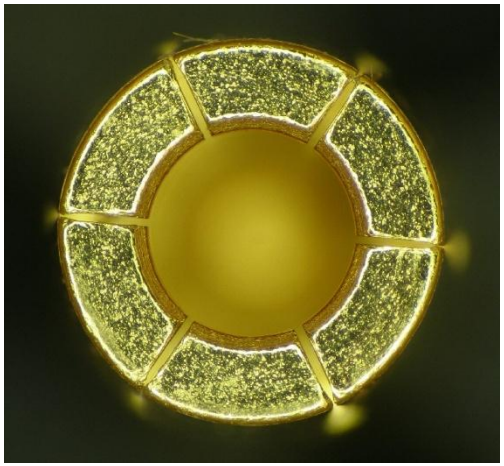
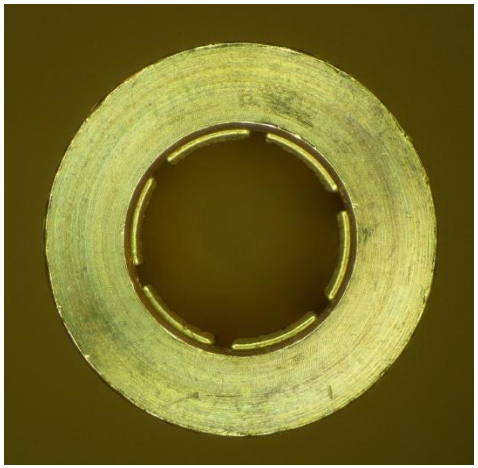
S-parameters of slotted and slotless connectors





Johannes Paul Hoffmann
Pascal Leuchtmann
Juerg Ruefenacht
Ken Wong

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

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Outline

- Motivation
- Connector Geometry
- Numerical Methods
- Measurements
- Conclusion

Motivation

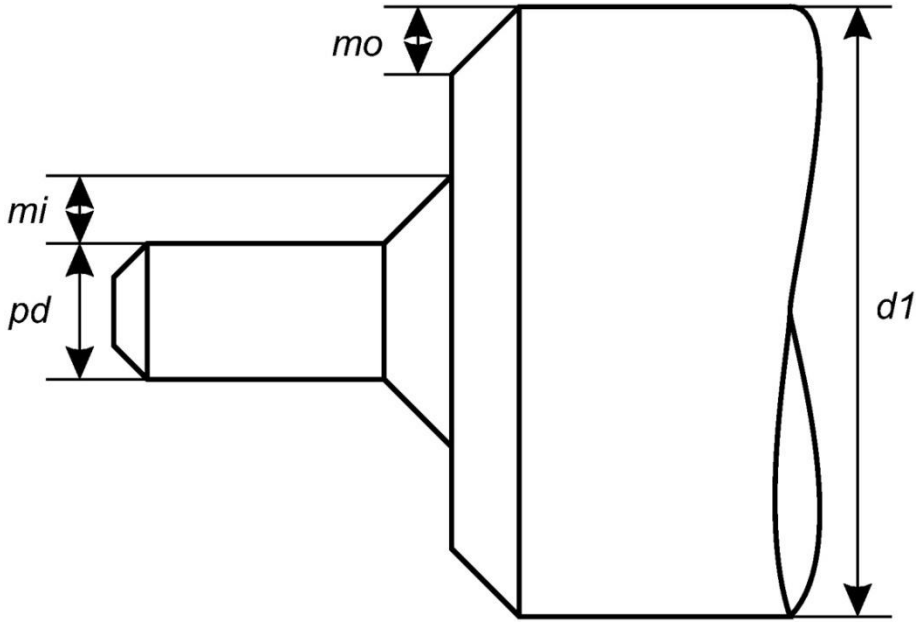
- Inconsistencies between established calibration methods
- Inconsistencies in established calibration methods
- Inconsistencies in standard definitions

Inconsistencies Observed

- Measurement results of the same device are inconsistent between calibration methods employed (LRL and OSLT)
- S11 and S22 measurements of low loss airlines are inconsistent in OSLT
- OSLT calibration standard definitions for male and female devices are the same

