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# Microstrip antenna design for use in 4G communication network systems

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ABSTRACT

4G service coverage only reaches 52.90% of the total area in Indonesia, with an average internet speed of 11.12 Mbps which is one of the lowest internet speeds in Southeast Asia. The increasing need for internet also affects all aspects of life if internet services are still not optimal. This research was conducted with the aim of producing a microstrip antenna to be used as a supporting antenna to get better internet quality, as well as providing additional insight for the general public about the concept of microstrip antennas starting from planning, designing, testing, and using microstrip antennas. In this research, a microstrip antenna is made using the peripheral slits method, to work at frequencies of 1800-2400 MHz for 4G networks. Microstrip antennas will pay attention and be analysed on the parameters of return loss (S-11), VSWR (Voltage Standing Wave Ratio), bandwidth, and antenna gain. Simulation results for several parameters such as return loss which gets a value of -13.33639 dB and the VSWR value is obtained at 1.5489645 at a working frequency of 2311 MHz. The Gain magnitude obtained is 2.35 dBi and the antenna bandwidth value obtained is 30.6 MHz. These values have met the criteria of a good microstrip antenna and are ready to be fabricated and implemented which can be useful for improving the quality of public internet usage.

ABSTRAK

Jangkauan layanan 4G yg hanya menyentuh 52,90% dari keseluruhan wilayah di Indonesia, dengan kecepatan rata-rata internet 11.12 Mbps yang merupakan salah satu kecepatan internet paling rendah di wilayah asia tenggara. Kebutuhan internet yang semakin melonjak juga berpengaruh pada segala aspek kehidupan jika layanan internet yang masih belum optimal. Penelitian ini dilakukan dengan tujuan untuk menghasilkan sebuah antena mikrostrip untuk digunakan sebagai antena pendukung untuk mendapatkan kualitas internet yang lebih baik, serta memberikan suatu wawasan tambahan bagi khalayak umum tentang konsep antena mikrostrip dimulai dari perencanaan, perancangan, pengujian, dan penggunaan antena mikrostrip. Dalam penelitian ini di buat sebuah antena mikrostrip dengan menggunakan metode peripheral slits, untuk bekerja pada frekuensi 1800-2400 MHz untuk jaringan 4G. antena mikrostrip akan memperhatikan dan dilakukan analisa pada parameter return loss (S-11), VSWR (Voltage Standing Wave Ratio), bandwidth, dan gain antena. hasil simulasi bagi beberapa parameter seperti returnloss yang mendapat nilai sebesar -13.33639 dB dan nilai VSWR didapatkan sebesar 1.5489645 pada frekuensi kerja 2311 MHz. Besaran Gain yang didapatkan yaitu sebesar 2.35 dBi dan nilai bandwidth antena yang didapat aadalah sebesar 30.6 MHz. Nilai-nilai tersebut sudah memenuhi kriteria sebuah antena mikrostrip yang baik dan siap untuk di fabrikasi serta di implementasikan yang dapat bermanfaat untuk dapat meningkatkan kualitas penggunaan internet masyarakat.

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## 1. Introduction

Today, the internet has become a very basic aspect in carrying out various human activities. The current digital era is closely related to the existence of a strong internet network, which plays a vital role in supporting a variety of activities, including in the economic, political, social, and educational sectors [1]. In Indonesia, the development of 4G (LTE - Long Term Evolution) network coverage is still ongoing. LTE itself is often referred to as the 4th generation or 4G in the development of telecommunications technology. Efforts to expand 4G network coverage in Indonesia remain the main focus in ensuring optimal service quality and availability for users [2].

Based on the latest data from the Ministry of Communication and Information of the Republic of Indonesia [3], in 2021 4G service coverage only touched 52.90% of all regions in Indonesia, with an average internet speed of 11.12 Mbps which is one of the lowest internet speeds in Southeast Asia. The increasing need for internet also affects all aspects of life if internet services are still not optimal. Internet services that are still commonly used today are 4G LTE networks, because the coverage of 5G services has not yet penetrated into various regions and is still undergoing development.

LTE was designed with the aim of improving upon previous technologies. In addition to having superior data transfer speeds, LTE also offers various advantages compared to its predecessor technologies [4]. This, LTE not only increases speed, but also presents a more efficient and comprehensively connected solution in the world of telecommunications. At this time, there are many ways to produce a good 4G network by creating one of the devices such as an antenna [5].

