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Directional Flat Panel Antenna Design for Analog to Digital TV Broadcast Transition in Indonesia

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Abstract: The television industry in Indonesia is currently in a transition phase from analog broadcasts to digital broadcasts. This study aims to design and manufacture directional flat panel antennas that optimize digital broadcast reception at frequencies in the 450-700 MHz range and produce optimal gain, return loss, bandwidth, and VSWR (voltage standing wave ratio) values in the manufacture of antennas using PCB with double layer FR4 Epoxy type with a thickness of 1.6 mm and a dielectric constant value of 4.4. The design of this dimensional antenna uses mathematical analysis. It is simulated with Ansys High-Frequency Structural Simulator (HFFS) software version 13 until the final optimization results are obtained according to the desired specifications. The design results with Ansys HFSS obtained a frequency range of 395 MHz to 821 MHz, in other words, a wide bandwidth of 426 MHz, a gain of 3.68 dB, a return loss of -14.0447 dB, and a VSWR of 1.4954. The results of the handmade antenna design obtained a frequency range between 410 MHz to 805 MHz or a bandwidth of 395 MHz, a gain of 3.85 dB, a return loss of -18.612 dB, and a VSWR of 1.26. Based on the test analysis results, the directional flat panel antenna design has better parameter values than previous studies.

Keywords: *Flat Panel Antenna, DVB-T2, Digital TV, HFSS, Directional*

1. Introduction

Frequency includes limited resources in telecommunication. The 5th generation of communication growth requires a rearrangement of radio frequencies in Indonesia. In turn, analog TV frequencies operating on VHF and UHF frequencies were stopped from broadcasting in Indonesia [1], [2]. Analog TV broadcasts were abolished and replaced with digital TV. The technology used in Indonesia is DVB-T2. Besides providing better picture quality, digital TV broadcasts provide significant bandwidth efficiency compared to analog TV. Digital TV requires lower bandwidth compared to Analog TV [3].

In the 2019 Ministry of Communication and Informatics survey, there is data that in Indonesia, around 66% or approximately 44.5 million households in Indonesia are still using Analog TV broadcasts. Meanwhile, approximately 26 percent already use subscription television broadcasts (cable, satellite dish, or streaming) [1], [2].

One problem that arises in the transition from Analog TV to Digital TV is that the existing TV antenna is still in the bandwidth range of Analog TV. For optimization, an antenna is needed that works according to the bandwidth of the Digital TV antenna. In addition, the dimensions of the existing antenna are quite space-consuming. In addition to disturbing neighbours, TV antennas often take up more space in the household. Moreover, this is problematic for residents living in flats or apartments.

This research will minimize the size of antenna dimensions. This research proposes a flat panel UHF directional antenna that works in the frequency range of 450-700 MHz. This antenna has a minimalist dimensional design but better gain than existing antennas. The goal is that the image quality of the broadcast is clean, and the sound is evident [4].

2. Basic Theory

2.1 Microstrip Antenna

Microstrip antennas have minimalist shapes and sizes, so they are usually used for government and commercial applications. Microstrip antennas consist of thin patches placed half the wavelength above the ground plane. Between the patch and ground plane separated by the dielectric sheet (otherwise known as substrate) [5], [6].

2.2. Flat Panel Directional Antenna Design

The directional flat panel antenna is an antenna with a rectangular patch shape or commonly called a rectangular patch [7]. Flat panel directional antennas can be modified

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to produce the desired range of impedance values, radiation patterns, and operating frequencies [8]–[11]. To determine the patch antenna width can be used Equation 1 [12].

$$W = \frac{c}{2 f_r \sqrt{\frac{\varepsilon_r + 1}{2}}} \quad (1)$$

where:

f_r : antenna frequency (Hz)

ε_r : substrate dielectric constant.

To determine the length of the patch antenna, it is necessary to determine the value of ΔL which is the increase in length from L due to the fringing effect, which can be formulated as Equation 2 [12].

$$\Delta L = h \times 0.412 \times \left| \frac{(\varepsilon_{eff} + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{eff} - 0.258)(\frac{W}{h} + 0.8)} \right| \quad (2)$$

where:

ε_{eff} : dielectric constant

h : substrate thickness

w : substrate width

The dielectric constant can be calculated by Equation 3.

