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Abstract. With the increasing use of mobile phones had to improve the quality of compiling devices on mobile phones. So that mobile phones can be of good quality. One of the devices on mobile phones that are needed to be improved is the antenna. The antenna is one key component of mobile phones. Various types of antennas have been designing and developing. One of them is a microstrip antenna. In this study, a folded dipole microstrip antenna with a Coplanar Stripline (CPS) structure would be design to use an FR-4 substrate and two plates of copper as a transmission medium of antenna based on the Finite-difference time-domain (FDTD) method. A silicon patch was added and located between two plates of copper as a switch on the microstrip antenna. There are two types of silicon used in this study, pure silicon with a resistivity of 2.3×10^5 Ω.cm and silicon of P-type doped by boron with a resistivity of 1 – 30 Ω.cm. For pure silicon, the frequency shift was 0.9 GHz, the Return Loss was -21.0746 dB, the VSWR was 1.1938, and the bandwidth was 0.4099 GHz. Then, pure silicon was irradiated with an infrared laser of 808 nm so that it can result in a frequency shift of 4.9 GHz. For p-type silicon can be shown that the most sensitive resistivity value for silicon of P-type was 15 Ω.cm, with the frequency shift was 5.84 GHz, the Return Loss was -43.9106 dB, the VSWR was 1.0128, and the bandwidth was 0.9455 GHz. Then, the p-type silicon was irradiated with an infrared laser of 808 nm so that it can result in a frequency shift of 0.06 GHz.

1. INRODUCTION

With the increasing need to communicate, it is necessary to have an easy and practical communication tool. Therefore, developed a communication tool that is simple and easy to carry everywhere. One of them is wireless technology. One of the communication tools that use wireless technology is a mobile phone. In this decade, the use of mobile phones has become very popular among the wider community, both in Indonesia and in all countries in the world. With the increasing use of mobile phones, the quality of compiling devices on mobile phones must also be improved so that mobile phones can have good quality. One of the devices on mobile phones that must be improved is the antenna. The Antenna is an important component for mobile phones so that cellphones can have a strong signal even if they are brought to rural or remote areas.

Various types of antennas have been designed and developed. One type of antenna that has been widely developed is the microstrip antenna. The microstrip antenna was chosen because of several things, namely its simple material, lightweight, easy to integrate with other systems, and relatively cheaper fabrication costs, as well as being able to provide the expected antenna parameters fairly well with only simple special techniques (1).

In this study, a folded dipole microstrip antenna with a CPS structure will be made using the FR-4 substrate which has a material permittivity of $\varepsilon_r = 4.3$. Then a copper plate patch is added consisting of a dipole as the transmission medium for the antenna, as well as a silicon patch as a liaison between the two copper plates that will be used as an optical switch on the antenna. Folded dipole antenna was chosen because it can be used at high frequencies, namely VHF, UHF, and SHF (2), has the same radiation pattern as the standard dipole antenna, namely single dipole antenna or half-wave dipole antenna. , small size, low profile, low cost of fabrication, wide impedance bandwidth, and stable radiation pattern (3).

Based on several research references above, the use of FR-4 as a substrate and copper as a patch on the folded dipole of a microstrip antenna can widen the frequency range used for communication channels. Meanwhile, the addition of silicon between the patch copper plates consisting of two poles on the microstrip antenna can be used to change the operating frequency as expected without having to change the position and size of the folded dipole patch on the microstrip antenna and can be used to increase the value of the operating frequency in the channel region. communication. The experiment that will be carried out is to provide silicon irradiation which functions as an optical switch on the antenna, causing the conductivity and electron mobility values in the silicon to change. With the change in the value of the conductivity and mobility of the electrons, it is expected to be able to obtain different working frequencies. The working frequency used will be very important in telecommunications media.

2. METHODS

Finite-difference time-domain (FDTD) is a technique of numerical analysis used to model computational electrodynamics (finding approximate solutions to a system of the associated differential equations). Since it is a time-domain method, solutions of FDTD can cover a wide frequency, range with a run of the single simulation, and naturally treat nonlinear material properties.

