

Design of a Directional Microstrip Antenna at UHF-Band for Passive Radar Application

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Abstract. Passive radar is an electromagnetic system that can receive the frequency signals from transmitted source such as FM radio, TV broadcasting station, or mobile communication base station to detect the presence of an object by utilizing its frequency reflection. One of the components of a passive radar is an antenna. An antenna in a passive radar is to receive an information signal from the reflection of an object and then the data that already received will be processed into the form of signal before it was displayed on the monitor. This paper aims to create a microstrip antenna with directional pattern for a passive radar. Microstrip antenna is a type of antenna that has a light weight, easy to fabricate, has a simple shape and lower cost. The design and simulation of antenna are using CST Studio Suite software. If the simulation results fit with the requirement, we fabricate and measure it and then compare it with the simulation results. The result of antenna has an ultrahigh frequency (UHF), directional pattern, gain 6dBi and range bandwidth minimum 470Mhz – 780Mhz.

1. Introduction

Passive radar is an electromagnetic system that can receive the frequency signals from transmitted source such as radio station, TV broadcasting station, or mobile communication base station to detect and track target by utilizing its frequency reflection [1]. Recently, passive radar can attract considerable interest of people due to its several advantages if compared with active system. Specifically, because a passive radar does not transmit, it is naturally convert and offers high tolerance to electronic countermeasure (ECM), it does not require additional spectrum and has been widely considered as a unique sensing capability to manage the radio spectrum congestion problem[2-3]. Passive radar can be generally classified into two categories, which are reference channel (RC) and surveillance channel (SC). In the first category, an RC is utilized at the receiver to collect the direct-path (transmitter-to-receiver) signal, while a separate surveillance channel (SC) is used to collect the target echo [1], [4], [5]. Work Principle passive radar can be seen in Figure 1.



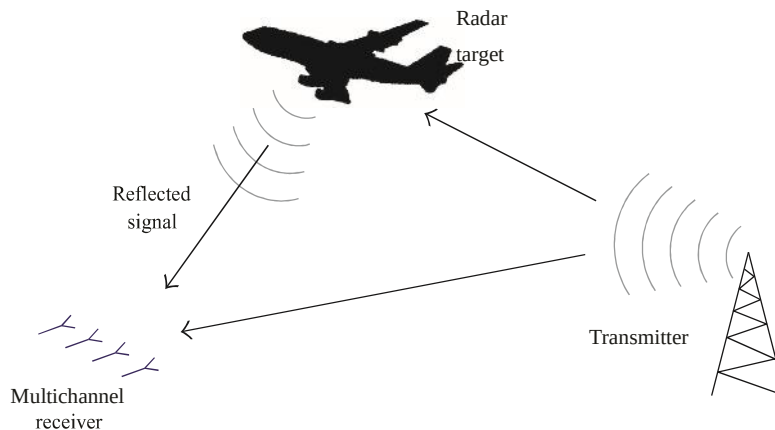


Figure 1. Passive radar principle

Antenna is one of the important components in a passive radar that acts as receiving a frequency signal. Passive radar antennas are generally large with microwave antenna type to be placed in certain positions. In this study the author will make a passive radar antenna using a type of microstrip antenna [1].

Microstrip antennas have become quite popular types of antennas in various applications. This is because the microstrip antenna has several advantages compared to conventional antennas. The advantages include: light, small, thin, and low-cost manufacturing. Because of the excess the microstrip antenna is called a low-profile antenna [6].

In this research, passive radar antennas utilize sources from TV transmitters. Frequency used is UHF (476-806 MHz) [7], in accordance with the regulation of TV broadcast spectrum in Indonesia. Antenna microstrip for passive radar applications have been made by Peter Knott [2], but uses an array method to obtain a large gain while in this research uses director and reflector to obtain a large gain.

