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Low Cost Antenna Design for the Application of Over the Horizon Surface Wave Radar

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Abstract*: The need for surveillance and security in Indonesian water region which can monitor activities of distance object such as illegal fishing, foreign vessels violation, piracy of vessels and smuggling can be done by using radio wave. Maritime radar over the horizon (OTH) surface wave is able to detect the existence of foreign vessels in Indonesian waters. Based on this, the study aimed to design a low cost antenna namely Yagi - Uda linear array antenna at 15 MHz frequency at frequency range 6 – 24 MHz for the application of over the horizon radar. Yagi - Uda antenna is superior in the spread of wave suitable to OTH Radar characteristic over the sea surface and big gain. Yagi - Uda antenna develops rapidly in communication system makes it applied in many modern communication devices nowadays. This antenna was designed and simulated using Simulator Ansoft High Frequency Structure Simulator (HFSS) version 13. The simulation result of the antenna design after doing optimization was return loss (S11) = -29,62 dB, VSWR = 1.068 and gain = 2,413 dBm.

***Keywords* : Gain, HFSS, High Frequency, OTHRSW Radar, Yagi-UdaAntenna**

I. INTRODUCTION

The development of technology and electronic communication occurs rapidly. This is marked by the existence of new technologies in different fields. The development of communication technology that can control the area of the Republic of Indonesia is still very limited so that the sea water area of Indonesia is prone to illegal fishing, foreign vessels violation, piracy of vessels, and smuggling. The appropriate surveillance system using radar communication system can operate 24 hours so that illegal action can be prevented. This radar operates at HF frequency band 3 – 30 MHz[1]. The government of the Republic of Indonesia commits to realize the self-reliance in the acquisition of sophisticated modern defense equipment. Various efforts have been done to secure the Indonesian sea region. One of the solutions is the development of technology.

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The appropriate solution to develop at present especially the security of the sea area is by using Early Warning Radar System technology having range Over the Horizon that is about 100 – 400 nautical mile[2]. The Early Warning Radar System was functioned as a warning provider placed at strategic points along the border area. The establishment of Early Warning Radar System was meat to control, detect, and identify in detail all violation activities such as illegal fishing, piracy, etc. This radar will operate accurately to replace patrol ships that can save the use of fuel in security of sea operation and vessels used particularly to drive away and capture foreign vessels[3].Radar technology is studied continuously to improve performance and distance range and identify objects. The development of radar especially at the field of maritime and defense in Indonesia was begun by coast surveillance radar such as Indonesian Radar (INDRA) and Indonesian Surveillance Radar (ISRA) to control ships in Indonesian waters, but the range was still very limited to tens nautical miles. The distance range can be determined from power transmitted, width of signal band received, antenna gain, antenna polarization, and antenna width. The designed antenna for the OTH radar has been developed widely such as log periodic antenna, parabola antenna, dipole antenna, and omni antenna.Some of them have small dimensions and some have big dimensions. The most known antenna model is Yagi-Uda antenna. This antenna has better direction effect and gain. At this study the Yagi-Uda antenna module design at 6 – 24 MHz was discussed with operation frequency 15 MHz for the application of OTHRSW radar.

II. LITERATURE REVIEW

Radar is an electromagnetic system technology used to detect and find target position by receiving echo signal from the target area. Radio wave transmitted from an object can be received by radar and analyzed to know the location, distance and types of object. Although the signal received was relatively weak, the radar can easily detect and strengthen the signal.The result of radar detection will be displayed by the display unit processed the received signal from the receiver into information, both in the forms of pictures and data so that it is easy for the users to analyze. The range was determined by the transmitted power, bandwidth signal transmitted/received, antenna gain, antenna polarization, and width of antenna[4].The radar system has three main components: transmitter, antenna, and receiver[5]. Antenna is a component that can determine the performance of radar system comprehensively in detecting target in certain distance. There are many types of antennas depending on their use and frequency such as microstrip antenna, Yagi antenna, monopole antenna, etc. Yagi-Uda antenna consists of dipole arranged from several elements: reflector, driven, and directory[6].

The reflector element functions as power for maximum signal transmission to target and driven element functions as receiver of power from the transmitter device to be transmitted[7]. In general the reflector element will be longer than the driven element and the directory element will be shorter than the driven element. The driven element is an element provided with electric voltage. The Yagi antenna model with three elements can be seen in the following figure.