Antenna is a device designed to send and receive radio waves by utilizing the principle of electromagnetic waves [6]. In this way, antennas can convert electrical signals into electromagnetic waves that are emitted into the free air, or conversely, receive electromagnetic waves from the air and convert them into electrical signals that can be processed or forwarded. Thus, antennas play an important role in wireless communications and systems that use electromagnetic waves, such as radio communications, television, and cellular technology [7]. In antennas, there are various types or types depending on the use and benefits to be enjoyed, one of which is the microstrip antenna.

Microstrip antenna is an antenna in the form of a thin board and is able to work at very high frequencies [8]. Physically, this antenna does look simple because it generally consists of a slab like a PCB (Printed Circuit Board) that is well known in the world of electronics. In its most basic form, a microstrip antenna consists of a radiating plane (patch) located on one side of the dielectric layer, while on the other side there is a ground plane [9]. Microstrip antennas are often used in various communication and wireless applications due to their efficiency in transmitting and receiving radio frequency signals. The figure below is the basic structure of a microstrip antenna.

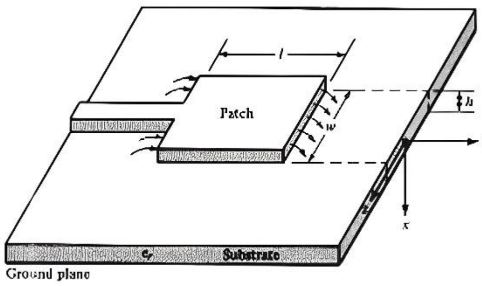


**Figure 1. Microstrip Antenna Structure** [9]

Microstrip antennas are popular today due to their low cost, small size, and ease of fabrication. In addition, microstrip antennas are easy to adjust the resonant frequency, input impedance, polarization, and radiation pattern [10]. The microstrip antenna has a ground plane component made of copper at the bottom layer which functions as a perfect reflector. The substrate above it has a dielectric constant (εr) and substrate thickness ($h$). There is also a patch located at the top that functions as a radiator which can have shapes such as rectangular, square, circular, and others [11]. The rectangular patch shape is easy to analyze and most accurate for thin substrates. The dimensions of the microstrip antenna can be found through calculations from simplified formulas [12]. An antenna will definitely be affected by electro-magnetic forces, where there is a radiation pattern that is formed when the antenna is working.

Antenna radiation pattern is defined as a mathematical function or graphical representation of the radiation properties of an antenna as a function of space coordinates [13]. Radiation has characteristics that include aspects such as power flux level, radiation intensity, field strength, and phase direction or polarization. The radiation pattern consists of a number of components known as lobes, which can be divided into major and minor parts (side and back lobe) [14]. The radiation pattern is formed by the distribution of the electromagnetic field at a considerable distance from the antenna. This radiated energy refers to the intensity of the electric field generated by the antenna in various directions [15]. The shape of the radiation pattern can be described as in the figure below.

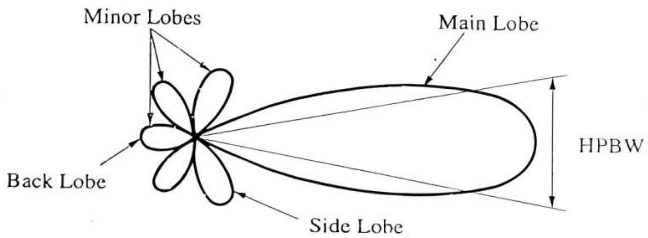


**Figure 2. Shape of Lobe Division of Radiation Pattern** [15]

In a microstrip antenna, we will always pay attention to several basic parameters that will determine the effectiveness of the designed microstrip antenna, including return loss, VSWR (Voltage Standing Wave Ratio), Bandwidth, and gain parameters. The first parameter is about return loss or can also be called S-Parameter (S1.1). Return loss is a parameter used to measure the extent to which an antenna's impedance is suitable [16]. This parameter measures how little energy is reflected back to the source, most of which must be absorbed by the antenna. Return loss is measured in decibels (dB) and is the inverse of the reflection coefficient. According to [17], a highly efficient antenna will have a return loss value that is close to zero or even negative, which is less than -10 dB, indicating that most of the signal is absorbed by the antenna and only a small amount is reflected back. Return loss can occur due to a mismatch between the transmission line impedance and the load input impedance [18]. This parameter will be continuous with the next parameter, VSWR.