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \sqrt{1 + 12(\frac{h}{W})} \quad (3)$$

The effective length (L_{eff}) can be calculated by Equation 4.

$$L_{eff} = \frac{c}{2 \times f_r \times \sqrt{\varepsilon_{eff}}} \quad (4)$$

where:

L_{eff} : Effective length

Then the patch antenna length can be calculated using Equation 5.

$$L = L_{eff} - 2\Delta L \quad (5)$$

Based on the above formula, f_r is the value of the specified frequency, ε_r is the value of the dielectric constant of a material used, then h is the value of the thickness of the material used. After determining the patch width and patch length values, the next step is to determine the values of the ground plane length (L_g) and ground plane width (W_g) using Equation (6) and Equation (7).

$$L_g = L + 6h \quad (6)$$

$$W_g = W + 6h \quad (7)$$

After determining the size of the ground plane, the following procedure is to determine the size of the transmission line. There are four transmission lines from an antenna: line feeding, coaxial feeding, and aperture terminal feeding to proximity coupled feeding, but this study uses line feeding using Equation (8) and Equation (9).

$$W_{Z0} = \frac{377 x h}{\sqrt{\varepsilon_r z_0}} \quad (8)$$

$$B = \frac{377\pi}{2 Z_0 \sqrt{\varepsilon_r}} \quad (9)$$

Equation (10) to Equation (12) is a calculation to find the size of a e feeding from a rectangular patch. Where L is the length of the feeding line, and W is the width of the feeding line.

$$W_{stripline} = \frac{2h}{\pi}(B - 1 - \ln(2B - 1) + \frac{\varepsilon_r - 1}{2\varepsilon_r}) \ln(B - 1) + 0.39 + \frac{0.61}{\varepsilon_r} \quad (10)$$

$$\lambda_d = \frac{\lambda_0}{\sqrt{\varepsilon_r}} \quad (11)$$

$$L_T = \frac{\lambda_g}{4} \quad (12)$$

2.3. Antenna Characteristics

2.3.1. VSWR

VSWR is the comparison ratio between the incident wave and the reflected wave, in which the two waves resemble standing waves. The transmission line has two voltage waves, namely the transmitted voltage (V_{0+}) and the reflected voltage (V_{0-}) which is called the voltage reflection coefficient Γ [13].

2.3.2. Return Loss

Return loss is the power lost due to a mismatched impedance between the transmission line and the input impedance of the load (antenna). Return loss has a relationship with VSWR, which is caused by mixing between the transmitted and reflected waves, determining the matching between the transmitter and the antenna [14].

2.3.3. Bandwidth

Bandwidth is the width of the operating frequency range of an antenna object, where the work of the antenna associated with several characteristics (such as input impedance, beamwidth, polarization, gain, efficiency, VSWR, and return loss) meets standard specifications. The bandwidth value is obtained from an antenna's known lower-frequency and upper-frequency values . The definition of lower frequency is a value at the initial frequency of the working frequency of the antenna, while the upper frequency is a value at the final frequency of the working frequency of the antenna [14].

2.3.4. Antenna Gain

Antenna gain is the character of an antenna in its ability to direct signal radiation or receive a signal from a specific direction. The antenna's gain in a particular direction is expressed in the intensity ratio to the intensity of the radiation obtained when the power received by the antenna is emitted isotopically [15]–[17].

2.3.5. The Radiation Patterns

The radiation pattern describes the radiation associated with the emission strength of the radio waves emitted by the antenna at different angles. The radiation pattern is known as Half Power Beamwidth (HPBW) and First Null Beamwidth (FNBW). Half Power Beamwidth (HPBW) is the width of the beam that separates between two points, half the main emission power of the radiation pattern. At the same time, First Null Beamwidth (FNBW) is the width of the beam between the two directions on the main lobe where the radiation intensity is zero [14], [18]–[20].