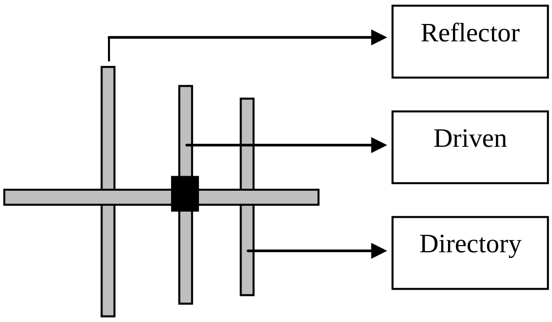

Fig. 1. Basic of Yagi Antenna

Radiation from an antenna is relatively wide which means that it has low gain. For long distance communication at the radar application, very high antenna gain is needed[8]. In order to get such antenna, the size can be enlarged to exceed the wave length[9].

The arrangement of several antennas according to particular geometric and electric configuration is called array antenna. The antennas of this group are usually similar, for examples, dipole array and microstrip array[10]. This is prioritized for easy analysis and fabrication. Total electric field of the array is superposition vectorially produced from each antenna. In producing a particular radiation diagram to prioritized direction to get high gain, the vector field was done by superposition constructively, whereas to other transmission, low gain superposition should be done destructively[11].

There are five parameters that can be used to control the radiation diagram of the array[12]:

1. Geometric configuration array
   a. Linear: the antenna was arranged in a particular line
   b. Circular: arranged on a circle
   c. Planar: arranged on a two dimensions field.
2. Distance from one antenna element to another element.
3. Current amplitude or voltage was put on antenna element feeding.
4. Current phase or voltage on feeding.
5. Radiation diagram from each element.

The estimation formulation to calculate the element length and a two element Yagi antenna spacing is as follows[13]:

Reflector = 0.495 x λ (meter)
Driven = 0.473 x λ (meter)
Directory = 0.44 x λ (meter)

Gain of a Yagi antenna was obtained by maximizing important element factors of Yagi parasitic antenna[14]. In improving the gain, The change of the driver arrangement of the Yagi antenna will not give much effect on its gain. The most effective way was by doing appropriate arrangement of the size and distance in placing the element.

The antenna parameters used to test or measure the antenna performance was antenna frequency, VSWR. bandwidth, antenna gain, and radiation pattern[15].

a. VSWR (Voltage Standing Wave Ratio).
   This is a comparison of voltage between maximum rms voltage (|V|max) and minimum (|V|min) occurred at mismatch channel.
b. Bandwidth
   Bandwidth antenna is defined as range of frequency with several characteristics according to fixed standard. Bandwidth can be considered as range of frequency, at the other part is used as mid frequency in which the antenna characteristics can be accepted as the mid frequency value for Broadband antenna, the bandwidth was regarded as a comparison of upper operation frequency and lower frequency[16].
c. Gain
   There are two types of gain at an antenna: absolute gain and relative gain. The absolute gain at an antenna is defined as comparison between intensity at certain direction with radiation intensity obtained when the received power by antenna was radiated isotropically.
d. Radiation Pattern
   Radiation pattern of an antenna can be defined as radiation pattern of mathematic function or illustration graphically from the radiation characteristics of an antenna as function of a space coordinate. At a comprehensive case, the radiation pattern was calculated/measured at far distance field and illustrated again as a coordinate of direction.

III. ANTENNA DESIGN

The planning shape of Yagi-Uda antenna with HFSS was done by determining the design dimension and antenna specification from the referential reference. With the simulator of ansoft HFSS v.13, important parameters show performance of an antenna: return loss (S_{11}),Voltage Standing Wave Ratio (VSWR), gain, and radiation pattern.

1. Antenna Specification
   Parameters in designing the antenna are:
   a. Working frequency (fo) was 15 MHz
   b. Types of antenna: Yagi-Uda
   c. Long dimension of elements consist several dipole antennas. Modification step was then done to obtain optimum result.
   d. Input impedance used in designing Yagi-Uda antenna was 50Ω.
2. Calculating dimension
   In designing an antenna, there are several parameters that must be calculated:
   a. Determining the wave length of the antenna which can be made by using the following equation:

$$\lambda_0 = \frac{c}{f} = 20 \text{ meters}$$

Determining the length of reflector by using the following equation:

R = λ x 0.495= 9.9 meters

b. Determining the driven length by using the following equation:

0.473 x 20 meters= 9.46 meters

c. Determining the director length:
D1=0.44 x 20 =8.8 meters
D2=0.435 x 20 =8.7 meters
D3=0.43 x 20 =8.6 meters
D4=0.425 x 20 =8.5 meters
D5=0.42 x 20 =8.4 meters
D6=0.415 x 20 =8.3 meters
D7=0.41 x 20 =8.2 meters

d. Distance between elements = 2.5 meters

The design of Yagi Uda antenna system is as follows:

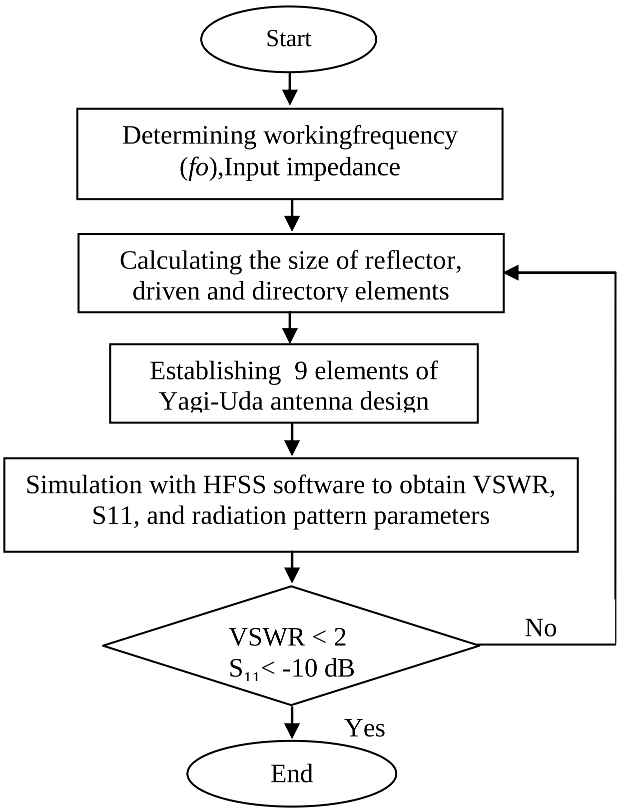

Fig. 2. Flowchart of Antenna Design

The result of further calculation was simulated by using HFSS simulator to find out the values of VSWR, S_{11}, gain and radiation pattern. If the obtained result based on simulation did not show the standard value of antenna, optimization of elements length was done, distance between elements, and addition of element expected had maximum result through trial and error process so that the design fulfilling the standard specification criteria was obtained.

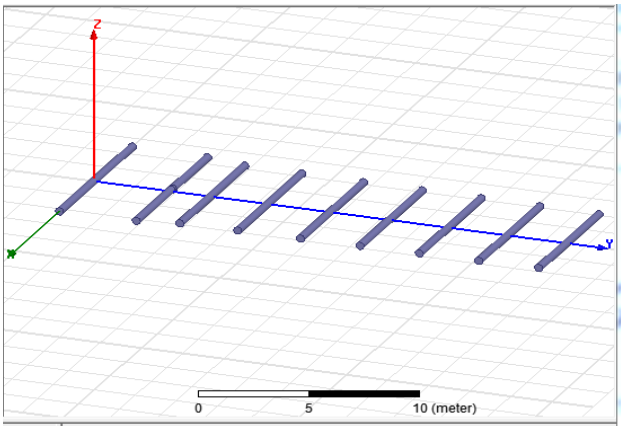

Fig. 3. Yagi-Uda 9 Elements Antenna

IV. SIMULATION RESULT

The obtained simulation result from the calculation and designing theoretically may not be the result of optimum calculation. In order to obtain maximum result, distance optimization can be done between elements and add directory element. The analyzed antenna after putting the frequency range determined from 6 MHz to 24 MHz. The output result showed in return loss (S_{11}), VSWR, gain, and radiation pattern graphic forms.

From the simulation result, it was found that the value of return loss was -29,62 dB at the frequency 15 MHz can be seen in Figure 4.