The FDTD method belongs in the grid-based general class of differential numerical modeling methods (finite difference methods). The time-dependent Maxwell's equations (on the partial differential form) have discretized using central-difference approximations to the space and time partial derivatives (4).

The resulting finite-difference equations have been solved either by software or hardware in a manner of leapfrog. First, the electric field vector components in a volume of space had done at a given instant in time. Second, the magnetic field vector components in the same spatial had done at the next in time. Third, the process has been repeated continuously until the desired transient or until the behavior of a steady-state electromagnetic field has fully evolved.

3. RESULTS

3.1 Dimensions of Antenna

Before determining the dimensions of the antenna, we can determine the frequency acting on the antenna and the substrate material used. In this study, we will make an antenna that works at a frequency of 9 GHz, and the substrate material used is FR-4. Then, we determine the dimensions of the antenna so that it can work at a frequency of 9 GHz, the relative permittivity of the substrate (ε_r) is 4.3, and the thickness of the substrate (*h*) is 1.6 mm.

- For the effective length of the dipole on the antenna (5):

$$L = \frac{143}{f(\mathrm{MH}z)} = \frac{143}{9000\mathrm{MH}z} = 0.0159\mathrm{m} = 15.9\mathrm{mm}$$

The length of each dipole is $\frac{L}{2} = \frac{15.9}{2}$ =7.95mm

To get the exact frequency at 9 GHz, it is necessary to optimize it by changing the antenna dimensions slightly. The radiation current can still work at its maximum, provided that the length which is changed is not more than 40%.

$$\frac{L}{2} = \frac{15.9}{2} = 7.95\mathrm{mm} - 5\% = 7.5\ \mathrm{mm}$$

- For the width of the antenna (6):

$$W = \frac{8e^{A}h}{e^{2A}-2} = \frac{8e^{(1.516)}(1.6)}{e^{2(1.516)}-2} = 3.1\mathrm{mm}$$

Where:

$$A = \frac{Z_{0u}}{60}\sqrt{\frac{\varepsilon_r + 1}{2}} + \frac{\varepsilon_r - 1}{\varepsilon_r + 1}\left(0.23 + \frac{0.11}{\varepsilon_r}\right) = \frac{50}{60}\sqrt{\frac{4.3+1}{2}} + \frac{4.3-1}{4.3+1}\left(0.23 + \frac{0.11}{4.3}\right) = 1.516$$

$Z_{0u} = 50\Omega$ (unbalanced characteristic impedance)

- Spacing between Dipoles (s) (7):

$s = 0.05\lambda = 0.05(2L) = 1.6\text{mm}$

- Gap between Strips (S) (8):

$$G = 21.385 \exp\left\{\left(\frac{\eta_0}{Z_{0b}\sqrt{\varepsilon_r + 0.86}}\right)\left[1 + \exp\left(\frac{0.1W\left(\varepsilon_r - 1.52\right)}{h\varepsilon_r}\right)^{0.68}\right]\right\}^{-3.753} = 0.921$$

$S = W.G = (3.1)(0.921) = 2.8\text{mm}$

Where :

$Z_{0b} = 150\Omega$ (balanced characteristic impedance)

$\eta_0 = 120\pi$

(to get Return Loss below -20 dB when silicon has been installed, then S is reduced by 20% to 2.2 mm)

- For feedline (Y_0) (9):

$$Y_0 = 10^{-4}(0.001699\varepsilon_r{}^7 + 0.13761\varepsilon_r{}^6 - 6.1783\varepsilon_r{}^5 + 93.187\varepsilon_r{}^4 - 682.69\varepsilon_r{}^3 + 2561.9\varepsilon_r{}^2 - 4043\varepsilon_r + 6697)\frac{L}{2}$$

