Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
Nationales Metrologie Institut

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Rückführung von Streuparametern im 0,8 mm-Koaxialleitungssystem bis 165 GHz

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330. PTB-Seminar

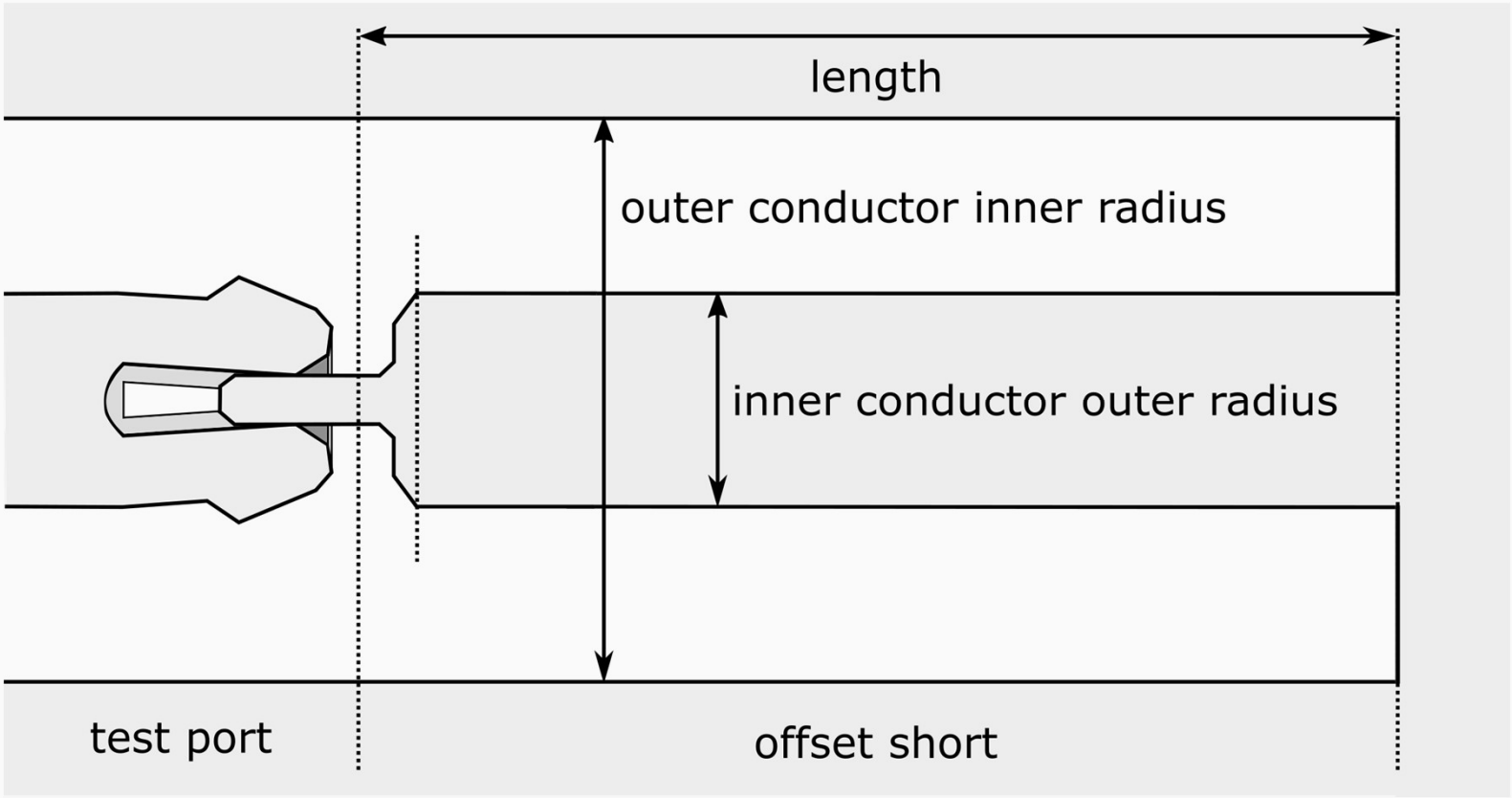
Outline

- Introduction
- Calibration Standard Definition
- Measurement Setup and Repeatability
- Measurements Results
  - High Reflect DUT: Flush Short
  - Low Reflect DUT: Broadband Match
- Summary and Conclusion

Motivation

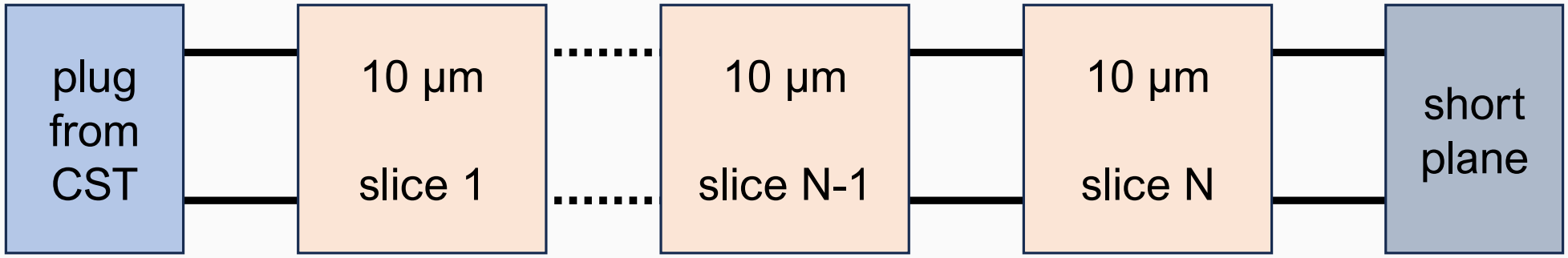
- VNA measurements need calibration standards e.g. open, short or match to characterize the VNA
- definitions are missing for new connector types like PC 0.8 mm
  - primary standards are needed
  - calculable from analytic formulas and simulations
  - air lines not feasible at small dimensions (800 µm outer conductor diameter, 348 µm inner conductor diameter)

