

Design a microstrip antenna 2 elements for 900 MHz GSM system

J Endri¹, Ciksadan¹, I Setiawan¹, A S Handayani¹, A Taqwa¹, N F Husni¹, C R Sitompul¹, J M Amin²

¹ Department of Electrical Engineering, Politeknik Negeri Sriwijaya, Jalan Srijaya Negara, Palembang, Indonesia

² Department of Chemical Renewable, Politeknik Negeri Sriwijaya, Jalan Srijaya Negara, Palembang, Indonesia

E-mail: ade_silvia@polsri.ac.id

Abstract. Microstrip antenna design aims to increase the reach of cellular devices using the GSM system because there are still areas in Indonesia that have not been reached by this service. This antenna is made with an epoxy substrate material that have a dielectric constant (ϵ_r) = 4.4 and a thickness of 1.6 mm. This antenna uses a microstrip feed channel to send information signals from radiating components to cellular devices. in this antenna design a linear array method is used which has two elements to increase the gain possessed by the antenna. in this study antenna simulation using CST Studio suite software. the results of the simulation show that the antenna has a Return loss of -59.38 dB, has a VSWR of 1.06 and have a Circular radiation pattern. Circular radiation pattern shows that the antenna can receive signals from an angle of 0 to 360 degree and can be used by mobile devices to increase the range of the GSM signal.

1. Introduction

One frequency that is widely used is the 900 MHz frequency for GSM systems. The 900 MHz frequency in various areas can be used as an alternative energy for low power supply for mobile devices that are far from electric power sources [1]. but until now not all regions in Indonesia get the services of the GSM system properly due to the limited range of BTS signals that can be captured by mobile devices. Therefore, we need a device that can increase the distance from the GSM signal that can be captured by GSM [2], one of them is the antenna.

In the research by Raja Patar Silitonga *et al.* Antenna has an important role in the process of sending and receiving that is perfect. Antenna is a device used in the process of sending and receiving in telecommunications [3-5]. In recently year, many antennas have been developed to meet these requirements, one of which is the microstrip antenna. Microstrip antenna is a type of antenna comprising a dielectric substrate sandwiched between ground plane and patch [5]. Microstrip Antennas have many advantages such as having a thin cross-sectional area, easy to fabricate, small and lightweight, and can be integrated with existing wireless communication device and according to research by Moleiro *et al.* Microstrip antennas also exhibit disadvantages: low power-handling capability, low gain, and narrow bandwidth [6]. The use of microstrip patch antennas at base stations is advantageous because of their physical and mechanical properties, such as light weight and thin profile, but also because they can be easily integrated into arrays [2, 7].



The microstrips antenna have surface waves arise. Surface waves arise when microstrip antennas radiate waves into the air, but there are waves that are trapped inside the substrate. These waves can reduce antenna efficiency and gain, limit bandwidth, increase end-fire radiation, increase cross-polarization. Based on research conducted by Z. Muludi, to increase the strengthening value of microstrip antennas can be done using the array method. The array method is done by making the microstrip antenna into a number of patches. in antenna array configurations, the most suitable rationing technique is to use a microstrip feed line. then from that in the paper will design an antenna with an array configuration using Microstrip feed line rationing techniques. The core factors required to estimate an antenna's performance include radiation pattern, gain, impedance bandwidth and polarization [8].

This research was conducted in order to make an antenna that can improve the quality and distance of the reception of GSM signals from a remote transmitter. In research [1] the antenna was made with a single path to receive GSM signals with 900 frequencies as the middle frequency, whereas in research [9] using 4 paths that cause the antenna to have a large dimension.

In this study the antenna made is an antenna that has a double path. the use of multiple elements will increase the gain of the antenna so that the antenna has a greater gain from the study [1] and also has a smaller dimension than the study [9]. This antenna uses a 50 ohm supply channel connected to a mobile device and uses a 100 ohm supply line connected to each path so that the antenna has the least possible VSWR and return loss so that the antenna can function as a GSM signal receiver with a middle frequency of 900 MHZ. the use of multiple elements will increase the gain of the antenna so that the antenna has a greater gain from the study [1] and also has a smaller dimension than the study [9].

