohms to the 50-ohm reference, while the fabricated one has a difference of 1.327 ohms. Therefore, the VSWR value on the antenna fabrication becomes 1.186 or an increase of 0.174 compared to the simulation results. Based on the explanation above, the return loss, impedance and VSWR values still meet the standard parameters in antenna design. While the frequency shift to 5.71 GHz can still be used for radar applications.

Based on the measurements, the radiation pattern of the fabricated antenna is obtained, as shown in Figure 18, with an azimuth beamwidth of 40^{o}. The beamwidth meets the needs of tsunami radar. Also, the bandwidth of 200 Mhz will provide a resolution of 0.75 m on the radar system and gain of antenna is 11.65 dB. Therefore, the proposed antenna can be applied to support tsunami radar at the SHF frequency.

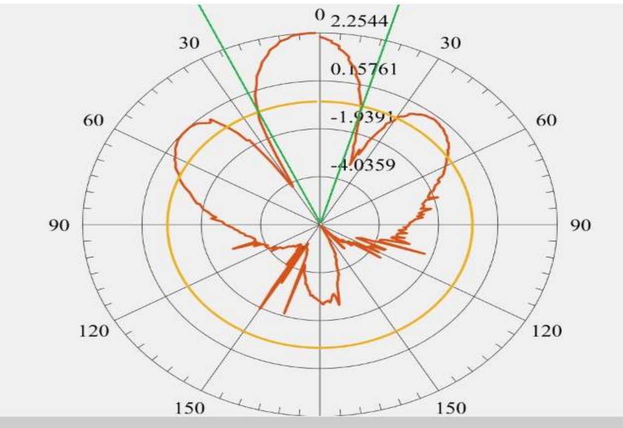


Figure 18. Measurement Radiation Pattern

CONCLUSIONS

This study proposed the 8-rectangular patch microstrip array antenna for the tsunami radar system. The antenna was designed with an operating frequency of 5.8 GHz with return loss ≤ -10 dB, VSWR ≤ 2, bandwidth > 150 Mhz, beamwidth > 20^{o}. After the simulation design meets the desired specifications, then fabrication and measurements are carried out. The measurement results obtained a frequency shift to 5.71 GHz with a return loss of -21,346, VSWR of 1.186, bandwidth of 200 Mhz, beamwidth of 40^{o} and gain 11.65dB. Based on these results, the designed antenna can be applied in radar antenna applications.

.

ACKNOWLEDGMENT

The author gratefully acknowledges the assistance rendered by the University Of Bengkulu for funding this research in the category of Fundamental Research. (contract No **1817/UN30.15/pg/2021)**

REFERENCES

[1] M. Galletti, G. Krieger, T. Börner, N. Marquart, and J. Schultz-Stellenfleth, “Concept design of a near-space radar for tsunami detection,” *Int. Geosci. Remote Sens. Symp.*, pp. 34–37, 2007, doi: 10.1109/IGARSS.2007.4422723.

[2] P. G. B. dan T. K. B. Geofisika, *Katalog Tsunami Indonesia Tahun 416-2018*. 2019.

[3] F. G. Becker *et al.*, “No 主観的健康感を中心とした在宅高齢者における 健康関連指標に関する共分散構造分析Title,” *Syria Stud.*, vol. 7, no. 1, pp. 37–72, 2015, [Online]. Available: https://www.researchgate.net/publication/269107473_What_is_governance/link/548173090cf22525dcb61443/download%0Ahttp://www.econ.upf.edu/~reynal/Civilwars_12December2010.pdf%0Ahttps://think-asia.org/handle/11540/8282%0Ahttps://www.jstor.org/stable/41857625.

[4] D. B. Trizna and V. Court, “Tsunami Detection using

Multi-frequency Beam-Forming HF Radar,” 2006.