2.4. Digital Video Broadcasting Second Generation Terrestrial (DVB-T2)

DVB-T2 (Digital Video Broadcasting–Second Generation Terrestrial) is a tool and equipment for terrestrial broadcast television transmitters that use digital modulation to transmit digital data, audio, and video signals using the DVB-T2 standard. Before discovering DVB-T2, the standard was DVB-T (Digital Video Broadcasting Terrestrial) for analog transmitters. Initially, analog TV transmitters with one frequency channel could only be used for one broadcast TV transmitter. However, with DVB-T2 technology, one frequency channel can be used for one or more TV broadcasts together and can include new techniques that were not previously available in the DVB standard [2]–[4].

3. Method

The flowchart for designing microstrip antennas for the research made is shown in Figure 1. The first thing to do is to determine the initial specifications for the directional flat panel antenna, as shown in Table 1.

Table 1. Antenna target specification

Parameter	Value
Operations Frequency	575 Mhz
Return Loss	< -10 dB
VSWR	< 2
Bandwidth	250 MHz
Gain	> 3 dBi

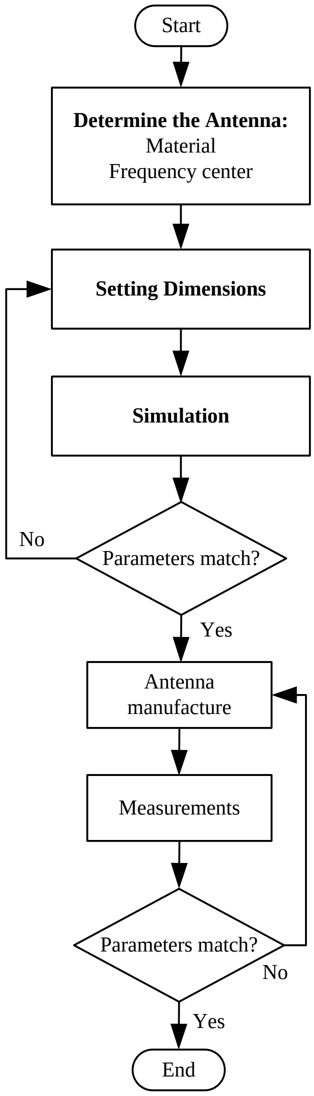


Fig. 1. Antenna Design Flowchart

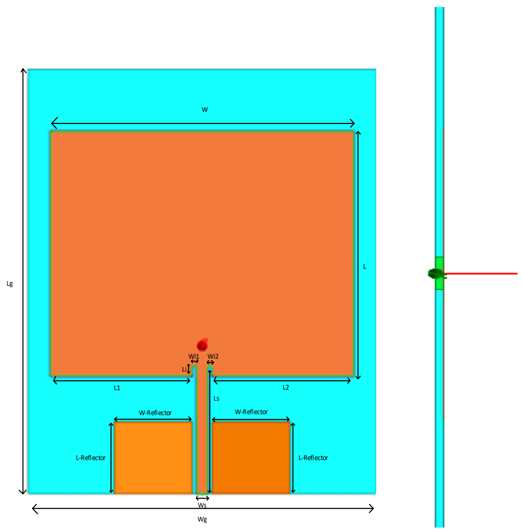
After determining the antenna specifications, the next step is to design a directional flat panel antenna by calculating the dimensions of the patch, substrate, transmission line, and ground plane of the directional flat panel antenna. Table 2 shows the dimensions of the directional flat panel antenna.

Table 2. Directional Flat Panel Antenna Dimensions

Parameter	*Dimension (mm)*
W	125
L	125
L_1	57,5
L_2	57,5
W_{i1}	3,5
W_{i2}	3,5
L_i	3
W_s	3

L_s	60
$W_{substrat}$	250
$L_{substrat}$	430
W_{ref}	30
L_{ref}	90
Range between *Reflector* and *Feedline*	18,5
W_{d1}	100
L_{d1}	112
Range direction d_1	20
W_{d2}	80
L_{d2}	112
Range direction d_2	60
W_g	250
L_g	50

Figure 2 shows the design of a flat panel directional antenna from the final simulation using Ansys HFFS V.13 software.



(a) (b)

Fig. 2. Flat Panel Directional Antenna Design (a) Front view (b) Side view

After getting the dimensions of the antenna then, do the simulation in the software, while the return loss and bandwidth results obtained from the best simulation are shown in Figure 3.

