DeEmbed, User manual ant theory of operation

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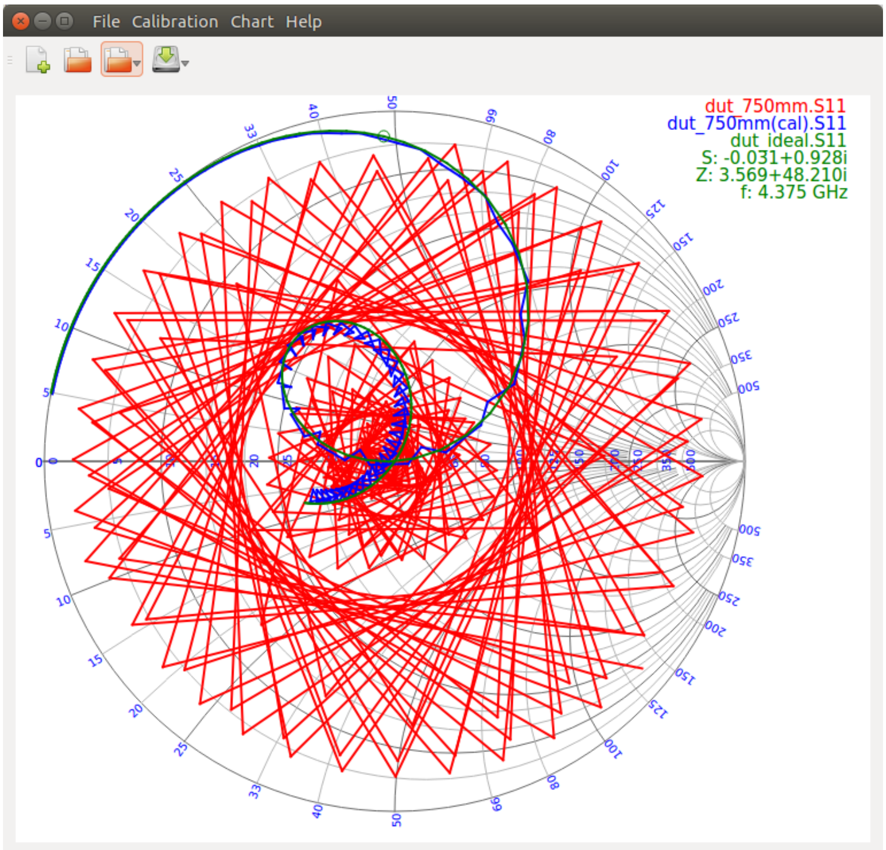
January 31, 2017



Contents

1 Introduction

DeEmbed is a GUI application that can read raw S-Parameter files in TouchStone format There is support for 1 to 4 port s-parameter files. The s-parameters can be de-embedded using the SOLTI (Short, Open, Load, Through, Isolation) method. If you create 1 or 2 port s-parameter files from your cables (through + isolation) and measure 1-port s-parameter files of a short, open and load, the original DUT can be shown in the different graphs as if they were measured without cables.

By default the application shows the data in a smith chart, but different charts are supported (Db, phase, magnitude, VSWR, polar and some combinations).

The application automatically interpolates (spline) the calibration sets to the desired touchstone file. Note that the frequency range of the first touchstone file is leading, any file loaded afterwards will also be interpolated.

2 SOLTI Calibration

SOLTI Calibration is a commonly used calibration method in network analyzers. SOL stands for Short-Open-Load, the standards that are commonly used for a single port calibration. In order to calibrate the s-parameters between different ports, also Through-Isolation (TI) can be used to calibrate S21 and S12.

2.1 SOL Calibration

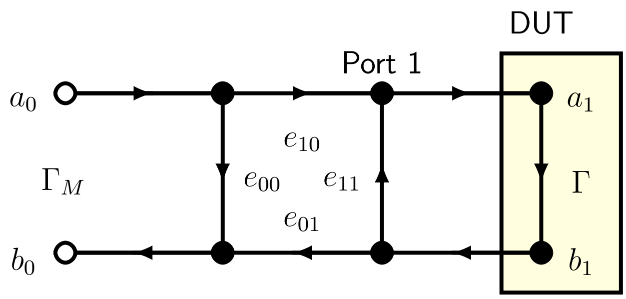


Figure 1: One port model

The measured S-parameter data can be de-embedded to the actual DUT with the lengths of the cables and the error coefficients of the network analyzer taken out of the data as if the DUT was measured directly.

