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Design and development of microstrip antenna circular patch array for maritime radar applications

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ABSTRACT

The maritime radar is a mobile station used by ships to cover large areas in Indonesian waters. Maritime radar is used to monitor Indonesia's marine waters. One of the maritime radar subsystems is the antenna. The antenna emits the electromagnetic waves into the air to detect an object. In this study, a 1 × 4 circular patch array microstrip antenna is proposed. This antenna is applied to maritime radar working in the frequency range of 2.2 – 4.2 GHz that are allocated by the Ministry of Communication and Information of the Republic of Indonesia. From the simulation results, the proposed antenna provides a return loss of -66.29 dB, and a gain of 7.14 dB at 3.2 GHz.

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1. INTRODUCTION

Indonesia is one of the largest countries in the world. Security and supervision of Indonesian territory which consists of approximately 17.504 islands with 2/3 of the area consisting of oceans requires a large number of apparatus and equipment. Currently, marine surveillance and monitoring vessels in Indonesia are equipped with radars, but the scope of the radar coverage emitted by Indonesian vessels is still small [1-3]. So until recently, only a small part of Indonesia's coast was guarded by coast guard radar, that cause this country is very vulnerable to illegal activities such as piracy, illegal fishing, smuggling, and illegal logging. Such illegal activities will cause huge losses to the country's economy every year.

Maritime radar is an important sensor used to deal with hazards and assist navigators in making timely decisions [4, 5]. Maritime is very affordable on surface-based radars. In addition, radar can also detect defective objects and materials [6-8]. To increase signal strength requires rebuilding the existing radar infrastructure, either option is expensive and can take a long time [9, 10]. A radar that interconnects multiple platforms breaks this paradigm, when operating a field far from the array the radar sensitivity in the array will connect the ideal scale to the number of cubic platforms, where an operational advantage is achieved by coherently coordinating even a very small number of radar [11-13]. Microstrip antenna is an antenna composed of four elements of radiation elements (radiators), dielectric substrate elements, transmission lines, and ground elements (ground) [14, 15]. Microstrips generally have a limited thickness, which affects the field distribution for moderate power applications. The fill layer and ground plane are made of conducting material. For microstrips with a thickness of $t/h \leq 0.005$, $2 \leq \varepsilon_r \leq 10$ and $w/h \geq 0.1$, this cannot be ignored. But at values smaller than w/h or values greater for t/h, the significance increases [16-18].

An array of high isolation antenna 32 patch microstrip square was designed for marine radar applications, which works at a frequency of 9.35 GHz with a bandwidth of 100 MHz. This antenna has a 3 dB side lobe bandwidth level and use metal maze to increase the isolation between the transmitting and receiving antennas by up to 60 dB [1]. Designing microstrip array antenna with S-band frequency for radar communication was developed by Anitha and Reddy (2009) [19]. This antenna array is used to increase the gain of different antennas with side lobe. An array of rectangular microstrip patch antennas with 3 × 3 dimensions was also studied by Faroqi et al. (2018) [20]. Designing a 2.4 GHz microstrip rectangular patch antenna inset feed for bluetooth applications was done by Midasala and Siddaiah (2016) [21]. A miniature series of H-slotted patch antennas for use in automotive radar applications working in the frequency range of 77 – 81 GHz was studied by Tandel and Shingla (2015) [22]. Horizontal polarized 4 × 24 element patch array antenna design for use in frequency modulated continuous wave (FMCW) marine radar applications operating at a center frequency of 9.4 [23]. Cross-fed rectangular array (CFRA) antennas have been designed and simulated for X-band applications such as radar or satellite communications [24].

This paper presents the design of a 1 × 4 patch array circular microstrip antenna for maritime radar applications with a frequency of 3.2 (2.2 – 4.2 GHz). This frequency is allocated by the Indonesia Ministry of Communication and Information. The inset feed technique is also applied in this design.

