Simulation of Microstrip Reflectometer System for Complex Reflection Coefficient Measurements

Ermeey Abd. Kadir  
Faculty of Electrical Engineering  
Universiti Teknologi MARA Terengganu, 23000 Terengganu, Malaysia  
e-mail: ermee461@tganu.uitm.edu.my

Husna Abd. Rahman  
Faculty of Electrical Engineering  
Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia  
e-mail: husna232@salam.uitm.edu.my

Abstract - This technical paper presents a simulation of three probes reflectometer system for complex reflection coefficient measurement. This involves designing a circuit of Reflectometer using Genesys software. The simulation results and data from published Three-Probe Reflectometer measurement system is being compared to show the accuracy of the simulation results. Using the design circuit, a microstrip circuit will be fabricated and complex reflection coefficients were measured using Vector Network Analyzer (VNA). A comparison was made among simulations, VNA and publishes data. From the comparison, it shows a close agreement among them. It shows that Microstrip Reflectometer measure Complex Reflection Coefficient.

Keywords – Complex Reflection Coefficient, Genesys, Vector Network Analyzer, Microstrip, Reflectometer

I. INTRODUCTION

The three-probe reflectometer is probably the oldest and the simplest implementation to measure complex reflection coefficient [1]. The Complex Reflection coefficient in a slotted waveguide partly loaded with a lossy dielectric can be determined accurately, in terms of the measured standing-wave pattern, it can be obtain by a computer program solving a set of transcendental equations [2,6]. A reflection coefficient magnitude of zero is a perfect match; a value of one is perfect reflection. Note that the reflection coefficient is a vector, so it includes an angle. Unlike VSWR, the reflection coefficient can distinguishes among short and open circuits [3]. A short circuit has a value of 1 (1 at an angle of 180 degrees), while an open circuit is one at an angle of 0 degrees.

II. METHODOLOGY

This slotted line is a rectangular waveguide with a longitudinal slot operates in TE10 mode [4, 5]. The slotted line detector equivalent diagram operating at 9GHz frequency is show at Figure 1. A circuit then being construct base on the arrangement show at Figure 1. Figure 2 is the equivalent circuit that being design to replace the arrangement of slotted line in Figure 1. The circuit of slotted line is being design to measure a value of complex reflection coefficients of short circuited waveguide and open-ended waveguide. DC blocks and RF bypass capacitors are use in this circuit as show in diagram above, both of these capacitors are simple filters by employing microwave capacitors. A DC block is a series capacitor that has low reactance for the Radio Frequency (RF) of interest (an RF short), but blocks DC because it is an open circuit at zero Hertz. A RF bypass is shunt (parallel) element that acts like a short circuit to microwave signals, but here it is meant to reflect RF signals by shorting them out. A capacitor often does not act as a capacitor at microwave frequencies. Microwave capacitors must be small enough to be considered lumped elements. Axial-led capacitors are not useful at microwave frequencies because of the need to keep small dimensions [4]. The publish results from [1] is show in Table 1, the output of simulation results of complex reflection coefficient should be getting the similar values.

Figure 1. Arrangement of slotted line in the transmission line
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III. RESULTS

A. Simulation of Open Circuit

The circuit is be simulated at frequency 9GHz. Using the slotted line equivalent diagram the complex reflection coefficient is being simulated. Genesys is use as to design and simulate the circuit.

| Load                      | $|\Gamma|$ | $\theta$ in degree |
|---------------------------|-------|-------------------|
| Open Circuited Waveguide  | 0.2253| 272.4             |
| Short Circuited Waveguide | 1     | 180               |

B. Simulation of Short Circuit

Figure 5 show the Simulation of Short Circuit diagram at 9GHz. Using the slotted line equivalent diagram the reflection coefficient is being simulated.

The graph below is reflection coefficient graph $S_{11}$ and voltage standing wave ratio (VSWR). The requirement of magnitude $S_{11}$ for short circuit nearly to 1 which is 0.9 already been achieved, and the angle meets the specifications $180^\circ$.
Table 2 below shows the simulation result of open circuit and short circuit.

