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On The Design of Array Microstrip Antenna with S-Band Frequency for Radar Communication

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Abstract. The research aims to design the prototype of microstrip array antenna with S-Band frequency for radar communication. The design methodology has done in several stages. The first stage was conducted the calculation of antenna parameter using manual calculation. The parameters are simulated using Computer Simulation Technology (CST). The optimization processes have done by various parameters are patch width, patch length, and the distance between patches. After finding the best result, the antenna was implemented and the parameter values are tested in the laboratory and compared with the simulation result. The simulation result showed that antenna performance at 3 GHz frequency with 7,07 dB gain, value VSWR 1.0272176, return loss -37,441025, and bandwidth 163,7 MHz the implementation of array microstrip antenna has size 210 x 84.5 mm, with parameter worked on the frequency of 3.04 GHz with gain value 8.6 dB, VSWR 1.068, return loss -29.790, and the bandwidth of 120 MHz. Its showed that the fabrication antenna can work on S-Band frequency as well as the research purpose.

1. Introduction

The increasing need for communication and information encourages the development of technology in the field of telecommunications, especially wireless communication systems. Wireless communication system is a communication system with transmission media in the form of electromagnetic wave propagation without having to be connected directly with cable media [1][2]. In its development, communication becomes one of the ways one conveys information from a distant place quickly and accurately. With the passage of time, telecommunication technology is widely used to help human life in addition to communication between humans, can also be used as a means to detect the circumstances surrounding us that we do not know [3,4,5]. The technology is often known as radar. Radar is being a highly developed technology nowadays due to its application in various aspects of life such as military,



aviation or marine. But here, a radar is developed by using a microstrip antenna which is arranged by array method so that not only one microstrip is applied but there are several microstrips in one antenna.

The development of antennas with different variations and designs is done to support wireless communication technology [1,6,7]. The expected antenna design and shape is the antenna that has high gain, great efficiency, wide bandwidth, small Return Loss (RL), Low Voltage Standing Wave Ratio (VSWR), relatively light weight, and low cost. One type of antenna that meets such criteria is a microstrip antenna. Each microstrip antenna design has different capabilities in responding to electromagnetic waves. This antenna is very suitable for communication using S-Band frequency because this type of antenna is light and has a small volume thus it is in accordance with the availability of limited space [8]. Its simple configuration simplifies the assembly and adjustment processes to radar conditions [9,10,11,12]. S-band frequency used is in the range of 2.9 Ghz to 3.1 Ghz, this frequency is suitable to be applied on the radar because the excess is very resistant to changes in weather both rain and heavy clouds. Radar itself stands for Radio Detection and Ranging. As the name implies, radar is used to detect the position of an object expressed in the direction of azimuth which refers to the north direction and at a certain range of the antenna [13,14,15]. Radar will be difficult to work if many objects block the signal emission, because the radar works by sending signals in the form of electromagnetic waves in a direction and receive the signal reflection results to other objects. In design, the antenna will be tested in a simulation that will determine how well the performance of the antenna is. So that will minimize errors in the design. Software used is Computer Simulation Technology (CST) [16].

2. Theoretical Foundations

2.1 Microstrip Antenna

Microstrip antenna can be defined as one type of antenna that is shaped like a blade / part whose size is very thin / small lies on the thin board as a substrate.

To determine the width of the patch, equation (1) can be applied.

$$W = \frac{C}{2f_r \sqrt{\frac{(\epsilon_r + 1)}{2}}} \quad (1)$$

Where W is the wanted value while C is the speed of light (3.108 m / s), f_r is the working frequency of the antenna and ϵ_r is the substrate dielectric constant. To calculate the length of the patch, apply equations (2) to (4).

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

$$l_{\text{eff}} = \frac{C}{2f_r \sqrt{\epsilon_{\text{reff}}}} \quad (3)$$

$$\Delta L = 0,412 \cdot h \frac{(\epsilon_{\text{reff}}+0,3) \left(\frac{W}{h}+0,264\right)}{(\epsilon_{\text{reff}}-0,258) \left(\frac{W}{h}+0,8\right)} \quad (4)$$

In the arrangement of the array antenna, what to note is the distance between the patch elements [4]. To determine the distance between the patches, apply the equation (5).

$$d = \frac{c}{2f} \quad (5)$$

2.2 Microstrip Feeder Channels

Microstrip antenna is an antenna that is composed by 3 components namely, ground plane, substrate, and irradiation patch. To calculate the 50 Ω wavelength channel width, equations (6) to (9) are applied.

