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An Advanced Contact Solution Probe Card for RF & 5G using MEMS Coaxial Technology

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Overview

- **I**ntroduction
- **C**oncept of coaxial probe
- **P**roposal of advanced contact
- **M**anufacturing
- **V**erification and characterizations
- **S**ummary

Introduction

- **5G** application, mobile developments and automotive network systems demand significantly higher data capacity and fastest response times.
- **The** demands on high-speed signal, extremely small size and dense packages have been steadily increasing within the semiconductor market.
- **Accordingly,** the need arises for an advanced contact solution on an RF probe card that will overcome many signal integrity problems such as signal loss, reflection, and crosstalk.
- **Therefore,** proposing a new high-speed probing technology for RF and 5G products less than 50GHz using 3D MEMS coaxial outer GND shield in collaboration with a MEMS probe pin.

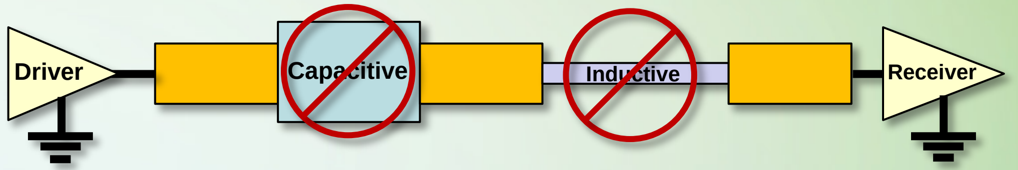
The beginning

- **T**he goal of the project is to have a shield RF signal in a coaxial cable and achieve maximum frequency bandwidth with a clean transmission.
- **I**t is important to consider fab and mechanical limitation to develop this new probe design.
- **F**rom the electrical part, impedance is fundamental.

High Speed Signal Consideration

- **I**mpedance: clean transmission and no reflection, which imply perfect impedance match, and less capacitive and inductive changes in the path.
- **N**o discontinuity: avoiding discontinuities like pads, stubs, branches, etc.
- **B**alanced traces: traces length matched and impedance control.

- **Signal design cases**



Signal bad case

Signal good case

Why is impedance so important?

The impedance is fundamental for preserving the signal integrity through the probe or any other interconnection; impedance mismatch may lead to significant reflections that distort signals (e.g., loss and crosstalk is originated).

The impedance is linked to:

- Stack-up material (capacitance)
- Shape of the probe (inductance)
- Pitch and ground configuration (inductance loop and capacitance)

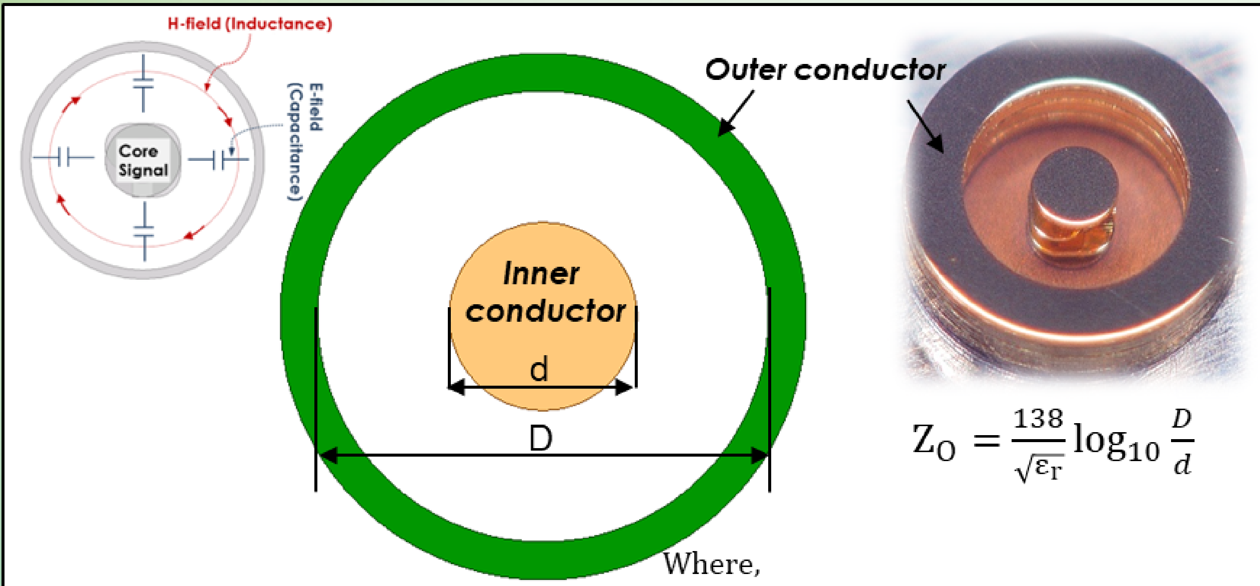
The inductance is linked to the current loop, geometric parameters of the conductor (probe) and frequency.

$$Z_{C\_LossLess} = \sqrt{\frac{L}{C}}$$

Dielectric loss: Defined by Dk and Df

Concept of coaxial probe

- **Coaxial theory - Features**



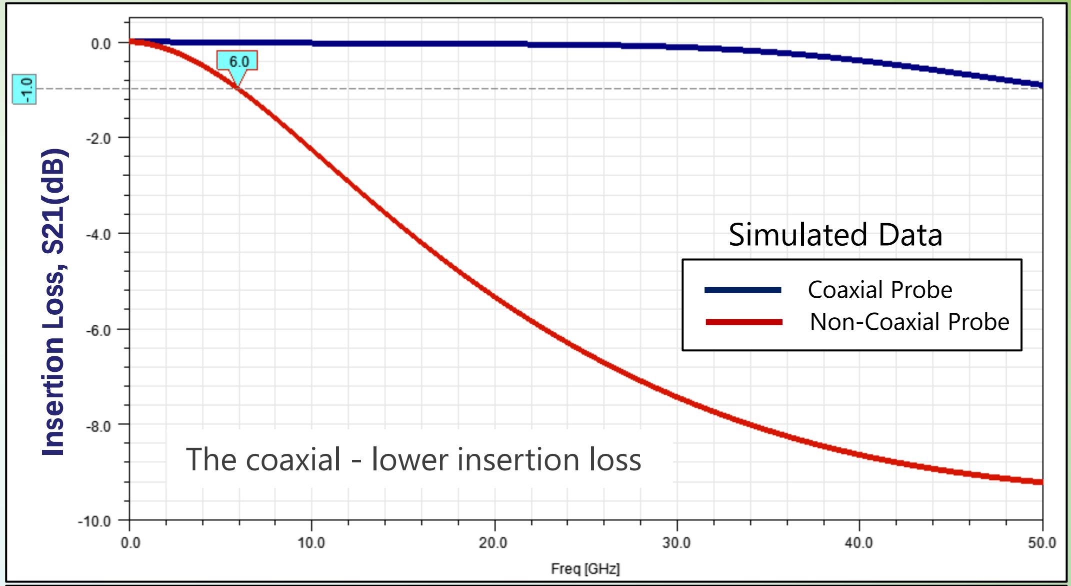
$$Z_O = \frac{138}{\sqrt{\varepsilon_r}} \log_{10} \frac{D}{d}$$

