



Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
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Federal Department of Justice and Police FDJP

Federal Office of Metrology METAS

# Pin diameter specifications and challenges

32nd ANAMET meeting (NPL, Teddington)

Juerg Riefenacht

16 October 2009



# Pin diameter aspects in metrological practice

- **The 1.85 mm traceability strategy (with connector)**
- **Air line calibration services provided at METAS**
- **Dimensional connector interface measurements**
- **IEEE Standard P287: 2.92 mm specifications**
- **Pin diameter effects in electrical quantities**



# The 1.85 mm traceability strategy (CoMo70)

- **Physical characterisation**
  - **Dimensional characterisation:** Air Lines, Offset Shorts, Connector interfaces
  - **Material properties:** conductivity, surface roughness (outcome from CoMo70)
- **Cal standard modelling process including connector effects**
  - **1.85 mm connector parameter tool** (outcome from CoMo70)
  - **Air Line and Offset Short modelling** (outcome from CoMo70)
- **VNA calibration – error correction**
  - **LRL calibration** -> Air Line modelling (challenging handling)
  - **Offset Short cal kit** -> Short modelling (robust and very easy handling)
  - **Offset Opens determined from LRL cal**
  - **Load determined from LRL cal and DC point measurement**
  - **New Bayesian VNA calibration algorithm** (outcome from CoMo70)
- **Uncertainty calculation -> “VNA Tools II” research project**
  - **Development of a free VNA metrology expert tool**



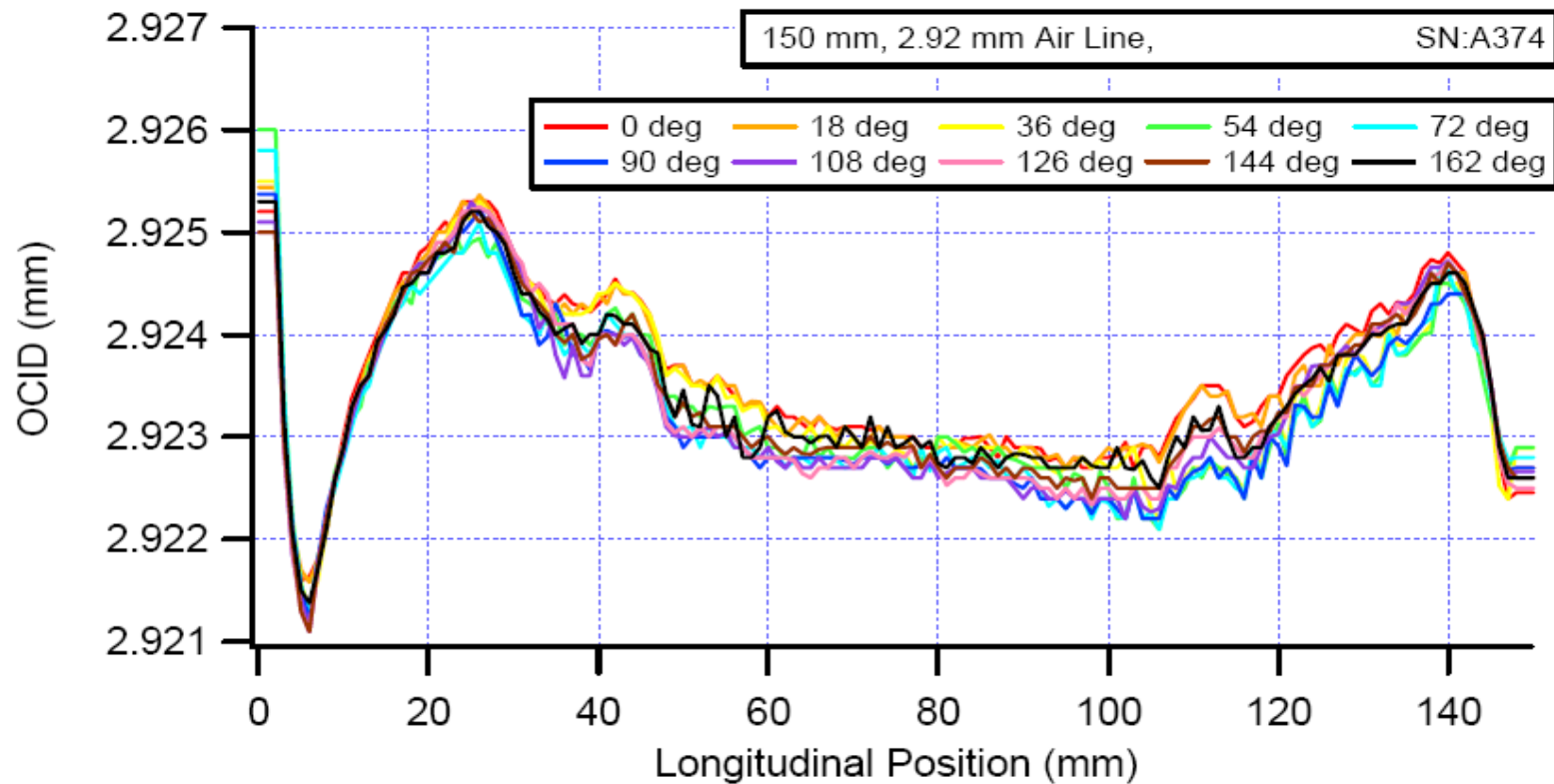
## **Air line calibration services provided at METAS**

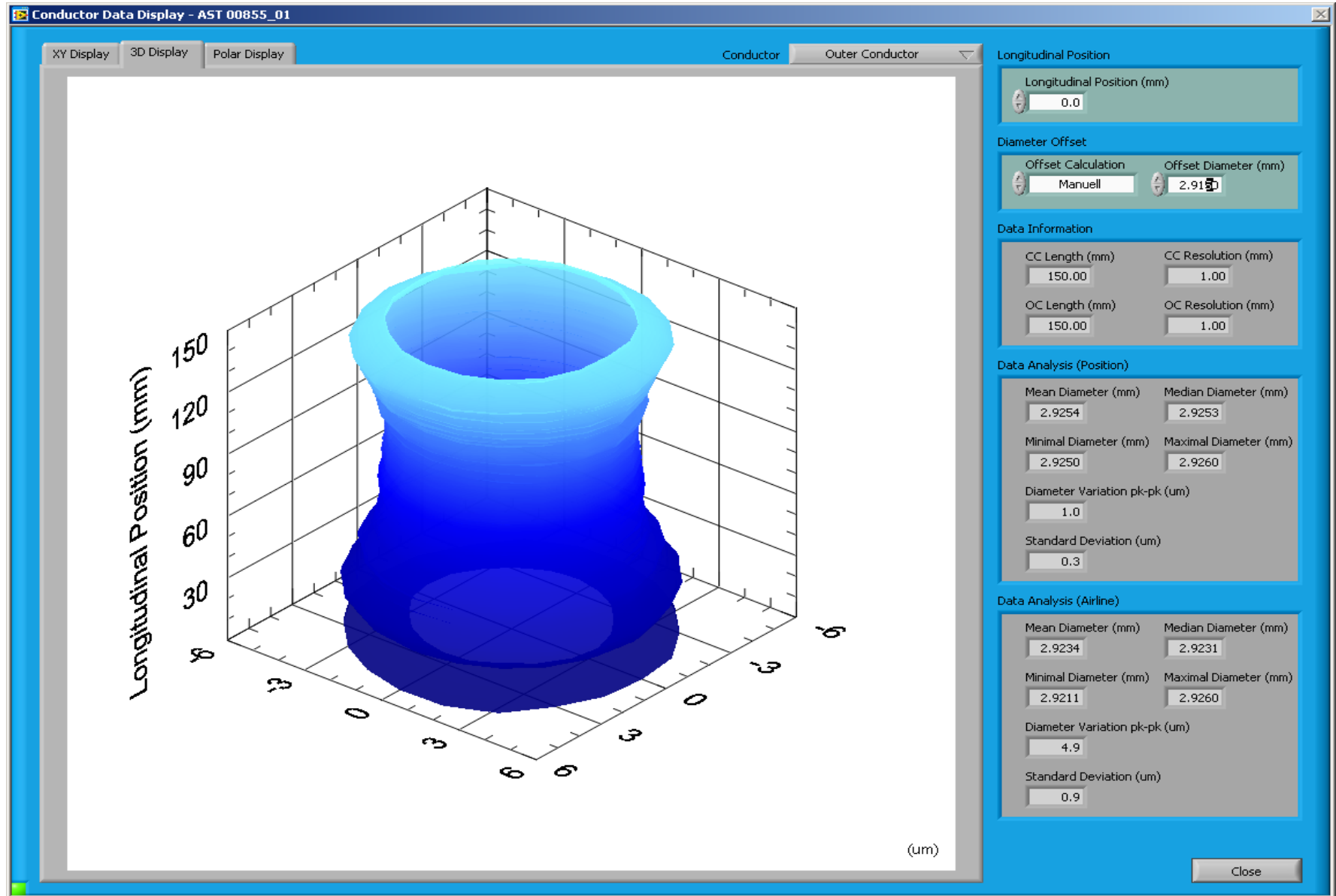
- **Outer Conductor diameter profile (OC)**
- **Centre Conductor diameter profile (CC)**
- **Calculation of the electrical quantities**
- **OC length measurements (direct or compressed)**
- **Pin-depth measurements (direct or compressed)**
- **Pin diameter profile and slotted cross section**
- **In the future: connector modelling (CoMo70)**



