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IEEE P370: A fixture design and data quality metric standard for interconnects up to 50 GHz

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Outline

- Background
- Conventions
- Test Fixture Design Criteria
- Verification Structures
- De-embedding methods and Verificatoin
- S-parameter Integrity and Validation
- Comparison of S-parameters
- Tutorials
- Best Practices
- Acknowledgements
- 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)

Test connector guidance

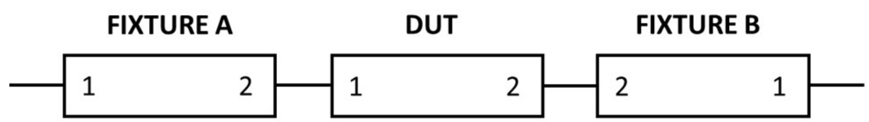
- Good quality connectors and PCB launches needed for devices characterized to 50 GHz

Connector inside diam., mm	7	3.5	2.92	2.4	1.85
Rated max. frequency, GHz	18	33	40	50	65
TE11 onset limit freq., GHz	19.4	38.8	46.5	56.5	73.3

Conventions

- DUT port labeling

- Component/port labeling

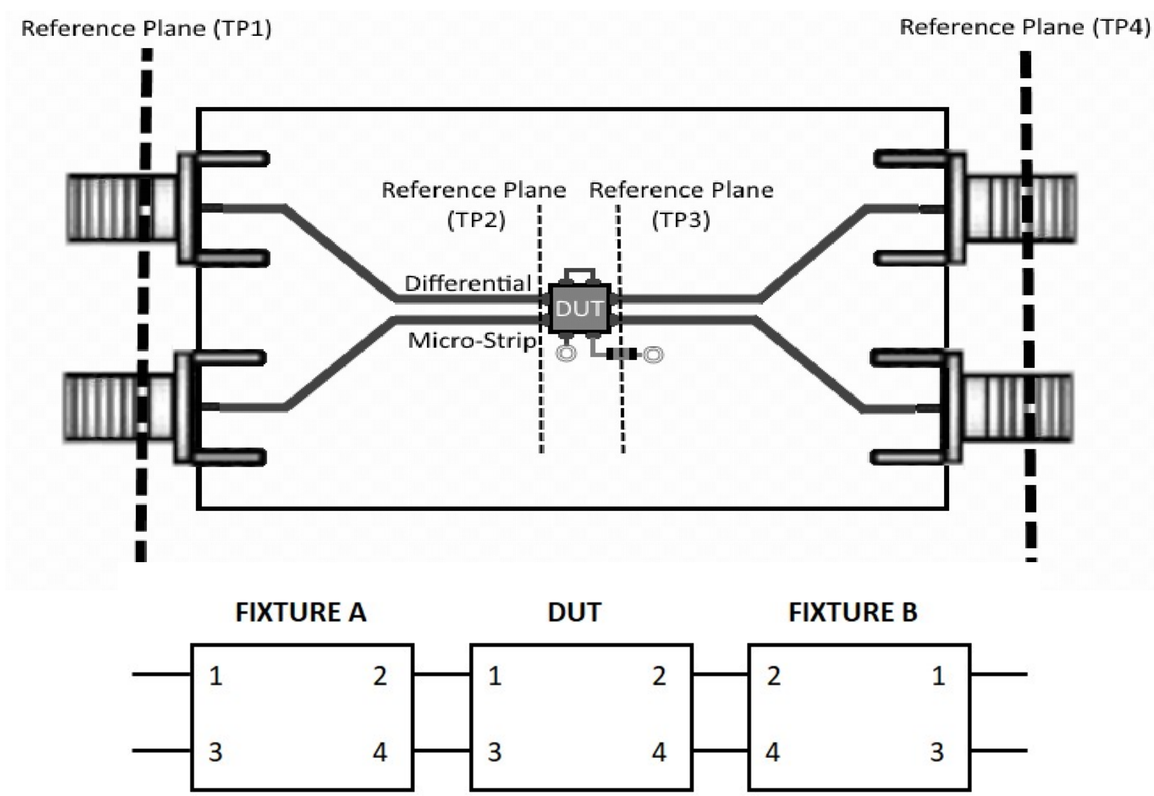


"FIX-DUT-FIX"

