



Practical Application of the IEEE P370 standard draft for measurement of interconnects up to 50 GHz

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Outline

- Background
- Best Practices
 - Test Fixture Design
 - PCB Design
- De-embedding methods
- S-parameter Quality Tools and Metrics
- Comparison of S-parameters
- De-embedding Verification
 - Using the S-parameter library
 - Using the Plug and Play fixtures
 - Using test board measurements
- References



Background

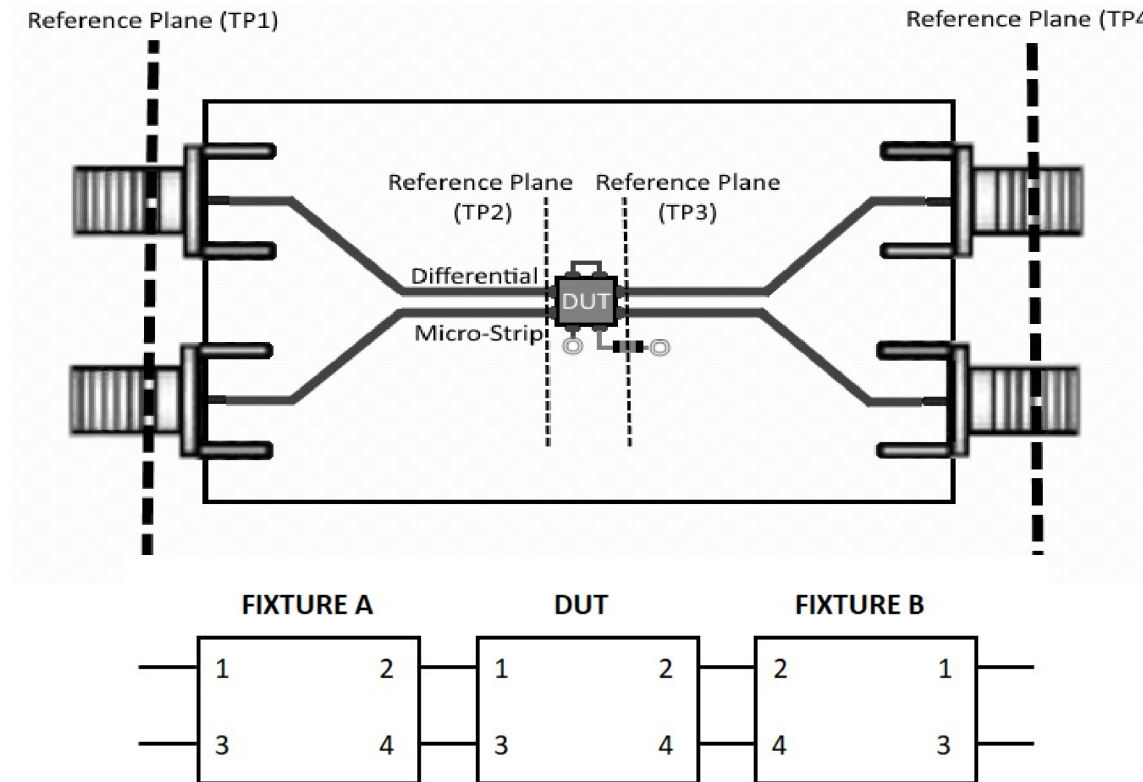
- Increased accuracy needed for simulation of systems using devices operating with significant spectral content at 50 GHz; e. g., 56 Gb/s
- Accurate de-embedding method needed for devices characterized to 50 GHz
- Different structures, different methods in use in industry
 - Lack of consistency
 - Proprietary algorithms, tools
 - Poor results due to poor fixture design
 - Poor quality S-parameter data -> inaccurate simulation
 - No objective way to evaluate quality of results
- P370 is not a calibration standard (see P378, now expired)



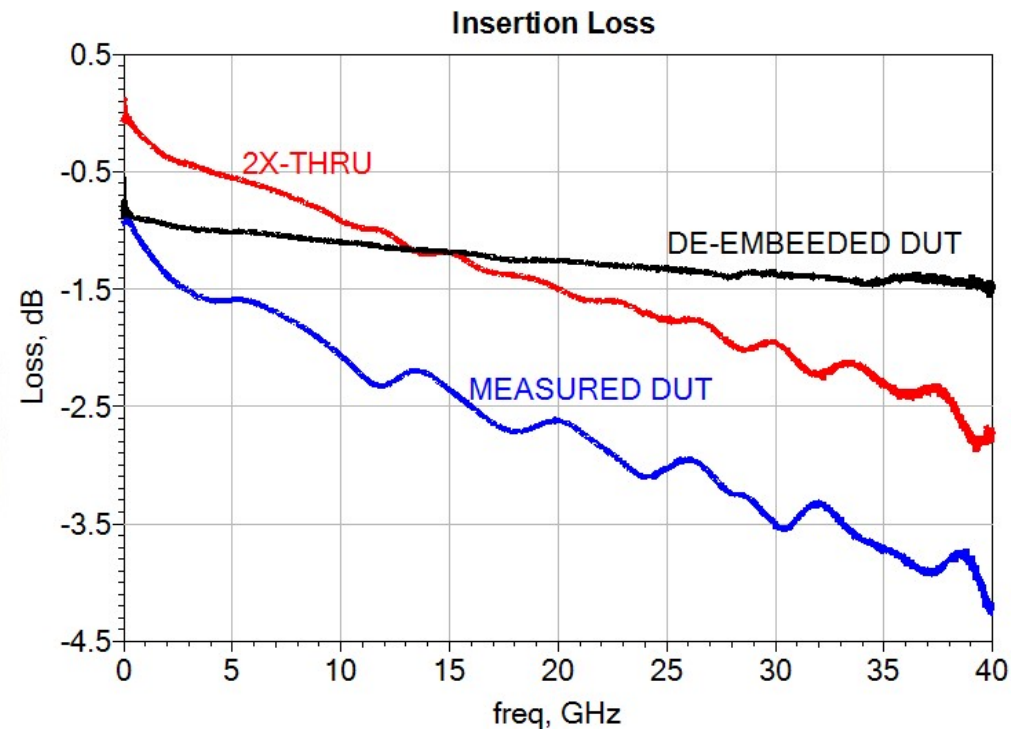
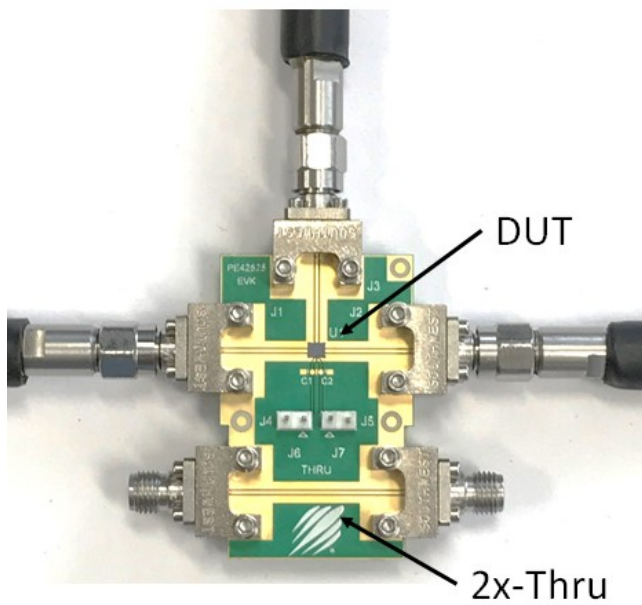
Best Practices – guidance on

