A Novel Phase Measurement System Based on Six Port Reflectometer and LabVIEW

Tyler Wang, Jiajun Bian, and Shouzheng Zhu
School of Information Science and Technology, East China Normal University, 200241, China

Abstract— A novel six port reflectometer (SPR) measurement system based on LabVIEW and a simple calibration method used to reducing the drastic complication of the calibration algorithms is proposed in this paper. The efficiency of manual device measuring is improved by this novel measurement system. This new system can be operated easily. The amplitude and phase's experimental and theory results are provided to demonstrate the performance of the developed SPR.

1. INTRODUCTION

Six port technology was first used to microwave and millimeter wave measurement and network analyzer. During the 1970s, Engen and Hoer began to investigate the six-port technique as the heart of a simpler and less expensive network analyzer [1–3]. Since then, there has been considerable work in the analysis, design, and testing of six-port systems [4–7]. Generally speaking, the six-port reflectometer (SPR) is a passive linear circuit with one port connected to the signal source, one port to a device under test (DUT) and the remaining four ports connected to power detectors. DUT's signal amplitude and phase information can be computed by measuring the four power detectors ports' voltage amplitude or power [8]. Using the amplitude replace phase measuring, its measurement process was simple and hardware's imperfection would be made up by appropriate calibration procedure which reduced the cost of automatic network analyzer and microwave component's machining precision [9].

Six port measurement system's calibration was the core of six port technology. Among the calibration methods proposed, the Engen's six port to four-port reduction is the most popular. However, the iterations required by the W-plane calibration algorithm tend to be lengthy and may fail. To achieve an accurate calibration task, many ingenious techniques based on Engen's method have been proposed in the literature [10–15]. It has to be mentioned that most of these works result often in a drastic complication of the calibration algorithms. Furthermore, all the previous methods assume a linear response at the four arms of the SPR, while most of the power detection circuits are built with nonlinear diodes that require an additional calibration step to linearize the diodes over the dynamic range of interest.

With the development of computer communication and measurement and control technology, LabVIEW has been turned into main tool in automatic measurement development system. In this paper, a novel six port measurement system based on LabVIEW and a simple calibration methodology used to reducing the drastic complication of the calibration algorithms and is proposed. This novel measurement system will improve the efficiency of manual device measuring. In Section 2, we first highlight the SPR working theory, then we present our novel calibration method. In Section 3, the provided amplitude and phase's experimental results are corresponded to the theory results which demonstrate the performance of the developed SPR.

2. SYSTEM DESIGN AND OPERATING PRINCIPLE

2.1. Review of the SPR Theory

The architecture comprises a source S, a passive six-port network and four power detectors at P_i ($i = 3, 4, 5, 6$). Incident and emergent waves have been identified at the six ports and labeled a_i ($i = 1, \ldots, 6$) and b_i ($i = 1, \ldots, 6$), respectively. Γ is the complex reflection, and P_i ($i = 3, 4, 5, 6$) is the reading of the power meter. The incident and emergent waves are coupled through the parameters of the six-port network by the following forms:

$$b_i = \sum_{j=1}^{6} S_{ij} a_j, \quad i = 1, \ldots, 6 \tag{1}$$

$$a_i = b_i \Gamma_i, \quad i = 3, \ldots, 6 \tag{2}$$

Consequently, there are only two degrees of freedom between these waves. Then, it is convenient to relate he emerging waves on the detectors as a linear superposition of the incident wave a_2 and the reflected wave b_2.

One of the four detectors is usually taken as reference to normalize the other detected powers and should ideally depend only on the source power.

Before doing any measurement, the SPR has to be calibrated to obtain the 12 real calibration constants (four real terms C_i $(i = 3, \dots, 6)$ and four complex terms q_i $(i = 3, \dots, 6)$). If a reference detector is used, then the number of calibration parameters is reduced to 11 [6].

2.2. Simple Calibration Method and Optimization

The calibration need one matched load and sliding short circuiter. The previous method had three steps, first step was using the matched load to calibrate q_i; the second step was calibrating C_3 by using the sliding short circuiter; the third step was getting the other C_i value by calibrating 9 equations, this process was very complex owing to the equations' solving. In order to simplify equations' solving, three more equations are added to the calibration process by adding one more short position. So the twelve equations are paired and can easily be solved utilizing their symmetry.

3. MEASUREMENT SYSTEM AND EXPERIMENTAL RESULT

We manufactured a kind of waveguide six port reflectometer, this novel device is given in Fig. 1.

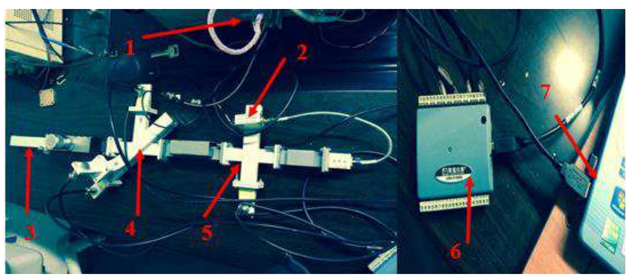

Figure 1: The system's hardware parts where part 1 is the power supply, part 2 is the 9375 MHz source, part 3 is the under test load, part 4 is the five port junction, part 5 is the directional coupler, part 6 is the DAQ board and part 7 is a computer that connected to the DAQ board by a USB line.

Figure 2 shows the LabVIEW working interface, it clearly indicates every step to get the reflection coefficient.

Figure 2: The LabVIEW working interface, the operating method is listed in detail.

To validate the proposed method and measurement system , the experimental and theory's amplitude and phase results in different sliding short circuiter position are compared in Table 1 and Table 2.

From these two tables, we can clearly say that experimental results are corresponded to the theory results both in amplitude and phase which means that the developed SPR owns a good precision.

Table 1: Amplitude results comparison.

Theory and experimental's amplitude results in different sliding short circuiter position (wavelength = 3.2 cm)					
Position (cm)	0	0.2	0.4	0.6	0.8
Theory	1.0	1.0	1.0	1.0	1.0
Experimental	1.03	1.05	1.07	1.02	1.09
Position (cm)	1.0	1.2	1.4	1.6	
Theory	1.0	1.0	1.0	1.0	
Experimental	1.03	1.02	1.08	1.01	

Table 2: Phase results comparison.

Theory and experimental's phase results in different sliding short circuiter position (wavelength = 3.2 cm)					
Position (cm)	0	0.2	0.4	0.6	0.8
Theory	0	45	90	135	180
Experimental	0	45.1	89.8	134.9	180.3
Position (cm)	1.0	1.2	1.4	1.6	
Theory	225	270	315	360	
Experimental	224.8	269.7	315.2	359.9	

4. CONCLUSION

With the development of computer communication and measurement and control technology, LabVIEW has been turned into main tool in automatic measurement development system. In this paper, a novel six port reflectometer (SPR) measurement system based on LabVIEW is proposed and a simple calibration method is used to reducing the drastic complication of the calibration algorithms. This novel measurement system improves the efficiency of manual device measuring and it is handled easily. Experimental results are provided to demonstrate the performance of the developed SPR both in amplitude and phase.

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