Design and Implementation of Digital TV Antenna with RF Amplification for Channels 478-694 MHz

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ABSTRACT

Digital television is a device used to capture digital TV broadcasts. This type of television employs digital modulation and compression systems to transmit signals containing images, sound, and data to television sets. The technology necessitates a device capable of facilitating digital TV communication functions, with antennas being a crucial communication tool. The biquad antenna, characterized by its loop design with square contour and parallel configuration for reduced impedance, is particularly noteworthy. Against the backdrop of digital television advancement and the imperative for high-quality antennas to ensure optimal signal reception, this research concentrates on the simulation and implementation of biquad antennas within the 478-694 MHz frequency range, aligning with Indonesia's digital TV broadcast standards. The research methodology encompasses simulation using CST Studio to design biquad antenna dimensions and conduct antenna parameter analysis, alongside testing the implemented antennas on digital TVs with RF amplifier installation. Simulation results from CST Studio indicate that the biquad antenna exhibits a VSWR value of 1.64, return loss of -12.26 dB, bandwidth of 114.44 MHz, gain of 9.080 dBi, and a directivity of 9.253 dBi. During application on digital TVs, antennas with RF amplification can capture strong signal strength and quality across all channels displayed on the digital TV screen, ensuring good image quality. Biquad antennas with RF amplification represent an effective solution for enhancing the reception quality of digital TV broadcasts. Proper antenna dimensions and the use of RF amplification can significantly improve signal strength and quality, enabling users to enjoy high-resolution images and stable signals on digital TVs.

Keywords: Digital TV, Biquad Antenna, VSWR, Bandwidth, Gain

1. INTRODUCTION

Digital television is a device used to capture digital TV broadcasts. This type of television utilizes digital modulation and compression systems to transmit signals of images, sound, and data to television sets. The evolution of digital broadcasting involves transforming information into digital signals in the form of data bits, akin to computers [1].

Digital TV broadcasting, or digital broadcasting, is a form of television transmission that employs digital modulation and compression systems to broadcast video, audio, and data signals to television sets. The development of digital television is motivated by external environmental changes, such as saturation in the analog TV market and competition from satellite and cable broadcasting systems. Additionally, advancements in technology, specifically digital signal processing technology, contribute to this evolution [2].

One crucial communication device in the operation of digital TV communication is the antenna. The quality of an antenna significantly affects the received information's quality. The primary function of an antenna is to transmit information by processing electrical signals into electromagnetic waves and sending these waves through the air. Conversely, the antenna also receives electromagnetic waves from the air, processes them back into electrical signals, and plays a role in their transmission. Antennas used in wireless communication always need to have small dimensions while being capable of efficiently receiving and radiating signals [3].

One type of antenna that is currently evolving is the biquad antenna. The biquad antenna is a loop antenna with a square-shaped contour, parallelized to achieve a lower impedance. In this research, the antenna's shape is a rhombus arranged in pairs, referred to as a biquad antenna. The biquad antenna was chosen for its effectiveness in wireless communication. Typically, biquad antennas are constructed using readily available
materials such as copper wire [4]. An ideal antenna is an antenna that can radiate all the power received towards the desired direction or any other direction. In practice, achieving such an ideal condition is not possible, but it can be approximated [5].

An RF (Radio Frequency) amplifier is a device designed to amplify high-frequency (RF) signals received by the antenna for transmission. The RF amplifier is crafted using components with special features and capabilities to amplify signals operating at radio frequencies. An ideal RF amplifier should exhibit high power gain, low noise figure, good dynamic stability, low reverse admittance to isolate the antenna with an isolator, and sufficient selectivity to prevent the entry of intermediate frequency (IF), image frequency, and other unwanted frequencies.

This research focuses on designing a biquad antenna for the 478-694 MHz frequency channel. This frequency range aligns with the latest transition to digital TV broadcasting, which is also in line with the government’s policy of shifting from analog to digital TV. Moreover, this frequency range encompasses nearly all digital TV broadcasts.

2. RELATED WORK
2.1. Previous Research
This study draws upon several earlier research works as reference materials. In a study conducted by Maulana Putra (2020) on the design of biquad antenna with parabolic grid reflector to optimize antenna gain at 450 MHz frequency, the research focused on rural internet applications. The results indicated that the parabolic grid reflector enlarged the bandwidth [4].