Conventions

- Touchstone File Header info proposed by IEEE P370
  - Data source – measured, calculated, simulated
  - Component type
    - De-embed structure – 1X reflect Short, 1X reflect Open, 2X thru
    - Calibration structure – Short, Open, Load, TRL Line 1, etc.
    - DUT
    - Composite – FIX-FIX (2x thru), FIX-DUT-FIX, etc.
    - Fixture
  - Calibration Method – SOLT, TRL
  - De-embedding Method – 1x Reflect, 2x Thru, Z-corrected 2x thru

De-embedding objective: Separate the DUT from the fixture



Test Fixture Design Criteria

- Test connector guidance
- Topology and electrical parameter limits for de-embedding structures
  - 1x Reflect
  - 2x thru
  - Single-ended fixture crosstalk
  - Mixed mode fixture crosstalk
- Fixture Electrical Requirements – limits on
  - Insertion Loss
  - Return Loss
  - Insertion/return loss separation
  - Intra fixture crosstalk
  - Impedance variation - difference between fixture in 2x thru and FIX-DUT-FIX
  - (Differential fixtures) Differential to Common Mode Conversion
  - Line to line or Pair to pair skew

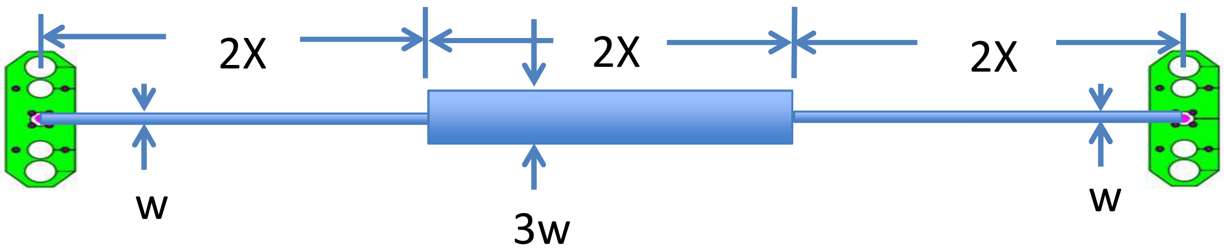
Test Fixture Design Criteria

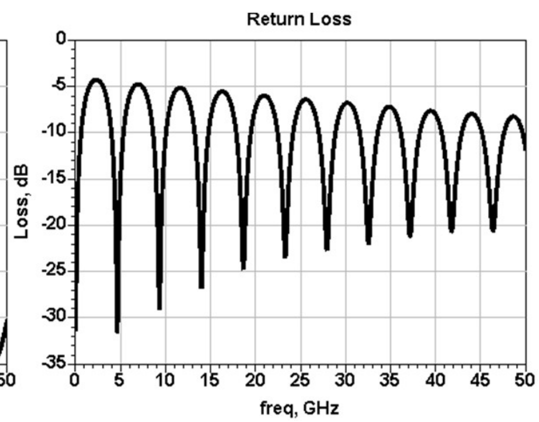
- Introduce concept of Compliance "Classes" to Electrical Criteria
  - FER 1, Insertion loss
    - Class A = min. -10 dB at all frequencies
    - Class B = min. -15 dB at all frequencies
    - Class C = min. -15 dB at all frequencies
  - FER 2, Return loss
    - Class A = max. -20 dB at all frequencies
    - Class B = max. -10 dB at all frequencies
    - Class C = max. -6 dB at all frequencies
  - FER 3, Insertion/Return loss separation
    - Class A = max. 5 dB at all frequencies
    - Class B = max. 0 dB at all frequencies
    - Class C = max. 0 dB at all frequencies

- Compliance “Classes,” cont’d
  - FER 4, Intra fixture crosstalk – less than DUT
  - FER 5, Impedance Variation - difference between FIX in 2x thru and FIX-DUT-FIX
    - -> Is the 2x thru really representative of all DUT paths?
    - Class A = max. ±2.5 dB at all frequencies
    - Class B = max. ± 5 dB at all frequencies
    - Class C = max. ± 10 dB at all frequencies
  - FER 6, Differential to Common Mode Conversion – max. -15 dB at all freqs.
  - FER 7, Line to line or pair to pair skew – max.

