Impedance Corrected De-embedding
Stefaan Sercu
INTRODUCTION

- The Measurement problem
- Calibration versus De-embedding
- Test Fixture Modeling: Standard 2X thru De-embedding
- Test Fixture Modeling: Impedance corrected De-embedding
The Measurement Problem

Network analyzer

Source

Measured signals:
Incident
Reflected
transmitted

DUT
Port 1
Port 2

Measurement reference planes

Measurement cables

Test fixture

DUT
Reference planes DUT

Measurement System

(4-port)

\[ S_{11}^{\text{measured}} = \frac{b_r}{a_i} \]

\[ S_{21}^{\text{measured}} = \frac{b_t}{a_i} \]

\[ S_{11}^{\text{DUT}} = \frac{b_1}{a_1} \]

\[ S_{21}^{\text{DUT}} = \frac{b_2}{a_1} \]

\[ S_{\text{DUT}} = f(S_{\text{measured}}, S_{\text{Measurement System}}) \]
Calibration

Measurement System (4-port)

DUT

DUT = Standard 1
Standard 2
Standard 3
...

Z_0

DUT

Thru
Line
Reflect

Reference plane

Standard
De-embedding

Measurement System (4-port)

Network analyzer Measurement cables (4-port)

PCB Test Fixture (2-port)

PCB Test Fixture (2-port)

INITIAL DUT
De-embedding

Calibration

Test fixture modeling

Test fixture de-embedding

$$T_{DUT} = \left( T_{fixture\ 1} \right)^{-1}. T_{Calibration}. \left( T_{fixture\ 2} \right)^{-1}$$
Test Fixture Modeling
(Standard 2X thru De-embedding)

2X Thru

bifurcation
Test Fixture Modeling (Standard 2X thru De-embedding)

De-embedded results are non causal
Test Fixture Modeling
(Standard 2X thru De-embedding)

Modeled test fixture impedance matches calibration trace impedance, not the actual test fixture impedance.
Are the de-embedded results function of the calibration trace performance?
Yes, de-embedded results are function of the calibration trace performance.
Test Fixture Modeling
(Standard 2X thru De-embedding)

Uncertainty on de-embedded results twice the uncertainty on calibration traces
Causal and non-causal uncertainty on impedance results.
Test Fixture Modeling
(Impedance Correct De-embedding)

Modeled test fixture impedance matches the actual test fixture impedance.
Test Fixture Modeling

(Impedance Correct De-embedding)
Test Fixture Modeling
(Impedance Correct De-embedding)
Test Fixture Modeling
(Impedance Correct De-embedding)

\[ Z_i, \gamma, \tau \]

\[ \tau = 0.5 \Delta t \]

\[ N = \frac{\text{Phase Delay} \times 2x \text{Thru cal trace}}{\Delta t} \]
Are the de-embedded results function of the calibration trace performance?
Test Fixture Modeling
(Impedance Correct De-embedding)

De-embedded Return loss and impedance no longer function of the calibration trace performance.
Test Fixture Modeling
(Impedance Correct De-embedding)

Insertion loss

Phase delay

Noise floor Return loss reduced from -20 dB to -40 dB!
Coupled Test Fixtures

Symmetrical

Differential mode

\[ T_1, T_2, T_3, \ldots, T_n = S_{DD} \]

Common mode

\[ T_1, T_2, T_3, \ldots, T_n = S_{CC} \]

Asymmetrical

Differential excitation port 1 and 2
SE observation port 3

\[ n_1, n_2, n_3, \ldots, n_n = S_{DD,1,2} \]

Differential excitation port 1 and 2
SE observation port 4

\[ n_1, n_2, n_3, \ldots, n_n = S_{DD,1,2} \]

Common mode excitation port 1 and 2
SE observation port 3

\[ n_1, n_2, n_3, \ldots, n_n = S_{CC,1,2} \]

Common mode excitation port 1 and 2
SE observation port 4

\[ n_1, n_2, n_3, \ldots, n_n = S_{CC,1,2} \]
Coupled Test Fixtures

Asymmetrical behavior accurately modeled
SUMMARY

• Presentations compares standard 2X thru de-embedding with impedance matched de-embedding

• Standard 2X thru de-embedding:
  - Accuracy IL, Phase delay, return loss, impedance determined by repeatability of the 2X thru standard

• Impedance matched de-embedding:
  - Accuracy IL, Phase delay determined by repeatability of the 2X thru standard,
  - Accuracy Return loss and impedance independent of the 2X thru performance
For information about Samtec’s gEEk® spEEk presentations, contact: gEEkspEEk@samtec.com

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