2. Microstrip antenna

Microstrip antenna is one type of antenna in the form of a thin board that is able to work at very high frequencies. Microstrip antenna is made by using a substrate that has three basic elements namely radiating (radiator), substrate element (substrate), and ground element (ground). Microstrip antenna, also known as patch antenna, is also an antenna made from PCB and consists of several plates with different functions [10].

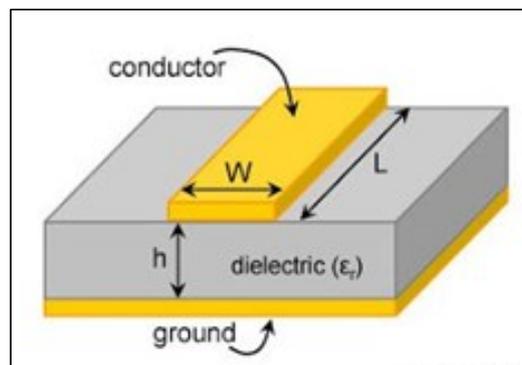


Figure 1. General microstrip antenna image.

Figure 1 above shows the general configuration of the microstrip antenna. And then the microstrip antenna dimension planning the following equations are used [11]:

$$W = \frac{c}{2f_0} \sqrt{\frac{2}{(\epsilon_r + 1)}} \quad (1)$$

W is the width of the patch. then c is the speed of light in free space that is equal to 3×10^8 m/s. f_0 is the antenna resonance frequency, and ϵ_r is the relative permittivity of the substrate material. The length increase due to the fringing effect is formulated (ΔL), h is the thickness of the substrate and ϵ_{reff} is a relatively effective permittivity that is formulated with [1]:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left(\frac{1}{\sqrt{1 + 12 \frac{h}{w}}} \right) \quad (2)$$

The effective patch length is formulated with [9]. Then the patch length is obtained by the Equation (3) [12].

$$L = L_{eff} - 2\Delta L \quad (3)$$

To determine the characteristic impedance, the microstrip channel width is adjusted. This is related to impedance matching between the microstrip channel and the trigger channel:

$$W = \frac{2h}{\pi} \left\{ B - 1 - \ln(2B - 1) + \frac{\varepsilon_r - 1}{2\varepsilon_r} \left[\ln(B - 1) + 0.39 \frac{0.61}{\varepsilon_r} \right] \right\} \quad (4)$$

And B obtained from the equation [9] :

$$B = \frac{60\pi^2}{Z_0\sqrt{\varepsilon_r}} \quad (5)$$

Meanwhile, to determine the length of the feed channel L_f using the following equation [9]:

$$\lambda_0 = \frac{c}{f_0} \quad (6)$$

$$\lambda_g = \frac{\lambda_0}{\sqrt{\varepsilon_{reff}}} \quad (7)$$

$$L_f = \frac{\lambda_g}{4} \quad (8)$$

3. Methodology

This antenna is made in order to increase the power received by telecommunications equipment in areas far from GSM transmitters. the increase in power is directly proportional to the magnitude of the gain of the antenna, therefore making microstrip antennas with array techniques is done in order to obtain a relatively large gain.

