TELKOMNIKA, Vol.14, No.4, December 2016, pp. 1345~1350
ISSN: 1693-6930, accredited A by DIKTI, Decree No: 58/DIKTI/Kep/2013
DOI: 10.12928/TELKOMNIKA.v14i4.4742

Rectangular Patch Antenna Array for Radar Application

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Abstract

This paper deals with the characterization of Rectangular Patch Antenna Arrays numerically and experimentally. This antenna is designed to work around frequency of 9.4GHz for radar applications. In the design process, the Computer Simulation Technology (CST®) simulator software is utilized to determine the value of the antenna parameters such as gain, radiation pattern, and voltage standing wave ratio (VSWR). The Rectangular Patch Antenna Arrays realized by using the 1x16 patch antenna array, while the patch antenna is implemented using microstrip lines. The Duroid/RT5880 substrate with a dielectric constant of 2.2 and a thickness of 1.57mm applied for implementation. The characterization results show that the VSWR of realized antenna is 1.052, and the gain is 15,26dB which is 1.4dB lower than the design result, while the radiation pattern is unidirectional and elliptical polarization.

Keywords: *Antenna Arrays, characterization, gain, microstrip lines, Rectangular Patch, VSWR*

1. Introduction

Currently, radar is one of the emerging technologies. This technology can replace the function of the human eye to monitor objects at long distances. Radar is a system of electromagnetic waves that useful to detect, measure distances and create a map of objects [1]. Today's modern ships are equipped with the navigation radar to detect other vessels, weather encountered at the front so that it can avoid the dangers that exist in front of the ship. In applications on maritime navigation radar, based on the International Maritime Organization (IMO), maritim radar should use a frequency-band (8 to 12 GHz), where the mobility of ships requires a very small antenna size and light weight. The higher the work frequency the radar will become lighter and smaller antenna size [2].

One of important component on system radar is an antenna system, if analogous to the human body, the antenna systems as an eye which is very vital. Due to the high price of imported of a radar set, Indonesia is required to develop radar. Therefore, in this paper will discuss the making of one of its component, that is radar antenna using microstrip technology and array methods with a material such as a dielectric substrate Duroid / RT5880, Computer Simulation Technology (CST®) simulator software was used on simulation process. Microstrip technology is used so the antenna which is implemented has small dimensions, light weight and easy in fabrication and low cost [3]. other than that, concerning the synthesis of aperture fields suitable for radar [4].

Design, rectangular shape patch is used with a modified form using a slot as a direction modifier of polarization resulting from vertical to horizontal [5]. The Designed Radar antenna consisting of 1x16 patch microstrip antenna in-array with uniform power distribution (uniform array), the working frequency of 9.4 GHz and a gain of > 12 dB.

2. Rectangular Microstrip Patch Antenna Arrays

2.1. A Short Overview Of The Microstrip Antenna Array

The initial stage of this activity is to design a single patch antenna with horizontal polarization to be expected according to the radar antenna parameters. The design is done by calculating the dimensions of the patch antenna in accordance with the specified operating frequency. Figure 1. shows a patch antenna [6].

Received August 17, 2016; Revised October 12, 2016; Accepted October 26, 2016

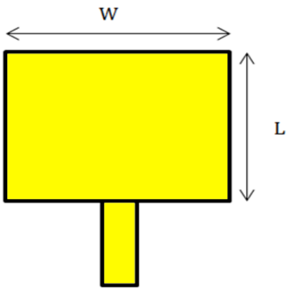
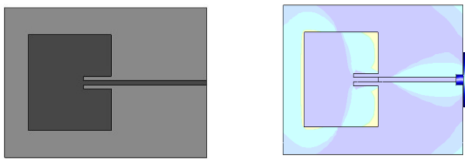


Figure 1. Patch antenna dimension



(a) Antenna design (b) Field movement

Figure 2. Antenna patch dimension version

This is the position of the transmission line to the sideways position, so the field is flowing horizontally aligned in the patch. In a patch antenna design with the condition of the transmission line as shown in Figure 2. has a difficulty in merging when doing the array with the desired arrangement, array design can be seen in Figure 3.