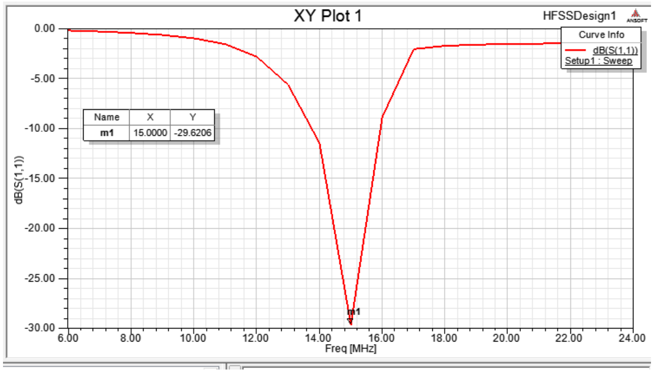

Fig. 4. Graphic of Yagi Antenna S_{11}

From the simulation result, the value of VSWR was 1,068 at the frequency 15 MHz can be seen in Figure 5.

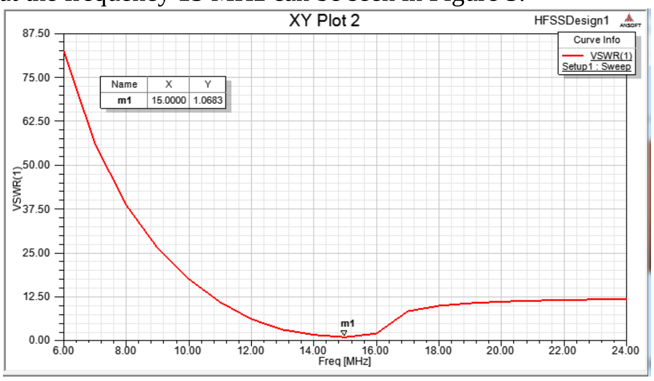

Fig. 5. VSWR Graphic

The simulation result shows the radiation pattern and the size of gain can be seen in Figure 6.

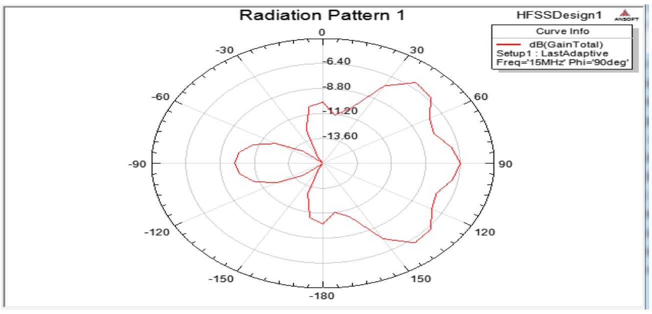

Fig. 6. Radiation Pattern

Figure 7 shows the gain value of the simulation result was 2,410 dB and radiation pattern produced was directional.

Figure 7 is the gain produced from Yagi-Uda 9 elements antenna.

The simulation results can be shown in tabular form as follows:

Table I. Simulation Result of the Antenna Design

Frequency	Return Loss (S11)	VSWR	Power Gain
15 GHz	-29,62 dB	1,068	2,413 dBm

All the simulation results above have shown that Yagi-Uda linear array antenna at 15 MHz can be designed for the application of Over the Horizon Surface Wave Radar. .

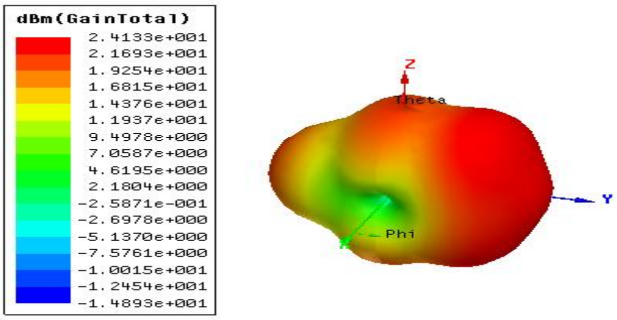

Fig. 7. Antenna Gain

V. CONCLUSION

It was found that the designed and simulated low cost antenna namely Yagi-Uda antenna can work at frequency 15 MHz by having gain as much as 2,413 dBm and can be applied for Over The Horizon Surface Wave Radar. In addition, other simulation result of the antenna design after doing optimization was return loss (S11) = -29,62 dB and VSWR = 1.068. The performance of this antenna is better by the choice of material and use of array technique combining in several modules of Yagi-Uda antenna so that theoretically it can have maximum gain to detect target in the distance of 100 – 400 nautical miles. Yagi-Uda antenna has a big gain and radiation pattern suitable with OTH radar transmitted from the coast. But the gain can be affected by quality of material, length of element, distance between elements and addition of element.

VI. FUTURE WORK

This study can still be developed further by making the hardware of the transmitter, receiver, and software of radar image.

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