There is a common problem in designing an antenna that is the parameters obtained do not match the expected parameters. if that happens then it takes time and money to design and rebuild the antenna. To overcome this problem, in the design and manufacture of these antennas, simulation and measurement methods are used so that the designed antennas can know the parameters by simulations. if the parameters are appropriate then the antenna is fabricated and then measured in the laboratory. This antenna design simulation uses CST Studio Suite software. While validating the parameter data of the simulation results is carried out through a measurement method using the Network Analyzer and conducted at the Indonesian Institute of Sciences (LIPI). This antenna design flow chart is shown in Figure 2. It shows the flow diagram of the microstrip antenna design is shown. Before starting the design, first determine the target parameters of the antenna parameters, such as: return loss < -10 dB, VSWR < 2 and Gain (maximum directivity) > 3 dB and have a radiation pattern and circular polarization. If the target value such as the middle frequency has not been reached, then the antenna transmitter dimensions are adjusted, the problem that also often occurs is the value of VSWR > 2. When the antenna has VSWR > 2 and Return loss < -10dB, it means the supply line impedance of the antenna does not match the impedance of the channel transmission that can be caused by damage to the channel at the time of fabrication. this can be prevented by using the method of printing a photo etching machine. When all antenna parameter targets have been met, the simulation process is complete. Continuation. then do the calculation and design the antenna dimensions using Equations (1) - (10). the design results are then simulated using CST studio suite software to find out whether the parameters are appropriate. if the parameters do not match, the antenna dimension design will be repeated. after the parameters match the target, the antenna will be made and then the hardware will be implemented.

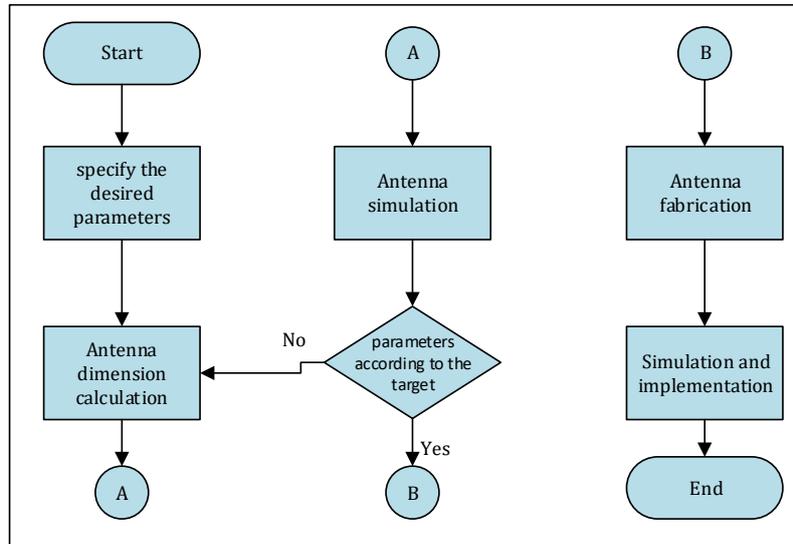


Figure 2. Antenna design flow chart.

Table 1 shows the results of antenna dimension calculations based on equations (1) - (8) the results of Table 2 will be used as antenna dimensions after simulation has been done first. the size of Table 2 is presented on a millimeter scale.

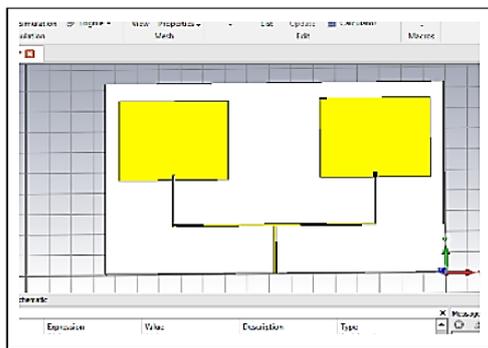


Figure 3. Simulation of antenna.

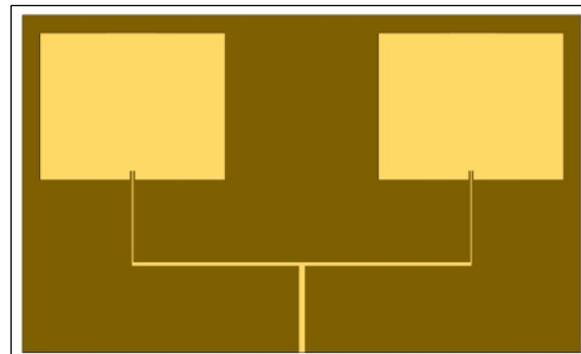


Figure 4. The results of the antenna design.