Calibration Standard Definition

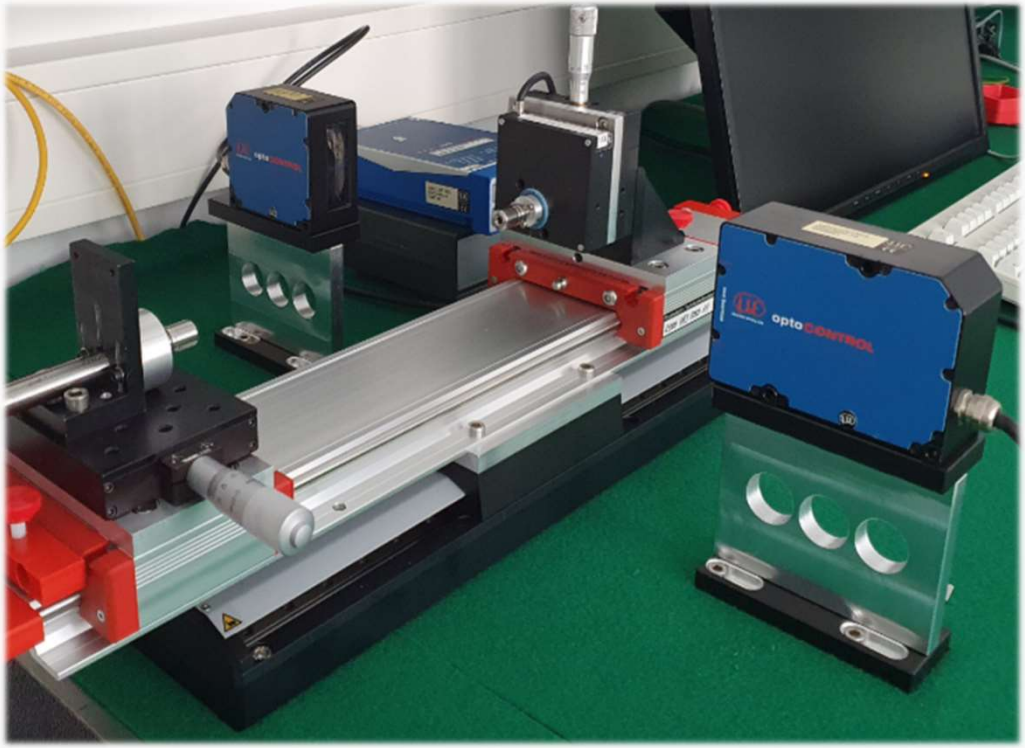


Calibration Standard Definition

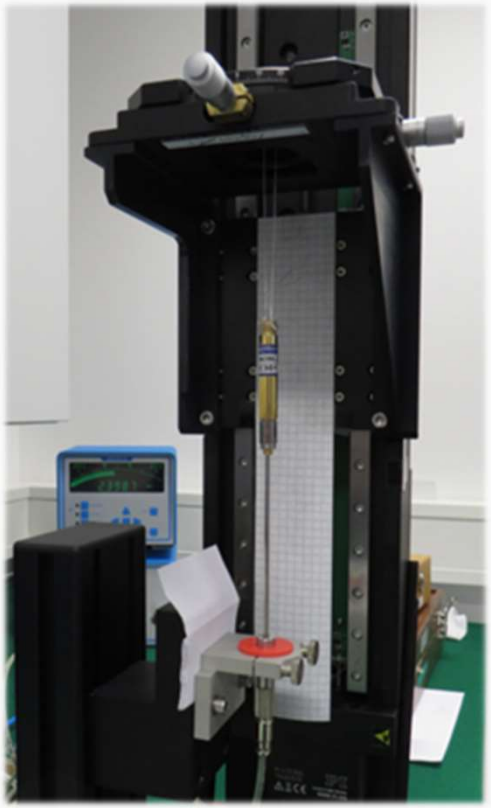
- traceability to the SI using dimensional measurements of inner and outer conductor diameter and length
- modeling of connector effects by 3D-full-wave simulation of the connector using e.g. CST Microwave Studio
- modeling of effective conductivity