Yuyu Wahyu (2016) conducted research on the Koch Fractal antenna with EMC loading in UHF for terrestrial digital television applications. Using a Finite Integration Technique (FIT) based antenna design simulator, the study achieved a bandwidth of 228.6 MHz at VSWR ≤ 1.8, a measured gain of 2.09 dB, bidirectional radiation patterns, and horizontal elliptical polarization [6].

In 2022, Ulfa Natasya conducted a study on the simulation and optimization of 4-element Microstrip dipole antenna at 2.4 GHz frequency. The research involved designing a four-element microstrip dipole antenna using CST Studio Suite 2019 software to operate at a frequency of 2.4 GHz. The design results aligned with initial specifications, enabling the realization of the microstrip dipole antenna at 2.4 GHz [3].

2.2. Theoretical Foundations
2.2.1. Definition of Antenna
An antenna is a component designed to transmit or receive electromagnetic waves. The proper selection, good design, and correct installation of an antenna ensure the performance of the system. As a transmitting antenna, it serves as an electromagnetic transducer, converting guided waves inside transmission cable channels into waves that propagate in free space. As a receiving antenna, it transforms free-space waves into guided waves within the transmission line [7]. With the above definition of an antenna, it is certain that in every wireless communication, there is a component capable of converting guided waves into free-space waves and vice versa, and this component is the antenna.

2.2.2. Biquad Antenna
A biquad antenna is an antenna that consists of two loops, where each loop has a length of ¼ of the wavelength. Generally, a biquad antenna has three basic components: the driver element (connected to the receiver or transmitter), the reflector (a component that reflects electromagnetic waves), and the cable or transmission line [5]. Figure 1 below is one of example from biquad antenna.

![Figure 1. Example of a Biquad Antenna](image)

2.2.3. Antenna Parameters
Antenna parameters are used to test or measure the performance of the antenna. Here are explanations of some commonly used antenna parameters: antenna directivity, antenna radiation pattern, antenna gain, and antenna bandwidth.
a. Directivity

Directivity of an antenna or an array of antennas is measured based on its ability to focus energy in one or more specific directions. The directivity of an antenna will affect how effectively it can direct its signal radiation towards television broadcasting stations, thus influencing the quality of the signal received by the television antenna. The higher the directivity of an antenna, the better it can focus its signal towards television broadcasting stations, thereby impacting the quality of the television signal received.

b. Radiation Pattern

The radiation pattern of an antenna is defined as a mathematical function or graphical representation of the antenna's radiation properties as a function of coordinates. The radiation pattern is a 3-dimensional plot of the signal distribution emitted by the antenna or the 3-dimensional plot of the signal reception level received by the antenna. It explains how the antenna radiates energy into free space or how the antenna receives energy.

Radiation patterns are divided into two types: unidirectional and omnidirectional. Unidirectional antennas have a focused radiation pattern and can reach relatively far distances. On the other hand, omnidirectional antennas have a radiation pattern described as a donut shape, with overlapping centers. Omnidirectional antennas generally have a 360˚ radiation pattern when viewed in their magnetic field plane.

c. Gain

Antenna gain is obtained by measuring the power in the main lobe and comparing it with the power of a reference antenna. Gain in antennas can be measured in units of decibels (dB), dBi, or dBd. If the reference antenna is a dipole, the antenna is measured in dBi. The "d" here represents dipole, so the antenna gain is measured relative to a dipole antenna. If the reference antenna is an isotropic antenna, the antenna is measured in dBi. The "i" here represents isotropic, so the antenna gain is measured relative to an isotropic antenna.

A high antenna gain can extend the signal range and enhance the quality of the received or transmitted signal. In the context of measuring television antenna signals, a high antenna gain can improve the antenna's ability to capture television signals, thereby affecting the quality of the signal received by the television antenna.

d. Bandwidth

The use of an antenna in a transmitter or receiver system is always limited by its operating frequency range. Within this frequency range, the antenna is expected to work effectively to receive or transmit waves within a specific frequency band. In measuring television antenna signals, bandwidth affects how much information can be transmitted via a television signal. This bandwidth also affects the quality of the signal received by the television antenna, especially in the context of digital television where a larger bandwidth can support faster data transmission and better image quality. In digital television systems, wider bandwidth can support the transmission of high definition (HD) signals that require more data. Therefore, bandwidth plays an important role in measuring television antenna signals, especially with the development of digital television technology.