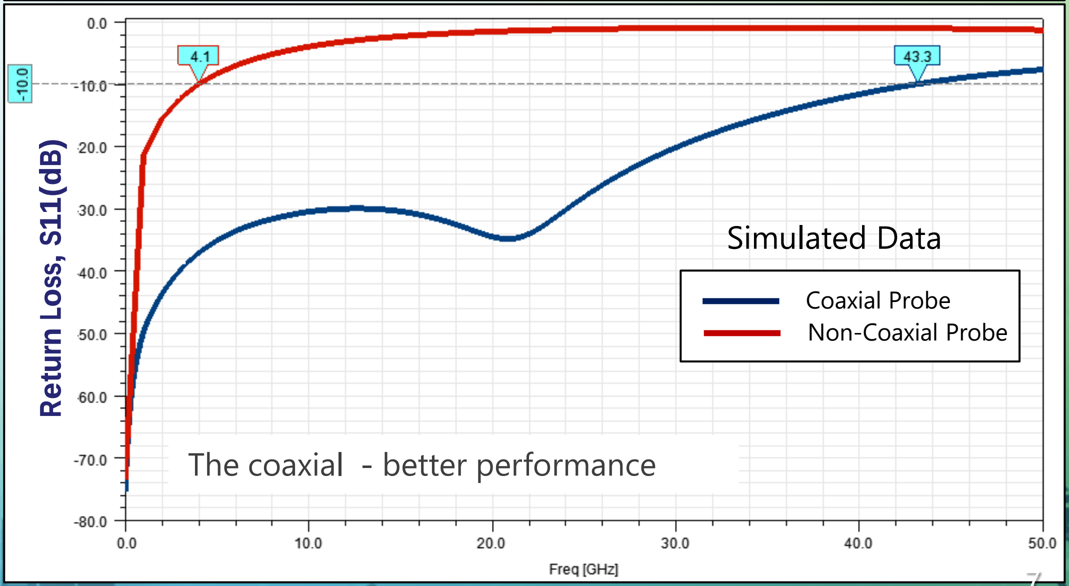
Where,
Z_O = Characteristic impedance of line
D = Inside Diameter of Outer Conductor
d = Outside Diameter of Inner Conductor
ε_r = Relative Dielectric Constant

Ex, If ε_r=1 Air & Z_O=50 ohms, D = 2.3d. D needs 2.3 times larger than d

Coaxial impedance theory

- An outer shield protects the inner core signal from electrical field interference.



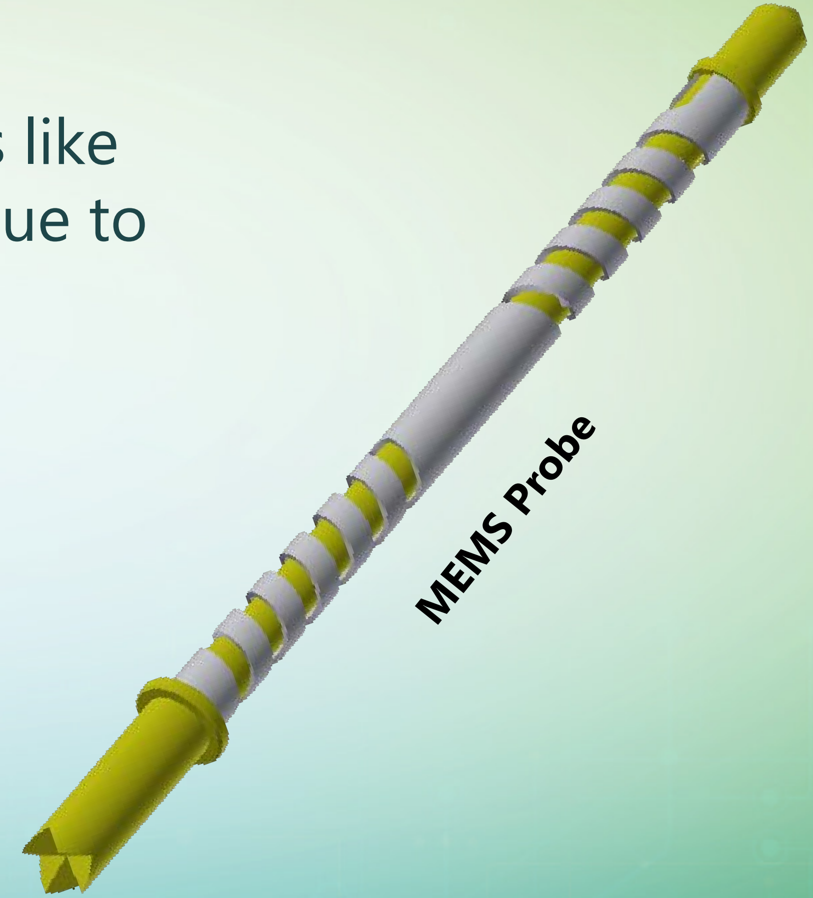


Concept of coaxial probe

- **Probe Selection**

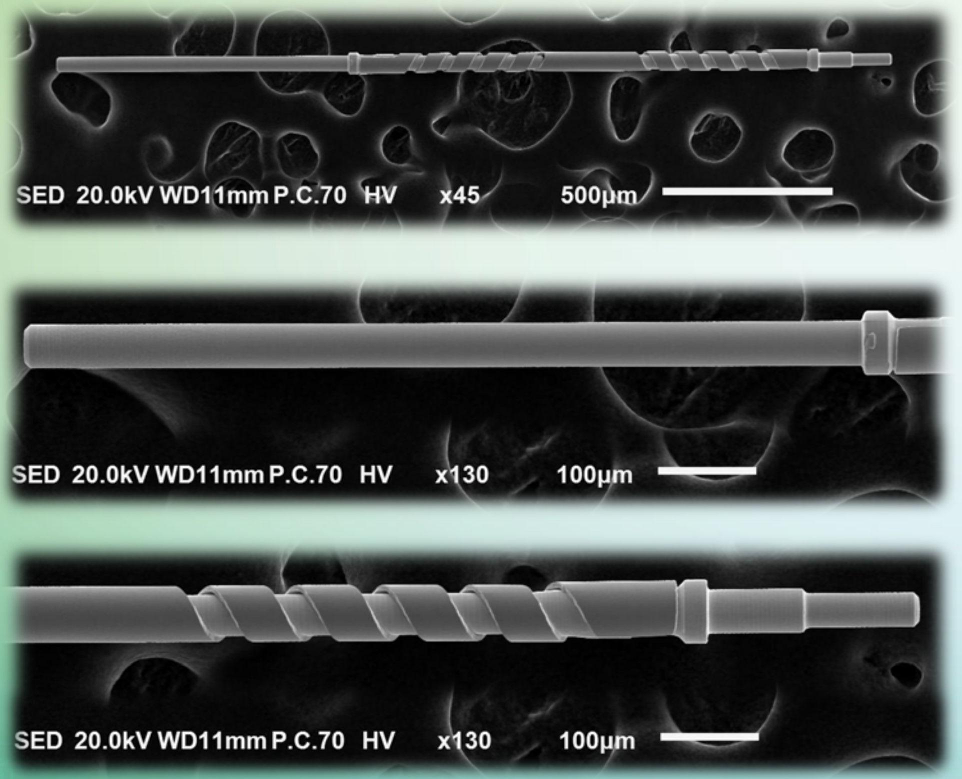
  For high frequency applications, vertical probes like MEMS are currently the most suitable option, due to following advantages:

  - Control of the probe path.
  - Flexibility in the probe head stack-up design.
  - Reduced probe length.
  - Small probe pitch.
  - Diameter probe options
  - Repeatable and reliable contact



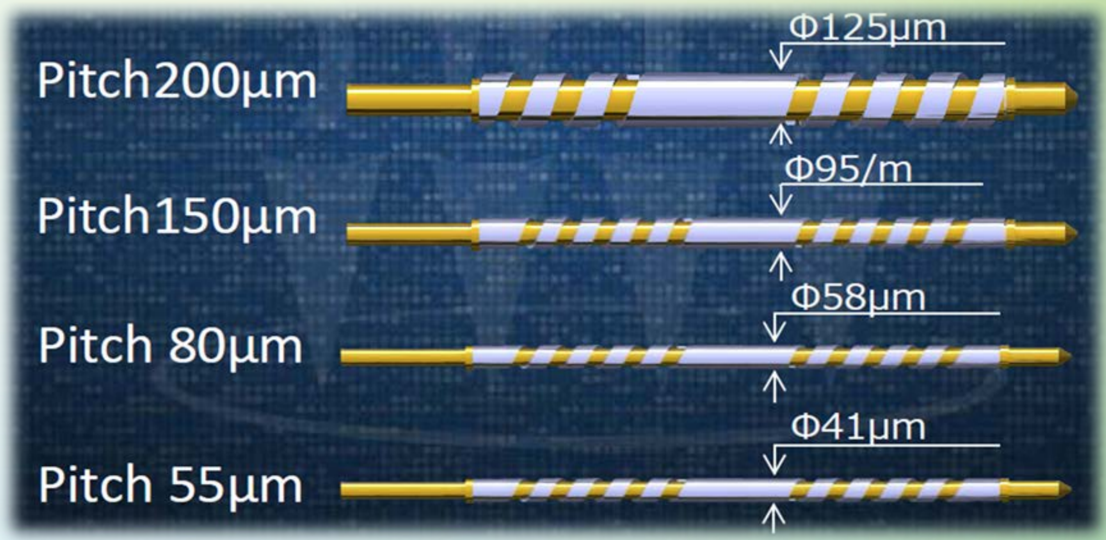
Concept of coaxial probe

- **MEMS spring probe build**



MEMS probe image by SEM

- **MEMS probe diameter options**



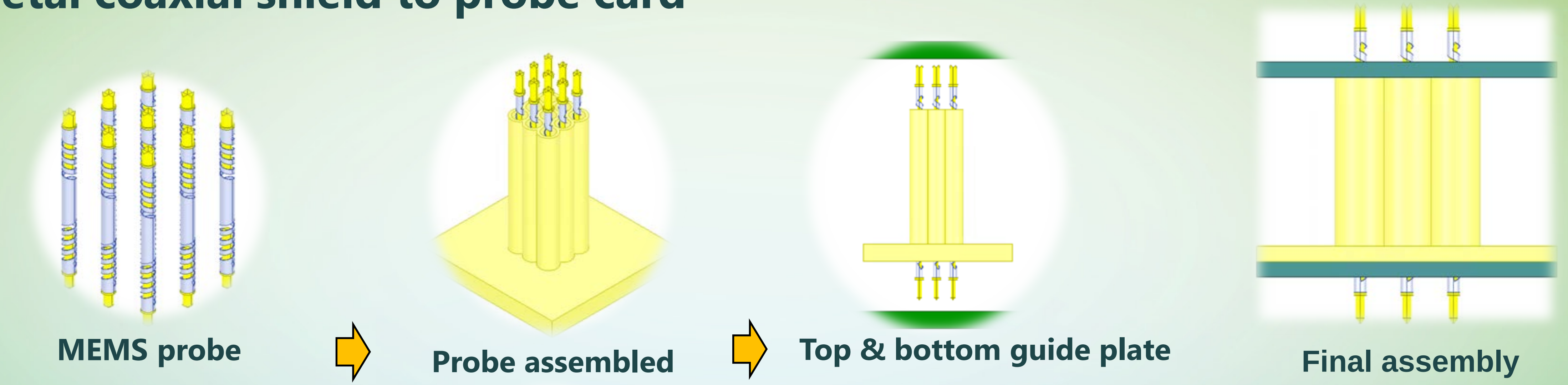
Reference

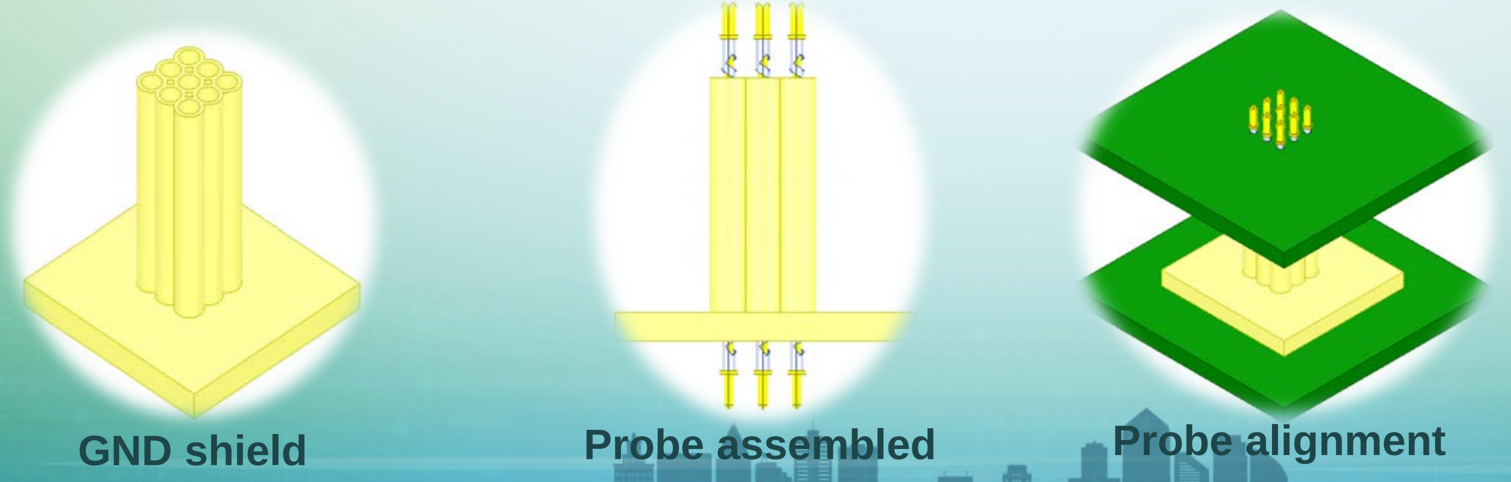
*SWTest2018 Technical Tutorials

- Title : Advances in MEMS Spring Probe Technology for Wafer Test Applications
- Presenters/Authors: Mr. Koji Ogiwara (SV TCL – Tokyo, Japan), Mr. Norihiro Ohta (Nidec-read – Kyoto, Japan)