- Test Fixture Design
 - Limits defined for insertion loss, return loss, crosstalk, crosstalk-IL difference, impedance, common mode conversion, skew
- Measurement equipment, test cables and connectors
- PCB Design
 - Launch connectors and footprints
 - Conductor geometry, plating, surface roughness
 - Dielectric material
 - Stitching vias, Ground plane cutouts, return paths

De-embedding objective: Separate the DUT from the fixture



De-embedding objective: Separate the DUT from the fixture





De-embedding methods

- 1x Reflect – uses single Open or Short standard
- 2x thru – uses measured 2x thru
- 2x Impedance-corrected thru – uses 2x thru
 - Compensates for Z mismatch between 2x-thru and FIX-DUT-FIX, reduces causality errors
- Tool developers: Evaluate the accuracy of the method (code)
- Tool users: Evaluate the quality/accuracy of the results



S-parameter Quality Tools and Metrics

- Tools developed for evaluating quality of S-parameters
 - Causality
 - Passivity
 - Reciprocity
- Metrics (limits) defined
- Tool developed for quantifying difference between two S-parameters



De-embedding Verification

- Using the S-parameter library
 1. Build network using desired library elements
 2. Simulate network
 3. De-embed the DUT
 4. Compare de-embedded simulated DUT results with library data for DUT

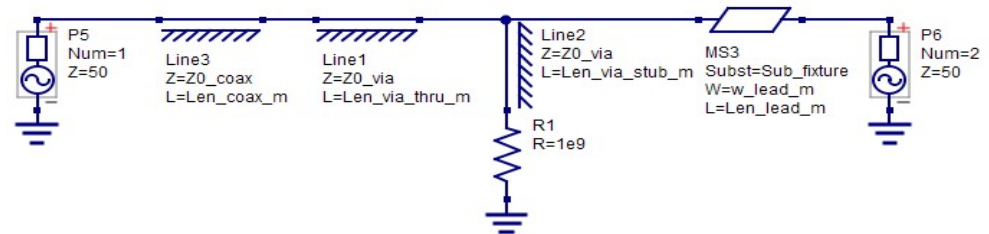
De-embedding Verification

- S-parameter library example:
Line structure

S parameter simulation

SP1
Type=lin
Start=20 MHz
Stop=50 GHz
Points=2500

FixtureL



Equation

coax_feed
Z0_coax=50
Len_coax_mm=5
Dk_coax=2.2

Equation

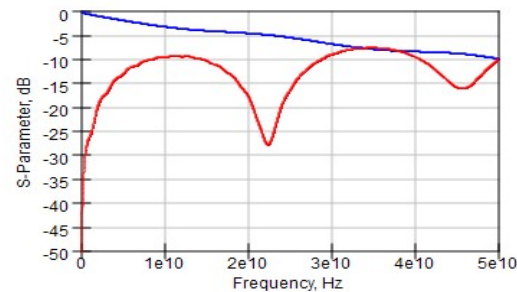
via
Z0_via=35
Len_via_thru_mm=3
Dk_via=3.8