3. METHOD

3.1. Research Location

This research is conducted on Jalan Tekam, Saigon Village, Pontianak Timur Subdistrict, with coordinates at 0°01’59”S 109°22’00”T which is shown in Figure 2 below.

Figure 2. Data Collection Location

In addition to the data collection location, also illustrates the locations of TV stations according to their respective frequencies in digital TV channels. On TVRI station includes several other TV channels including channels RCTI, TVRI KALBAR, TVRI WORLD, TVRI SPORT, NET TV, and RTV. This station is 2.75 km from the research location as shown in Figure 3. On Trans TV stations including channel Trans TV, Trans 7, INEWS, CNN Indonesia, TV ONE, and MNC TV. Trans TV station is 4.13 km from the research location as
shown in Figure 4. Meanwhile, SCTV stations include SCTV channels and is 3.37 km from the research location as shown in Figure 5.

3.2. Antenna Specifications

The following are the specifications for the antenna parameters that will be designed, namely show Table 1:

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Antenna</th>
<th>Expected Specification Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital terrestrial television frequency</td>
<td>(478-694) MHz</td>
<td></td>
</tr>
<tr>
<td>Operating frequency</td>
<td>586 MHz</td>
<td></td>
</tr>
<tr>
<td>Bandwidth</td>
<td>Bandwidth ≥ 100 MHz</td>
<td></td>
</tr>
<tr>
<td>Radiation Pattern</td>
<td>Directional</td>
<td></td>
</tr>
<tr>
<td>VSWR</td>
<td>1≤ VSWR &lt;2</td>
<td></td>
</tr>
<tr>
<td>Gain</td>
<td>Gain ≥ 1.39 dBi</td>
<td></td>
</tr>
<tr>
<td>Antenna Impedance</td>
<td>50 ± 2 Ω</td>
<td></td>
</tr>
<tr>
<td>Return Loss</td>
<td>≤-10,590 dB</td>
<td></td>
</tr>
</tbody>
</table>

3.3. Flowchart Research

The research methodology for this study comprises several stages. It commences with a Literature Review, where research data is gathered from various sources such as books, the internet, articles, and other materials to support the formulation of the research report.

Subsequently, the Experimental Method is employed. This involves designing, simulating, creating, and testing antennas specifically tailored to meet the specifications required for digital TV. The next phase involves Antenna Design. Here, the focus is on developing an appropriate antenna design for digital TV applications. This includes determining the antenna’s operating frequency, specifying its characteristics, selecting suitable materials, and establishing dimensions. The design is then simulated using CST Studio Suite 2019 software. In the event that the antenna fails to meet the desired specifications, an optimization process ensues.

Following the simulation and optimization phases, the designed antenna is realized for digital TV reception. This is to assess the signal quality of digital TV before and after antenna implementation, whether using an RF amplifier or not. Finally, Data Analysis is conducted. This stage involves processing relevant data and facts obtained from the research to effectively address the research question.

As for the research flow, it is presented in the flowchart diagram of the research shown below in Figure 6:
4. RESULTS AND DISCUSSION

4.1. Antenna Simulation Results

The antenna simulation was conducted using CST Studio Suite 2019 software, employing a biquad antenna. Figure 7 below is the design of the biquad antenna in the CST Studio Suite 2019 software.

![Figure 7. Biquad Antenna Design for Digital TV](image)

The antenna design consists of the following dimensions: each side of the biquad is 12.3 cm, the length of the reflector's rod is 39 cm, the length of the reflector is 31.5 cm with a spacing of 6.7 cm, and the air gap or distance between the antenna and the reflector is 5.8 cm. In Figure 7, during the reflector design process, additions were made without perforating the reflector's rod.

Upon simulating the antenna design, several antenna parameters were obtained, such as VSWR and return loss. The VSWR value from the biquad antenna simulation shown in Figure 8 below which is 3.72 at a frequency of 586 MHz, exceeding the antenna design specification as the VSWR value is higher than 2. In Figure 9 displays the return loss value at a frequency of 586 MHz, which is -4.775 dB, also not meeting the desired antenna specifications, necessitating an optimization process.
The gain parameter obtained from biquad antenna simulation of -19.19 dBi at a frequency of 586 MHz are shown in Figure 10, is not meeting the antenna design specification as the gain value is less than 1.39 dBi.