Verification Structures

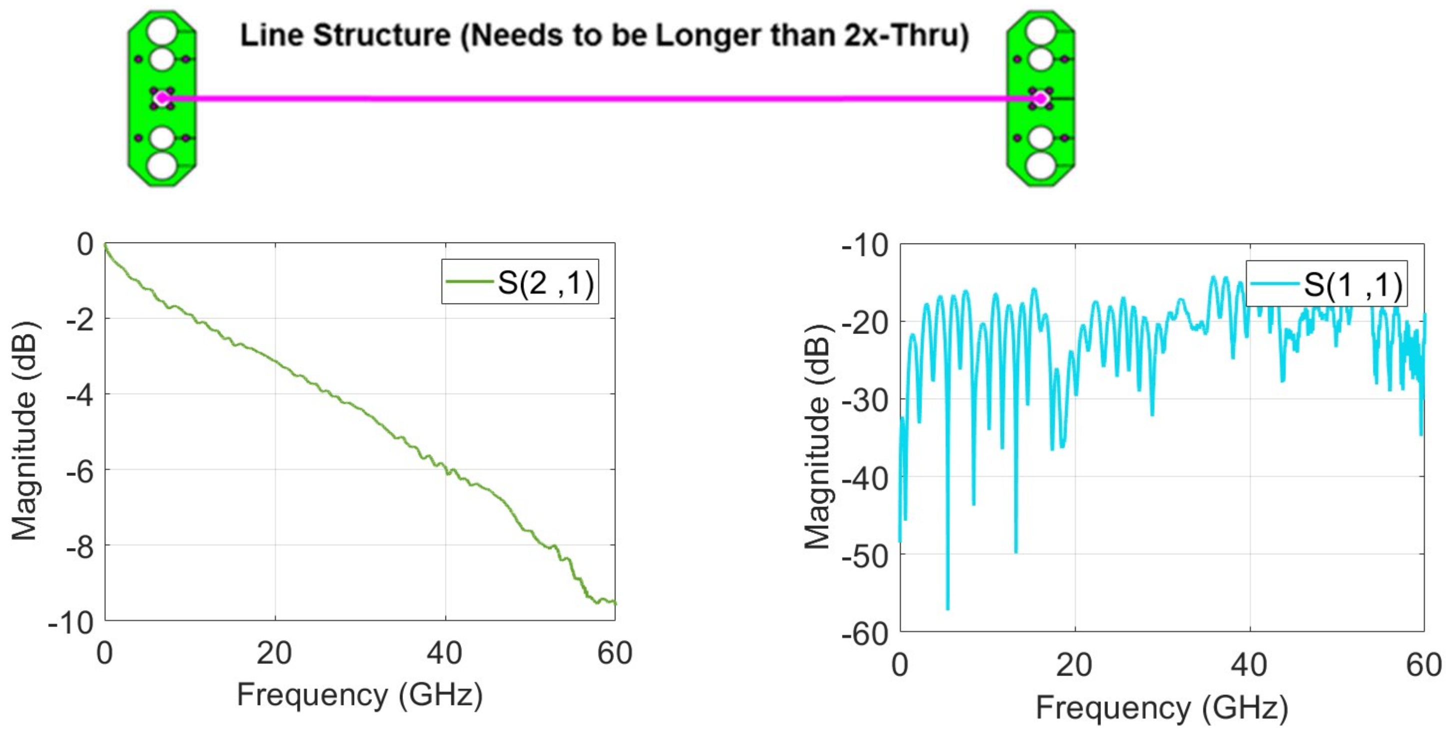
- Beatty





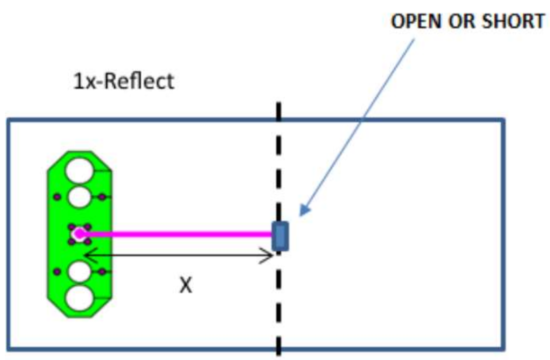
Verification Structures, cont'd

- Line structure



De-embedding methods

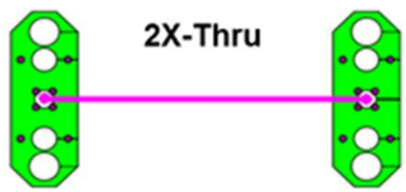
- 1x Reflect – uses single Open or Short standard