Before starting antenna making, it is necessary to do a simulation using CST Studio Suite software as shown in Figure 3. The antenna design results can be seen in Figure 4. If the parameters of the simulation results are in accordance with the desired parameters, then the next is the antenna printing process. The PCB Etching process is carried out using the UV Photoresist Laminate technique. The author chose this process because the level of accuracy of the UV Photoresist Laminate technique is very high, so it is suitable when used for Etching PCB antennas in order to obtain the appropriate dimensions. The results of the printed antenna can be seen in Figure 5 and Figure 6.

Table 1. The results of the antenna dimension design calculations.

| Component | Dimension (mm) |
|-------------------------------------|----------------|
| Path Width | 101.43 |
| Patch Length | 79.271 |
| The Distance Between Elements | 83.30 |
| Feed Channel Length (100 Ω) | 15.215 |
| Feed Channel Length (70 Ω) | 83.93 |
| Feed Channel Length (50 Ω) | 45.48 |
| Feed Channel Width (100 Ω) | 0.60 |
| Feed Channel Width (70 Ω) | 1.58 |
| Feed Channel Width (50 Ω) | 3.0 |
| Width of The Ground Plane | 307.3 |

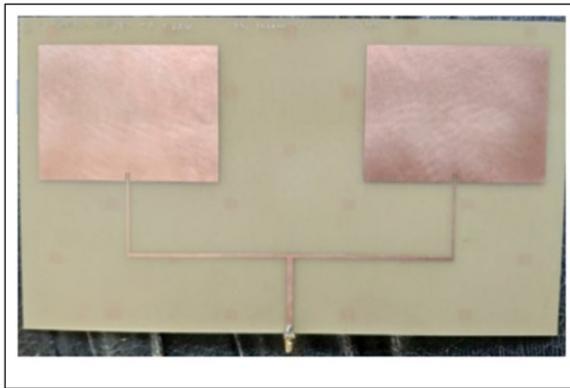
**Figure 5.** The results of antenna fabrication (front view).**Figure 6.** The results of antenna fabrication (rear view).

Figure 5 and Figure 6 show the results of antenna fabrication that have been previously designed and have the dimensions listed in Table 1. Then the next step is to measure the gain of the antenna through Real measurements. This measurement was carried out at the Indonesian Institute of Sciences (LIPI) Research Centre for Electronics and Telecommunications. the next step is to measure the gain of the antenna through Real measurements. This measurement was carried out at the Indonesian Institute of Sciences (LIPI) Research Centre for Electronics and Telecommunications.

4. Test and implementation results

If the antenna impedance matches the impedance of the Transmission line VSWR will be 1 this is said to be the ideal condition of the antenna that can transmit all signals well without the reflected signal. The maximum tolerance value of a good VSWR antenna is 2. If VSWR is 2, then the Return loss value is -9.8. This value is the maximum tolerance of the antenna return loss.

If the return loss has a value < -10 then the antenna is a good antenna. At this stage, the parameters tested are return loss, VSWR, radiation pattern and polarization. Figures 7 and 8 show the return value obtained is -59.38 dB. Meanwhile the VSWR value obtained is 1.06.

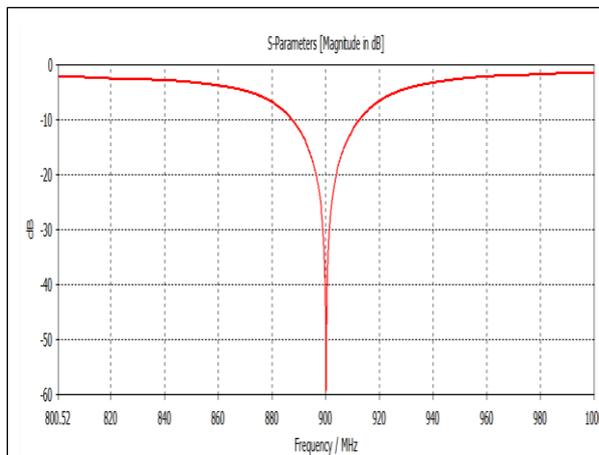


Figure 7. The result of return loss antenna.