# Example: OC cross section f(longitudinal position)

## Graphical Representation: Outer Conductor

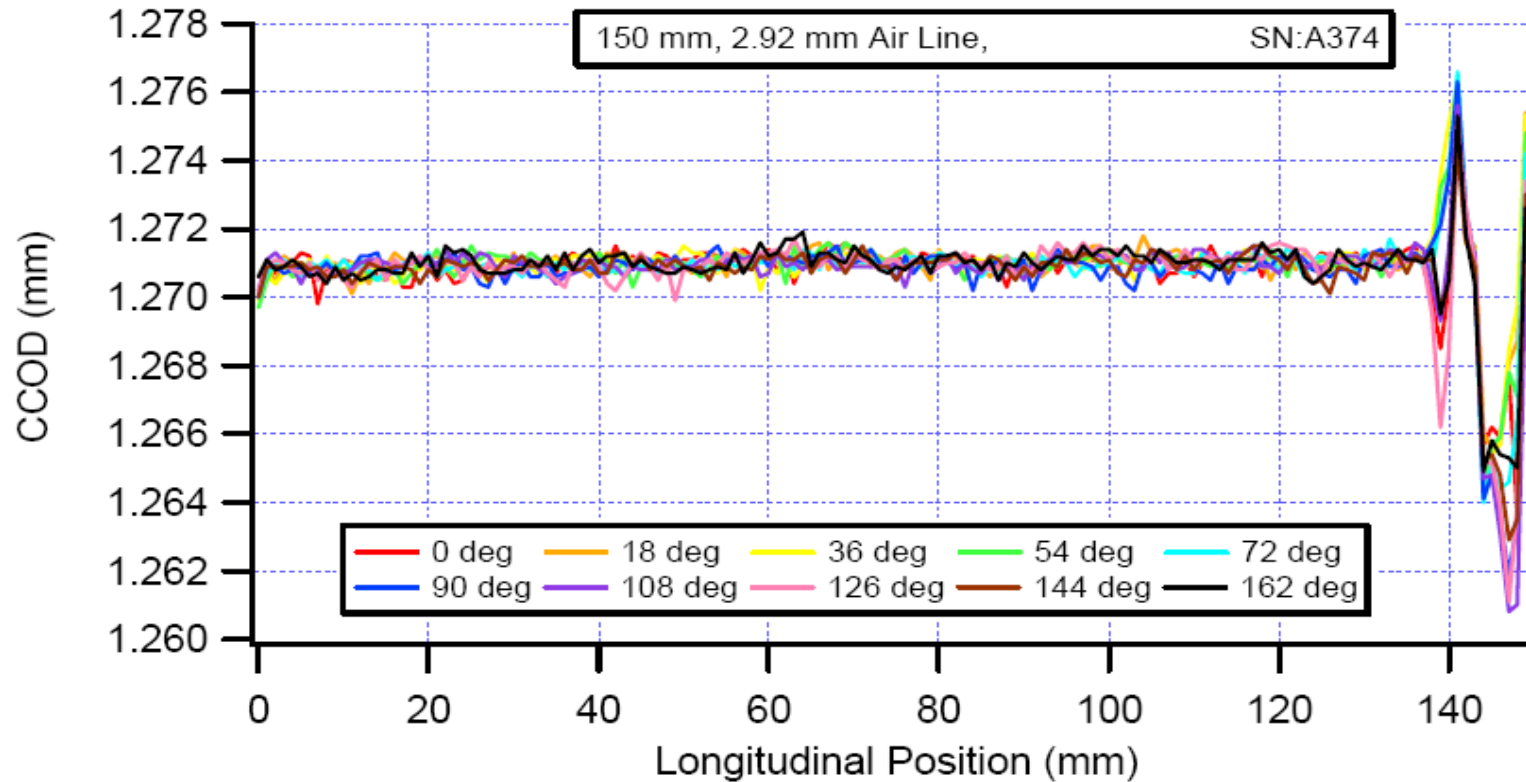






# Example: CC cross section f(longitudinal position)

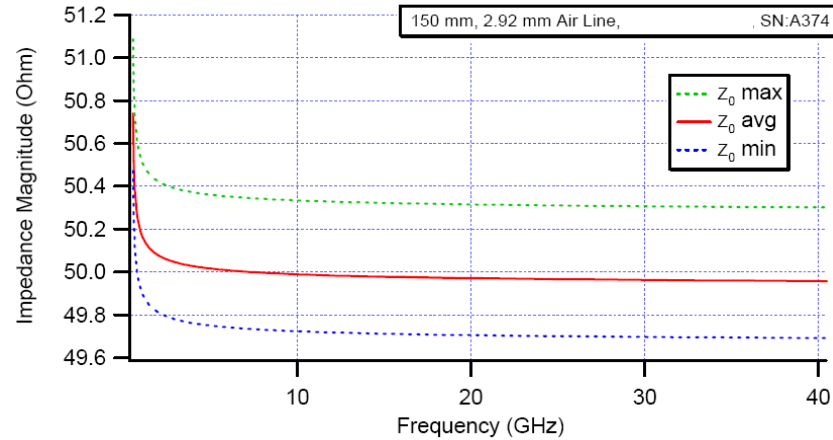
## Graphical Representation: Center Conductor



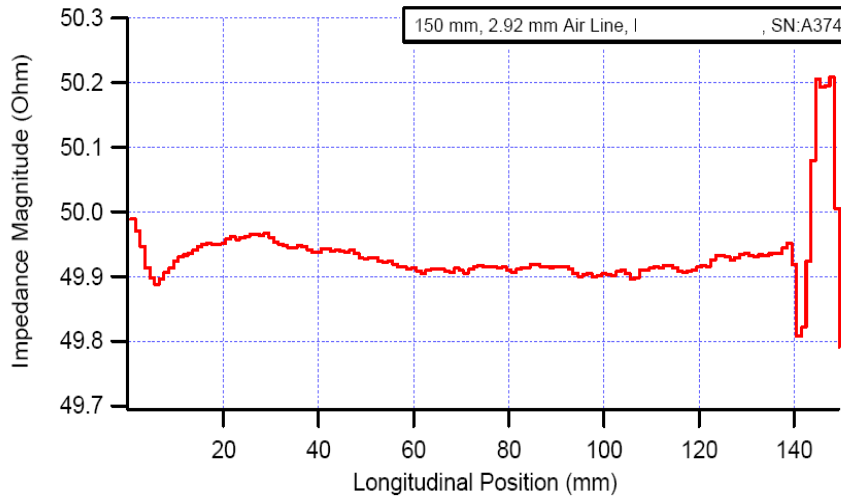
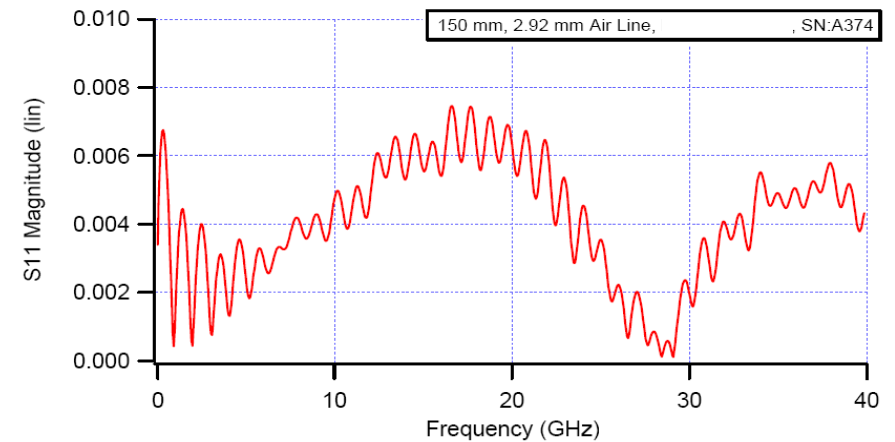