2. Antenna design

Before designing of microstrip antenna to determine a specification and materials used for which antenna, In this research we use FR-4 as a substrate with dielectric constant of 4.5 and thickness 1.6 mm. To obtain the dimension of microstrip patch antenna we use equation (1) while to obtain patch length can be obtain from equation (2) – (10).

The width of dimension a patch microstrip antenna using the following equation [8].

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

where,

W = Width of the patch

c = Speed of light in free space (3×10^8 m/s)

ϵ_r = dielectric constant

$$L = \frac{c}{2f\alpha\sqrt{\epsilon_r}} - 2\Delta L \quad (2)$$

where,

$$\Delta L = 0,412h \frac{\frac{\epsilon_r e}{\epsilon_r e} + 0,3}{\frac{\epsilon_r e}{\epsilon_r e} - 0,2} \frac{w/h + 0,2}{w/h - 0,8} \quad (3)$$

where,

h = height of the substrate and ϵ_r :

$$\varepsilon_r = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left[1 + 12 \frac{h}{w} \right] - 1/2 \quad (4)$$

The dimension of ground plane length (lg) and width (wg) of microstrip antenna can be obtain from equation (5) and (6) [9].

$$Lg = 6h + L \quad (5)$$

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

The calculation of feed width (Wr) to achieve 50 Ω characteristic impedance.

$$\frac{W_0}{h} = \frac{2}{\pi} \left[B - 1 - \ln(2B - 1) + \frac{\varepsilon_r - 1}{2\varepsilon_r} \left(\ln(B - 1) + 0.39 - \frac{0.61}{\varepsilon_r} \right) \right] \quad (7)$$

Where,

$$B = \frac{3}{2} \frac{\pi}{Z_0 \sqrt{\varepsilon_r}} \quad (8)$$

And formula of the length a feed antenna

$$L = \frac{\lambda_g}{4} \quad (9)$$

Where,

$$\lambda_g = \frac{\lambda_u}{\sqrt{\varepsilon_r}} \quad (10)$$

The result of design antenna used that formula L x W (117.18 mm x 150 mm) and Lg x Wg (126.78 mm x 159.6 mm) have a 58.603 mm for a length of feed and 7.93 mm for width of feed antenna for specification frequency 586 MHz and used FR-4 epoxy of dielectric constant 4.5 for bandwidth 216 MHz. In the Figure 2 and Figure 3 is the result design antenna and result of return loss before modify.

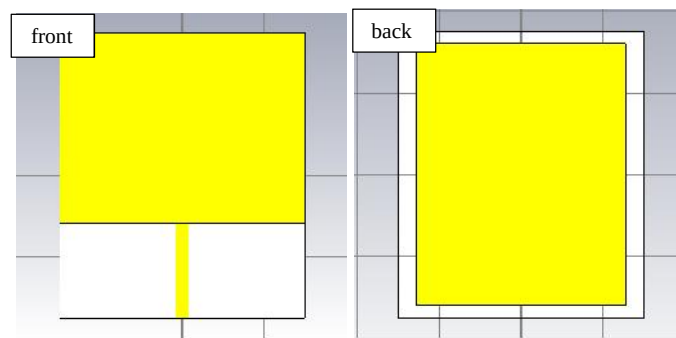


Figure 2. Design of antenna before modify.

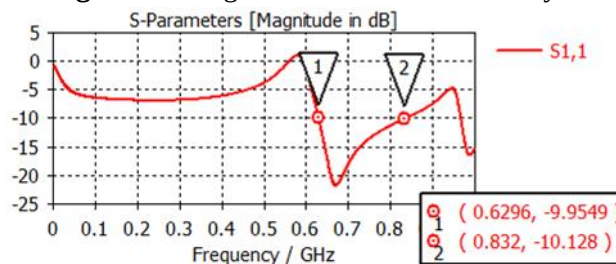


Figure 3. The result of return loss and bandwidth before modify design of antenna

The modify antenna used substrate FR4 epoxy of dielectric constant (ϵ_r) 4.5 and thickness (h) 1.6 mm. The proposed antenna design is shown in Figure 4 and the dimensions of the proposed design are listed in Table 1. The design of antenna inspired by antenna DVB-T [6].

