Advanced Deembedding – Accurate Fixture Modelling for Precise VNA Measurements of Non-Coaxial DUTs

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Make ideas real

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Agenda

- Introduction and Basics: S-Parameter and Calibration
- Fixture Compensation Methods Overview
- Advanced Deembedding and Fixture Modelling

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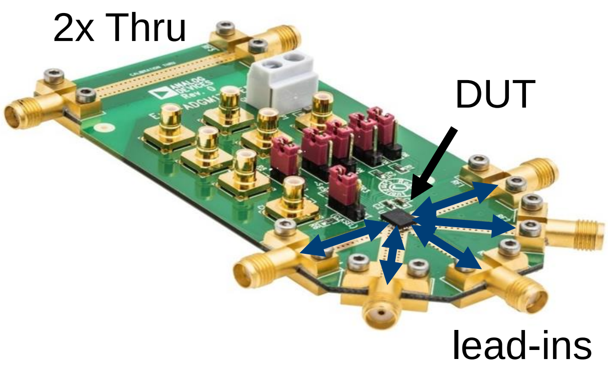
- ► Introduction and Basics:
  S-Parameter and Calibration
- ► Fixture Compensation
  Methods Overview
- ► Advanced Deembedding
  and Fixture Modelling

Why use Advanced De-embedding Tools?

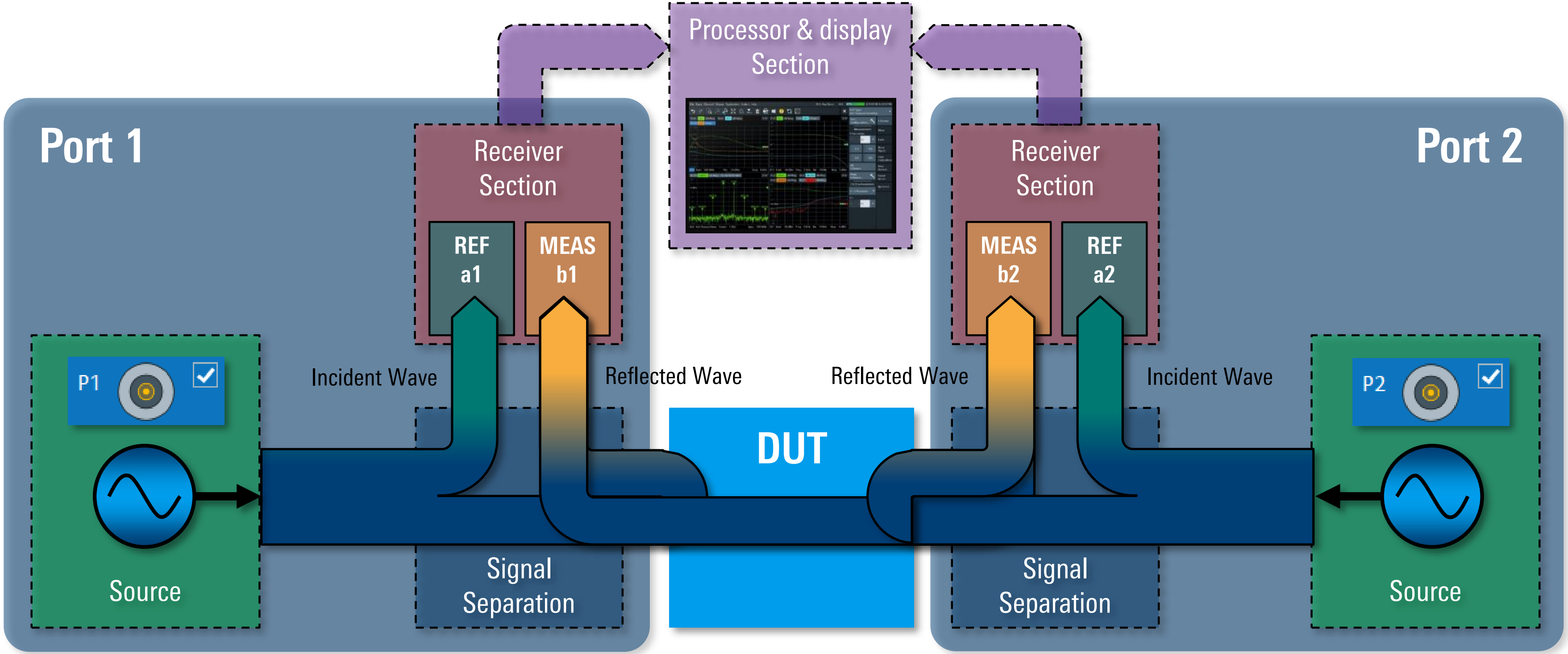
► VNA calibration usually calibrates up to end of coaxial cables

► But many DUTs do not have coaxial adapters
  – DUT on PCB
  – Fixtures needed for special connectors

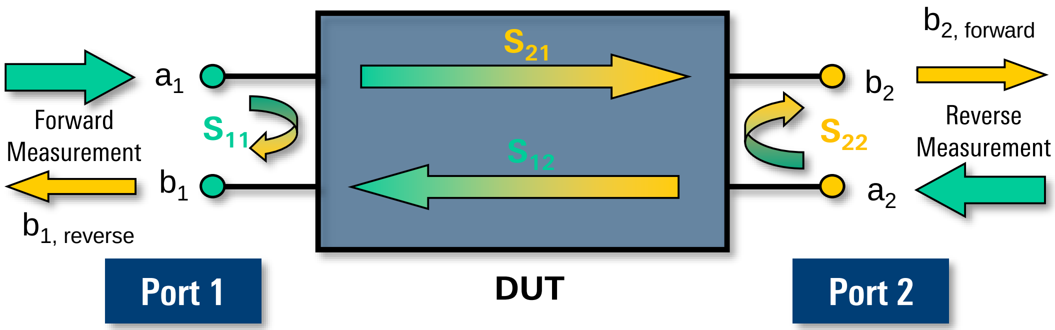
► Use of S-Parameter de-embedding to accurately compensate effects of fixtures or lead-ins



S-Parameter Basics
Realization of Network Analyzer Test Set



S-Parameter Basics



$S_{11} = b_1/a_1 |_{a2=0}$ Forward reflection coefficient (input match)

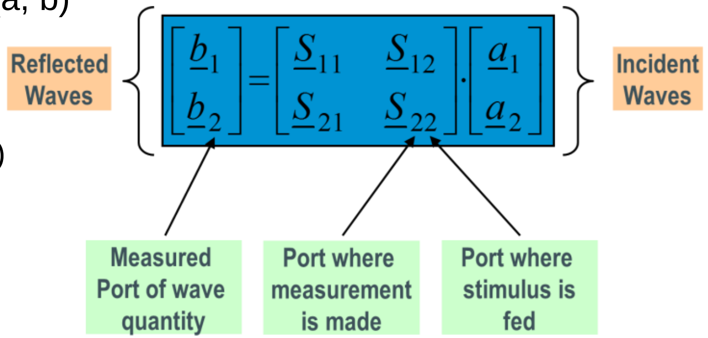
$S_{22} = b_2/a_2 |_{a1=0}$ Reverse reflection coefficient (output match)

$S_{21} = b_2/a_1 |_{a2=0}$ Forward transmission coefficient (gain or loss)

$S_{12} = b_1/a_2 |_{a1=0}$ Reverse transmission coefficient (isolation)

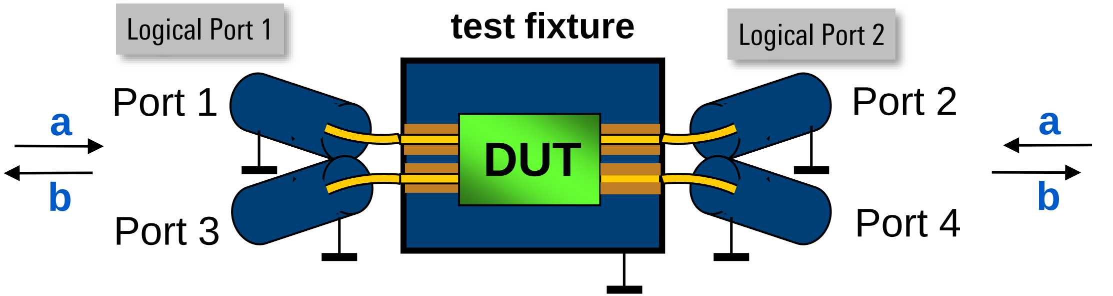
Scattering parameters represent the relationship between the waves (a, b)

