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82nd ARFTG Conference
NVNA Users' Forum

The S-matrix Method for High Frequency Capacitance Calibration

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POLITECNICO DI TORINO

19th Nov. 2013
@ Columbus, Ohio, USA

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

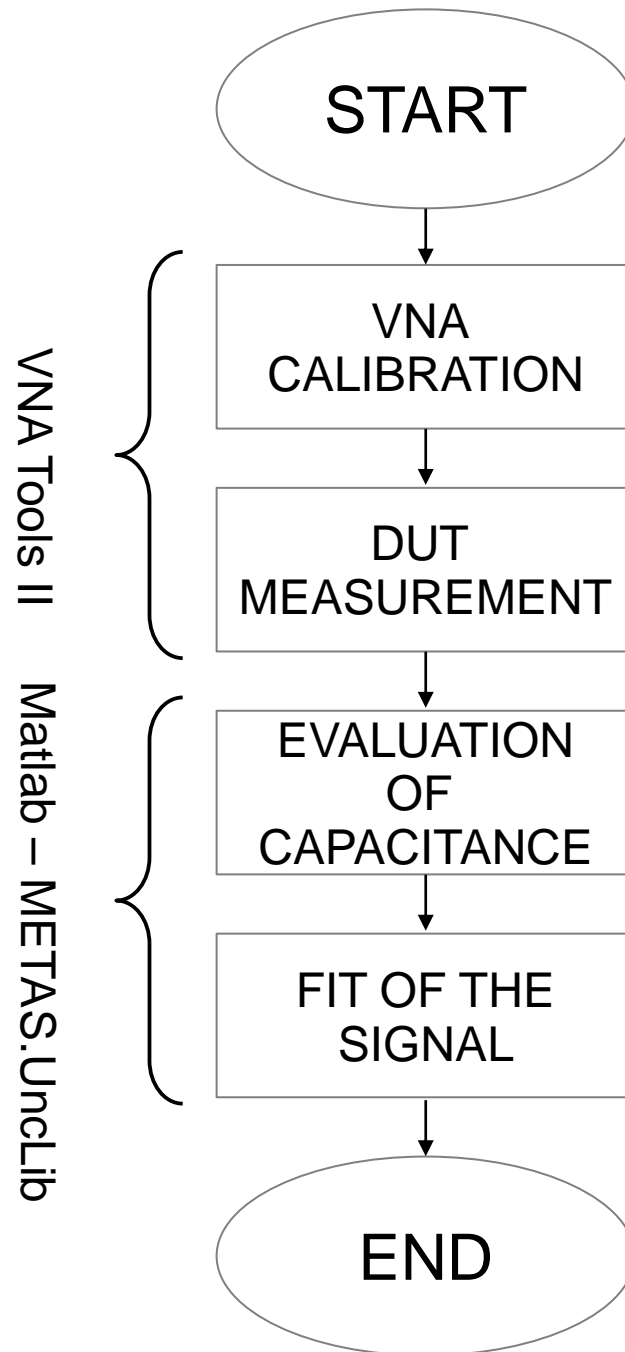
- The measurement results are combined according to the following equation [1]:

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

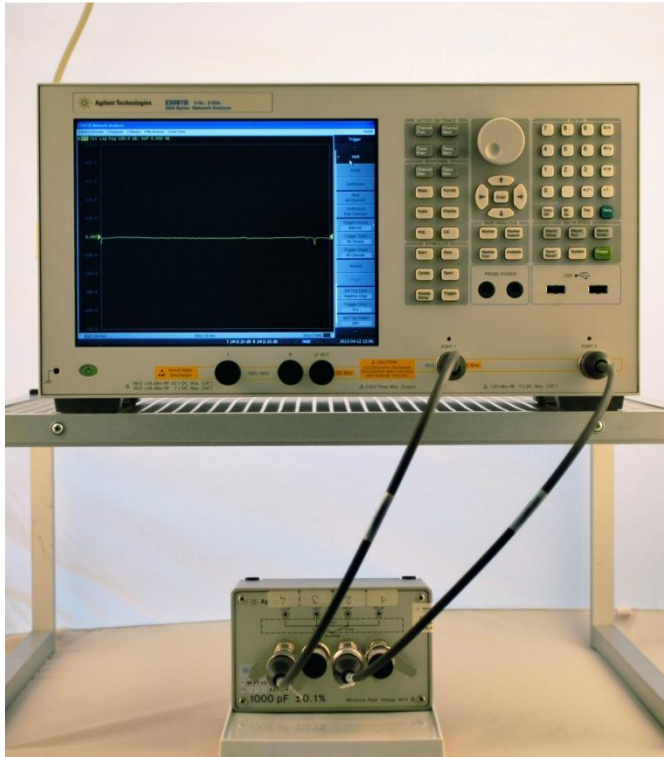
- All measurements are performed with the VNA Tools II program developed by METAS
- The data analysis is performed using the METAS.UncLib library in MATLAB

