

Development of Coastal Radar Network at Sunda Strait

**Mashury Wahab*, Deni Permana Kurniadi, T. T. Estu, D. Mahmudin,
Yudi Yulius Maulana, Sulistyaningsih**

Research Center for Electronics and Telecommunication-Indonesian Institute of Sciences (PPET-LIPI),
Kampus LIPI, Jl. Sangkuriang Building 20, 4th floor, Cisitu, Bandung 40135, Indonesia
Phone: +62-2504660 Fax:+62-250-4659

*Corresponding author, e-mail: mashury.wahab@gmail.com

Abstract

In this paper, development on a coastal surveillance radar network, which is called ISRA (Indonesian Sea Radar), is presented. This radar network was developed for surveillance at the Sunda strait. The radar network monitors the sea traffics and activities at the Sunda strait, which an international shipping route. There were three radars installed for this network. All these radars in this research use FMCW (Frequency Modulated Continuous Wave) technology. This FMCW has an advantage of low power consumption, low cost of operational, longer life time and high reliability. Another important feature of this radar is the LPI (Low Probability of Intercept) capability, where the signal transmission of this radar cannot be easily detected by a radar detector (Electronic Support Measure) so that this radar can be used for a covert operation. Detected targets by radars are shown on the display and on the web based display for the radar network. These three radars on the remote sites can be monitored and controlled via an internet connection from the control room in our Bandung office, which is 300 KMs away. The results of this research and development show the Indonesian capability to build a complex system such as a chain of coastal surveillance radar network. The knowledge obtained from this research will be used to develop more advanced radars for different applications.

Keywords: coastal surveillance, FMCW technology, radar network, Sunda strait.

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1. Introduction

Indonesia territory is surrounded by many countries including Singapore, Malaysia, Philippine, New Guinea and Australia. There are a lot of activities occurred in the Indonesian waters. The Sunda strait is an international waterway with the traffic of ships is very high. The security and transportation safety can be increased by the use of coastal radar along the Indonesian coastal lines and at the remote Island close to boundary regions.

Surveillance and navigation of Indonesian waters, which consist of more than 17.000 islands and 2/3 of Indonesia territory are seas, will be greatly helped by the use of marine radar. Medium and long range radars on coastal areas can be used to monitor the seas up to tens of nautical miles or until the border of economic exclusive zone. Fix and transportable coastal surveillance radars have been developed by the PPET-LIPI using FMCW technology and these are primary researches at the PPET-LIPI.

Radio Detecting and Ranging (Radar) is a technology that is very famous and reliable for identifying unknown objects. The Radar were developed and widely used in many applications such as for air surveillance, weather predictions, traffic controlling, military applications and so on [1, 2]. Recently, research on radar is still being conducted to improve its performance such as increasing the resolution of radar, the accuracy of radar, improve the performance of the radar antenna system and so on [3, 4]. Furthermore, the performance of the radar systems can be improved by adopting optical technology for data transfer and signal processing. Also the scanning system to improve the ability of the antenna system [5, 6].

In this paper, development on a coastal surveillance radar network system, which is called ISRA (Indonesian Sea Radar) is discussed. The radar network system contain of three radar systems where are placed at 3 sites as shown on Figure 1. Each of Radar works at a frequency X-band (9.3-9.5 GHz). The coverage of each radar is average 14 KMs, it depends on the height of the tower. The radar network system was developed aims to reach a larger coverage area be compared a radar system. The radar network system was also developed to

facilitate the monitoring of vessel traffic in the Sunda Strait which is an international shipping line by placing the display and control of the radar systems of remote radar system by using the Internet network.

These radars was developed by use FMCW (Frequency Modulated Continuous Wave) technology. The FMCW technology have advantages of low power consumption, low cost of operational, longer life time and high reliability. Also this technology is hard detected by a radar detector (Electronic Support Measure) so that this radar can be used for a covert operation [6].