Concept of coaxial probe

- **Metal coaxial shield to probe card**





- Basic concept of coaxial probe
- MEMS probe & GND shield
- Top & bottom guide
- Assembly & alignment

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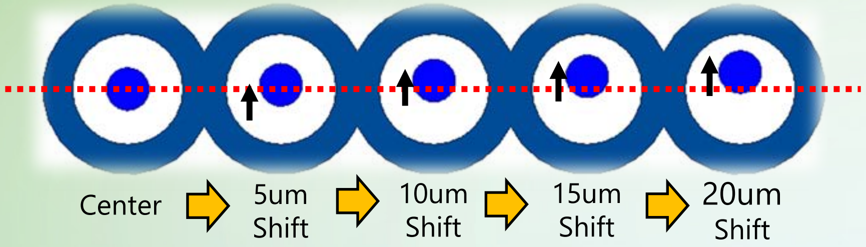
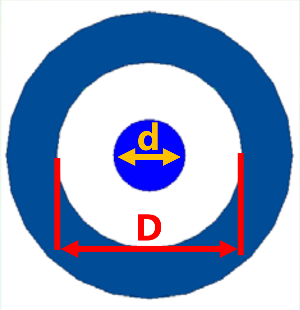
Concept of coaxial probe

- **Impedance case study for misalignment**

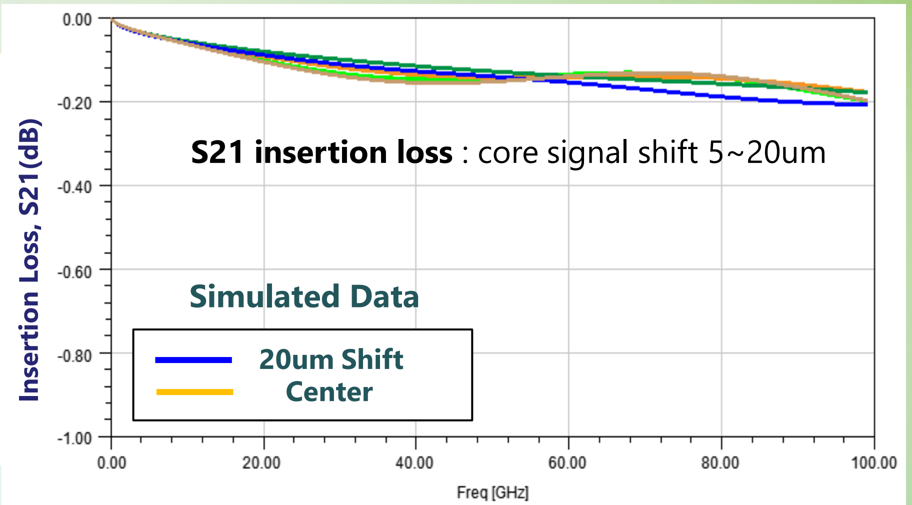
Case study for misalignment

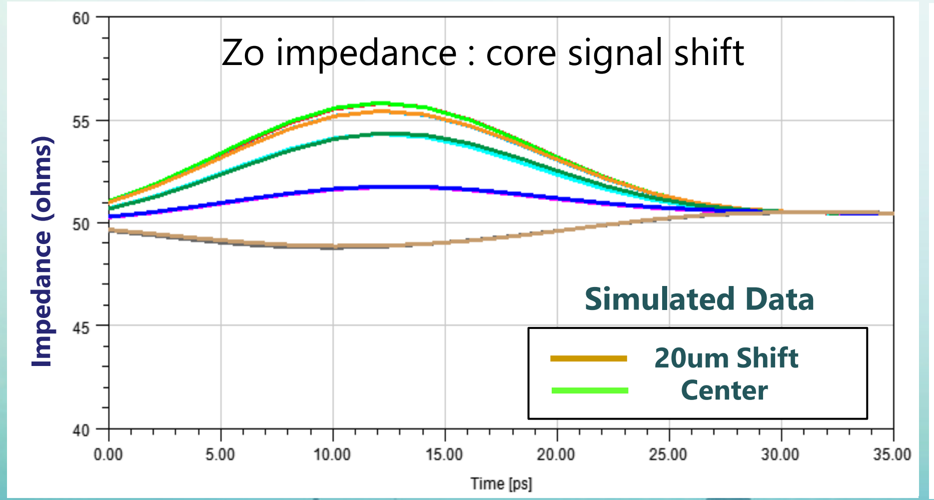


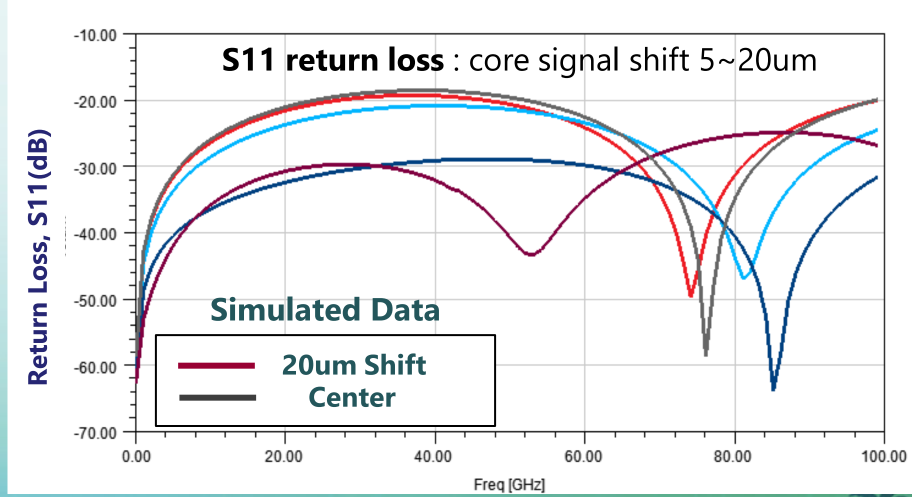


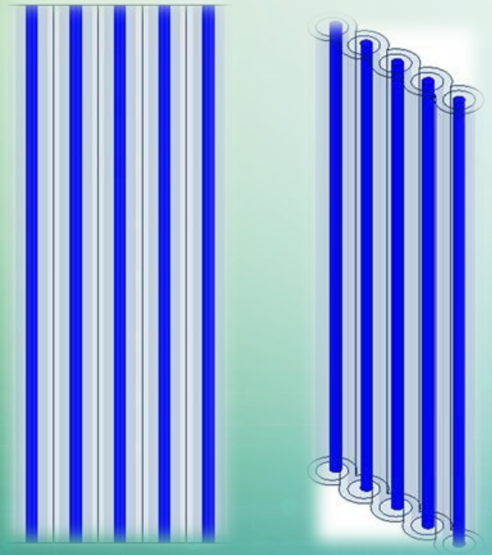
D=130um, d=50um

Insertion and return loss









Ideal coaxial probe shape

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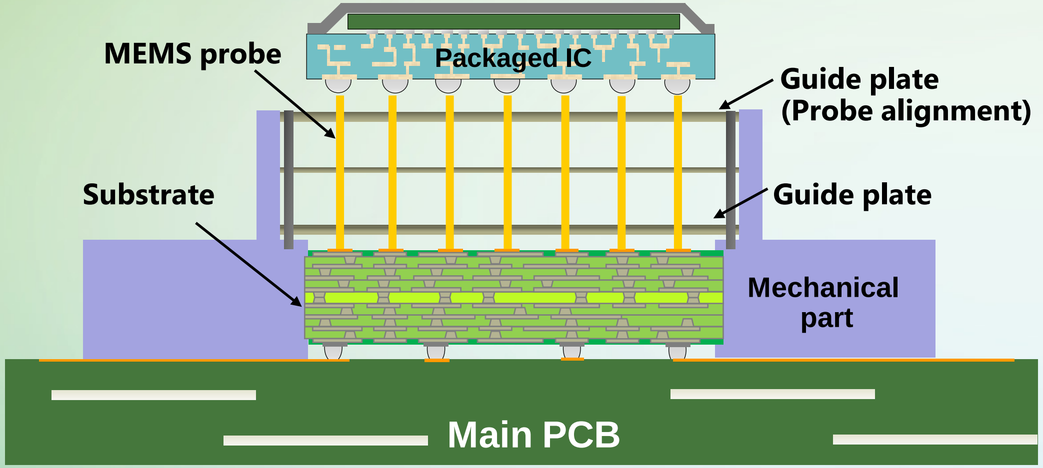
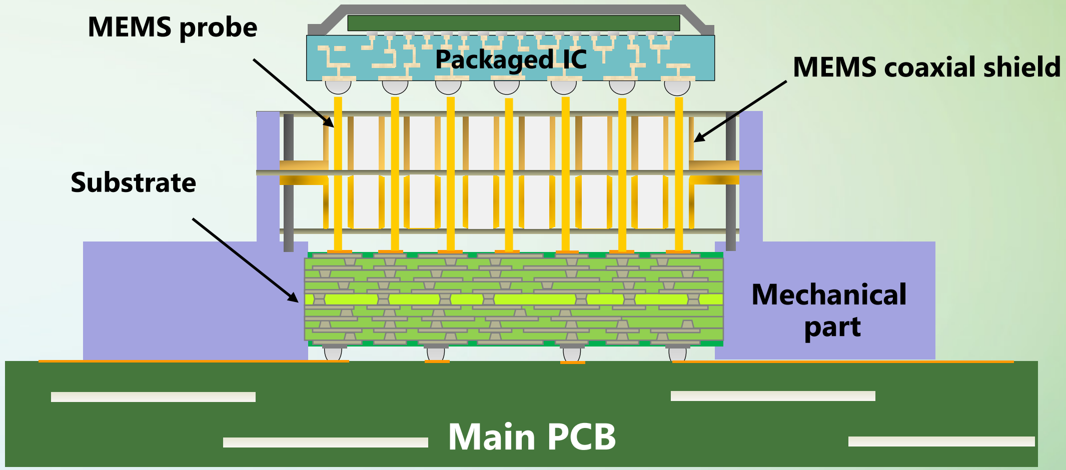
Proposal of advanced contact solution