# Example: derived electrical quantities

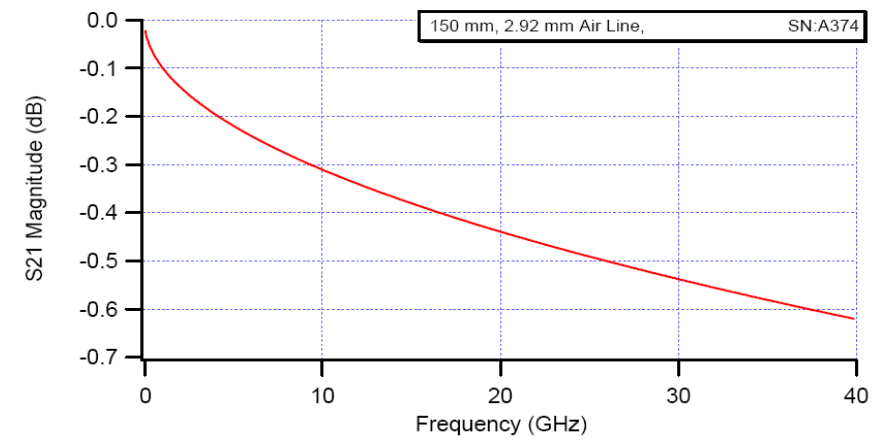
Graphical Representation: Impedance

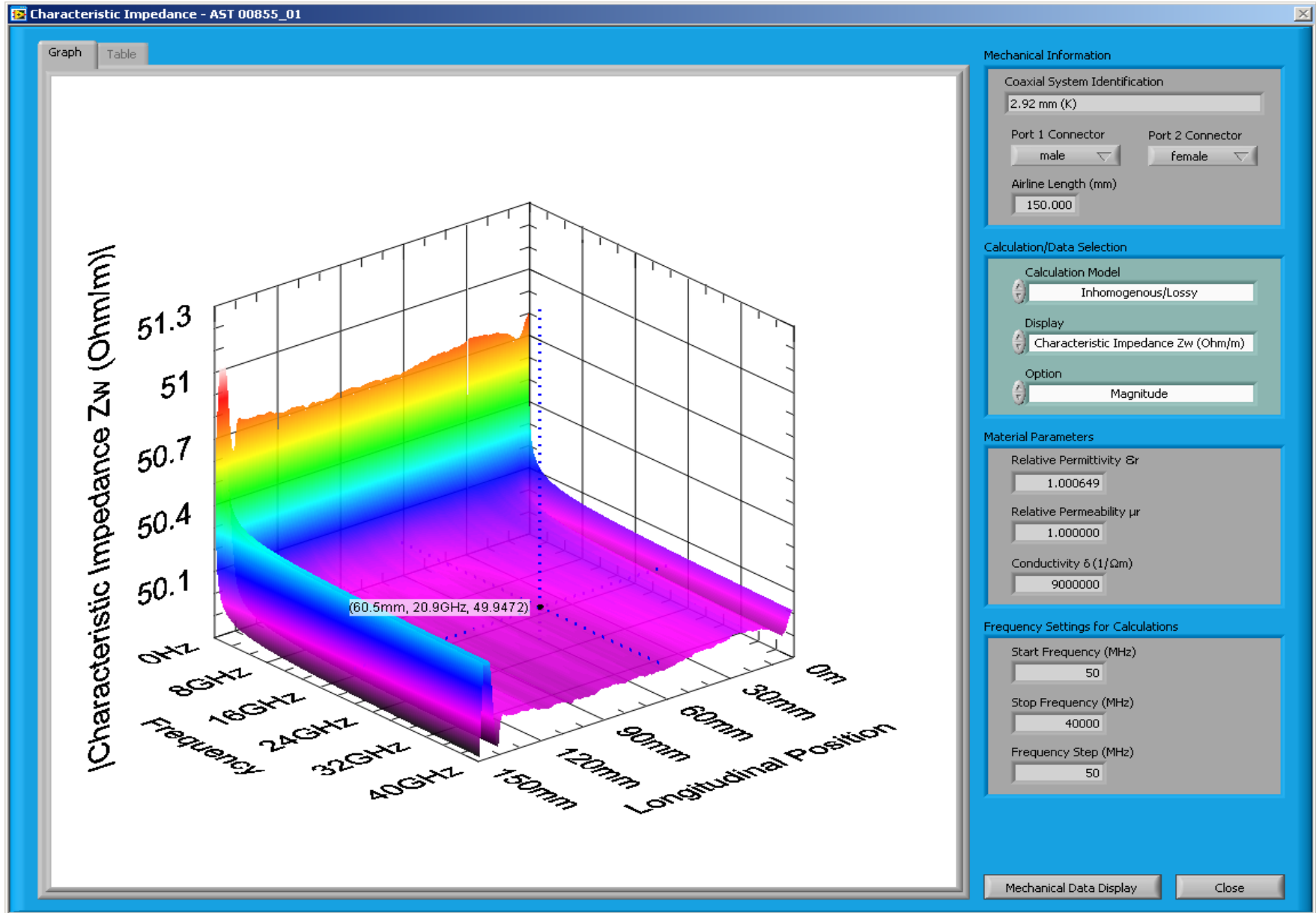


Graphical Representation: Scattering Parameter



**inhomogeneous and lossy case**

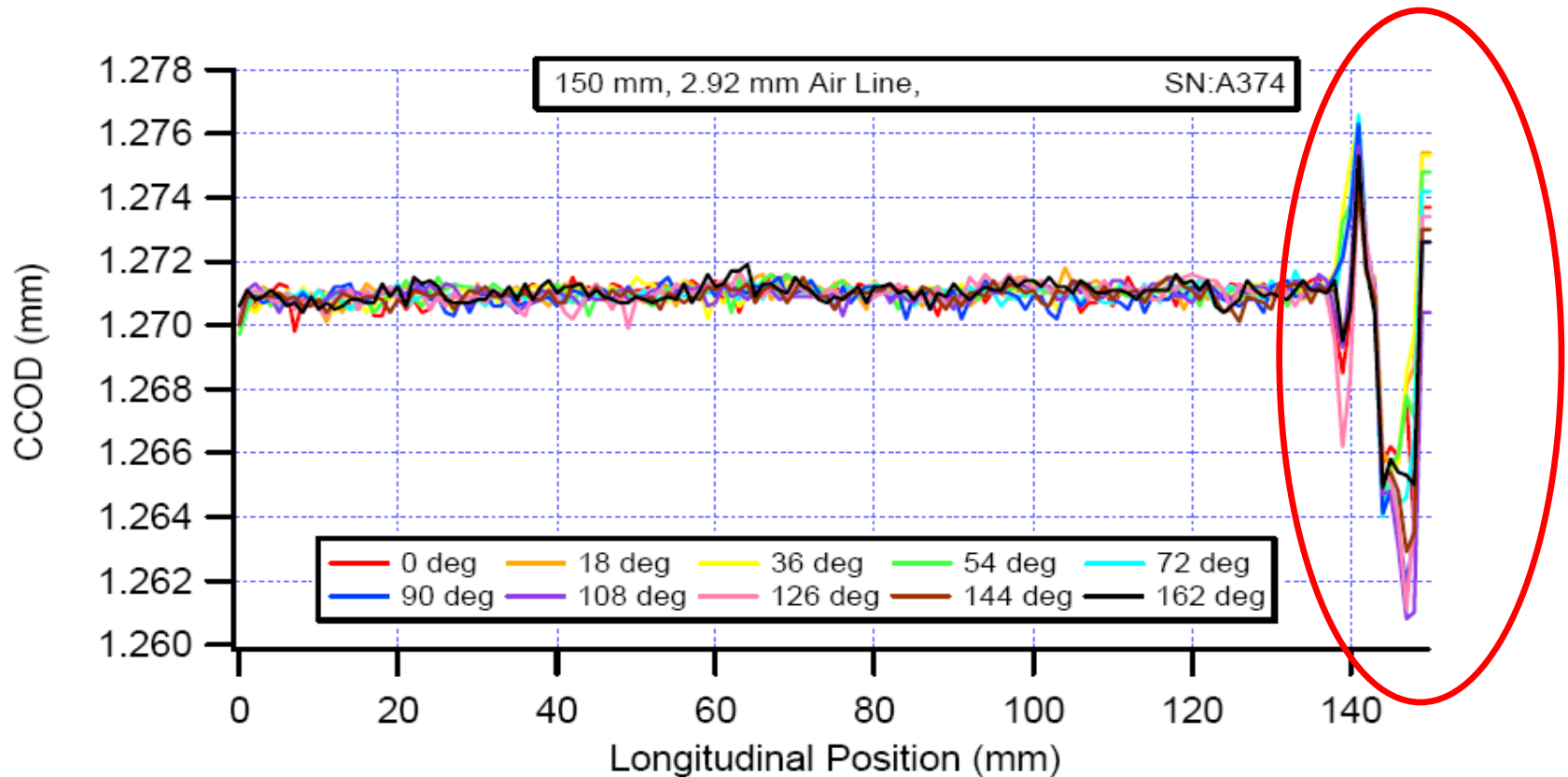






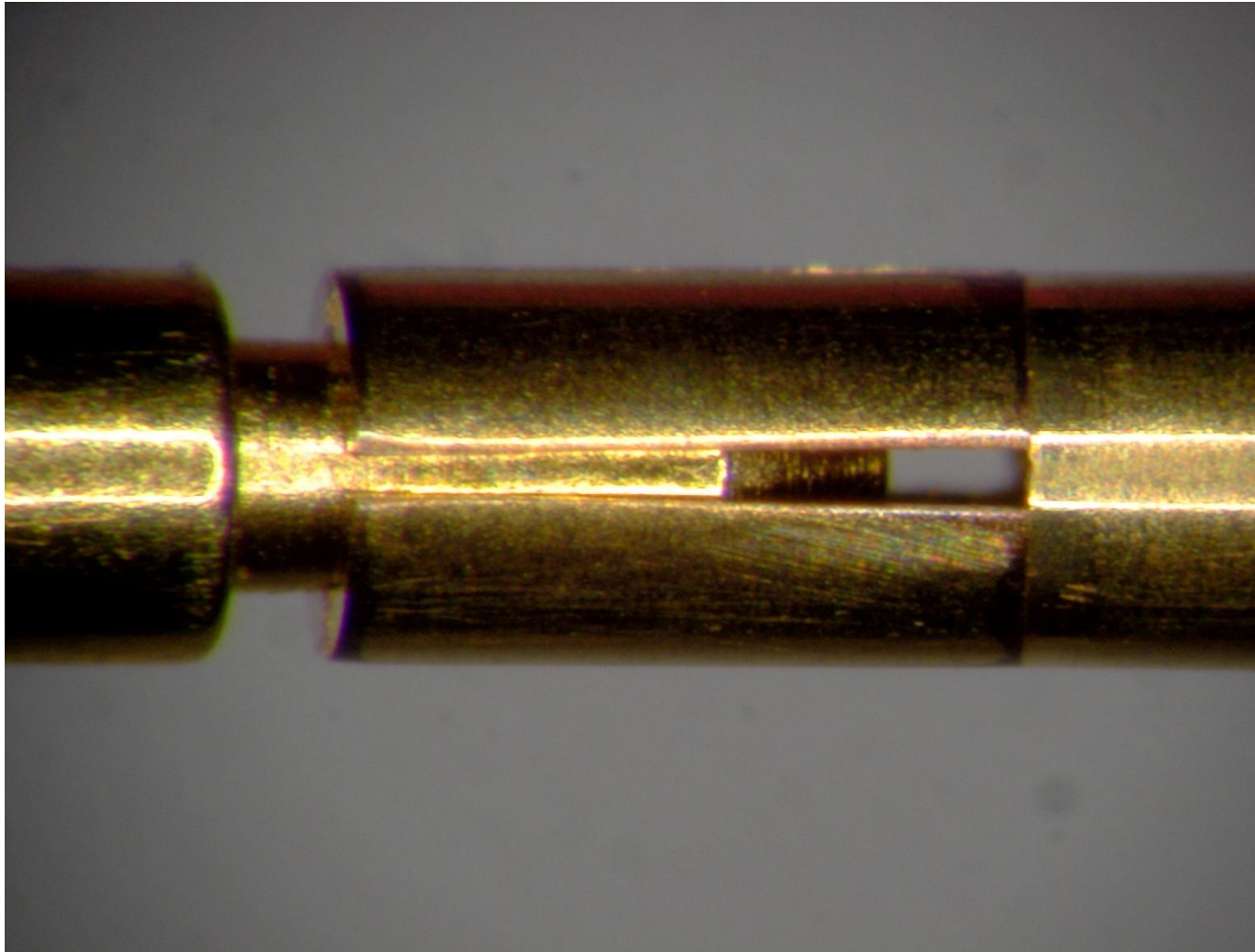
# Example: CC cross section f(longitudinal position) **slotted interface** mated with nominal pin (0.927 mm)