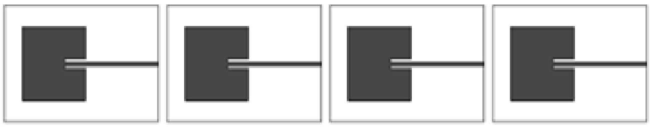


Figure 3. Design antenna array as in version 1

Figure 4, the second position is a modification of the transmission line to the first version, by doing curvature of the transmission line, so that it can feed from the bottom of the vertical position. Figure 5, this third position are doing modification to the path by adding slot as a field direction modifier which flowing from the transmission line, so that the polarization become horizontal.

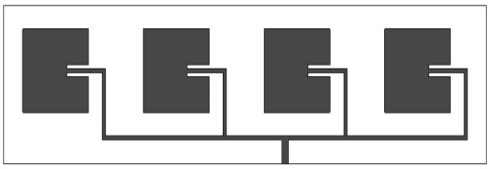


Figure 4. Design antenna array antenna as in version 2

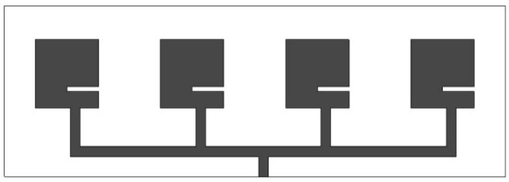


Figure 5. Antenna patch dimension version 2

From the three version of the antenna before which generates horizontal polarization antenna, the third version have the most good of return loss, gain and in reducing the level of difficulty in the process of realization.

2.2. Design of Rectangular Patch Antenna Arrays

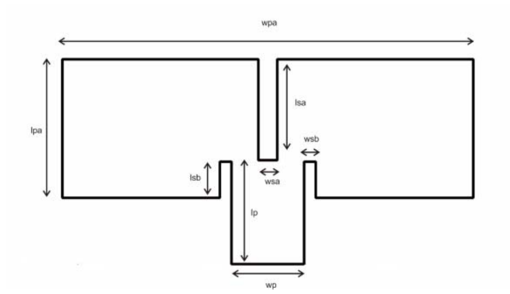
In order to obtain the optimal antenna design, some characterization were done such as changing the feed channel length, changes in the dimensions of the patch and the distance between the patch antenna. By doing some simulations using a software simulator CST® subsequently obtained a more optimal design results such as voltage standing wave ratio (VSWR), gain and radiation patterns.

Figure 6. show the antenna design parameter, antenna materials used in this design is the dielectric substrate Duroid / RT5880 with a dielectric constant of 2.2 and a thick substrate

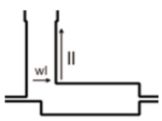
1.57 mm. According to the specifications of the desired antenna, the operating frequency is 9.4 GHz with impedance of 50 Ohm and has a return loss ≤ -10 dB, then the dimensions of the patch antenna, feeding line, ground plane and the distance between the patch antenna were calculated. Optimization results can be seen in Table 1. As shown in Figure 7, the design of rectangular patch Antenna Arrays built using 16 pieces Rectangular Microstrip patch antenna that equipped with an additional slot each patch antenna.

Table 1. Microstrip Array Antenna Design Dimensions using Duroid/Rt5880 Substrate with Dielectric Constant (Er) of 2.2 and Thickness of 1.57 mm

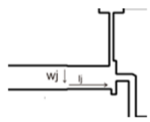
Parameter	**Value (mm)**	**Symbol**
Distance between antenna	24.0	Dz
Length Feedline 1	17.0	Lm
Length Feedline 2	4.9	La
Length Feeding	7.0	Lp
Length Patch	9.6	Lpa
Length substrate	381.82	Ls
Length upper stub	7.0	Lsa
Length bottom stub	2.5	Lsb
Thickness substrate	1.57	Ts
Width Feedline 1	5.0	Wm
Width Feedline 2	2.0	Wa
Width Feeding	5.0	Wp
Width patch	28.5	Wpa
Width substrat	63.58	Ws
Width upper stub	0.8	Wsa
Width bottom stub	0.8	Wsb
Length Line 1	8.58	Lj
Length Line 2	10	Ll