- **Logic probe card (vertical type) overall concept**



RF probe card without coaxial

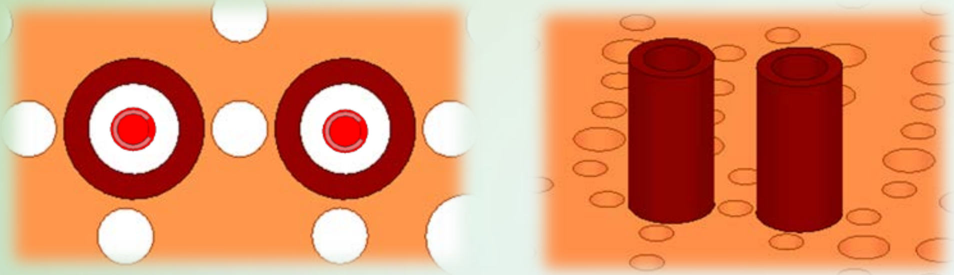


RF probe card with coaxial shield

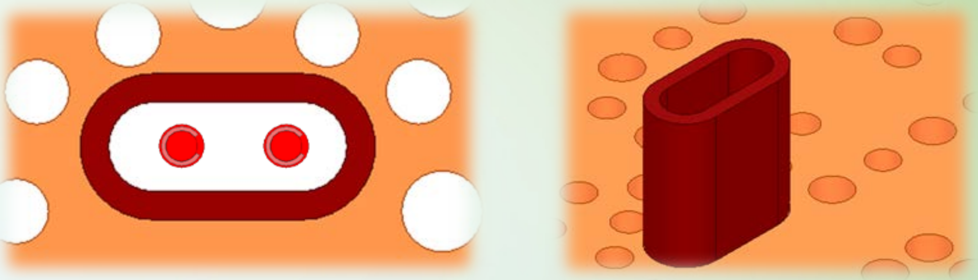
- Logic probe head needs fine pitch, probe durability, stable resistance, high bandwidth
- Adopt advanced contact solution probe card for RF using MEMS coaxial technology

Proposal of advanced contact solution

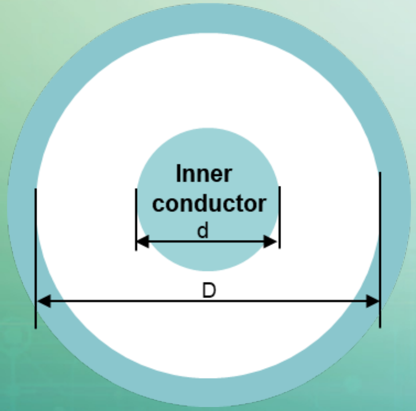
- **Probe head coaxial shield design**



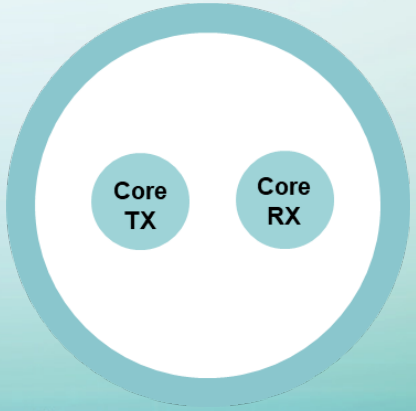
Single-ended coaxial design



Differential pair coaxial design



- Impedance Zo 50Ω+/-10%
- For single-ended, the coaxial shield size can be changed in order to fix impedance.



- Impedance Zo 100Ω+/-10%
- For differential pair, the coaxial shield covers the pair line in order to satisfy the impedance.

