4 port VNA versus 2 port VNA: A comparison of methods for measuring the S parameters of a directional coupler

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Overview

- A comparison of three different methods for measuring the S-parameters of a 4-port directional coupler (two methods using a 2-port VNA and one method using a 4-port VNA)
4-port directional coupler

- Marki Microwave 10 dB coupler, 6-67 GHz, female 1.85 mm connectors
- Measure S-parameters by different methods and compare results
Methods to measure S-parameters of coupler

- Method 1: Measurement of the DUT using a 2-port VNA with no correction applied for the mismatch of the terminating loads

- Method 2: Measurement of the DUT using a 2-port VNA with a correction applied for the mismatch of the terminating loads using the “matrix renormalisation” method

- Method 3: Measurement of the DUT using a 4-port VNA
VNA Calibration (1)

- SOLR ("unknown thru") calibration – either 2-port or 4-port
- Short-circuit, open-circuit, load (SOL) female calibration standards
- Female-female adapter as unknown reciprocal thru
VNA calibration (2)

- 1-port calibration (SOL) at VNA measurement ports – either two ports or four ports

- Thrus
  - 1-2 (2-port VNA)
  - 1-2, 1-3, 1-4 (4-port VNA)
Characterisation of the calibration standards

- Characterise short-circuit, open-circuit and near matched load standards with respect to an LRL calibration of the VNA (define “data-based” standards)

- Estimate the electrical delay of the thru by measuring the input VRC of the adapter terminated in an offset short-circuit with measured VRC
Method 1: 2-port VNA with no mismatch correction

- 6 connections of DUT to VNA
- Terminate two unused ports of DUT with near matched loads
- Near matched loads assumed perfect (no mismatch correction applied)
Method 2: 2-port VNA with mismatch correction

- 6 connections of DUT to VNA
- Four loads – each assigned to terminate a specific port of the DUT
  - Port 1: Near matched load 1
  - Port 2: Near matched load 2
  - Port 3: 3 dB attenuator + open-circuit
  - Port 4: 20 dB attenuator + short-circuit
- Measure VRCs of loads
- Apply mismatch correction for loads using matrix renormalisation
Method 2: 2-port VNA with mismatch correction

- Renormalise each of the six measured 2 by 2 scattering matrices for the partial 2-ports to $Z_i$ and $Z_j$ where $i$ and $j$ are the DUT ports connected to ports 1 and 2 of the VNA and $Z_i$ and $Z_j$ are the impedances of the corresponding terminating loads;

- Combine the six renormalised 2 by 2 scattering matrices into a single 4 by 4 scattering matrix for the 4-port (normalised to $Z_1$, $Z_2$, $Z_3$ and $Z_4$);

- Renormalise the 4 by 4 scattering matrix for the 4-port to 50 ohms at all ports.
Method 3: 4-port VNA

- 1 connection of DUT to VNA
- No terminating loads required
Match – S11
Transmission – S21
Coupling – S31
Isolation – S23
## Differences between methods - summary

<table>
<thead>
<tr>
<th>S-parameter</th>
<th>Typical observed EVM between measurement methods</th>
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<tbody>
<tr>
<td></td>
<td>Below 50 GHz</td>
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<tr>
<td>S11</td>
<td>0.02</td>
</tr>
<tr>
<td>S21, S31 &amp; S23</td>
<td>0.015</td>
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</tbody>
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Acknowledgement

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