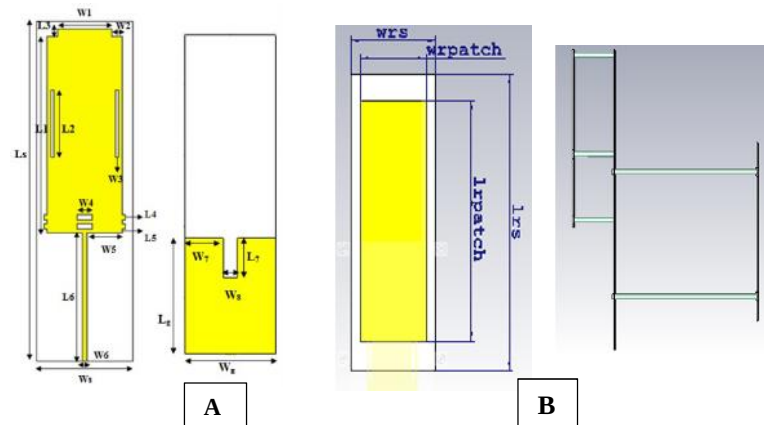


Figure 4. A. Microstrip patch antenna

B. Design of director, reflector and antenna in side view

Table 1. Dimension list of antenna design

Parameter	Value (mm)	Parameter	Value (mm)
W1	36	L1	130
W2	7	L2	44.5
W5	11	L5	3.5
W6	3	L6	85
W7	32	L7	60
W8	7	Ls	225
Ws	64	Lg	82
Wg	64	Lrs	200
Wrs	64	Lrpatch	162.5
Wpatch	50		

The substrate dimension of antenna is 225 mm x 64 mm x 1.6 mm. The impedance that was obtained is 50 Ω , this value is gotten after setting W6 with 3 mm. This director design has a function to direct the radiation pattern become previously directional omni-directional with the size of director substrate about 200 mm x 64 mm x 1.6 mm and the patch size is 162.5 mm x 50 mm x 0.035 mm. The patch design greatly influences with radiation pattern.

The distance between reflector to driver, and vice versa is using the equation of 0.35λ for reflector and 0.14λ for director [10]. The size is adjusting the antenna size and using parameter sweep for simulation in order to analyze the expected result.

3. Results and discussion

This antenna is designed and simulated by using CST Studio Suite software with 50 Ω impedance. The return loss value and the wide of bandwidth is 300 MHz. Figure 5 and Figure 6 is the simulation result from antenna before it was added by reflector and director. From Figure 5 it can be seen that the badhwidth is narrower before adding director and reflector. The radiation pattern is omnidirectional and the antenna gain is 2.16 dBi as shown in Figure 6.

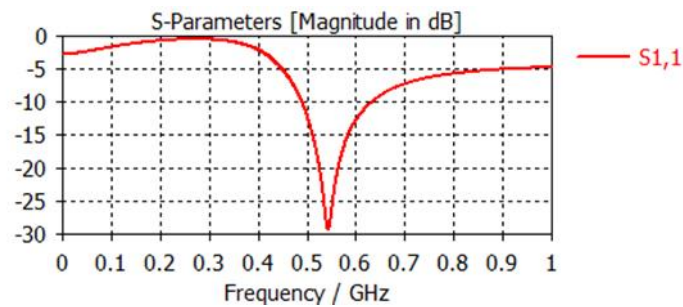


Figure 5. Return loss before adding the reflector and director.