$Y_0 = 4.7\text{mm}$

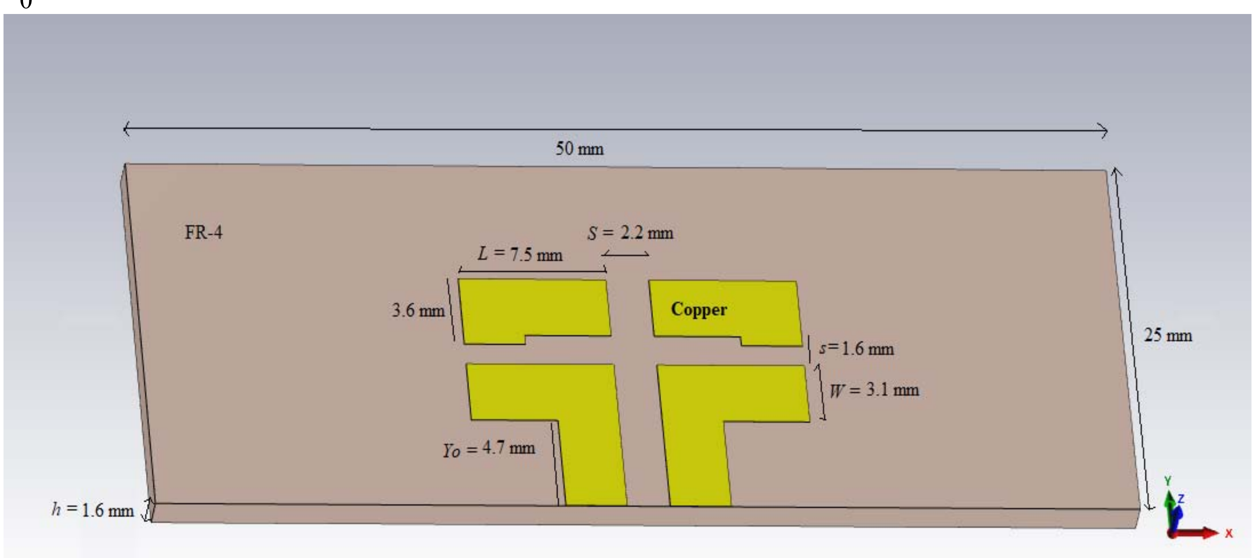

FIGURE 1. Dimensions of antenna.

3.2 Pure Silicon

In the next step, we have to determine the specifications on pure silicon that has been used as a switch in this folded dipole microstrip antenna. In this study, the type of pure silicon used is by the specifications below.

TABLE 1. Some of the significant specifications of pure silicon measured at room temperature (300 K) (10).

Parameter	Value
Energy Gap (E_G)	1.12 eV
Density (Solid) (ρ_r)	2.329 g/cm^3
Electrical Conductivity (σ)	4.3478×10^{-6} S/cm
Electron Mobility (μ_e)	≤ 1400 cm^2/V s
Heat Capacity (C_P)	0.7 kJ/K/Kg
Hole Mobility (μ_h)	≤ 450 cm^2/V s
Thermal Conductivity (κ)	1.57 W/cm.K
Thermal Diffusivity (α)	0.963013 cm^2/s
Intrinsic Resistivity (ρ)	2.3×10^5 Ω.cm

Then, we can determine the dimensions of the pure silicon used as a switch in this folded dipole microstrip antenna. In this study, there are three switches used in the antenna, so that there are three pure silicon plates at different positions. The thickness of pure silicon used is 525 µm. To obtain a higher frequency shift, a silicon slab is stacked into three layers so that its thickness is 1575 µm. So that they can stick together, then between the pure silicon plates are pasted using silver solder. Meanwhile, the cross-sectional area of pure silicon used as a switch on the folded dipole microstrip antenna is 8.525 mm^2.