VSWR (Voltage Standing Wave Ratio) is the ratio between the maximum voltage amplitude and the minimum voltage amplitude in a standing voltage pattern on a transmission line [19]. It is used to measure the extent of power level fluctuations due to mismatch between the transmission line and the load connected to it. The magnitude of the VSWR value can vary in the range between 1 (ideal) to infinity. According to [20], The higher the VSWR value, the greater the mismatch between the transmission line and the load. In other words, the higher the VSWR, the more energy is reflected back to the source rather than absorbed by the load, which can result in power losses and reduced transmission efficiency [21]. The antenna also has an optimal working frequency range when operating, this is called bandwidth.

The bandwidth of an antenna can be defined as the frequency range over which the antenna's performance, which includes characteristics such as input impedance, radiation pattern, radiation width, polarization, gain, efficiency, VSWR, return loss, and axial ratio, meets predefined standard requirements or specifications [22]. In this frequency range, antennas are usually designed to provide optimal performance according to the needs of a particular application. Bandwidth is one of the important parameters in designing, configuring, and understanding the performance of an antenna [20]. Bandwidth in an antenna measures how much frequency an antenna can receive or transmit with a good level of efficiency. Antennas are required to be able to direct electromagnetic waves in a certain direction, this is called gain.

The gain of an antenna is a parameter that describes the ratio between the power focused by an antenna in a particular direction and the power radiated by a reference antenna. Gain measures the antenna's ability to direct or focus electromagnetic energy in a particular direction [23]. The higher the gain value, the more efficient the antenna is in directing the signal in the desired direction. In practice, gain measurement is carried out using the Gain comparison Method or gain transfer mode. The principle of this measurement is to use a reference antenna (usually a standard dipole antenna) whose gain value is already known [24].

In the end, with the increasing need for optimal internet services, especially on the 4G internet network, many studies have been carried out to create a solution to help overcome these problems. Therefore, this research was conducted with the aim of producing a microstrip antenna to be used as a supporting antenna to get better internet quality, as well as providing additional insight for the general public about the concept of microstrip antennas starting from planning, designing, testing, and using microstrip antennas.

## 2. Research Methodology

The implementation of the research was carried out using such stages to be able to obtain results in accordance with the objectives of this research. The microstrip antenna to be designed is a microstrip antenna with a rectangular patch type with antenna specifications made to work at 1800-2400 MHz frequencies for use in 4G network systems. This microstrip antenna is designed using the peripheral slit method, this method is one of the microstrip antenna size miniaturization techniques that works by forming several slits on the sides of the antenna patch [25].

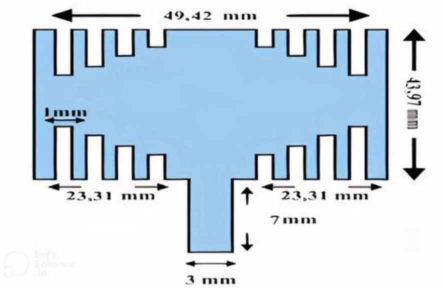


**Figure 3. Microstrip Antenna Structure with Slits**

The use of slits in antennas can affect current flow on the top surface, resulting in current deflection which in turn increases the electrical length of the patch. The effect of this is a decrease in the operational frequency as the physical dimensions of the patch become longer. Exclusively, the frequency value can be further reduced by adding more slits. The use of multiple slits can direct the current flow around them, resulting in a change in the radiation pattern of the antenna. This is one of the techniques used in designing antennas to change their operational characteristics, especially in terms of working frequency and radiation pattern [17].

The microstrip antenna is designed using the help of the CST Studio Suite Application, the following is the flow of research implementation as outlined in the flow chart. CST Studio Suite (also known as Microwave Studio) is a comprehensive software used to analyze and design electromagnetic systems, especially in the high frequency range [26]. Once the model is built, a fully automated splicing procedure is applied before starting the simulation process. With an advanced visualization engine and flexible post processing capabilities, CST Studio Suite enables users to analyze and improve designs in a relevant and efficient manner. The software is mainly used in product development and research in various fields involving electromagnetics, such as microstrip, antenna, and other high-frequency circuits [27]. This research will be carried out with the stages as stated in the following figure.