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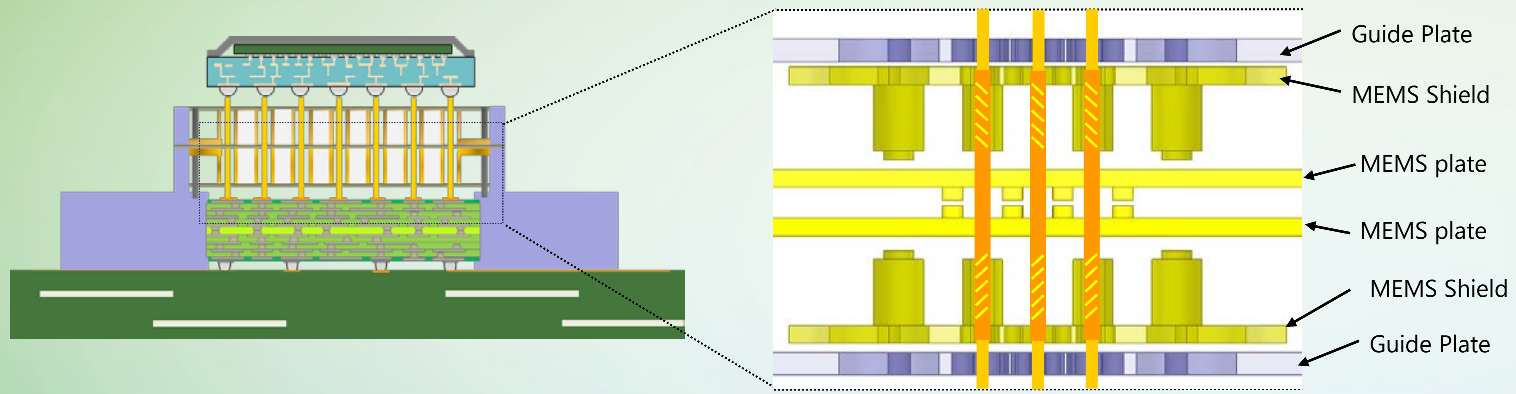
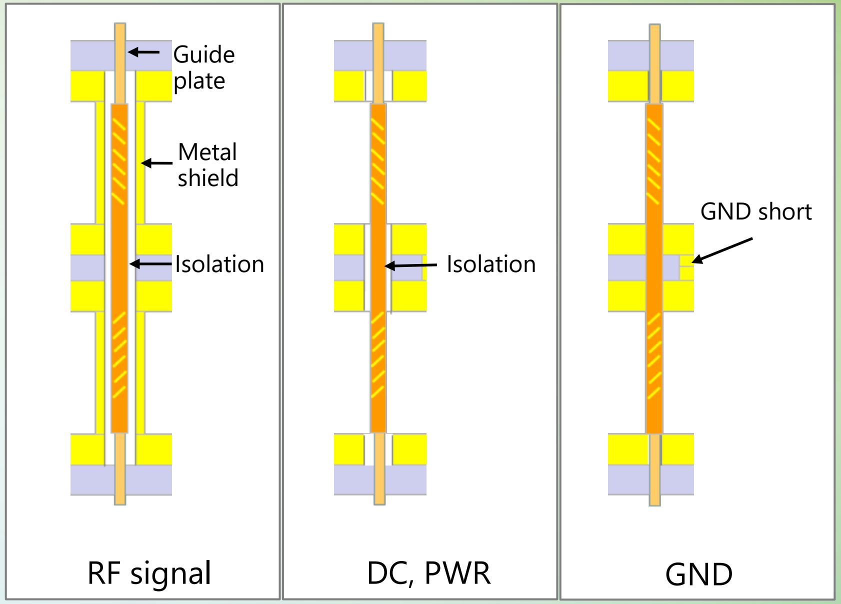
Proposal of advanced contact solution

- **The schematic of coaxial probe head**



RF probe card with coaxial head

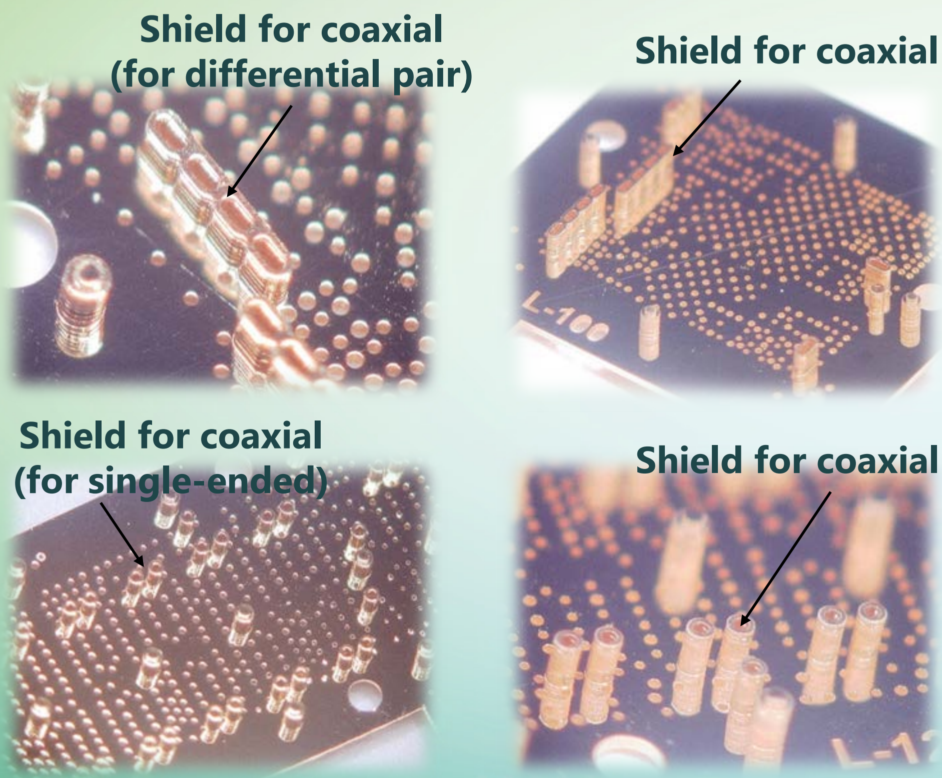


Channel assignment

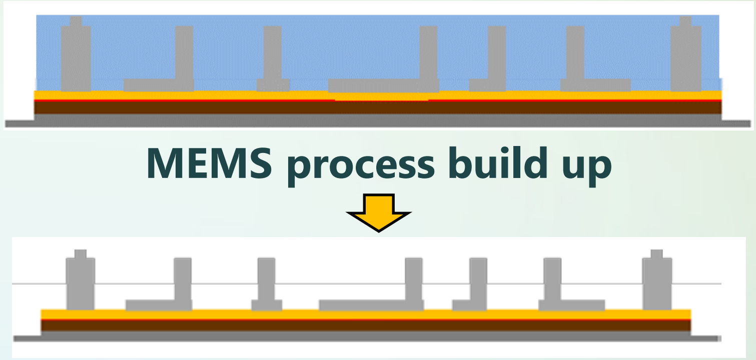
- The different designs for probes : RF signal, DC signal, power, ground
- The only RF signal channel adopt MEMS coaxial shield to satisfy the electrical characteristics.
- The pins are well-aligned by using guide plates (top, center, bottom)

