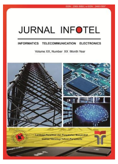

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Modeling and Simulation of Dual-band Yagi Antennas for Voice Communication on Microsatellite

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Abstract — The design of the dual-band Yagi antenna was developed to support voice communication through voice repeaters on microsatellites in the UHF-VHV frequency from ground stations. The Yagi antenna is a type of half lambda dipole antenna that makes it easy to obtain direction and increase gain. The antenna is designed using the method of moment through a simulation with the CST microwave studio software application. The design used as an antenna element material is a type of copper pipe cylinder. The results of the Yagi antenna design in the VHF frequency consist of one driven element, one reflector element, and three director elements, while the UHF frequency consists of one reflector element and seven directors. The results of simulation parameters are obtained, such as Bandwidth of return loss below 10 dB is 4.3 MHz (VHF), and 44 MHz (UHF), VSWR (2:1) is 1.24 (VHF) and 1.36 (UHF), Gain is 9.19 dBi (VHF) and 10.5 dBi (UHF) and Beam Width is 64 degree (VHF) and 58 degree (UHF). The suitability of the antenna design target is dual-band, and Gain value in UHF is higher than VHF.

Keywords – Yagi antenna, VHF, UHF, Simulation.

I. INTRODUCTION

Microsatellite technology developed by the National Institute of Aeronautics and Space (LAPAN) Indonesia continues to increase its use in various information and communication needs. LAPAN-A2 microsatellites have voice communication access technology with the presence of voice repeaters on satellites. In line with the development of microsatellite technology in Indonesia, the National Aeronautics and Space Institute (LAPAN), in collaboration with the ORARI organization (Amateur Radio Organization of the Republic of Indonesia) launched the LAPAN-A2 / ORARI [1] satellite. LAPAN-A2 Satellite Technology is equipped with a VR (voice repeater) application. The Voice Repeater has a function as a transmission repeater, where radio signals will be re-transmitted in voice mode in amateur radio communications [1,2]. The voice repeater charge occupies the VHF spectrum (Very High Frequency) for uplinks at frequencies of 145.880 MHz and UHF (Ultra High Frequency) for the downlink is 435.880 MHz [2]. Figure 1 shows flow of VR communication system via satellite for voice through ORARI radio using LAPAN-A2 satellite access. For access, uplinks are used to send signals to satellites in VHF, and access downlinks are used to send signals from satellites to receivers in UHF. The availability of such access must be supported and utilized with the existence of transceiver communication devices on ground stations [2,3]. The Yagi antenna is a dipole type antenna that is given an additional parasitic element in the form of reflector and director so that it can easily produce a Gain value in a certain direction [4,5,13,14]. The purpose of the design of the Yagi antenna is dual-band on the transceiver is to gain access to transmission from the ground station to the satellite repeater load [5,7,8,15]. To build a dual-band Yagi antenna in this study, CST microwave studio 2017 software simulation method was used. The simulation method was carried out to obtain the right antenna model or structure based on the target parameters expected by the system [6]. The target parameter value results from the design of a dual-band antenna, namely: bandwidth from return loss below 10 dB, VSWR (Voltage Standing Wave Ratio) below 2

(2:1) and Gain values less or equal to 10 dBi [9,13,14]. The dual-band Yagi antenna structure consists of two models, namely: an antenna structure that operates in the VHF and UHF spectrum. The Yagi VHF antenna design model is known to be a 2-meter antenna (2m band), while the Yagi UHF antenna is known as a 70 cm antenna [10,11]. As a dual-band antenna for both models, a driven element is used together on the side of the 2 m antenna.

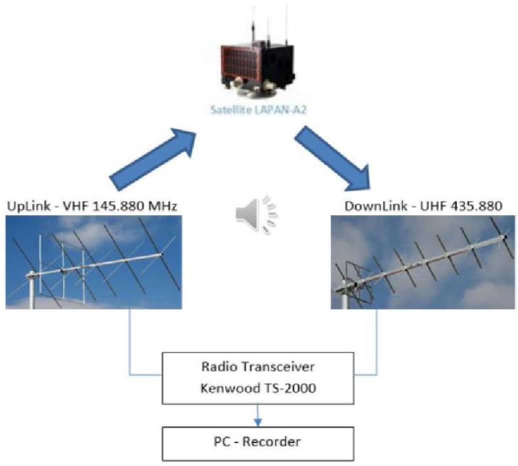

Fig.1. The Flow of VR Communication System Via Satellite [2]

The research of the dual-band Yagi antenna is expected to be a solution for voice communication through the LAPAN-A2 microsatellite voice repeater. So that voice communication that can be reached by ORARI can reach a wider area.