### TABLE 2. SIMULATION RESULTS

<table>
<thead>
<tr>
<th>Load</th>
<th>Λ</th>
<th>θ in degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Circuit waveguide</td>
<td>0.266</td>
<td>285.43</td>
</tr>
<tr>
<td>Short Circuit waveguide</td>
<td>0.9</td>
<td>180</td>
</tr>
</tbody>
</table>

IV. MICROSTRIP REFLECTOMETER CIRCUIT

A microstrip circuit uses a thin flat conductor which is parallel to a ground plane. Microstrip can be made by having a strip of copper on one side of a printed circuit board (PCB) or ceramic substrate while the other side is a continual ground plane. The width of the strip, the thickness of the insulating layer (PCB or ceramic) and the dielectric constant of the insulating layer determine the characteristic impedance. A microstrip is a thin, flat electrical conductor separated from a ground plane by a layer of insulation or an air gap. The design is integrated using a microstrip transmission lines and shunt stubs. The lumped element should be converted to distributed element to make it easier to design the layout on the microstrip since the lumped element cannot operate at high frequency. Hence the length and the width of lumped elements should be estimated by calculation to convert them into distributed elements. Firstly the width, W and effective relative permittivity, ε_{eff} determine by using “Line-Calc” in Libra. The data that have to be entered as parameter for the “Line-Calc” to perform the calculation for W and ε_{eff}. For this research Rogers RT Duroid 5880 is use. The properties for the microstrip are as follow:

a) Thickness = 0.035 mm  
b) Height = 0.508 mm  
c) Loss tangent = 0.0001  
d) Relative permittivity of substrate, ε_r = 2.2  
e) Operating frequency, f = 9 GHz  
f) Characteristic impedance  
   - Z_o = 50 Ω (for normal transmission line)  
   - Z_b = 130 Ω (for shunt inductor)  
   - Z_L = 25 Ω (for shunt capacitor)

B. Distributed Circuit for Open Circuit

The circuit in Figure 7 is a transformation from Figure 2. The graph in Figure 8 shows that the reflection coefficient after being optimize. The value of reflection coefficient (S_{11}) for magnitude is 0.2 meanwhile for the angle is 282.39°.

C. Circuit Layout for the Designed Slotted Line

Circuit layout produce by Genesys software is done by using option “Add Layout”. The width and the length of the transmission line or stub are measured to produce correct size of layout. The measurement of the transistor and chip resistor has to follow the dimension to get it fixed correctly with the circuit layout. The circuit layout produce is shown as below;
V. CONCLUSION AND DISCUSSION

From Table 3, it shows the comparison of Reflection Coefficient ($\Gamma$) among three methods of measurement. VNA results are obtained from the Microstrip Reflectometer tested for Short and Open circuit. The Simulation results are obtained using the reflectometer circuit tested with the same test and simulated using Genesis software. Reflectometer results are from published data. All measurement is tested at 9.0 GHz; Reflectometer results are published results at this frequency.

For Short Circuit test, close agreement for each system. First comparison is among VNA and Reflectometer results. The agreement is $\pm 0.06$ for magnitude and $\pm 0.5^\circ$ for phase. Second comparison is among Simulations and Reflectometer results, the agreement is $\pm 0.1$ for magnitude and $\pm 0^\circ$ for phase. For Open Circuit test, it shows an agreement for each measurement. The agreement is $\pm 0.07$ for magnitude and $\pm 13^\circ$ for phase, among VNA and Reflectometer results. Comparison among Simulations and Reflectometer results shows an agreement for about $\pm 0.04$ for magnitude and the $\pm 13.03^\circ$ for phase.

From these results it shows that, the Three-probe reflectometer can be transform to a smaller system using microstrip. Using short circuit and open circuit test, it shows a close agreement among these three systems.

A conclusion can be made from the results obtained. Using Microstrip Reflectometer, it can also measure Reflection Coefficient $\Gamma$ same as an expensive Vector Network Analyzer and Three-probe Reflectometer System. Using Microstrip Reflectometer, the measurement of the Reflection Coefficient for any material can be made easily and accurately.

ACKNOWLEDGEMENTS

This research was supported by Universiti Teknologi MARA under Dana Kecemerlangan grant. I would like to thank all friends who have contributed ideas to completing this works. Also I would like to thank Microwave Technology Centre (MTC) Universiti Teknologi MARA Shah Alam.

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AUTHORS’ BIOGRAPHY

K. A. Ermeey was born in Sentul Kuala Lumpur,Malaysia. He is a lecturer at Faculty of Electrical Engineering, Universiti Teknologi MARA Terengganu. He received his Bachelor in Electrical Engineering 2000 from Universiti Teknologi MARA Shah Alam Malaysia and received his Masters in Electrical Engineering 2005 from same. K. A. Ermeey is a member of The Institute of Electrical and Electronics Engineers.
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Engineers (IEEE). Email: ermee461@tganu.uitm.edu.my

R.A Husna was born in Malaysia. She is a lecturer at Faculty of Electrical Engineering, Universiti Teknologi MARA Shah Alam. She received his B.Sc (Hons) in Electronics – Multimedia University (MMU) and received his M.Sc in Mobile Communication System- Universiti of Surrey, UK. R.A. Husna is a member of The Institute of Electrical and Electronics Engineers (IEEE). Email: husna232@salam.uitm.edu.my