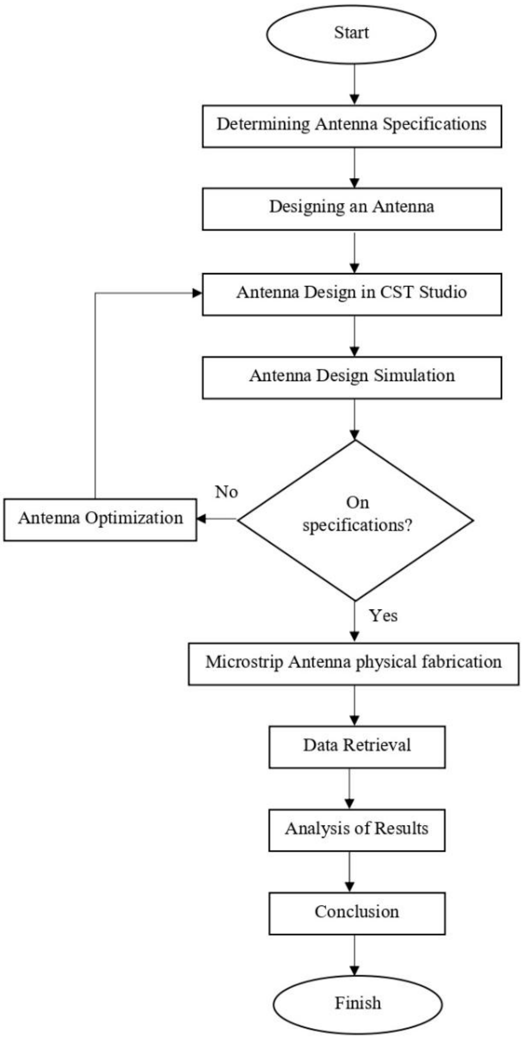


**Figure 4. Research Flow**

## 3. Results and Discussions

### *3.1 Microstrip Antenna Design*

The physical properties test of the original soil consists of soil water content test, specific gravity, bulk density, liquid limit, plastic limit, grain size analysis, standard compaction, and unconfined compressive strength test [15]. Where each test is carried out in based on standard using the SNI procedures for each test. Table 1 shows the soil property test results of the original soil samples.

In designing a microstrip antenna, the initial stage is to perform calculations to determine the specifications and dimensions of the microstrip antenna to be made. In this calculation, there are several formulas used according to [28], to determine the dimensions of the microstrip antenna to be made, including:

- Patch Width (Wp)

$$Wp = \frac{c}{2f}\sqrt{\frac{2}{\varepsilon r+1}} \quad (1)$$

- Patch length (Lp)

$$L_{eff} = \frac{c}{2f\sqrt{\varepsilon eff}} \quad (2)$$

$$\varepsilon r_{eff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left[\frac{1}{\sqrt{1+\frac{12h}{Wp}}}\right] \quad (3)$$

$$\Delta L = 0{,}412h\frac{(\varepsilon eff+0{,}3)(\frac{Wp}{h}+0{,}264)}{(\varepsilon eff-0{,}258)(\frac{Wp}{h}+0{,}8)} \quad (4)$$

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

- Groundplane

$$Wg = 6h + Wp \quad (6)$$

$$Lg = 6h + Lp \quad (7)$$

- Slit Dimension

$$Ls = 0.15 \times Lp \quad (8)$$

Description:

| | |
|---|---|
| c | = $3x10^8$ m/s (Speed of Light) |
| $\varepsilon r$ | = Dielectric Constant |
| h | = Substrate Thickness (mm) |
| Wp | = Patch Width (mm) |
| Lp | = Patch Length (mm) |
| $\varepsilon r_{eff}$ | = Effective dielectric constant |
| $L_{eff}$ | = Effective length |
| Lg | = Groundplane Length |
| Wg | = Groundplane Width |
| Ls | = Slit Length |

The calculation is carried out with reference to the working frequency of the antenna to be made, namely 1800-2400 MHz. Based on the calculations carried out using the formulas above, and the results of the dimensions of the microstrip antenna to be made are outlined in the following table.