II. RESEARCH METHOD

Figure 2 shows a structure of the Yagi antenna with the placement of each element. Dimensionally these three elements have differences on the long side. As a reference, the side length of the reflector element and the director are the lengths of the driven element. The length of each element is determined by the value of the wavelength or lambda (λ) obtained from the working frequency [9,10,11].

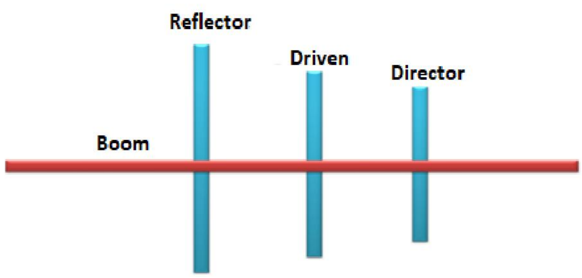

Fig.2. The Structure of the Yagi Antenna

Figure 3 shows a graph of the relationship between the number of elements to the Gain parameter value. To obtain Gain parameters on Yagi antennas is strongly influenced by the number of elements [10].

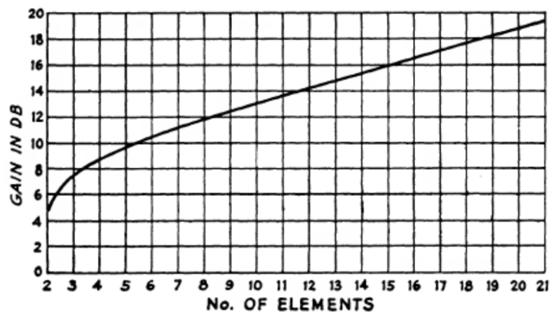

Fig.3. Graph of the Number of Elements to the Gain Value [10]

The design concept of a dual-band Yagi antenna is made with some different elements according to the operation frequency. In order to reach the target Gain parameter, the antenna is designed with the number of five elements for the VHF frequency and eight elements for the UHF frequency. Fundamentally from a Yagi antenna is a type of Lambda half dipole antenna that is determined by value-driven. To determine the value of the wavelength or lambda (λ) for a driven using (1) [10]:

$$\lambda = 300/f\ (\text{MHz}) \quad (1)$$

Where λ is the wavelength in meters, and f is the frequency in MegaHertz. For the element driven length can be obtained through (2) [10,13,14]:

$$L = 0.5 \times K \times \lambda \quad (2)$$

Where L is the driven length in meters, and K is the velocity factor in the metal used at 0.95.

The length of the reflector element is generally designed 7% longer than the driven element. Whereas for the first director length, it is used 5% shorter than the driven element. Setting distance or position between elements is regulated through the lambda (λ) limit. For the distance between the driven element and the reflector element is 0.2λ - 0.25λ and the distance between the driven element and the first element of the director is as far as 0.1λ - 0.15λ. Likewise for the distance of the first director with the second director is 0.15λ - 0.2λ and the second director with the third director is 0.2λ - 0.25λ and so on according to the number of directors used in the design [10,12].

III. RESULT

A. Antenna Design

To realize the design of a Yagi antenna in this study used a simulation method. Simulations were carried out using CST microwave studio software. In the CST application, the antenna design begins with a choice of frequency. Next include the elements of the material type as well as the size of the diameter of the cylinder pipe according to the choice of the type of copper as shown in Fig.4. Then set the position of the cylinder reflector position and set the pick point at the drive as a feeder as shown in Fig.5.

The design of a dual-band Yagi antenna is built through two stages, namely: first for a VHF antenna with a working frequency of 145.880MHz and second for a UHF antenna with a working frequency of 435.880 MHz. The basic step for designing an antenna is to determine the length value of the driven element. This is because the driven element used is the VHF frequency. The length of the driven element can be analyzed through the calculation of equations (1) and (2). Then the calculation is made of the length of the reflector and director elements.