- S-Parameters represent reflection and transmission coefficients
- S-Parameters are dimension free (units disappear when ratioed)
- These coefficients are based on a defined line-system (usually 50 ohms)

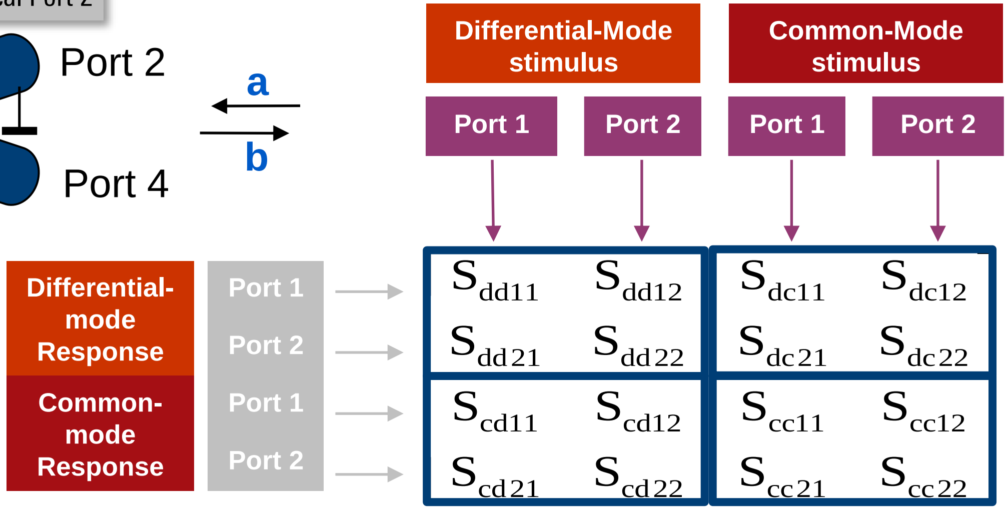


Balanced/ Mixed Mode S-Parameters

Measure the balanced 2-port device as unbalanced 4-port device with unbalanced VNA.
VNA Calculates mixed mode S-Parameters out of measured single ended S-Parameters.



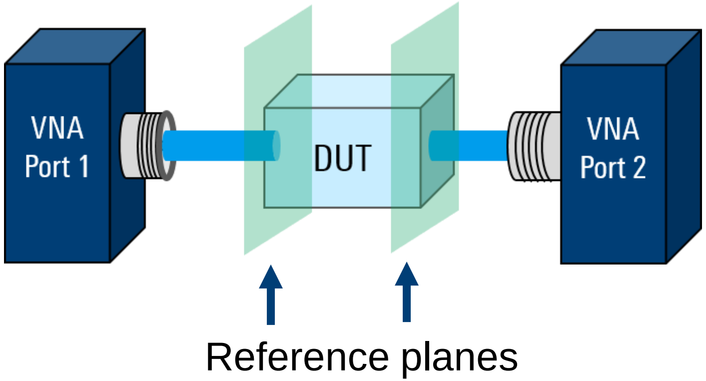
$$\begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{21} & S_{22} & S_{23} & S_{24} \\ S_{31} & S_{32} & S_{33} & S_{34} \\ S_{41} & S_{42} & S_{43} & S_{44} \end{bmatrix} * \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \end{bmatrix}$$



Naming Convention: S mode res., mode stim., port res., port stim.

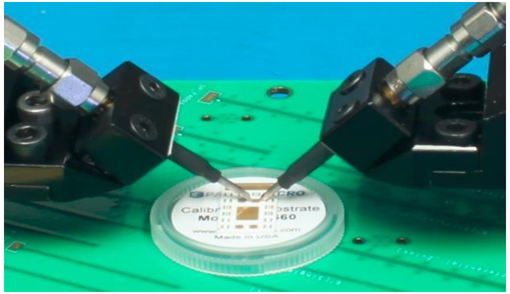
VNA System Error Correction (Calibration): Coaxial Interface

- ► Correction of systematic errors of the instrument and cables (test set)
- ► Applying a set of **known** calibration standards at the desired reference plane to characterize the test set for correction in the calibration
- ► Typically used calibration kits consists of Through, Open, Short and Match standards (TOSM)
- ► Also automatic calibration units available



VNA System Error Correction (Calibration): PCB Probes
Example: Packet Micro PCB Probing Solutions

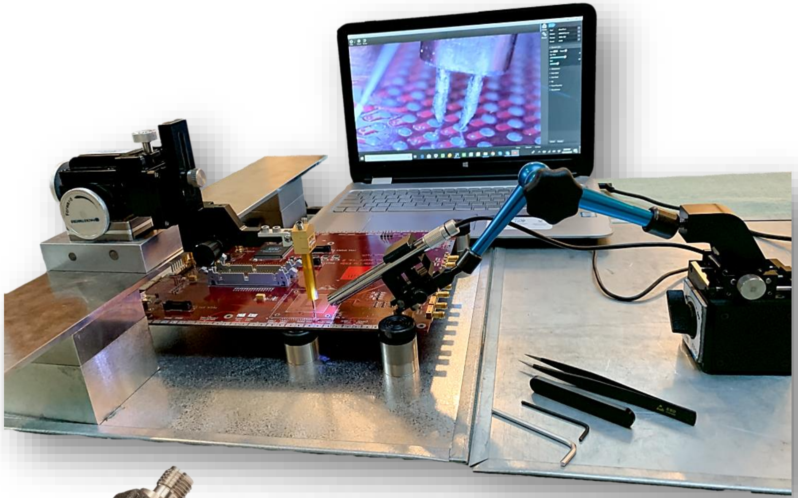
- Precise positioning with XYZθ-Positioners
- Reference plane on the PCB with cal substrate
- Single ended & differential probes
- Microscope for close up view of your PCB
- Calibration substrate for TOSM calibration
- Up to 20 GHz



PACKETMICRO

VNA System Error Correction (Calibration): PCB Probes Example: DVT Differential Probing Solutions

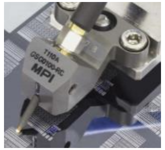
- 40/50/70 GHz differential probes, no ground
- Use of coaxial calibration
- Deembedding of differential probe model
- Use de-embedding tool to create probe model



Design Verificaion Test
DVT Solutions

VNA System Error Correction (Calibration): Wafer Probes Example: MPI Wafer Probing Solutions

- ► Micro Positioners
- ► Unique puck controlled air bearing stage
- ► MPI Titan Probes



- ► Use of mmW Converters possible
- ► Calibration software “QAlibria”

MPI CORPORATION

DUT courtesy: FBH, Berlin.