[1] L. Callegaro, F. Durbiano, "Four-terminal-pair impedances and scattering parameters", Meas. Sci. Technol. 14 (2003), 523-529

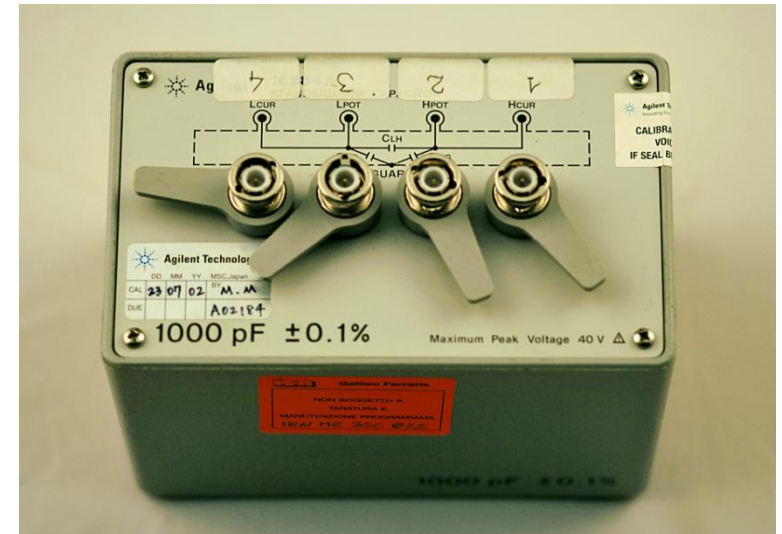
FLOW CHART



MEASUREMENT SETUP