Equation

viaStub
Len_via_stub_mm=0.25

Equation

Eqn7
Len_lead_mm=25
w_lead_mm=0.15
Dk_lead=3.8
Df_lead=0.02
MS_aspectRatio_w_h=2

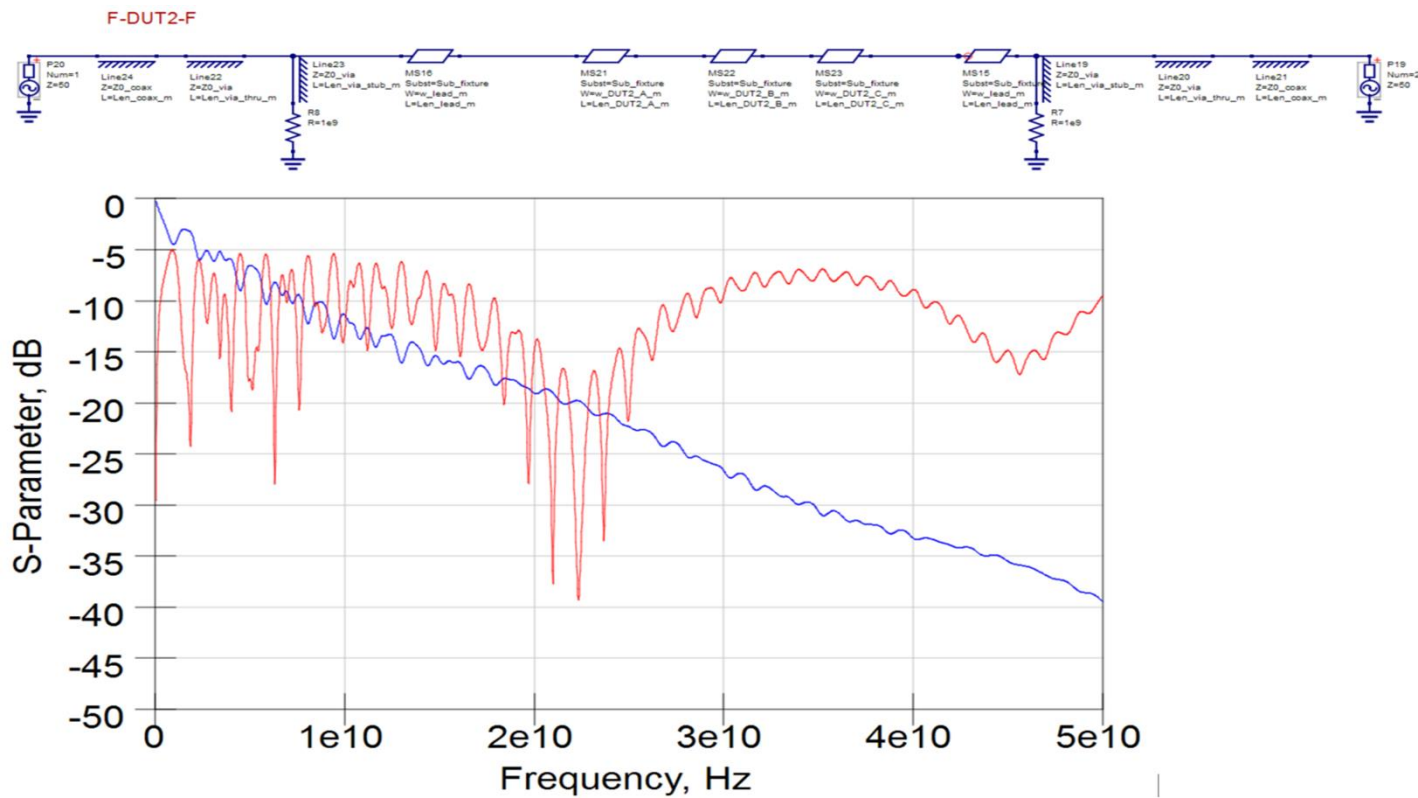


Sub_fixture
er=Dk_lead
h=h_lead_m
t=17 um
tand=Df_lead
rho=0.022e-6
D=0



De-embedding Verification

- S-parameter library example:
FIX-DUT-FIX



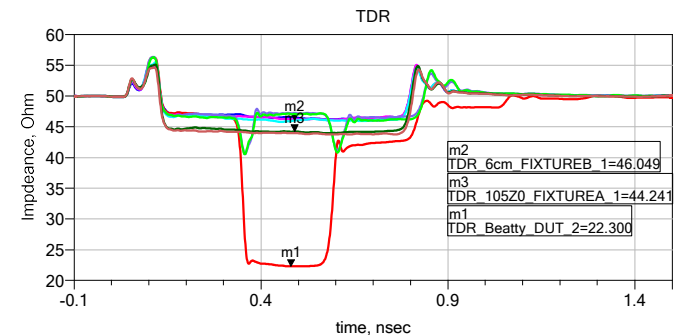
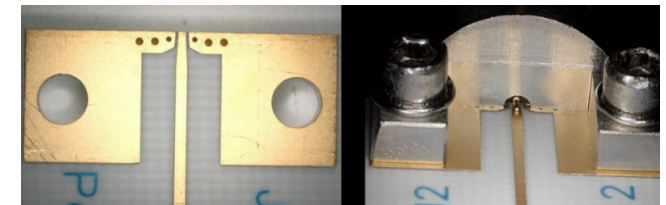
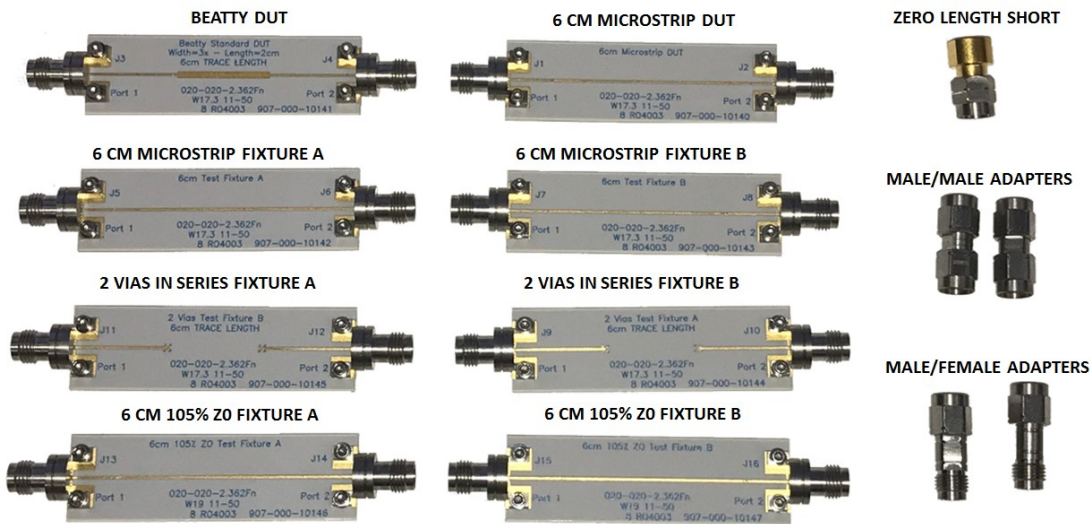


De-embedding Verification

- Using the Plug and Play Fixtures
 1. Build network using desired Plug and Play components
 2. Measure network
 3. De-embed the DUT
 4. Compare de-embedded measured DUT results with Plug and Play data for DUT

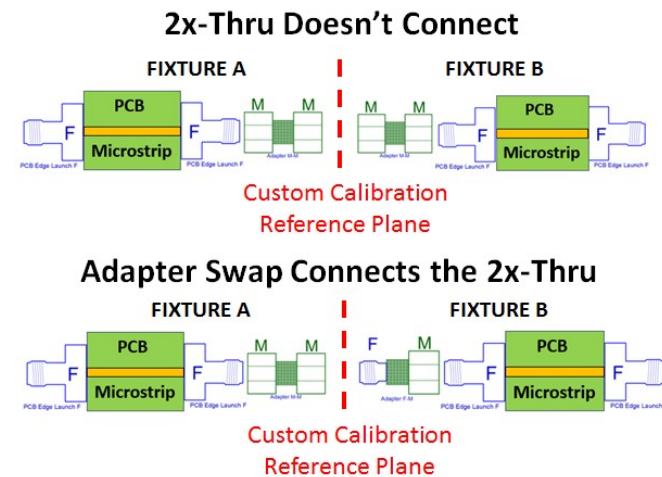
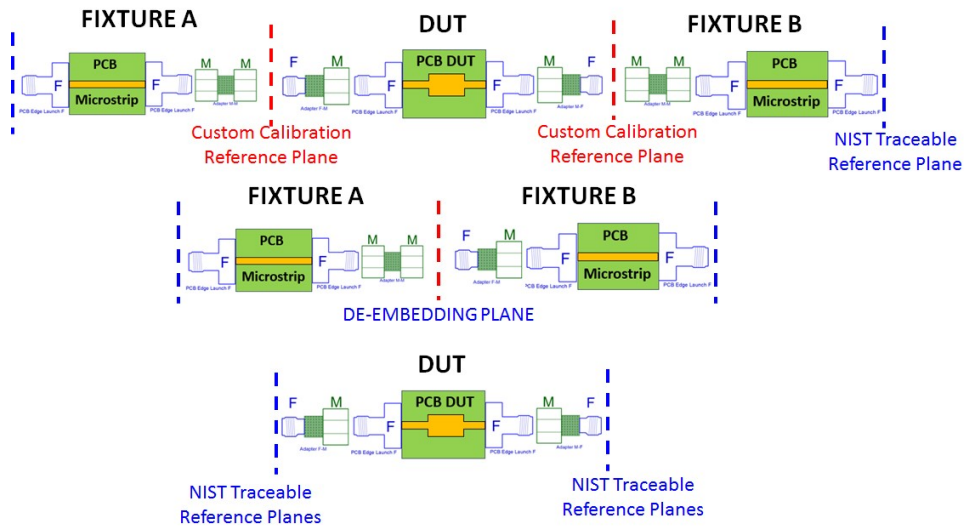
De-embedding Verification