Agenda

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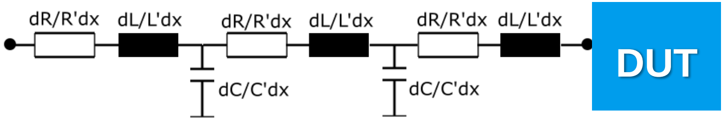
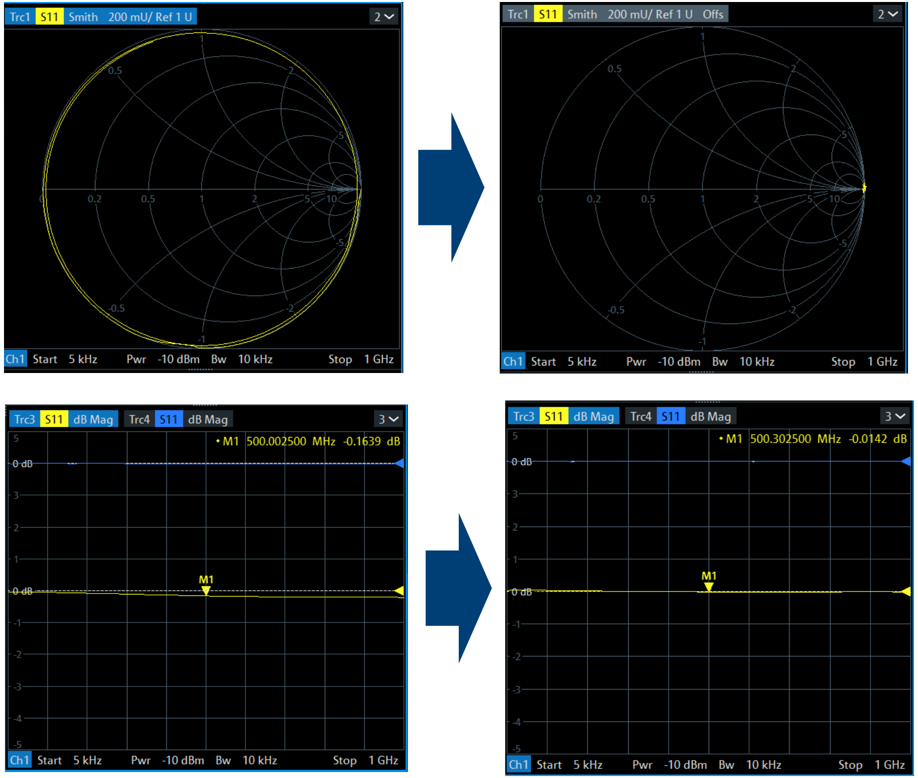
Offset Compensation

► Offset compensation of fixtures:



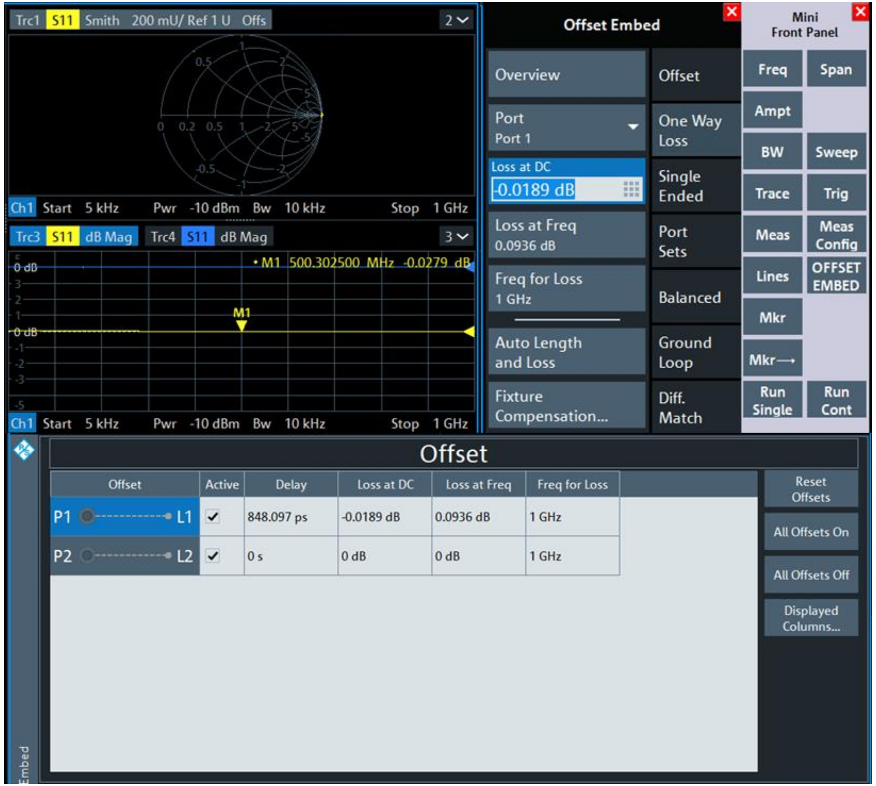
Transmission line equivalent serial circuit

► "Auto length and loss" compensates magnitude and phase offsets



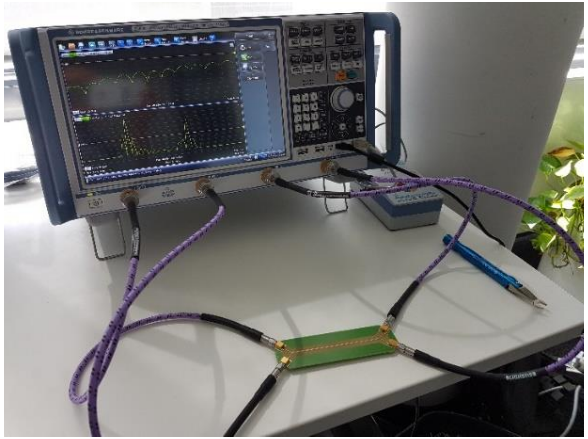
Offset Compensation

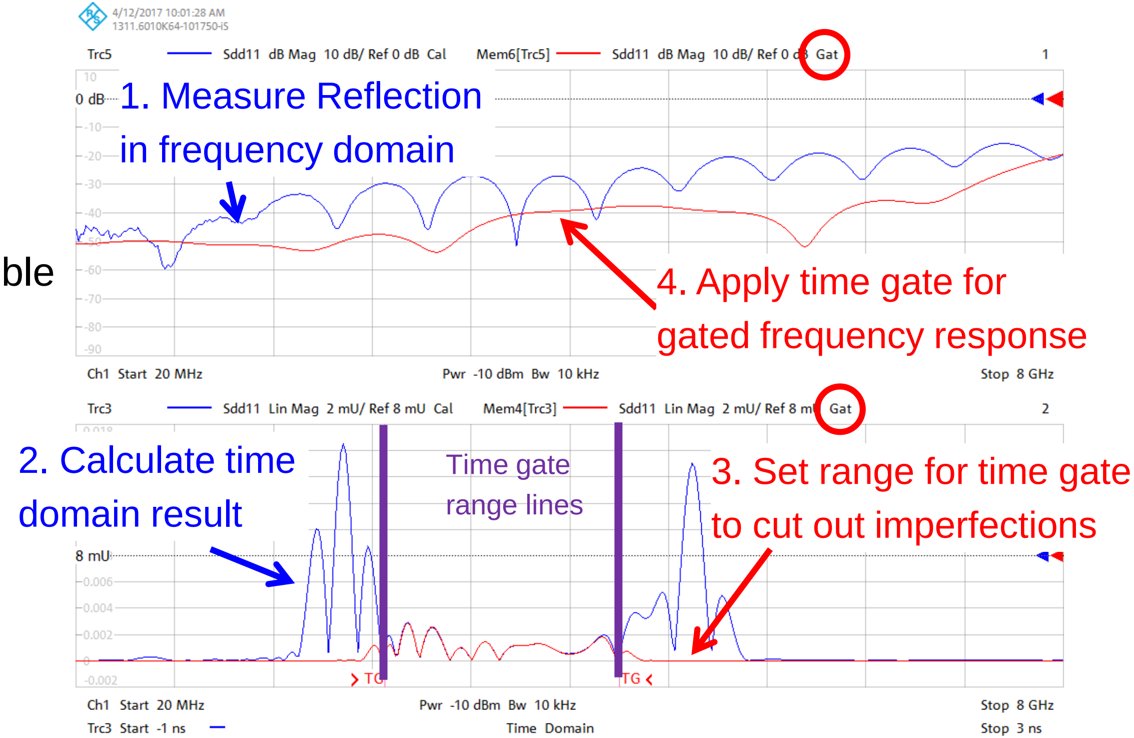
- ► Standard feature of the R&S®VNAs
- ► Works best if a short length has to be compensated
- ► Should be used only up to some GHz
- ► Uses “open” and/or “short” measurements for compensation
- ► No correction of mismatches, it is not a type of calibration!



