Agilent Metrology Workshop
2012-04-18

Investigation of a Precision Waveguide as Phase Standard for Millimeter-Wave Vector Network Analysis

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Outline

- Introduction
- Precision Waveguide
- Reflection measurements
- Conclusion

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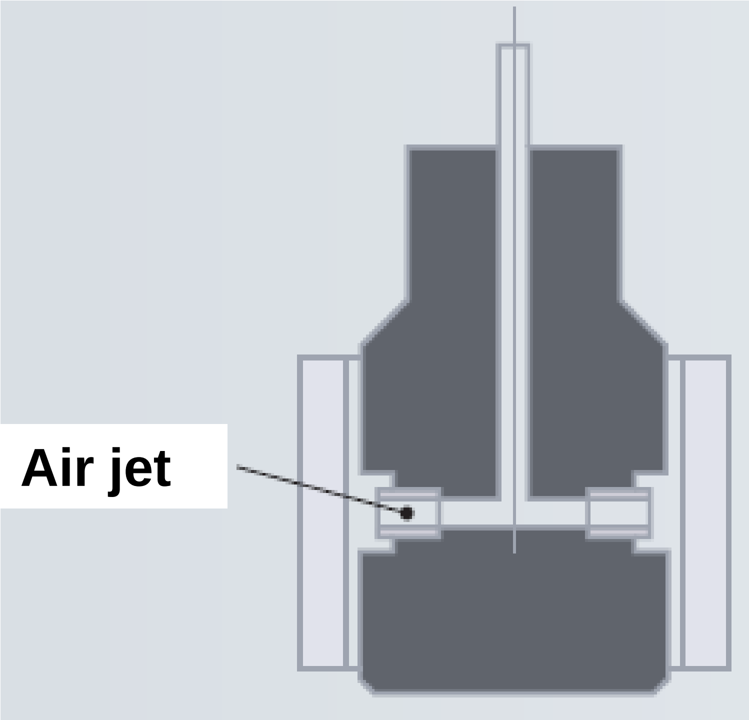
Introduction

Traceability of coaxial VNA measurements

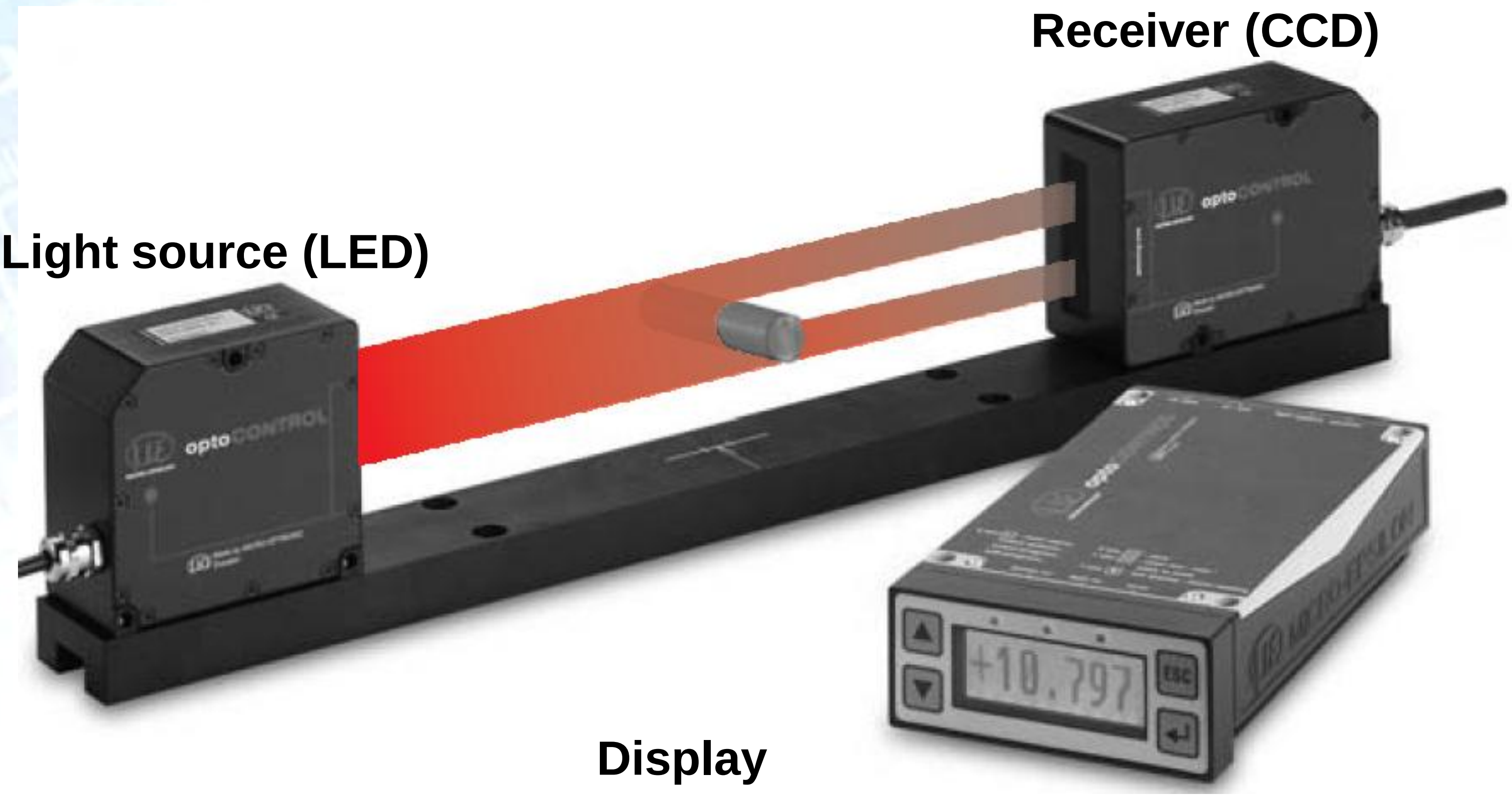
- Precision beadless coaxial airlines are used as impedance and phase standards
- Air gauge and optical systems for determination of inner and outer conductor diameter (both measurements are contactless)