## Graphical Representation: Center Conductor



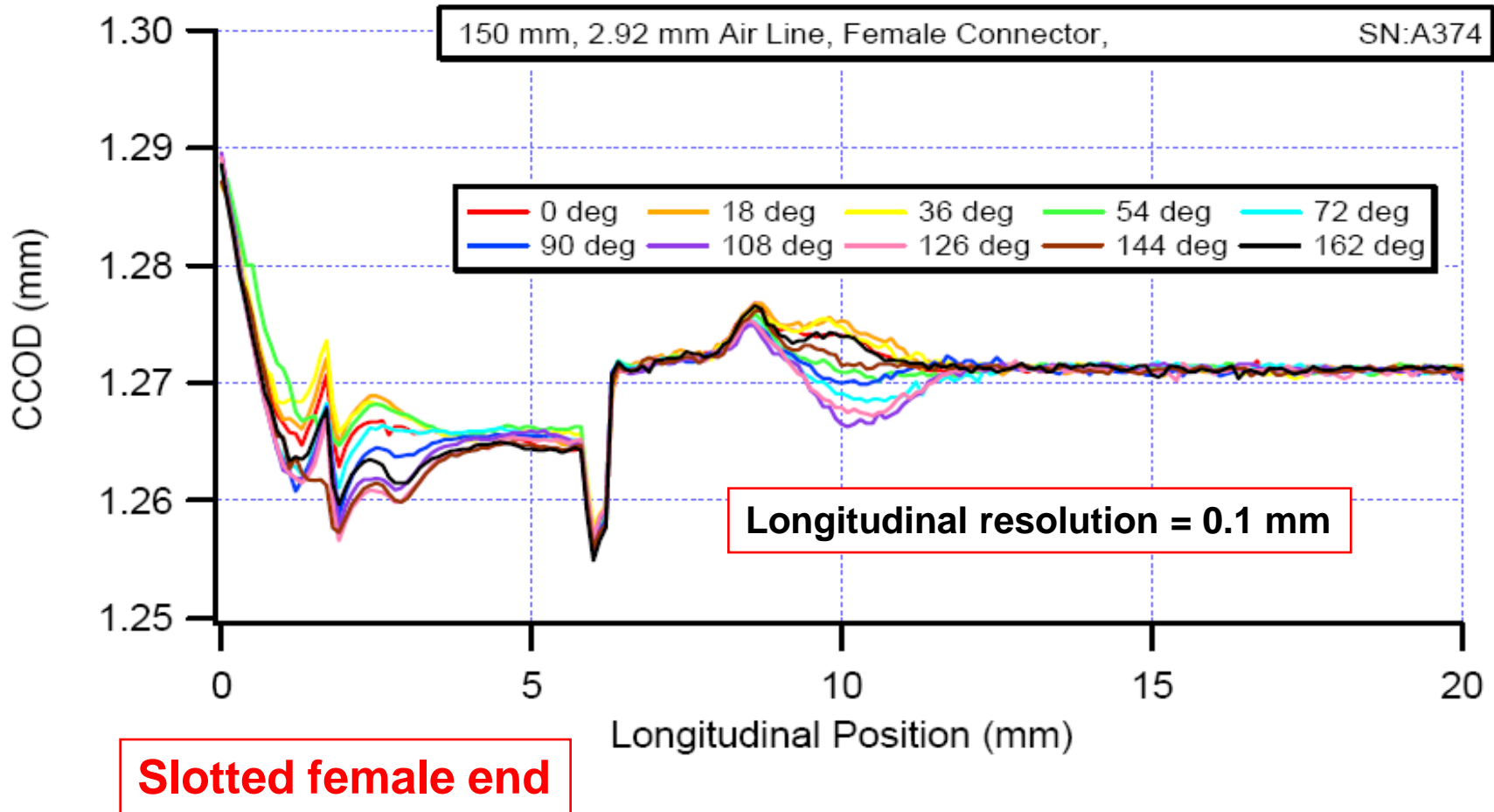


# Example: slotted connector cross section



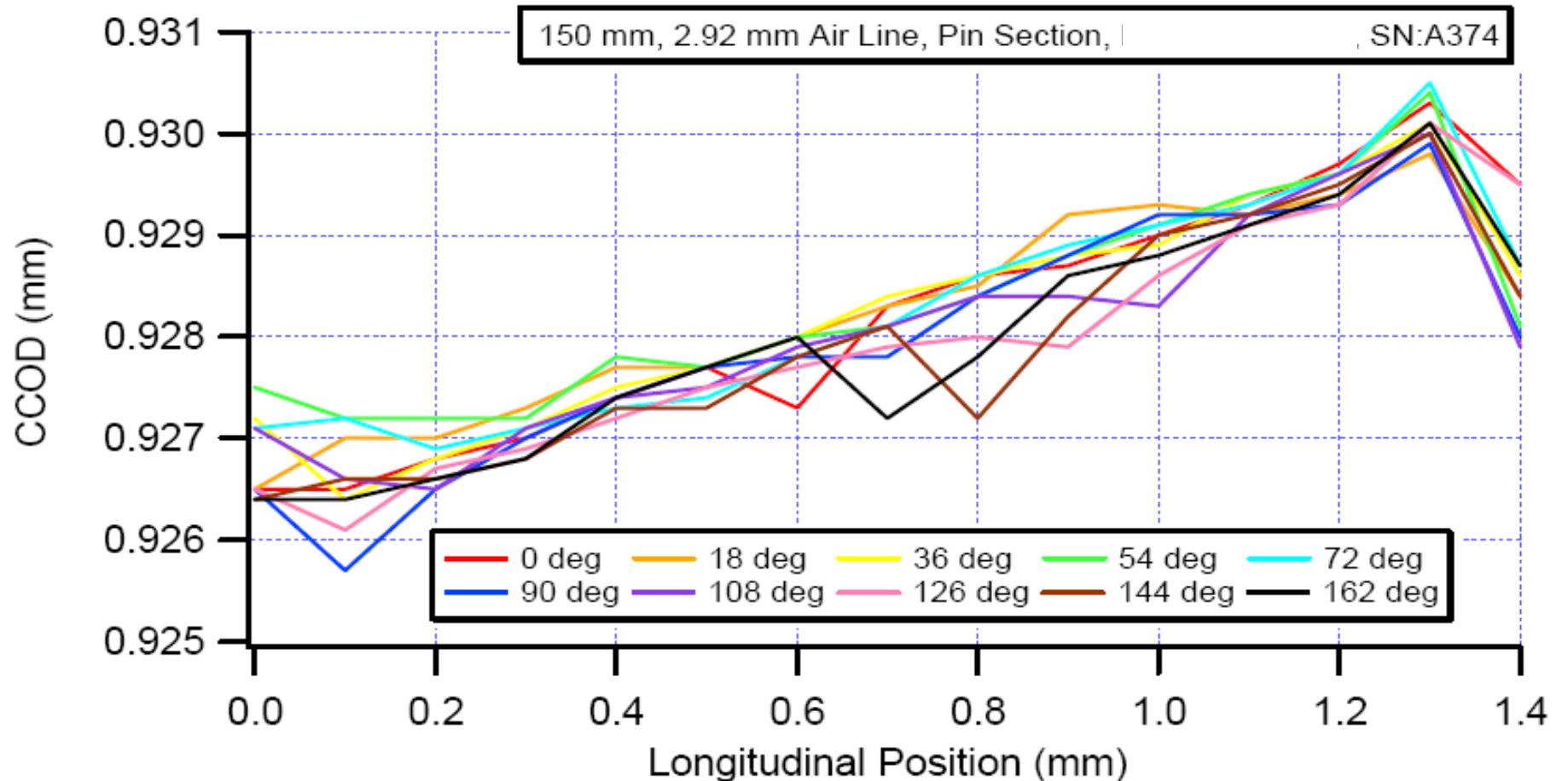


# Graphical Representation: Center Conductor Female Connector Cross Section



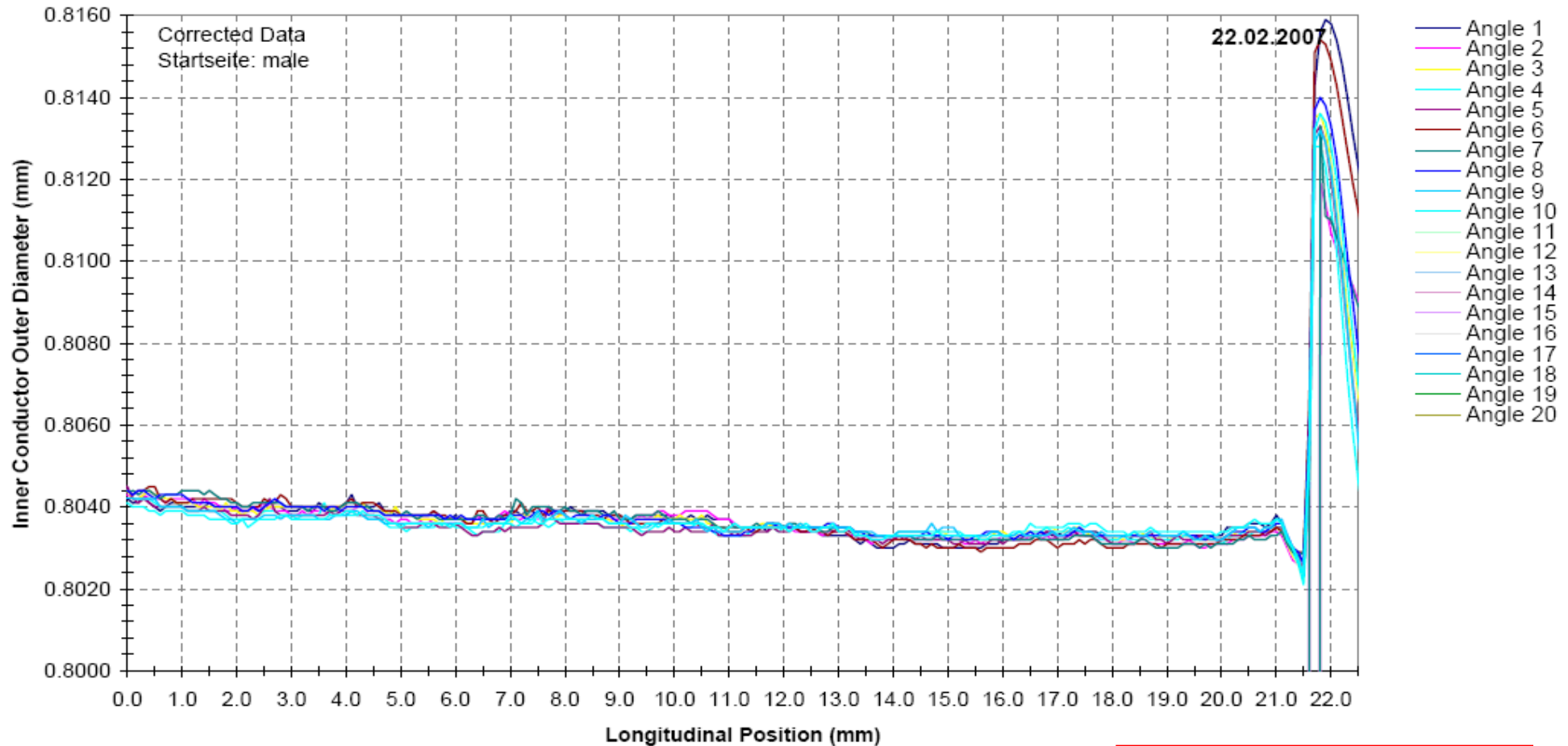


# Graphical Representation: Center Conductor Male Pin Cross Section



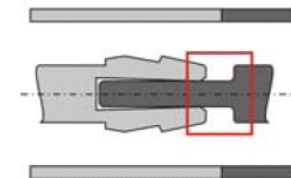
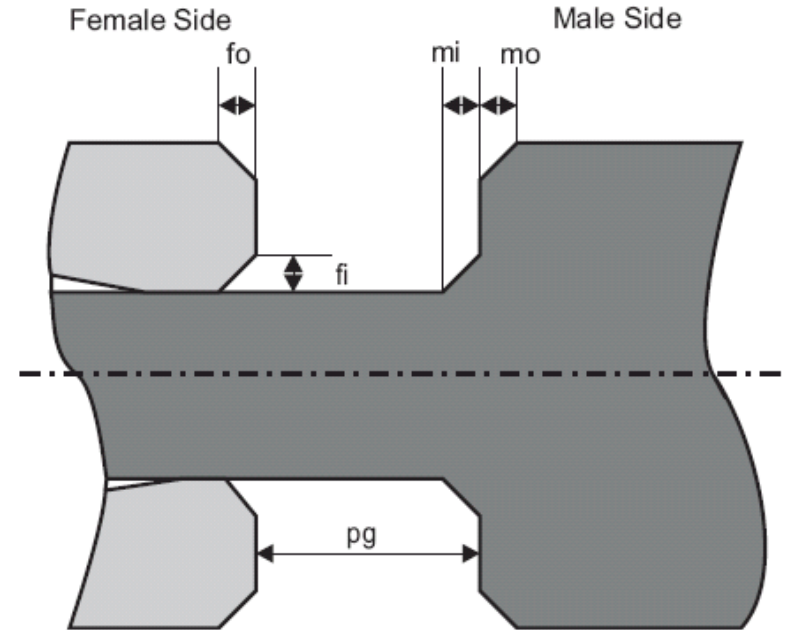
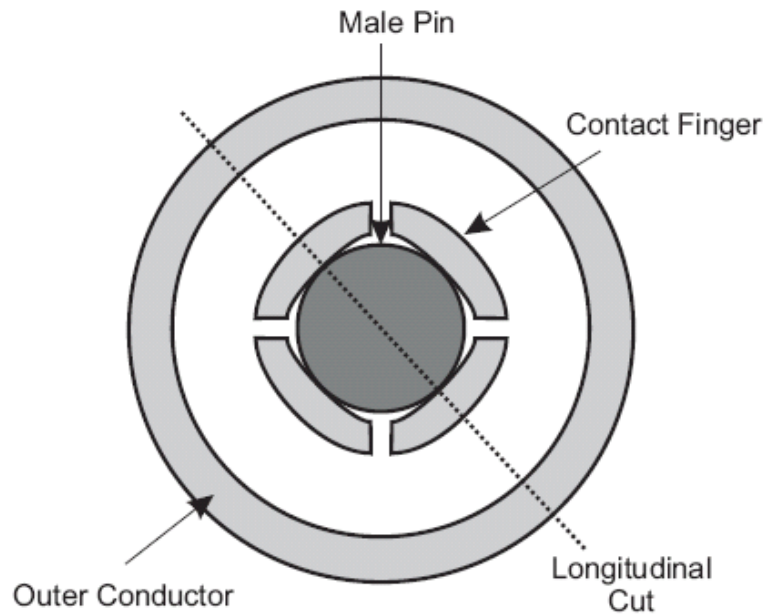


# Example: 1.85 mm CC with connector cross section



**Slotted female end**

# Future calibration services: connector characterisation and modelling



Johannes Hoffmann, ETHZ, CoMo70 project (Paper published at the EuMW 2007, PhD-thesis Nov 2009)



## Customer request

**Calibration of a 2.92 mm(female) cross section when mated with a nominal male pin having a diameter of **0.914 mm** (according the new IEEE Standard P287-2007)**

**Problem:** the reference 2.92 mm (male) pins used at METAS have a nominal diameter of **0.927 mm +/-0.001 mm** (same reference pin used as for the 3.5 mm system)

**Resulting pin diameter difference = -0.013 mm**



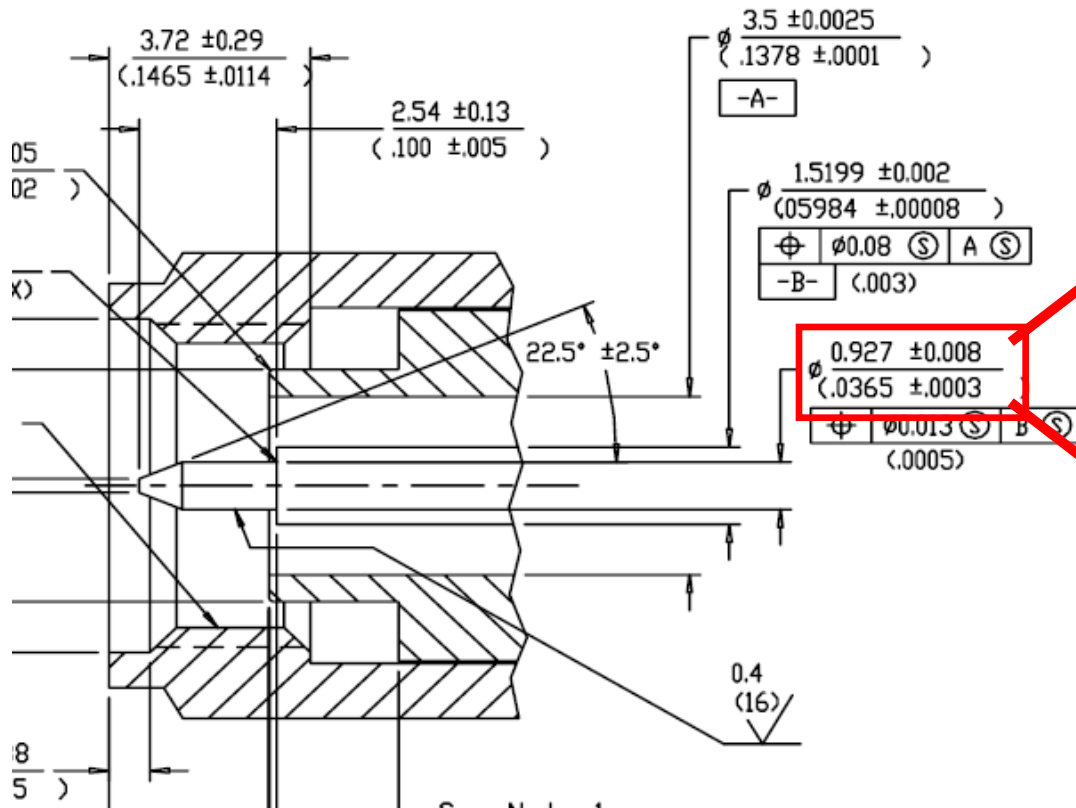


# IEEE Standard for Precision Coaxial Connectors (DC to 110 GHz)

**IEEE Std 287™-2007**

(Revision of  
IEEE Std 287-1968)

## Detail specifications for the precision coaxial 3.5 mm male connector (LPC)



**Ø 0.927 mm +/- 0.008 mm**

**Ø 0.919 mm - Ø 0.935 mm**

**Conversion factor: 25.4**

**Ø 0.0365 in +/- 0.0003 in**

**Ø 0.0362 in - Ø 0.0368 in**

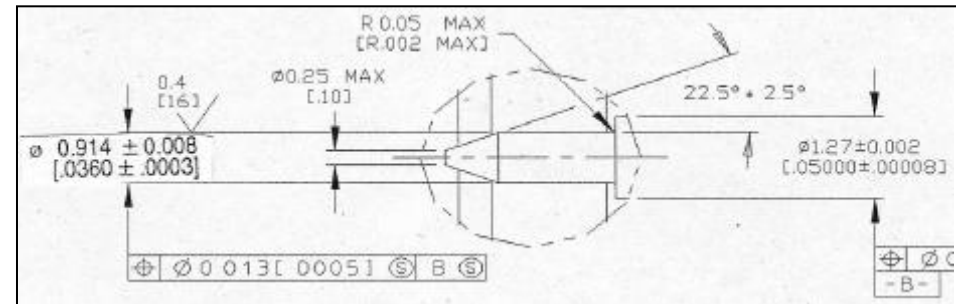
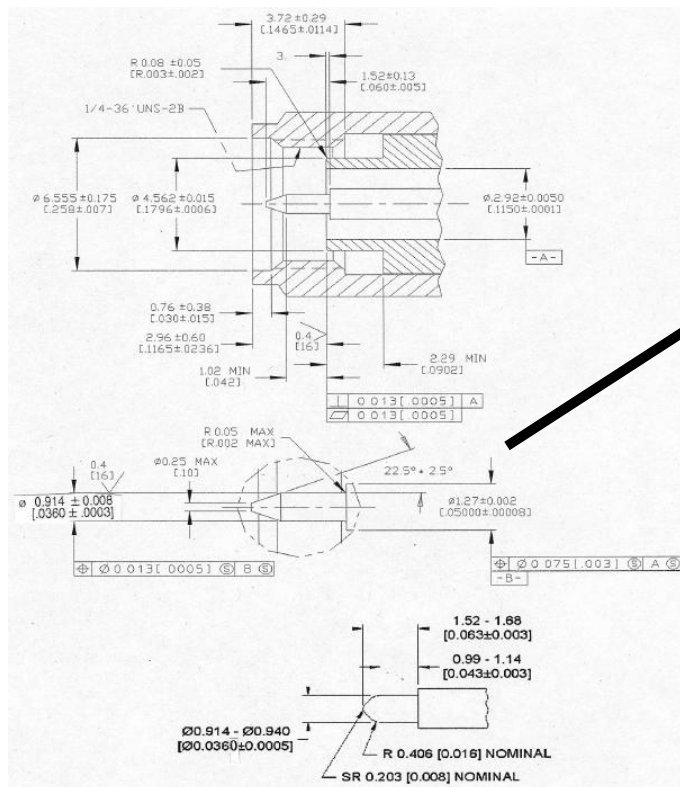