- Measured s11 data converted to time domain
- Fixture s11 calculated from converted, measured s11 data
- 2x thru calculated from either time domain converted s11 and measured s11 (Keysight patent) or additional measured standard 1x data

De-embedding methods, cont'd

- 2x thru – uses measured 2x thru



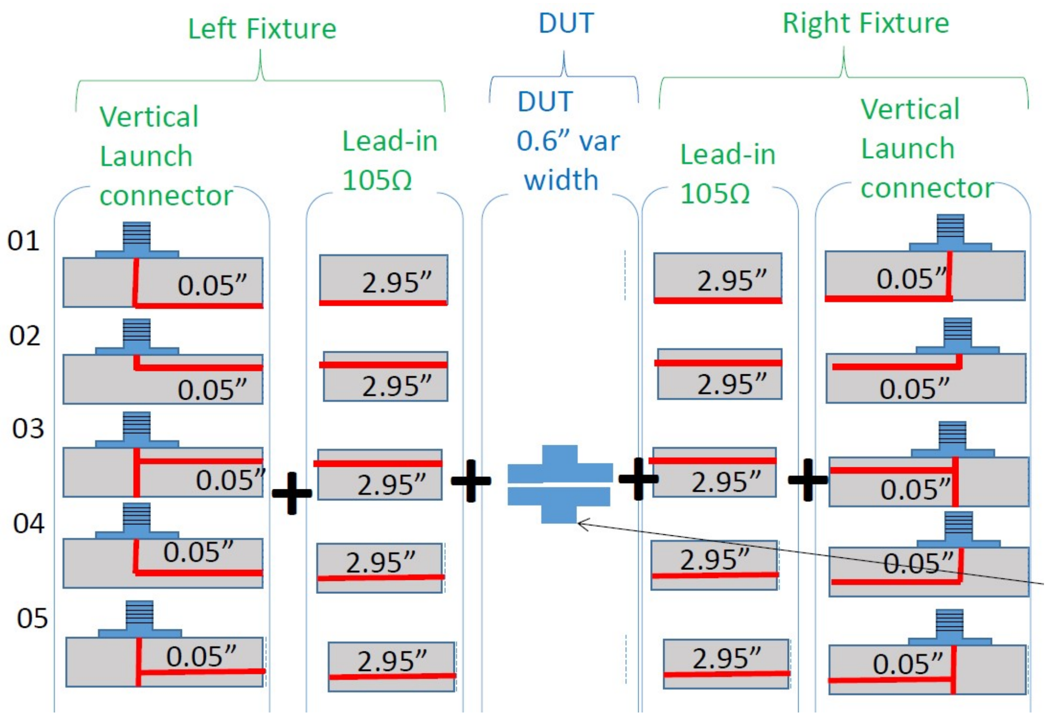
  - Measured s11 data converted to time domain, reflect data used to calculate fixture s11
  - Results dependent on Z match between 2x-thru and FIX-DUT-FIX, can cause causality errors

De-embedding methods, cont'd

- 2x Impedance-corrected thru – uses 2x thru
  - Compensates for Z mismatch between 2x-thru and FIX-DUT-FIX, reduces causality errors
- De-embedding algorithm acceptance criteria – compare extracted data to known-good
  - Time domain
  - Frequency domain
    - Error vector magnitudes
    - Three quality classes