Manufacturing

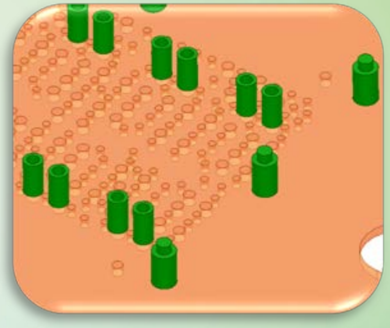
- **3D MEMS metal shield manufacturing**



MEMS coaxial shield product



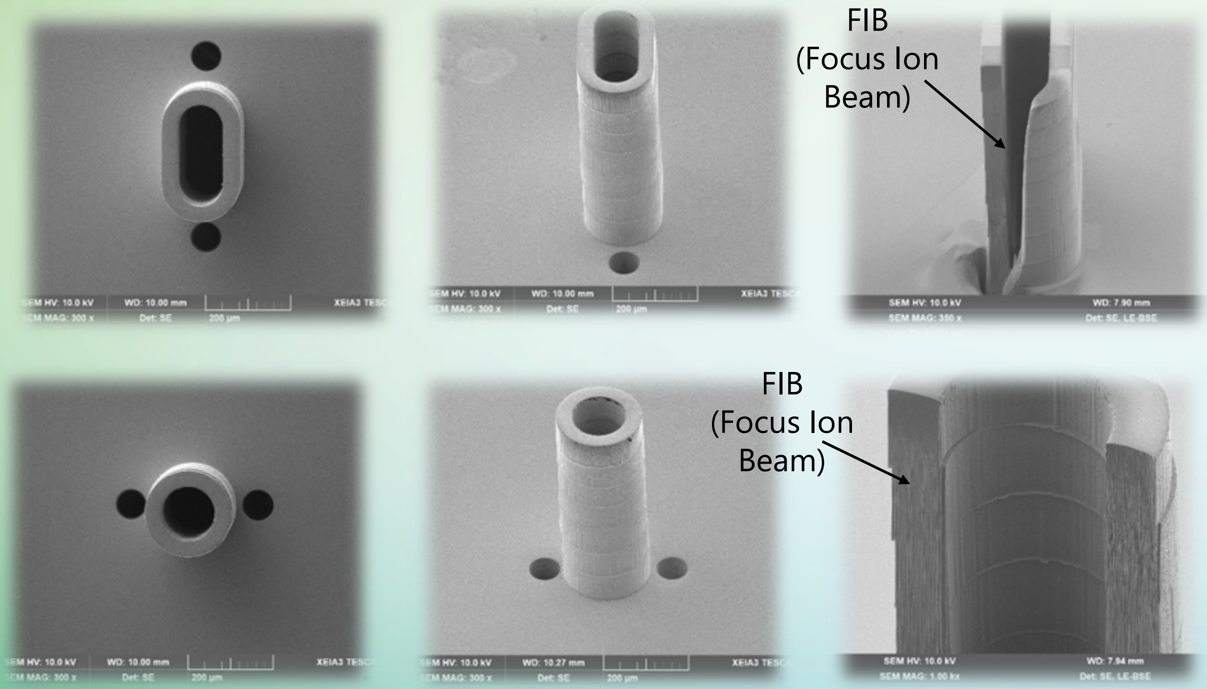
Final product



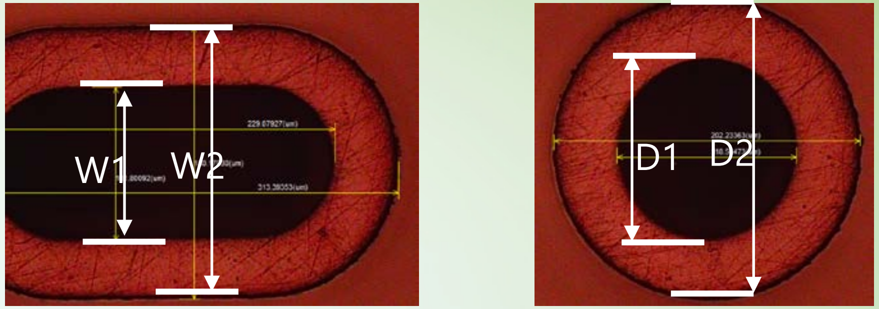
- MEMS process (photo, etch, polishing, deposition)
- Metal shield for RF signal
- Shield shape (single-ended and differential pair)

Manufacturing

- **MEMS manufacturing inspection**



MEMS metal shield inspection by SEM image



MEMS metal shield measurement image

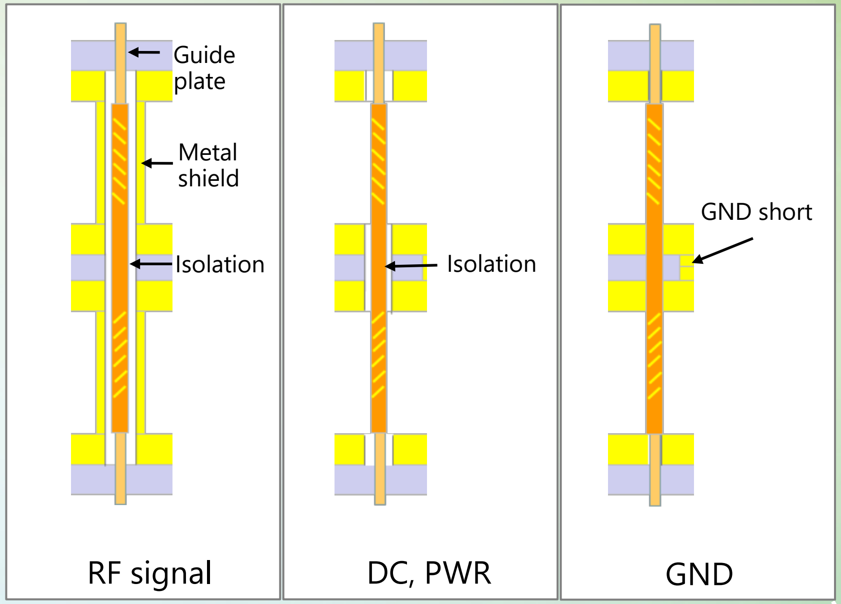
Type	width	Design	Measure
Single ended	W1	100 um	101.8um
	W2	180 um	180.1um
Diff. Pair	D1	120 um	202.2um
	D2	200 um	118.5um

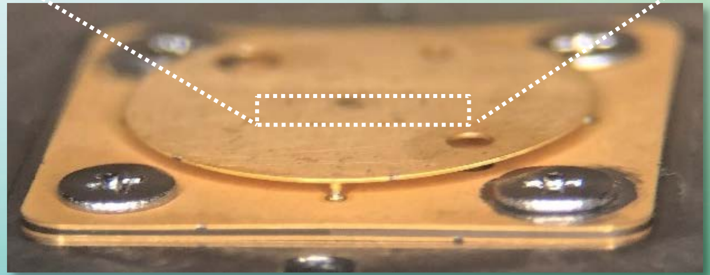
- MEMS manufacturing accuracy reliable
- Tolerance +/- 1.5um (with scope error)
- Layer stack up less misalignment

Assembly of the Probe Head

- The probe head with coaxial shields for the signal probes was assembled.
- The mechanical limitations such as contact force, planarity and alignment were considered in the design of the full assembly.

