1. Introduction

This paper describes the antenna system of the first Indonesian radar called INDERA [1]. INDERA is an X-band FMCW maritime radar which can be deployed either as ship or coastal surveillance radar. As Indonesia is the world’s largest archipelago state with one of the longest coastlines, a large number of such radars are needed in this country for maritime security, navigation and sea traffic monitoring. In accordance with this, in recent years a lot of effort has been put by a group of Indonesian engineers in research and development of maritime radar in cooperation with the International Research Centre for Telecom and Radar (IRCTR) of Delft University of Technology in The Netherlands. INDERA is the first radar delivered through the mentioned R&D cooperation.

2. The INDERA Radar

INDERA has been developed by Radar & Communication Systems (RCS) in Indonesia in collaboration with IRCTR. This X-band FMCW radar operates at 9.4 GHz with maximum transmit power of 2 W. It has a maximum frequency sweep of 60 MHz with sweep repetition frequency of 2 kHz. INDERA has been designed to have a maximum range of at least 16 nm and a maximum range resolution of 2.7 m at the smallest range scale (0.75 nm). It employs range FFT to provide 512 cells for each range scale. The radar prototype is depicted in Figure 1.

3. Antenna Design

INDERA makes use of separate yet identical TX and RX antennas. The antennas employed in INDERA are the so-called “microstrip-patch-array offset-fed reflector antenna”, which to the best knowledge of the authors is here used for the first time in FMCW radar. The advantages of the reported antenna in comparison with traditional slotted waveguide antennas commonly used in this application are its lighter weight and lower cost, while larger dimensions are its main disadvantage.

As the name suggests, it employs a microstrip patch array for the reflector feed in an offset position with respect to a parabolic reflector. The offset feed configuration is chosen to minimize feed blockage. The concept of the reported antenna is illustrated in Figure 2. As indicated in the figure, the RF and electronics of INDERA are integrated with the antennas and mounted at the rear part of the rotor.

The antennas of INDERA have been designed to exhibit H- and E-plane beamwidth of 2.5° and 20°, respectively. The former is achieved by using an array of microstrip patches while the later by adjusting the reflector height. Pre-production analysis has been carried out using the commercial method-of-moment software FEKO.

The employed microstrip patch array consists of 4 modules and each module comprises 8 patch elements [2], resulting in an array with 32 elements in total. Each module is connected to a power splitter/combiner using a phase-matched coaxial cable as illustrated in Figure 3.
The radiation pattern of the patch module has been computed using both finite and infinite substrate / ground plane models. Good agreement between both models is achieved within azimuths of ±60° as shown in Figure 4. The computed gain, -3 dB beamwidth and first sidelobe level of the patch module are 15 dBi, 8.5° and -13 dB, respectively. These results have also been confirmed experimentally. Furthermore, the computed radiation pattern of the whole microstrip array consisting of the 4 patch modules (4 × 8 elements) is presented in Figure 5. The computed gain, -3 dB beamwidth and first sidelobe level of the array are 19.5 dBi, 2.2° and -13 dB, respectively.

4. Measurement Results

The antenna prototype of INDERA is depicted in Figure 6. The rotor of the radar, which comprises the TX-RX antennas and RF/electronic part, measures 90 (l) × 40 (w) × 35 (h) cm. As can be seen, various parts such as the reflector perimeter and construction supports of the antennas are covered with absorbing materials to minimize unwanted diffractions of the signals.

The H-plane pattern of the antenna in the form shown in Figure 6 has been measured outdoor due to the relatively large distance to its far-field zone. On the other hand, the E-plane pattern has been measured in an anechoic chamber since in this case the distance to its far-field zone is smaller than the chamber’s dimensions. The measured H-plane pattern is plotted in Figure 7(a) where only the main lobe and the first few sidelobes are shown for clarity, while the E-plane pattern is shown in Figure 7(b). The measured gain, -3 dB H-plane beamwidth, -3 dB E-plane beamwidth and the first H-plane sidelobe level are 22.5 dBi, 2°, 20°, and -10 dB, respectively. In addition, the measured VSWR and TX-RX antenna coupling are found to be 1:1.2 and less than -70 dB, respectively.

A field test of the INDERA radar with the reported antenna has been carried out on board a vessel cruising around the Jakarta bay. The antenna has been installed at an elevation of app. 4 m above sea level. The PPI display of the radar is depicted in Figure 8 where the detection result of the radar using the reported antenna can be observed. It is shown in the figure that vessels of various sizes and bearings within a range of 3 nm around the radar can be clearly detected.

5. Conclusions

A microstrip-patch-array offset-fed reflector antenna for FMCW radar has been reported. To the best knowledge of the authors this kind of antenna is here applied for the first time in FMCW radar. The reported antenna has been integrated with the Indonesian FMCW maritime radar INDERA. A field test on board a vessel has demonstrated satisfactory detection capability of the radar using the reported antenna.

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References

Figure 1: Prototype of INDERA

Figure 2: Concept of the microstrip-patch-array offset-fed reflector antenna of INDERA.

Figure 3: Microstrip patch array of INDERA and its feed system.

Figure 4: H-plane radiation pattern of the patch module.

Figure 5: Computed H-plane pattern of the whole microstrip patch array (4 x 8 elements) without reflector.
Figure 6: Antenna prototype of INDERA.

Figure 7: (a) Measured H-plane pattern and (b) measured E-plane pattern of the array with reflector.

Figure 8: Example of detection result of INDERA on board a vessel in the neighbourhood of the main harbour of Jakarta, Indonesia. Using the reported antennas elevated 4 m above sea level, vessels of various sizes and bearings are clearly detected within the range of 3 nm.