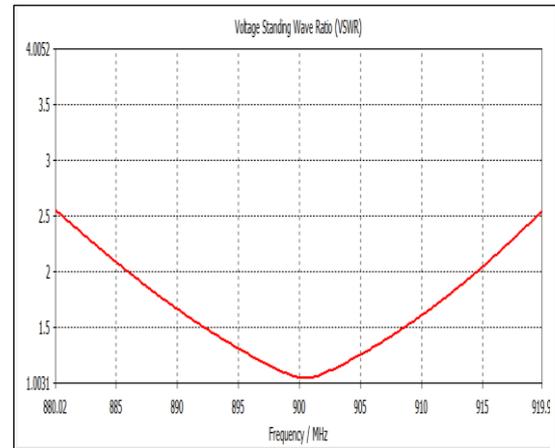


Figure 8. The result of VSWR antenna.

An ideal antenna is an antenna that has a VSWR of no more than 2 and must have a Return loss value below -10dB. Figures 7 and Figure 8 show very good results because the antenna parameters have a vswr value of less than 2 and even close to 1. This shows that very little information signal will bounce back to the system so that this reflected wave will not change the phase of the incoming information wave to the antenna [9]. Figure 7 shows that the antenna have a Return loss value well below -10dB so that the reflected wave value is very small compared to the transmitted wave and it can be concluded that the transmission line is suitable [13].

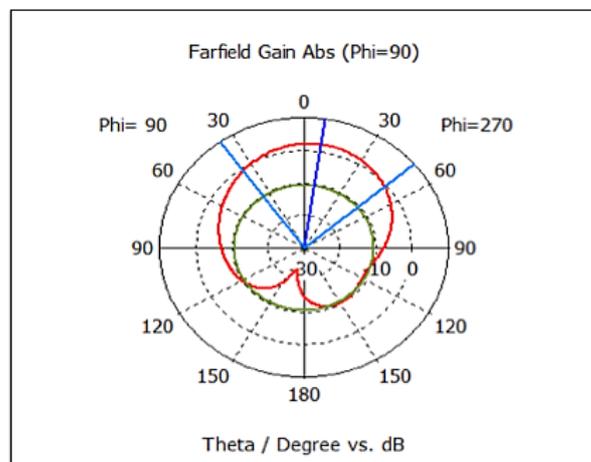


Figure 9. The result of simulation antenna (radiation pattern).

Figure 9 shows that the antenna have a circular radiation pattern. When compared to antennas that have directional radiation patterns (cannot receive signals from all angles) antennas with circular radiation patterns have the advantage of being able to capture signals from all angles, so this antenna is suitable if used in GSM systems. Gain measurements are carried out using the Reference Antenna method whose gain is known. The antenna is placed in a position as shown in Figure 10.

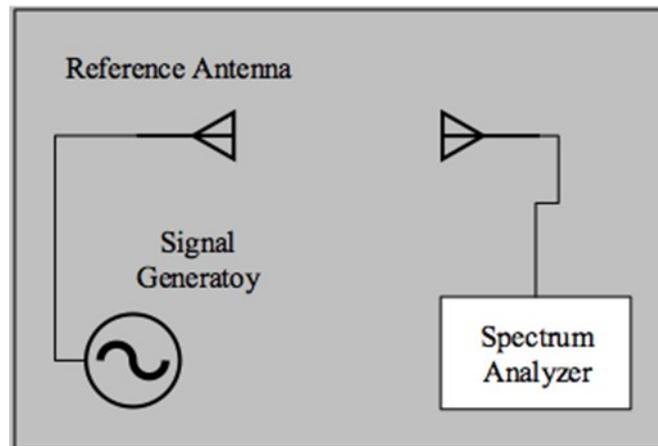


Figure 10. Antenna configuration when measuring gain.