- Using the Plug and Play Fixtures



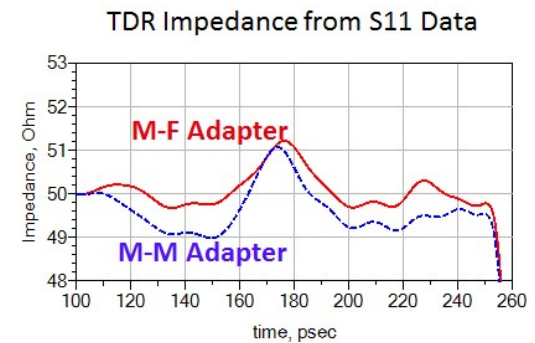
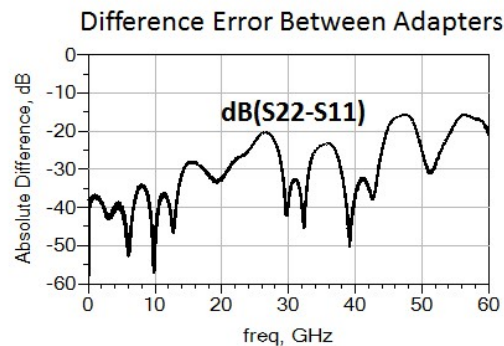
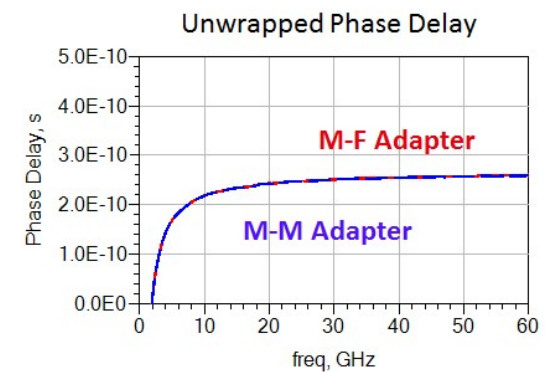
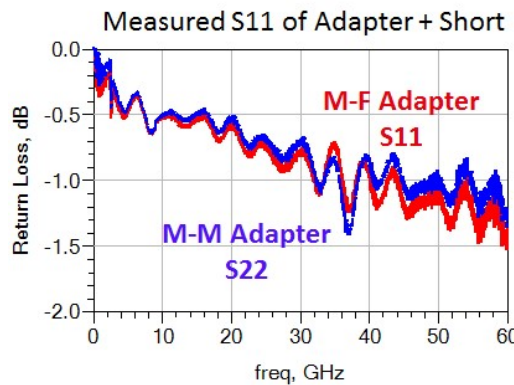
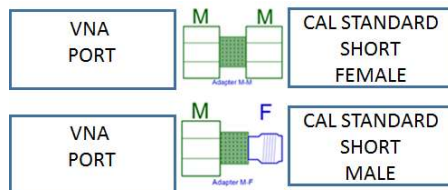
De-embedding Verification

- Using the Plug and Play Fixtures



De-embedding Verification

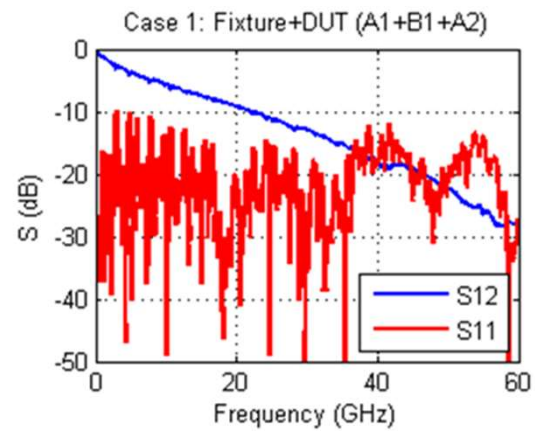
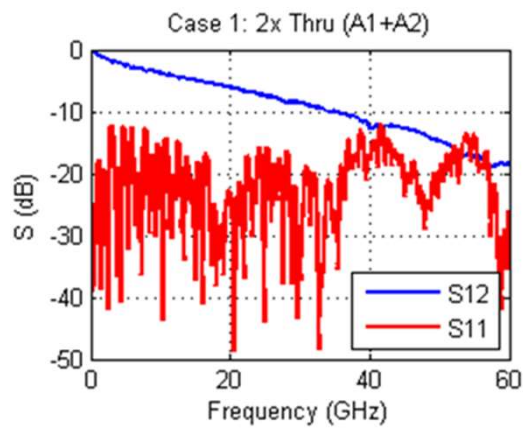
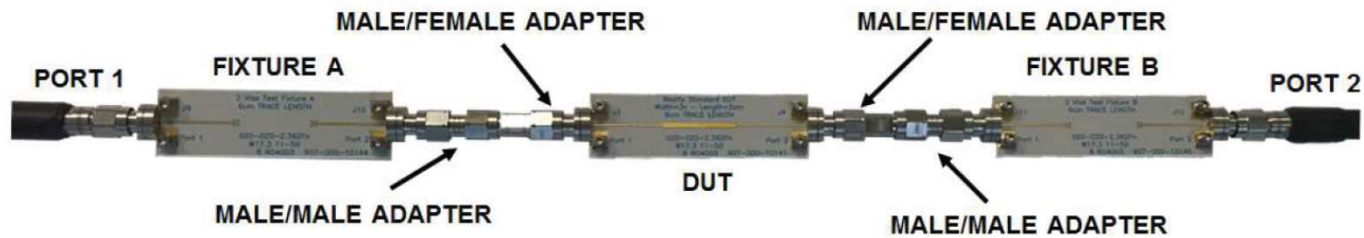
- Plug and Play Fixture adapter swap procedure