**Table 1.** Microstrip Antenna Specifications

| Parameters | Specifications |
|---|---|
| Dielectric material | FR-4 |
| Dielectric constant | 4.3 |
| Dielectric thickness | 1.6 mm |
| Patch material | Copper |
| Patch thickness | 0.035 mm |
| Patch length | 47.4 mm |
| Patch width | 34.3 mm |
| Substrate length | 57 mm |
| Substrate width | 43.9 mm |
| Ground length | 57 mm |
| Ground width | 43.9 mm |
| Wavelength (λ) | 181.8 mm |
| Length of peripheral slits | 7.11 mm |
| Width of peripheral slits | 1 mm |
| Dielectric lambda (λd) | 87.67 mm |

The microstrip antenna specification data is then entered into the antenna design stage using the CST Studio Suite application. In the application, simulation experiments will also be carried out on the results of the microstrip antenna design made by paying attention to parameters such as returnloss (S1.1), VSWR (Voltage Standing Wave Ratio), Bandwidth, and Gain. Based on the results of these calculations which are poured into the antenna design made with the CST Studio Suite application, the results of the rectangular patch microstrip antenna design with the peripheral slit method are obtained as shown below.

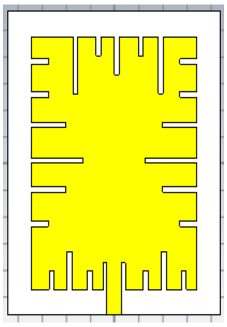

**Figure 1. Microstrip Antenna Design Results**

### *3.2 Return Loss and VSWR Result*

The microstrip antenna design above is used in antenna simulation experiments in the CST Studio Suite application, the following are the results of the parameters considered in the microstrip antenna simulation.

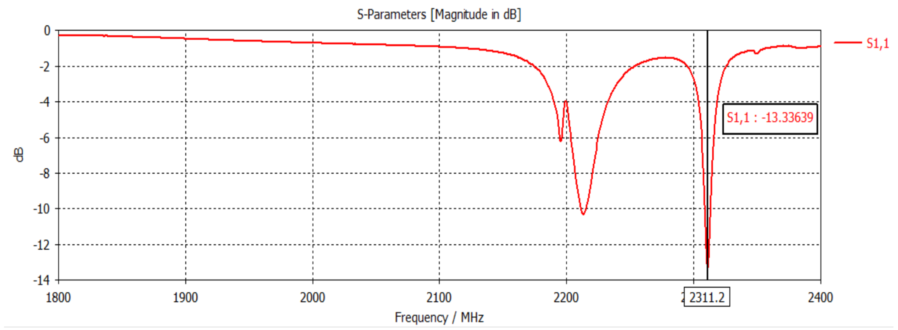


**Figure 2. Return loss result**

Based on the simulation results carried out on the microstrip antenna design made, a return loss value of -13.33639 dB was obtained, at a working frequency of 2311 MHz. This value is included in the criteria for a good antenna because the provisions of a good return loss are <10 dB. The results obtained are influenced by how the antenna patch shape is used and also the antenna union technique in accordance with the intended use of the antenna.

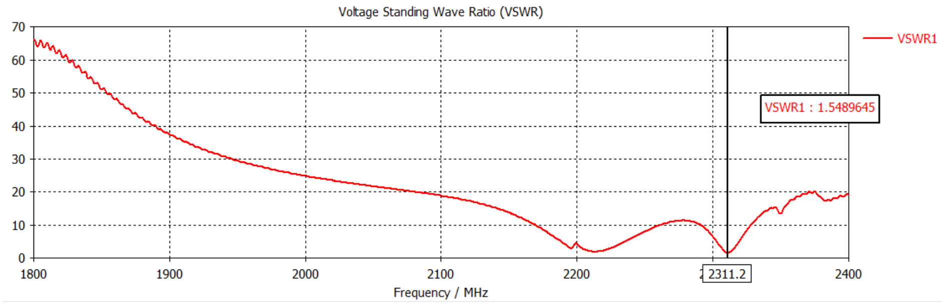


**Figure 3. VSWR Result**

Based on the results obtained in the simulation process, the VSWR parameter is obtained with a value of 1.5489645 at a working frequency of 2311 MHz. This value is still between the values of 1 and 2, where a good antenna will have a VSWR value close to the value of 1. Therefore, based on these results it can be said that the designed microstrip antenna has met the criteria of a good antenna to use.