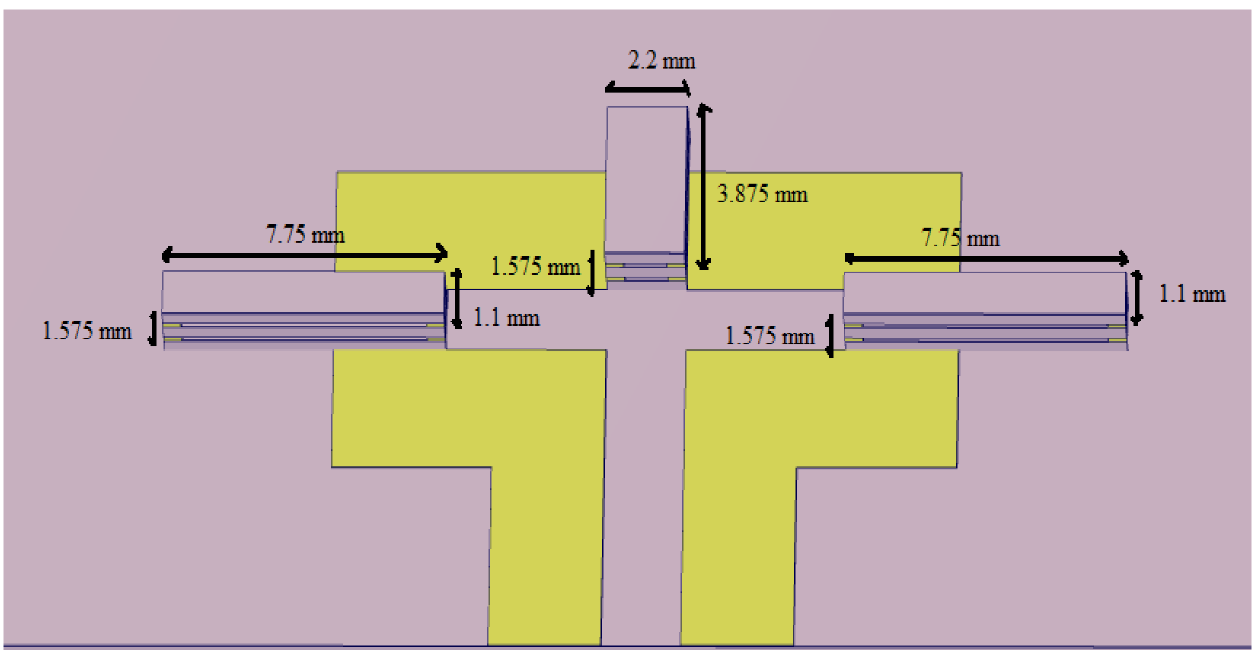

FIGURE 2. Dimensions of pure silicon.

Before installing pure silicon, a folded dipole microstrip antenna had fabricated at a frequency of 9.02 GHz. When pure silicon has been installing as shown in Figure 2 above, the working frequency of the antenna becomes 8.12 GHz, resulting in a frequency shift of 0.9 GHz. When pure silicon is irradiated with 808 nm infrared light, the working frequency becomes 3.22 GHz so that it experiences a frequency shift of 4.9 GHz to pure silicon without irradiation. There were changes in the physical quantities of the antenna when the antenna had not been installed with pure silicon, when pure silicon had installed without irradiation, and when pure silicon had installed with 808 nm the infrared as shown in table 2.

TABLE 2. Some some changes in the physical quantities of the antenna when the antenna had not been installed with pure silicon, when pure silicon had been installed without irradiation, and when pure silicon had been installed with 808 nm infrared.