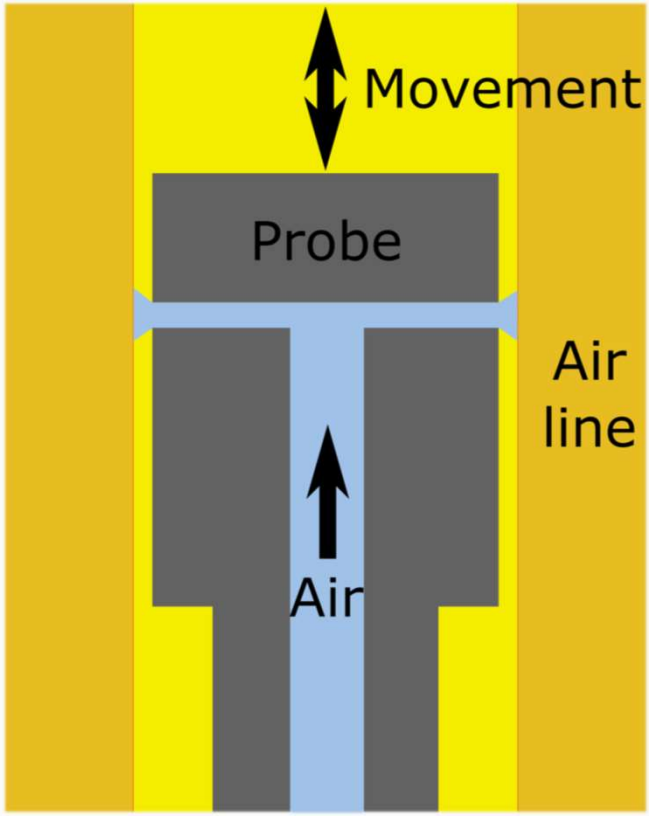


Inner Conductor Outer Diameter

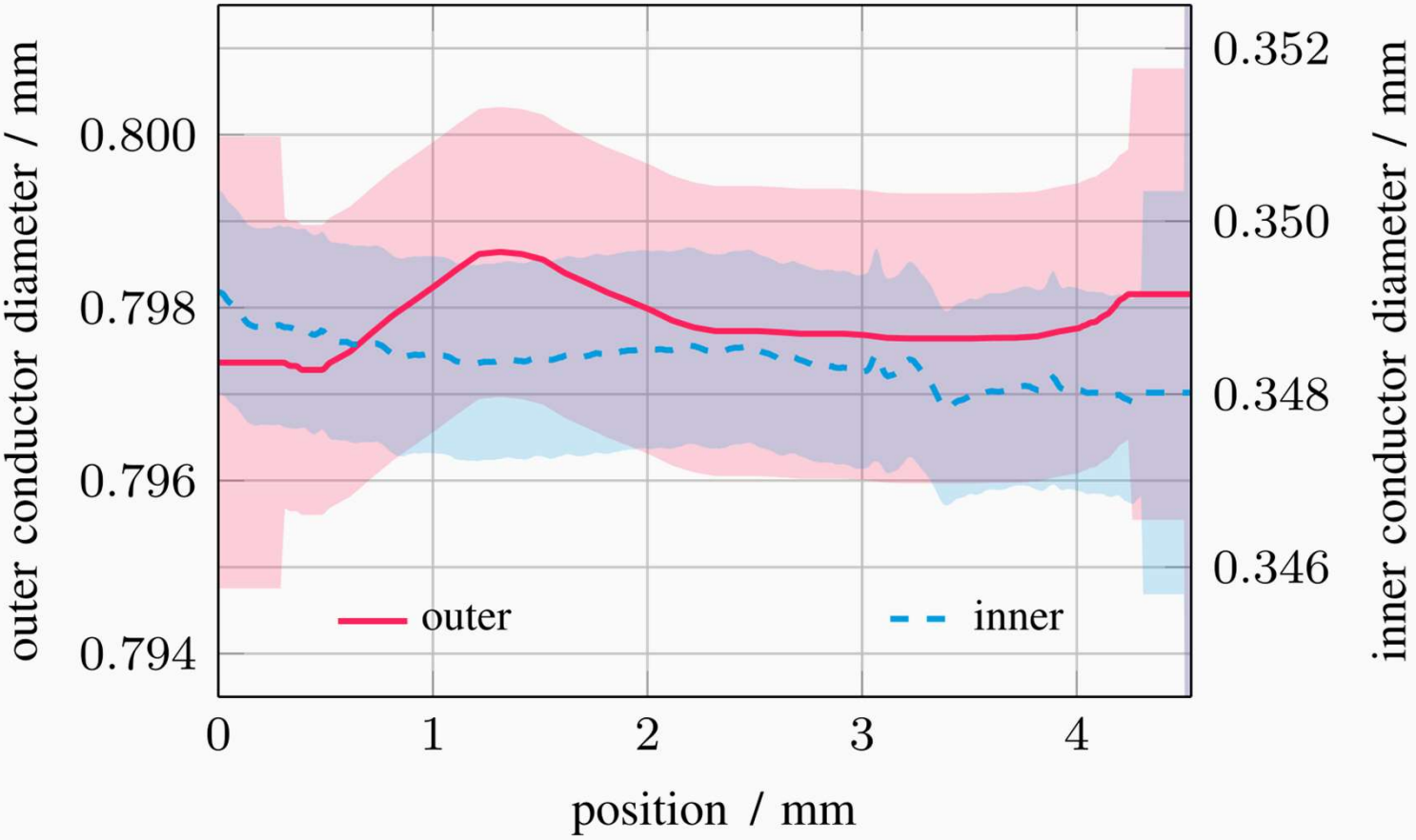


Outer Conductor Inner Diameter

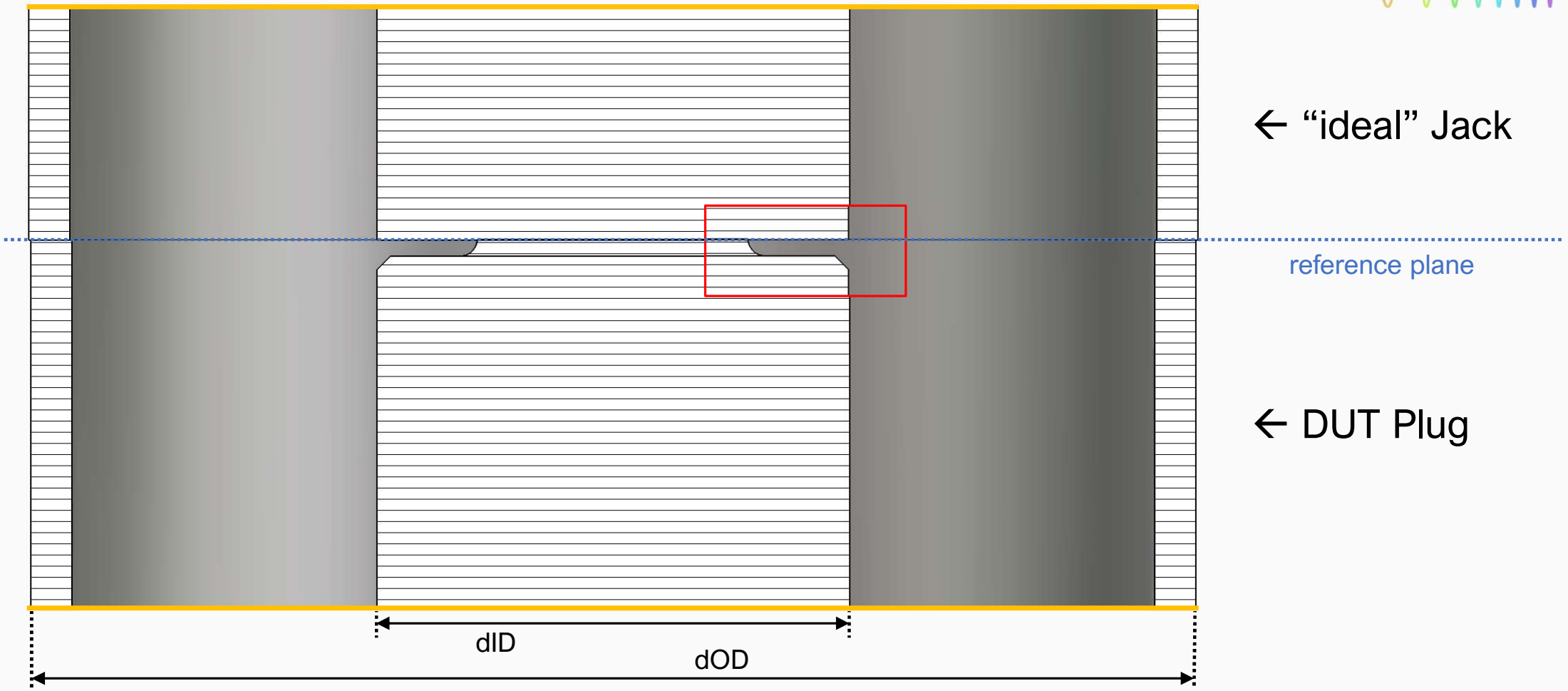




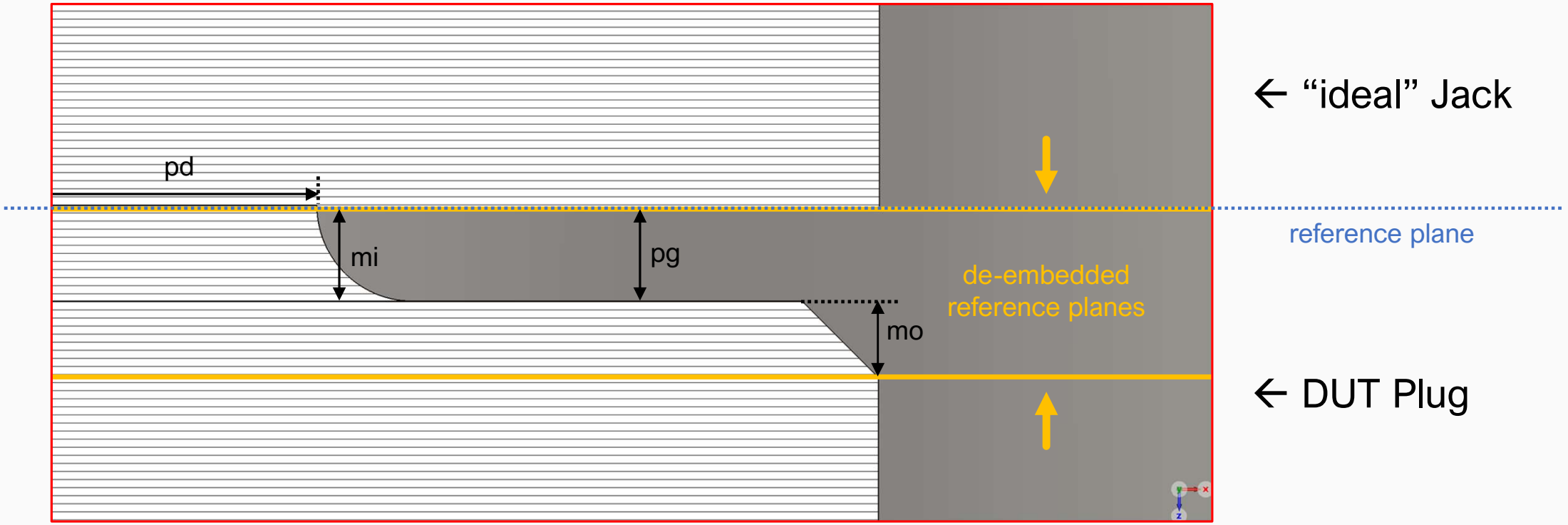
Dimensional Measurement Results



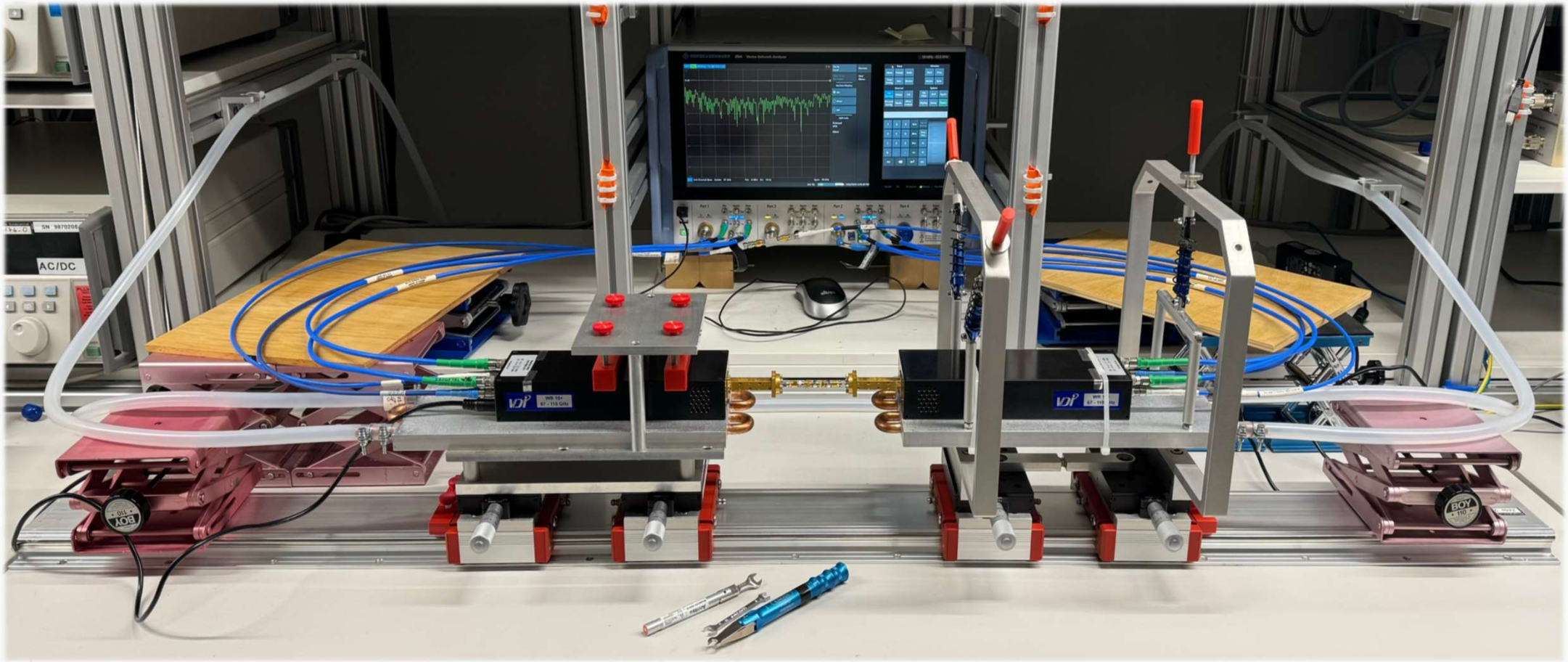
Connector Simulation



Connector Simulation

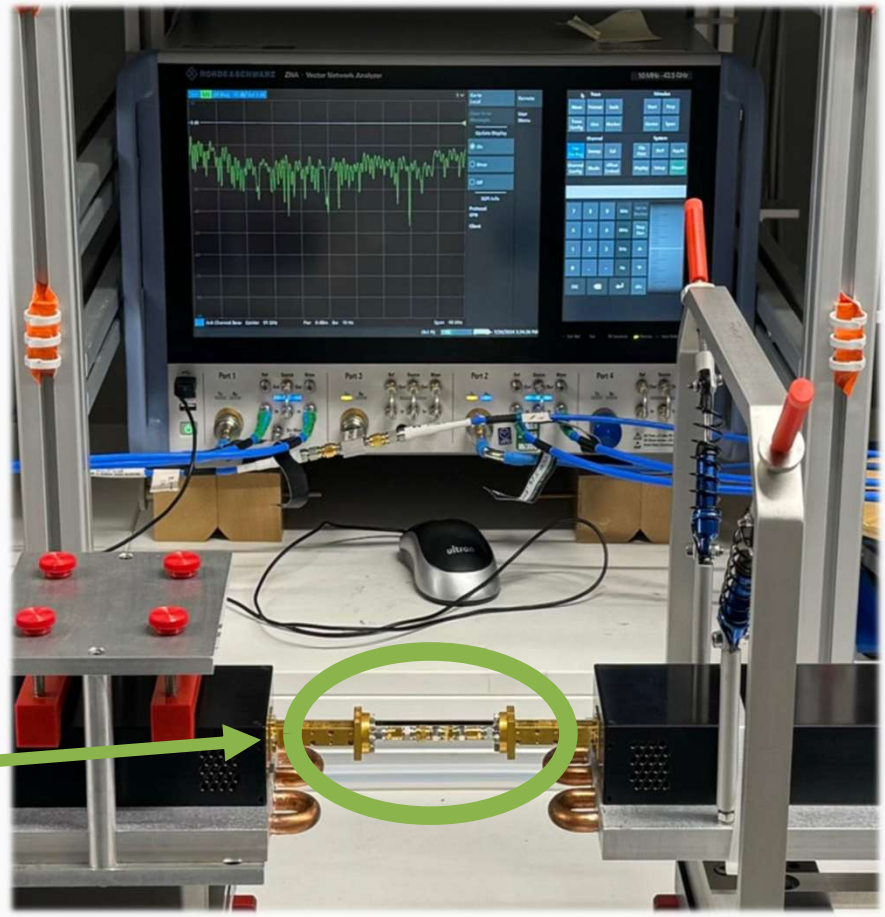