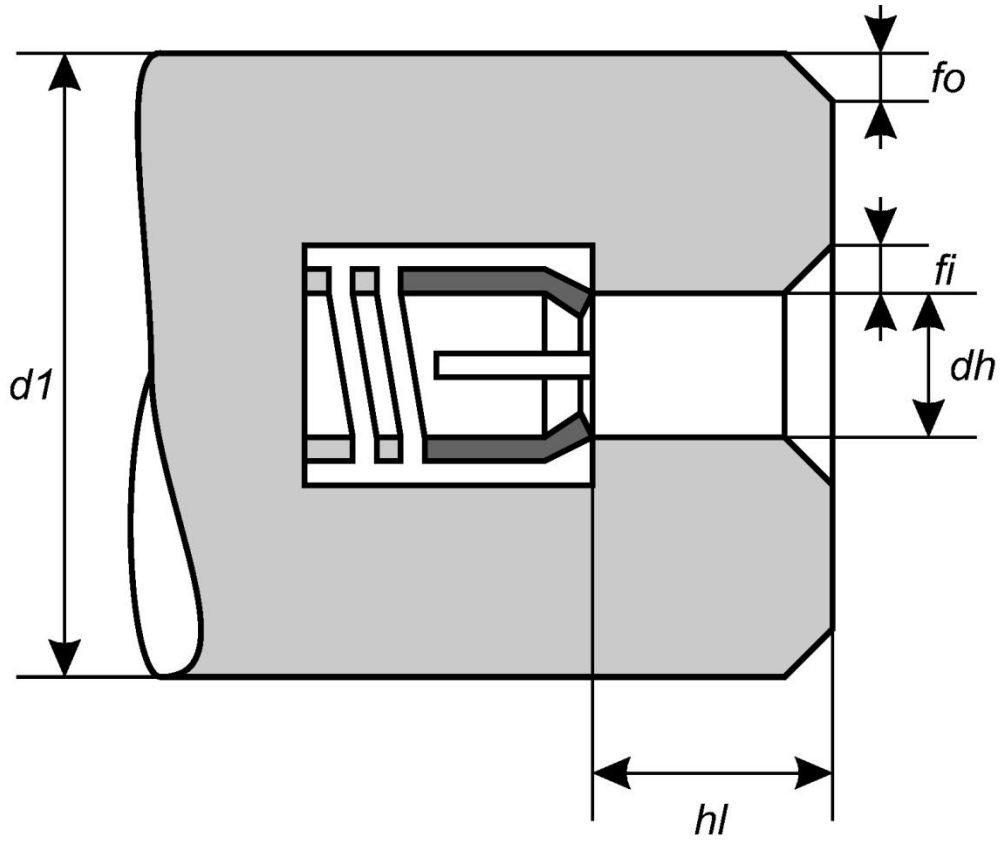
A More Accurate Connector Model?

Real Slotless and Slotted Connectors (male part)



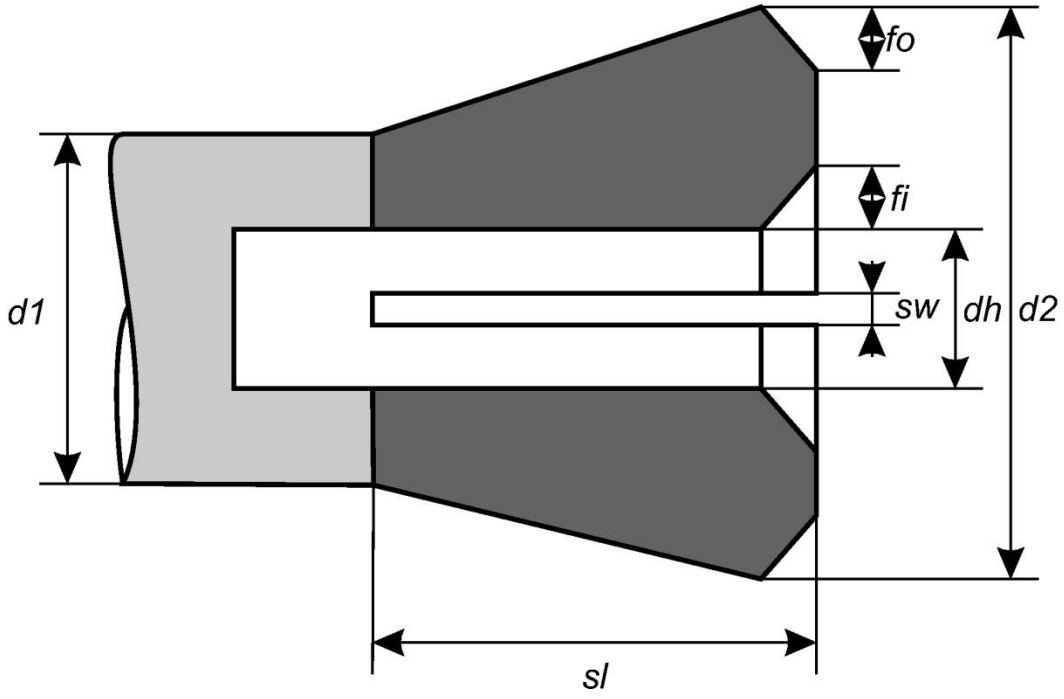
- Lathing
- Chamfers not avoidable

Real Slotless Connector (female part)



- Simplified geometry
- Complicated manufacturing
- *hl* and *dh* critical for performance

Real Compensated Slotted Connector (female part)



- Simplified geometry
- Complicated manufacturing
- *d2* critical for performance