B. *Length of Element*

Figure 6 and Table 1 show the structure model and element value of a simulated dual-band antenna design. For a VHF antenna (2 m band) a structurally designed model consists of one unit reflector element and three director units in addition to its element driven. The driven element length obtained is 962 mm. By the concept of the dipole antenna Yagi the length of the reflector element is 7% of the length of the driven, then the length of the VHF reflector element is 1022 mm. While for the length of the first director element 5% shorter than the length of the driven element, the length of the element of the first director is 918 mm. Furthermore, for the second and third directors each is 905 mm and 984 mm.

This is the case with the design of the UHF antenna (70 cm). The antenna structure model consists of 8 element units with 1 unit element as a reflector and 7 elements director. For long values, the reflector and director elements are almost the same. The wavelength or lambda with the UHF frequency divider, then the element length is 320 mm.

C. *Position of Element*

Placement of the initial position on the Yagi VHP antenna design (2 m band) for a reflector is placed at zero, where the position is placed as far as 0.2λ to 0.25 λ from the driven element. The simulation results obtained a 280 mm position from the reflector. Furthermore, the location of the director towards driven is placed as far as 0.1λ to 0.15λ. The simulation results obtained 430 mm position from the reflector. It is also the same as placing the position of the position between the first director and the second director as far as 0.15λ to 0.2λ. The simulation result between the second director of the reflector is the position of 950 mm. For Yagi UHF antennas (70 cm) the placement or position of the reflector and director elements is the same. The same calculation is carried out on the zero position of the VHF antenna reflector location. In the design through the simulator the position of each reflector and director is measured against the zero position of the VHF reflector seen in Table 1. The closest position of the UHF reflector is the position of 160 mm, and the farthest position is located at the seventh director as far as 1450 mm. For the diameter size specifically the driven element is 12.7 mm. While for other elements the same size is 9.5 mm.

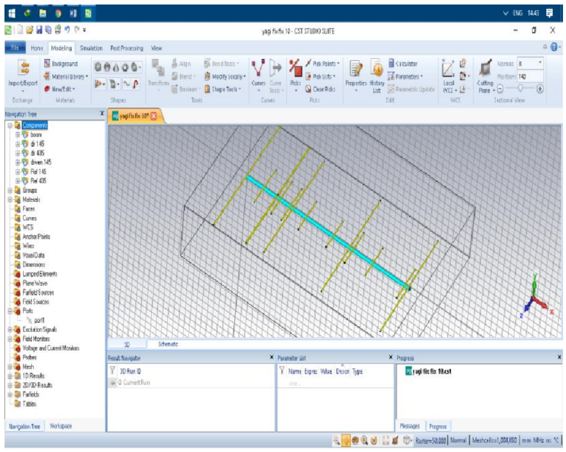

Fig.4. Design of Antenna Dual-Band in the Simulator

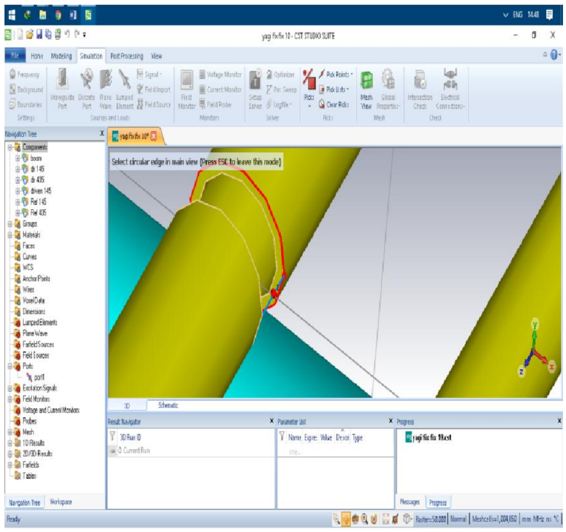

Fig.5. Position of Feed Point for a Driven Element in Simulator

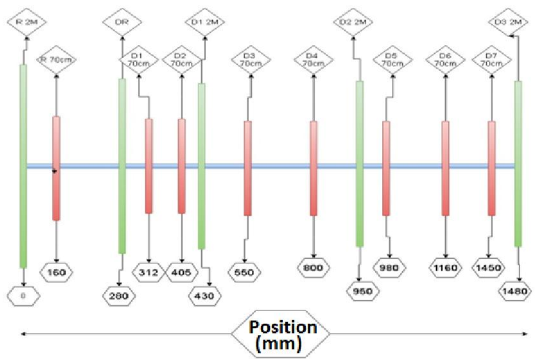

Fig.6. Design of Structure Element for Dual-Band Yagi Antenna

Table 1. Dimensional of Yagi Antenna Elemets

Element	Length of Element (mm)	Position of Element (mm)
Reflector/R (2m)	1022	0
Reflector /R (70cm)	320	160
Driven/Dr	962	280
Director/D1 (70 cm)	319	312
Director/D2 (70 cm)	312	405