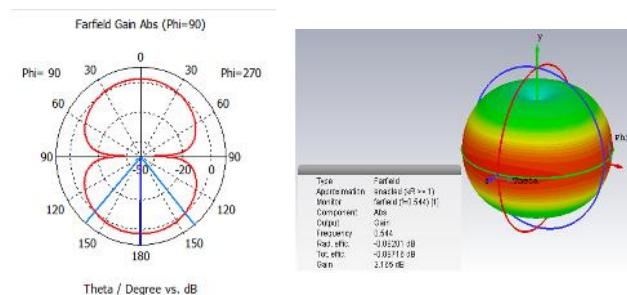


Figure 6. Radiation Pattern before adding the reflector and director.

After simulating the antenna before it is added by director and reflector, then add director with design that has been made. In the Figure 7 to 10 is the parameter sweep for optimization to matching the antenna specifications, the result of simulation after added director only can be seen in the Figure 11 until Figure 13.

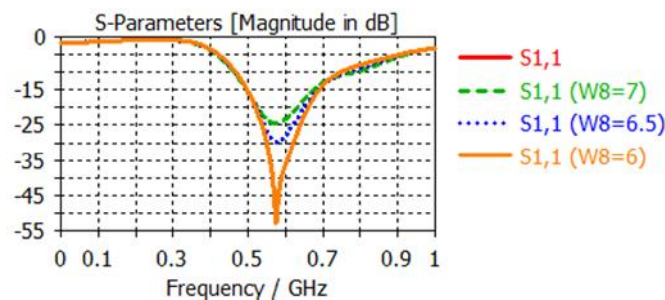


Figure 7. Simulation result of return loss with different w_8 at $l_7 = 50$ mm.