Numerical methods

Preliminary model of connector consists of perfect conductors and dielectric

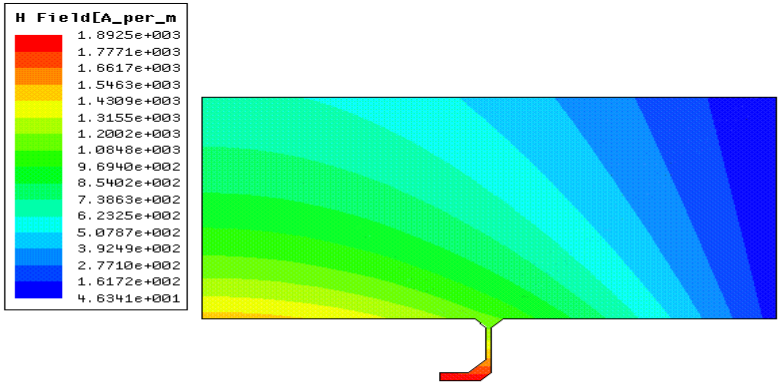
→ Allows to apply HFSS and CST Microwave Studio with small expected errors

- **HFSS (FEM)**
- **Frequency domain**
- **Tetrahedral mesh**

- **CST Microwave Studio (FDTD)**
- **Time domain**
- **Hexahedral mesh**

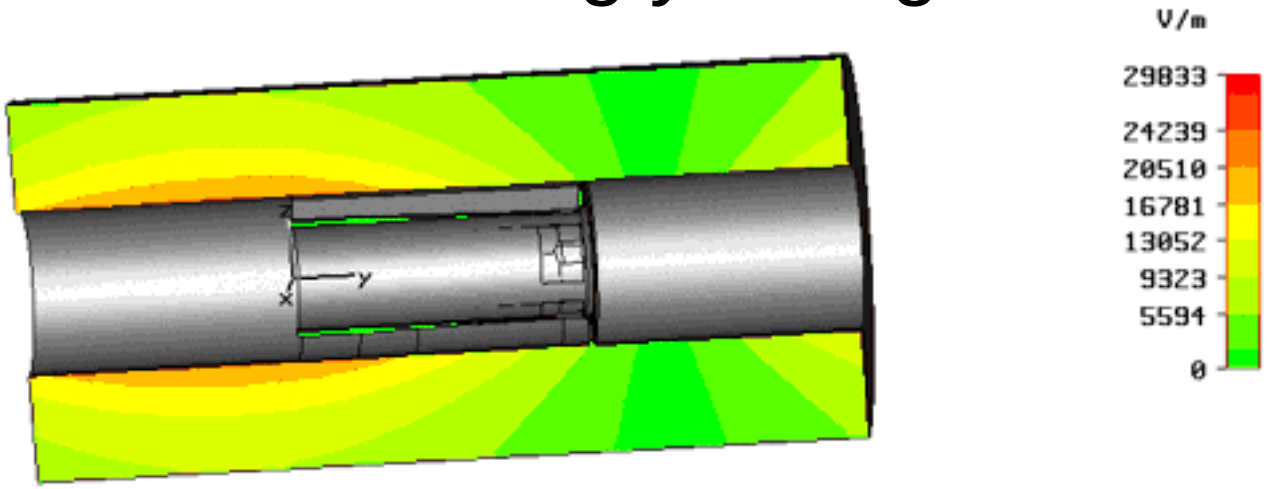
Finite Element Method (HFSS)

- Allows to exploit axial symmetry
- Well suited for slotless connectors
- Automatic meshing yields erroneous results
- Mesh must have at least 90 nodes on circumference



Finite Difference Time Domain (CST Microwave Studio)

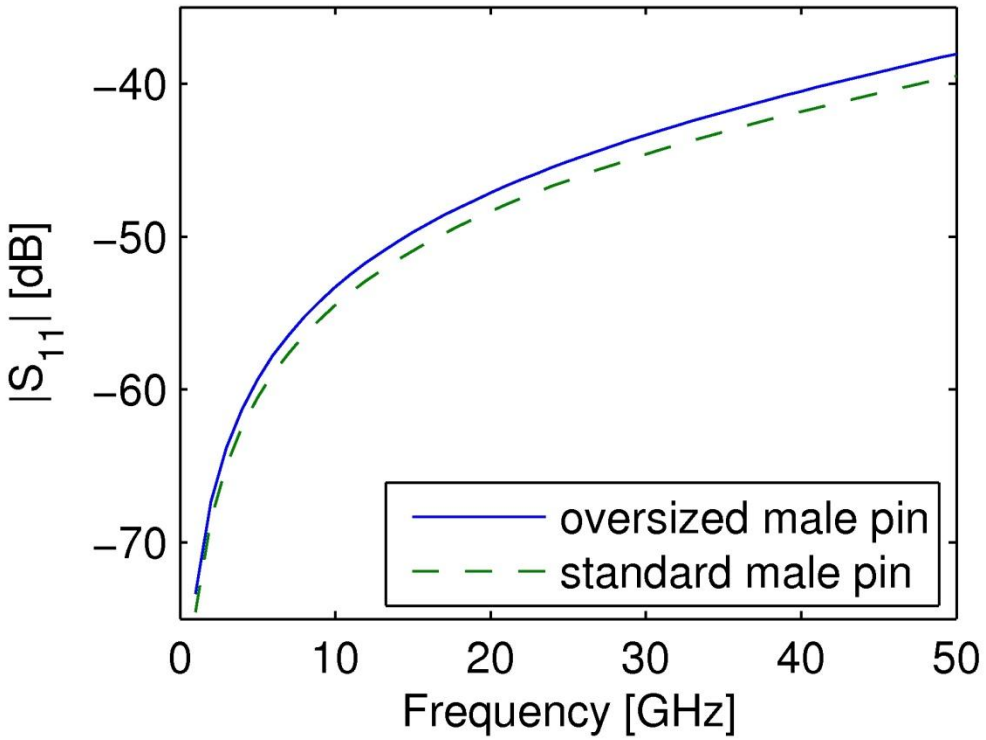
- Allows to exploit simple symmetries
- Well suited for slotted connector
- Automatic meshing yields good results