$$S11 = \frac{S11_M - e_{00}}{(S11_M e_{11}) - \Delta_e} \tag{1}$$

- e_{00} is the Directivity
- e_{11} is the port match
- $\Delta_e = e_{00}e_{11} - (e_{10}e_{01})$, of which $(e_{10}e_{01})$ is the tracking.
- $S11$ is the one port S-parameter that you want to display (De-embedded)
- $S11_M$ is the measured S-parameter including the cable and the errors of the port

The 3 error coefficients can be obtained from 3 independent measurements of known standards. The commonly used standards are Short, Open and Load, but any known standard can be used instead. (see section 2.1.1)

2.1.1 Obtaining error coefficients for SOL calibration

Equation 1 contains 3 error coefficients e_{00}, e_{11} and Δ_e. From [1] the equations 2, 3 and 4 are obtained. We see 3 times the same equations, but with different measurements. Γ_1, Γ_2 and Γ_3 are the known independent calibration standards, in this case Short, Open and Load. The standards don't have to be perfect though, a short can for instance have some series inductance or loss (see 2.3). Γ_{M1}, Γ_{M2} and Γ_{M3} are the measured traces, this data is obtained by connecting the well-defined calibration standard to the network analyzer, through the cable that is also used in the measurement and measure the reflection (S11). Equations 2, 3 and 4 still contain our 3 unknown error coefficients e_{00}, e_{11} and Δ_e that we need to solve equation 1.

$$\Gamma_{M1} = e_{00} + \Gamma_1 \Gamma_{M1} e11 - \Gamma_1 \Delta_e \tag{2}$$

$$\Gamma_{M2} = e_{00} + \Gamma_2 \Gamma_{M2} e11 - \Gamma_2 \Delta_e \tag{3}$$

$$\Gamma_{M3} = e_{00} + \Gamma_3 \Gamma_{M3} e11 - \Gamma_3 \Delta_e \tag{4}$$

In order to solve e_{00}, e_{11} and Δ_e we need to substitute equations 2, 3 and 4 into one equation and extract the 3 error coefficients. The result is 3 lengthy equations, but with modern computers they can easily be computed for all the data points in our measurement.

$$e_{00} = -\frac{(\Gamma_2\Gamma_{M_3} - \Gamma_3\Gamma_{M_3})\Gamma_1\Gamma_{M_2} - (\Gamma_2\Gamma_3\Gamma_{M_2} - \Gamma_2\Gamma_3\Gamma_{M_3} - (\Gamma_3\Gamma_{M_2} - \Gamma_2\Gamma_{M_3})\Gamma_1)\Gamma_{M_1}}{\Gamma_1(\Gamma_2 - \Gamma_3)\Gamma_{M_1} + \Gamma_2\Gamma_3\Gamma_{M_2} - \Gamma_2\Gamma_3\Gamma_{M_3} - (\Gamma_2\Gamma_{M_2} - \Gamma_3\Gamma_{M_3})\Gamma_1} \tag{5}$$

$$e_{11} = \frac{(\Gamma_2 - \Gamma_3)\Gamma_{M_1} - \Gamma_1(\Gamma_{M_2} - \Gamma_{M_3}) + \Gamma_3\Gamma_{M_2} - \Gamma_2\Gamma_{M_3}}{\Gamma_1(\Gamma_2 - \Gamma_3)\Gamma_{M_1} + \Gamma_2\Gamma_3\Gamma_{M_2} - \Gamma_2\Gamma_3\Gamma_{M_3} - (\Gamma_2\Gamma_{M_2} - \Gamma_3\Gamma_{M_3})\Gamma_1} \tag{6}$$

$$\Delta_e = -\frac{(\Gamma_1(\Gamma_{M_2} - \Gamma_{M_3}) - \Gamma_2\Gamma_{M_2} + \Gamma_3\Gamma_{M_3})\Gamma_{M_1} + (\Gamma_2\Gamma_{M_3} - \Gamma_3\Gamma_{M_3})\Gamma_{M_2}}{\Gamma_1(\Gamma_2 - \Gamma_3)\Gamma_{M_1} + \Gamma_2\Gamma_3\Gamma_{M_2} - \Gamma_2\Gamma_3\Gamma_{M_3} - (\Gamma_2\Gamma_{M_2} - \Gamma_3\Gamma_{M_3})\Gamma_1} \tag{7}$$