Introduction

Micro-Epsilon optoCONTROL 2600

– Range: 40 mm
– Smallest diameter: 0,3 mm
– Resolution: 0,1 µm



Introduction

Traceability/Validation of waveguide VNA measurements

- Precision waveguide components (Shims)
- Optical and mechanical measurements near waveguide ends

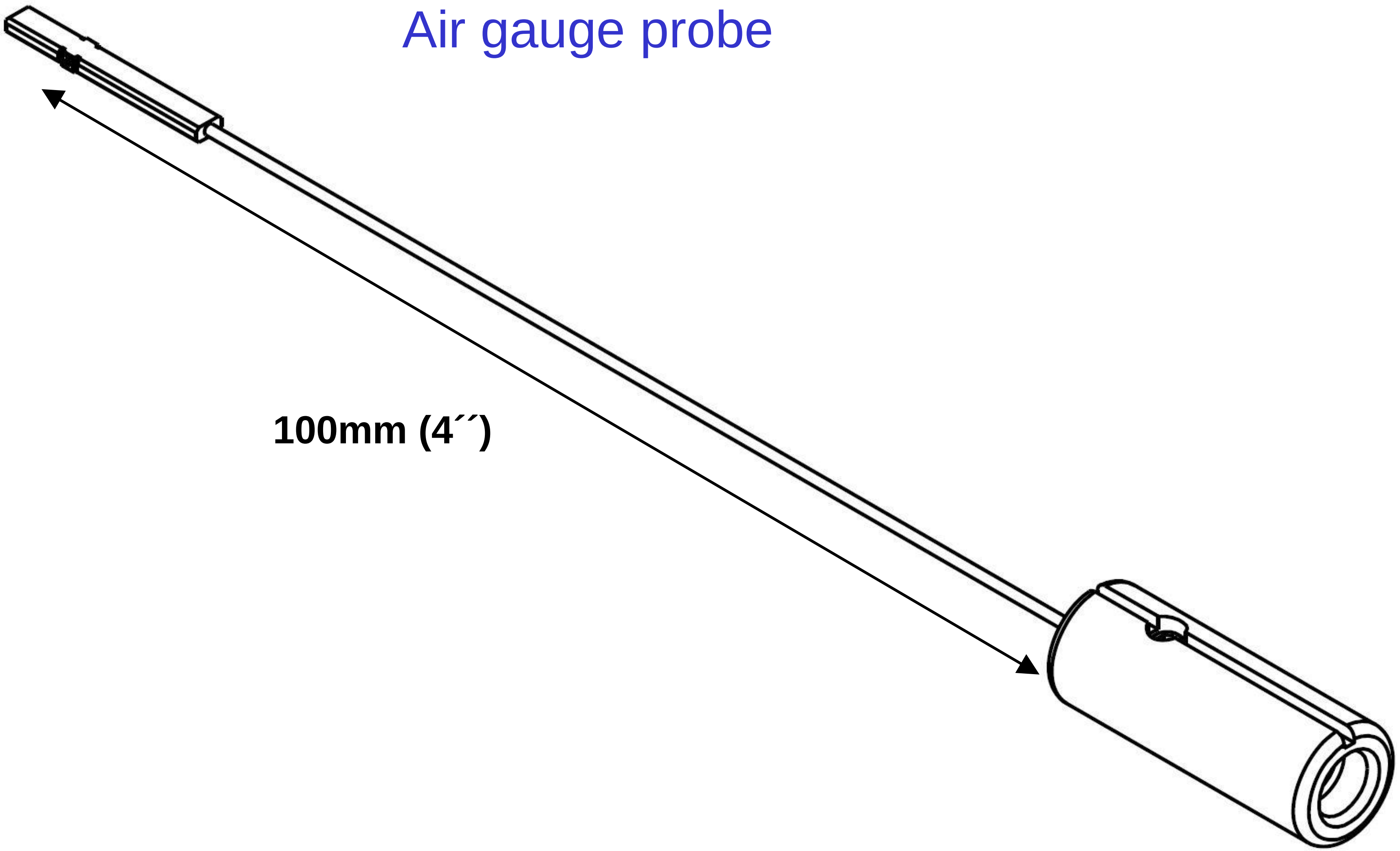
New approach

- Air gauge measurement for an electrically long waveguide (here WR10, 76mm)