Measurement Setup and Repeatability



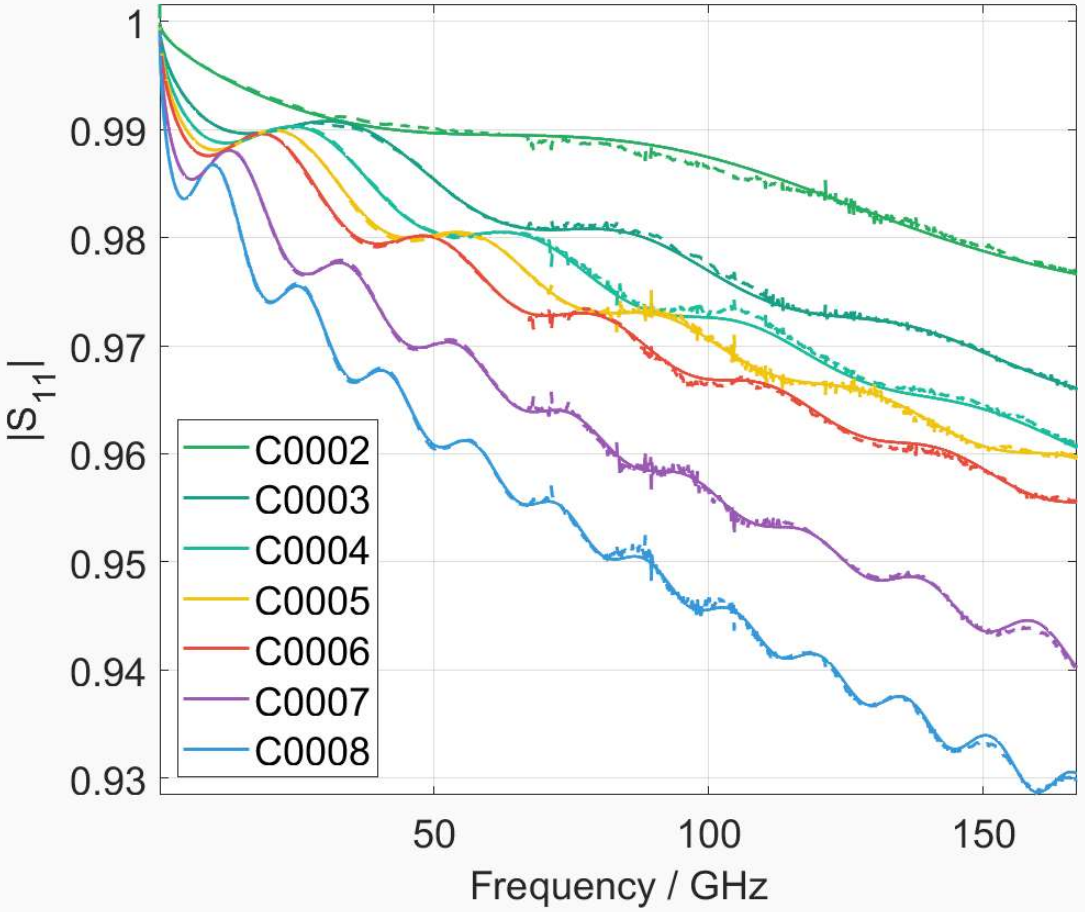
Measurement Setup and Repeatability

- three frequency bands / setups
  - waveguide frequency extensions
    for WR 10 and WR 7
  - test port adapters for PC 1.85,
    WR 10 and WR 7
  - over-determined least-squares
    calibration on port 1
    using seven offset short standards
  - copy calibration on port 2