De-embedding Verification

- Plug and Play Fixture example: 50 Ohm microstrip, 50 Ohm fixture





De-embedding Verification

- Plug and Play Fixture example: 50 Ohm microstrip, 50 Ohm fixture, cont'd

IEEE_P370_Sparam_Quality_rev0p5

IEEE P370 S-param Quality rev0.5

D:\Users\jdiep\Documents\IEE_stuff\Tools\AtaiTec\data\Case1_DUT_Dmbd1_S2_M16.s2p
 D:\Users\jdiep\Documents\IEE_stuff\Tools\AtaiTec\data\Case5_DUT_Dmbd1_S2_M16.s2p
 D:\Users\jdiep\Documents\IEE_stuff\Tools\AtaiTec\data\Case5_DUT_Dmbd2_S2_M16.s2p

Add
Delete

Time Domain Setting

Data Rate [Gbps]
 Rise Time [psec]
 Sample per UI

internal setting
 Pulse Shape
 (1:Gaussian, 2:Butterworth filter)

SQM in FD

Passivity Quality in FD
 Causality Quality in FD
 Reciprocity Quality in FD

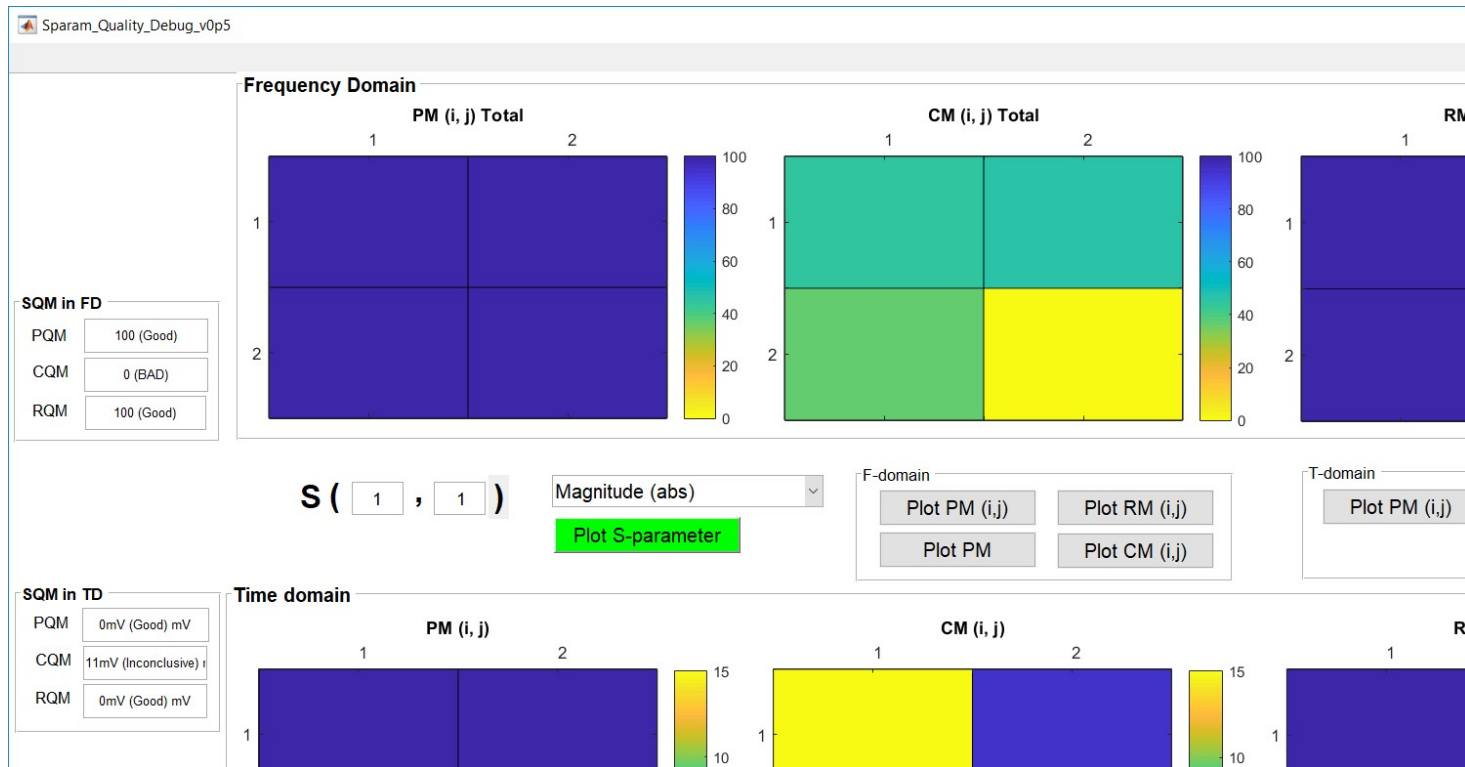
SQM in TD

Passivity Quality in TD



De-embedding Verification

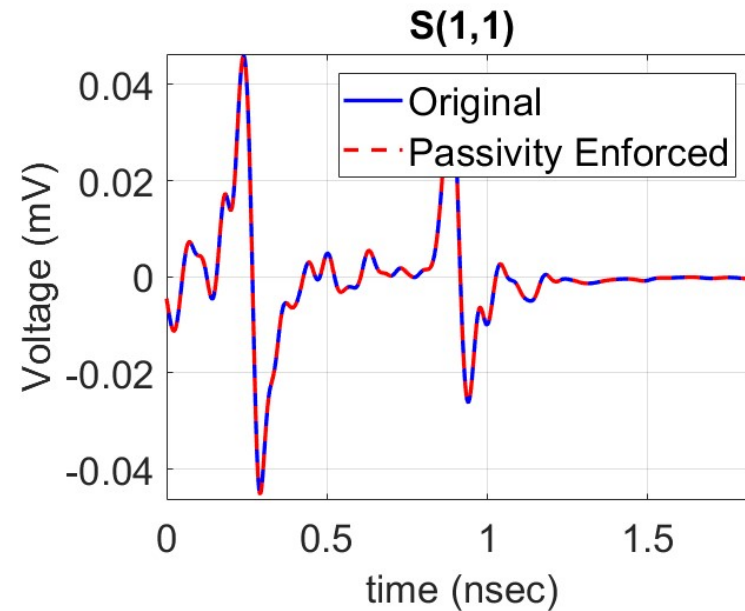
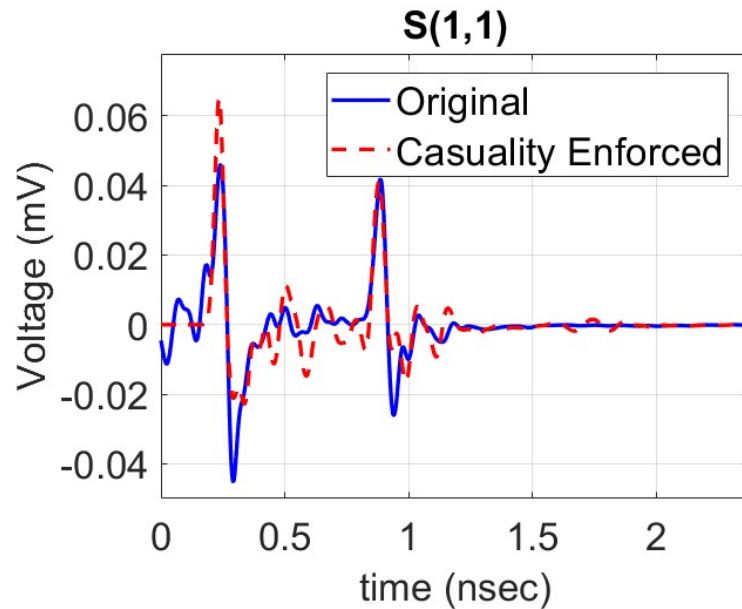
