

The S-matrix Method for High Frequency Capacitance Calibration

*Original*

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**82nd ARFTG Conference**  
***NVNA Users' Forum***

# ***The S-matrix Method for High Frequency Capacitance Calibration***

**Nosherwan Shoaib<sup>1,2</sup>, Marco Sellone<sup>1</sup>, Luca Callegaro<sup>1</sup>, Andrea Ferrero<sup>3</sup>,  
Michael Wollensack<sup>4</sup> and Luciano Brunetti<sup>1</sup>**

<sup>1</sup>Electromagnetism Division, Istituto Nazionale di Ricerca Metrologica - INRiM, Strada delle  
Cacce 91, Turin, 10135, Italy

<sup>2</sup>Department of Industrial Engineering and Production - DIGEP, Politecnico di Torino, Corso  
Duca degli Abruzzi 24, Turin, 10129, Italy

<sup>3</sup> Department of Electronics and Telecommunications - DET, Politecnico di Torino, Corso  
Duca degli Abruzzi 24, Turin, 10129, Italy

<sup>4</sup> Bundesamt für Metrologie (METAS), Lindenweg 50, 3084 Wabern, Switzerland



**POLITECNICO DI TORINO**

19<sup>th</sup> Nov. 2013  
@ Columbus, Ohio, USA

# S-MATRIX METHOD

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- 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

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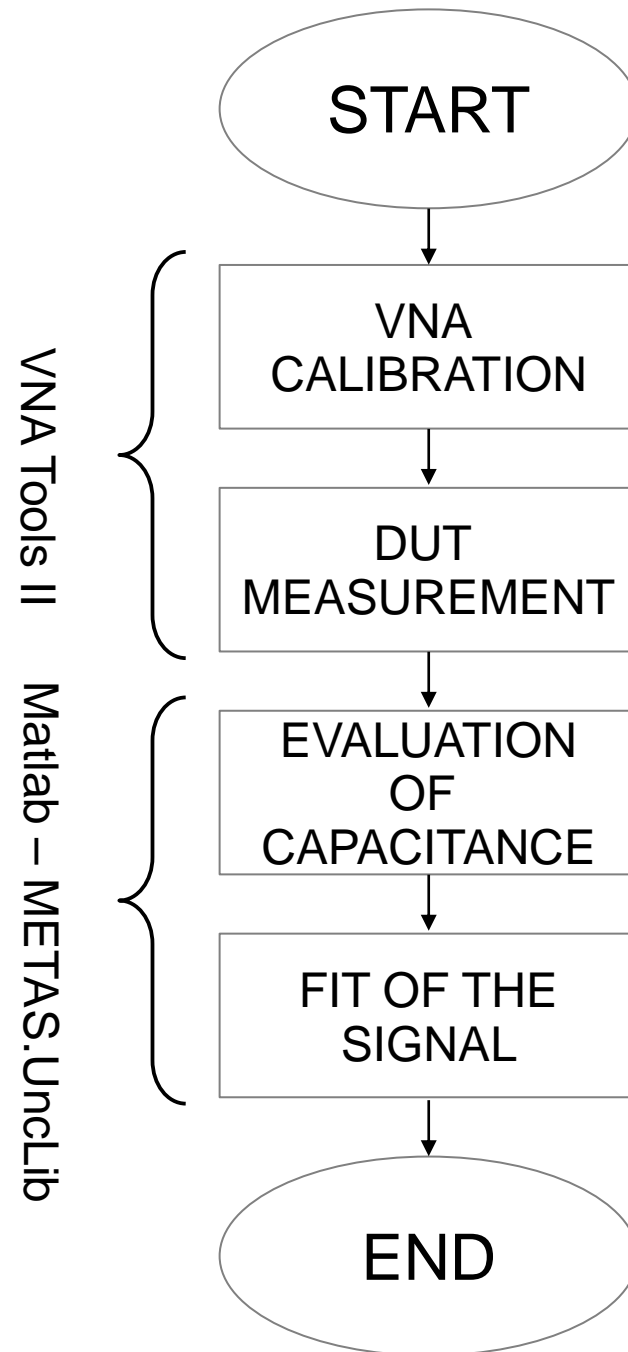
- The measurement results are combined according to the following equation [1]:

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

- 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

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

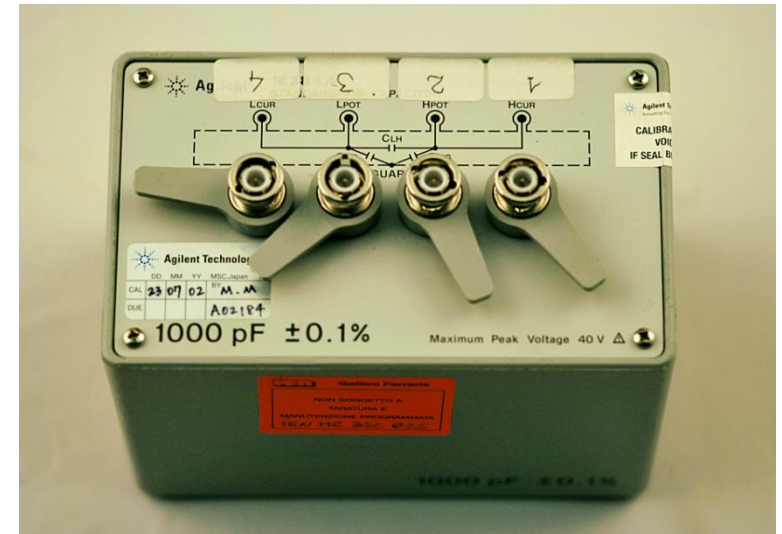
# FLOW CHART



# MEASUREMENT SETUP



Vector Network Analyzer:  
Agilent E5061B

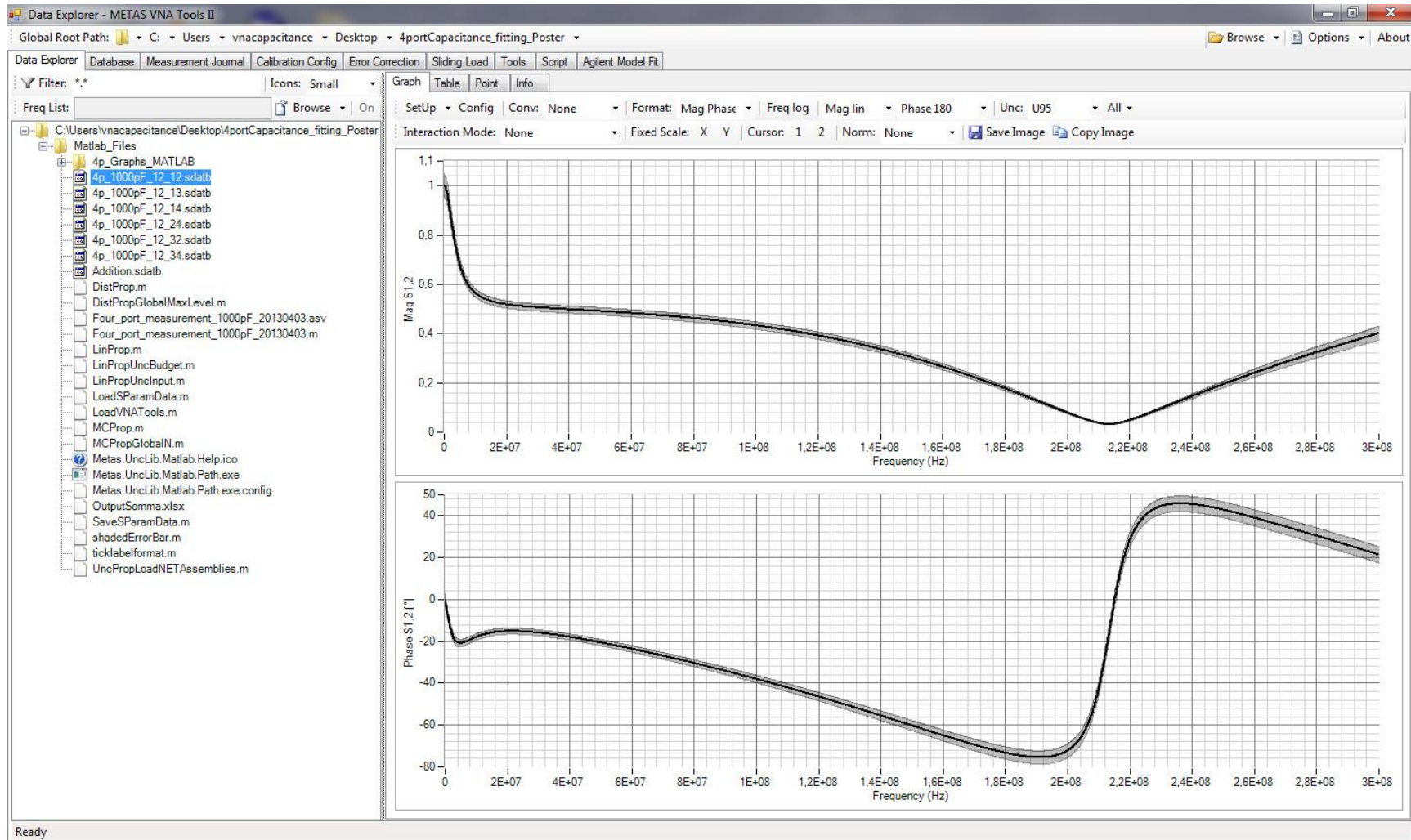


Standard: Agilent 16384A  
1000 pF capacitor



Calibration Kit: Maury Microwave  
8550 - Coaxial BNC