Validation

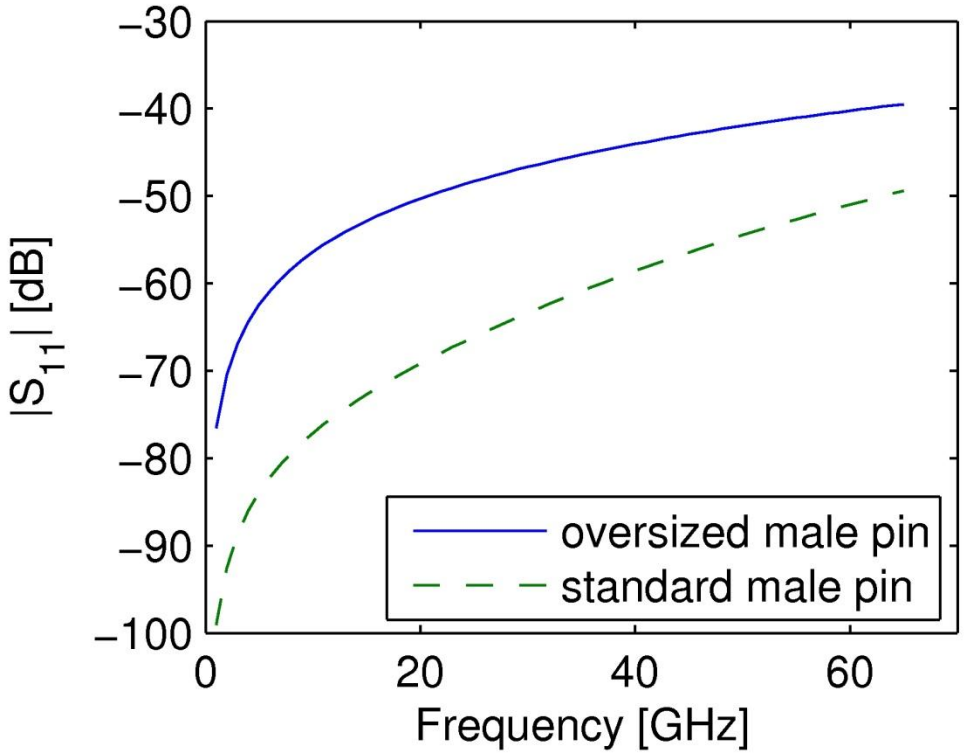
- Convergence with finer mesh for each method
- Plausible S-parameters: e.g. larger chamfers have similar effect as larger pin gap
- FDTD and FEM discrepancy is
  $|S_{11FEM} - S_{11FDTD}| < 0.001$