# IEEE Standard for Precision Coaxial Connectors (DC to 110 GHz)

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## Detail specifications for the precision coaxial 2.92 mm male connector (LPC)



→ **Ø 0.914 mm +/- 0.008 mm**  
**Ø 0.906 mm - Ø 0.922 mm**

**Conversion factor: 25.4**

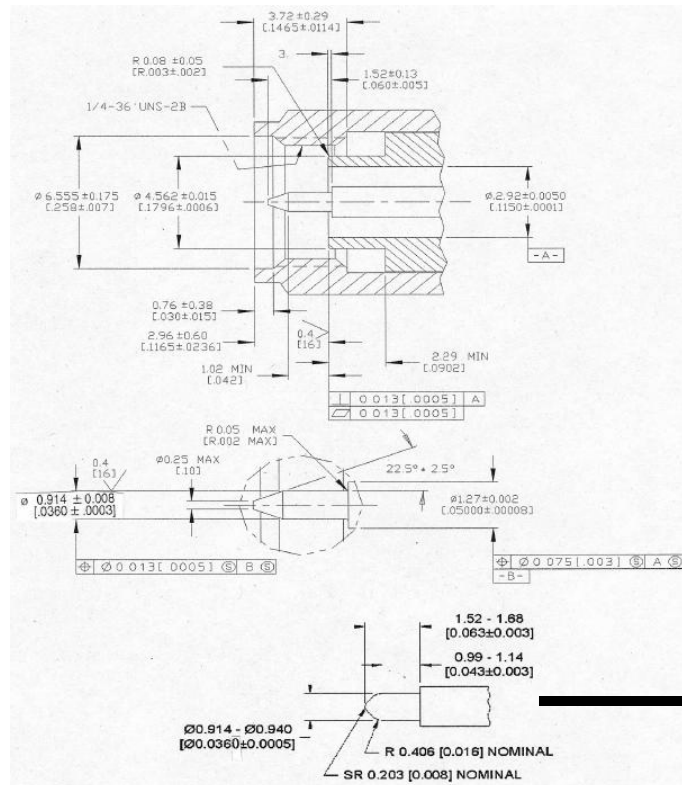
→ **Ø 0.0360 in +/- 0.0003 in**  
**Ø 0.0359 in - Ø 0.0363 in**



# IEEE Standard for Precision Coaxial Connectors (DC to 110 GHz)

**IEEE Std 287™-2007**  
(Revision of  
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Detail specifications for the precision coaxial 2.92 mm male connector (LPC)



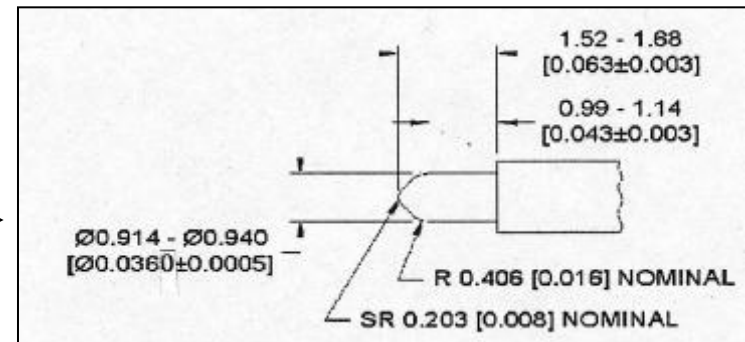
$\varnothing 0.927 \text{ mm} \pm 0.013 \text{ mm}$

→  $\varnothing 0.914 \text{ mm} - \varnothing 0.940 \text{ mm}$

**Conversion factor: 25.75**

→  $\varnothing 0.0360 \text{ in} \pm 0.0005 \text{ in}$

$\varnothing 0.0355 \text{ in} - \varnothing 0.0365 \text{ in}$



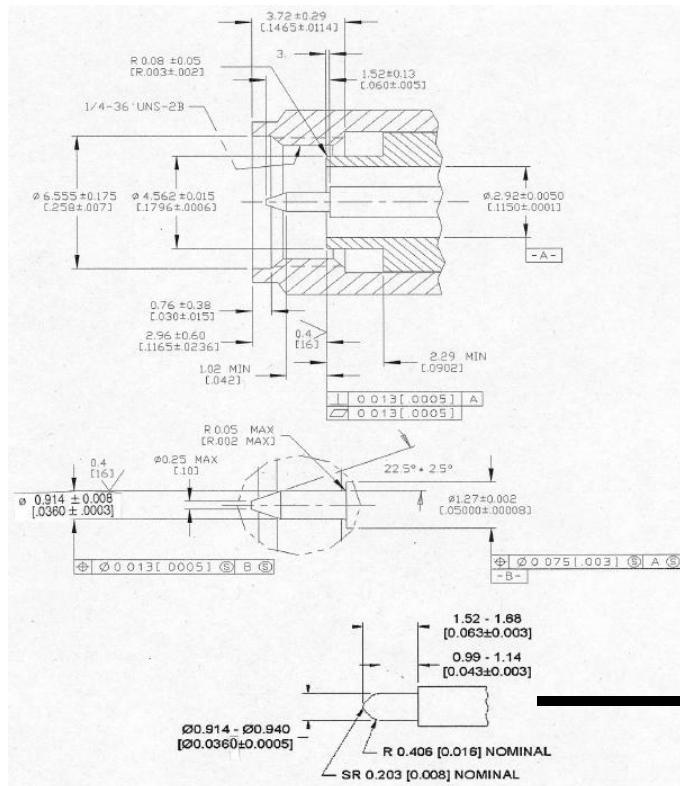


# IEEE Standard for Precision Coaxial Connectors (DC to 110 GHz)

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Detail specifications for the precision coaxial 2.92 mm male connector (LPC)