- Plug and Play Fixture example: 50 Ohm microstrip, 50 Ohm fixture, cont'd





De-embedding Verification

- Plug and Play Fixture example: 50 Ohm microstrip, 50 Ohm fixture, cont'd





De-embedding Verification

- Plug and Play Fixture example: 50 Ohm microstrip, 45 Ohm fixture, Z-corr.

IEEE_P370_Sparam_Quality_rev0p5

IEEE P370 S-param Quality rev0.5

D:\Users\jdiep\Documents\IEE_stuff\Tools\AtaiTec\data\Case1_DUT_Dmbd1_S2_M16.s2p
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Add
Delete

Time Domain Setting

Data Rate [Gbps]
 Rise Time [psec]
 Sample per UI

internal setting
 Pulse Shape
 (1:Gaussian, 2:Butterworth filter)

SQM in FD

Passivity Quality in FD
 Causality Quality in FD
 Reciprocity Quality in FD

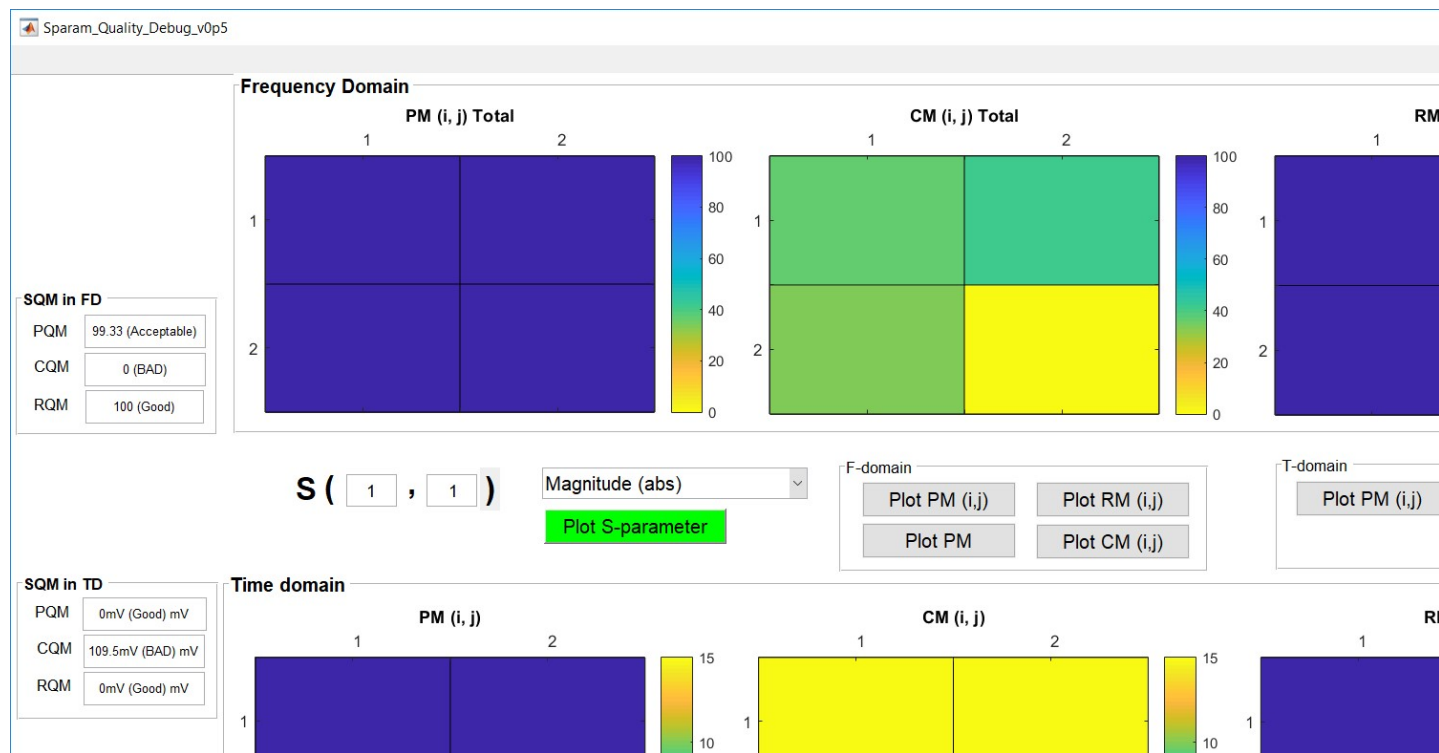
SQM in TD

Passivity Quality in TD



De-embedding Verification

- Plug and Play Fixture example: 50 Ohm microstrip, 45 Ohm fixture, uncorr.





De-embedding Verification

- Plug and Play Fixture example: 50 Ohm microstrip, 45 Ohm fixture, uncorr.