(a) Antenna parameter



(b) Feeding line A



(c) Feeding line B

Figure 6. Design parameter

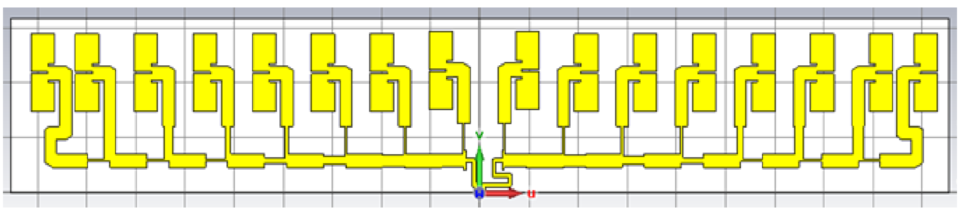


Figure 7. Rectangular microstrip patch antenna arrays design

3. Deployment and Characterization

Based on the design described in the previous section, the prototype of Rectangular patch Antenna Array is realized to be characterized experimentally as shown in Figure 8. and Figure 9. respectively. In addition, the design results Return Loss, VSWR, radiation pattern and gain also depicted together in each respected figure as a comparison.

Although the results of the experimental characterization of Return Loss and VSWR shown in Figure 10. slightly different from the results obtained from CST® simulator design software, however in general both results have similar tendency to one another. From the research, the prototype antenna has a Return Loss of -31.924 dB and VSWR 1.052 at a frequency of 9.4 GHz. Whereas at the same frequency with the design one has Return Loss -29.359 dB and VSWR 1.070.

Figure 8. Picture of realized antenna arrays prototype (top view)

Figure 9. Picture of realized antenna arraysprototype (bottom view)

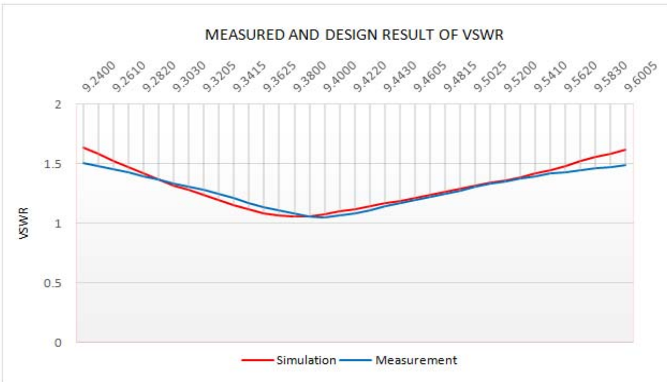


Figure 10. Measured and design results of VSWR

Figure 11 and Figure 12 is an azimuth and elevation radiation patterns, show that the antenna is an unidirectional because half power beamwidth (HPBW) for azimuth direction is around 4^{o} and elevation direction is around 27^{o}.

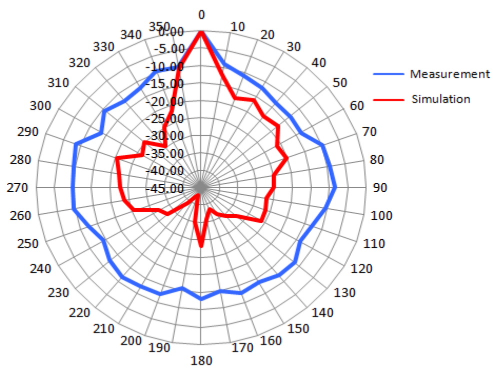


Figure 11. Measured and design results of radiation pattern (azimuth)

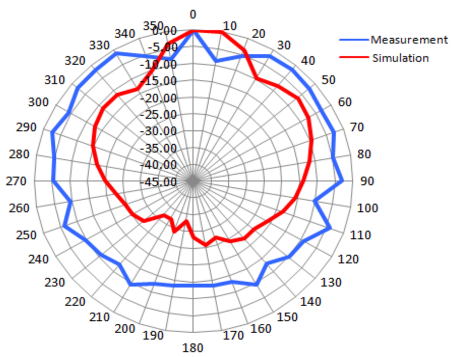


Figure 12. Measured and design results of radiation pattern (elevation)

Figure 13 is a results graph of the polarization measurements, showed that the largest and smallest received power is -29.99dBm and -57.13dBm respectively. From these values, it can produce 23.735 comparison of major and minor. The comparison of the results obtained that is elliptical polarization measurement results with the conditions, 1 < ellipse < ∞.