For $u = w/h < 2$ apply equation (2.8) and (2.9) [8].

$$w/h = \frac{8e^A}{e^{2A} - 2} \left(\text{for } \frac{w}{h} < 2 \right) \quad (6)$$

$$A = \frac{Z_0}{60} \left\{ \frac{\epsilon_r + 1}{2} \right\} + \frac{\epsilon_r - 1}{\epsilon_r + 1} \left\{ 0,23 + \frac{0,11}{\epsilon_r} \right\} \quad (7)$$

for $u = w/h > 2$ apply equation (2.10) and (2.11) [3].

$$w/h = \frac{2}{\pi} \left\{ (B - 1) - \ln(2B - 1) + \frac{\epsilon_r - 1}{2\epsilon_r} \left[\ln(B - 1) + 0,39 - \frac{0,61}{\epsilon_r} \right] \right\} \quad (8)$$

$$B = \frac{60\pi^2}{Z_0\sqrt{\epsilon_r}} \quad (9)$$

Hammerstad and Jensen gave a more precise formula.

$$\epsilon_{r,eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left(1 + \frac{10}{u} \right)^{-a,b} \quad (10)$$

Which is,

$$a = 1 + \frac{1}{49} \ln \left[\frac{U^4 + \left(\frac{U}{52}\right)^2}{U^4 + 0,432} \right] + \frac{1}{18,7} \ln \left[1 + \left(\frac{U}{18,1}\right)^3 \right] \quad (11)$$

$$b = 0,564 \left(\frac{\epsilon_r - 0,9}{\epsilon_r + 3} \right)^{0,053} \quad (12)$$

2.3 Impedance Matching

In the Wilkinson method, the impedance value Z is given by equation (13).

$$Z = Z_0\sqrt{N} \quad (13)$$

To determine the feeder channel width in T-junction we use (8). While to determine the length of feeder T-Junction channels equations (14) to (17) are applied.

$$L = \frac{\lambda g}{4} \tag{14}$$

Which is,

$$\lambda g = \frac{\lambda_0}{\sqrt{\epsilon_{r,eff}}} \tag{15}$$

$$\lambda_0 = \frac{c}{f} \tag{16}$$

$$\epsilon_{r,eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[\frac{1}{\sqrt{1 + 12 \left(\frac{h}{w} \right)}} \right] \tag{17}$$

3. Design and simulation

The design stage of this array microstrip antenna is shown in the flow chart of Figure 1.

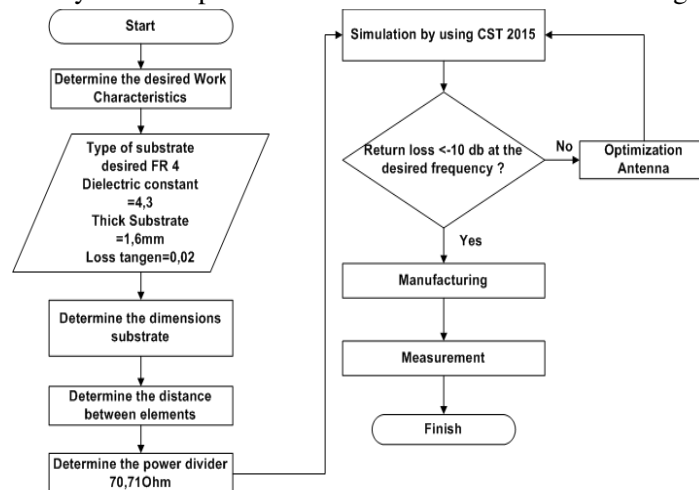


Figure 1. Flowchart Design of Microstrip Array antenna

3.1 Simulation of Antenna Microstrip Array

Using the equation of the calculation results, the following dimensions of the antenna are obtained.