2.4 mm slotless connector male pin variations



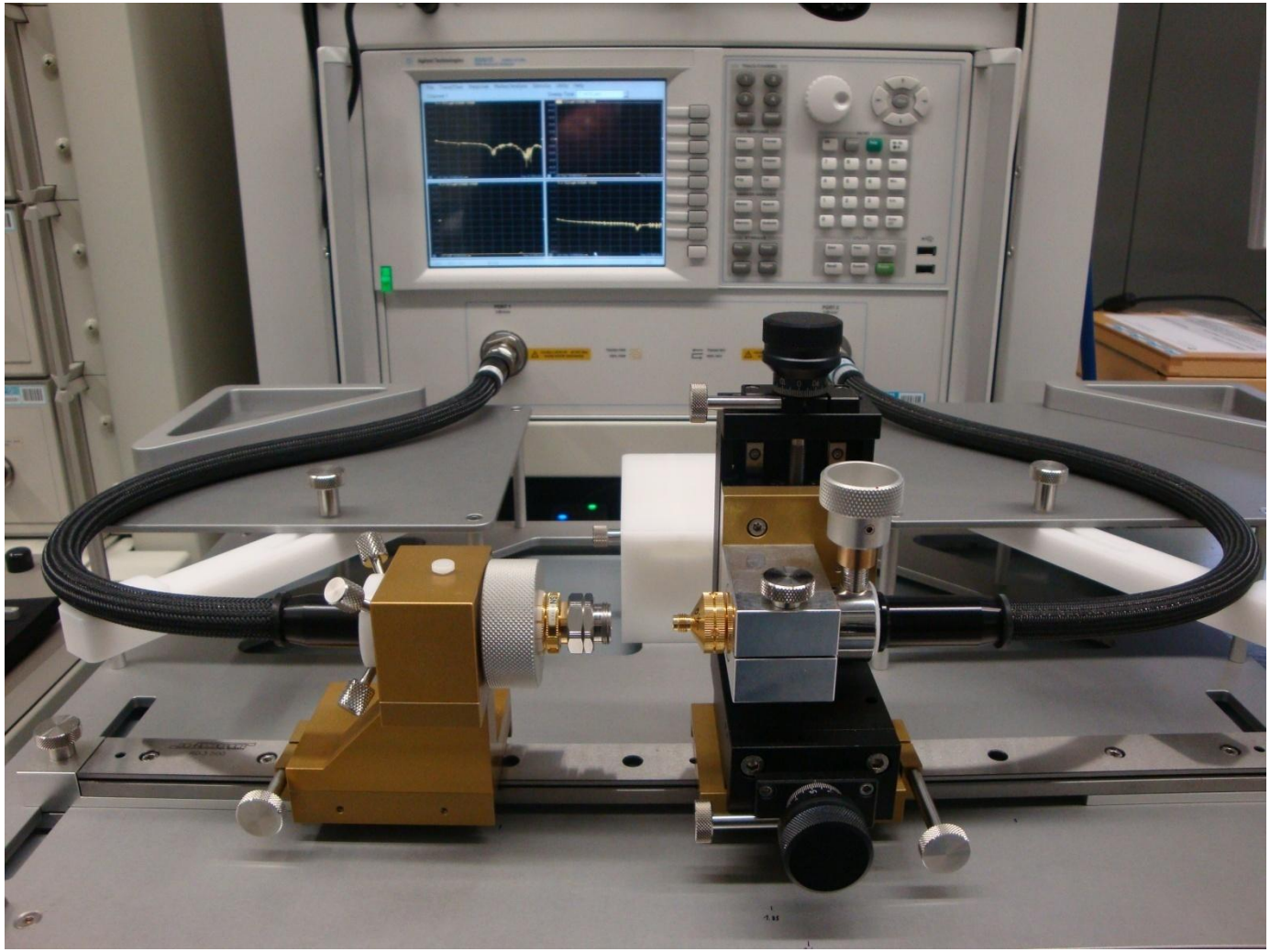
- Reflection of “standard” 2.4 mm connector
- Reflection of “standard” 2.4 mm connector with 10 µm oversized male pin

1.85 mm compensated slotted connector male pin variations

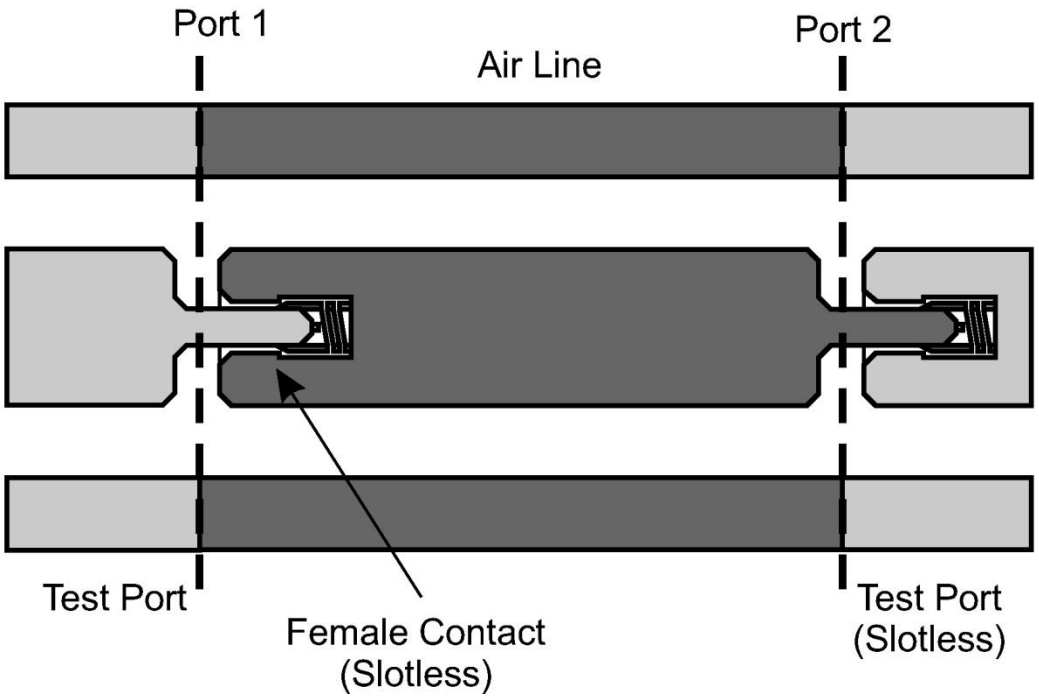


- Reflection of “standard” 1.85 mm connector
- Reflection of “standard” 1.85 mm connector with 10 µm oversized male pin

