Evaluating SOLT calibration performance at RF using an LA Techniques VNA

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Outline

- LA Techniques VNA
- SOLT with a characterised load
- Ripple plots – residual directivity and test port match
- Uncertainty/Best Measurement Capability (BMC)
- Conclusions
LA19-13-01 - a new type of VNA:

- PC-driven
- Built-in transmission & reflection test set (3 MHz to 3 GHz)
- Small size/portable
- Low cost
- Precision performance from non-precision cal kits (!)

www.latechniques.com
3 GHz Vector Network Analyser

- 3 MHz – 3 GHz range
- 100 Hz resolution
- 80 dB dynamic range
- Time domain facility
- P1dB measurements
- AM-PM measurements
- Light weight and small footprint
- Low cost
SOLT calibration

• Usually assume ‘perfect’ standards:
  Short with $|\Gamma| = 1$
  Open with $|\Gamma| = 1$
  Load with $|\Gamma| = 0$

• However, for non-precision load, $|\Gamma| \neq 0$

• This causes significant post-calibration errors (directivity, test port match, etc)
Solution:

- Measure complex voltage reflection coefficient (VRC) for a candidate cal load using a ‘reference calibration’

- NPL’s ‘national standard’ - Primary Impedance Measurement System (PIMMS) - provides the ‘reference calibration’

- PIMMS uses TRL with an air line to provide traceability to SI

- Impedance renormalisation is used to give (50 + j0) ohms as the reference impedance (correcting for LF skin depth effects, etc)
For each candidate cal load:

• Fit a curve to:
  measured complex VRC data
  measured DC ‘VRC’ (i.e. resistance)

• Use fit to provide cal load complex VRC values during calibration at all required frequencies

(This procedure follows the method used for NPL’s national standard RF System.)
Let’s look at three different cases

Case 1 - SOLT assuming ‘perfect’ cal load

Case 2 - SOLT using ‘characterised’ cal load

Case 3 - SOLT using ‘characterised’ 2.0 VSWR mismatch (as the cal load)

{Use a 150 mm long ripple line - 2.92 mm connectors throughout}
Case 1 - SOLT assuming ‘perfect’ cal load

Residual directivity ripple plot

$D \approx 0.015 \equiv -36 \text{ dB}$
Case 1 - SOLT assuming ‘perfect’ cal load

Residual test port match ripple plot

\[ M \approx 0.021 \equiv -34 \text{ dB} \]
Case 2 – SOLT using characterised cal load

Residual directivity ripple plot

\[ D \approx 0.0025 \equiv -52 \text{ dB} \]
Case 2 – SOLT using characterised cal load

Residual test port match ripple plot

\[ M \approx 0.010 \equiv -40 \text{ dB} \]

![Diagram showing the residual test port match ripple plot with linear VRC magnitude against frequency (MHz). The plot indicates a ripple magnitude of approximately 0.010, equivalent to -40 dB.]
Case 3 – SOLT using characterised mismatch

Residual directivity ripple plot

\[ D \approx 0.006 \approx -44 \text{ dB} \]
Case 3 - SOLT using characterised mismatch

Residual test port match - ripple plot

$M \approx 0.016 \equiv -36 \text{ dB}$
Summary performance

<table>
<thead>
<tr>
<th></th>
<th>Perfect load cal</th>
<th>Characterised mismatch cal (VSWR = 2.0)</th>
<th>Characterised load cal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residual Directivity</td>
<td>0.015 (-36 dB)</td>
<td>0.006 (-44 dB)</td>
<td>0.0025 (-52 dB)</td>
</tr>
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</tbody>
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(By comparison, some previously published values for SOLT cals (using fixed high precision loads) in 7 mm to 18 GHz are: $D = 0.01$ and $M = 0.03$.)
Reflection coefficient - linear magnitude uncertainty

Using the EA Guide approach with:

\[ D = 0.0025 \]
\[ M = 0.010 \]
Reflection coefficient - phase uncertainty

Using:

\[ U(\phi) = \sin^{-1}\left(\frac{U(|\Gamma|)}{|\Gamma|}\right) \]
Summary

- An assumed 'perfect' cal load can be the major source of systematic error in a calibrated VNA
- The cal load can be 'characterised' in terms of its measured VRC
- The LA Techniques VNA enables characterised cal load data to be stored for use during calibration
- Residual directivity improvement (from -36 dB to -52 dB)
- Residual Test Port Match improvement (from -34 dB to -40 dB)


“EA guidelines on the evaluation of vector network analysers (VNA)” European co-operation for Accreditation, EA-10/12, May 2000.