Parameter	Without Silicon	With Pure Silicon	
		Without Laser 808 nm	With Laser 808 nm, 30 mW
Bandwidth (GHz)	0	0.4099	0.9002
Directivity (dBi)	4.9852	4.2366	2.3414
Efisiensi	0.7585	0.6127	2.8761
Frequency (GHz)	9.02	8.12	3.22
Gain (dBi)	3.7813	2.5957	-6.7341
Reflection Coefficient	0.3361	0.0883	0.0258
Return Loss (dB)	-9.4698	-21.0746	-31.7544
VSWR	2.0126	1.1938	1.0530
Wavelenght (cm)	3.3259	3.6946	9.3167

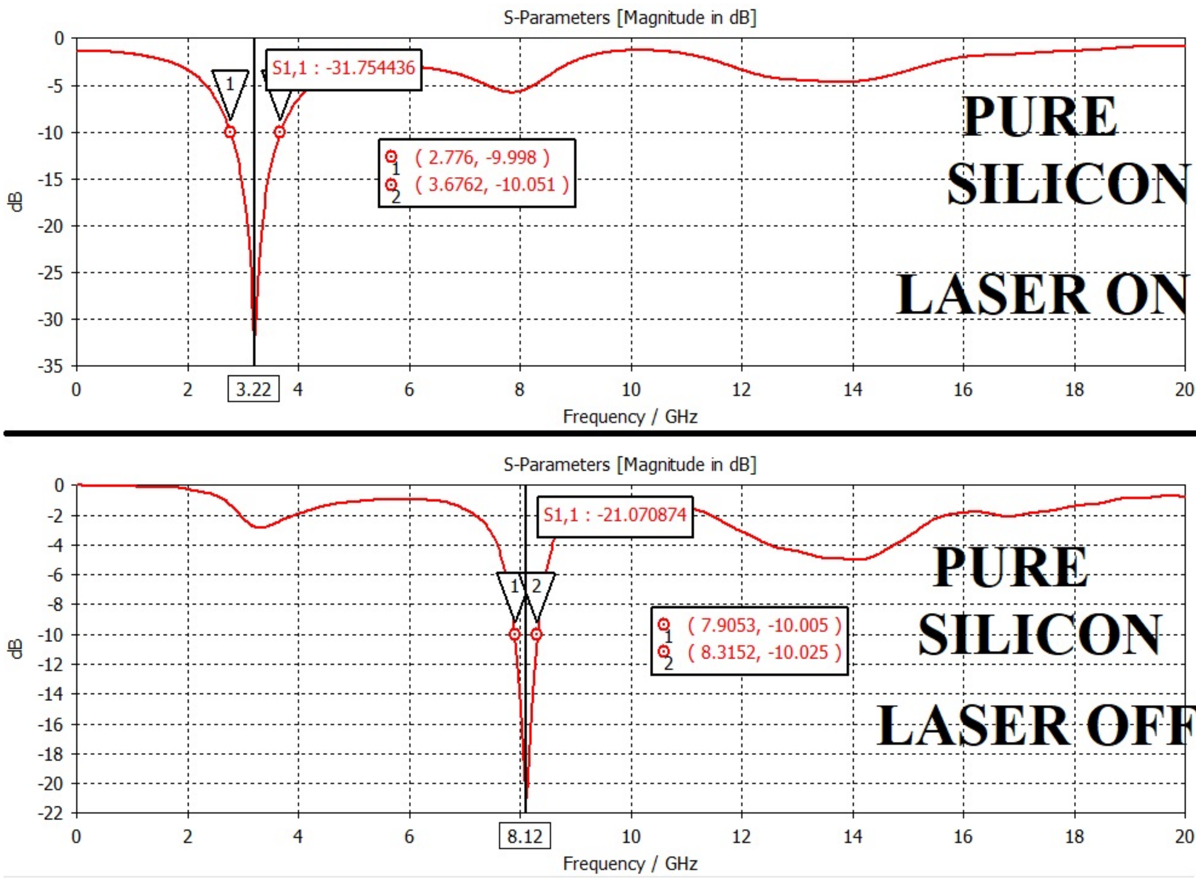

FIGURE 3. Graph return loss of pure silicon for laser on dan laser off.

3.3 Silicon of P-type Doped by Boron

As with pure silicon, we must specify the silicon of P-type doped by boron with a resistivity of 1-30 Ω.cm used as a switch in this folded dipole microstrip antenna. Before we determine the specifications of the silicon of P-type doped by boron, we must find the most sensitive region in the resistivity range from 1 Ω.cm to 30 Ω.cm. Figure 3 shows that the most sensitive area with the lowest return loss is at a resistivity of 15 Ω.cm. The specifications had used for the silicon of P-type doped by boron is a resistivity of 15 Ω.cm is shown in Table 3.