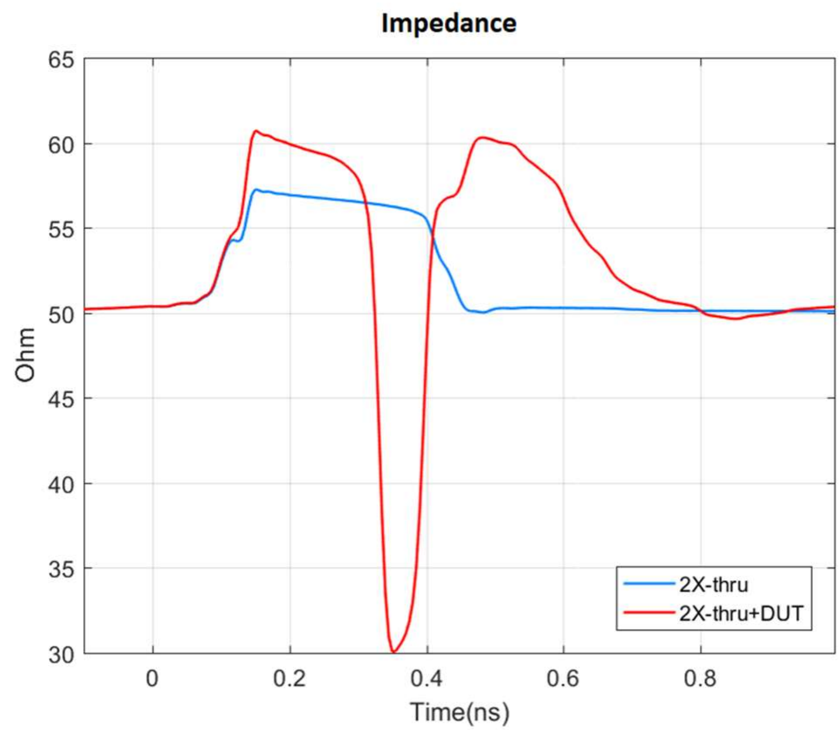
De-embedding Verification, cont'd

- Synthesized Library

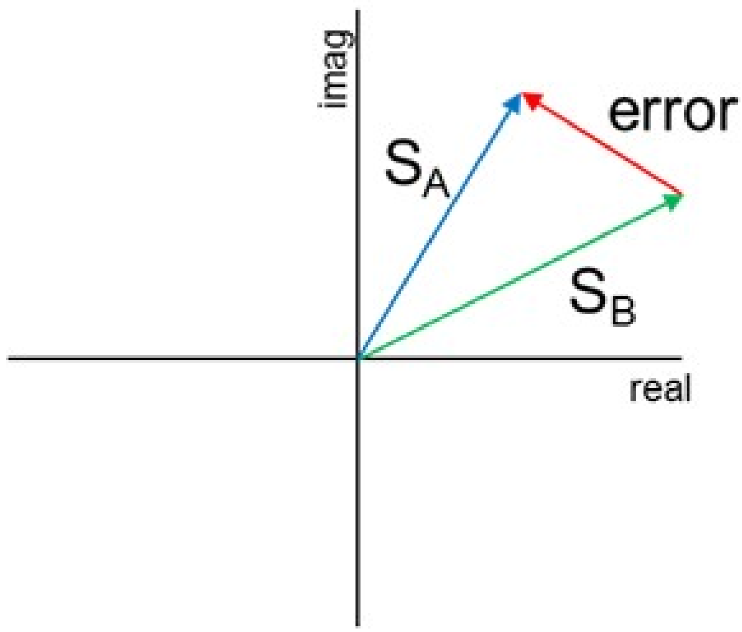


De-embedding Verification, cont'd

- Synthesized Library - sample



Comparison of S-parameters – Error vector

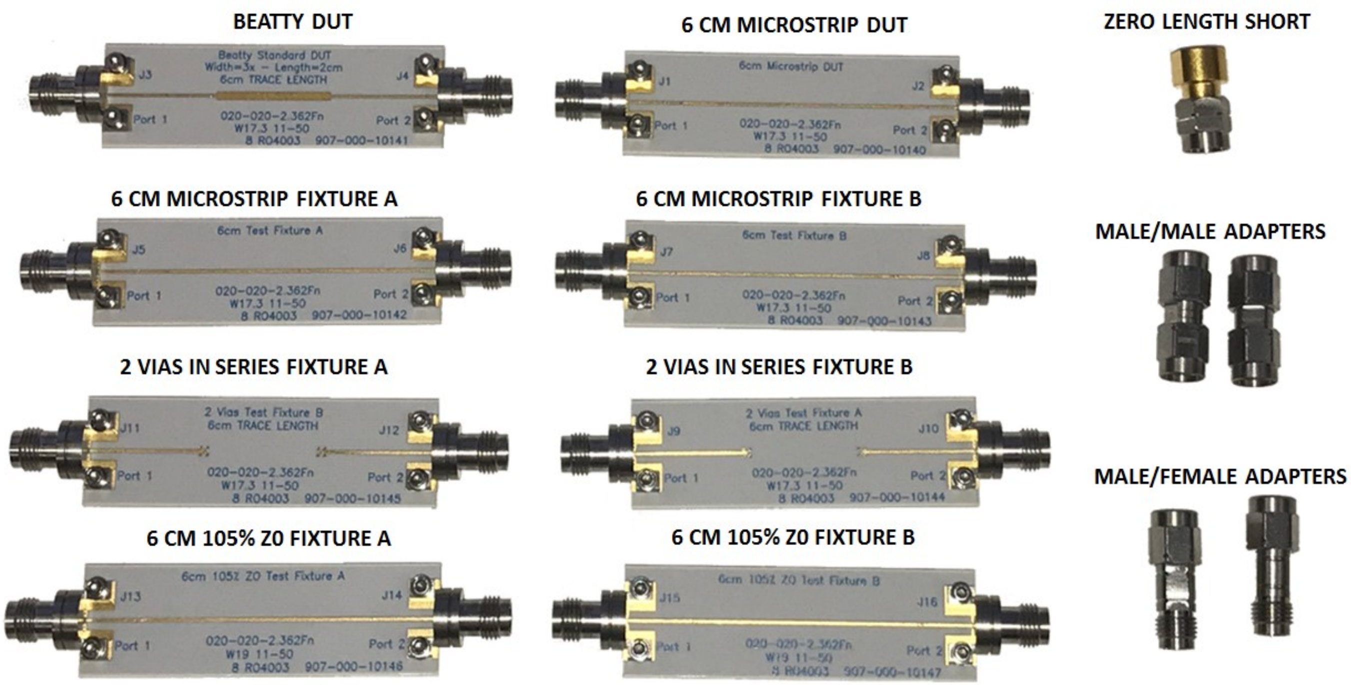


$$EF_{ij}(f) = \mathrm{mag}\left[S_{ij}^{A}(f) - S_{ij}^{B}(f)\right]$$

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

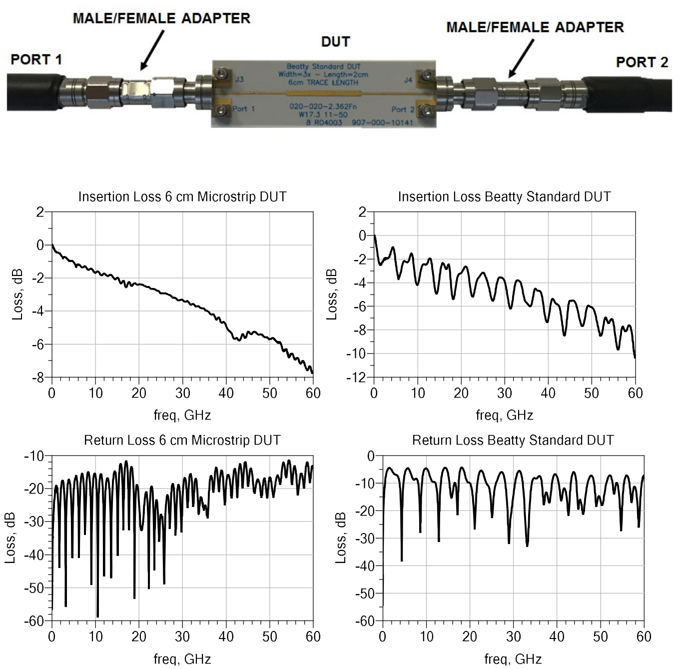
De-embedding Verification, cont'd

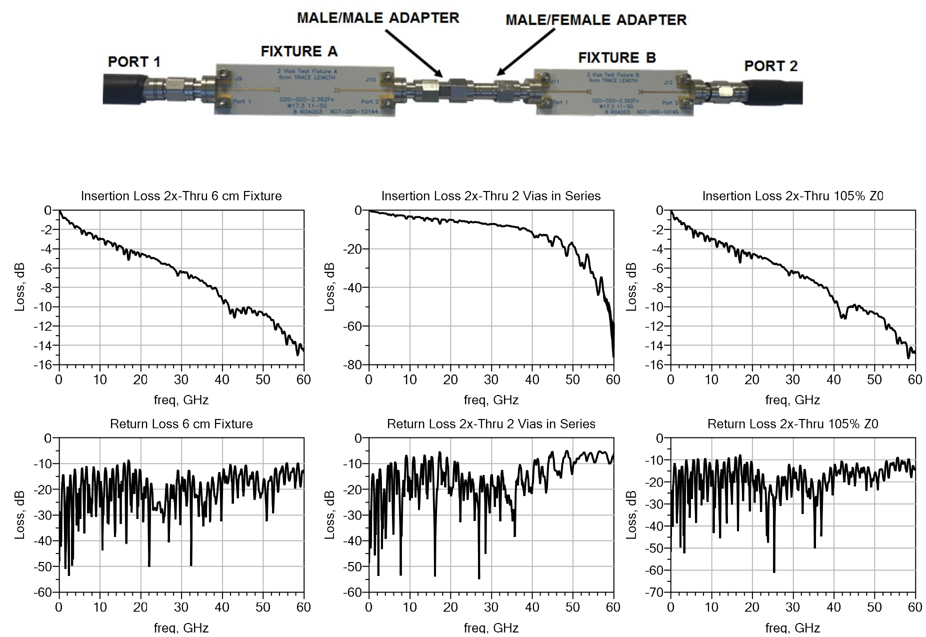
- Plug and Play Boards



De-embedding Verification, cont'd

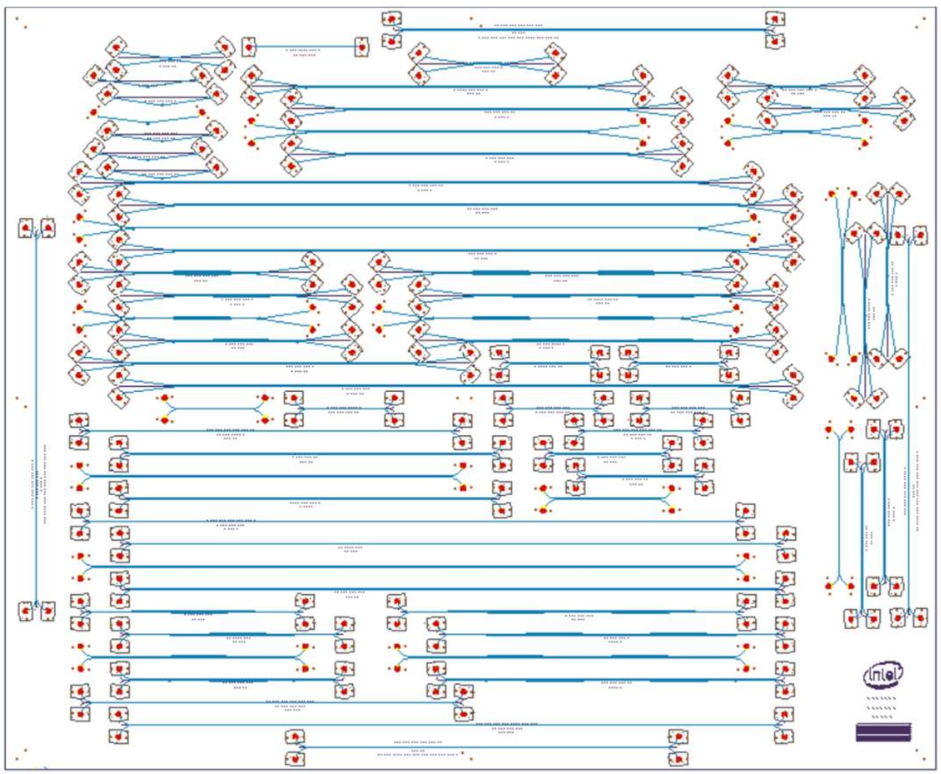
- Plug and Play Board example





De-embedding Verification, cont'd

- Demonstration Boards



Annexes in the P370 Draft

- Network parameters, incl. multiports
- Calibration and de-embedding
- Sensitivity analysis with synthesized library elements

Annexes: Best Practices

- Design & manufacturing considerations
  - Trace geometry, coupling, routing
  - Conductor plating
  - Dielectric material
  - Surface roughness
- Fixture Design
  - Via design
  - Test connector launches – coaxial via structures
  - Stitching vias
  - Ground plane cutouts

Best Practices, cont'd

- Test equipment, cables
- Max. frequency extrapolation
- Analytical input pulse creation
- DC extrapolation
- Interpolation

More Information

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

Acknowledgements

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References

1. Frei, J., Cai, X.-D., and Muller, S.: "Multiport S-Parameter and T-Parameter Conversion with Symmetry Extension," IEEE Trans. Microwave Theory and Techniques, vol. 56 no. 11, November, 2008, pp. 2493-2504.
2. 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.
3. Y. Shlepnev, Quality Metrics for S-parameter Models, presentation at DesignCon 2010 IBIS Summit, Santa Clara, February 4, 2010.