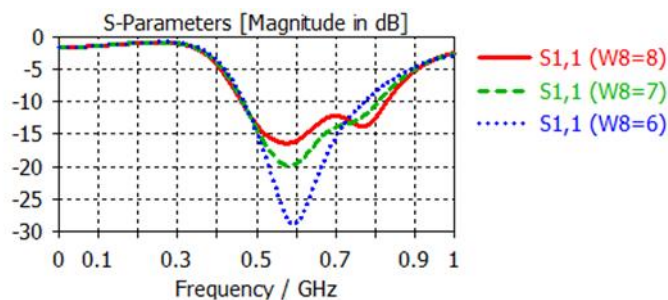


Figure 8. Simulation result of return loss with different w_8 at $l_7 = 60$ mm

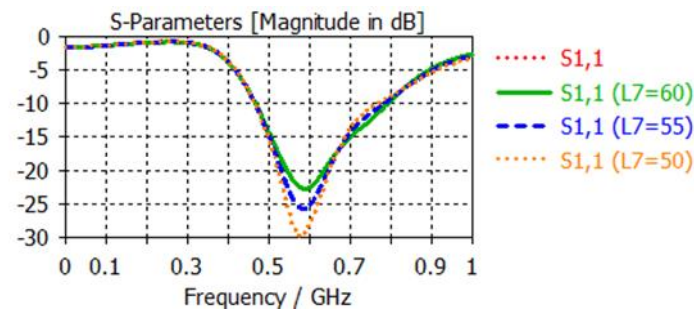


Figure 9. Simulation result of return loss with different $L7$ at $w8 = 6$ mm

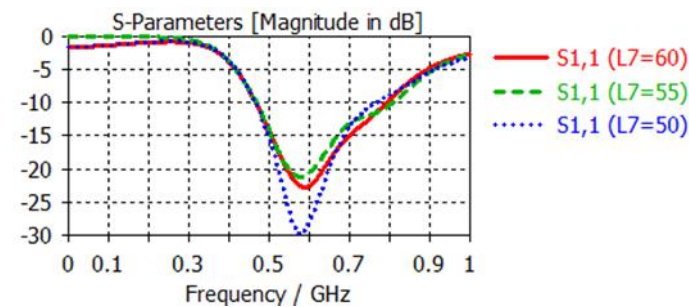


Figure 10. Simulation result of return loss with different $L7$ at $w8 = 6.5$ mm

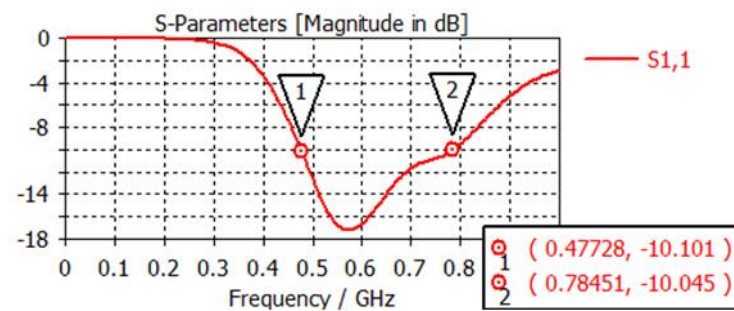


Figure 11. Optimization of bandwidth result before added reflector

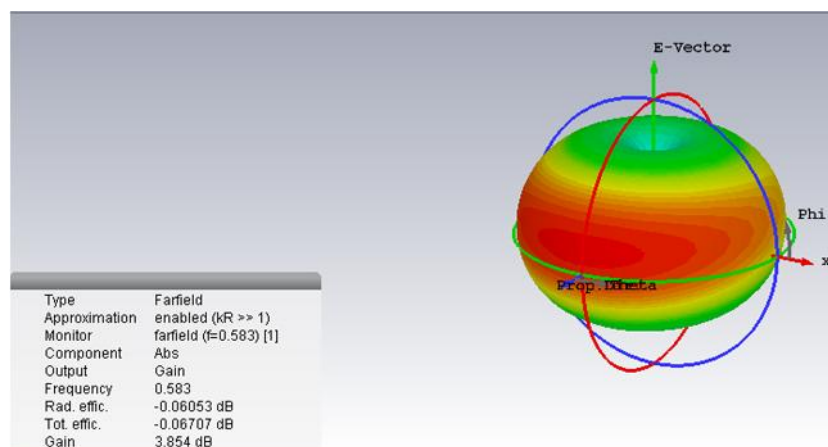


Figure 12. Radiation pattern and gain result after added reflector

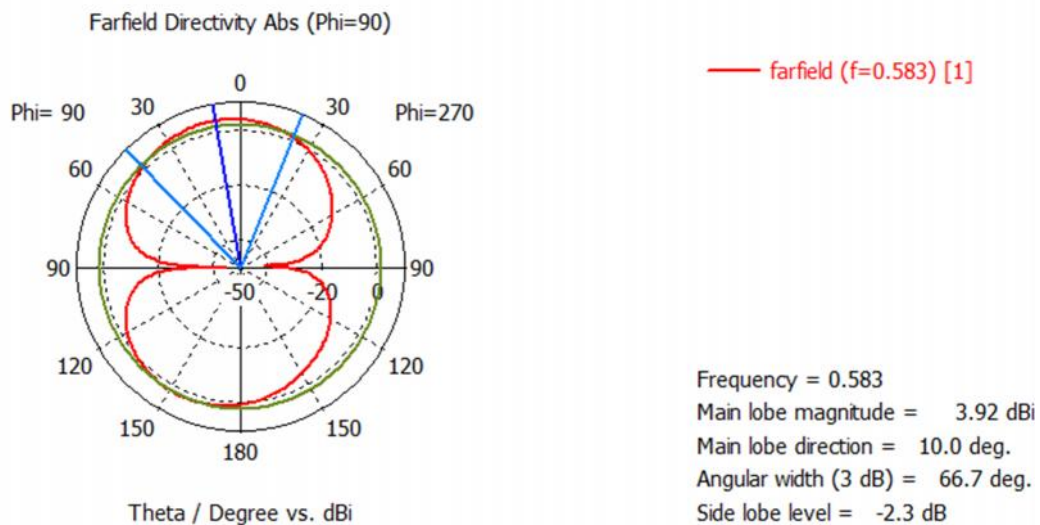


Figure 13. Radiation pattern result after added reflector

After adding the director, this antenna is added with reflector to obtain the better gain, but not reduce the bandwidth, as in the Figure 14 and Figure 15. From Figure 14 we can see that the return loss is better than before added the reflector. The antenna gain also increase after adding the reflector as shown in Figure 15.