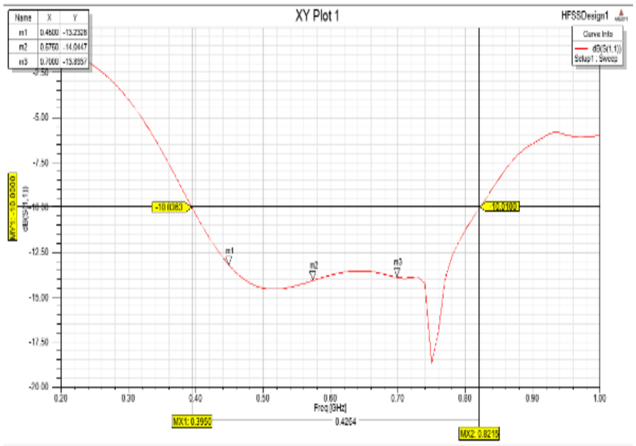


Fig. 3. Simulation Results of Return Loss and Bandwidth

Figure 3 shows the return loss value of the antenna at a frequency of 575 MHz of -14.0447 dB with a bandwidth of 426 MHz at an upper frequency of 821 MHz and a lower frequency of 395 MHz. The return loss value results are under the expected specifications, less than -10 dB.

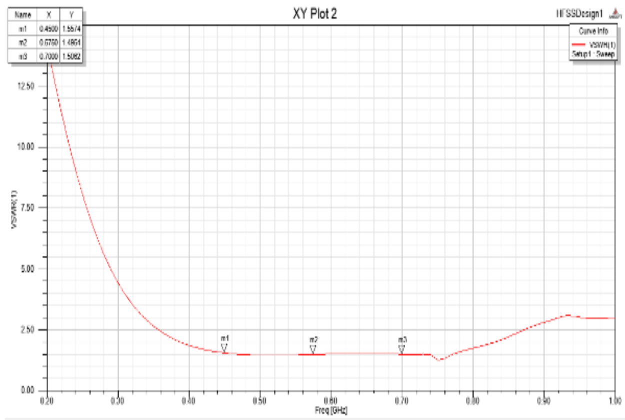


Fig. 4. VSWR Simulation Results

Figure 4 shows the VSWR value obtained at 1.4954. The value of the VSWR parameter is under the expected specifications of less than 2 dB.

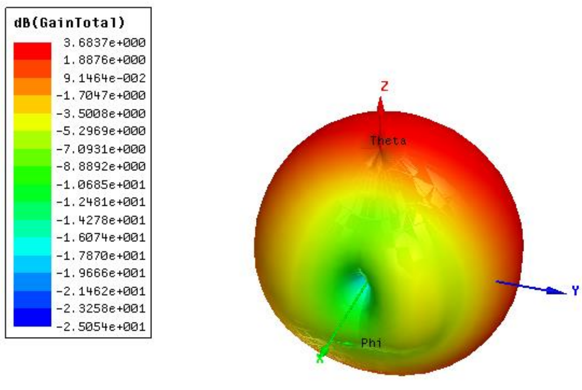


Fig. 5. VSWR Simulation Results

Figure 5 shows the antenna gain value at a frequency of 575 MHz which is 3.6837 dB. The gain parameter values results follow the expected specifications, which are above 3 dB.

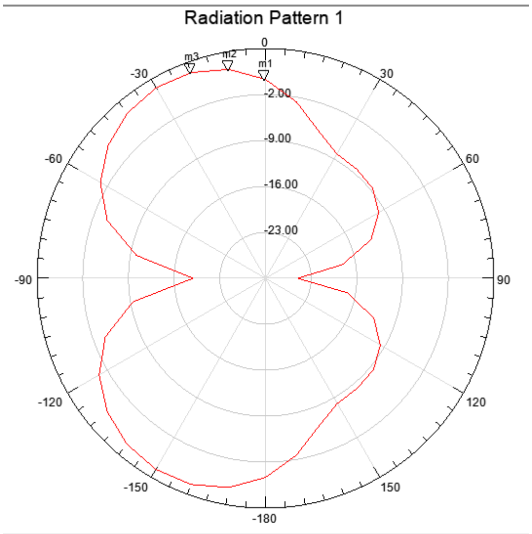


Fig. 6. Radiation Pattern Simulation Results

Figure 6 shows that the radiation pattern obtained at the antenna with a frequency of 575 MHz is omnidirectional with an HPBW of 54 degrees. After designing the antenna utilizing simulation and optimization, obtaining good parameter values , and meeting the expected antenna specifications, antenna fabrication is the next step. The steps taken when fabricating by handmade the antenna are:

1. Prepare some tools and materials. The tools and materials needed include SMA female, lossy double layer FR-4 PCB, oracle sticker cutting connector, solder, tin, $FeCl_3$, file, and sandpaper.
2. Make the antenna size on the PCB using a pencil, followed by cutting the PCB that has been measured according to the design.
3. Remove the rust layer on the PCB by sanding the front and back surfaces of the PCB.
4. Pasting the oracle cutting sticker on the PCB, then dissolving the copper material on the PCB (etching) using $FeCl_3$. The PCB results after copper dissolution can be seen in Figure 7.
5. Install the SMA female connector on the microstrip antenna feed line.

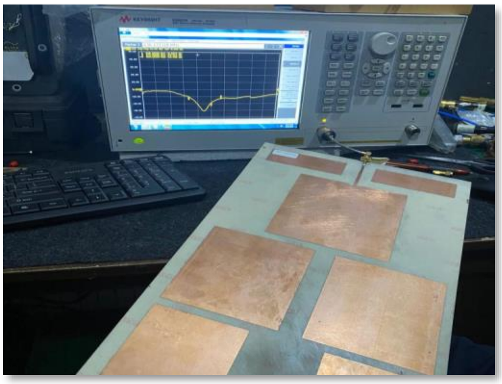


Fig.7. Antenna Fabrication Results

4. Results and Discussion

The most significant in antenna testing, the parameters tested are return loss, VSWR, gain, impedance, and radiation pattern. The results of the return loss value comparison between the simulation and test results can be seen in Figure 8.

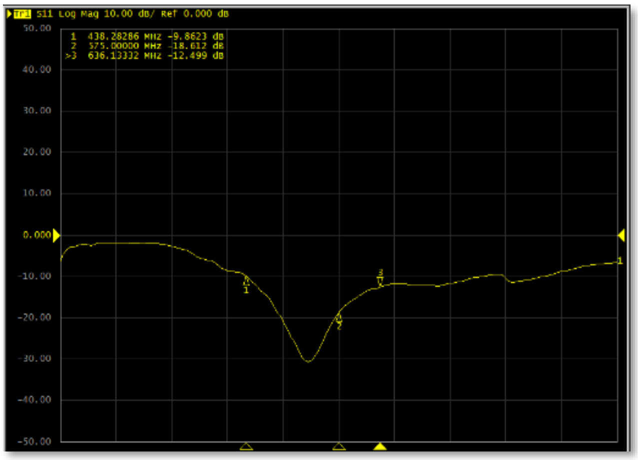


Fig.8. Return Loss Measurement Results

Figure 8 shows the results of a Measurement results after fabricating by handmade the microstrip antenna. The return loss value generated after production at the center frequency of 575 Mhz has a value of -18.612 dB, while the return loss value during the simulation is -14.0447 dB. The results of the comparison of the VSWR measurement results can be seen in Figure 9.