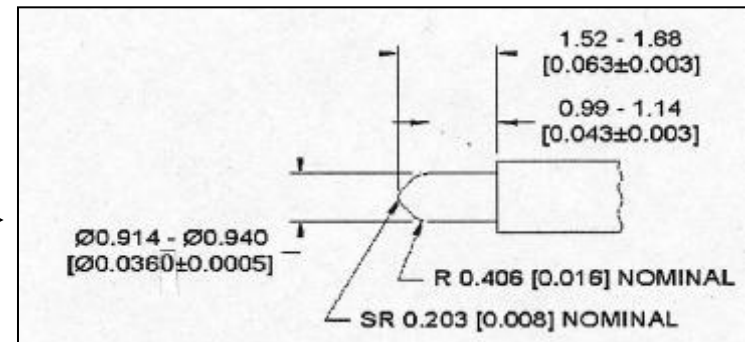
$\phi 0.927$  mm +/- 0.013 mm

→  $\phi 0.914$  mm -  $\phi 0.940$  mm

**Mean comply with 3.5 mm pin spec !**

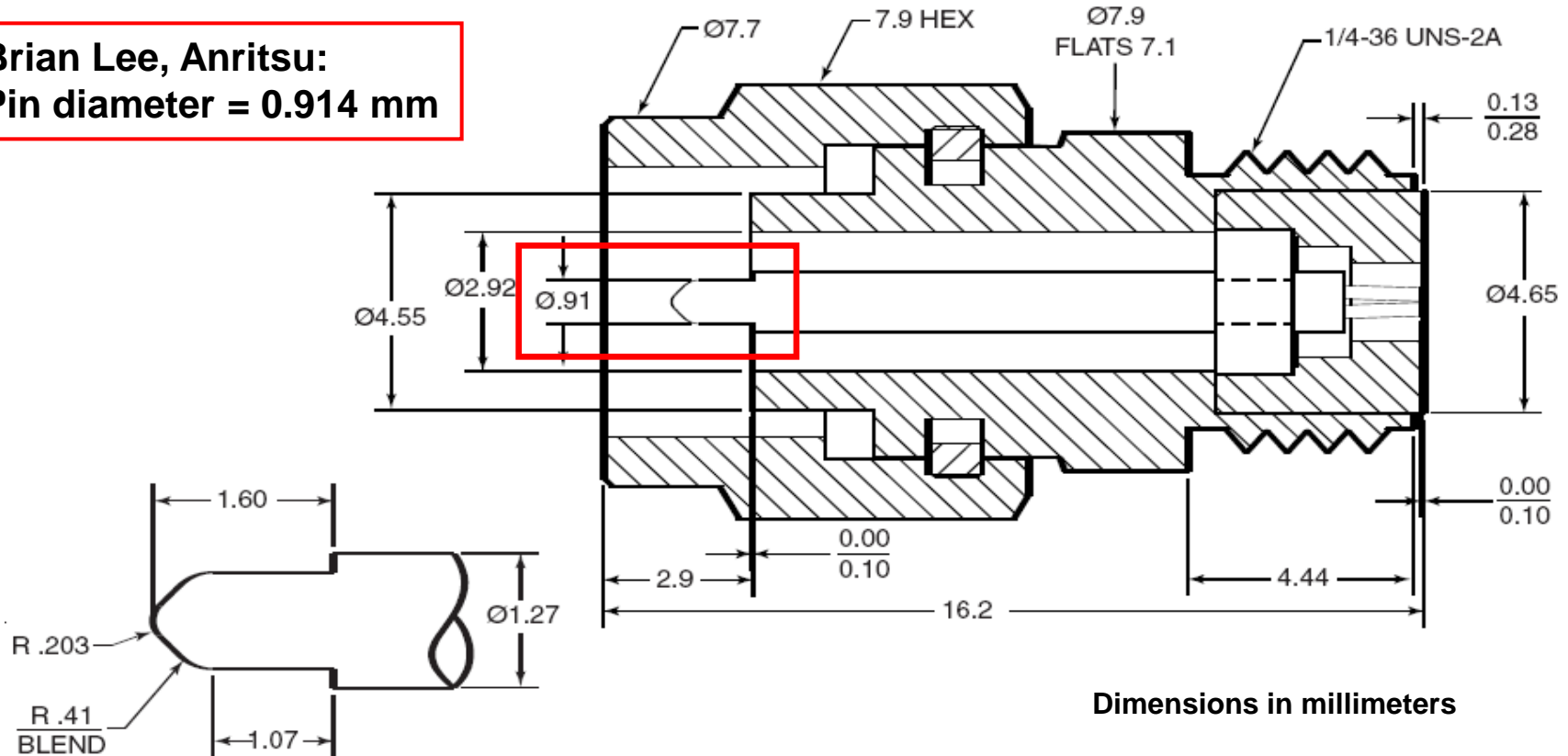
→  $\phi 0.0360$  in +/- 0.0005 in

**Comply with other 2.92 mm pin spec**



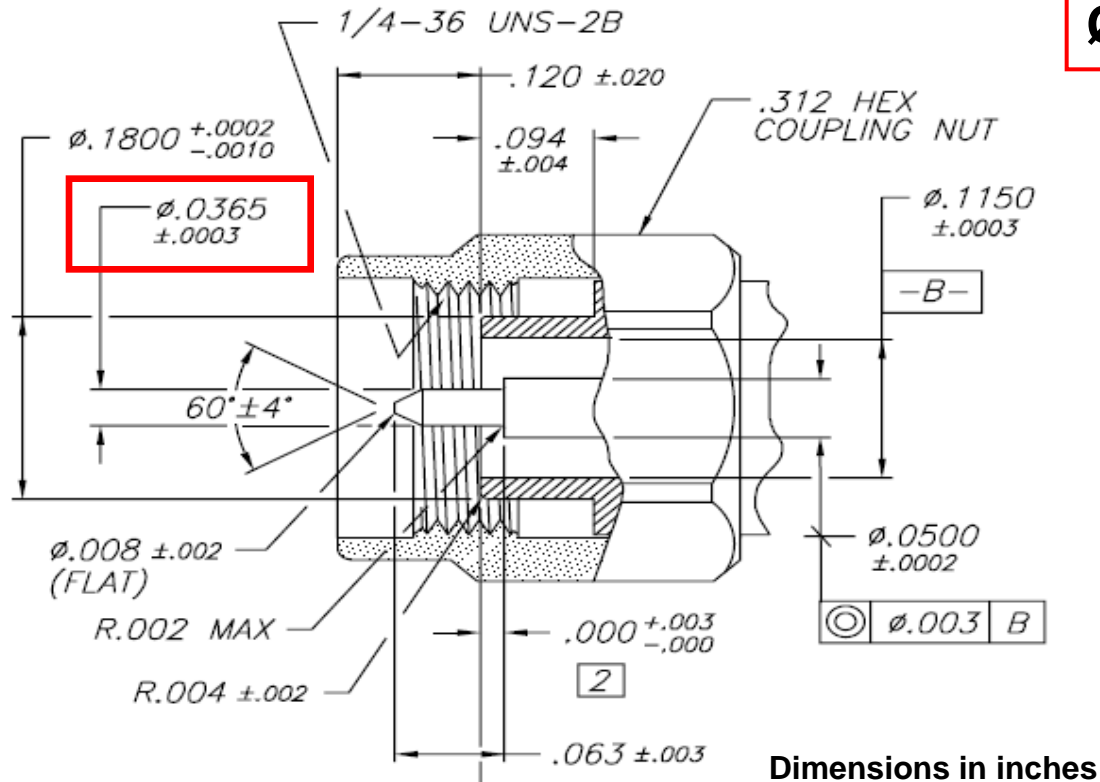
## Anritsu: Precision RF & Microwave Components product catalog (2.92 mm or K connector specifications)

Brian Lee, Anritsu:  
Pin diameter = 0.914 mm



**3.5 mm<sub>IEEE</sub> – 2.92 mm<sub>Anritsu</sub> nom. pin diameter difference = - 0.013 mm**

## Maury: Precision 2.92 mm (K) specifications (drawing 5E-063)



**$\phi 0.927 \text{ mm} \pm 0.008 \text{ mm}$**

**Same nominal pin diameter specification used from:**

- Rosenberger
- Rohde&Schwarz
- Agilent
- Huber+Suhner
- ...

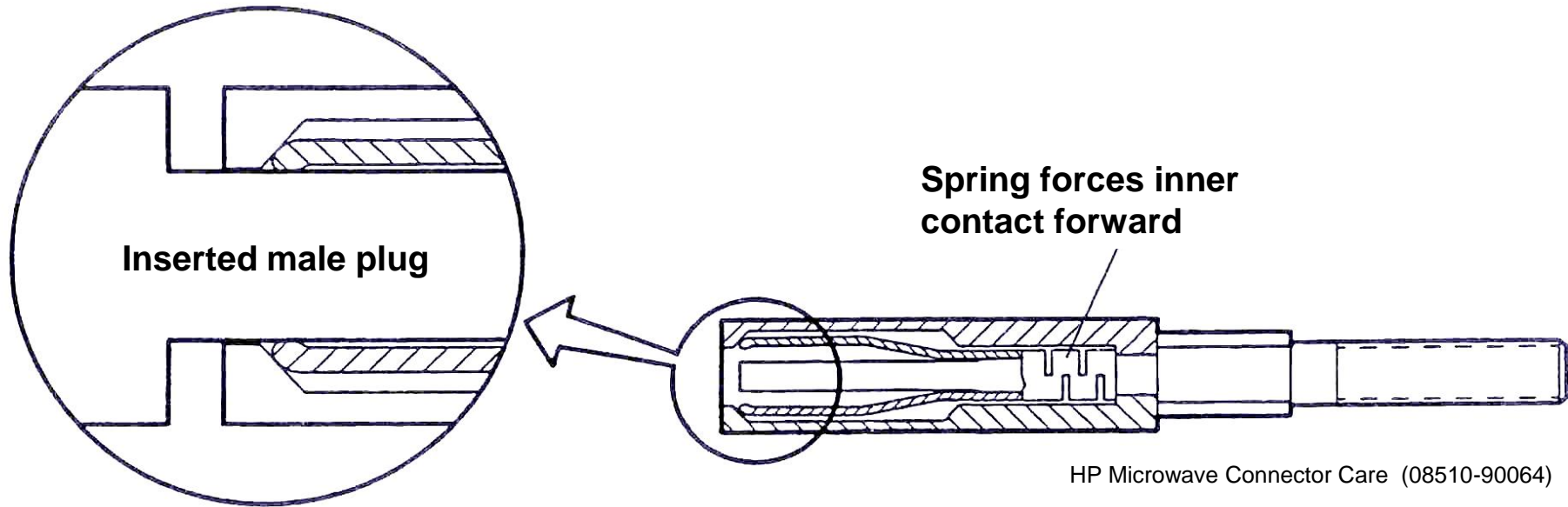
**$3.5 \text{ mm}_{\text{IEEE}} - 2.92 \text{ mm}_{\text{Maury}} \text{ nom. pin diameter difference} = - 0.000 \text{ mm}$**



# **Pin effects and traceability issues**

- **Slotted versus slotless connectors**
- **Spreading of the contact fingers**
- **Length and diameter profile of the male pin**
- **Contact point and design of the fingers**
- **Contact resistance: plating, material properties**

# Slotted versus slotless female connector design



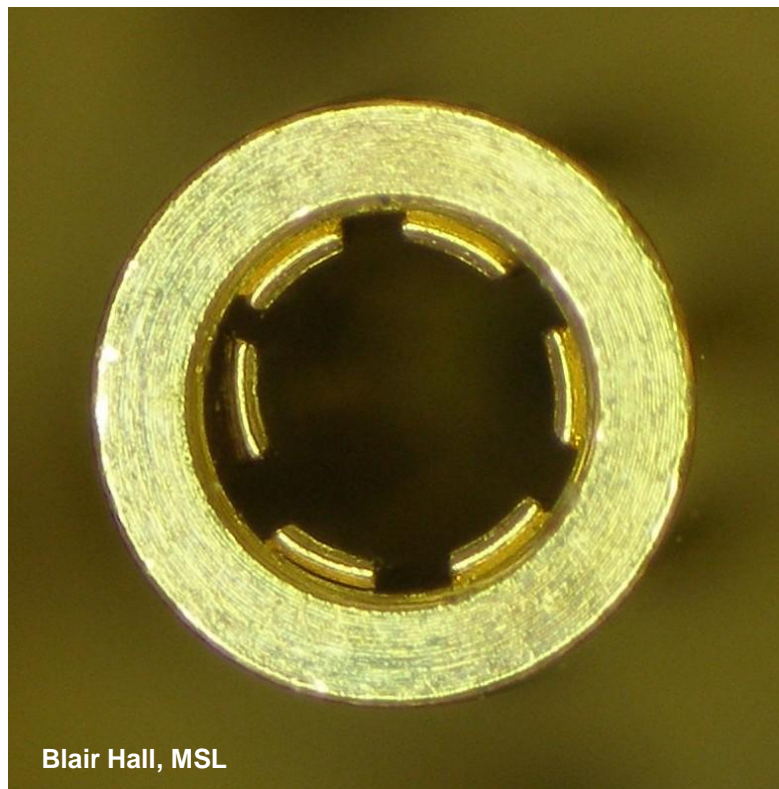
Detail of precision slotless female centre conductor developed by Agilent

Slotless female conductors are available for **Type-N**, **3.5 mm** and **2.4 mm** connectors

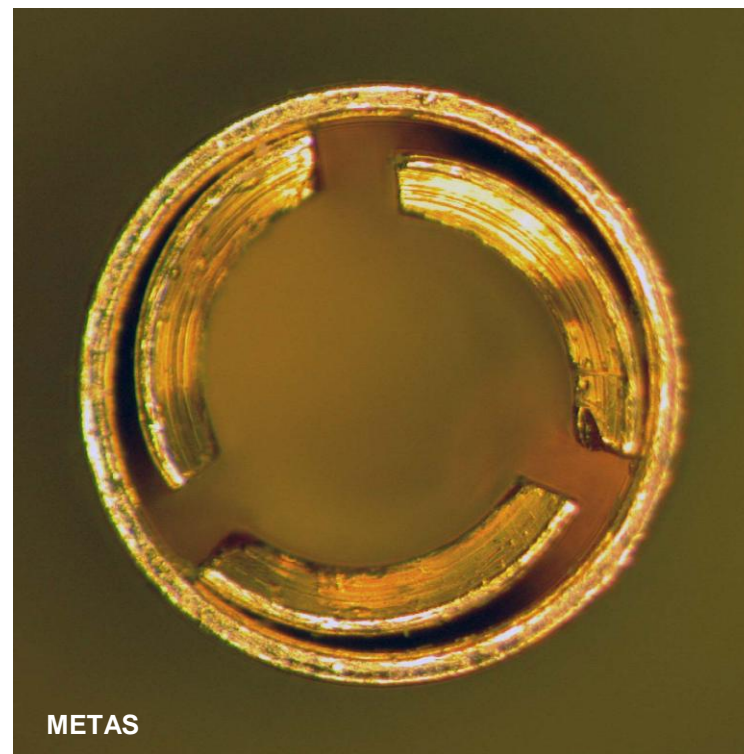
They are **not** available for **2.92 mm (K)** and **1.85 mm (V)** connectors