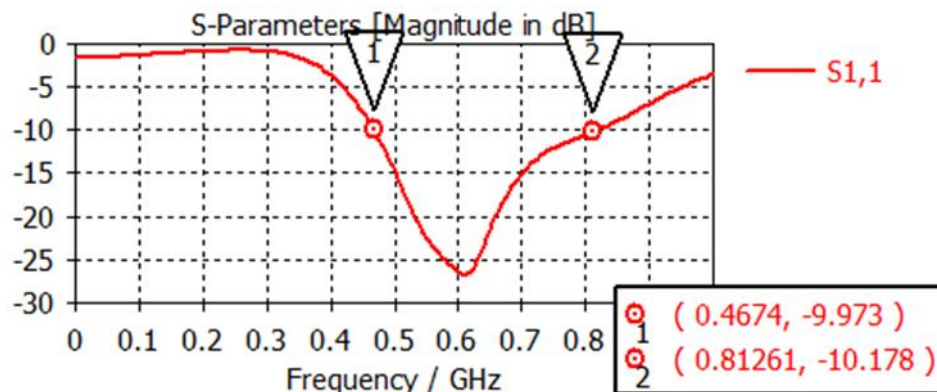


Figure 14. Bandwidth result after added reflector

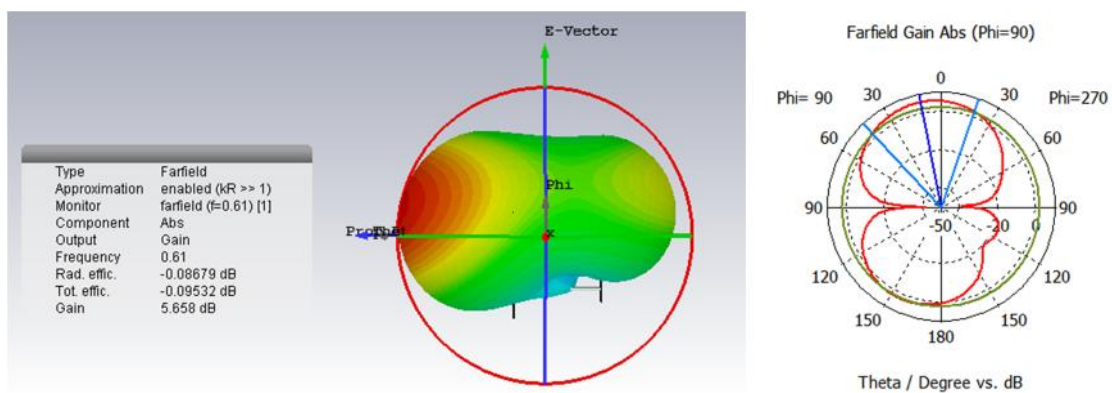


Figure 15. Gain result after added reflector

The gain can optimization applying by enlarge the dimension of reflector 225 mm x 64 mm to 225 mm x 225 mm with the same range, as in Figure 16 design of enlarge the reflector. In the Figure 17 is the result the gain after added reflector has been enlarge, and Figure 18 is the result radiation pattern.