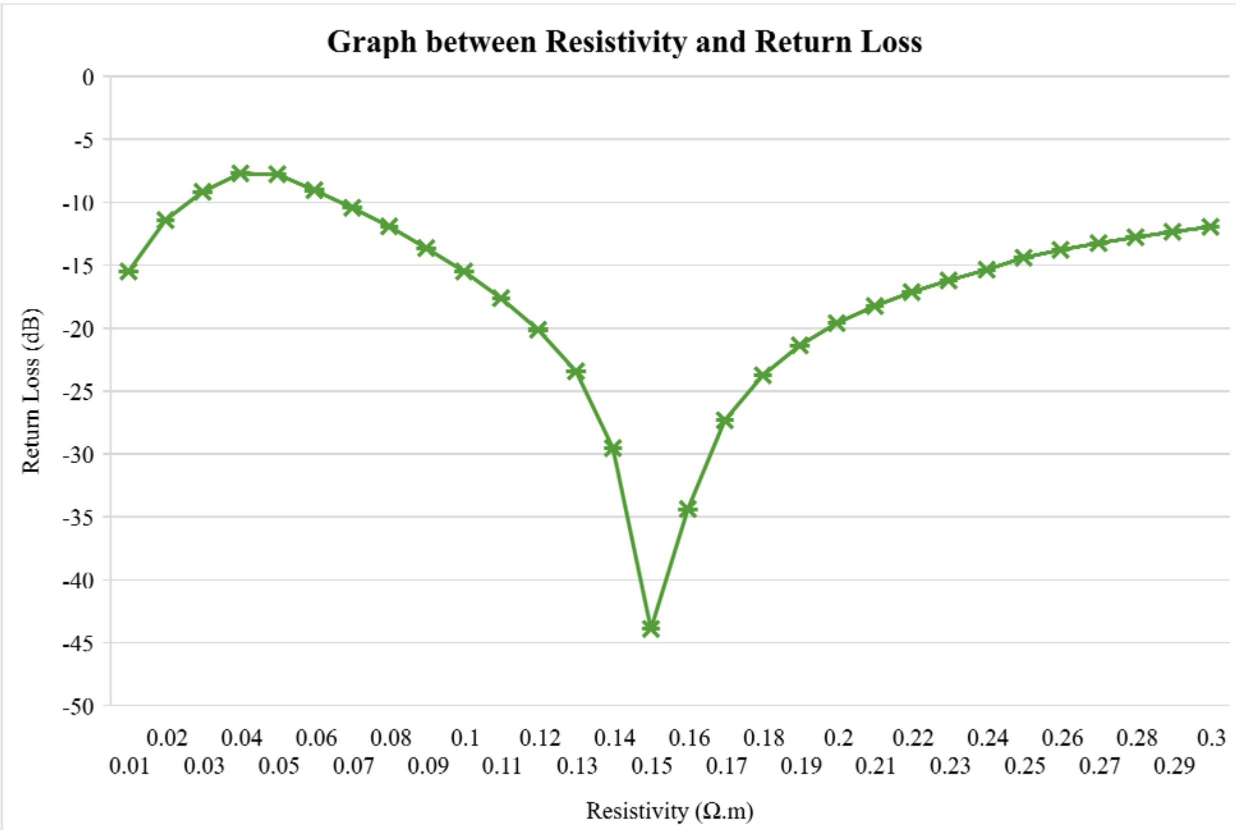

FIGURE 4. Graph between resistivity and return loss.

TABLE 3. Some of the significant specifications are the silicon of P-type doped by boron with a resistivity of 15 Ω.cm measured at room temperature (300 K).