[5] A. Dzvonkovskaya, “HF surface wave radar for tsunami alerting: From system concept and simulations to integration into early warning systems,” *IEEE Aerosp. Electron. Syst. Mag.*, vol. 33, no. 3, pp. 48–58, 2018, doi: 10.1109/MAES.2018.160267.

[6] S. Grilli, “UHF radar signature of a tsunami approaching coastal areas : modeling , experiments and application to tsunami warning December,” no. December, 2007.

[7] “A BASIC STUDY OF UTILIZATION OF DBF OCEAN RADAR WITH VHF BAND FOR TSUNAMI DETECTION IN OPEN SEA * 1 Central Research Institute of Electric Power Industry , 1646 Abiko , Abiko-shi , Chiba 270-1194 , Japan * 2 Chubu Electric Power Co ., Inc ., 1 Higashi-shi,” pp. 4924–4927, 2015.

[8] D. Wijoyono, S. Ramadhanty, D. Rakmatullah, and F. Y. Zulkifli, “Uniform Microstrip Array Antenna with Low Sidelobe Level for Coastal Surveillance Radar Application at 9 . 37 – 9 . 43 GHz,” *IEEE*, pp. 22–25, 2017.

[9] M. Wahab, Y. P. Saputera, and Y. Wahyu, “Design and realization of archimedes spiral antenna for Radar detector at 2-18 GHz frequencies,” *2013 19th Asia-Pacific Conf. Commun. APCC 2013*, pp. 304–309, 2013, doi: 10.1109/APCC.2013.6765961.

[10] Y. Yuliyus Maulana, Y. Wahyu, F. Oktafiani, Y. Perdana Saputra, and A. Setiawan, “Rectangular Patch Antenna Array for Radar Application,” *TELKOMNIKA (Telecommunication Comput. Electron. Control.*, vol. 14, no. 4, p. 1345, 2016, doi: 10.12928/telkomnika.v14i4.4742.

[11] S. A. Rahayu, J. Suryana, L. Tursilowati, H. -, and G. A. Nugroho, “Design Analysis of Microstrip Rectangular Patch Array Antenna 16×1 on X-band Radar,” *J. Elektron. dan Telekomun.*, vol. 19, no. 1, p. 7, 2019, doi: 10.14203/jet.v19.7-12.

[12] V. Midasala and P. Siddaiah, “Microstrip Patch Antenna Array Design to Improve Better Gains,” *Procedia Comput. Sci.*, vol. 85, no. Cms, pp. 401–409, 2016, doi: 10.1016/j.procs.2016.05.181.

[13] M. L. Heron *et al.*, “Tsunami observations by coastal ocean radar,” *Int. J. Remote Sens.*, vol. 29, no. 21, pp. 6347–6359, 2008, doi: 10.1080/01431160802175371.

[14] A. A. Qureshi, M. U. Afzal, T. Taqueer, and M. A. Tarar, “Performance analysis of FR-4 substrate for high frequency microstrip antennas,” *2011 China-Japan Jt. Microw. Conf. Proceedings, CJMW 2011*, no. January, pp. 159–162, 2011.

[15] Y. P. Saputera, Y. Wahyu, and M. Wahab, “Antenna co-planar array of X-band frequency 9.4 GHz for radar,” *Proc. 2014 8th Int. Conf. Telecommun. Syst. Serv. Appl. TSSA 2014*, 2015, doi: 10.1109/TSSA.2014.7065924.

[16] B. Y. U. Putri, E. S. Nugraha, A. Prakasa, and S. F. Siddiq, “Design and Performance Analysis of Linear Array Microstrip Antennas with Mitered-Bends Feeding Network for X-Band Radar Applications,” *J. Elektron. dan Telekomun.*, vol. 20, no. 1, p. 9, 2020, doi: 10.14203/jet.v20.9-15.