Then in Figure 11 displays the directivity value at a frequency of 586 MHz, which is 4.259 dBi.

4.2. Antenna Simulation Results After Optimization
From the previous data, it was observed that VSWR, return loss, and gain did not meet the antenna design specifications. Hence, further optimization was carried out by changing the distance between the reflector tubes from the initial 6.7 cm to 7 cm. In addition to modifying the reflector spacing, a redesign of the
reflector rod was performed, where each side entering the reflector was perforated, resulting in the design shown in Figure 12.

![Figure 12. Biquad Design with Reflector Tube Spacing of 7 cm](image)

The dimensions of the antenna after optimization are presented in the following Table 2.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value (cm)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pbr</td>
<td>39</td>
<td>Reflector Rod Length</td>
</tr>
<tr>
<td>Psb</td>
<td>12.3</td>
<td>Biquad Side Length</td>
</tr>
<tr>
<td>Pr</td>
<td>31.5</td>
<td>Reflector Length</td>
</tr>
<tr>
<td>Dt</td>
<td>0.6</td>
<td>Tube Diameter</td>
</tr>
<tr>
<td>Jr</td>
<td>7</td>
<td>Reflector Spacing</td>
</tr>
<tr>
<td>Tbr</td>
<td>5.8</td>
<td>Reflector Rod Height</td>
</tr>
</tbody>
</table>

From the optimized antenna design, simulation results were obtained for various antenna parameters such as VSWR, return loss, bandwidth, gain, directivity, and radiation pattern, as shown in the figures below.

![Figure 13. VSWR Values for the Optimized Biquad Antenna](image)

![Figure 14. Return Loss Values for the Optimized Biquad Antenna](image)
Figure 13 shows the VSWR value from the simulation of the directional biquad antenna, which is 1.64 at a frequency of 568 MHz. This value aligns with the antenna design specifications, as the VSWR is greater than or equal to 1 and less than 2. Figure 14 also displays the return loss value at a frequency of 568 MHz, which is -12.26 dB and is in accordance with the desired antenna specifications.

![Antenna Bandwidth](image)

Figure 15. Antenna Bandwidth

The bandwidth of the antenna, measured at the -12.28 dB reference boundary, can be calculated using the formula:

\[
Bw = f_2 - f_1
\]

\[
= 644.81 - 530.26
\]

\[
= 114.44 \text{ MHz}
\]

Then the gain, directivity, and radiation pattern parameters can be shown in the Figure 16, Figure 17 and Figure 18 below.

![Gain Values](image)

Figure 16. Gain Values for the Optimized Biquad Antenna

![Directivity Values](image)

Figure 17. Directivity Values for the Optimized Biquad Antenna
In Figure 16, the gain value of the optimized biquad antenna from the simulation is 9.080 dBi. This value meets the antenna design specifications, where the gain is greater than or equal to 1.39 dBi. Figure 17 represents the directivity value of the antenna at a frequency of 568 MHz, which is 9.253 dBi. Additionally, Figure 18 shows that the radiation pattern has maximum radiating power on one side, indicating a directional pattern, aligning with the specifications.

### 4.3. Antenna Implementation Results on Digital TV

Observations were made by assessing the image quality on digital TV before the antenna implementation. The data regarding the image quality observations on digital TV are shown in the following graphs in Figure 19 and Figure 20 below.

From the strength graph in Figure 19, it is evident that almost all channels have values below 60%. Although there are two channels with strength above 80%, this does not influence the results in Figure 20 because the signal quality percentage remains at 0%, resulting in no image on the digital TV screen.
Subsequent data collection was performed using the antenna. The antenna made from aluminum was a directional biquad antenna. This antenna was implemented on digital TV through its broadcasts on specific channels. Before implementing the antenna, an RF booster was installed on the coaxial cable and the set-top box (STB) for optimal results. Then, the antenna was placed outside the house (outdoor), specifically on the second floor. The realization of the antenna is shown in Figure 21 and Figure 22 when FR Amplifier is applied on STB.

The comparison of signal strength and quality after antenna implementation can be seen in Figure 23 and Figure 24.