Time Domain Gating

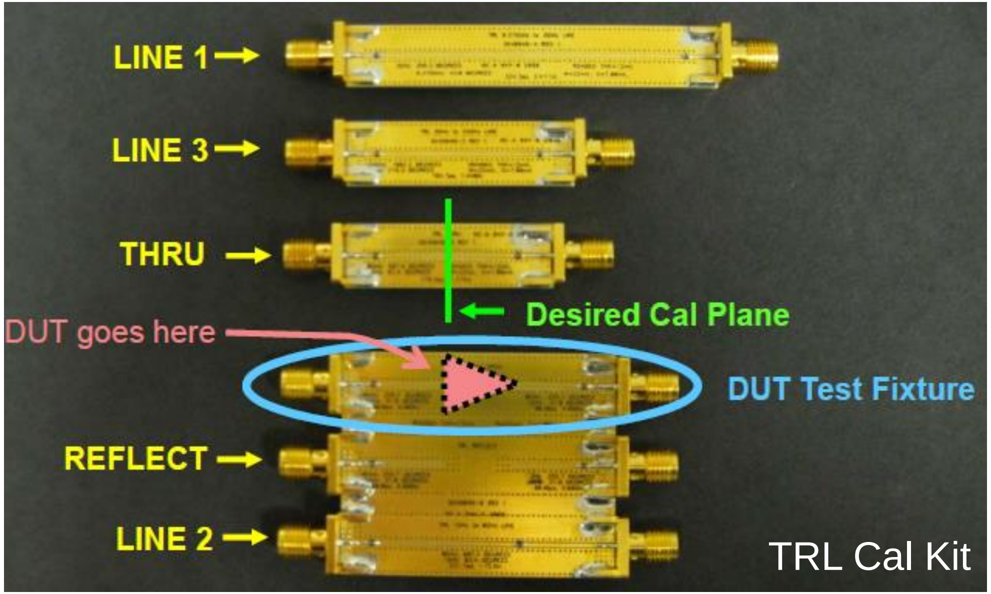
- ► Selection of relevant parts of the DUT in time domain
- ► Retransformation into frequency domain
- ► No insertion loss data
- ► No S-Parameter file creation possible





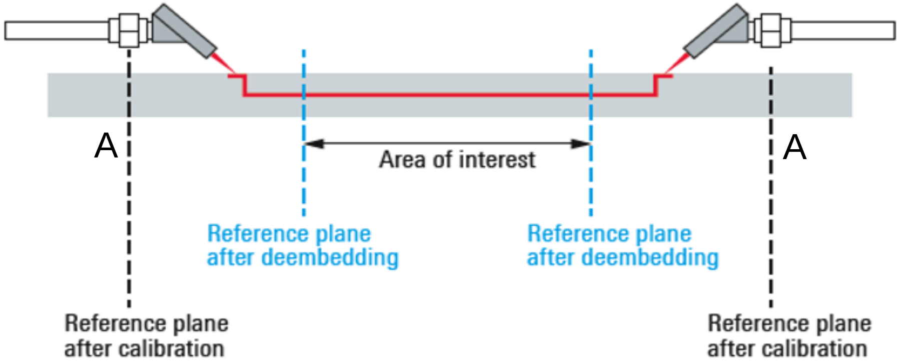
TRL/ LRL / TRLLLM Calibration

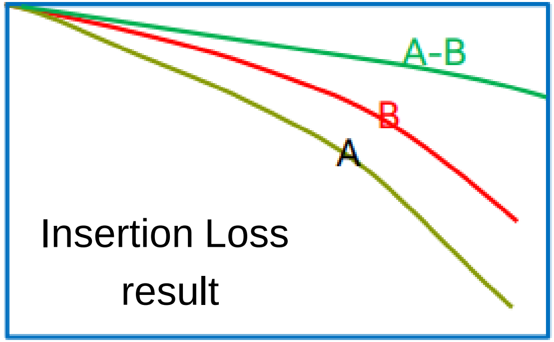
- Shift of reference plane to Thru/2
  - Cal data definition of thru: length = 0
- Limited frequency range
  - More lines needed to cover higher frequency range
  - Match needed to cover low frequencies
  - → High effort
- Different behavior of cal kit and fixture leads to errors



Delta-L Measurements with R&S VNA

- ► Introduced by Intel
- ► Motivation: Insertion loss characterization of (quasi-ideal) PCB transmission lines
- ► Delta-L 4.0 example: Eigenvalue Method





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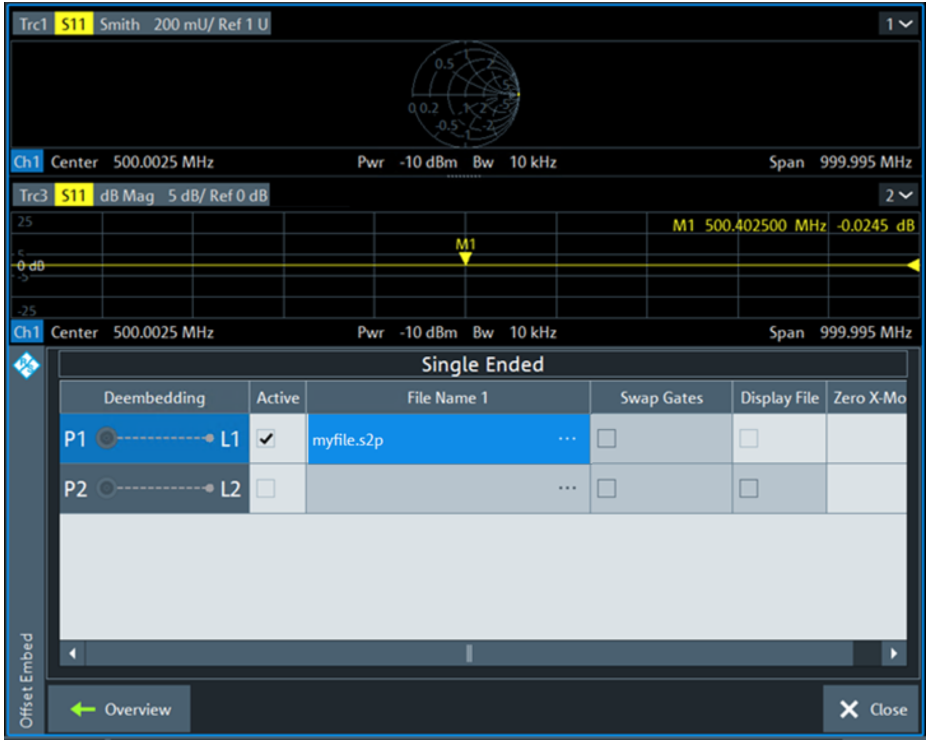
S-Parameter De-embedding

- ► Use S-Parameter deembedding feature of R&S VNA to deembed fixture influence
- ► But: How to get S-Parameter file of your fixture?