Measurement setup (hydraulic chuck)

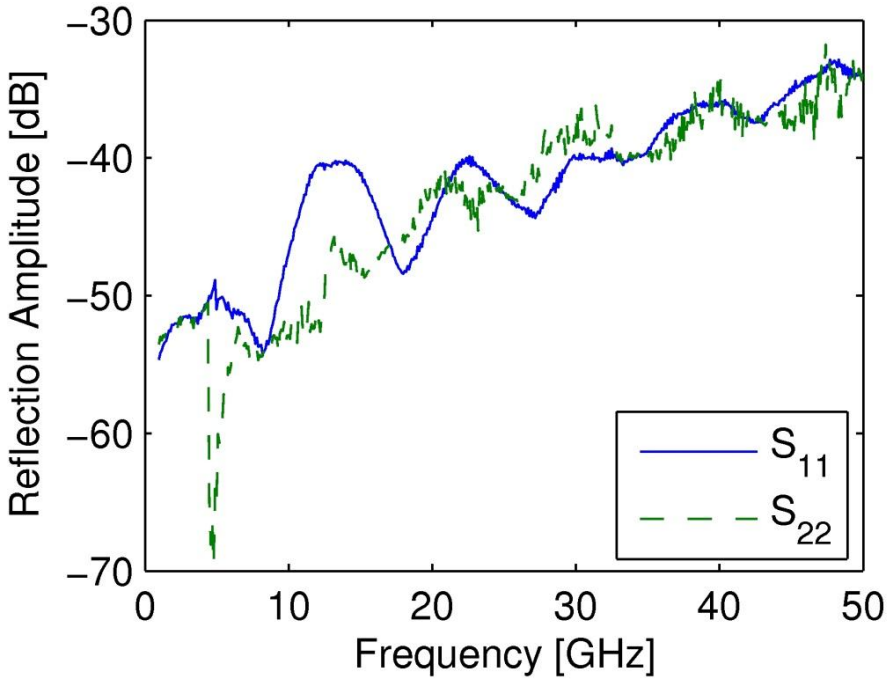


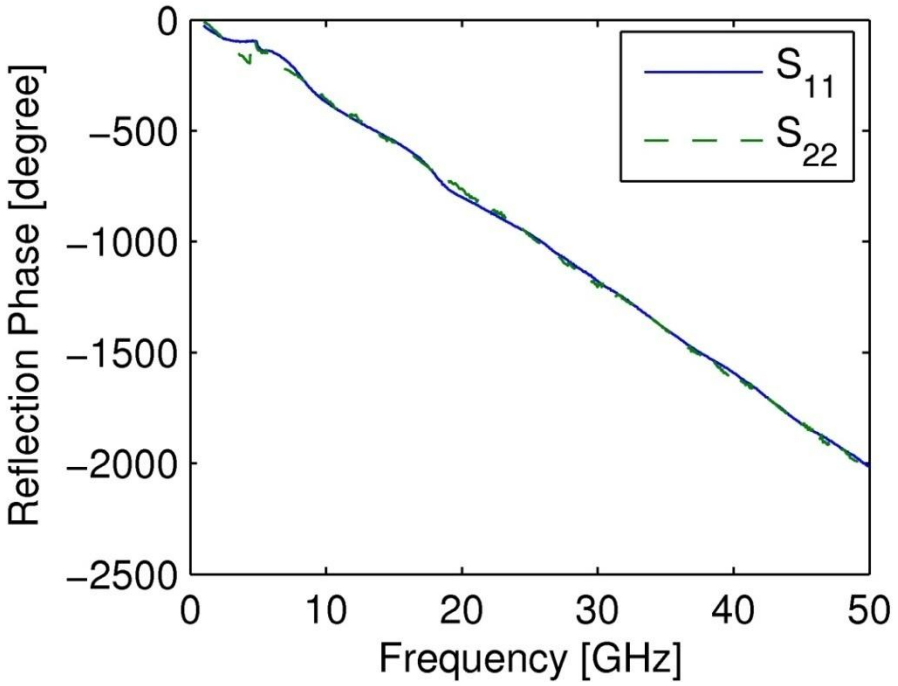
Measurement of 2.4 mm Air Line



- **Air Line:** length = 17 mm, beadless, slotless