Figure 1. Locations of the Radar Network System at the Sunda Strait (Selat Sunda)

2. Basic Theory

2.1. Radar

Radar stands for radio detecting and ranging. Radar is a remote sensing system that is able to detect and determine the distance of an object using electromagnetic waves. Wavelength used is the radio wave spectrum, the width of the spectrum between 105 km to 0.1 cm (3 Hz - 300 GHz). Radar systems typically work at the microwave frequencies [7-16]. Radar system is divided into two main parts: the transmitter and receiver. Radar detection results will be displayed by the display unit that processes the signals received from the receiver to the information, in the form of images and data, making it easy to be analyzed by the user. Block diagram of the Frequency Modulated Continuous Wave (FMCW) radar system and its waveform, in general, can be seen in Figure 2.

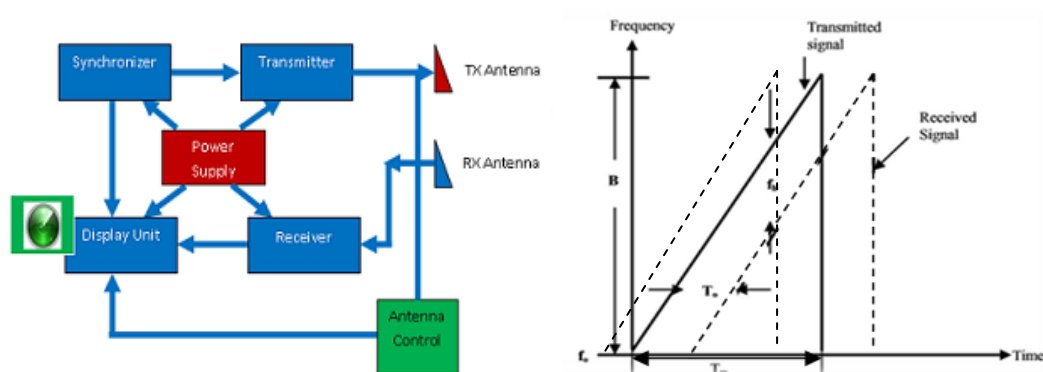


Figure 2. Block Diagram of the FMCW radar system and Waveform

2.2. FMCW (Frequency Modulated Continuous Wave) Radar

In the FMCW radar system, the energy is emitted along or nearly all the time. This means that at least 10% of the time spent by the signal to reach target. This is a very large percentage compared to that of normally used in radar pulses, where the energy emitted is usually less than 0.1% of the time. Thus, to obtain the same average received by the target, the pulse radar requires much higher transmitter output power than that of an FMCW radar transmitter [7-16].

2.3. Computation of Distance to Horizon

The radar range distance is also determined by the height of radar antenna position to sea level, the height of the target in the distance and also the curvature of the earth factor. Range distance is called distance to the horizon. Geometrical horizon distance can be seen in Figure 3.

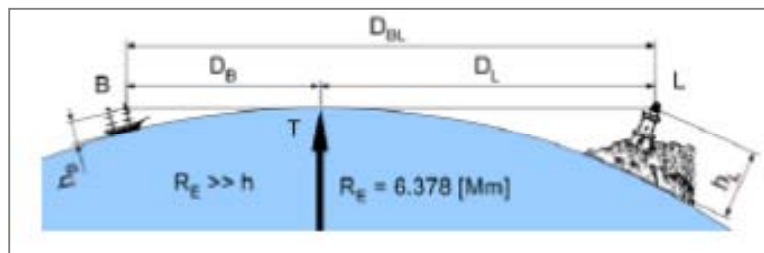


Figure 3. Based on the theory of distance to horizon formula is as follows [1]:

$$D_{BL}[Km] = D_B + D_L = \sqrt{(2xR_xh_B) + h_B^2} + \sqrt{(2xR_xh_L) + h_L^2} \sim 3.57(\sqrt{h_B} + \sqrt{h_L}) \quad (1)$$

$$D_B[Km] = \sqrt{(2xR_xh_B) + h_B^2} \sim \sqrt{2x6.378xh_B} = \sqrt{12.756xh_B} = 3.57\sqrt{h_B}$$

$$D_L[Km] = \sqrt{(2xR_xh_L) + h_L^2} \sim \sqrt{2x6.378xh_L} = \sqrt{12.756xh_L} = 3.57\sqrt{h_L}$$

$$D_{BL}[Km] = 3.57(\sqrt{h_B} + \sqrt{h_L})$$

$$D_{BL}[Km] = 3.57(4+3.16) Km = 25.569 Km$$

where:

D_{BL} = distance to the horizon

h_B = high target/ship = 16 m

h_L = Radar antenna height = 10 m

3. System Design

The general specifications for the coastal surveillance radar can be described as follows [4], [8-9]:

1. Transmitter:
 - a. Frequency: X-Band (9.3-9.5 GHz).
 - b. Ranges: 48 NM, 24 NM, 12 NM, 6 NM, 3 NM, 1.5 NM.
 - c. Output power: 2/10 Watt.
2. Receiver:
 - a. IF bandwidth: 512 kHz.
 - b. Number of range cells: 1024.
 - c. Range cells: 125 m, 62 m, 31 m, 12 m, 6 m.
 - d. PC-Based processing system.
 - e. Standard PC display.
 - f. Maximal beat frequency 2 MHz.
 - g. Beat signal sampling by 16 bit ADC
3. Frequency Generation

- a. Main frequency generator DRO (dielectric resonant oscillator).
 - b. FM – Modulation.
 - c. Linear saw-tooth by using DDS (direct digital synthesizer).
 - d. Sweep (Sweep Repetition Frequency): 1.5 KHz.
 - e. Fixed sweep time of 0.66 mS.
 - f. Frekuensi Sweep: 2MHz, 4MHz, 8MHz, 16 MHz, 32 MHz.
4. Antenna:
- a. Microstrip Patch array with gain ~ 30 dB.
 - b. Dual antenna configuration for transmit and receive.
 - c. Azimuth range: 180 degree
 - d. Elevation range: -5 degree up to 10 degree
 - e. Beamwidth: < 1 degree.
 - f. Vertical beamwidth: ~10 degree.
5. Software : IMO Standard + ARPA+ ECDIS
6. Features of the coastal Radar
- a. Low transmit power (≤ 10 W)
 - b. Low Probability of Intercept (LPI) Radar
 - c. No interference to other Radars
 - d. Target tracking
 - e. Doppler capability
 - f. Able to be integrated into a Radar network

4. Development of the ISRA Radar Network

Three coastal surveillance radars have been installed at the Sunda strait. The location was chosen because there are a lot of sea traffics, where Sunda strait is one of the international routes in Indonesia and there are busy connecting transportations between Java and Sumatra islands. These three locations can be reached by land transportation from our office PPET-LIPI in Bandung with a distance of about 300 KMs. The three locations are Anyer, Merak and Lampung Selatan. These three radars can be connected and monitored remotely via internet connection from the office in Bandung. The following figures show the installed radar network.

Figure 1 shows the locations of these three radars that close to the Sunda strait. The coverage of these radars is like a triangle where one point at the southern part of Lampung province, the other two points is located at the northern part of Banten province. It is expected that these radar network can monitors the sea traffic along the Sunda strait, which is an international route. Anyer radar station is depicted on Figure 4.



Figure 4. Anyer Radar Station

This station has a small shelter for keeping the radar equipment. The Lampung Selatan radar station is shown on Figure 5. A permanent small house was constructed for this site so that this radar site can be used for several years. The other radar station is Merak radar station,

where this site was established in 2010. The radar at this Merak site has been running since 2011 for the purpose of radar running test and field test. This Merak site is in a straight line from the Lampung Selatan without any obstructions. While from the Anyer site to the Lampung Selatan site, there are a few small islands that can obstruct the coverage. The Merak radar station is shown on Figure 6.



Figure 5. Lampung Selatan Radar Station



Figure 6. Merak Radar Station

Figure 7 shows the control system of the radars installed in the network. Several parameters such as power level, attenuation and temperature can be adjusted and detected. An example of radar display is depicted on Figure 8. For information, all radars installed in this network use the same hardware configuration and software so that the appearance of the radar display will be the same. Some detected targets will be shown as small dots, large dots, and lines, which are depend on the shape and size of the targets. The Automatic Identification System (AIS) monitors the information sent by the ships such as ID, destination, type of cargo. This AIS is a supplementary to the radars. Figure 8 shows the display of this AIS for the Sunda Strait.