→ R&S VNA Deembedding Options

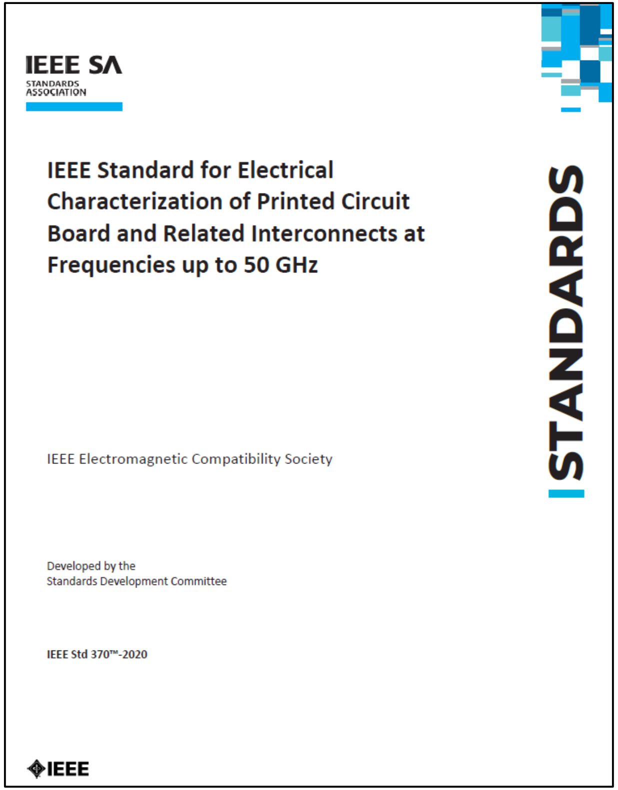


IEEE 370 Standard

- "Electrical Characterization of Printed Circuit Board and Related Interconnects at Frequencies up to 50 GHz"

- 3 major topics:
  - Test-fixture Design Criteria
  - **De-embedding Verification**
  - S-Parameter Integrity and Validation

- R&S tools fulfill requirements of IEEE STD 370
  - Ataitec - In Situ De-embedding
  - CSS / Packet Micro - Smart Fixture De-embedding
  - Arcane - Eazy De-embedding


IEEE SA
STANDARDS ASSOCIATION

IEEE Standard for Electrical Characterization of Printed Circuit Board and Related Interconnects at Frequencies up to 50 GHz

IEEE Electromagnetic Compatibility Society

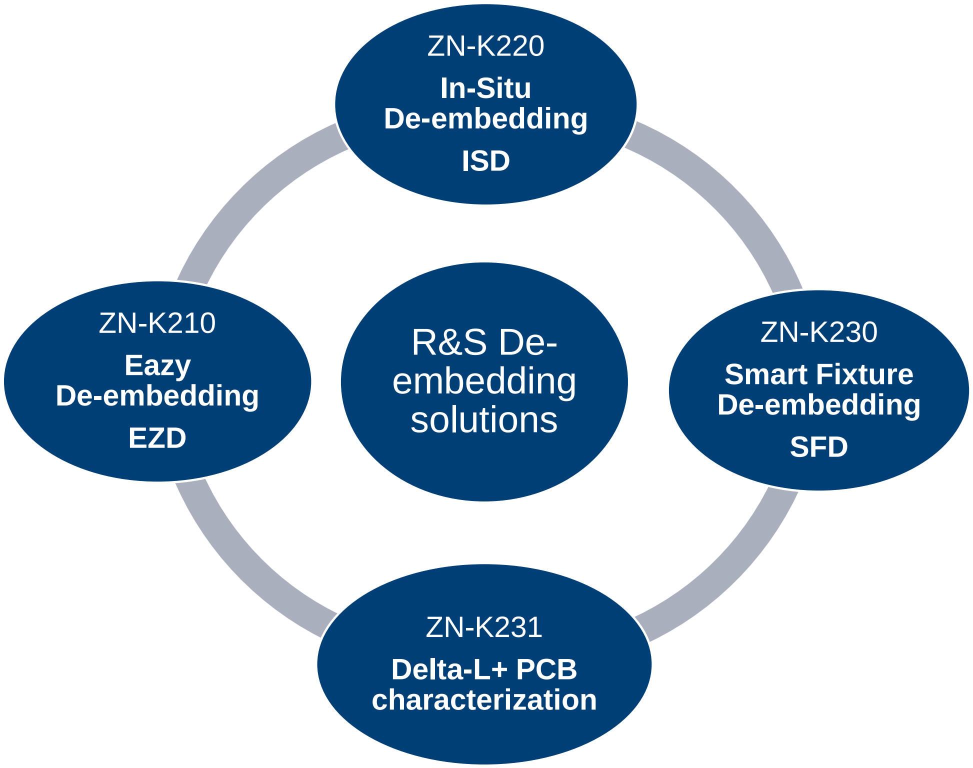
Developed by the
Standards Development Committee

IEEE Std 370™-2020

IEEE

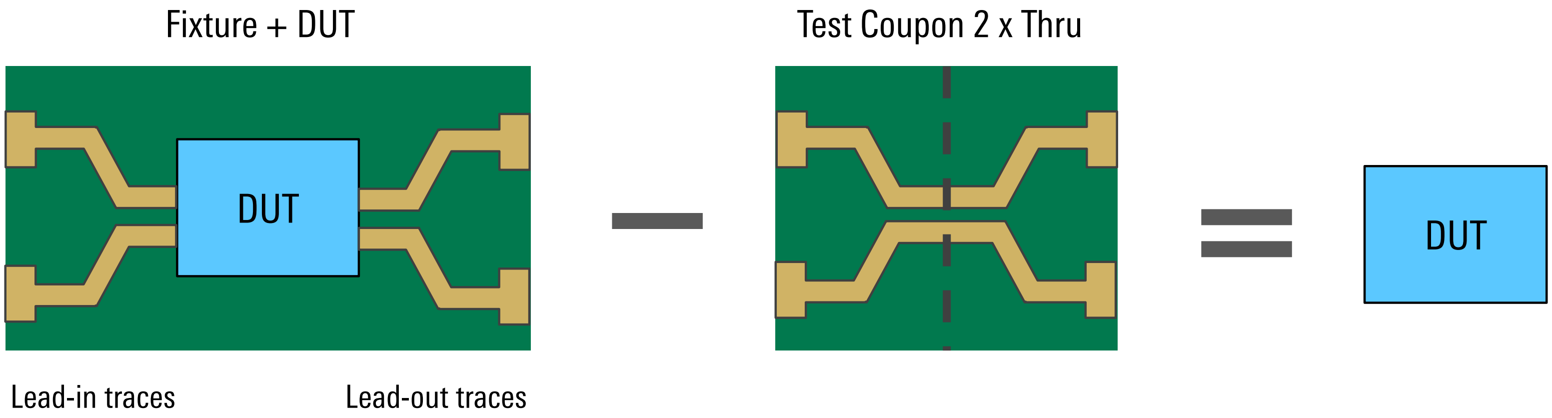
STANDARDS

New R&S De-embedding Tools



- Available for R&S ZNA, R&S ZNB / ZNBT and R&S ZND
- Deembedding workflow implementation
  - ZN-K210 EZD (Arcane)
    → based on IEEE 370 open source code
  - ZN-K220 ISD (Ataitec)
    → meets IEEE 370 requirements
  - ZN-K230 SFD (CSS/PacketMicro)
    → meets IEEE 370 requirements
- Delta-L workflow implementation
  - ZN-K231 Delta-L+ (CSS/PacketMicro)
    → Intel technology