    using a direct thru connection



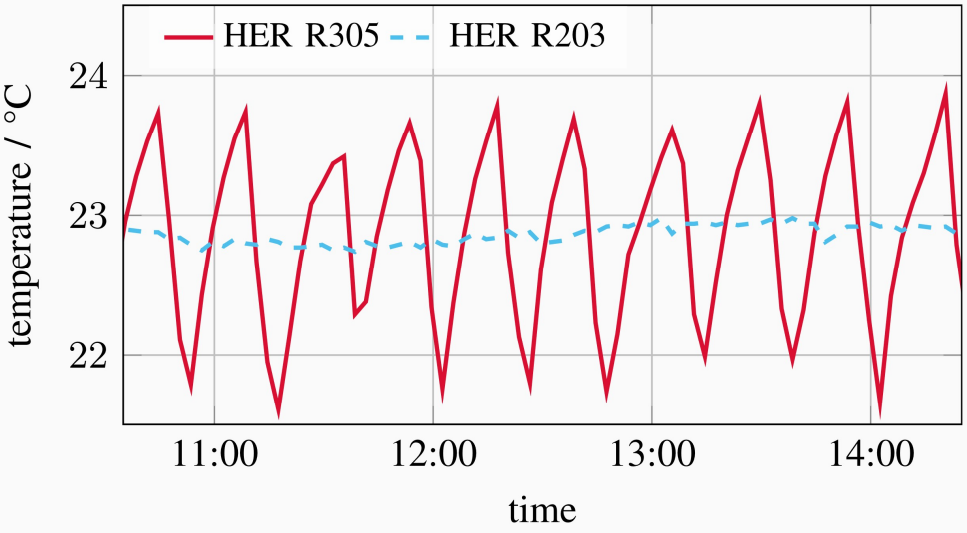
Measurement Setup and Repeatability

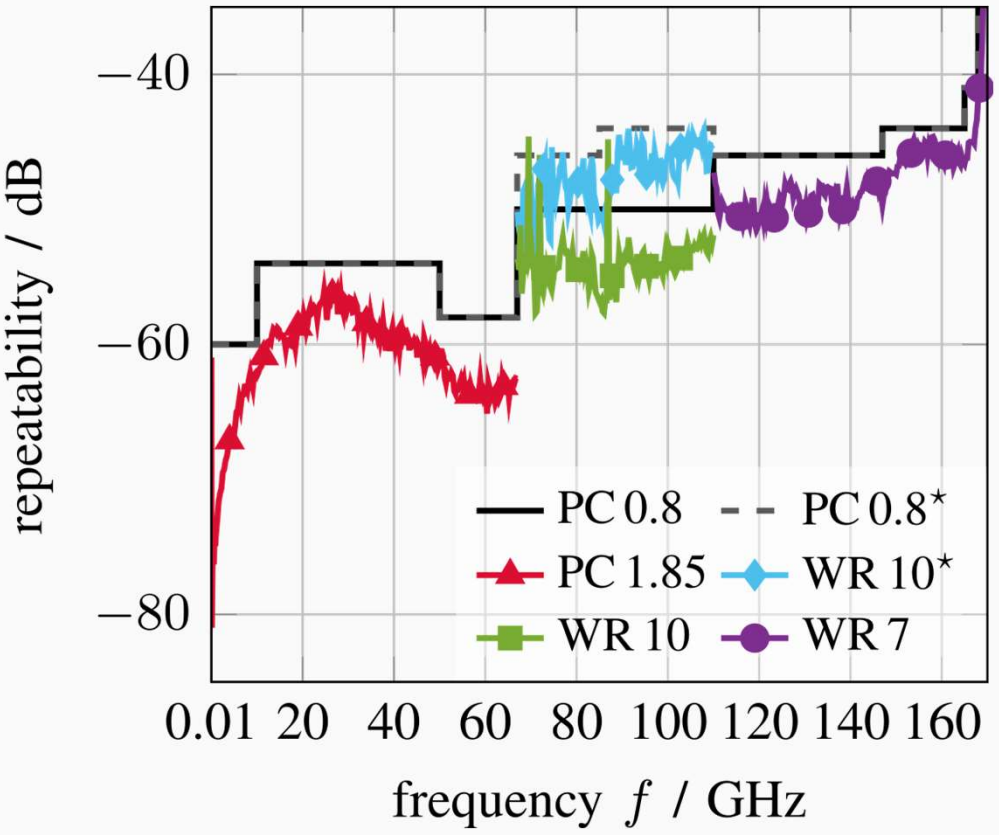
- optimization of material parameters
  - DC conductivity and
  - surface roughness
- model for calculation of effective conductivity of the standard
- minimization of residuals
  - difference between analytic calculation and calibration result