[17] M. Wahab, Y. P. Saputera, and Y. Wahyu, “Research and Development of Transportable Coastal Radar at S-band Frequency with FM-CW Technology for Supporting C4ISR,” *Proc. 3rd Int. Conf. Electr. Electron.*, vol. 69, no. Eeic, pp. 172–177, 2013, doi: 10.2991/eeic-13.2013.40.

[18] V. Ramamurthy, D. V Katrodiya, J. N. Peshavaria, and V. Ramamoorthy, “Design of Microstrip Patch Antenna Array for Wireless Applications,” *Iject*, vol. 6, no. 2, pp. 1–5, 2015, [Online]. Available: https://www.researchgate.net/publication/281643519.

[19] M. I. L. Prasetyani, S. Alam, and I. Surjati, “Perancangan Antena Mikrostrip Array Menggunakan Metode Truncated Corner dengan U-Slot pada Frekuensi 2,3 GHz,” *JTERA (Jurnal Teknol. Rekayasa)*, vol. 6, no. 1, p. 85, 2021, doi: 10.31544/jtera.v6.i1.2021.85-92.

[20] R. Solomon, “Tsunami Warning Plan,” p. 13, 2007.

[21] R. Jaya Lakshmi and T. Mary Neebha, “Design of Antenna Arrays Using Chaotic Jaya Algorithm,” *Adv. Intell. Syst. Comput.*, vol. 949, no. January 2020, pp. 337–349, 2020, doi: 10.1007/978-981-13-8196-6_30.

NOMENCLATURE

Δr : Spatial resolution
fo : The resonance frequency (this study used 5.8Ghz)
$\in_r$: The relative dielectric constant
h : The thickness of subtrate
$\in_{reff}$: Effective dielectric constant patch
c : $3x10^8$ m/s

Fitrilin received the B.E. degree in Electrical Engineering from the University of Andalas, Indonesia, in 2005. The M.E.degree in Electrical Engineering (Telecommunication Engineering Option) from Institut Teknologi Bandung, Indonesia, in 2010. She is currently a lecturer in the Electrical Engineering Department, Faculty of Engineering at Bengkulu University, Indonesia. His research interests include telecommunication systems and speech processing.

Junas Haidi received the B.E. degree in Electrical Engineering from the University of Ageng Tirtayasa, Indonesia, in 2007. The M.E.degree in Electrical Engineering from Trisakti University, Indonesia, in 2012. He is currently a lecturer in the Electrical Engineering Department, Faculty of Engineering at Bengkulu University, Indonesia. His research interest is antenna dan telecommunication system

Alex Surapati received the B.E. degree in Electrical Engineering from the University of Sriwijaya, Indonesia, in 1996. The M.E.degree in Informatics Engineering from Gadjah Mada University, Indonesia, in 2004. He is currently a lecturer in the Electrical Engineering Department, Faculty of Engineering at Bengkulu University, Indonesia.

Hendi Santosa received the B.E. degree in Electrical Engineering from Gadjah Mada University, Indonesia, in 2004. The M.E.degree in Electrical Engineering (Telecommunication Engineering Option) from Institut Teknologi Bandung, Indonesia, in 2013. He is currently a lecturer in the Electrical Engineering Department, Faculty of Engineering at Bengkulu University, Indonesia. His research interests include electromagnetic wave propagation and its numerical analysis

Firdaus (IEEE Member) received the B.eng and M.eng degrees in Electrical Engineering from Institut Teknologi Sepuluh Nopember (ITS) Surabaya in 2005 and 2010, respectively. He is a senior lecturer in the Department of Electrical Engineering, majoring in telecommunication, Politeknik Negeri Padang, Indonesia. His research interest includes antenna and propagation, microwave and telecommunication systems. He conducts several researches in his area of interest.

Rudy Fernandez received his S.T and M.T degrees from Universitas Indonesia in 1997 and 2010, respectively. Since 1999, he has been a lecturer at Electrical Engineering Department, Universitas Andalas, Padang, Indonesia. His research interests are Electromagnetic devices and Antenna Design.