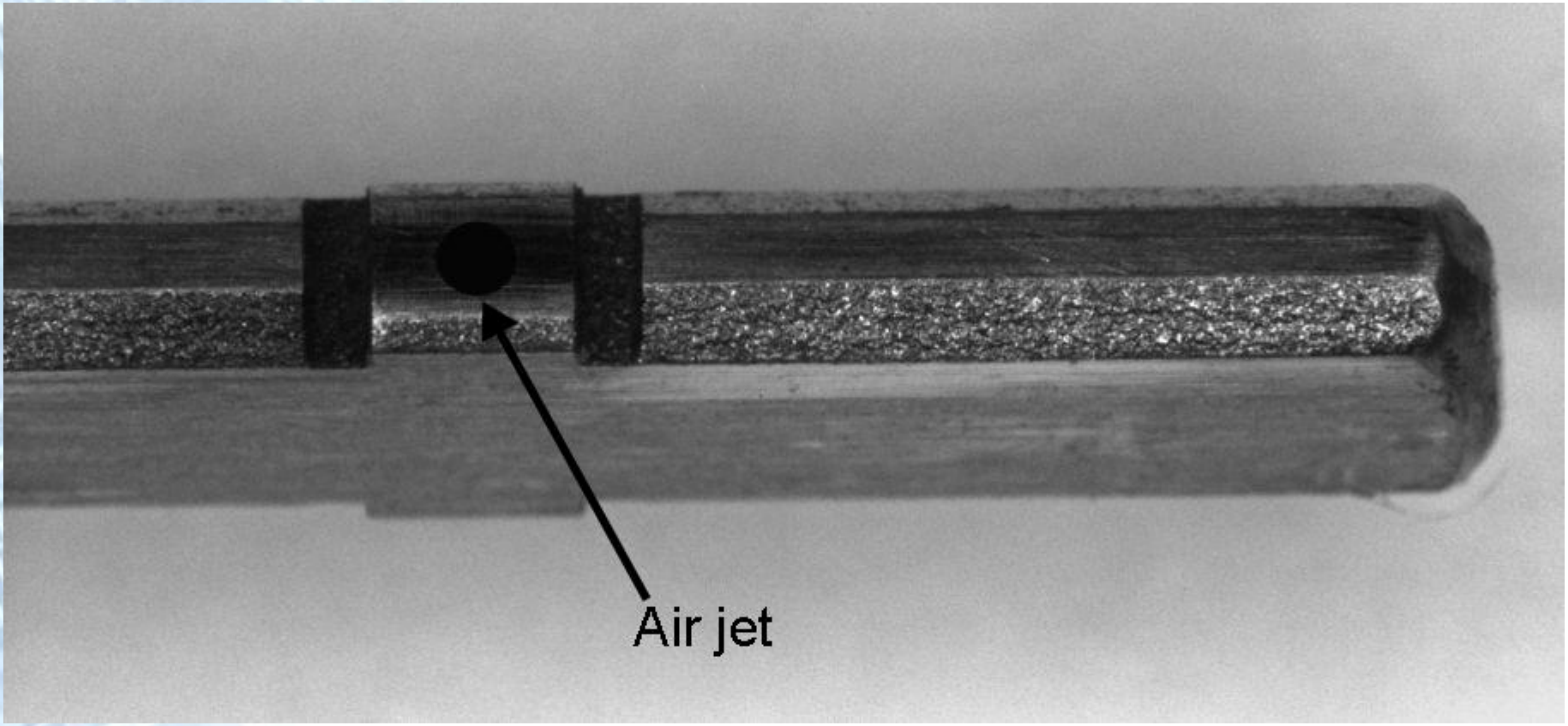
Result

- Propagation constant $\gamma = \alpha + j\beta$ from waveguide width and conductivity

Air gauge probe



Air gauge probe tip



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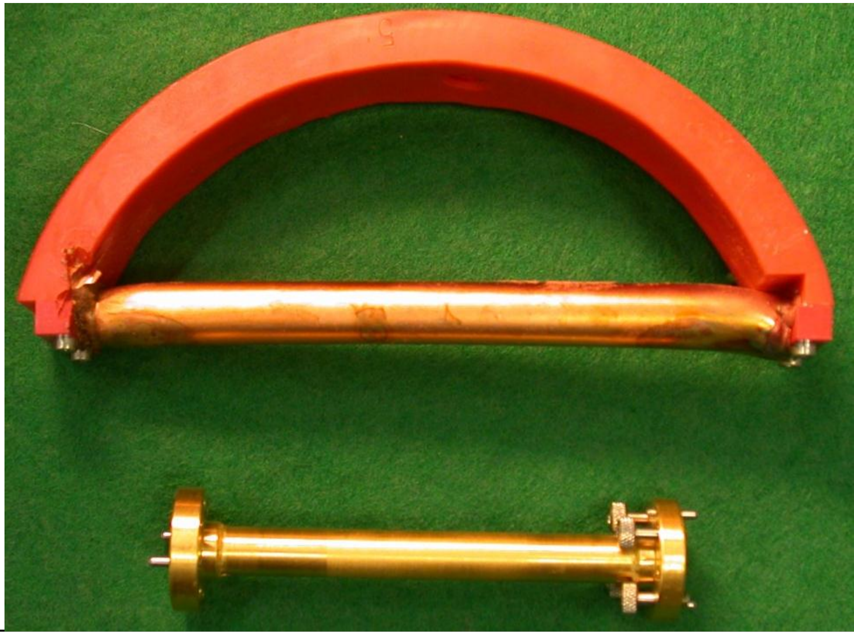
Precision Waveguide