Element	Length of Element (mm)	Position of Element (mm)
Director/D1(2m)	918	430
Director/D3 (70 cm)	274	550
Director/D4 (70cm)	257	800
Director/D2 (2m)	905	950
Director/D5 (70cm)	298	980
Director/D6(70cm)	263	1160
Director/D7 (70cm	283	1450
Director/D3 (2m)	894	1480

IV. DISCUSSION

The performance of the design of the dual-band Yagi antenna is shown on several antenna parameters through simulation. Some parameters are measured, such as bandwidth from return loss (S-Parameters) below 10 dB, standing wave ratio between 1 to 2, beamwidth and gain. The bandwidth of a parameter can be calculated using (3) [14],

$$BW = f_H - f_L \quad (3)$$

Where BW is bandwidth in Hz, f_H is height frequencies in Hz, and f_L is low frequencies in Hz. Fig.7 shows a graph of return loss versus frequency of the simulation results. Fig.8 shows a graph of VSWR versus frequency of simulation result. The bandwidth of the return loss (S-parameters) below 10 dB measured there are two. The first bandwidth is 8.18 MHz (VHF) with a resonance frequency of 145.880 MHz on a minimum return loss of 16.37 dB (VSWR = 1.36). The second bandwidth is 23 MHz with a resonance frequency of 435.880 MHz (UHF) on a minimum return loss of 19.54 dB (VSWR = 1.24).

Figure 9 shows the radiation pattern of the simulation results at the frequency of 145 MHz, and Fig.10 shows the radiation pattern at a frequency of 435 MHz. The maximum directivity (gain) obtained is 9.1 dBi (VHF) and 10.5 dBi (UHF). Fig.11 and Fig.12 show of the linear polarization (dipole) simulation results at frequencies of 145 MHz and 435 MHz. The measured beam width (3 dB) is 64.2 degrees (VHF) and 58.9 degrees (UHF).

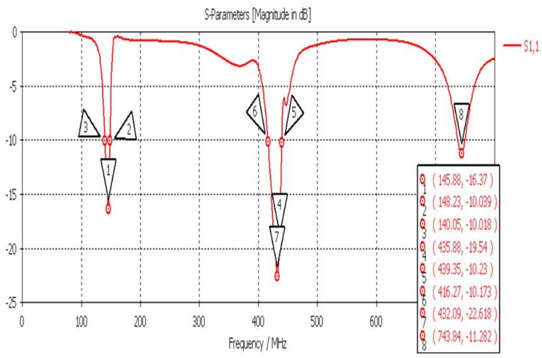

Fig.7. Graph of Return Loss Vs Frequency Simulation Result.

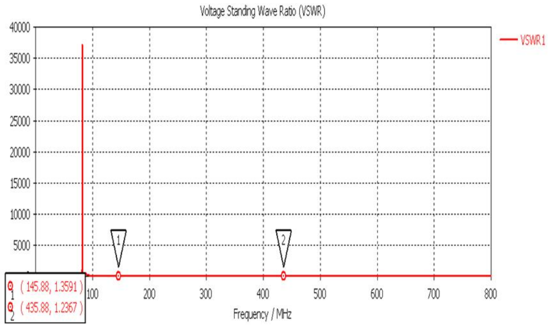

Fig.8. Graph of VSWR vs Frequency Simulation Result.