### *3.3. Bandwidth and Antenna Gain Result*

Based on the results obtained from the simulation process carried out, the microstrip antenna bandwidth value obtained can be seen from the returnloss parameter graph. As in the picture above there is marker 1 at a frequency of 2294.7 MHz and marker 2 at a frequency of 2325.3 MHz, the bandwidth is obtained by calculation using the following formula.

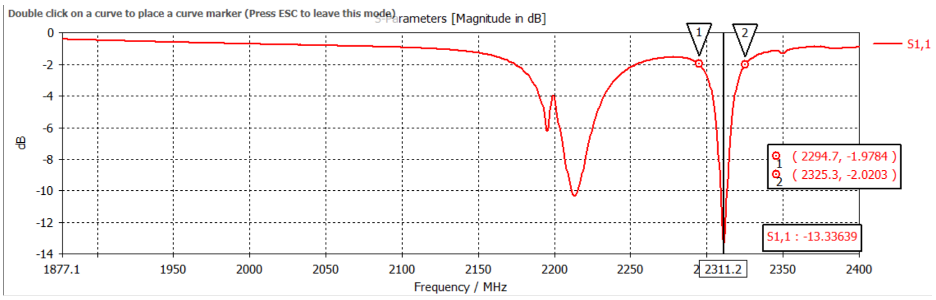


**Figure 4.** Bandwidth Result

$$BW = fh - fl \quad (9)$$

Then:

fh = 2294.7 MHz

fI = 2325.3 MHz

BW = 2325.3 - 2294.7

= 30.6 MHz

Description:

BW = Bandwidth

fh= Top Frequency

fI = Lower Frequency

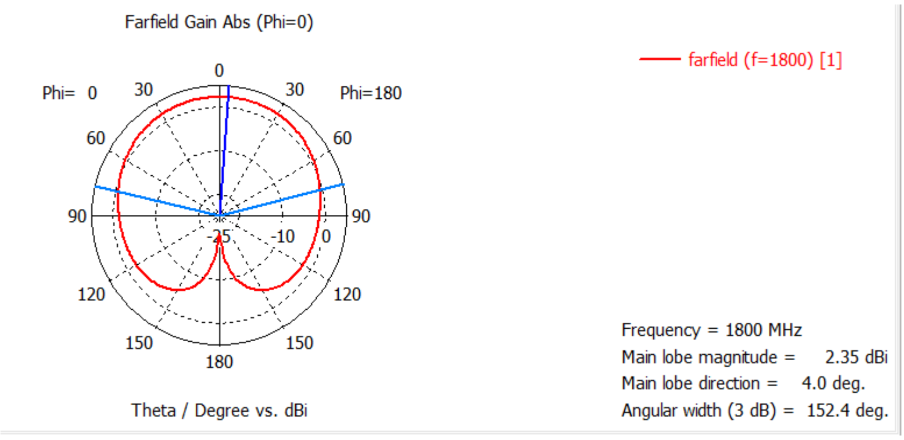


**Figure 5. Antenna Gain Result**

Based on the results of the simulations performed, the microstrip antenna gain was obtained at 2.35 dBi. This value is quite large and is above the initial design of the antenna which aims to have a gain value above 2 dBi. From these parameters, it has met several criteria for each parameter or the value planned at the beginning, but it can also still be further developed or optimized to be able to produce better parameter values in order to create a microstrip antenna that is more capable of being used

## 4. Conclusion

Research conducted on microstrip antennas has produced antenna designs that can be fabricated for direct field use, with a rectangular patch shape to work at frequencies of 1800-2400 MHz as an antenna for 4G communication systems obtained simulation results for several parameters such as returnloss which gets a value of -13.33639 dB and VSWR value obtained of 1.5489645 at a working frequency of 2311 MHz. The Gain magnitude obtained is 2.35 dBi and the antenna bandwidth value obtained is 30.6 MHz. These values meet the criteria of a good microstrip antenna and are ready to be fabricated and implemented. These results can still be further developed in further research to produce better parameter values, especially in bandwidth results which are still small, further optimization can be done using other types of patches or using more optimal methods so that it will get more concise antenna results but good effectiveness.

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