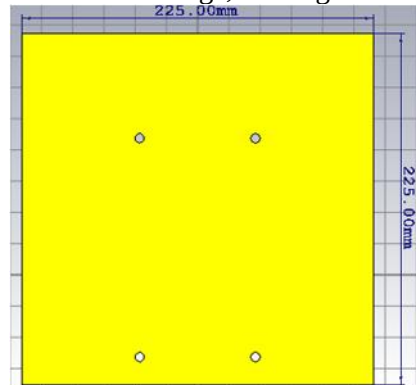


Figure 16. The design reflector 225 mm x 225 mm to optimization the gain and magnitude of frequency

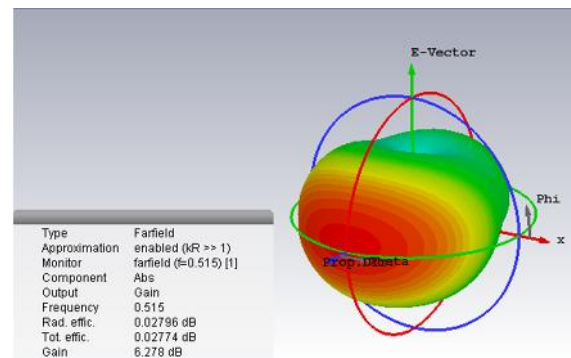


Figure 17. The result of gain after added reflector 225 mm x 225 mm

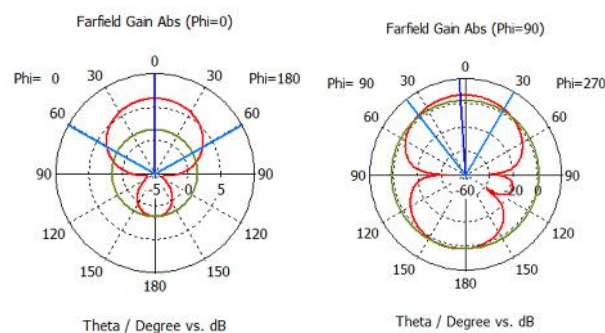


Figure 18. The result of radiation pattern with cos phi 0° and 90° after added reflector 225 mm x 225 mm.

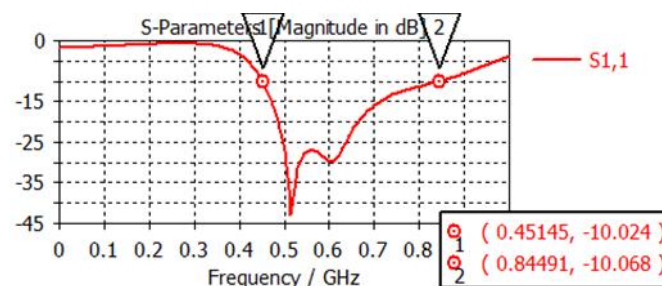


Figure 19. The result of return loss after added reflector 225 mm x 225 mm.

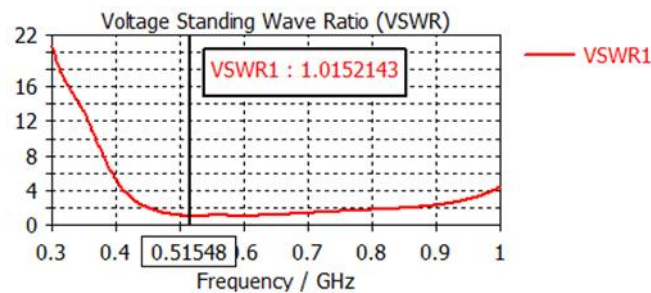


Figure 20. VSWR of the optimal design

The final result of return loss can be seen in Figure 19 with 393 MHz of bandwidth and the result of the VSWR can be seen Figure 20.

4. Conclusions

Design of antenna microstrip with directional radiation pattern for radar passive system that operate in Indonesia has UHF-band frequency range correspond with the frequency of television transmitter. This antenna used director and reflector to have gain that was expected, with 0.14λ for the distance of director to driver and 0.35λ for the distance of reflector to driver. The substrate materials that used are FR-4 with 4.5 dielectric constant, while the size is 255 mm and 64 mm. The dimension of director is 200 mm x 64 mm and the dimension of reflector is 225 mm x 225 mm in order to the result of gain is 6.27 dBi and bandwidth 393 MHz from 451 – 844 MHz for return loss less than -10 dB.

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