IEEE_P370_Sparam_Quality_rev0p5

IEEE P370 S-param Quality rev0.5

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Add
Delete

Time Domain Setting

Data Rate [Gbps]
 Rise Time [psec]
 Sample per UI

internal setting
 Pulse Shape
 (1:Gaussian, 2:Butterworth filter)

SQM in FD

Passivity Quality in FD
 Causality Quality in FD
 Reciprocity Quality in FD

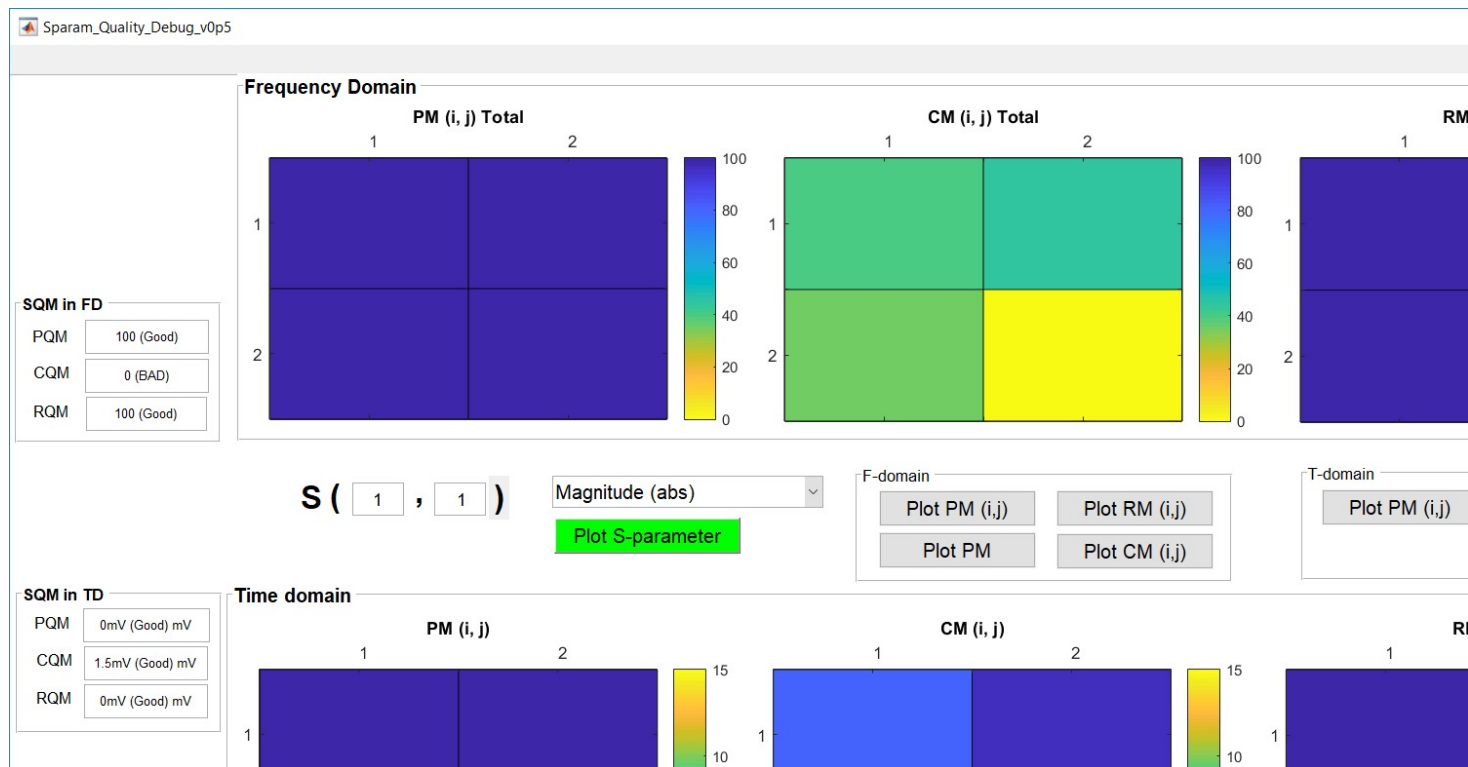
SQM in TD

Passivity Quality in TD



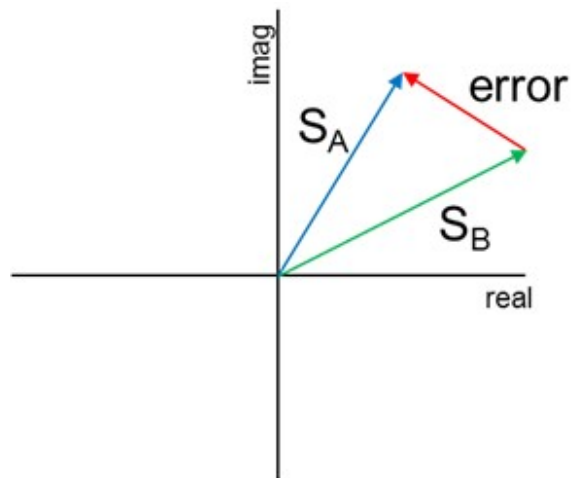
De-embedding Verification

- Plug and Play Fixture example: 50 Ohm microstrip, 45 Ohm fixture, uncorr.



Comparison of S-parameters

- Method needed for comparison besides “eyeball the plot”
 - Feature Selective Verification (FSV) – not recommended
 - Recommend Error Vector method