Measurement Setup and **Repeatability**

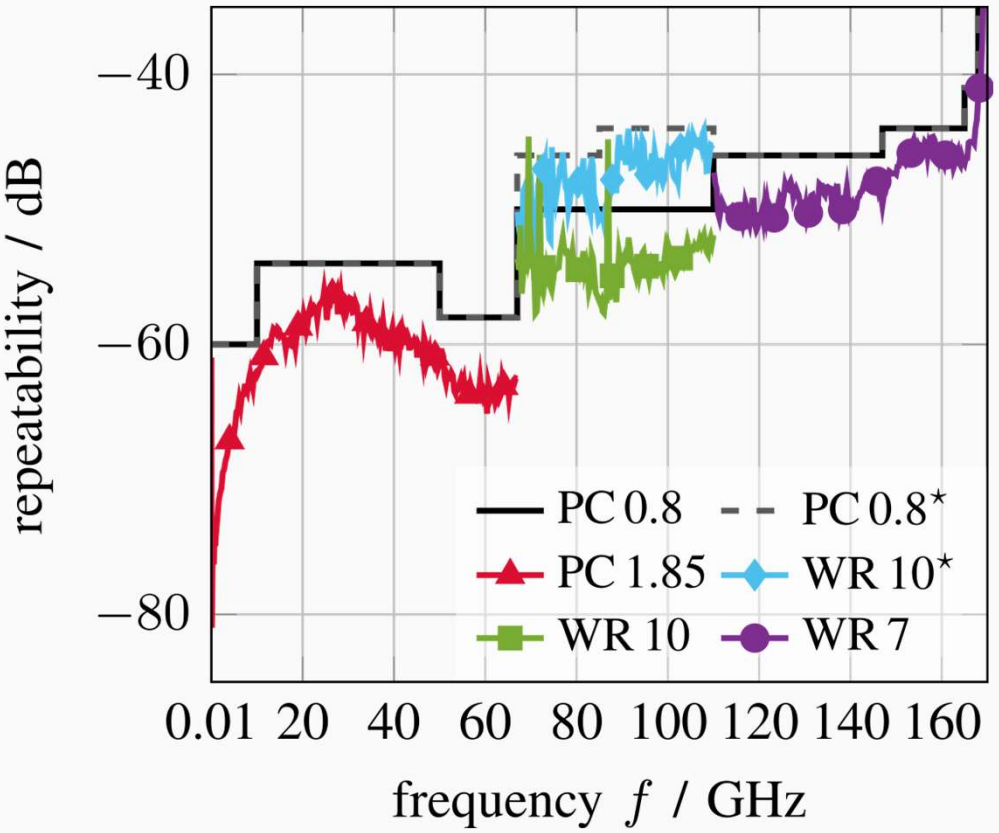
- repeatability definition for use in VNA Tools II based on CG-12
  - average of about 40 DUTs from different manufacturers





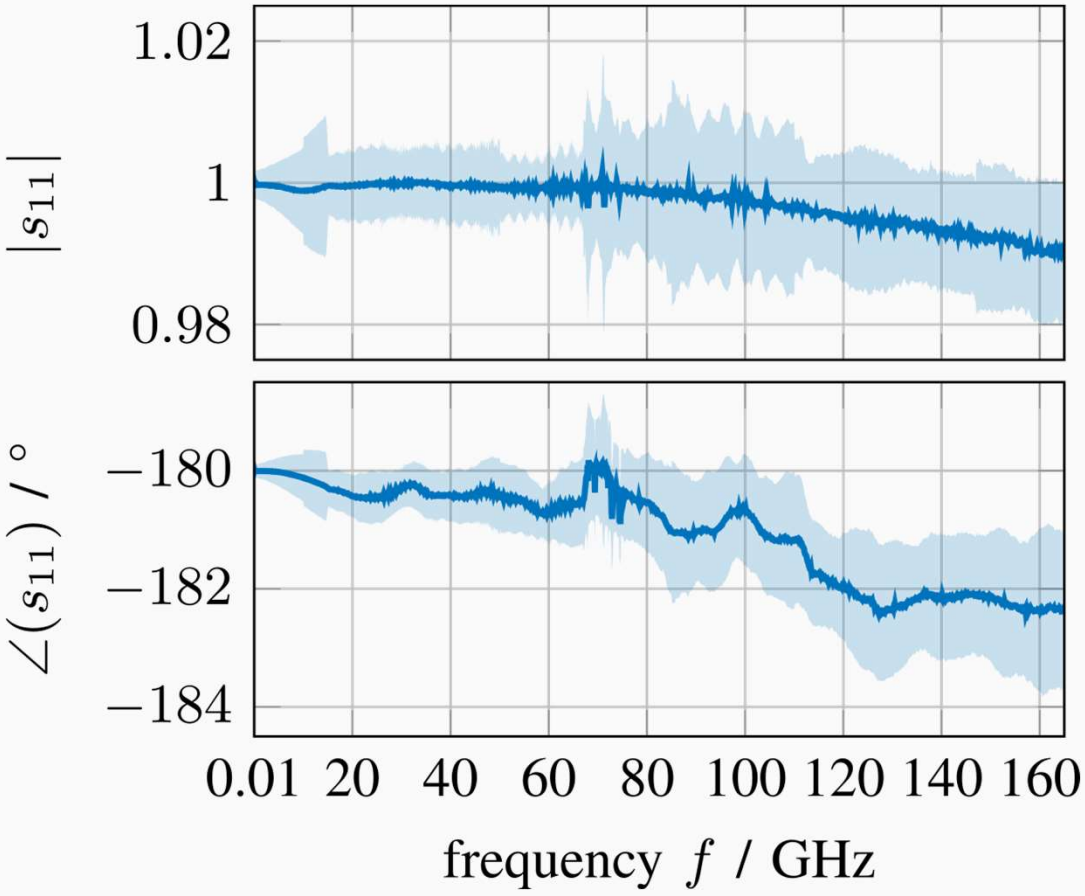
Measurement Setup and **Repeatability**

- repeatability definition for use in VNA Tools II based on CG-12
  - average of about 40 DUTs from different manufacturers
  - re-measurement (⋆) of the WR 10 band due to temperature fluctuations of 2°C in 20 min
  - further improvements by water cooling the VNA extenders