This equation is used to find out the antenna gain value [14]:

$$Ga = Gr + (P_{RA} - P_{Rr}) \quad (9)$$

Note:

- Ga = Gain of a Microstrip antenna
- P_{RA} = Signal Level of Microstrip antenna
- P_{Rr} = Signal Level of reference Antenna
- Gr = Gain of reference Antenna

The following values are obtained:

- $Gr = 6.5$ dBi
- $P_{RA} = -25$ dBi
- $P_{Rr} = -25.3$ dBi

Thus:

$$Ga = 6.5 + (-25 - (-25.3)) = 6.8 \text{ dBi}$$

Table 2 shows the results of the antenna parameters that have been simulated. These results indicate that all antenna parameters have met the target of this microstrip antenna design.

Table 2. Antenna parameter results.

| Antenna Parameters | Expected Antenna Parameters | Design parameters | Target achievement |
|--------------------|-----------------------------|-------------------|--------------------|
| Middle Frequency | ± 900 MHz | 900 MHz | √ |
| Return loss | < -10 dB | -59.38 dB | √ |
| Gain | >3 | 6.8 dBi | √ |
| VSWR | $1 < \text{VSWR} < 2$ | 1.06 | √ |
| Radiation Type | Circular | Circular | √ |

This implementation phase is carried out at a point in an area that does not yet get GSM services properly, namely in the village of Karang Anyar, Muara Telang, Banyu Asin Regency. Figure 11 and Figure 12 shows the process of testing and implementing the antenna carried out in Karang Anyar village.



Figure 11. Antenna implementation in Karang Anyar village (back view).



Figure 12. Antenna implementation in Karang Anyar village (front view).

The antenna is implemented by measuring it at a point far from the range of the GSM transmitter. This implementation is also carried out to find out how many additional signals can be captured by the modem that is installed with this microstrip antenna.

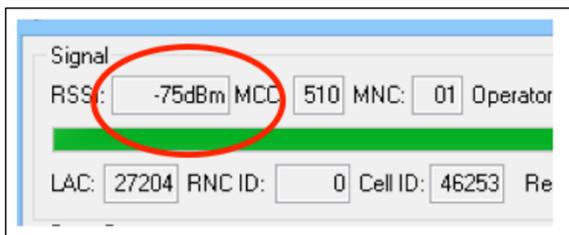


Figure 13. signal level modem without microstrip antenna.

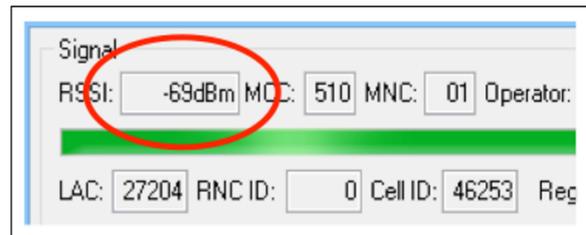


Figure 14. modem signal level when attached to a microstrip antenna as an external antenna.

Figure 13 and Figure 14 show the results of the implementation of the antenna that is before using a modem microstrip antenna have a signal level of -75 dBm. The modem has a signal level of -69 dBm when a microstrip antenna is installed. This shows that the antenna can strengthen the capture power of the modem. Then from the previous measurement point, the antenna is kept away from the BTS macro until the modem can only capture a small signal.

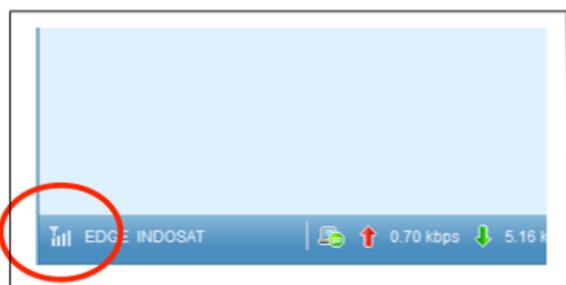


Figure 15. The results before the antenna installed (signal totalling 4 bars).