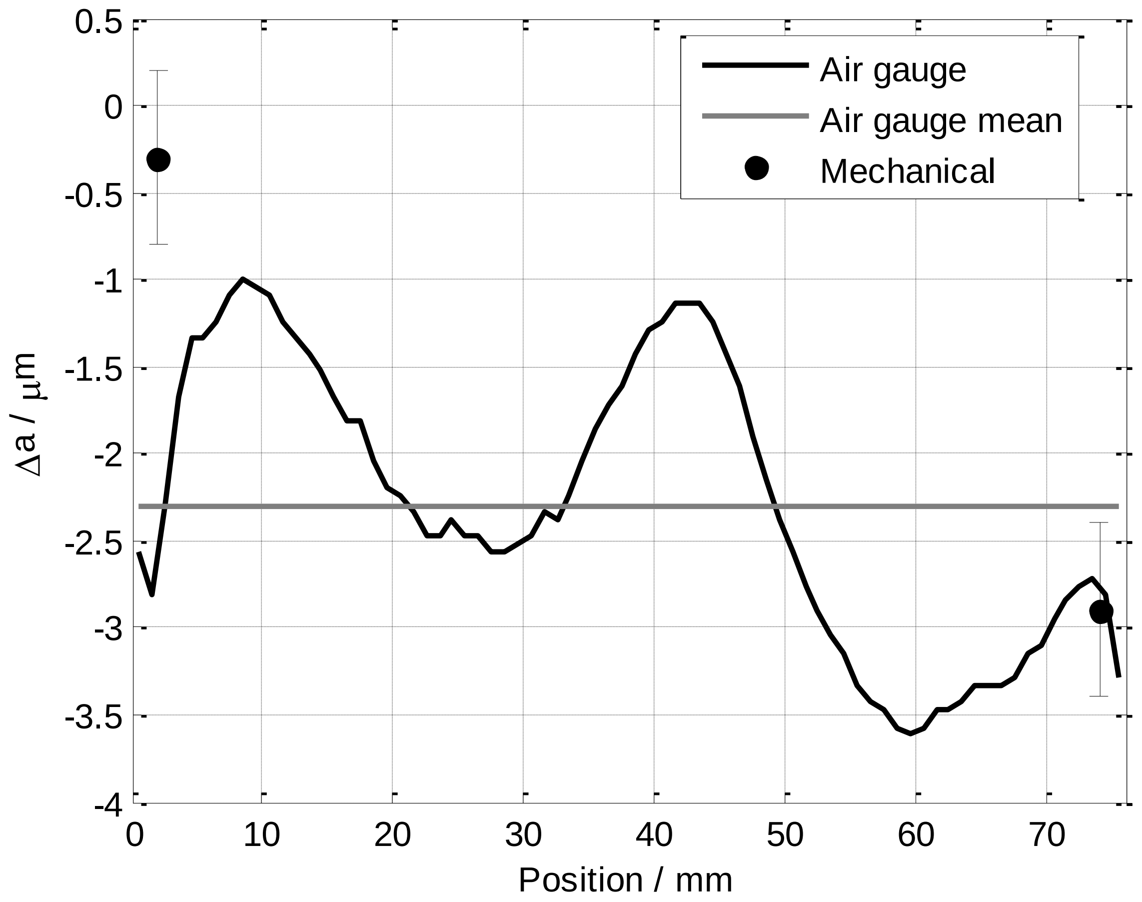
Manufacturing:

1. Hardening of stainless steel core
2. Centreless grinding/polishing with precision of ±2 *μm*
3. Mounting under tension
4. Electroplating
5. Pulling the stainless steel core
6. Attaching the flanges



