March - April 2020
ISSN: 0193-4120 Page No. 8061 - 8067

Investigation on Substrate Materials Effects in Aluminum Tape Dipole-Based Antenna

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Abstract

A dipole antenna is one of the most commonly used antenna for telecommunication. This research discusses substrate effects, design optimization, and fabrication of dipole antennas at a frequency of 600 MHz. This frequency is included in television frequency. The fabrication was done to compare the simulation results with the real implementation. Fabrication uses two different substrate materials, namely Styrofoam and Acrylic. Aluminum tape conductors that have 3 different width types, namely 1 cm, 2.5 cm, and 5 cm were used as the patches. Research has been carried out by determining the operating frequency, designing, simulating, optimizing, and testing. The testing location is Telkom University, 4th floor of the School of Applied Science, Bandung. Design performance can be seen from the simulation and implementation results. In this paper, the antennas with aluminum foil tape which has 3 different widths have been fabricated and presented in this paper. The results in this research are compared and analyzed the simulation and measurement results.

Keywords; *dipole antenna, Styrofoam substrate, Acrylic substrate, aluminum foil tape*

I. INTRODUCTION

The dipole antenna was discovered by a German physicist named Heinrich Hertz around 1886. He was the one who pioneered experiments with radio waves. The dipole antenna is a fundamental antenna for transmitting and receiving radio waves [1]. The dipole antenna is realized by a straight wire spaced between 2 wires [8]. The following are the most popular formations of dipole antennas: Biconical, Bow-Tie, Folded Dipole, Sleeve Dipole [7].

Dipole antenna includes a wire antenna. The dipole antenna has a current distribution for the dipole of length 2l = λ / 10, λ / 2, λ and 1.5λ. The dipole antenna that is often used is a single dipole antenna or a half-wave dipole antenna. The length of a single dipole antenna is ½λ at the operating frequency having a feeder point in the middle, the corresponding input impedance is 73Ω and has a figure-eight shaped radiation pattern toward the front of the wire [4]. Fig.1 shows the structure of the dipole antenna λ/2.

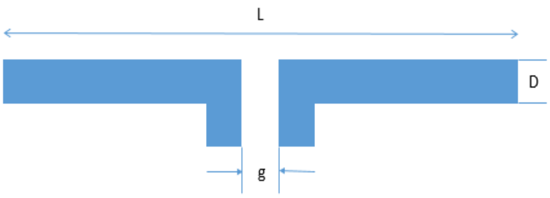

Fig.1. Dipole Antenna λ/2

The wavelength of the dipole antenna can be determined by using eq.1, eq.2, eq.3, eq.4 [3].

$$\lambda = \frac{c}{f} \qquad 1$$

where:

λ = wavelength

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March - April 2020
ISSN: 0193-4120 Page No. 8061 - 8067

C = velocity of electromagnetic wave (3x10^8 m/s)

f = center frequency

To determine the total length of the dipole antenna wire we use eq.2, eq.3 and eq.4.

Length of a half-wave dipole antenna,

$$L = \frac{143}{f} \quad (2)$$

Feeding gap of the antenna,

$$g = \frac{L}{200} \quad (3)$$

Radius of the wire,

$$R = \frac{\lambda}{1000} \quad (4)$$

Until now, research on dipole antenna is still being discussed, start from microstrip dipole antenna that work at 2.4 GHz [5]. Microstrip dipole antenna which has been analyzed with different widths and lengths at the 2.4 GHz frequency [6]. Based on the above research, this paper will discuss the dipole antenna using aluminum foil tape which has different widths as the patches and will be analyzed between simulation results and measurement results.

II. METHODOLOGY

This paper will present a dipole antenna using aluminum foil tape that has different widths as a patch. This dipole antenna will use 2 different substrates to see if there are any effects when it has been fabricated. As the transmission media is a coaxial cable that has a 50-ohm impedance of 2 pieces which is connected to the patch the inner part only becomes a balanced cable. The first step is to do a simulation and if the results are still not fulfilled, an optimization step is performed.