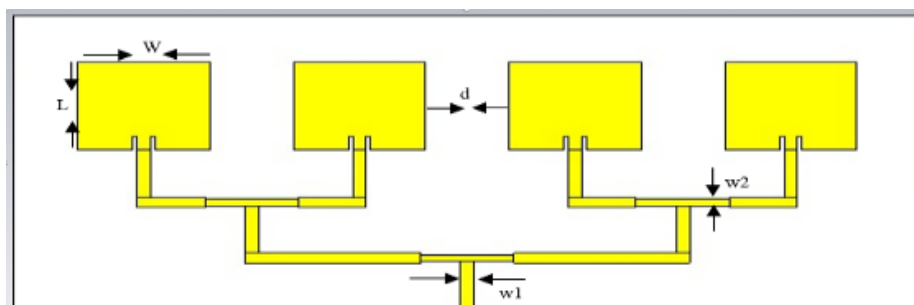


Figure 2. Array Microstrip Antenna Calculation

Figure 2 above is the antenna dimension of the result of the calculation which is then incorporated into the simulation design of the microstrip array antenna. From the design based on the calculation, obtained the value of VSWR and return loss with a frequency of 2.5941 GHz with a value of VSWR 1.0617253. As for the return loss of -30.476193 dB.

In this study, 6 samples were taken by changing the distance between patch (d), patch width (w) and patch length (l) to obtain VSWR value and return loss according to desired specification.

Table 1. Six Data Samples of Antenna Optimization

Optimization	W(mm)	L(mm)	w1(mm)	w2(mm)	d(mm)	Lm(mm)
1	28,429	25,885	3	1,97	21,571	21,73
2	32,429	25,885	3	1,97	17,571	21,73
3	32,429	22,885	3	1,97	17571	21,73
4	33,429	22,775	3	1,97	16,571	21,73
5	34,429	22,885	3	1,97	15,571	21,73
6	34,429	24,775	3	1,97	15,571	21,73

The results of each optimization can be seen from the VSWR simulation output and return loss using the data from table 2.

Table 2. Optimization Result Data

Optimization	Frequency (GHz)	Return Loss (dB)	VSWR
1	2,598	-22,905714	1,154168
2	2,592	-48,185427	1,0078233
3	2,98	-55,741618	1,0032737
4	3	-37,445004	1,0272049
5	2,994	-28,763316	1,075683
6	2,666	-18,157588	1,2821387

From the results of the optimization data which is seen in table 2, it can be seen that the antenna design is in accordance with the specification at the time of the fourth optimization with the working frequency 3 GHz, return loss -37,445004, and VSWR 1,0272049.

3.2 Antenna Bandwidth Simulation Results

The upper and lower frequencies in the simulation can be seen above antenna limit of 3.0766 GHz and antenna lower limit of 2.9129 GHz.

$$\begin{aligned} \text{Bandwidth} &= |f_2 - f_1| = |3,0766 - 2,9129| \\ &= 163,7 \text{ MHz} \end{aligned}$$

$$\text{Bandwidth (\%)} = \frac{f_2 - f_1}{f_c} \times 100\% = 5,4\%$$

4. Analysis and Measurement

Microstrip array antenna measurements were done using instrument Network Analyzer ADVANTEST R3770 with frequency range of 300 KHz - 20 GHz. This measurement is done with the purpose of identifying the specification of microstrip array antenna that has fulfilled the expected requirement before, so that can be recognized and analyzed. Parameters measured are return loss and Voltage Standing Wave Ratio (VSWR).

4.1 Measurement and Analysis of Return Loss Value

From the results obtained return loss value of -29.790 dB with a middle frequency of 3.046 GHz. In this measurement occurs a frequency shift of 46 MHz

4.2 Measurement of Radiation Pattern and Antenna Gain

To measure the antenna radiation pattern, apply Signal Generator and Spectrum Analyzer devices. The antenna is rotated with an angle gain of 10^0 , which starts from an angle of 0^0 to 360^0 .

The radiation pattern of the array antenna microstrip at 3.04 GHz frequency tends to be directional because it is more focused in one direction.

5. Conclusion

- With the parameters obtained from the simulation results, this array microstrip antenna meets the desired specification.
- From the measurement results, the value obtained occurred shift from the simulation results that is equal to 46 MHz
- From the measurements and simulations performed, there are some differences. The difference between the two is due to several factors, such as humidity, temperature, less accurate layout fabrication process, less precise port soldering, losses in coaxial cable on network analyzer, losses in Anechic Chamber room during measurement, and conduction loss owned by PCB material.

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