Precision Waveguide

First air gauge Measurements



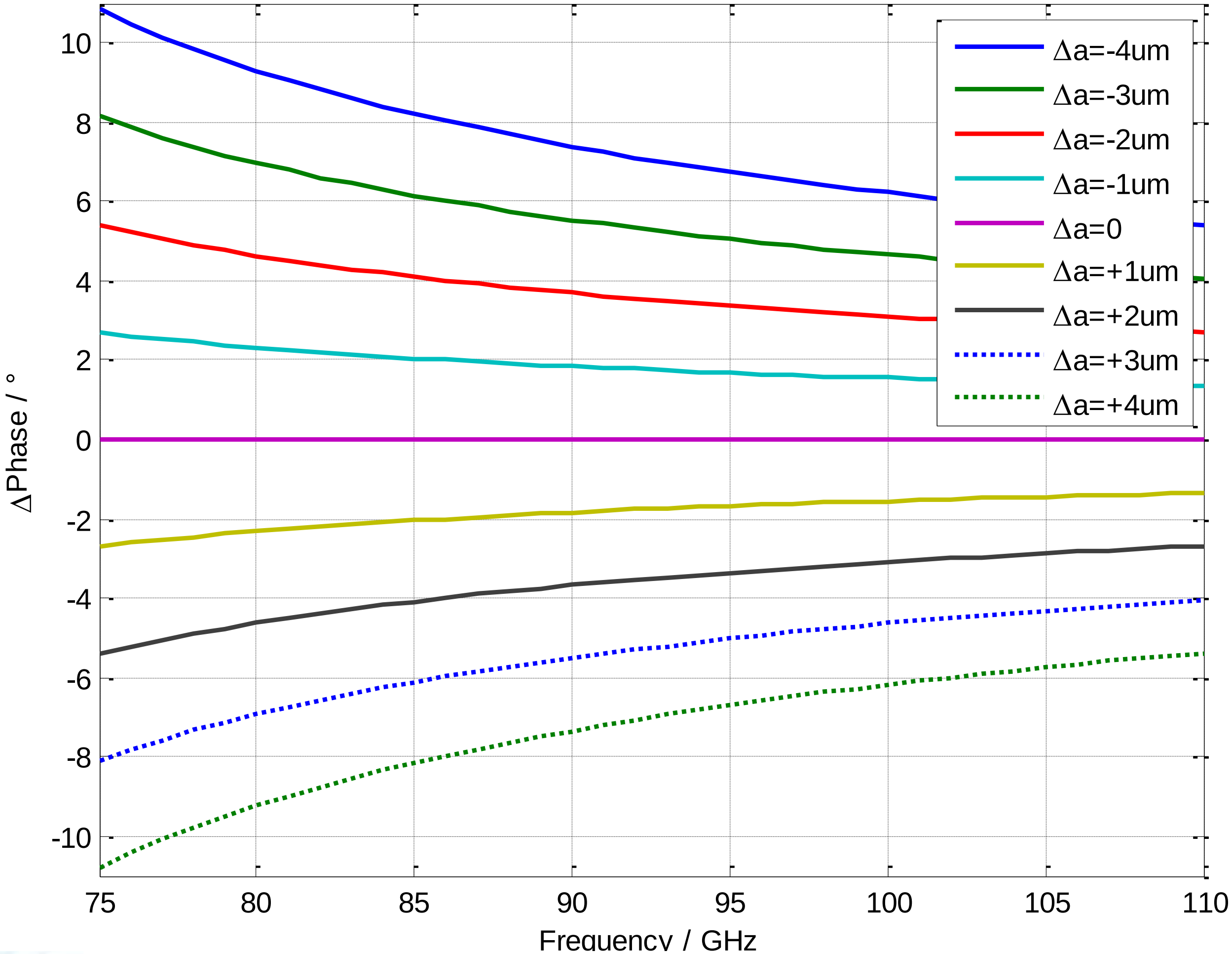
Reference a=2.54mm
***l* = 76mm**

Precision Waveguide

PTB

Phase change for small waveguide width change

Nearly linear behavior

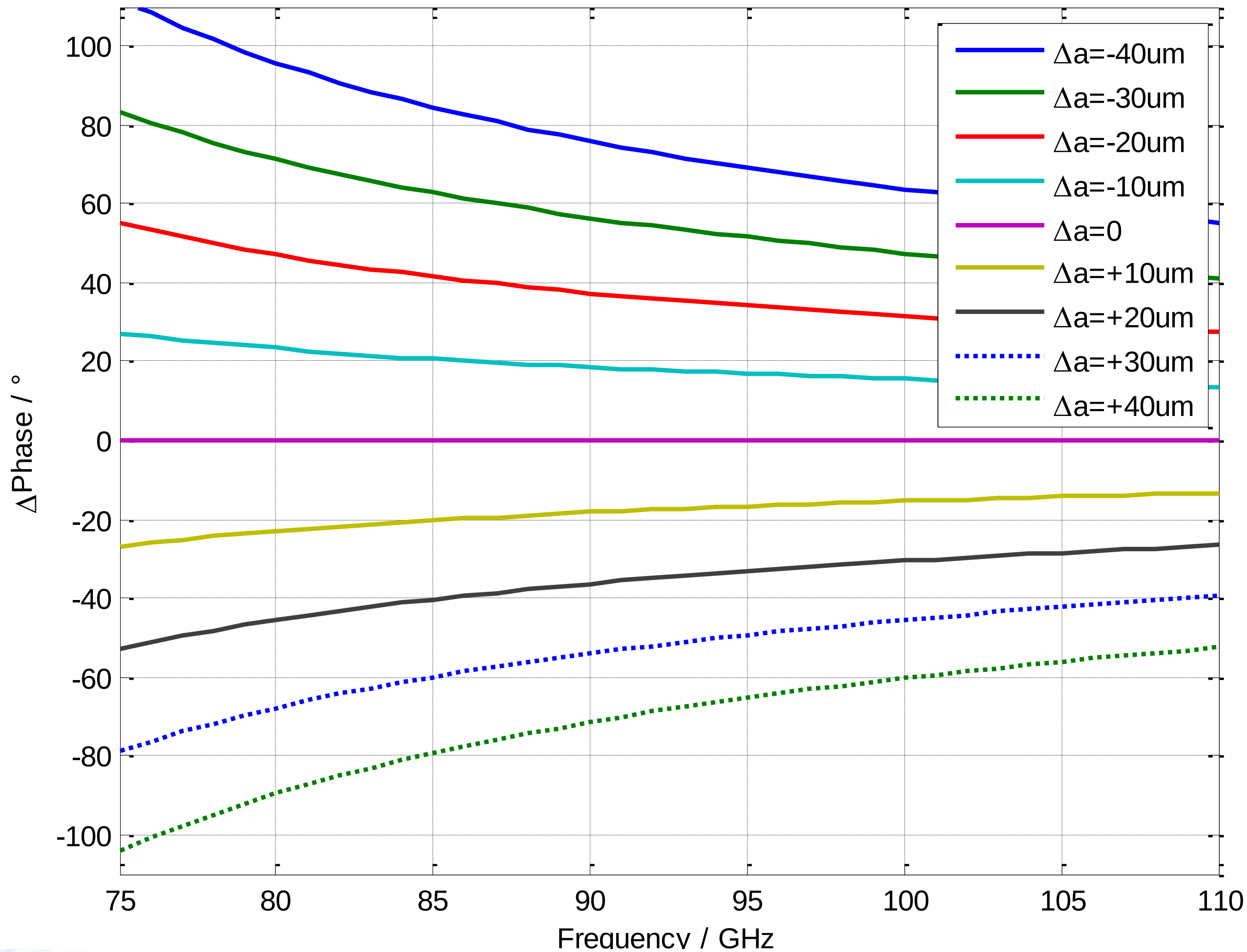


l **= 76mm**

Precision Waveguide

Phase change for large waveguide width change

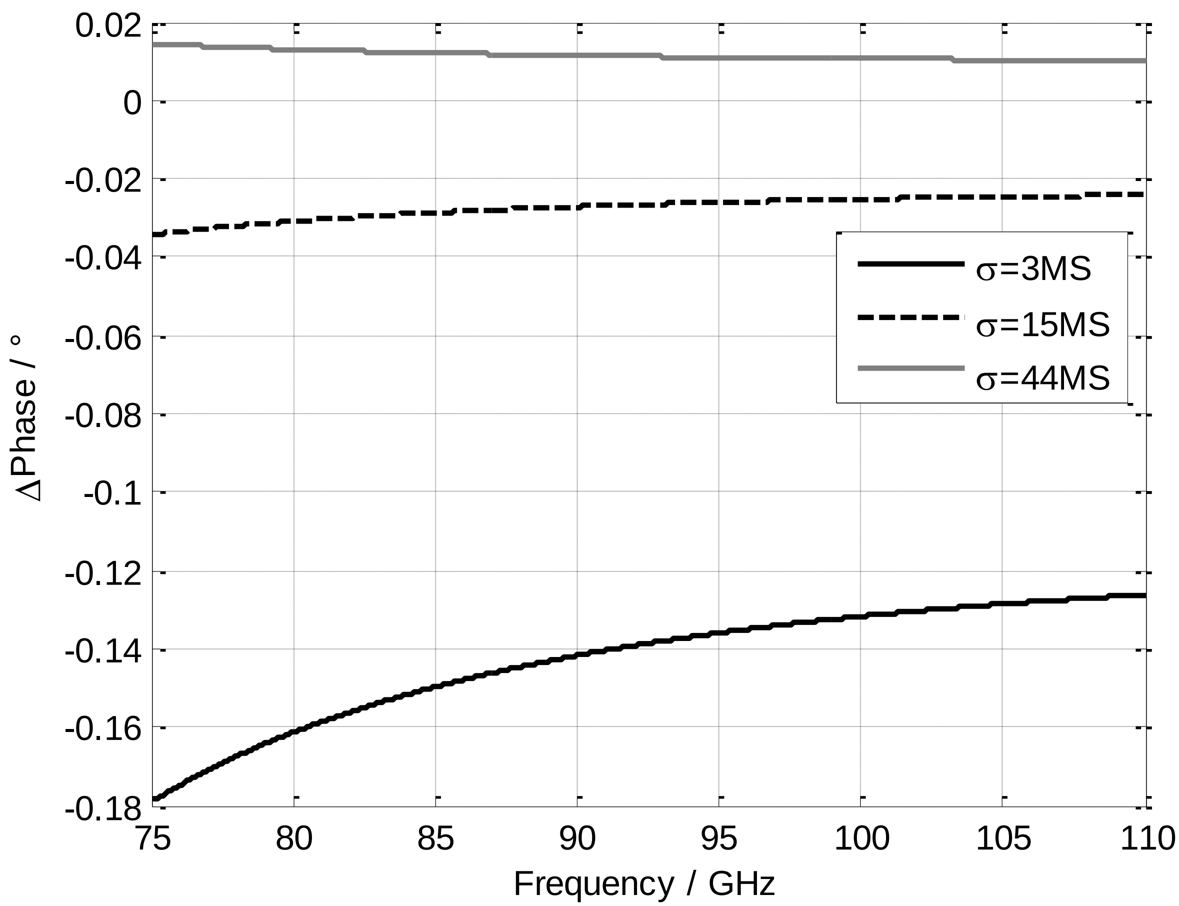
Nonlinear behavior



***l* = 76mm**

Precision Waveguide

Phase dependency for conductivity change



***l* = 76mm**

***σ* = 30 MS/m**

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Reflection measurements

- Several calibrations
  - Two offset shorts and a sliding load (OOL)
  - TRL
  - Second-order correction of OOL (time domain approach)