Dipole antenna designed at a frequency of 600 MHz. This antenna using Styrofoam and Acrylic as a substrate with dielectric permittivity εr =1.03 for Styrofoam and εr =2.90 for Acrylic and height h = 13 mm for Styrofoam and h = 4 mm for Acrylic. For a patch of the antenna using aluminum foil tape with thickness t = 0.025 mm and different widths. In figure 2 – figure 4 is the result of designing of the dipole antenna. This antenna was designed using CST Studio Suite 2018 software and the design has been optimized to achieve the desired characteristic values.

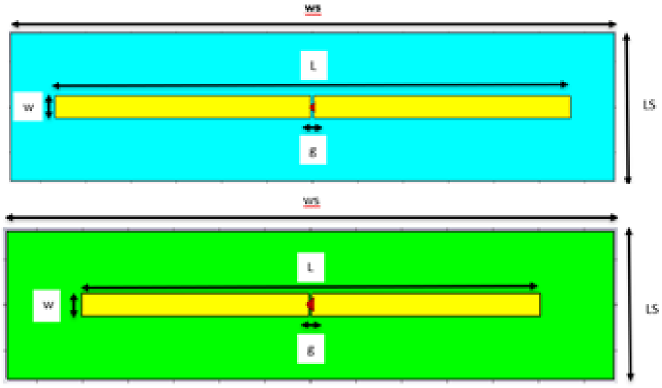

Fig.2. Design of Dipole Antenna With 1 cm Wide Aluminum Foil Tape

TABLE I. ANTENNA PARAMETER I

Antenna Parameter	Symbol	Styrofoam Value (mm)	Acrylic Value (mm)
Patch length	L	225.75	200.18
Patch width	w	10	10
Substrate length	Ls	266	266
Substrate width	ws	65	65
Substrate thickness	h	13	4
Aluminum foil tape thickness	t	0.025	0.025
Gap	g	1.12	1

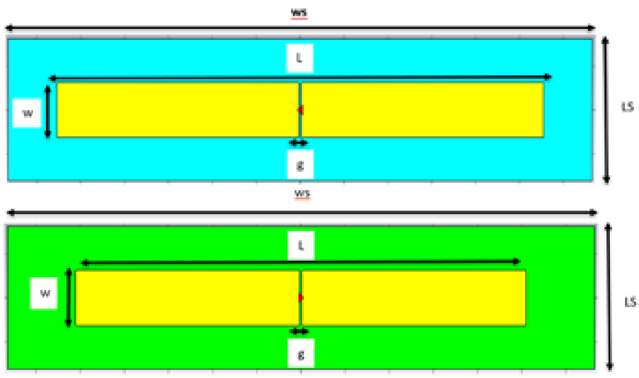

Fig.3. Design of Dipole Antenna With 2.5 cm Wide

Aluminum Foil Tape

TABLE II. ANTENNA PARAMETER II

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March - April 2020
ISSN: 0193-4120 Page No. 8061 - 8067

Antenna Parameter	Symbol	Styrofoam	Acrylic
		Value (mm)	Value (mm)
Patch length	L	220.12	202.99
Patch width	w	25	25
Substrate length	Ls	266	266
Substrate width	ws	65	65
Substrate thickness	h	13	4
Aluminum foil tape thickness	t	0.025	0.025
Gap	g	1.10	1.01