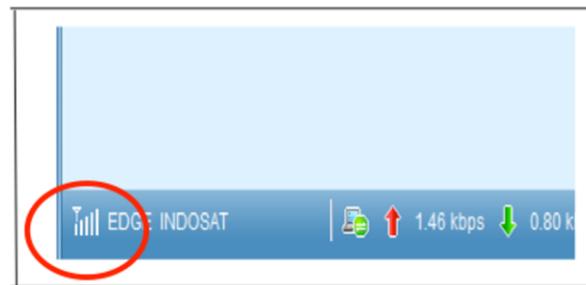


Figure 16. The results after the antenna installed (read the signal totalling 5 bars).

Figure 15 and Figure 16 show the antenna can increase the number of signal bars. Before the antenna is installed, the device only has a 4-bar signal. Meanwhile, when the antenna is mounted the device has a 5-bar signal. in conclusion, the antenna is functioning properly.

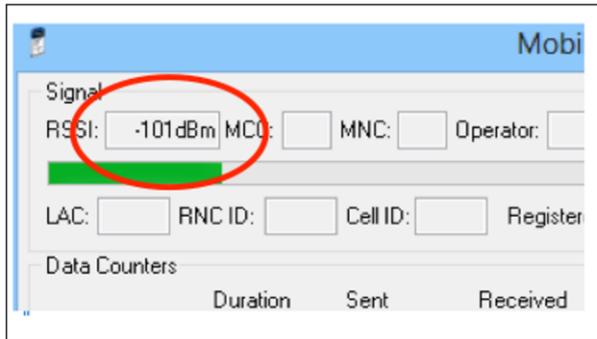


Figure 17. The results before the antenna is installed.

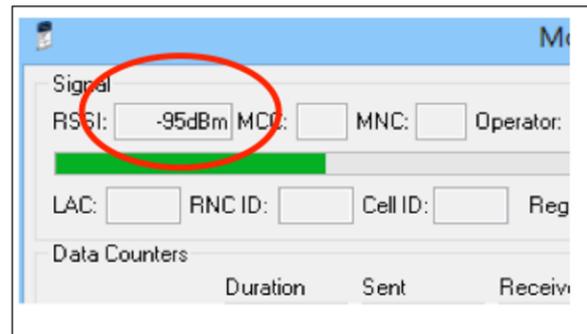


Figure 18. The results after the antenna is installed.

From Figure 17 and Figure 18 show that the device has a 6 dBm signal increase from -101 to -95 dBm. Then the test is done by finding the point until the signal condition cannot be captured by the modem to compare the signal condition when the modem is attached to the antenna and before the antenna is mounted. To see if there is an increase in distance that can be captured by the modem if the antenna is mounted. From the measurement results obtained as follows:

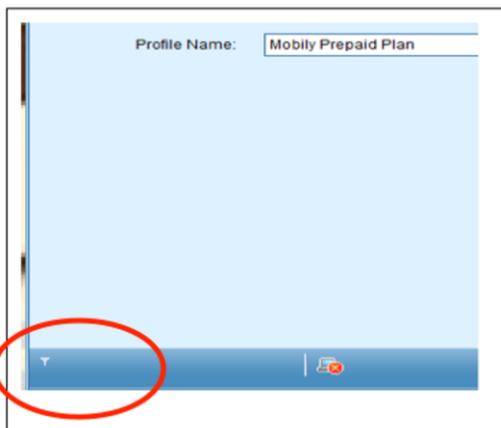


Figure 19. The number of signal bars on the modem when it is outside of GSM service coverage. (modem state without microstrip antenna attached).