- **Test Port 2:** slotless

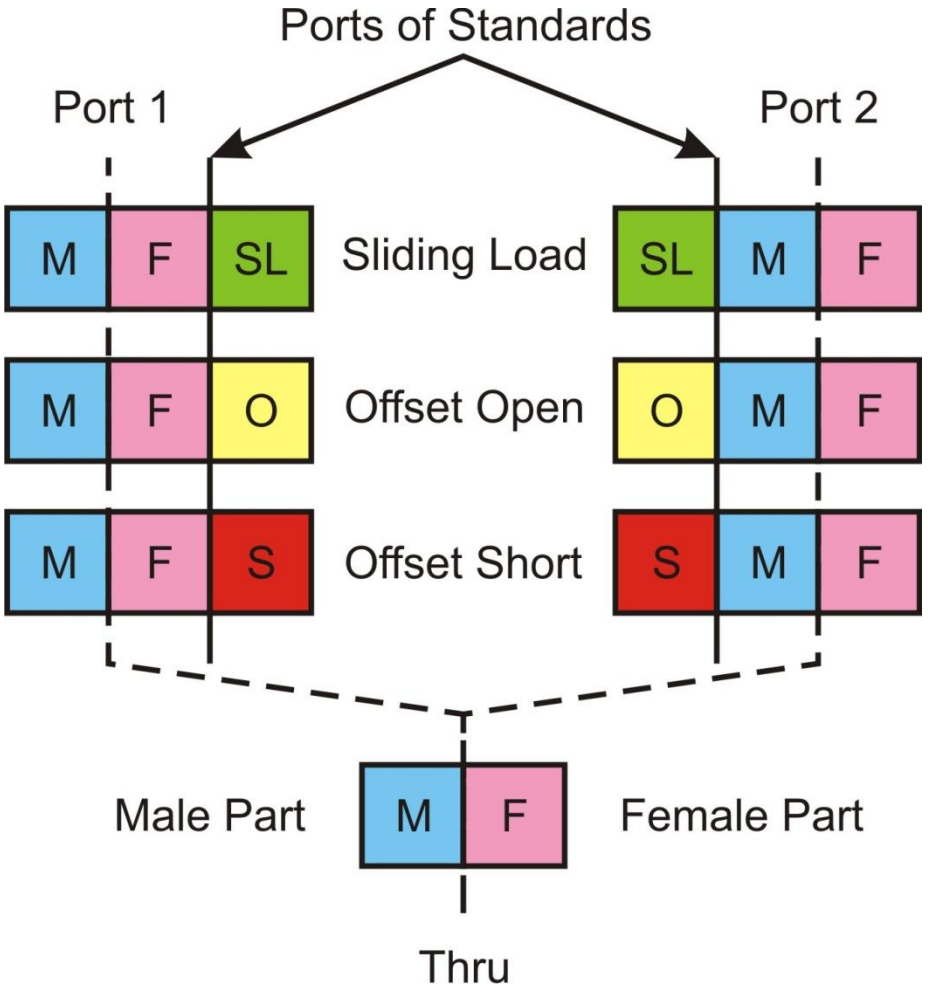
Reflections of the 17 mm air line
(Sliding load calibration)





- **S11 → dominant reflection at Port 2 !**
- **S22 → dominant reflection at Port 1 !**