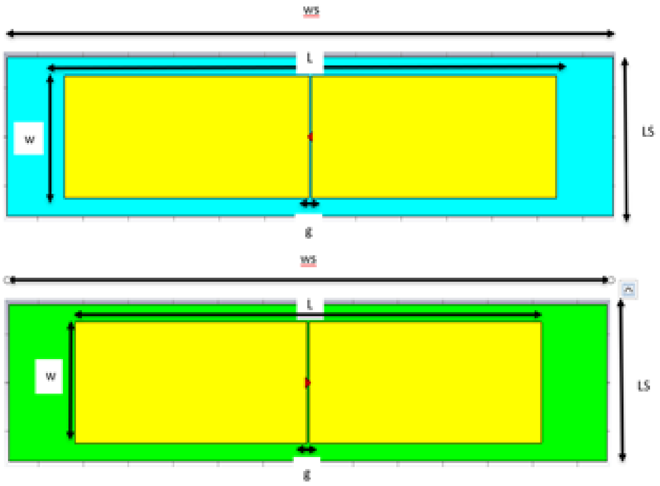

Fig.4. Design of Dipole Antenna With 5 cm Wide Aluminum Foil Tape

TABLE III. ANTENNA PARAMETER III

Antenna Parameter	Symbol	Styrofoam	Acrylic
		Value (mm)	Value (mm)
Patch length	L	215.09	206.56
Patch width	w	50	50
Substrate length	Ls	266	266
Substrate width	ws	65	65
Substrate thickness	h	13	4
Aluminum foil tape thickness	t	0.025	0.025
Gap	g	1.07	1.03

Optimization of antenna dimensions needs to do to achieve the desired antenna specifications Optimization was done by changing the patch length antenna to shift the antenna operating frequency.

III. RESULTS AND DISCUSSION

In this section, the results of the dipole antenna measurements will be discussed. The purpose of the measurement is to find out whether the simulation results are the same as the measurement results. In Figure 5, the results of manual fabrication are shown:

Fig.5. Fabrication Result

A. Result of Simulation

Based on the results of the optimization for antenna I, the antenna specifications have been reached. This is stated in Figure 5 which VSWR 1,410, with a bandwidth of 72.11 MHz or 12.044 % for Styrofoam and VSWR 1.248, with a bandwidth of 83.7 MHz or 14.049 % for Acrylic.

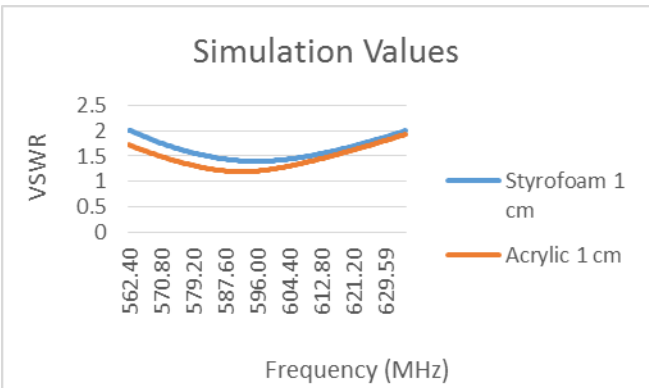

Fig.6. VSWR Graph Simulation Result for Antenna I

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March - April 2020
ISSN: 0193-4120 Page No. 8061 - 8067

Based on the results of the optimization for antenna II, the antenna specifications has been reached. This is stated in Figure 6 which VSWR 1,393, with a bandwidth of 98.4 MHz or 16.328 % for Styrofoam and VSWR 1.322, with a bandwidth of 107.04 MHz or 17.896 % for Acrylic.

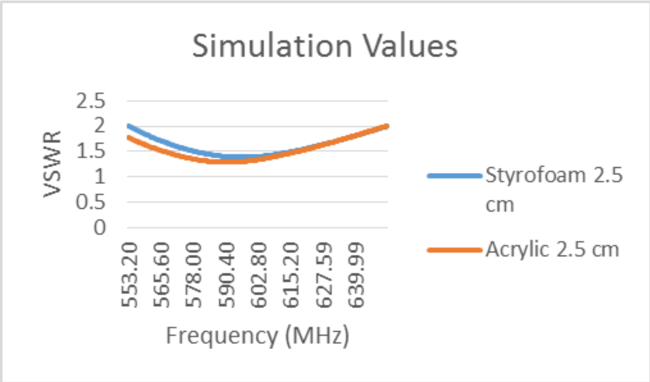

Fig.7. VSWR Graph Simulation Result for Antenna II

Based on the results of the optimization for antenna III, the antenna specifications has been reached. This is stated in Figure 7 which VSWR 1,363, with a bandwidth of 143.19 MHz or 23.348 % for Styrofoam and VSWR 1.479, with a bandwidth of 128.32 MHz or 21.329 % for Acrylic.