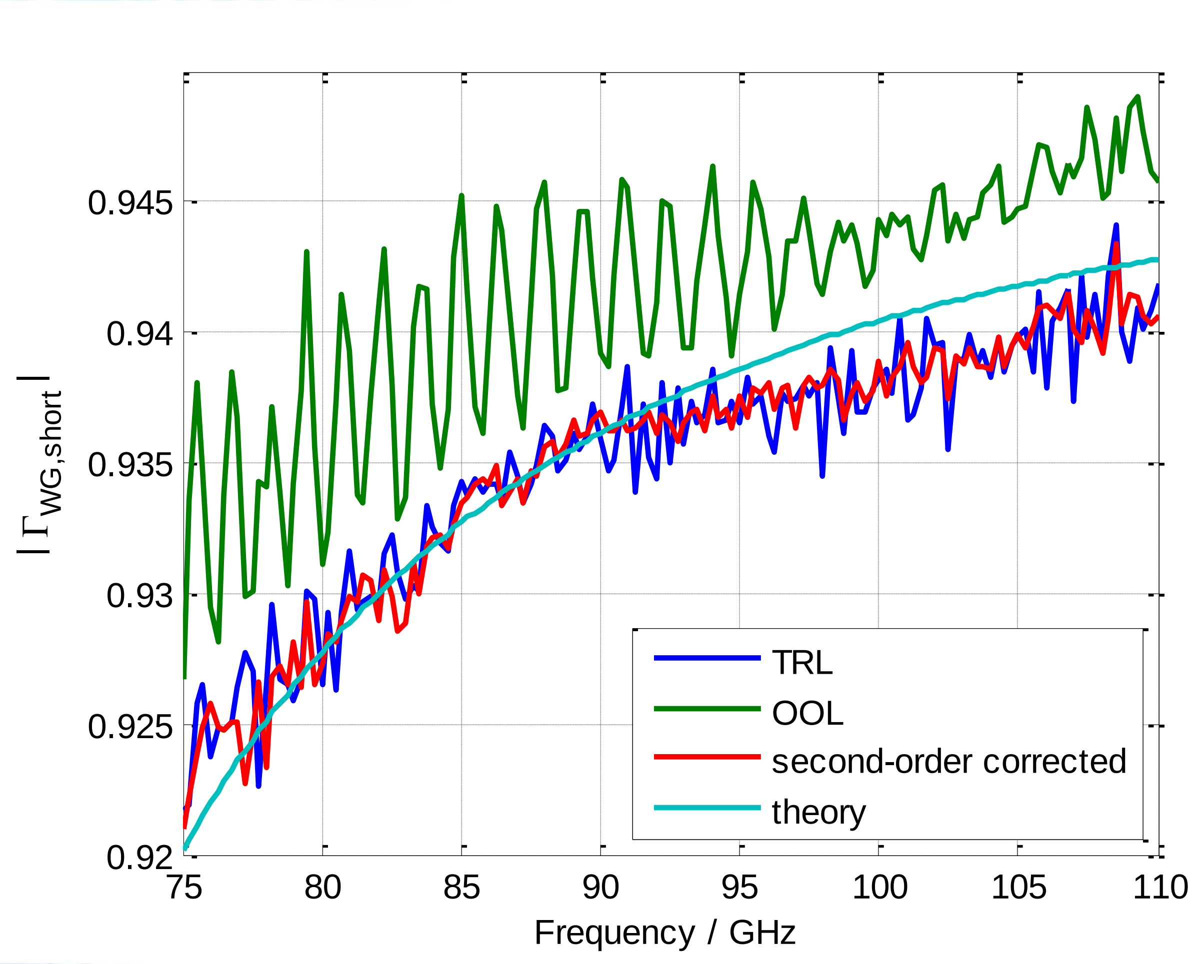
- Measurements
  - Flush short
  - Waveguide terminated with flush short

[Lit] R. H. Judaschke, “Second-Order Waveguide Calibration of a One-Port Vector Network Analyzer,” 77th ARFTG Conf. Digest, Jun. 2011.