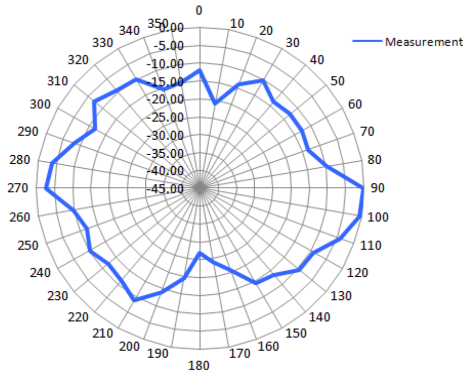


Figure 13. Measured of polarization

Figure 14 shows that the gain of the simulation results of microstrip antenna is 16.66 dB. This proves that by making the array antenna increases gain.

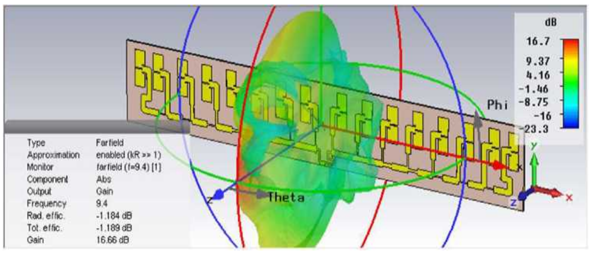


Figure 14. Gain simulation results

The calculation of gain is expressed in (1).

$$G_T = G_S + 10\log\left(\frac{P_T}{P_S}\right) \quad (1)$$

For:
G_S = Reference antenna gain
G_T = Total gain
P_T = Measured received antenna power
P_S = Reference received antenna power

The different results of experimental characterization are also found for the value of gain value as shown in the calculation of the measurement results. However, it is seen that the experimental characterization results have the same tendency. By using (1), the realized Rectangular Patch Antenna Array prototype has gain of 15.26dB at frequency of 9.4GHz frequency, whilst the design result is 1.46dB higher than the measured results, i.e. 16.66dB. There are some possibilities which evokes these discrepancies. One of them is caused by the dielectric loss of Duroid/RT5880 dielectric substrate used in the realization. It should be noted that the dielectric loss and relative permittivity in the design are set to be constant and assumed to be flat for all frequency ranges. Whilst in implementation, the dielectric loss and the dielectric constant are almost frequency-dependent. In case of measured gain, it is probably caused by the dielectric loss which has actual value slightly higher than in the design. Due to the higher value of the dielectric loss, some amount of energy from the input port that should be actually transmitted to the output port is then absorbed by the dielectric substrate affecting to the decrease of measured gain [7].

4. Conclusion

The Characterization of Rectangular Patch Antenna Arrays for radar applications has been demonstrated numerically and experimentally. The Antennas which has been designed to work around frequency of 9.4GHz has been constructed by use of 1x16 patch antenna array. The prototype Rectangular patch antenna arrays has also been implemented on a Duroid/RT5880 dielectric substrate. Although there were some discrepancies in the experimental characterization results for Return Loss, VSWR, radiation pattern and gain compared to the design results. In general, the realized prototype has shown acceptable performance to work at the desired working frequency of 9.4GHz for radar applications. The realized prototype has demonstrated the gain of 15.26dB at frequency of 9.4GHz with the value of VSWR of 1.052. The design antenna has shown the gain of 16.66dB with the value of VSWR of 1.070. In addition, a further investigation on the enhancement of the antenna array performance by implementing some design method for the form of patches and feed system is still in the progress where the results will be reported later [7].

Acknowledgements

This work was financially supported by Ministry of Research, Technology and Higher Education of the Republic of Indonesia (RISTEKDIKTI) under the scheme of the national innovation systems research incentives (Insinas). Thanks also to Electrical Engineering Department, University of Indonesia for supporting on simulation.

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