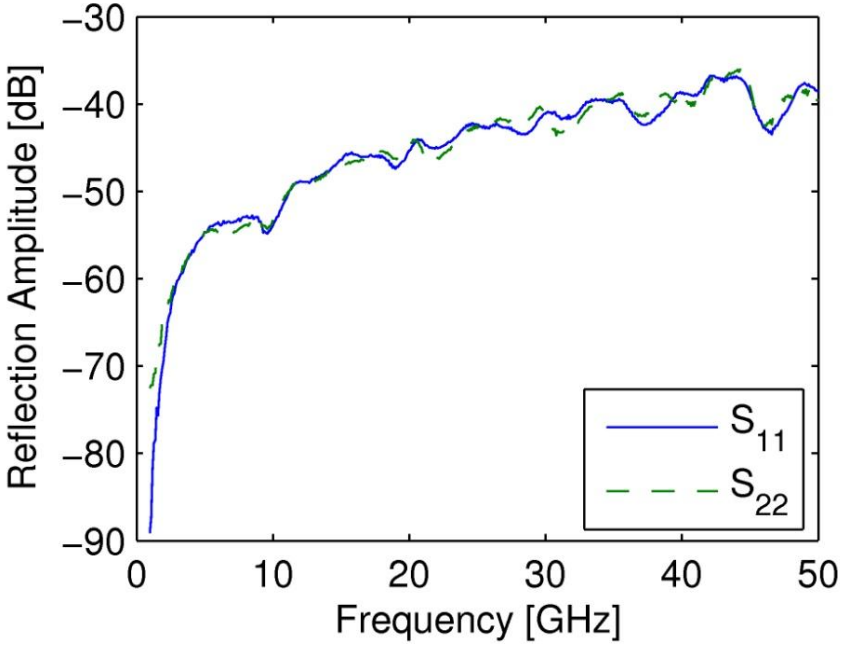
Sliding load calibration

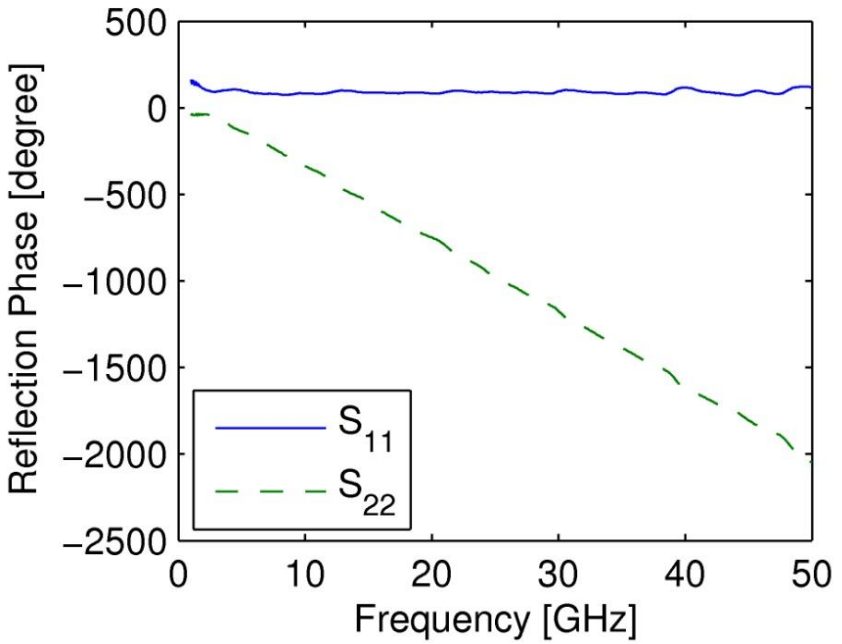


- Reflection standard definitions ignore connector
- Thru accounts for connector

→ **Inconsistent S-parameters**

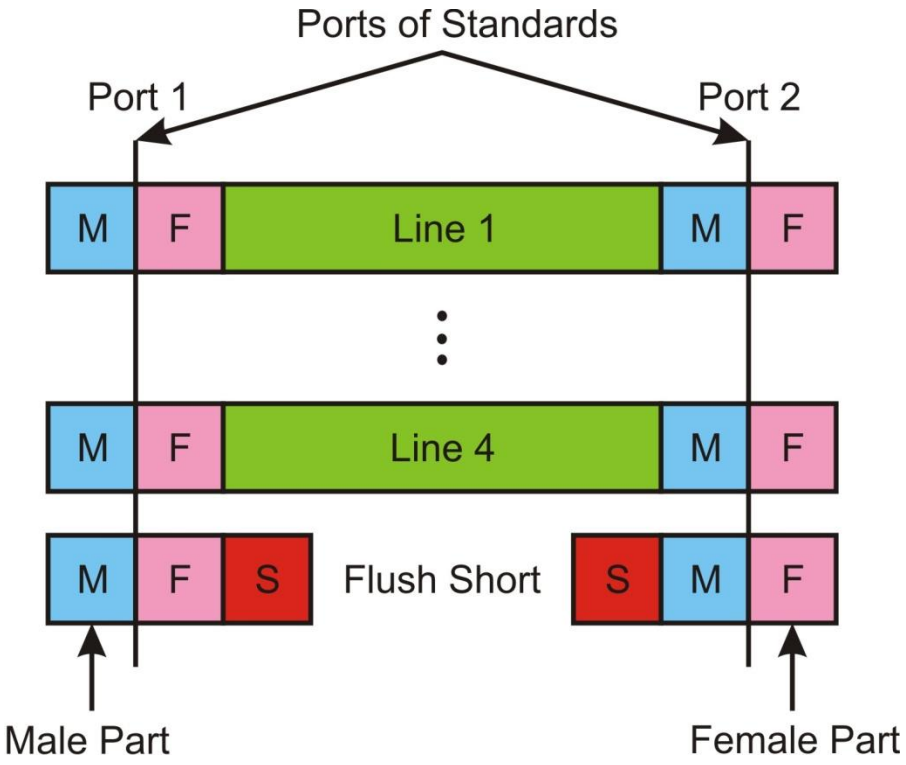
Reflections of the 17 mm air line (LRL calibration)





- **S11 → dominant reflection at Port 1**
- **S22 → dominant reflection at Port 1**

LRL Calibration



- Used LRL algorithm accounts for connectors of Lines and Shorts
- 4 Lines used

→ **Consistent S-parameters**

Conclusion

- 2.4 mm female DUTs change by $\Delta S11 \approx 0.02$
- Connectors have to be included in standard definitions.
- Ignoring connector effects results in degraded accuracy for all calibration kits.

Thanks for your attention !

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