De-embedding of Lead-in / Lead-out Traces

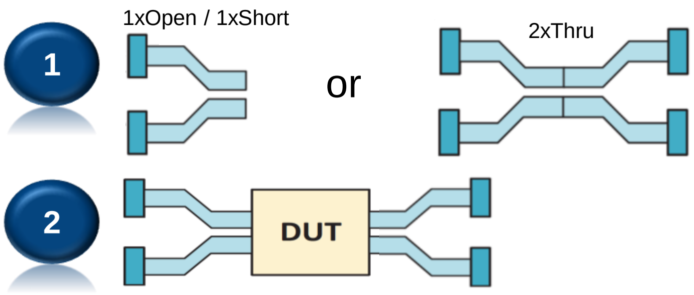


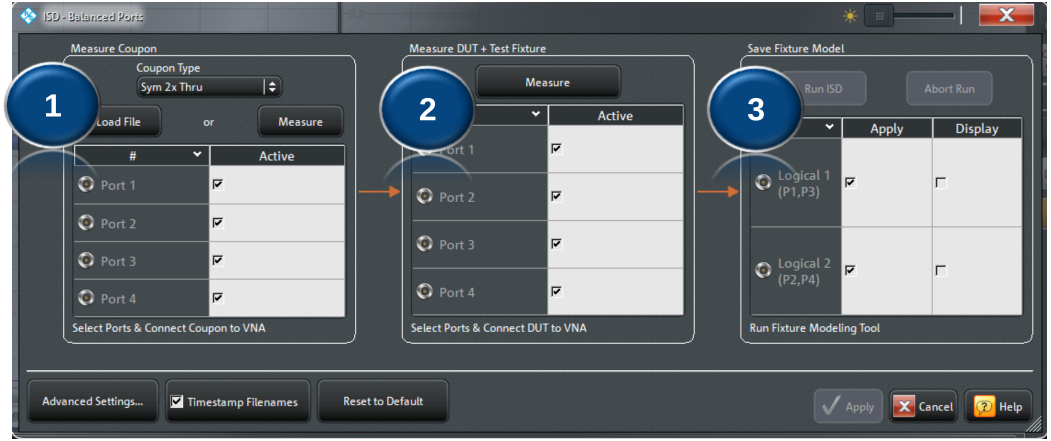
- Problem:
  Differences between coupon and test fixture would lead to errors
  (different connector and line impedances (e.g. fiber weave), different signal routing, etc.)
- Solution:
  - "Impedance Correction" feature creates fixture *.snp files out of Fixture + DUT measurements
  - Algorithm only determines length of fixtures from coupon measurement

Partner De-embedding Tools VNA Firmware Integration

Problem DUT has no standard adapters where calibration is possible

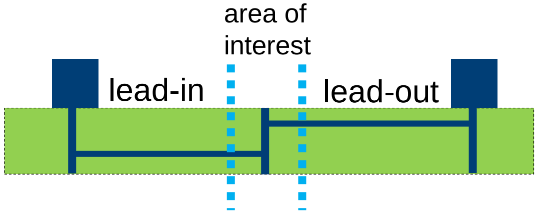
1. Measure test fixture
   "coupon": 2xThru or 1xOpen/ 1xShort
2. Measure DUT + test fixtures
3. VNA shows result for DUT only
   (by implementing fixture *.snp files
   in de-embedding menu)



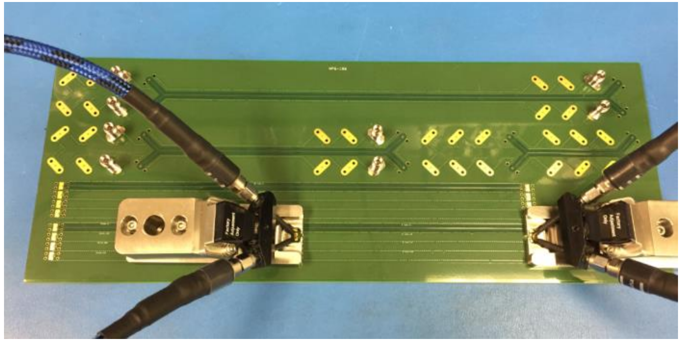


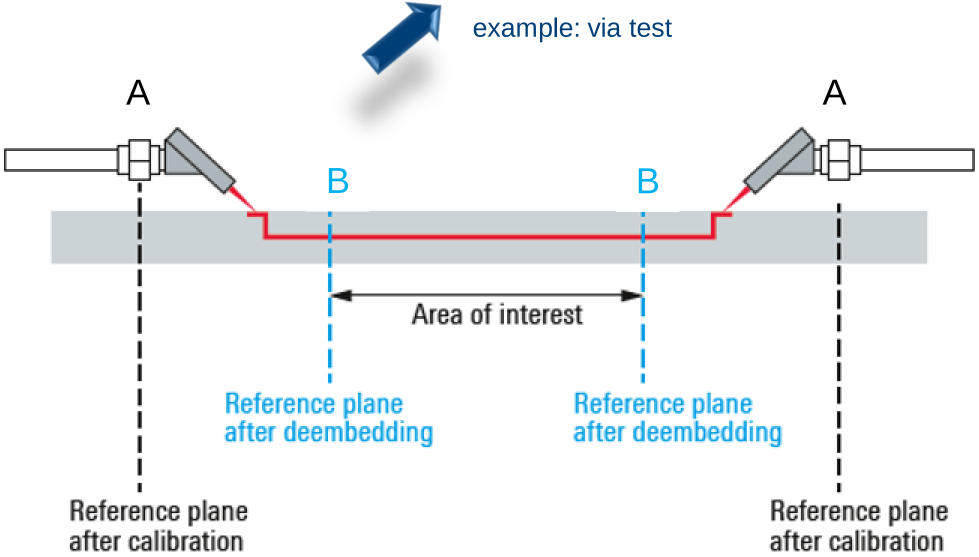
Use Case #1:
PCB Test with De-embedding

- ► Step 1: Coaxial calibration
- ► Step 2: De-embedding of lead-in and lead-out
- ► All measurements at new reference plane



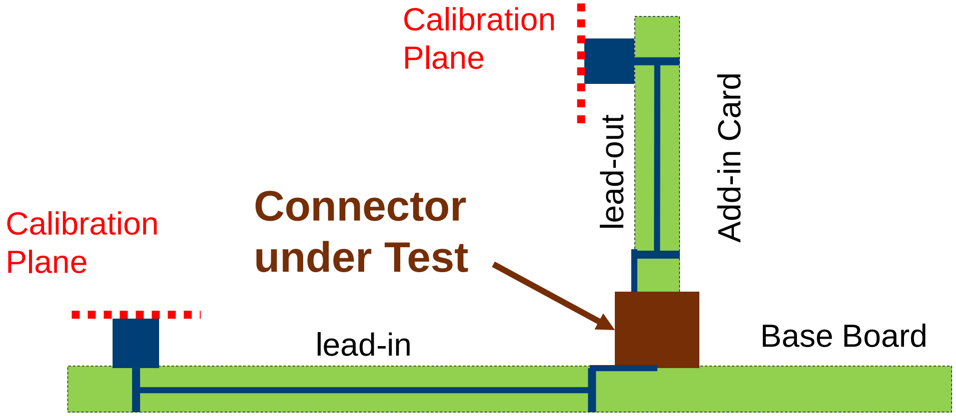
example: via test

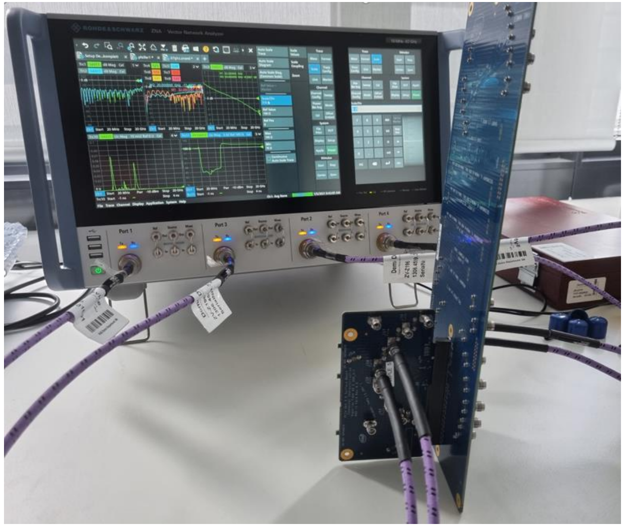




Use Case #2:
Connector Test Fixture Compensation

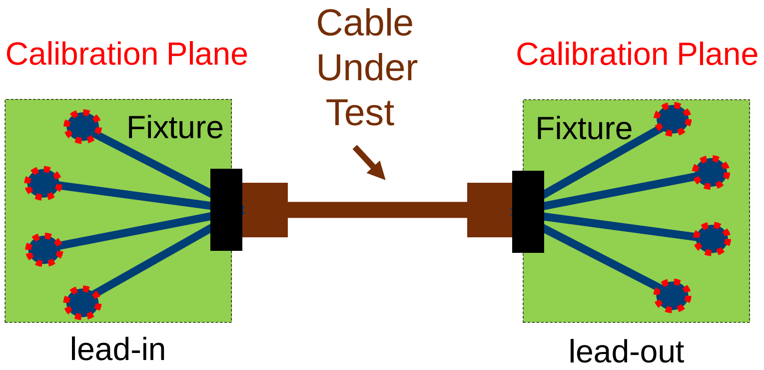
- ► Step 1: Coaxial calibration
- ► Step 2: De-embedding of lead-in and lead-out
- ► Reference plane at connector under test