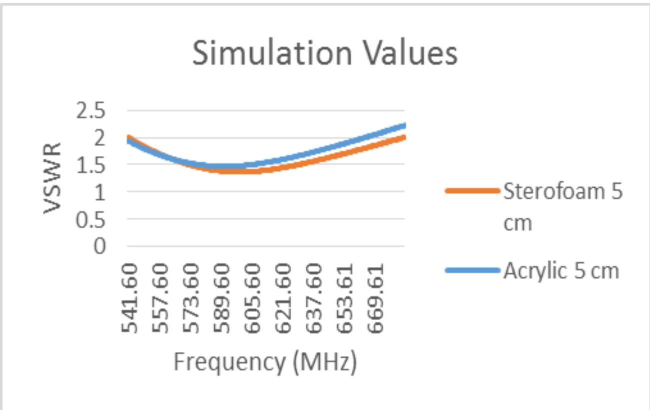

Fig.8. VSWR Graph Simulation Result for Antenna III

The simulation gain results are shown in Table IV. From Table IV the wider of aluminum foil tape makes the gain results greater between the Styrofoam substrate and the Acrylic substrate.

TABLE IV. SUMMARY OF GAIN SIMULATION RESULTS

Antenna Parameter	Styrofoam			Acrylic		
	1 cm	2.5 cm	5 cm	1 cm	2.5 cm	5 cm
Gain	2.075 dB	2.009 dB	2.175 dB	2.097 dB	2.111 dB	2.116 dB

From Table V it showed off the all value in simulation the antenna. It has been simulated and has the desired value, therefore it is continued to the next stage, namely fabrication.

TABLE V. SIMULATION VALUE OF ALL DIPOLE ANTENNAS

Antenna Parameter	Styrofoam			Acrylic		
	1 cm	2.5 cm	5 cm	1 cm	2.5 cm	5 cm
Return Loss	-15.378 dB	-15.683 dB	-16.266 dB	-19.116 dB	-17.159 dB	-14.278 dB
VSWR	1.410	1.393	1.363	1.208	1.322	1.479
ABW	72.11 MHz	98.4 MHz	143.19 MHz	83.7 MHz	107.04 %	128.32 MHz
FBW	12.044 %	16.328	17.896 %	14.049 %	17.896 %	21.329 %
Gain	2.075 dB	2.009 dB	2.175 dB	2.097 dB	2.111 dB	2.116 dB

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March - April 2020
ISSN: 0193-4120 Page No. 8061 - 8067