Connection of these three radar sites is provided by an internet connection where data from each site can be sent to a repository (cloud). The data link is also used to control the radars by the control room in our office which is located about 300 Kms away from these sites. Data will be stored to a database. Figure 9 depicts an example of data base and web based display of data collected from the radar network. The detected targets will be plotted on the display overlaid with the geographical map of the radar network locations. This radar network display can be accessed any where via an internet connection.

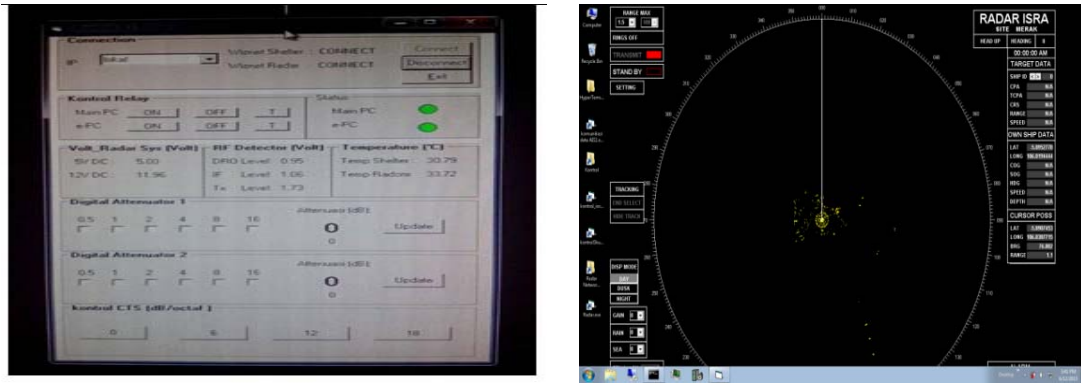


Figure 7. Example of Radar Display and control system at the Radar Network

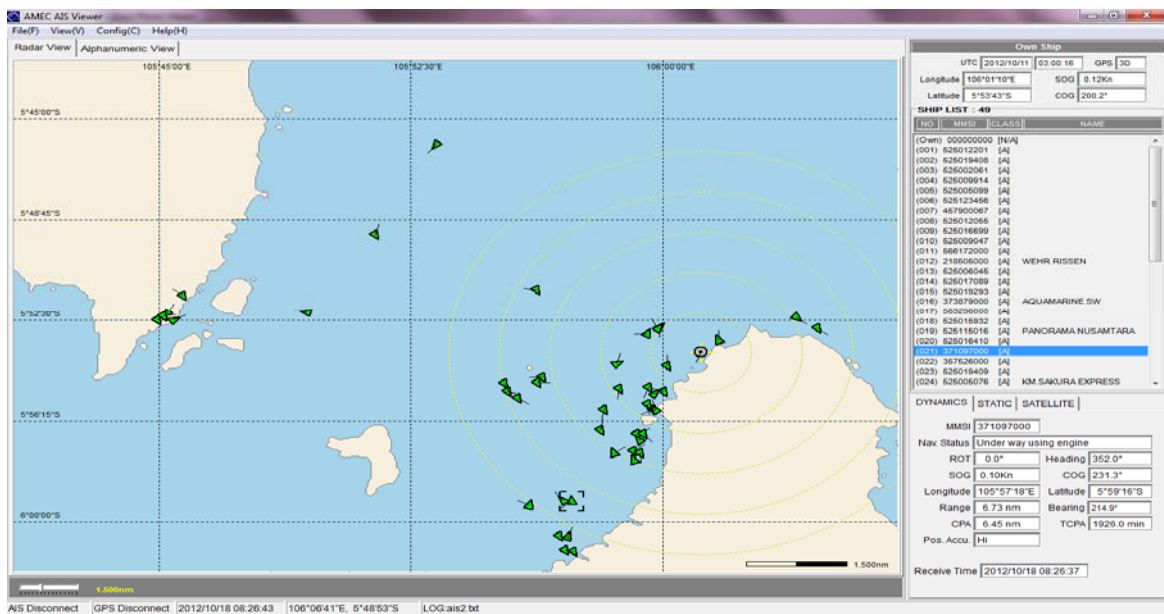


Figure 8. Display of Automatic Identification System (AIS) application software

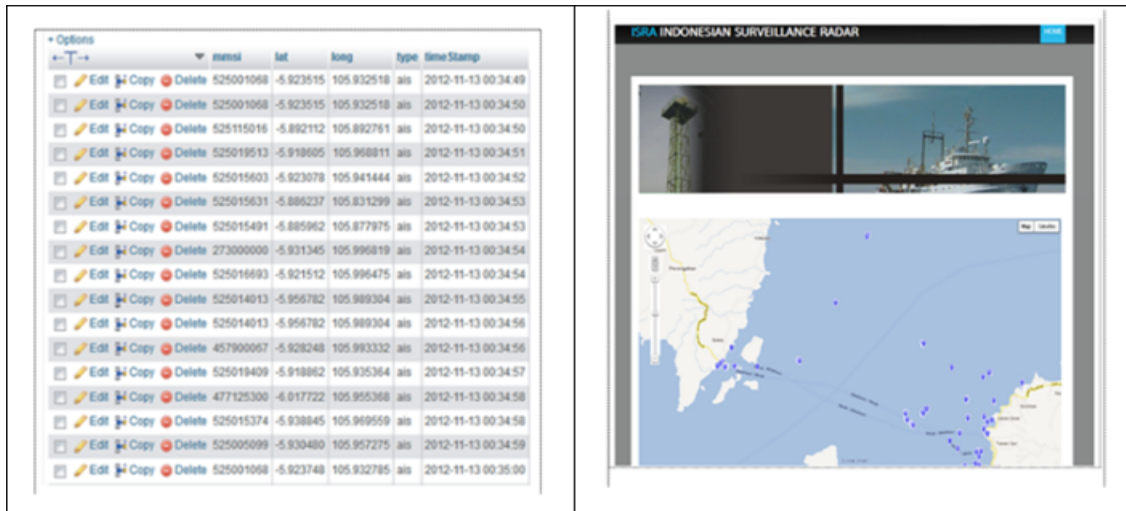


Figure 9. Database dan web display for the Radar Network

5. Results and Discussion

Development of coastal surveillance Radar network has been presented. There are three Radars installed for this network at the Sunda Strait. The locations for the network are in Anyer, Merak and Lampung Selatan. Based on Equation (1), the height of Radar tower in Anyer is 10 meter so that the distance to horizon is about 11 KMs. While, the height of tower in Merak and Lampung Selatan is 15 meter with a distance to horizon is about 14 KMs. The distance from one end of the Java Island to the Sumatra Island for the ferry crossing is about 25 KMs. Thus, the coverage of these three Radars is enough to cover the area within the ferry crossing and the international route. Data collection and testing are still ongoing in order to improve the Radar performance and to monitor the traffic.