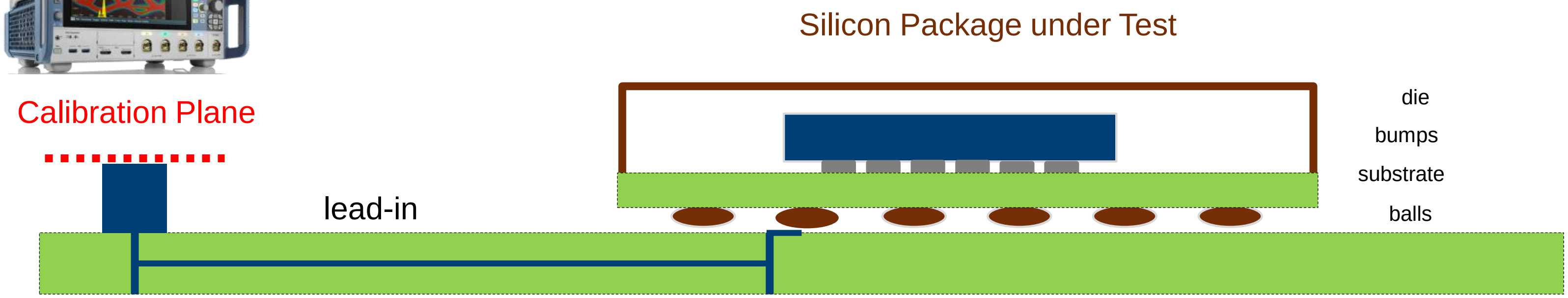
Use Case #3: Cable Test Fixture Compensation

- Step 1: Coaxial calibration
- Step 2: De-embedding of lead-in and lead-out
- Reference plane at cable under test



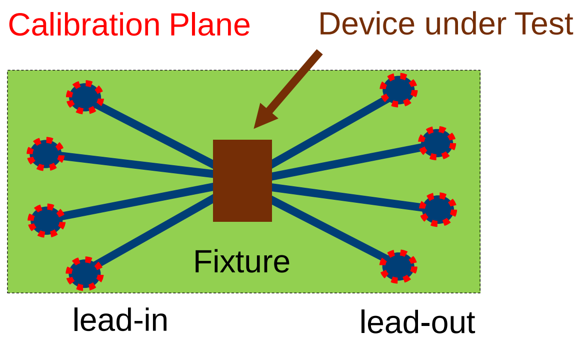
Use Case #4:
SoC Test (System on Chip) Fixture Compensation

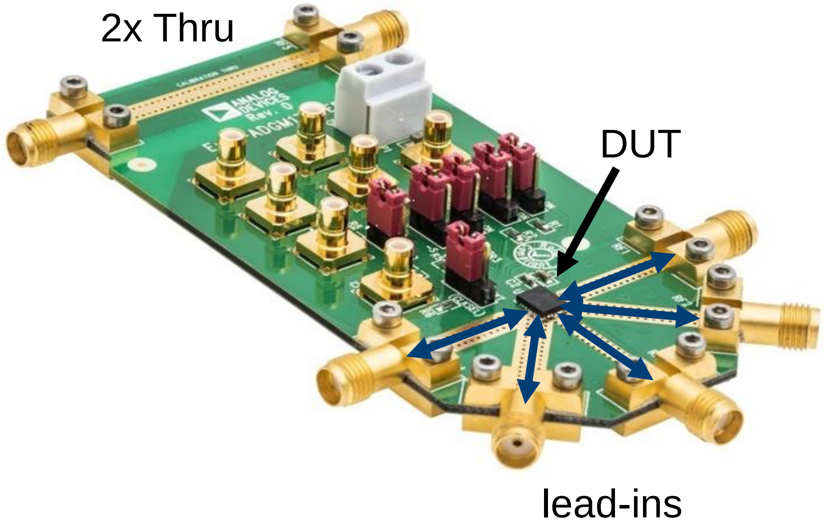
- ► Step 1: Coaxial calibration
- ► Step 2: Characterization of lead-in with VNA and extrapolation to DC
- ► Step 3: Import to Oscilloscope



Use Case #5:
RF Devices without Coaxial Connectors

- Step 1: Coaxial calibration
- Step 2: De-embedding of lead-in and lead-out
- Reference plane at device under test

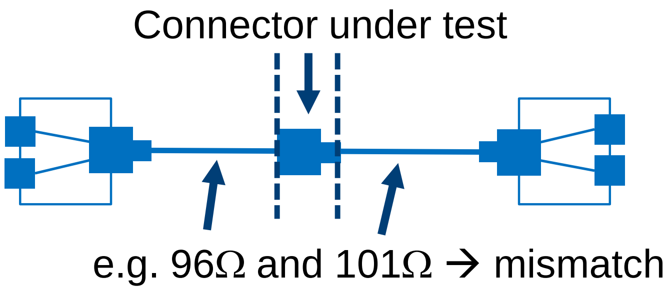




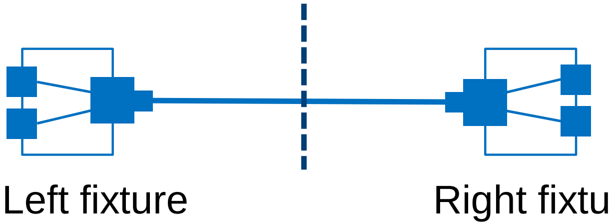
De-embedding with Impedance Correction: Example R&S ZNB with ZNB-K220 / ISD

- Automotive Ethernet 1000BASE-T1 STP
- Task: measure „inline connector“ return loss
- Problem:
  - time domain gating will show reflection due to cable mismatch
- Solution:
  - use ZNB with K220 / ISD and impedance correction to get S-Parameter for De-embedding

DUT + Fixtures:



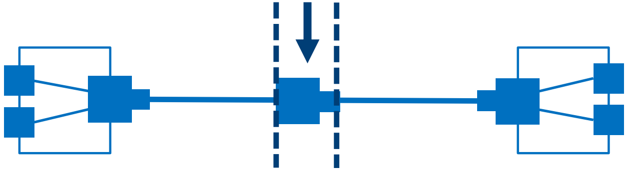
2 x thru „coupon“ to get de-embedding files:

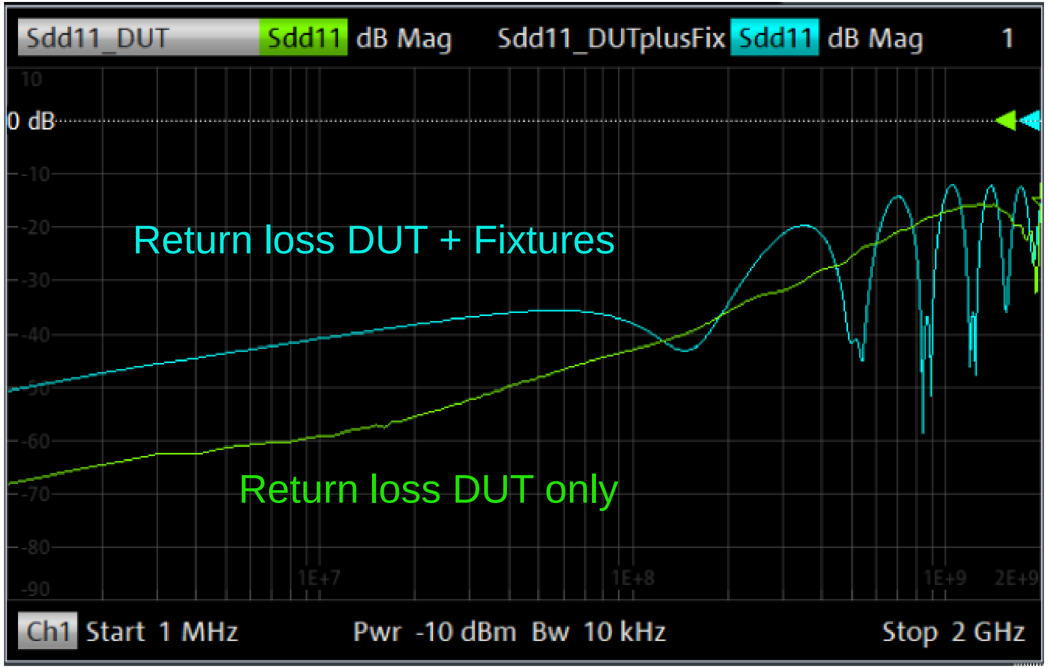


R&S ZNB with Integrated De-embedding Workflow
Example: ZNB-K220 / ISD

► Inline Connector **Return Loss** result with ISD deembedding

Connector under test

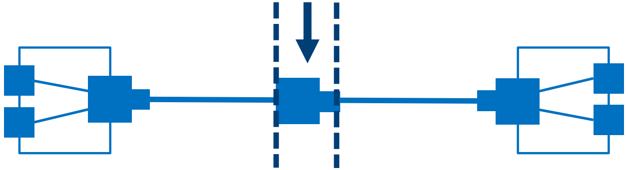


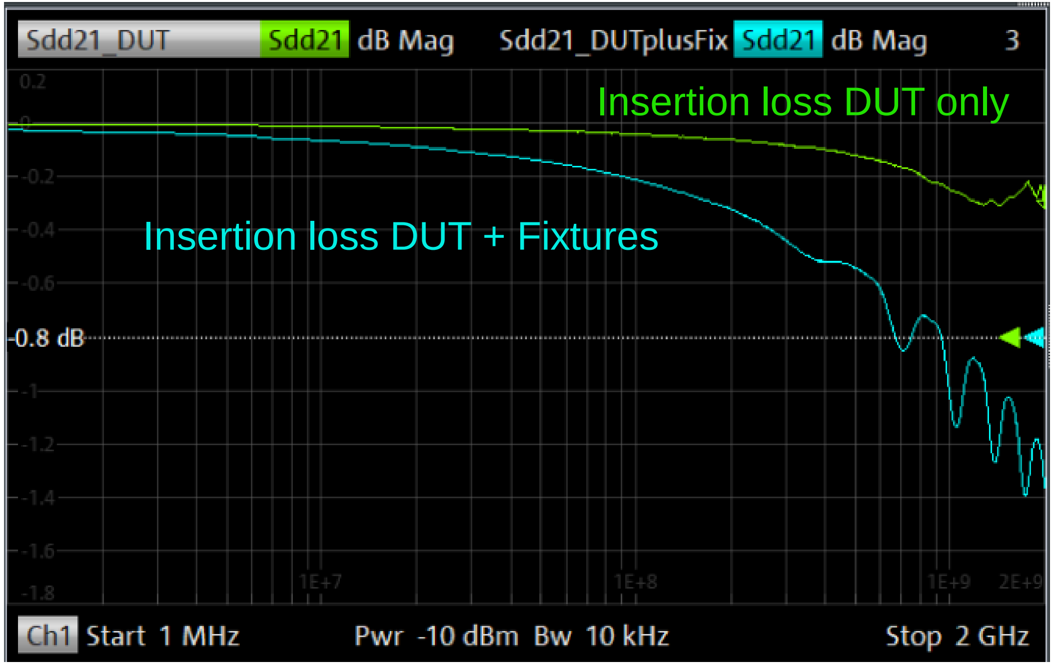


R&S ZNB with Integrated De-embedding Workflow
Example: ZNB-K220 / ISD

► Inline Connector **Insertion Loss** result with ISD deembedding

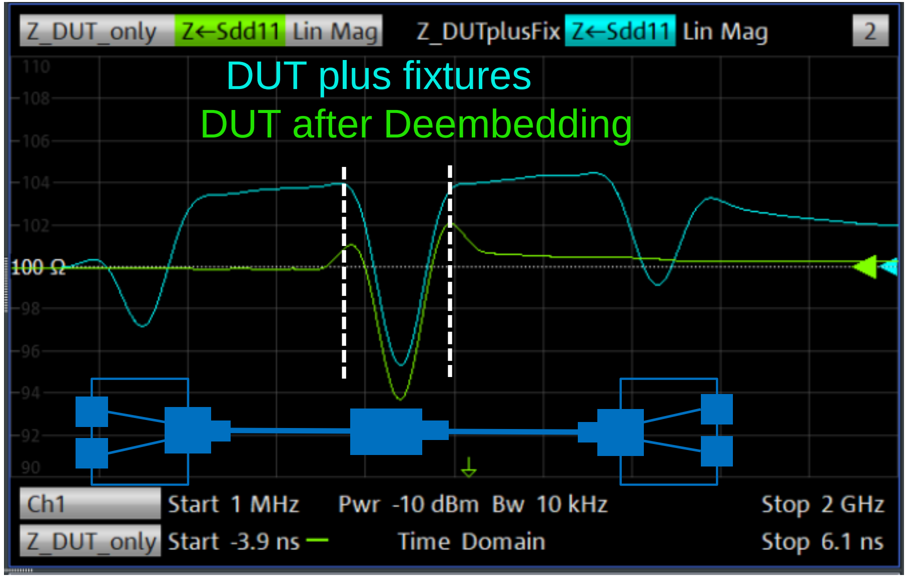
Connector under test

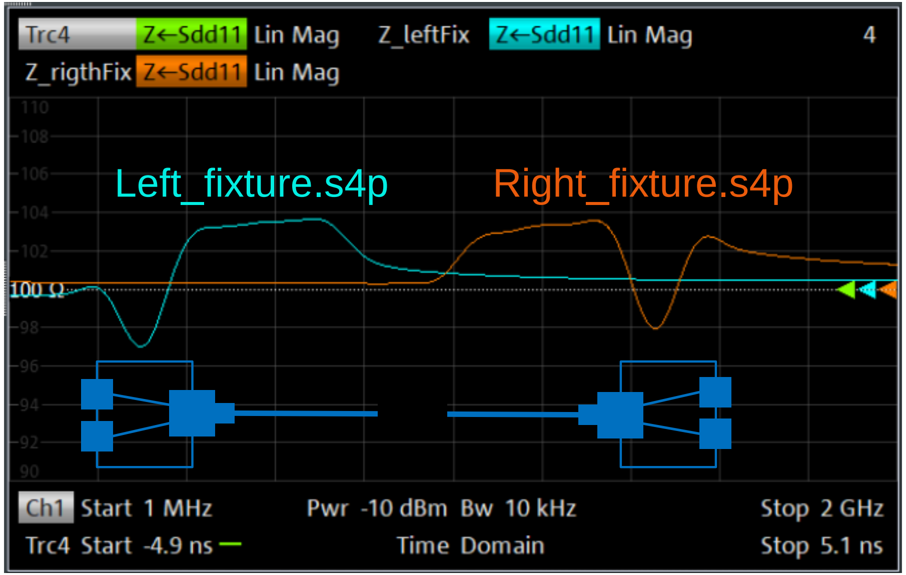




R&S ZNB with Integrated De-embedding Workflow Example: ZNB-K220 / ISD

- TDR Impedance of Fixtures and DUT
- S-Parameter view in postprocessing

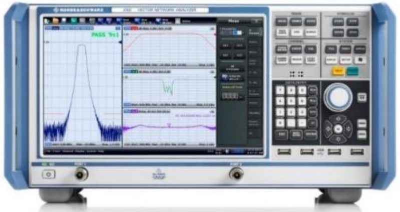




R&S De-embedding Tools

For R&S Network Analyzers ZNA / ZNB / ZNBT / ZND:

R&S ZNA



R&S ZND

R&S ZNB

R&S ZNBT

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Thank you!

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