Vector Network Analyzer:
Agilent E5061B

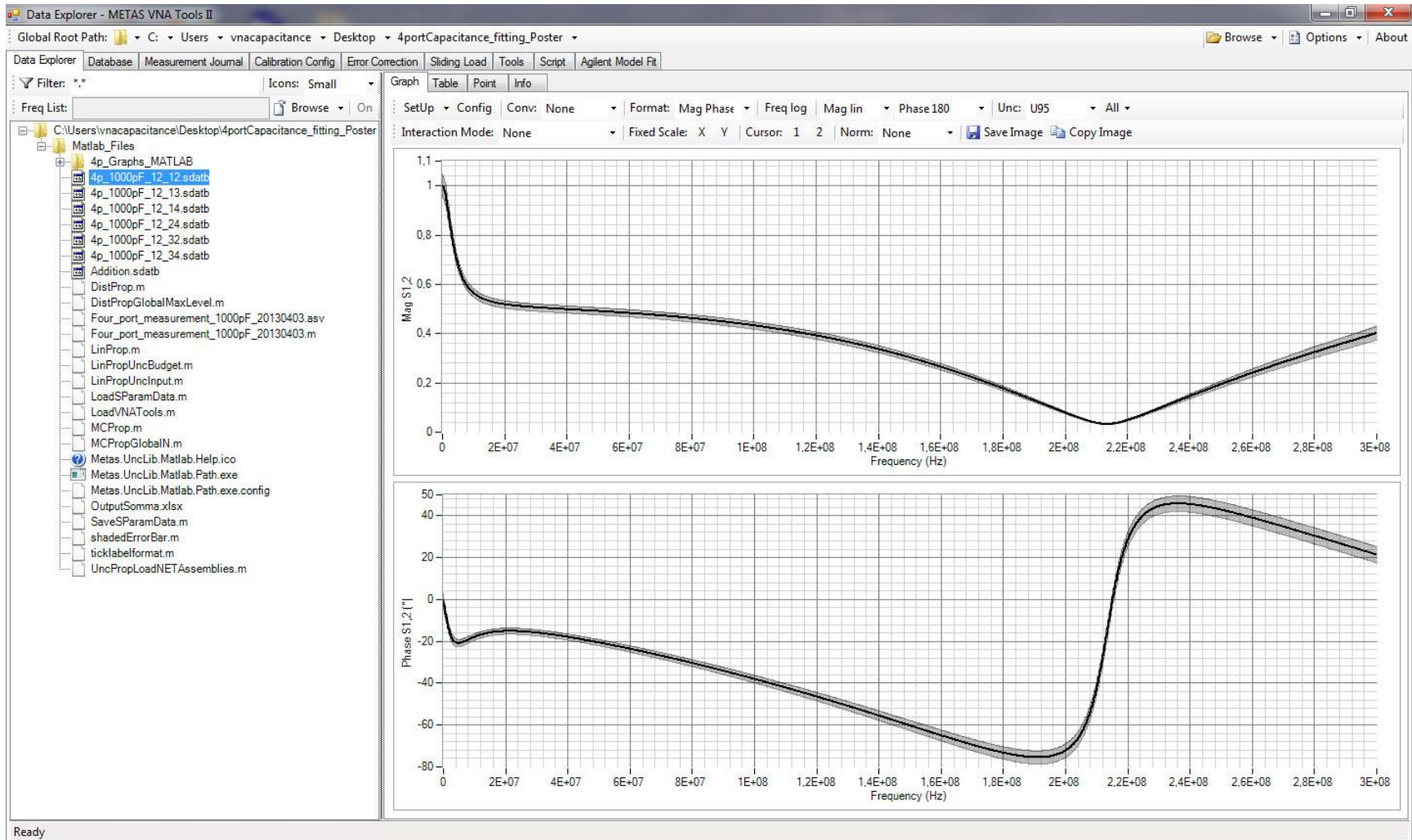


Standard: Agilent 16384A
1000 pF capacitor



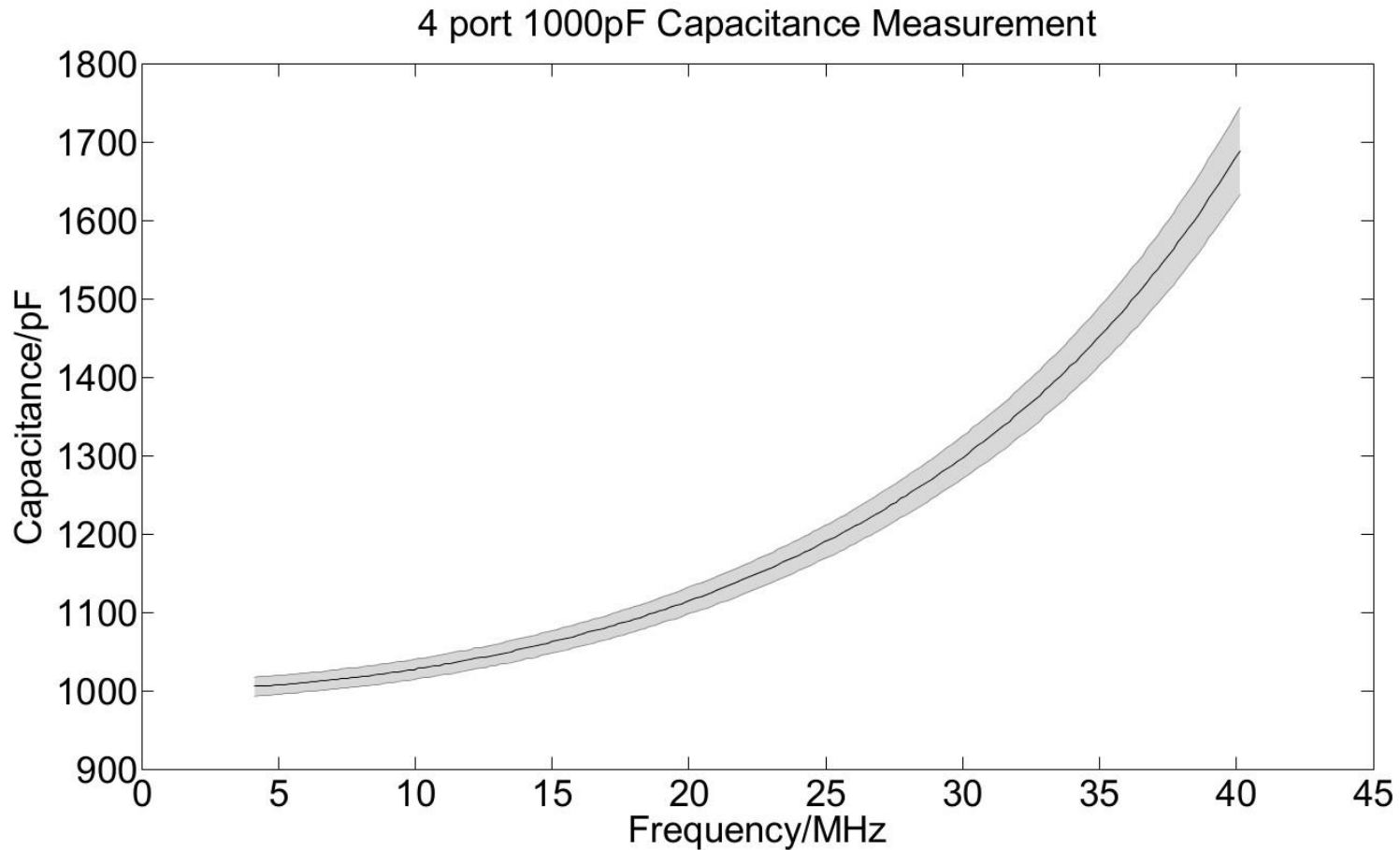
Calibration Kit: Maury Microwave
8550 - Coaxial BNC