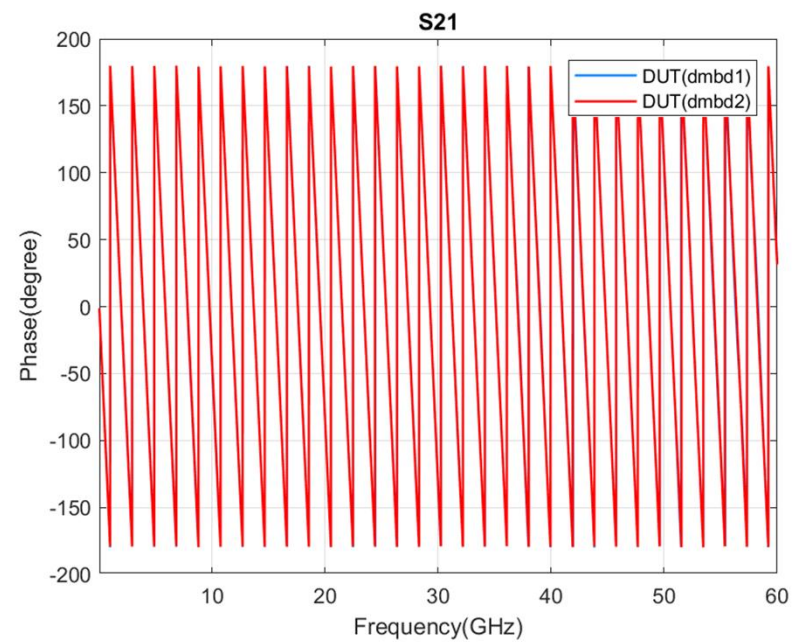
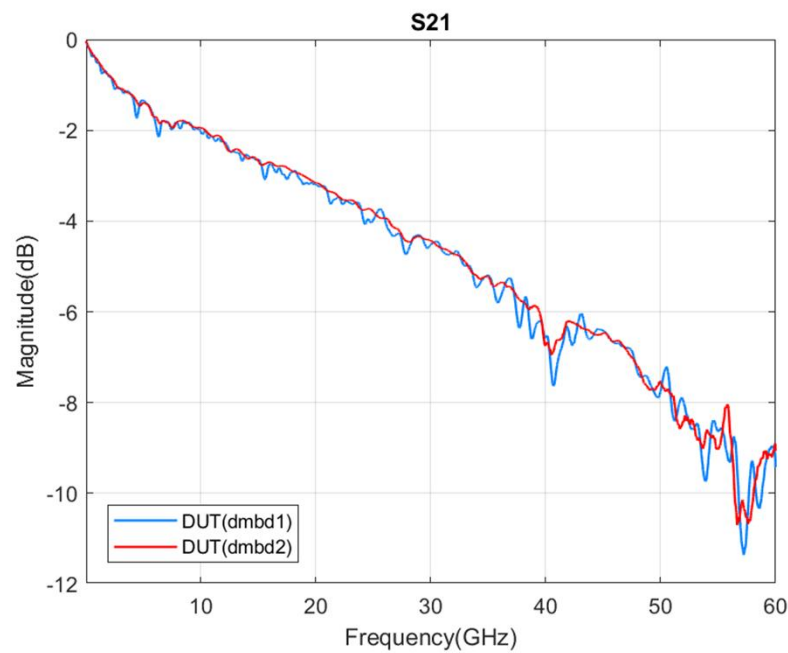
$$EF_{ij}(f) = \text{mag}[S_{ij}^A(f) - S_{ij}^B(f)]$$

$$rEF_{ij} = \frac{\text{mag}[EF_{ij}(f)]}{0.5 \times \text{mag}[S_{ij}^A(f) + S_{ij}^B(f)]}$$



S-parameter Comparison

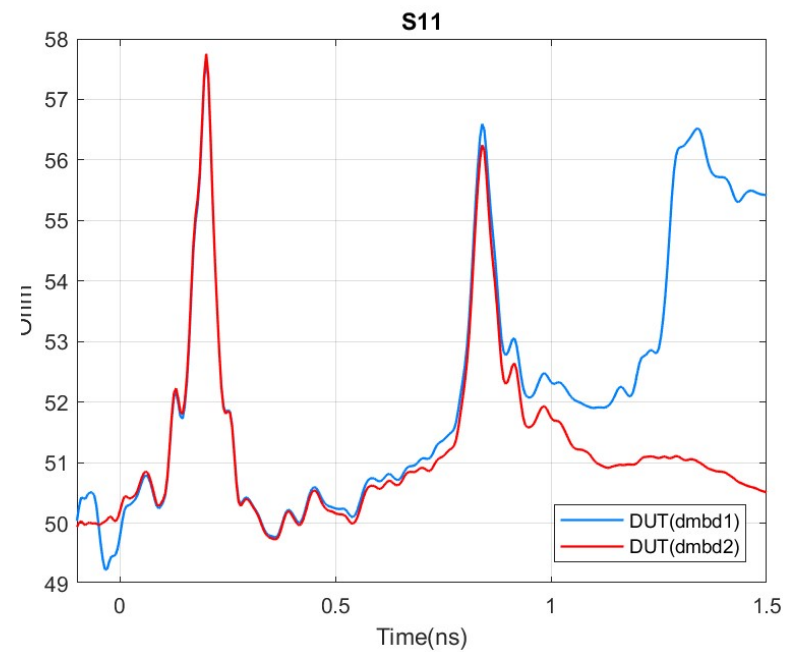
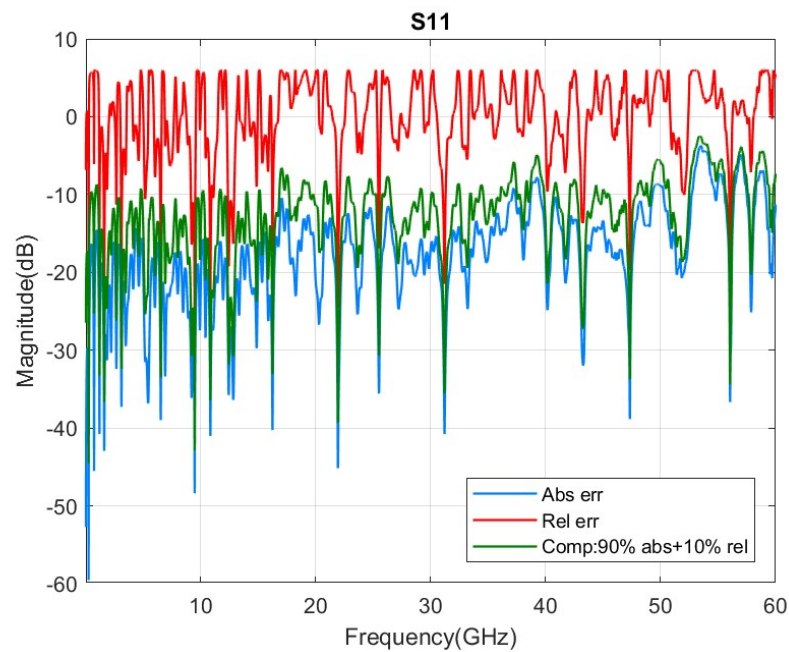
- Plug and Play Fixture example: 50 Ohm microstrip, 50/45 Ohm fixture, Z corr.





S-parameter Comparison

- Plug and Play Fixture example: 50 Ohm microstrip, 50/45 Ohm fixture, Z corr.





More Information

See <https://standards.ieee.org/develop/project/370.html>

Acknowledgements

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References

1. Barnes, H., Bogatin, E., Moreira, J., Ellison, J., Nadolny, J., Huang, C.-C., Tsiklauri, M., Moon, S.-J., and Herrmann, V.: "A NIST Traceable PCB KIT for Evaluating the Accuracy of De-Embedding Algorithms and Corresponding Metrics", DesignCon 2018.
2. Y. Shlepnev, Quality Metrics for S-parameter Models, presentation at DesignCon 2010 IBIS Summit, Santa Clara, February 4, 2010.