Parameter	Value
Energy Gap (E_G)	0.6212 eV
Density (Solid) (ρ_r)	1.5189×10^{-4} g/cm^3
Electrical Conductivity (σ)	6.67×10^{-2} S/cm
Electron Mobility (μ_e)	$\leq 2.1467 \times 10^{7}$ cm^2/V s
Heat Capacity (C_P)	4.5652 10^{-5} kJ/K/Kg
Hole Mobility (μ_h)	$\leq 6.9 \times 10^{5}$ cm^2/V s
Thermal Conductivity (κ)	2.5548×10^{4} W/cm.K
Thermal Diffusivity (α)	1.4766×10^{4} cm^2/s
Intrinsic Resistivity (ρ)	15 Ω.cm

Next, we determine the dimensions of P-type silicon doped by boron with a resistivity of 15 Ω.cm used as a switch in this folded dipole microstrip antenna. In this study, the dimensions of P-type silicon doped by boron with a resistivity of 15 Ω.cm are the same as those of pure silicon as shown in Figure 2.

Before installing P-type silicon, a folded dipole microstrip antenna had fabricated at a frequency of 9.02 GHz. When P-type silicon has been installing as shown in Figure 2 above, the working frequency of the antenna becomes 3.18 GHz, resulting in a frequency shift of 5.84 GHz. When P-type silicon is irradiated with 808 nm infrared light, the working frequency becomes 3.24 GHz so that it experiences a frequency shift of 0.06 GHz to P-type silicon without irradiation. There were changes in the physical quantities of the antenna when the antenna had not been installed with P-type silicon, when P-type silicon had been installed without irradiation, and when P-type silicon had been installed with 808 nm the infrared as shown in Table 4.

TABLE 4. Some some changes in the physical quantities of the antenna when the antenna had not been installed with P-type silicon, when P-type silicon had been installed without irradiation, and when P-type silicon had been installed with 808 nm infrared.

Parameter	Without Silicon	With P-type Silicon	
		Without Laser 808 nm	With Laser 808 nm, 30 mW
Bandwidth (GHz)	0	0.9455	0.650
Directivity (dBi)	4.9852	2.1095	2.3414
Efisiensi	0.7585	3.4871	3.6270
Frequency (GHz)	9.02	3.18	3.24
Gain (dBi)	3.7813	-7.3560	-8.4922
Reflection Coefficient	0.3361	0.0064	0.2832
Return Loss (dB)	-9.4698	-43.9106	-10.9564
VSWR	2.0126	1.0128	1.7903
Wavelenght (cm)	3.3259	9.4340	9.2593