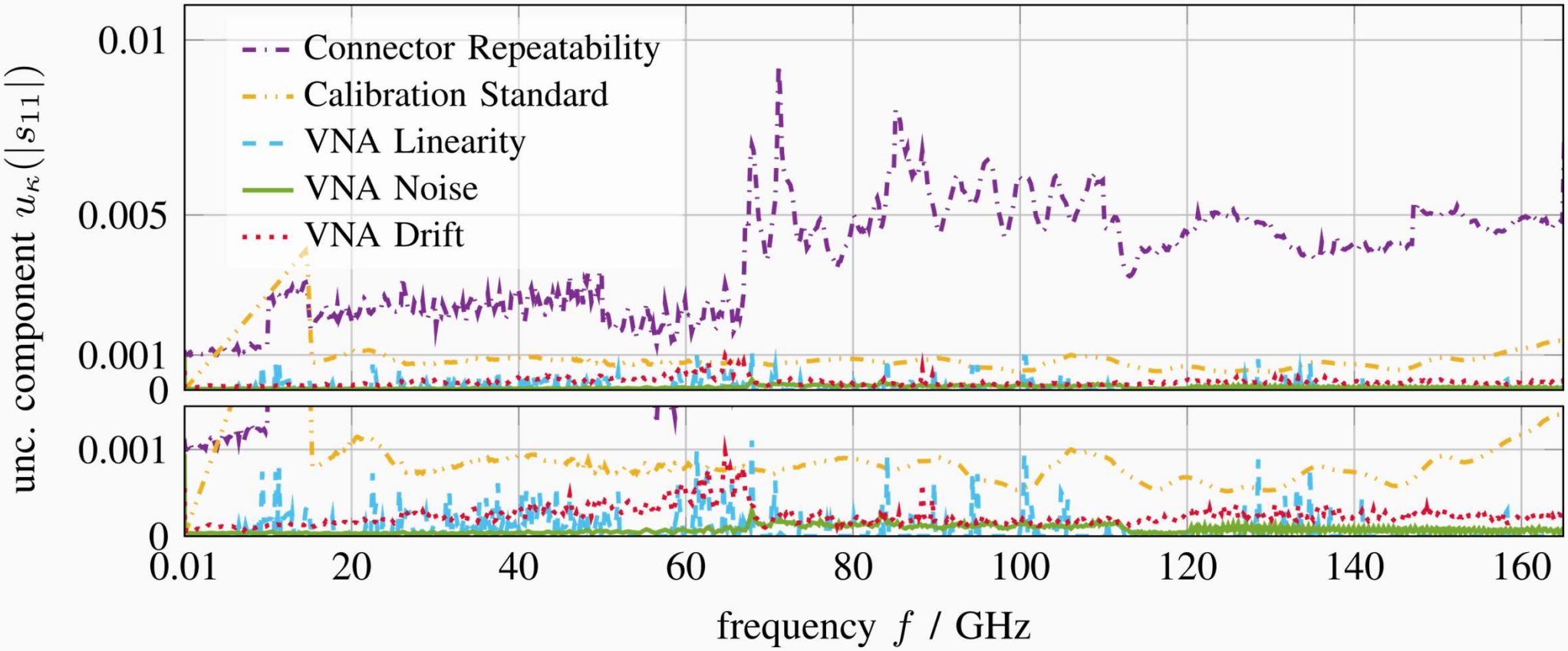


Measurement Results – Flush Short

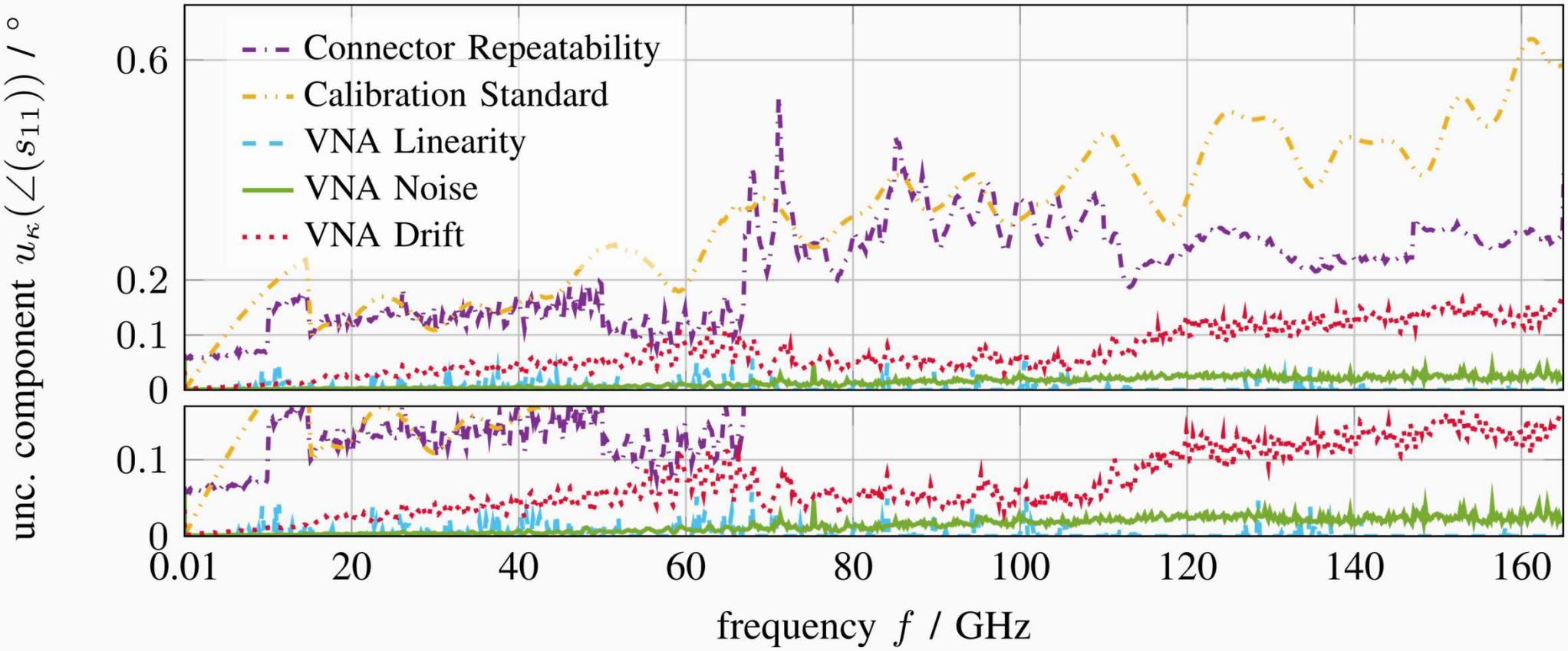
- expected behavior of
  - magnitude starts at 1 and slowly decreases
  - phase starts at -180° and slowly decreases
- expanded uncertainty of
  - magnitude: 0.002 – 0.019
  - phase : 0.1°– 1.5°
- main uncertainty contribution
  - repeatability
  - length measurement (phase)