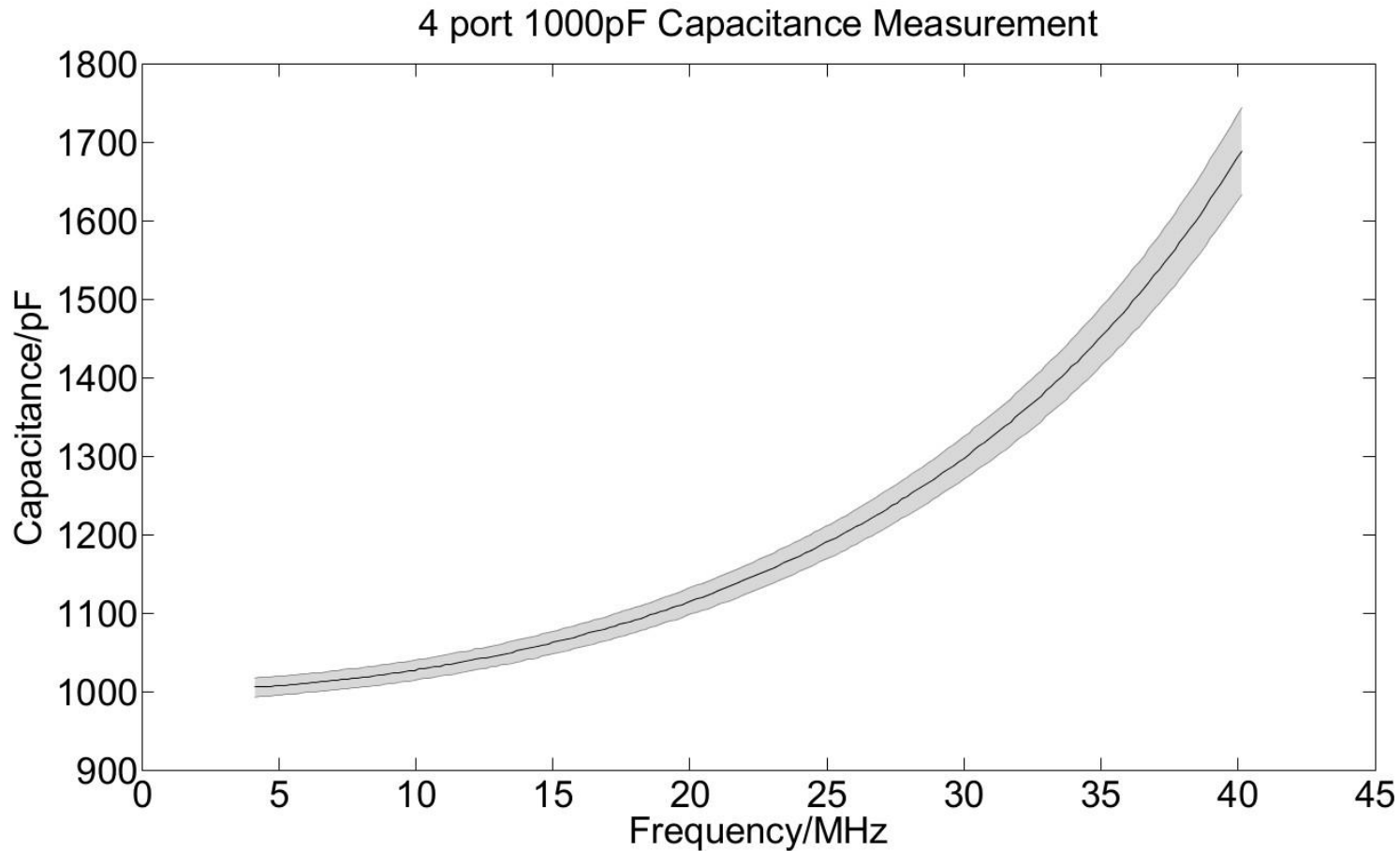
# RESULTS



VNA Tools II – Display of S-parameters

# RESULTS

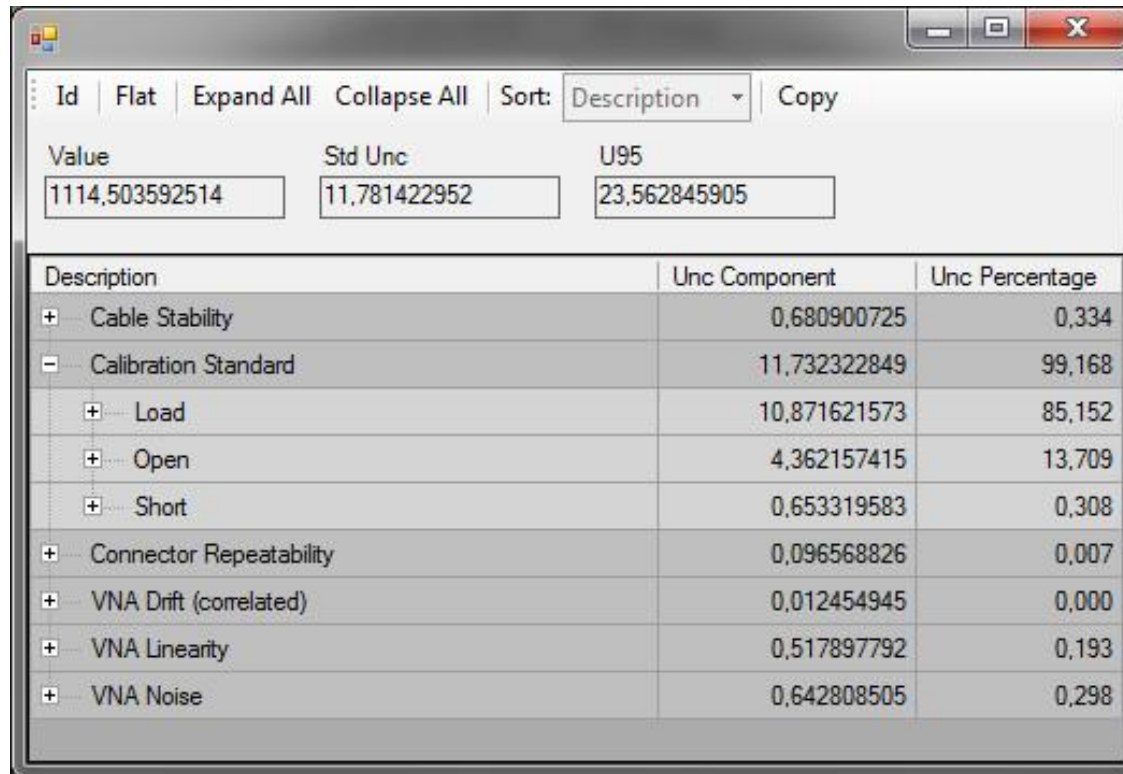
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1000 pF capacitance graph(grey)  
with uncertainty (MATLAB METAS.UncLib)



# RESULTS



The screenshot shows a software window with a menu bar (Id, Flat, Expand All, Collapse All, Sort: Description, Copy) and three input fields for Value (1114,503592514), Std Unc (11,781422952), and U95 (23,562845905). Below these is a table with columns: Description, Unc Component, and Unc Percentage.

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

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- 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!!!**

**Nosherwan Shoaib**  
**E-mail: [nosherwan.shoaib@polito.it](mailto:nosherwan.shoaib@polito.it)**

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