2.2 TI Calibration

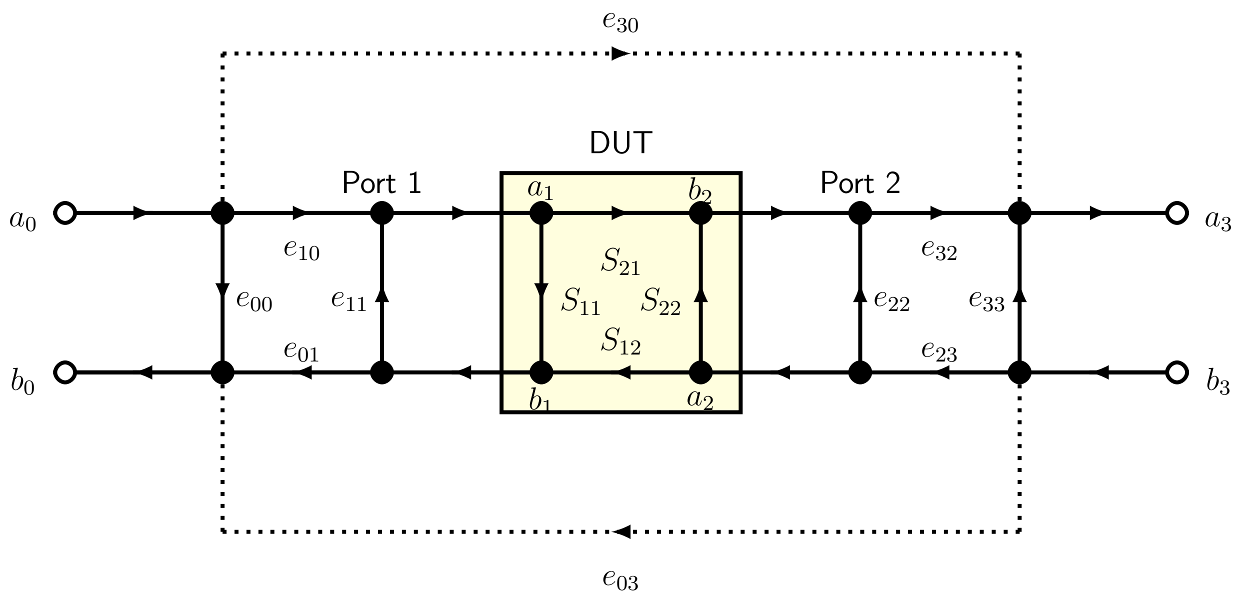


Figure 2: One port model

The Through - Isolation calibration depends on the SOL calibration, this calibration has to be done first. The two port isolation measurement file is created with the measurement cables connected to a 50Ω load. From this file the following error terms are obtained:

- e_{30} is obtained from S_{21}, this is the forward isolation
- e_{03} is obtained from S_{12}, this is the reverse isolation

$$S_{21} = \frac{\left(\frac{S_{21M}-e_{30}}{e_{10}e_{32}}\right)\left[1+\left(\frac{S_{22M}-e'_{33}}{e'_{23}e'_{32}}\right)(e'_{22}-e_{22})\right]}{D} \tag{8}$$

$$S_{12} = \frac{\left(\frac{S_{12M}-e'_{03}}{e'_{23}e'_{01}}\right)\left[1+\left(\frac{S_{11M}-e_{00}}{e_{10}e_{01}}\right)(e_{11}-e'_{11})\right]}{D} \tag{9}$$

$$D = \left[1+\left(\frac{S_{11M}-e_{00}}{e_{10}e_{01}}\right)e_{11}\right]\left[1+\left(\frac{S_{22M}-e'_{33}}{e'_{23}e'_{32}}\right)e'_{22}\right] - \left(\frac{S_{21M}-e_{30}}{e_{10}e_{32}}\right)\left(\frac{S_{12M}-e'_{03}}{e'_{23}e'_{01}}\right)e_{22}e'_{11} \tag{10}$$

2.3 Calibration Standards

References

[1] Network Analyzer Error Models and Calibration Methods, Doug Rytting - Agilent Technologies
http://www2.electron.frba.utn.edu.ar/~jcecconi/Bibliografia/04-Param_S_y_VNA/Network_Analyzer_Error_Models_and_Calibration_Methods.pdf