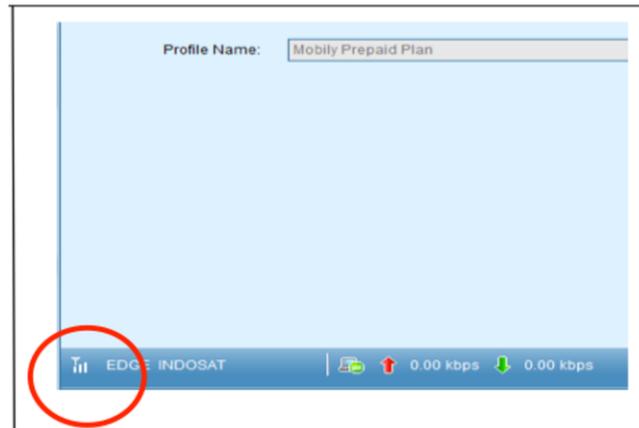


Figure 20. The number of signal bars on the modem when the microstrip antenna is attached.

Figure 19 and Figure 20 show that this microstrip antenna can increase the range of the modem. when the modem is out of GSM signal coverage, the modem has no signal bars. Then when the modem is installed with a microstrip antenna, the modem has a signal bar of 3 bars because the antenna has strengthened as shown by Figure 13 and Figure 14 then this makes the number of signal bars on the interface also increase because the number of bars of this signal indicates the strength of the received signal.

5. Conclusions

The antenna has a return loss well below -10 dB which is equal to -59.38 dB and has a VSWR below 2 even very close to 1. The value of this parameter indicates that the antenna is working well. This shows that very little information signal will bounce back to the system so that this reflected wave will not change phase from the wave of information that goes to the antenna. That it can be said the value of the

reflected wave is very small compared to the wave that is sent and it can be concluded that the transmission channel is matching.

The antenna has a circular radiation pattern. Antenna that have a radiation pattern is very suitable for use in GSM systems because it can capture information from various angles. the antenna works best at an angle of 0 - 90 degrees. Therefore, antenna can increase the signal power of the modem and can increase the distance of the modem range in capturing GSM signals.

6. References

- [1] Khabzli A 2011 *Design of 900 MHz Microstrip Antenna* (Riau: Politeknik Caltex Riau)
- [2] Hraga H I, See C H, Zhou D, Adnan S, Elfergani I T E, Excell P S and Abd-Alhameed R A 2010 *Proceedings of the Fourth European Conference on Antennas and Propagation* 8-11
- [3] Nunes R, Moleiro A, Rosa J and Peixeiro C 2000 *Antennas and Propagation Society International Symposium* 2-5
- [4] Barreiros J, Cameirao P and Peixeiro C 1999 *IEEE Antennas and Propagation Society International Symposium* 3 2074-2077
- [5] Muludi Z and Aswoyo B 2017 *2017 International Electronics Symposium on Engineering Technology and Applications (IES-ETA)* 87-92
- [6] Colles D and Arakaki D 2014 *2014 IEEE Antennas and Propagation Society International Symposium (APSURSI)* 1879–1880
- [7] Moleiro A, Rosa J, Nunes R and Peixeiro C 2000 *Antennas and Propagation Society International Symposium* 4 2188–2191
- [8] Abdulhadi A E and Sebak A R 2007 *2007 2nd International ITG Conference on Antennas* 162–165
- [9] Saleh F 2014 *Building Design of Microstrip Antenna use Phase Array Method Rectangular Shape 4 Elements Patch Frequency 900 MHz* (Jember: Universitas Jember)
- [10] Balanis C A, 2005 *Antenna Theory: Analysis and Design 3rd* (New Jersey: John Willey & Sons)
- [11] Utami E Y D, Setiaji F D and Pebrianto D 2017 *Jurnal Nasional Teknik Elektro* 6 196-202
- [12] Dhengale B B and Karia D C, 2015 *2015 International Conference on Advances in Computing, Communications and Informatics (ICACCI)* 116–120
- [13] Fertas K, Kimouche H, Challal M Aksas H and Aksas R 2015 *4th International Conference on Electrical Engineering (ICEE 2015)* 3–7
- [14] Endri J, Handayani A S, Jannah R and Al-kausar J 2019 *Journal of Physics: Conference Series* 1167 1-12