Some features of this radar network have been presented. The radar has a facility to control the transmitted power, to monitor the environment, and to detect failing components and modules. Radar display shows that some detected targets can be captured by the radar. Results of radar detection depend on the traffic intensity and weather. At night, the traffic intensity increases. The radar facility is equipped with the AIS in order to provide additional information on ships passing through this Sunda strait. The radars are connected via an internet connection where data are collected and stored to a database. The radars also can be controlled via this internet connection. The results of detection of this radar network is displayed on the web so that it can be accessed anywhere.

6. Conclusion

Research and development on coastal surveillance radar, which is called ISRA (Indonesian Sea Radar), have been presented. This type of radar was developed for a radar network at the Sunda strait. The radar network monitors the sea traffics and activities at the Sunda strait, which an international shipping route. There were three radars installed for this network. All these radars were used FMCW (Frequency Modulated Continuous Wave) technology. From the tested results in the Sunda strait, the coverage of the radar depends on the height of the tower, the transmitted power, the antenna isolation, the receiver sensitivity and dynamic range, and the signal processing algorithm to mitigate the clutter, interference, and false alarm. Detected targets are shown on the display and on the web based display for the radar network. These three radars on the remote sites can be monitored and controlled via an internet connection from the control room in our Bandung office, which is 300 KMs away. The results of this research and development show the Indonesian capability to build a complex system such as a chain of coastal surveillance radar network. The knowledge obtained from this research will be used to develop more advanced radars for different applications.

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