IV. REALIZATION AND MEASUREMENT

A. Measurement Result of Dipole Antenna

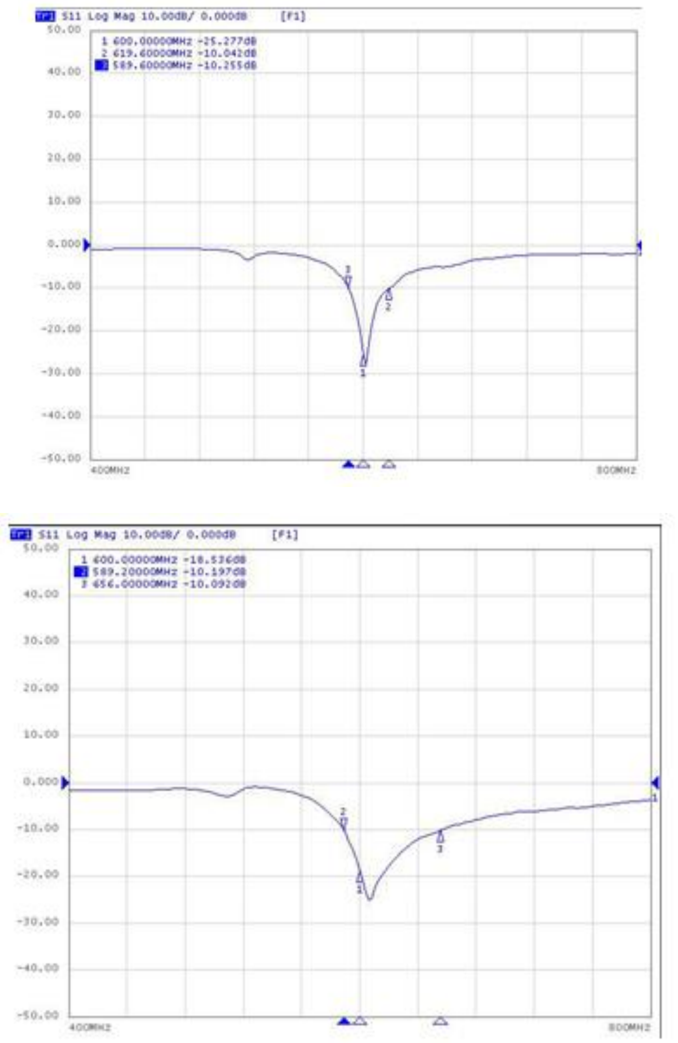

Fig.10. Measurement Result for Antenna I

In Figure 10 it is shown that the two antennas can operate well at a frequency of 600 MHz. This is evidenced because the results of measurements and simulations are not very different. based on measurements, the return loss value is -25.277 dB with VSWR 1.115 and bandwidth 30 MHz or 4.96 %, while the simulation results obtained have return loss value of -15.378 dB with VSWR 1.410 and bandwidth 72.11 MHz or 12.044 % for Styrofoam. The return loss value is -18.536 dB with VSWR 1.2684 and bandwidth 66.8 MHz or 5.36 %, while the simulation results obtained have return loss -19.116 dB with VSWR 1.248 and bandwidth 83.7 MHz or 14.049 % for Acrylic. The difference between the simulation results and measurements is caused by differences in antenna dimensions that are not the same while on fabrication.

Fig.11. Measurement Result for Antenna II

In Figure 11 it is shown that the two antennas can operate well at a frequency of 600 MHz. This is evidenced because the results of measurements and simulations are not very different. based on measurements, the return loss value is -18.097 dB with VSWR 1.284 and bandwidth 59.688 MHz or 9.92 %, while the simulation results obtained have return loss value of -15.683 dB with VSWR 1.393 and bandwidth 98.4 MHz or 16.328 % for Styrofoam. The return loss value is -18.135 dB with

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March - April 2020
ISSN: 0193-4120 Page No. 8061 - 8067

VSWR 1.282 and bandwidth 39.2 MHz or 6.56 %, while the simulation results obtained have return loss -17.159 dB with VSWR 1.322 and bandwidth 107.04 MHz or 17.896 % for Acrylic. The difference between the simulation results and measurements is caused by differences in antenna dimensions that are not the same while on fabrication.