Measurement Results – Flush Short

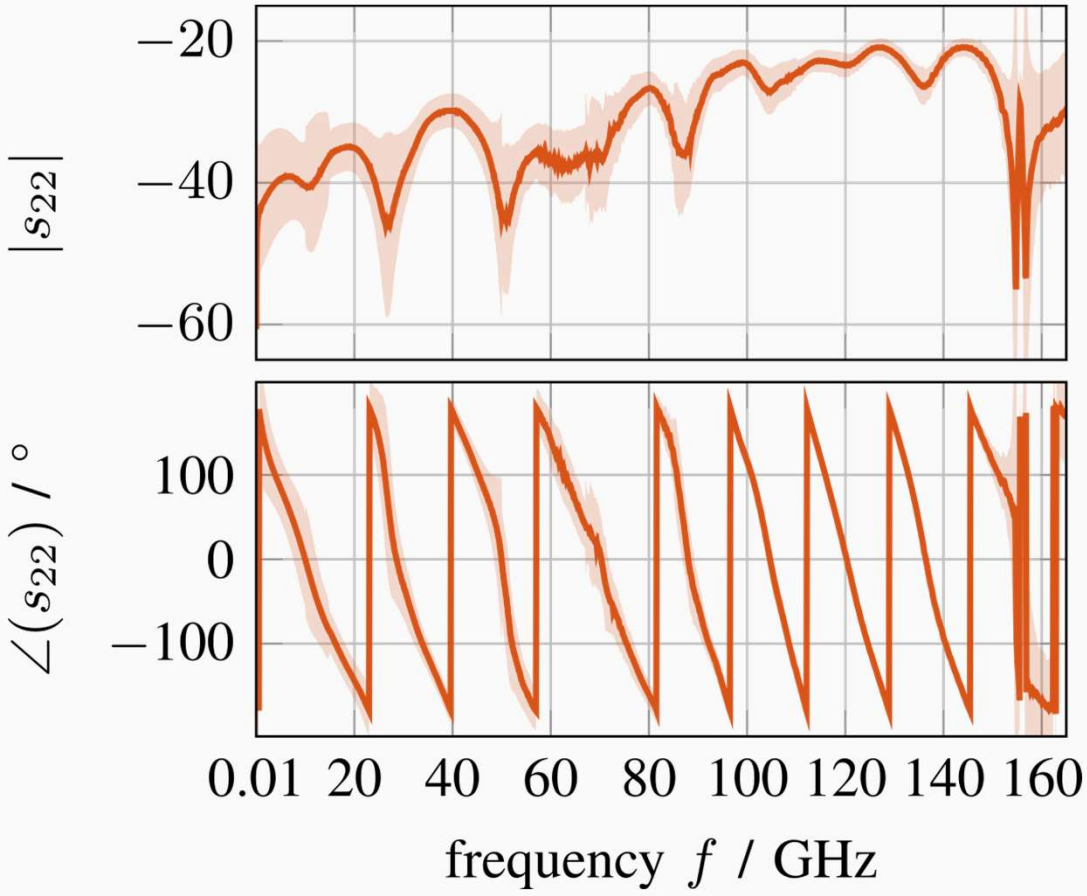


Measurement Results – Flush Short

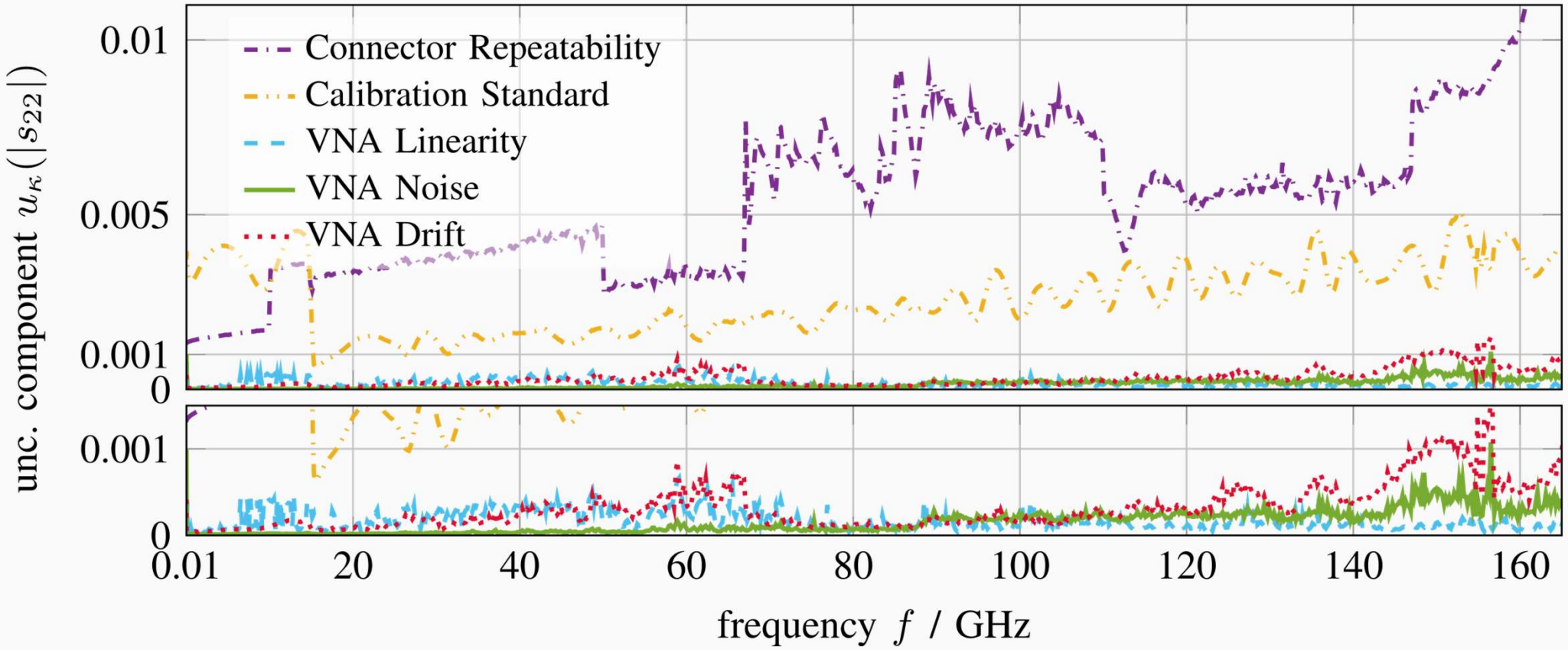


Measurement Results – Broadband Match

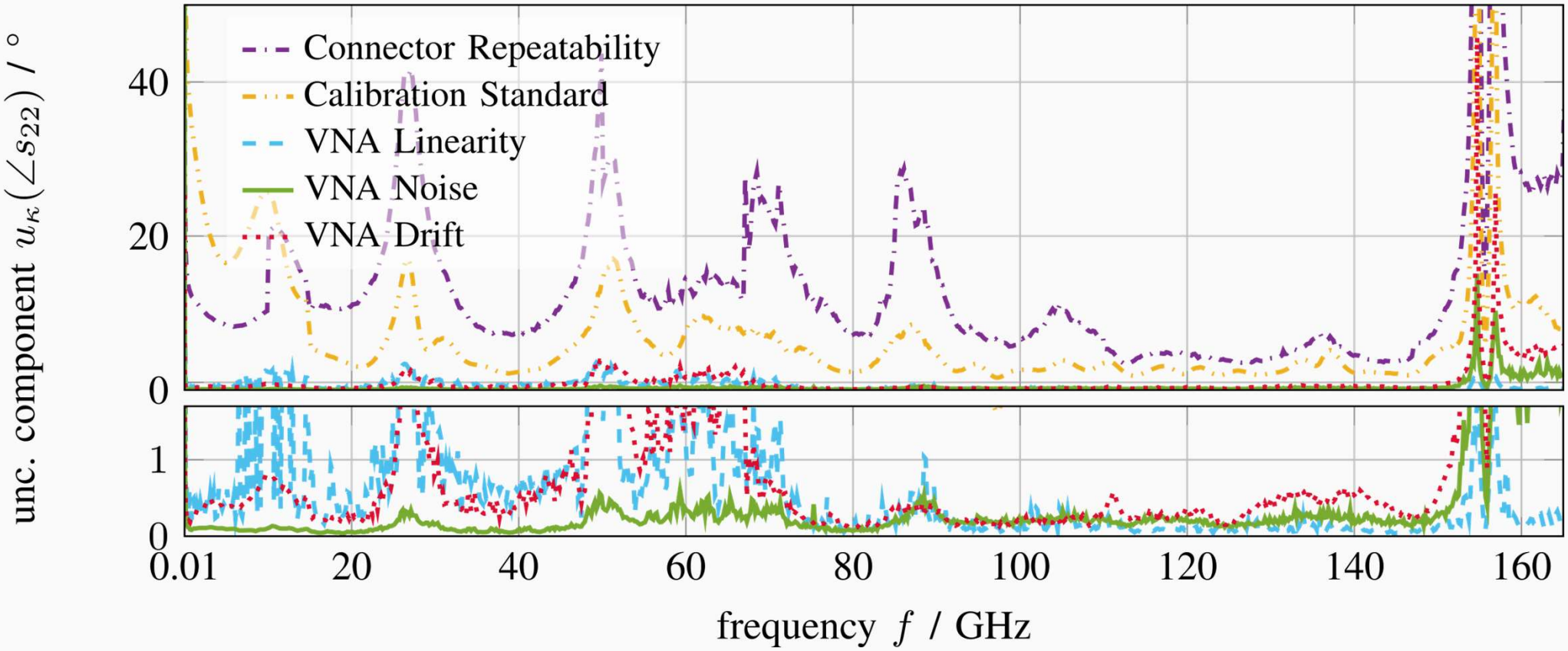
- good behavior
  - magnitude smaller than -20 dB
  - resonance effect / higher order mode around 152 / 156 GHz
- maximum uncertainty of
  - magnitude: 0.006 – 0.031
  - phase: 8°– 97°
- main uncertainty contribution
  - repeatability
  - calibration standard definition



Measurement Results – Broadband Match



Measurement Results – Broadband Match



Summary and Conclusion

- successful establishment of traceability for PC 0.8 mm to the SI up to 165 (167) GHz
- excellent metrological performance due to
  - small uncertainties
  - very good connection repeatability
- CMC values submitted in March 2025
- comparison of frequency and time domain measurements using PTBs electro-optic sampling system are under way
- publication and presentation at IMS 2025 in June in San Francisco

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