The S-matrix Method for High Frequency Capacitance Calibration

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The S-matrix Method for High Frequency Capacitance Calibration

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S-MATRIX METHOD

- Measurement of a four terminal pair ($Z_{4TP}$) air capacitance standard in terms of S-parameters
- The capacitance is measured using a two-port vector network analyzer (VNA)
- The VNA is equipped with BNC connectors
- The two ports of the device not employed are terminated on matched impedances
S-MATRIX METHOD

- The measurement results are combined according to the following equation [1]:

\[
Z_{4TP} = 2Z_0 \left\{ s_{21} s_{34} - s_{31} s_{24} \right\} s_{31} + \left( s_{21} s_{32} - s_{31} s_{44} - s_{31} s_{22} + s_{41} s_{34} \\
- s_{21} s_{32} s_{44} + s_{21} s_{34} s_{42} + s_{31} s_{22} s_{44} - s_{31} s_{42} s_{24} - s_{41} s_{34} s_{22} + s_{41} s_{24} s_{32} \right\}^{-1}
\]

- All measurements are performed with the VNA Tools II program developed by METAS
- The data analysis is performed using the METAS.UncLib library in MATLAB

FLOW CHART

START

VNA Calibration

DUT Measurement

EVALUATION OF CAPACITANCE

FIT OF THE SIGNAL

END

VNA Tools II
Matlab – METAS UncLib
MEASUREMENT SETUP

Vector Network Analyzer: Agilent E5061B

Standard: Agilent 16384A
1000 pF capacitor

Calibration Kit: Maury Microwave
8550 - Coaxial BNC

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RESULTS

VNA Tools II – Display of S-parameters
RESULTS

4 port 1000pF Capacitance Measurement

1000 pF capacitance graph (grey) with uncertainty (MATLAB METAS.UncLib)
RESULTS

Uncertainty budget of capacitance fit [pF] (MATLAB METAS.UncLib) @ 15 MHz

<table>
<thead>
<tr>
<th>Description</th>
<th>Unc Component</th>
<th>Unc Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cable Stability</td>
<td>0.680900725</td>
<td>0.334</td>
</tr>
<tr>
<td>Calibration Standard</td>
<td>11.732322849</td>
<td>99.168</td>
</tr>
<tr>
<td>Load</td>
<td>10.871621573</td>
<td>85.152</td>
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<tr>
<td>Open</td>
<td>4.362157415</td>
<td>13.709</td>
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<tr>
<td>Short</td>
<td>0.653319583</td>
<td>0.308</td>
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<tr>
<td>Connector Repeatability</td>
<td>0.096568826</td>
<td>0.007</td>
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<tr>
<td>VNA Drift (correlated)</td>
<td>0.012454945</td>
<td>0.000</td>
</tr>
<tr>
<td>VNA Linearity</td>
<td>0.517897792</td>
<td>0.193</td>
</tr>
<tr>
<td>VNA Noise</td>
<td>0.642808505</td>
<td>0.298</td>
</tr>
</tbody>
</table>
SUMMARY

- With the proposed method it is possible to measure a four terminal pair capacitance with a 2-port VNA

- METAS VNA Tools II assists the measurement process and collects data

- With METAS.UncLib it is possible to evaluate the desired results together with an uncertainty estimation compliant with the GUM

- Reduction of the uncertainty due to the standards (that now use manufacturer specifications) by characterizing the Load standard

- Future work will involve a comparison of the S-matrix method with a different one
THANK YOU!!!