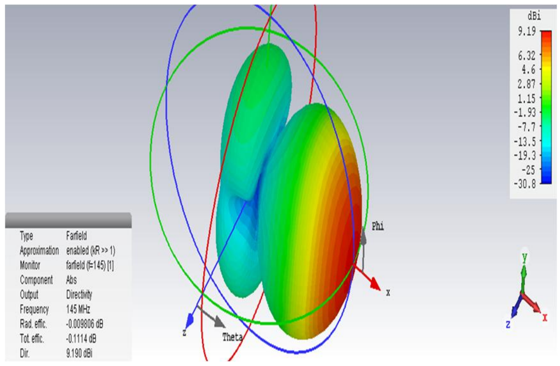

Fig.9. Radiation Pattern at 145 Mhz Frequency Simulation Result

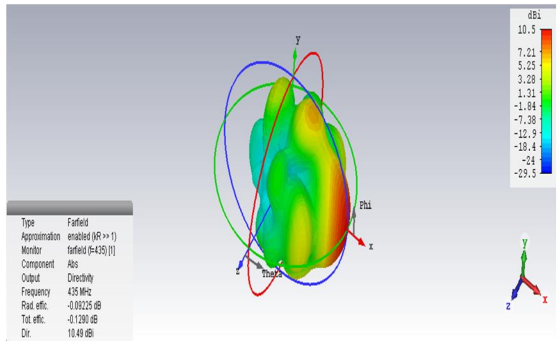

Fig.10. Radiation Pattern at 435 Mhz Frequency Simulation Result

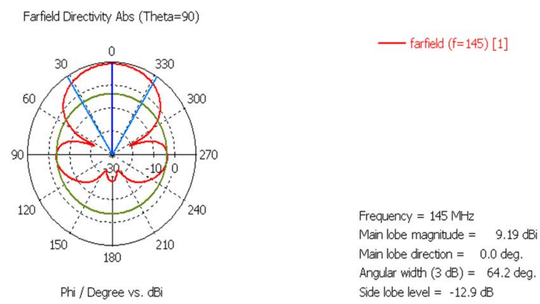

Fig.11. Polarization at Frequency 145 Mhz Simulation Result

Yagi antenna modeling for UHF and VHF in this research shows the form of linear parallel structures. Some director antenna elements arranged at UHF frequencies have more director elements with higher Gain values compared to VHF frequencies. This is suitable for UHF frequencies as receivers of transmission power from satellites (downlink). Analysis of the parameters of the simulation results shows the bandwidth of the return loss (S-parameters) below 10 dB for both the VHF and UHF frequencies occupying the narrowband spectrum. The radiation pattern produced shows directional antennas at both frequencies.

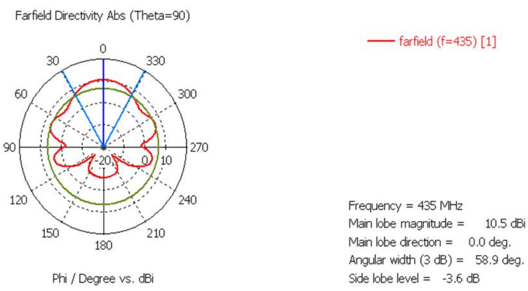

Fig.12. Polarization at Frequency 435 Mhz Simulation Result

Table 2 shows the performance of the simulation antenna design. The narrowband nature of the bandwidth (s-parameter) for the two frequencies is seen below 100 MHz (VSWR 2:1), where VHF is 18 MHz, and UHF is 23 MHz. The radiation intensity from the measured radiation pattern results for the VHF frequency is 9.19 dBi (Gain), and the UHF frequency is 10.5 dBi (Gain). The directional nature of the vertical polarization at measured beam width (angular width -3dB) for VHF frequencies is 64 degrees, and for UHF frequencies is 58 degrees.

Table 2. Parameters Antenna of Design

Parameters	VHF Frequency	UHF Frequency
Bandwidth	8.18 MHz	23 MHz
VSWR	1.4	1.23
Gain	9.19 dBi	10.5 dBi
Beam width(3dB)	64.2^0	58.9^0
Polarization	linear	linear

V. CONCLUSION

The results of the Yagi antenna design simulations have characteristics as antennas operating in the VHF and UHF frequencies. The bandwidth obtained by the UHF frequency is higher than the VHF frequency of 64% (VSWR 2:1). The resulting radiation pattern shows the maximum directivity value (Gain) at the UHF frequency 12.5% higher than that in VHF. In polarization the same result is linear, where the directional value of the beamwidth of main lobe at level 3 dB at UHF is 8% smaller than VHF. The Yagi antenna design results are as expected and need to be followed up through the manufacturing process so that they can be tested as actual antennas.

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