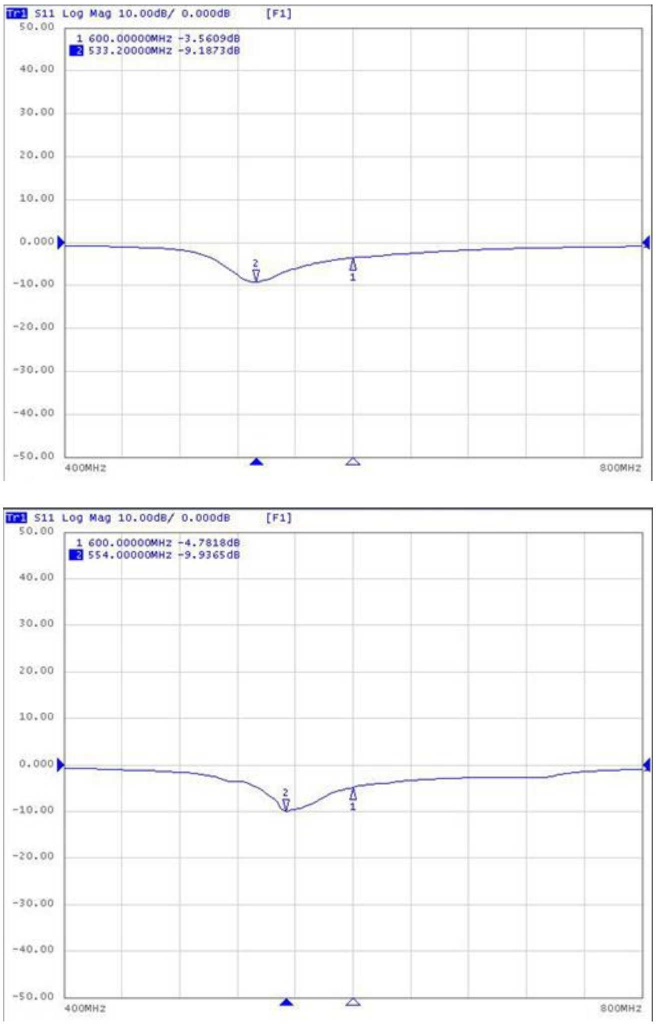

Fig.12. Measurement Result for Antenna III

In Figure 12 it is shown that the two antennas cannot operate well at a frequency of 600 MHz. This is evidenced because the results of measurements and simulations is very different. based on measurements, the return loss value is -3.560 dB with VSWR 4.496 and didn't have any bandwidth, while the simulation results obtained have return loss value of -16.266 dB with VSWR 1.363 and bandwidth 143.19 MHz or 23.348 % for Styrofoam. The return loss value is -4.781 dB with VSWR 3.724 and didn't have any bandwidth, while the simulation results obtained have return loss -14.278 dB with VSWR 1.479 and bandwidth 128.32 MHz or 21.329 % for Acrylic. This antenna cannot operate well caused by the effect of capacitance that appears on the gap between the two patches which causes the return loss value along with the VSWR to be incompatible.

Table VI shows the measurement result of all the dipole antennas. From Table VI the antennas are shown to have the best and the worst results, there are several things behind the fabricated antenna that has different results from the simulation. However, based on the explanation above, it is understood why there are differences in results between simulation and fabrication.

TABLE VI. MEASUREMENT RESULT OF ALL DIPOLE ANTENNAS

Antenna Parameter	Styrofoam			Acrylic		
	1 cm	2.5 cm	5 cm	1 cm	2.5 cm	5 cm
Return Loss	-25.27 dB	-18.09 dB	-3.56 dB	-18.53 dB	-18.13 dB	-4.78 dB
VSWR	1.115	1.284	4.49	1.268	1.282	3.72
ABW	30 MHz	59.68 MHz	-	66.8 MHz	39.2 MHz	-
FBW	4.96 %	9.92 %	-	5.36 %	6.56 %	-

V. CONCLUSION

Dipole antenna was made in this research that best meets the desired standard is a dipole antenna that used aluminum tape which has a width of 1 cm because it has little capacitance effect on the gap between the patches, on the other hand, dipole antenna that used aluminum tape that has a width of 5 cm the results obtained are not in accordance with the standard because the effect of capacitance is large on the gap between the two patches.

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March - April 2020
ISSN: 0193-4120 Page No. 8061 - 8067

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