VECTOR MEASURING WITH 7-STATE PERTURBATION TWO PORTS

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Abstract: *A novel construction of a 7-state perturbation two-port vector network analyzer is presented. It consists of 7 basic passive two-port discontinuities, which enable a simple realization with good electrical parameters in certain parts of Smith chart. The new approach makes it possible to choose the best states for any specific area in Smith Chart. Mathematical backgrounds of the approach, as well as new test criteria are designed.*

Introduction

Vector network analyzers (VNA) based on frequency conversions are widely used for wideband vector measurements. They are complex and costly systems. On the other hand, scalar network analyzers (SA) are simpler and cheaper, but they only give scalar information. A concept for vector measurement based on SA and perturbation two-port (PTP) was presented in [1]. In this paper, a significant improvement of the original concept based on 7-state perturbation two-port is presented. A typical arrangement of the new PTP vector network analyzer with seven switched discontinuities is presented in Fig.1.

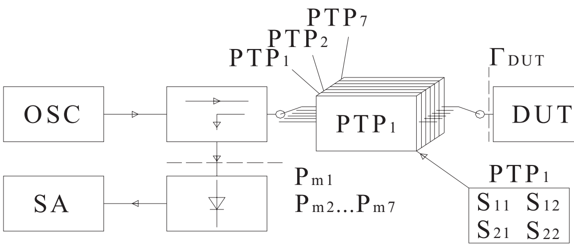

Fig. 1: Measuring system with SA and 7-state perturbation two-port

Theory

The main idea of vector measuring with a scalar analyzer and PTPs is derived from the relation (1) between Γ_{DUT} and P_m, where P_m is the measured reflection power and Γ_{DUT} is the reflection coefficient of the device under test (DUT). This relation could be modified to the quadratic plane equation where A_x, B_x, …, G_x are real coefficients. The quadratic plane given by (2) is completely defined at one frequency by these seven real constants. The constants can be found by calibration [2].

$$P_m = |\Gamma_m|^2 = \left| S_{11} + \frac{S_{21}\cdot S_{12}\cdot \Gamma_{DUT}}{1 - S_{22}\cdot \Gamma_{DUT}} \right|^2 \qquad (1)$$

$$A_x|\Gamma_{DUT}|^2 + B_x\Re(\Gamma_{DUT}) + C_x\Im(\Gamma_{DUT}) + D_xP_m\Re(\Gamma_{DUT}) + E_xP_m\Im(\Gamma_{DUT}) + F_xP_m|\Gamma_{DUT}|^2 + G_x + P_m = 0 \qquad (2)$$

For example, if we have the 3-state PTP with optimally spaced quadratic plane, and one DUT with reflection coefficient Γ_{DUT}=0.3+0.8j, we get three measured reflection power P_m. Primary value Γ_{DUT} is given as a solution of three linear equations, where P_m and A_x, B_x,…, G_x are required. The graphic representation is described at Fig.2 where the vertical line with diamonds determines the Γ_{DUT} position.

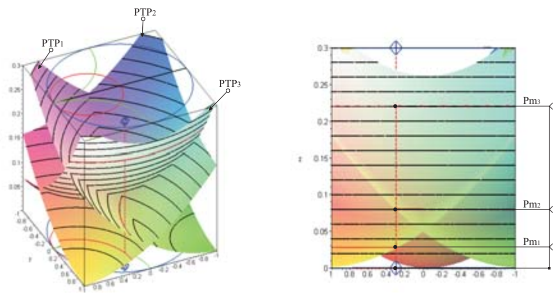

Fig. 2: Measuring with 3-state optimally spaced PTP quadratic planes

7-State PTP

Because 3-state PTPs with optimally oriented frequency independent quadratic planes are difficult to construct, the novel 7-state PTP consists of elementary two ports discontinuities, which were simulated and measured. Typical quadratic planes are shown at Fig.3.

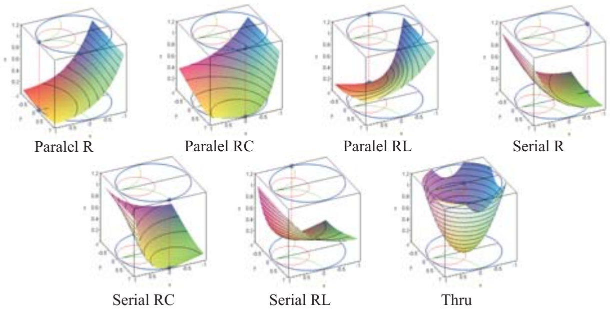

Fig. 3 Examples of 7-state PTP quadratic planes

Test criteria

Now we have 7-state PTP system where only three states for Γ_{DUT} determination are needed. The question is to find out how to choose the three best quadratic planes, which produce the lowest measuring error in a specific area of Smith Chart. Three basic test criteria can then be used.

The gradient criterion: If a state of the PTP has lower gradient at a specific area, even a small error in the measured reflected power P_m will produce significant error during Γ_{DUT} determination. Fig.4 shows an example of this criterion.

The angle criterion: Two quadratic planes can be considered for any given Γ_{DUT}. It is possible to construct a vertical line perpendicular to the x-y plane where the Γ_{DUT} is localized. The distance between the x-y plane and quadratic plane cross point is equal to the measured reflected power P_m, see Fig.2. Then the reverse task is solved during measurement. For two quadratic planes we have two measured P_m that define a set of Γ_{DUT}. These two sets are represented as two circles which have two cross points. One is at the Γ_{DUT} position and the second is a mirror. This criterion is then to find the circle cross angle for the whole x-y plane. Angles between 30-90 degrees are acceptable, producing low errors in Γ_{DUT} determination process, see Fig.4.

The vector product test: This is a more complex criterion. For two quadratic planes, we can define two gradient vectors in each point of the x-y plane. The module of the vector product of the gradient vectors displayed at the x-y plane gives information about both gradient and angle results.

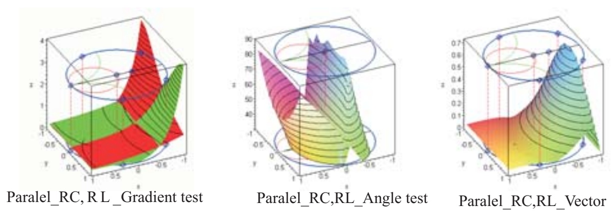

Fig. 4: Three basic criteria for one pair of quadratic planes

The error power test: In real measurements some noise error signal superimposed on measured power must be considered. This noise will produce error during the Γ_{DUT} space determination. Oscillating circles which determine the Γ_{DUT} position will provide the error area with four border cross points. When the geometric distance between the Γ_{DUT} position and the most outlaying point is computed and displayed in the x-y plane, it is

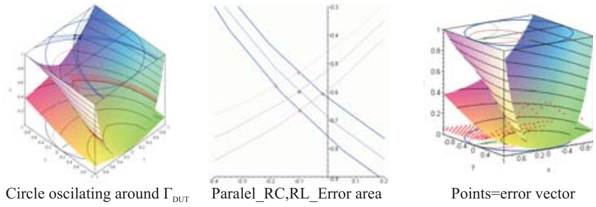

Fig. 5 Error power test

Conclusion

A new concept for vector measurement based on scalar network analyzer and 7-state PTPs was designed. New test criteria for 7-state to 3-state PTP reduction were developed and verified by computer simulations. This approach allows a simple realization of individual states of the PTP and low measurement uncertainties.

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