## Slotless female connector design examples: 3.5 mm



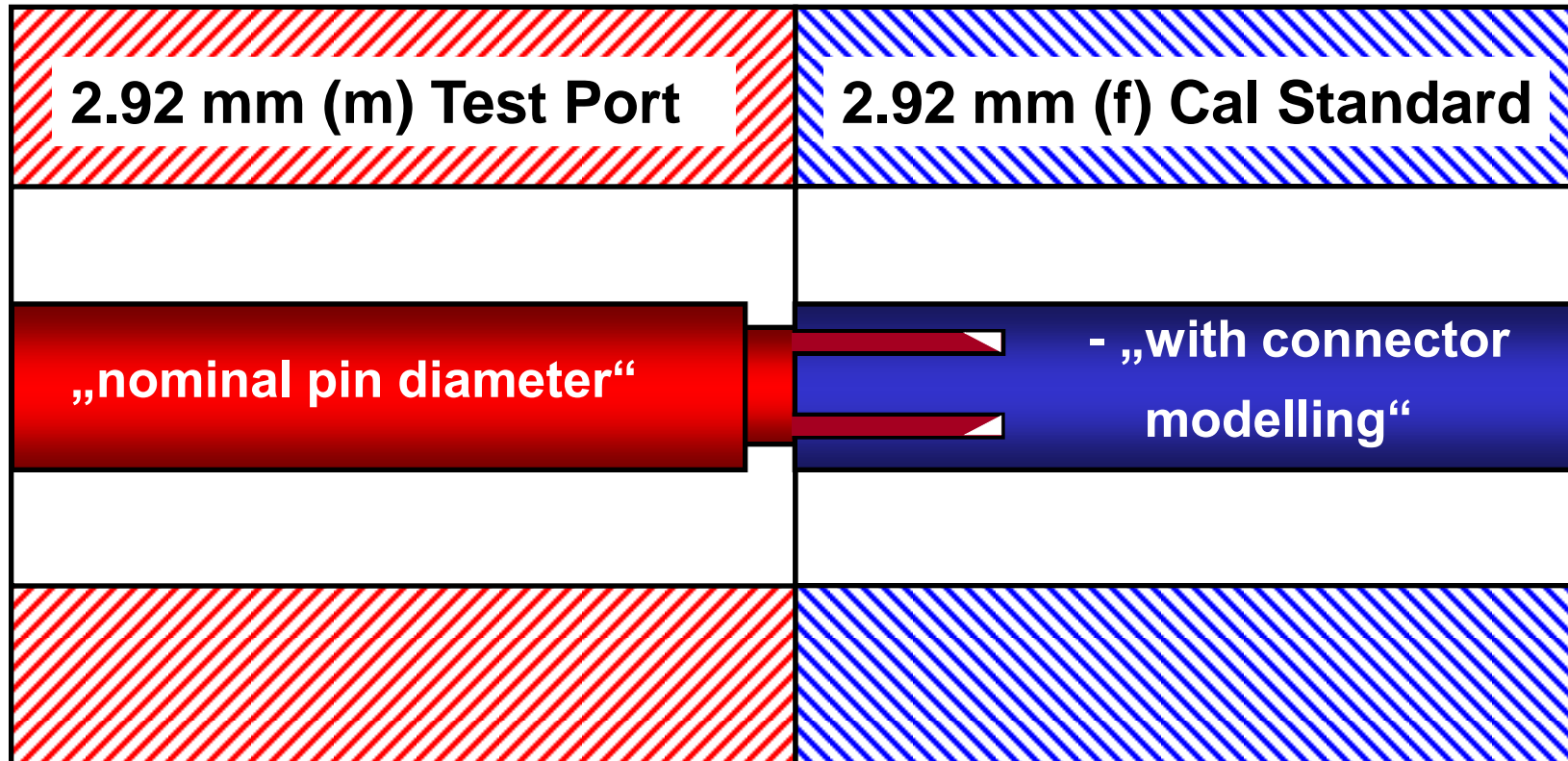
**3.5 mm contact developed by Agilent**



**WSMA contact developed by Anritsu**



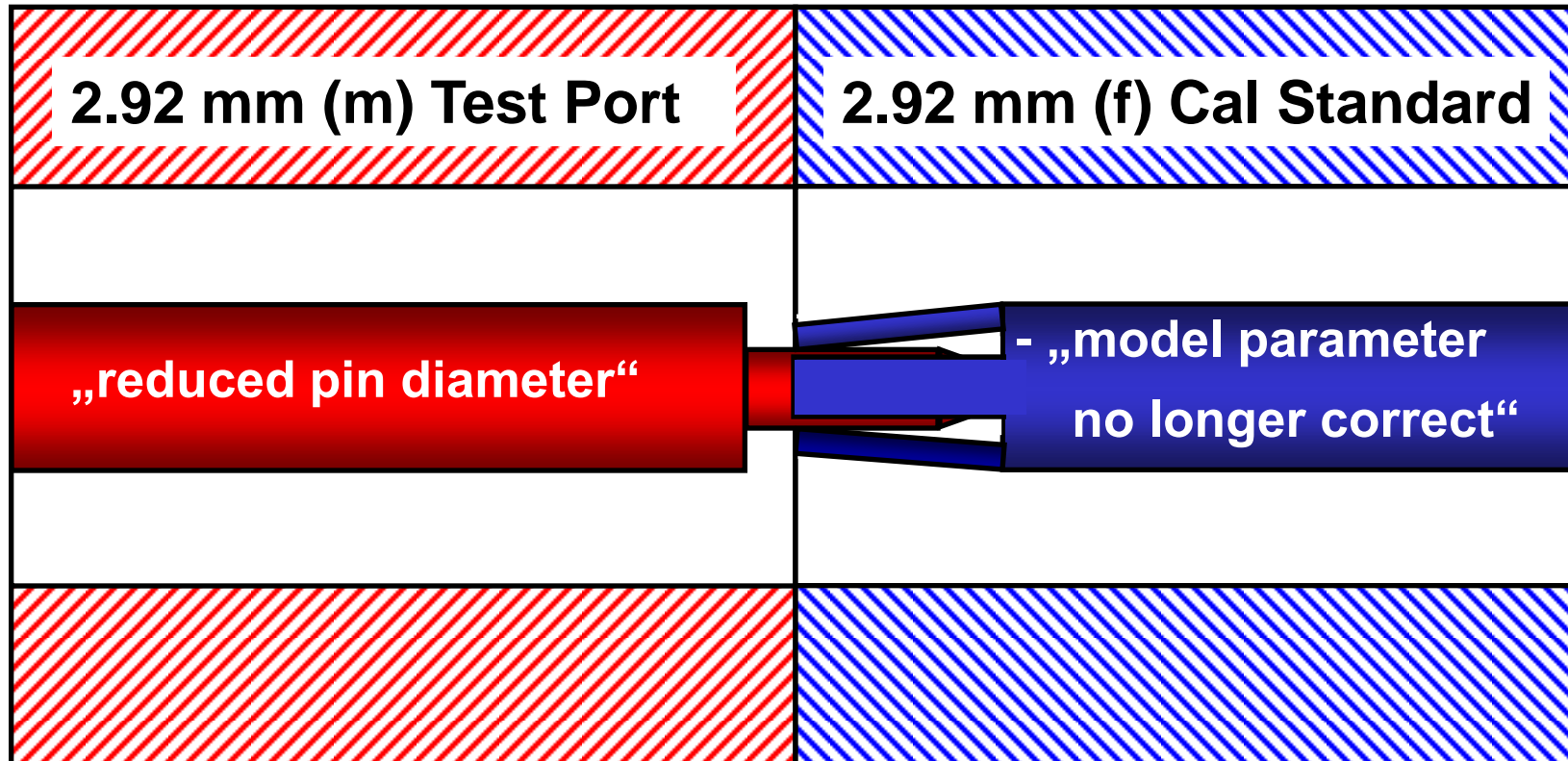
- Slotted female CC
- Cal Standard „corrected“



**The error introduced by the TP will become „absorbed“ into the error box of the calibration model of the VNA**



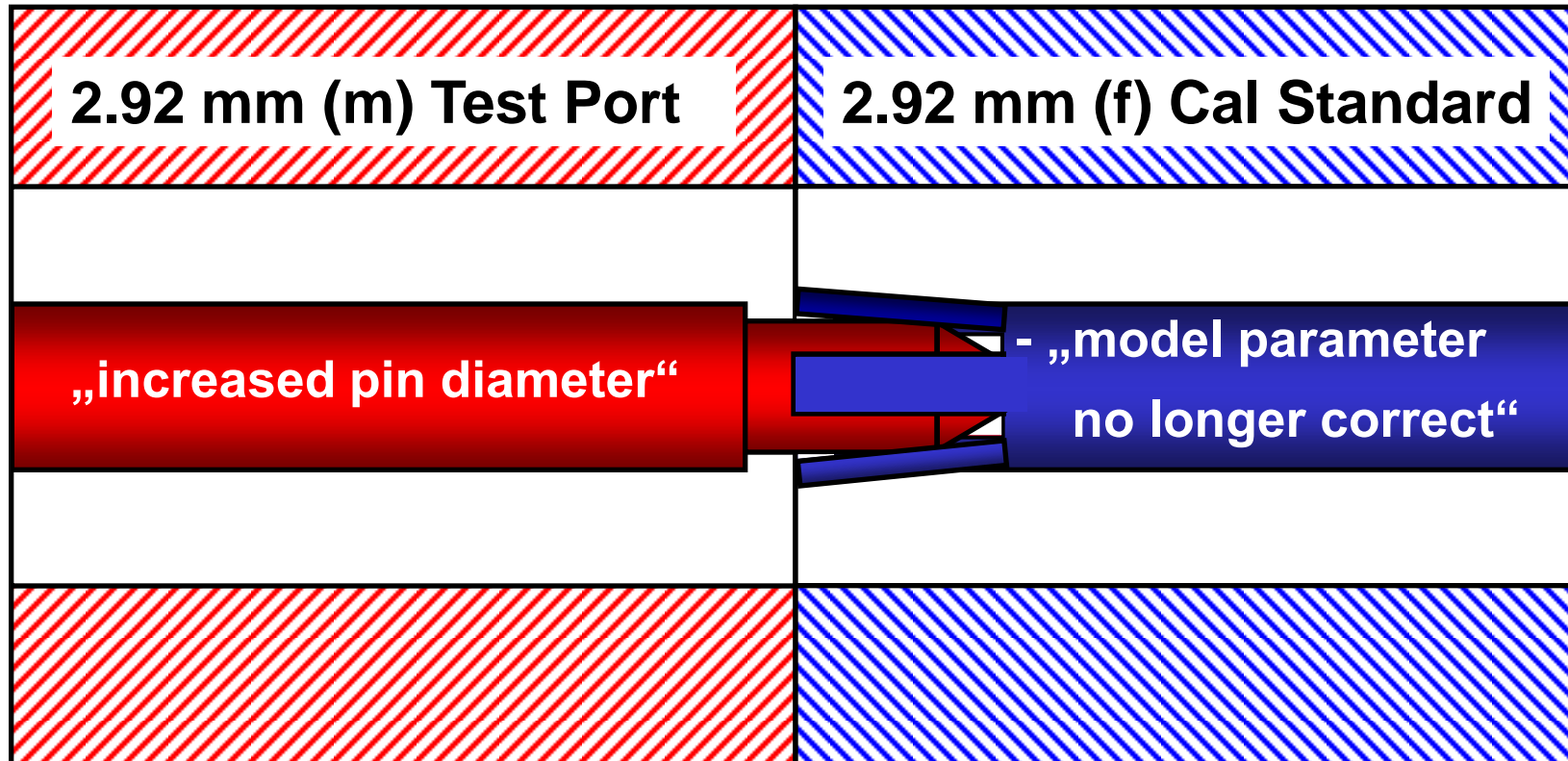
- Slotted female CC
- **Problem:** pin diameter



**The error introduced by the TP pin will change the impedance characteristics of the connected calibration standard**



- Slotted female CC
- **Problem:** pin diameter



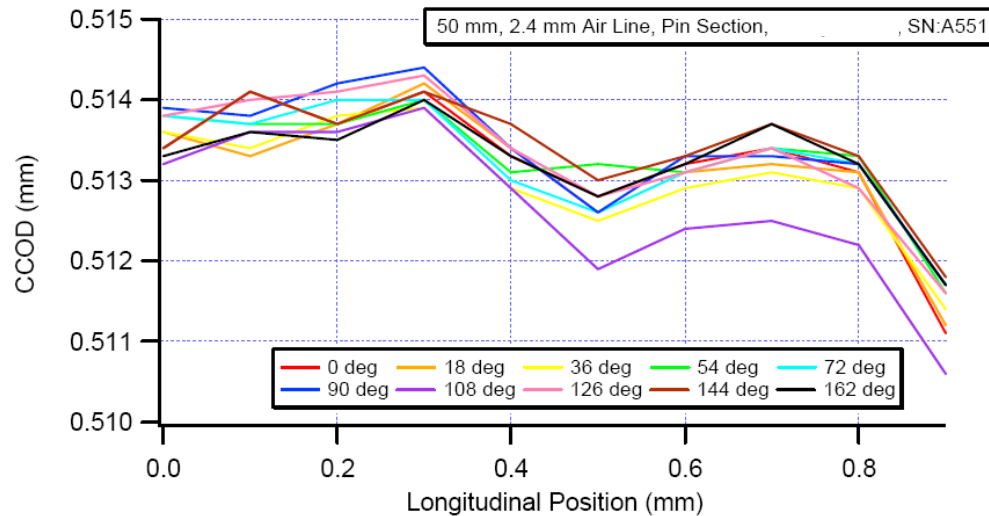
**The error introduced by the TP pin will change the impedance characteristics of the connected calibration standard**