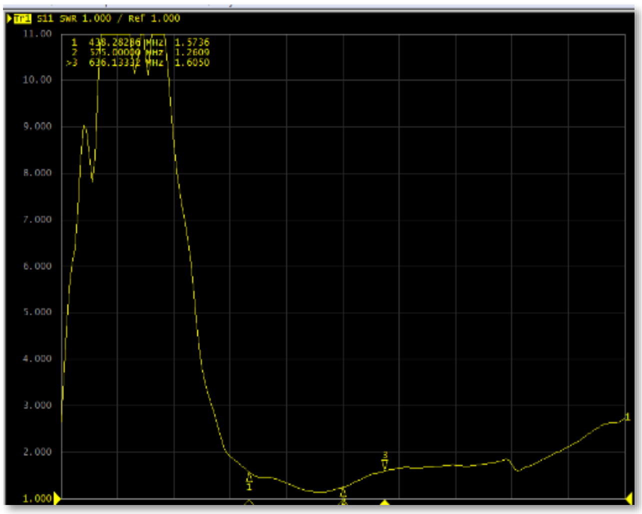


Fig. 9. VSWR measurement Results

Figure 9 shows the results of VSWR measurement results. The comparison between the design and handmade antenna test is 1.2609, while the VSWR value during the simulation is 1.4954. The results of the radiation pattern can be seen in Figure 10. The results of the antenna radiation pattern are omnidirectional, with the HPBW from the azimuth radiation pattern test being 79°.

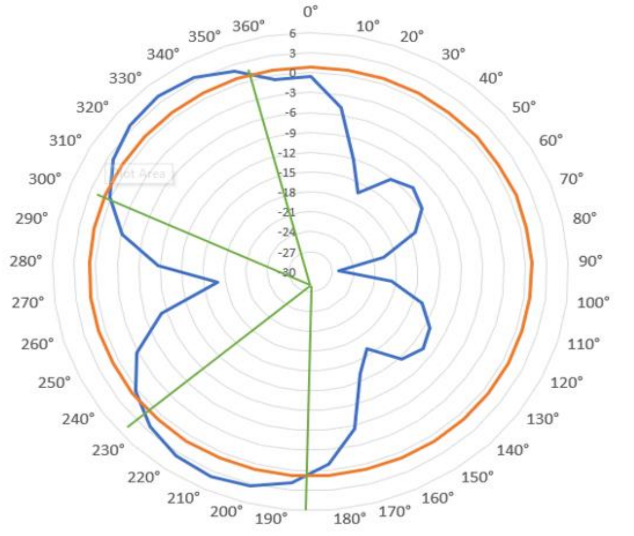


Fig. 10. Results of the Radiation Pattern Test and Half Power Beamwidth

From the results of the antenna testing target at the beginning of the study, namely, return loss less than -10 dB, VSWR less than 2, gain more than 3 dB, and bandwidth 150 MHz. The following is Table 3 of the comparison of the simulation results with the test results. Table 3 shows the relative error in the simulation and test results, where the relative error value in the return loss parameter is 15.567%, VSWR is 3.7%, bandwidth is 2.647%, and gain is 7.35.

Table 3. Relative Error Simulation Results with Testing

Parameter	*Simulation*	*Measurement*
Return Loss	-14,0447 dB	-18,612 dB
VSWR	1,4954	1,2609
Bandwidth	426 MHz	395 MHz
Gain	3,68 dB	3,85 dB

The difference between the design and manufacture of the antenna is due to several factors. The level of precision in making antennas by hand is the main obstacle, such as the accuracy of the transmission line and the failure in soldering the SMA connector. The environmental conditions in the measuring room may not be optimal, and there may be frequent reflections from unexpected objects, such as floors or walls, that need better conditioning.

5. Conclusion

The return loss value at the center frequency of 575 MHz obtained in the simulation using Ansys HFSS v13 software is -14.0447 dB, while the test results after fabrication are -18.612 dB. The bandwidth value at the center frequency of 575 MHz obtained in the simulation using Ansys HFSS v.13 software is 426 MHz in the operating frequency range of 395-821 MHz. The results of the bandwidth on the fabricated antenna cannot be seen from the marking because the position of the marking is not at the highest and lowest frequency points. So, to determine the bandwidth value of fabricated antenna testing based on estimates from the return loss graph. To estimate the range of the highest and lowest frequency points, namely the working frequency of 410-805 MHz with a bandwidth value of 395 MHz. The gain value at a frequency of 575 MHz obtained in the simulation using Ansys HFSS v13 software is 3.6837 dBi. In comparison, the gain in the Yagi antenna fabrication is 3.85 dBi so the design results of this directional flat panel antenna can be used at a frequency of 575 MHz for Digital Video Broadcasting in Indonesia.

Author contributions

Rianto Nugroho: Conceptualization and Methodology **Ruliyanta:** Data curation, Writing-Original draft preparation, Software, Validation, Field study **ER Nugroho:** Visualization, Writing-Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

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