RESULTS



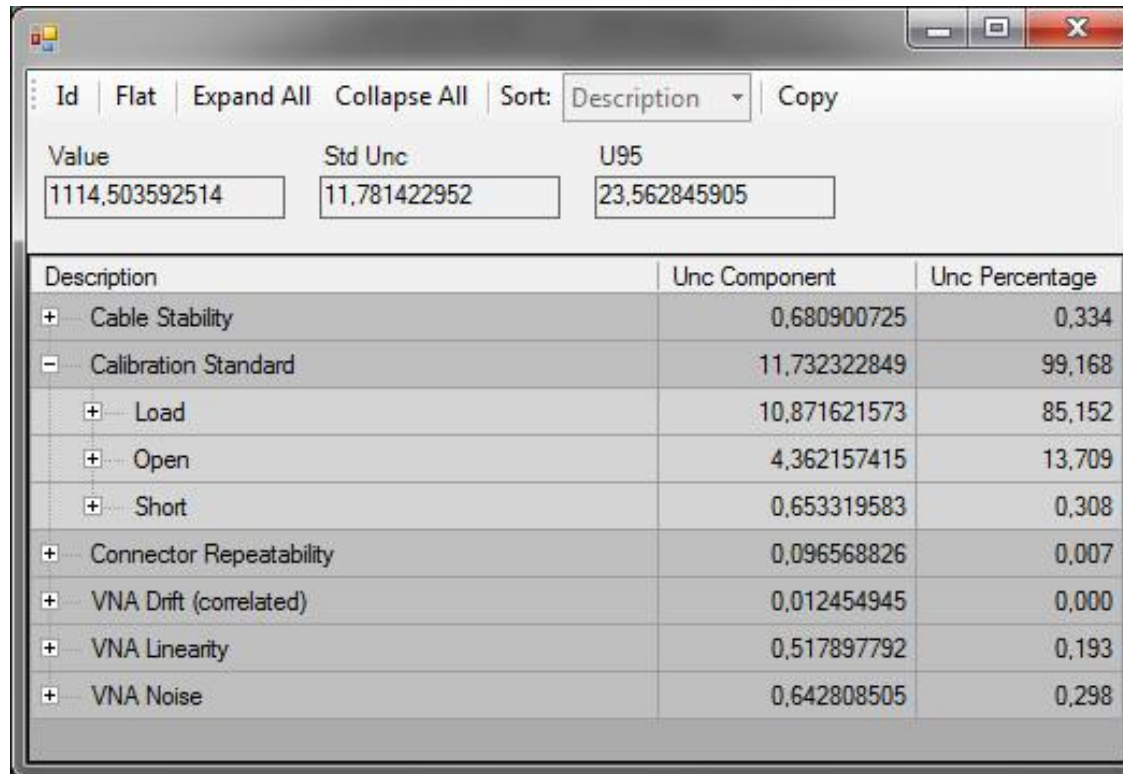
VNA Tools II – Display of S-parameters

RESULTS



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

RESULTS



Description	Unc Component	Unc Percentage
+ Cable Stability	0,680900725	0,334
- Calibration Standard	11,732322849	99,168
+ Load	10,871621573	85,152
+ Open	4,362157415	13,709
+ Short	0,653319583	0,308
+ Connector Repeatability	0,096568826	0,007
+ VNA Drift (correlated)	0,012454945	0,000
+ VNA Linearity	0,517897792	0,193
+ VNA Noise	0,642808505	0,298

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

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!!!

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