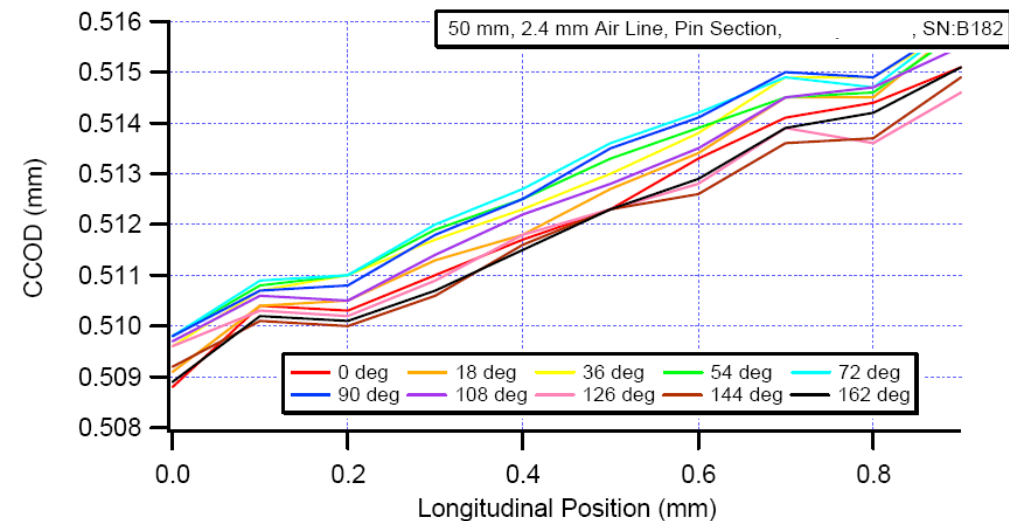
# Manufacturing issues

## Profile of two 2.4 mm precision air line male pins

Graphical Representation: Center Conductor



Graphical Representation: Center Conductor

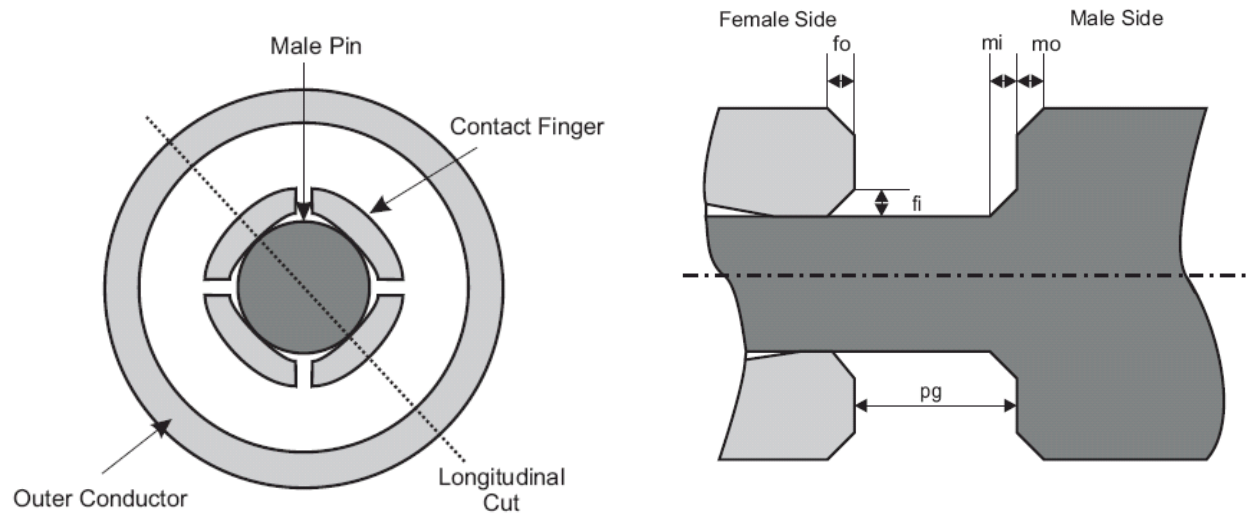
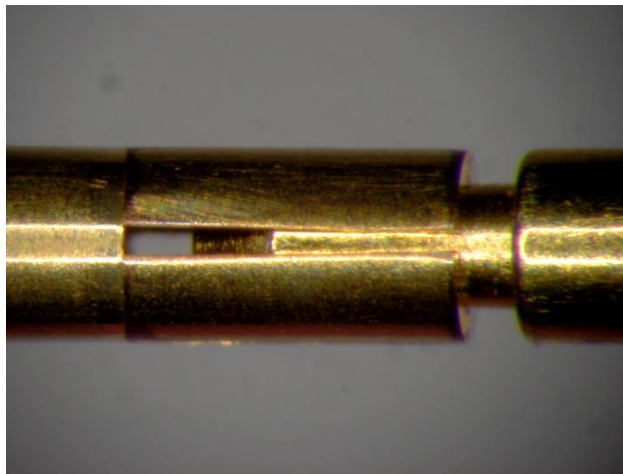


# Pin diameter effects in electrical quantities

## CoMo70 modelling:

1.85 mm male pin diameter reduction of 10  $\mu\text{m}$

1.85 mm nominal male pin  $\varnothing = 0.511$  mm



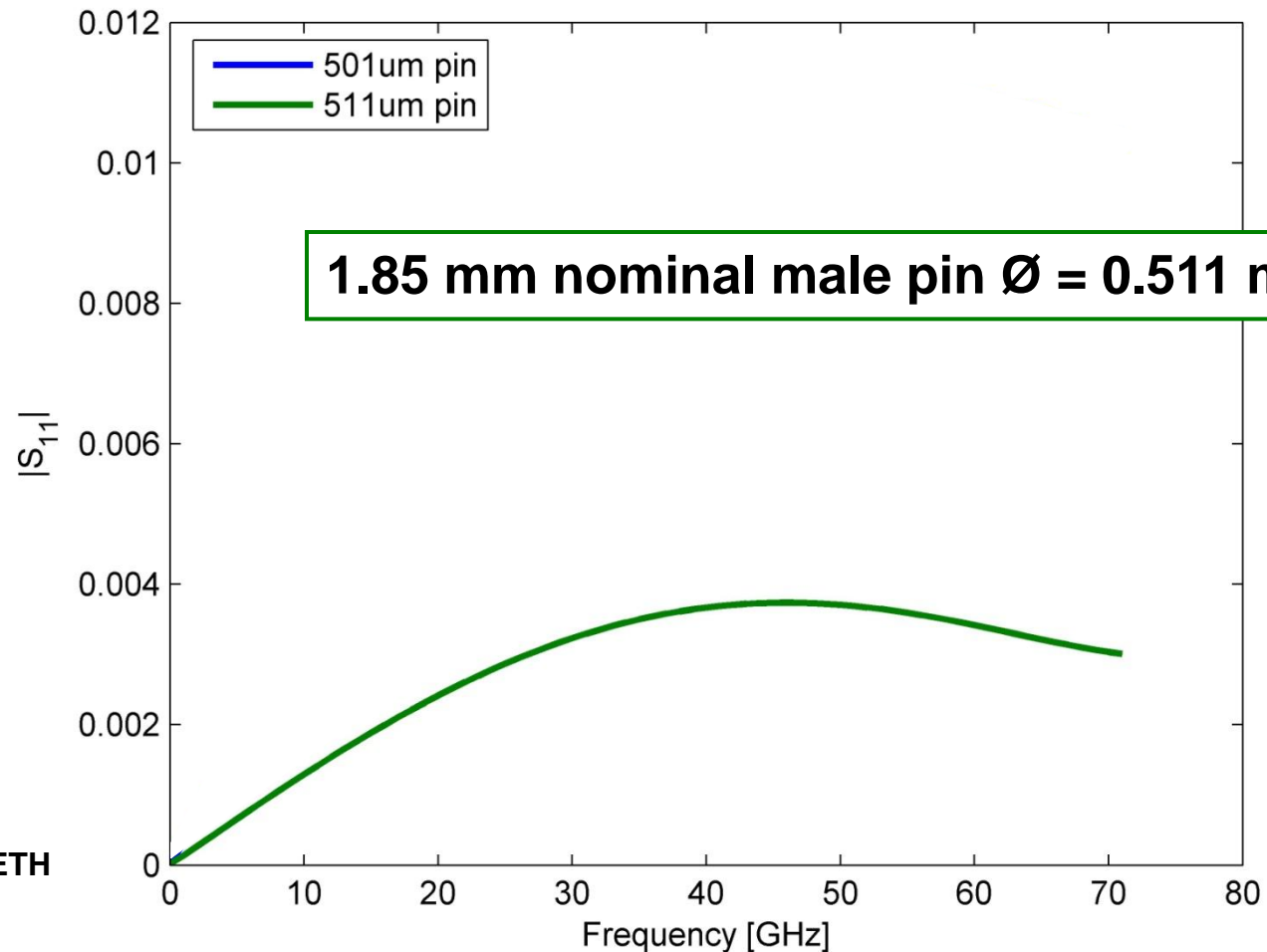
Johannes Hoffmann, ETHZ, CoMo70 project (Paper published at the EuMW 2007)



# Pin diameter effects in electrical quantities

**CoMo70 modelling:**

**1.85 mm** male pin diameter reduction of **10  $\mu\text{m}$**



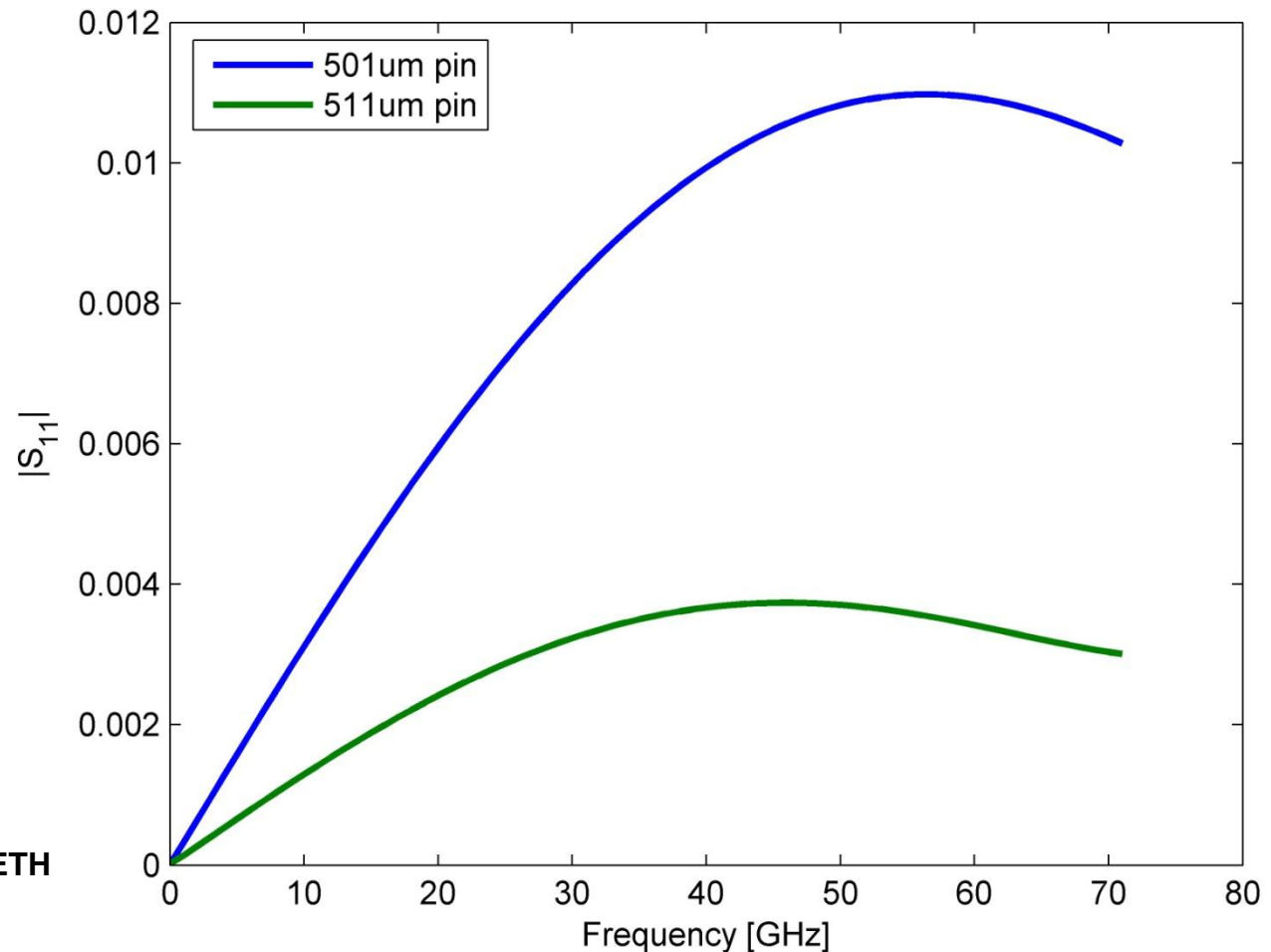
Johannes Hoffmann, ETH



# Pin diameter effects in electrical quantities

**CoMo70 modelling:**

**1.85 mm male pin diameter reduction of 10  $\mu\text{m}$**



Johannes Hoffmann, ETH



## Conclusions : “Standard versus market”

- **IEEE Std P287-2007: be careful with the specifications**
- **Modelling: a must for millimetre-wave coaxial connectors**
- **Traceable pin-diameter and slotted area measurements – a must for accurate modelling**
- **NMIs: need the detailed connector specifications**
- **Impact of pin diameters in measurement comparisons?**
- **Other critical effects not discussed (near field effects, ...)**

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**Thank you very much for your attention !**





**The dissertation from Johannes Hoffmann (ETHZ)  
can be downloaded from our website soon:**

**[www.metas.ch/HF](http://www.metas.ch/HF)**

**“Traceable S-parameter measurements in coaxial  
transmission lines up to 70 GHz”**

**-> will be free available beginning of November**