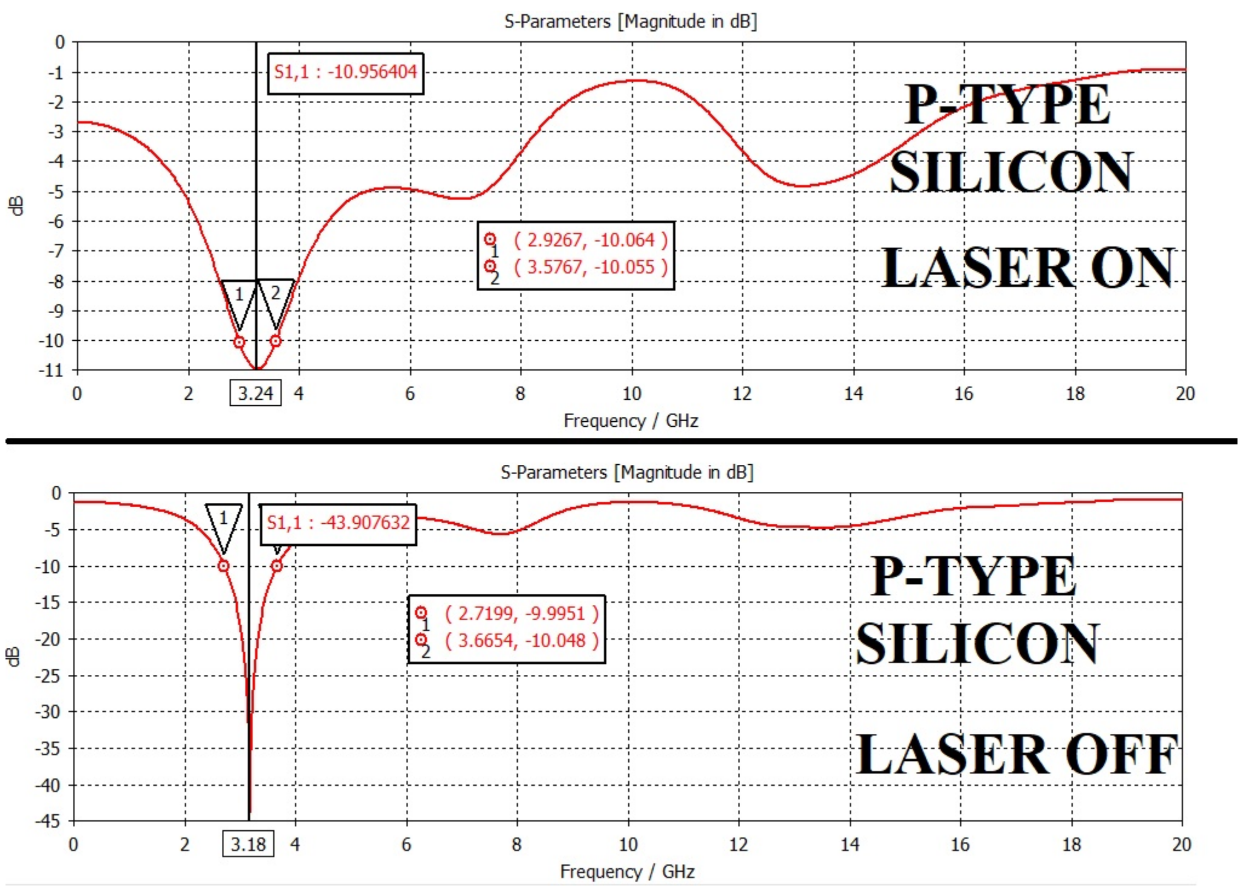

FIGURE 5. Graph return loss of P-type silicon for laser on dan laser off.

4. DISCUSSION

Based on Figure 1, the microstrip antenna has made at a frequency of 9 GHz, which is in the SHF (Super High Frequency) spectrum. Therefore, so that it can be applied to mobile phone frequencies. The higher the frequency on the microstrip antenna, the greater the frequency shift when other materials are attached to the antenna. In addition, two the other things are the folded shape of the antenna and the number of switches on the antenna that can cause high-frequency shifts.

In this study, the type of material added is silicon. Because silicon is a type of semiconductor material. It can turn into an insulating material at a low temperature. However, it can turn into a conducting material at a high temperature. At room temperature, silicon can turn into a conductor. So it can be caused a frequency shift in the microstrip antenna.

In pure silicon, there is a relatively small change in frequency when mounted on an antenna. However, when irradiated with an 808 nm infrared laser, frequency shift can occur very large. Because of pure silicon, there is a high sensitivity to light energy, but there is a low sensitivity to electrical energy. Whereas in P-type silicon, the frequency shift can occur very large when P-type silicon had installed on the antenna. However, when irradiated with an 808 nm infrared laser, a relatively small frequency change can occur. Because the P-type silicon has a high sensitivity to electrical energy, but there is a low sensitivity to light energy.

5. CONCLUSION

The frequency shift in the antenna of the microstrip can be increased in three ways. First, the antenna of the microstrip has formed a folded dipole structure. Second, it has made the SHF spectrum upwards. Third, it has been made by installing multiple switches. At room temperature, silicon can act as a conductor. Pure silicon is more sensitive to light energy. However, P-type silicon is more sensitive to the energy of electrical.

6. ACKNOWLEDGMENTS

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