Reflection measurements

Simulation and measurement results for flush short

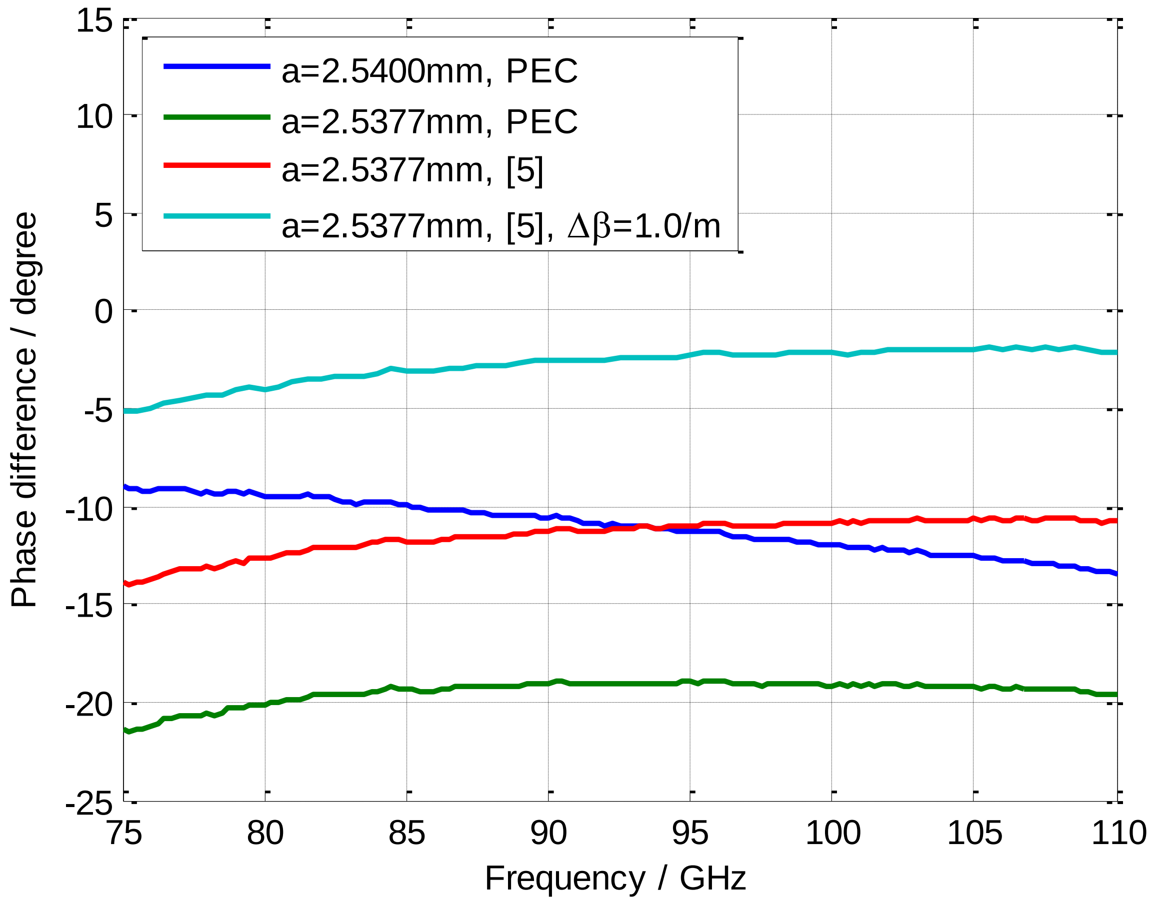
σ = 30 MS/m



Reflection measurements

Simulated and measured phase for short-circuited waveguide

Length = 2 x 76 mm = 23.5 to 47.1 wavelengths (75-110GHz)



- **σ = 30 MS/m**
- **Difference to corrected OOL**

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Conclusion

- Traceability/Verification of VNA measurements for
  - Coaxial
  - Waveguide

- Manufacturing of precision waveguide

- Reflections measurements
  - Reflection coefficient of short and phase difference for short-circuited waveguide agree well with simulation

- To do
  - More full wave EM simulations
  - Corner radius cannot be determined by air gauge

Thank you very much for your attention!

Questions?

References

(1) J. P. de Vreede, N. M. Ridler, “Beadless air lines as phase standards,”,CPEM Digest, pp. 286-287, July 2006.

(2) M. Horibe, N. M. Ridler, “Comparison Between NPL and NMIJ of Diameter and Scattering Parameter Measurements of Precision 1.85 mm Coaxial Air Lines,” IEEE Trans. Instrum. Meas., vol. 60, no. 7, pp. 2327-2334, 2011.

(3) R. H. Judaschke, “Second-Order Waveguide Calibration of a One-PortVector Network Analyzer,” 77th ARFTG Conf. Digest, Jun. 2011.

(4) M. Kohler, H. Bayer, “Feld und Ausbreitungskonstante im Rechteck-Hohlrohr bei endlicher Leitf¨ahigkeit des Wandmaterials,” Zeitschrift für angewandte Physik, 18. Bd., Heft 1, pp. 16-22, 1964.

(5) C. E. Balanis, Advanced Engineering Electromagnetics, Wiley, 1989.

(6) J. Hoffmann, P. Leuchtmann, J. Ruefenacht, and C. Hafner, “PropagationConstant of a Coaxial Transmission Line with Rough Surfaces,” IEEE Trans. Microwave Theory Tech., vol. 57, no. 12, 2009.