2. MATERIALS AND METHOD

In this study, the authors will design a microstrip circular patch array 1 × 4 antenna for maritime radar operating at 3.2 GHz. This antenna is designed in a compact size with FR4 dielectric substrate (ε_r = 4.4) and thickness of 1.6 mm. The CST software is used to model the antenna structure. This antenna has the dielectric constant of the substrate (ε_r), the resonant frequency f_r (GHz), and the substrate height h (mm). The patch shape of the microstrip antenna is circular with a radius calculated by the following equation [25]:

$$a = \frac{F}{\left\{1+\left(\frac{2h}{\pi\varepsilon_r F}\right)\left[\ln\left(\frac{\pi F}{2h}\right)+1.7726\right]\right\}^{0.5}} \quad (1)$$

$$F = \frac{8.791\times10^9}{f_r\sqrt{\varepsilon_r}} \quad (2)$$

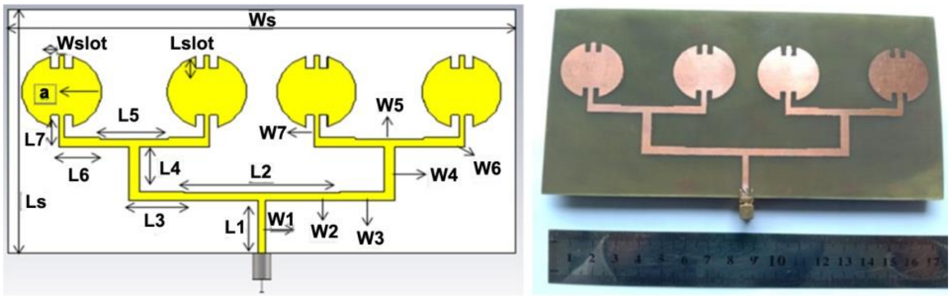

Figure 1. Microstrip.antenna circular patch (front view).

Figure 2. Microstrip antenna circular patch (back view).

This antenna uses the T-junction feeding technique with a 50 ohms. 4 slots on the top and bottom edges of each patch are added. The geometry of antenna is shown in Figure 1 and 2. Table 1 lists the dimension of the antenna. The antenna was developed and tested by using a pocket vector network analyzer (VNA).

Table 1. Antenna dimensions.

Parameter	Value (mm)	Parameter	Value (mm)	Parameter	Value (mm)
A	14	L2	55	W5	2.9
Ls	178	W2	3	L6	29
Ws	93	L3	38	W6	3.5
Lg	178	W3	3.5	L7	2
Wg	93	L4	17	W7	17.5
L1	2.5	W4	3.5	Lslot	5
W1	20	L5	24	Wslot	2.8

3. RESULTS AND DISCUSSION

The simulated return loss and radiation pattern are illustrated in Figure 3 and 4 below. A center frequency of 3.2 GHz with a return loss of -50.708 dB and a bandwidth of 136.6 MHz is presented. The antenna gain of 7.35 dBi with nearly omnidirectional radiation pattern is shown.

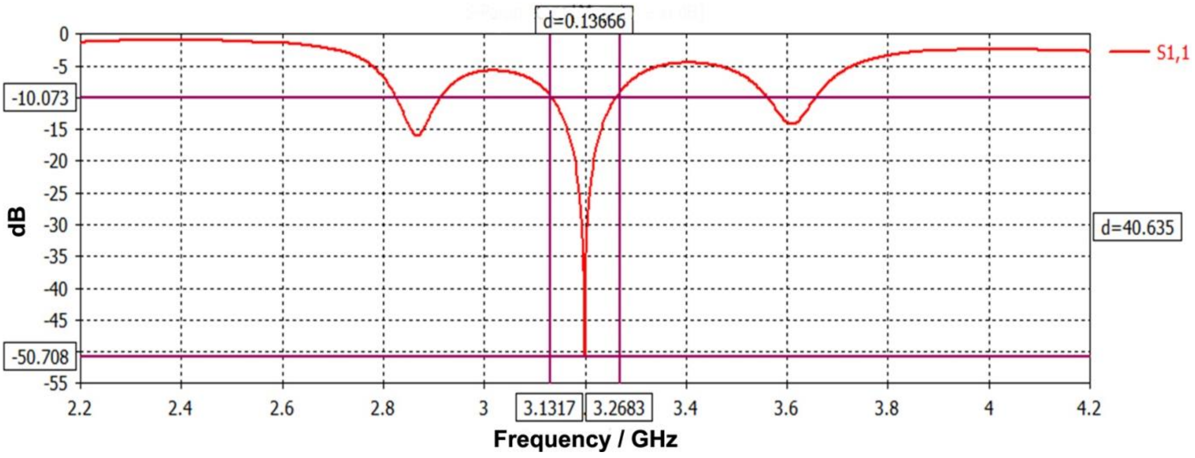

Figure 3. Simulated return loss.