![Figure 21. Antenna Implementation](image1)

![Figure 22. Implementation of RF Amplifier on STB](image2)

![Figure 23. Percentage Strength Graph After Antenna Implementation](image3)

![Figure 24. Percentage Quality Graph After Antenna Implementation](image4)
In Figure 23, it is observed that the signal strength after antenna implementation has very good values. Almost all channels have strength above 90%. While there are two channels below 80%, this is still considered good as they are not below 60%. Then, Figure 24 shows the signal quality after antenna implementation. This is noteworthy because before antenna implementation, all signal quality values were 0%. Unlike the strength values, there is still a measurable value even though it is not considered good when the antenna is not implemented.

From the signal quality graph, three types of results are apparent from the percentage obtained during field data collection. First, there are several channels with perfect values, i.e., 100%. Second, there are several channels with values ranging from 70% to 75%, and one channel with a value of 82%. This falls into the category of good signal quality, especially with several channels having perfect values.

However, if we observe closely, the classification of signal quality values follows the categorization of the working frequency of each channel. Channels at a frequency of 538 MHz have very good signal quality. In this frequency, channels include RCTI, TVRI Kalbar, TVRI World, TVRI Sport, NET TV, and RTV. Then, channels at a frequency of 634 MHz also have good signal quality. Channels at this frequency include Trans TV, Trans 7, iNews, CNN Indonesia, TV One, and MNC TV. Finally, at a frequency of 682 MHz, there is only one channel with observed signal quality, namely SCTV. The frequency 682 MHz also obtains very good signal quality.

The difference in signal quality obtained is caused by several factors. Environmental factors, such as humidity, weather, wind, sunlight, or tall buildings, for example, can affect the quality of the image results. The location of television broadcasting stations at a considerable distance also affects the quality of the image results. These variables have effects on signal transmission and signal reception degradation. All signals are absorbed by atmospheric vapor; if atmospheric absorption decreases, it will result in weak power or long-distance radio signal strength.

TVRI station covers channels at a frequency of 538 MHz, with a distance from the data collection location to the TVRI station being 2.75 km. For Trans TV station covering channels at a frequency of 634 MHz, the distance from the data collection location to the Trans TV station is 4.13 km. Then, the SCTV station at a frequency of 682 MHz, with a distance from the data collection location to the SCTV station being 3.37 km. These distances were obtained by drawing a straight line from the data collection location to the TV station using the Google Earth application. Thus, the closer the distance between the transmitter and the TV receiver, the greater the possibility of obtaining good signal quality. This applies if there are no physical obstacles or other interferences that can hinder the signal path. As the distance between the TV transmitter and the TV receiver increases, the signal weakens. This can lead to the loss of some channels or produce blurry images.

From the above data, it can be inferred that the antenna created, combined with an RF booster, was successful and achieved satisfactory results. With the signal strength and quality obtained, it is possible to produce clear images on digital TV, high-definition image resolution, and stable signals. Thus, watching TV can be done comfortably and satisfactorily.

5. CONCLUSION

From the conducted research, it can be concluded that the biquad antenna designed and simulated using aluminum material, with a biquad side length of 12.3 cm, a reflector rod length of 39 cm, a reflector tube length of 31.5 cm, a reflector spacing of 7 cm, and a reflector rod height of 5.8 cm, operates at a frequency of 568 MHz. The CST Studio simulation yielded the following values: VSWR of 1.64, return loss of -12.26 dB, bandwidth of 114.44 MHz, gain of 9.080 dBi, and antenna directivity of 9.253 dBi. In the simulation, the spacing between the antenna reflectors and the perforation on the reflector rod influenced the antenna parameters. Inappropriate spacing led to antenna parameter values not meeting specifications, necessitating the optimization process.

The biquad antenna with an RF booster that has been produced and implemented on digital TV through the STB is capable of producing images with good signal strength and quality compared to before the antenna was implemented. The frequency on each digital TV channel has an impact on signal strength and quality, with almost all signal strengths having good percentages and good signal quality even though there are differences in each frequency.

The difference in signal quality obtained is caused by several factors. Environmental factors, such as humidity, weather, wind, sunlight, or tall buildings, for example, can affect the quality of the image results. The location of television broadcasting stations at a considerable distance also affects the quality of the image results. The closer the distance between the TV transmitter and the TV receiver, the greater the possibility of obtaining good signal quality. This applies if there are no physical obstacles or other interferences that can hinder the signal path. As the distance between the TV transmitter and the TV receiver increases, the signal weakens. This can lead to the loss of some channels or produce blurry images.

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BIOGRAPHY

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