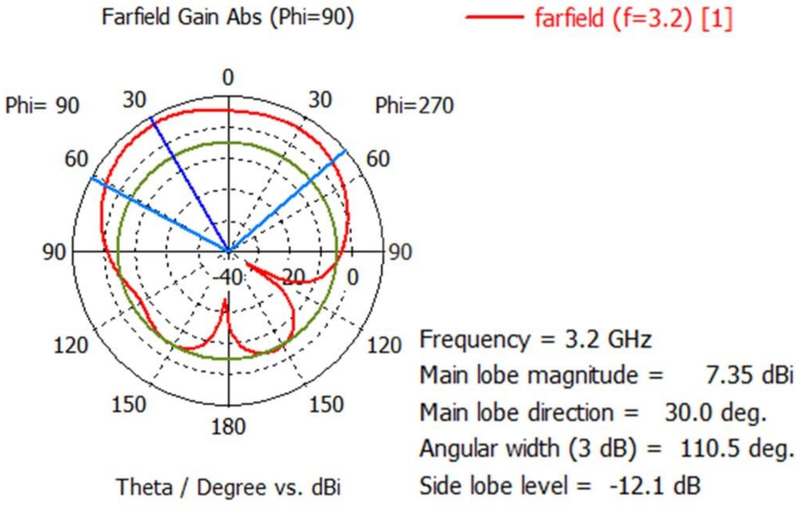

Figure 4. Farfield of antenna.

Figure 5 presents the comparison between simulated and measured return loss of the antenna. It shows that the measured return loss is the worst compared to the simulated one. The prototype has return loss of -12.58 dB at 3GHz with only 30 MHz of bandwidth. Others, at 3.2 GHz, the bandwidth of 38 MHz is obtained with return loss of -11.88 dB. The lowest return loss of -14 dB is obtained at 3.92 GHz. This very large difference the results is possible occurred due to the lack of accuracy in fabrication process and human error during measurement.

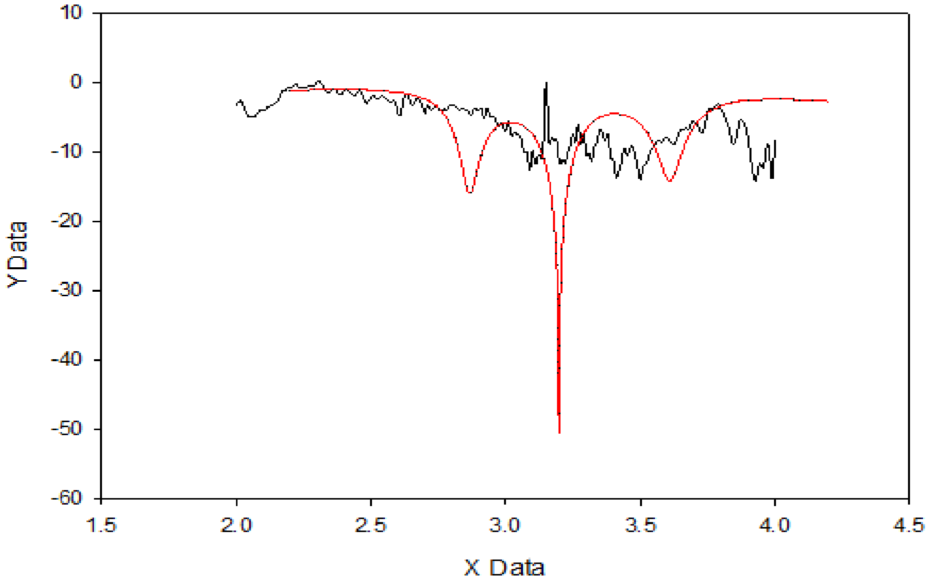

Figure 5. Measured (black) vs simulated (red) return loss.

Table 2. Comparison of antenna.

Simulation results	References paper		This work
	[1]	[16]	
Return loss (dB)	-24.1348	-26.6	-50.708
Bandwidth (MHz)	210	200	136.6
Impedance (Ohm)	53.9255	-	49.91
Gain (dBi)	7.4	10.7	7.35
Dimension (mm)	12.3 × 9.85	113 × 485	178 × 93

Table 2 lists the comparison between the existing references with this work. The results obtained from the simulated is comparable with others. However, during the prototype development and measurement, the measured result is different with the simulated one. The frequency is shifted from the desired one.

4. CONCLUSION

This paper has designed and developed a microstrip 1 × 4 circular patch array antenna operating at 3.2 GHz. In this design, there are 4 antenna elements form an array configuration. The simulated return loss of -50.708 dB, VSWR of 1.04, gain of 7.35 dB are obtained. However, the measured results are different to the simulated one. The shifted frequency and the highest return loss are occurred. This is possible due to the lack of accuracy during the prototype development and human error in measurement.

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