Channel assignment

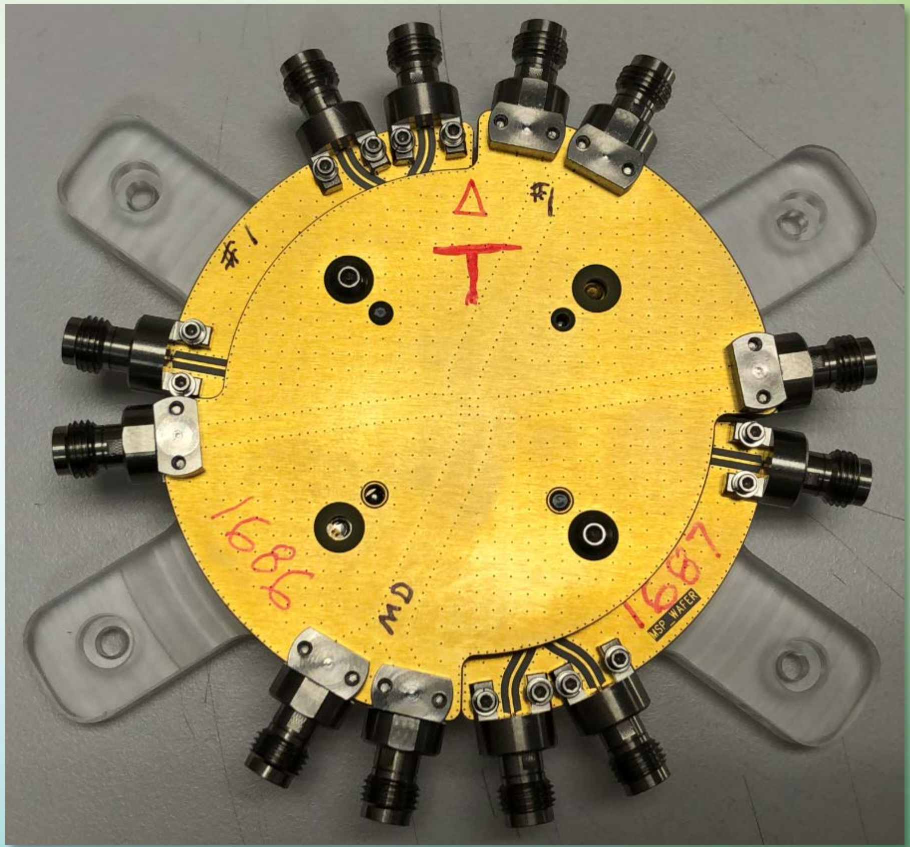




Test Vehicle

Assessment of the Probe Head

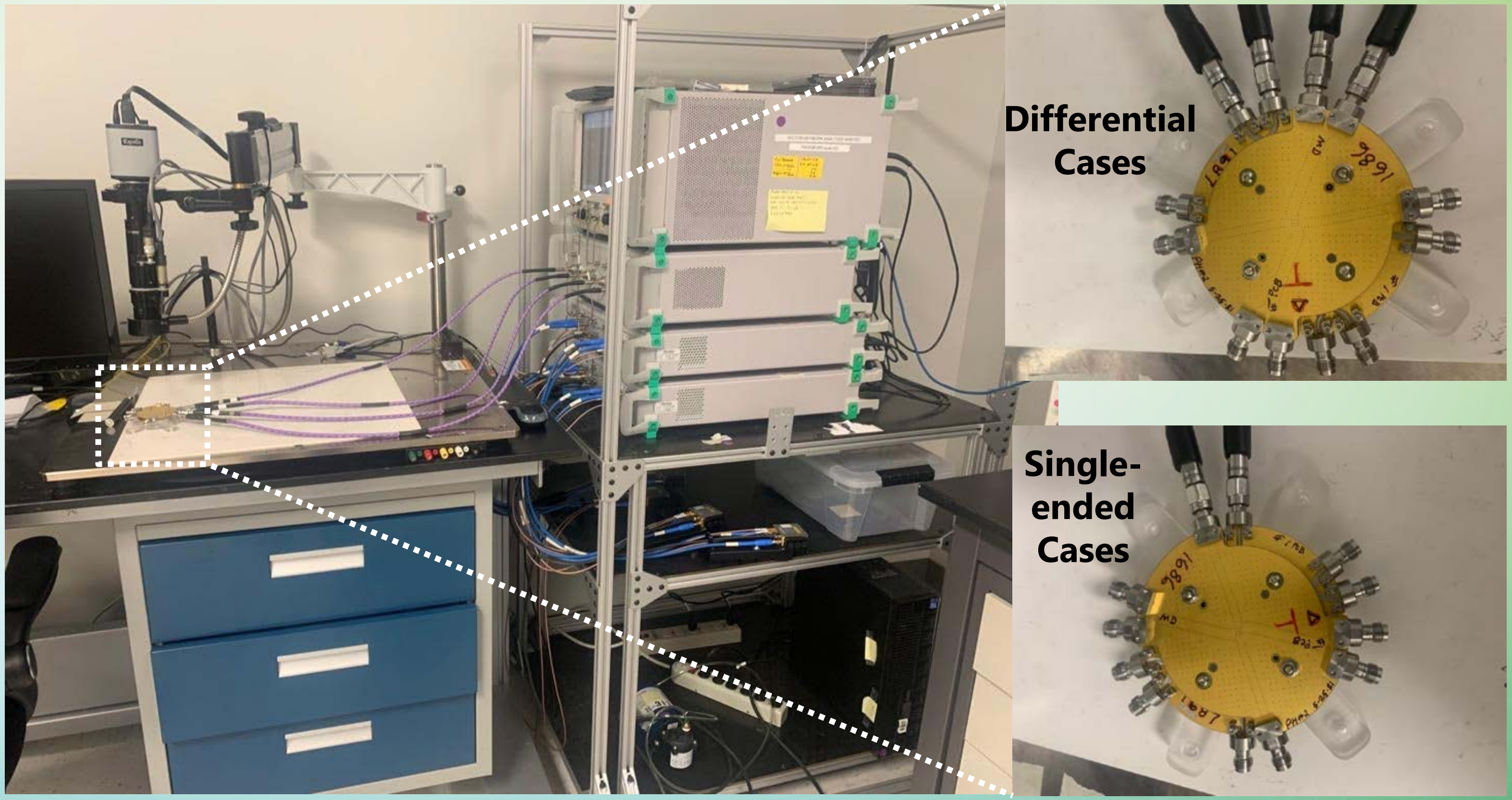
- For the evaluation of the probe head performance, a set of PCBs was designed.
- These PCBs were mirror cases with pads to connect probe tips and tails to Taper-CPW transmission lines designed to 50 Ω impedance. For the connection to RF Cables, an Edge coaxial connector (type V) was used.
- The CPW exhibits stitching ground vias to improve the ground path.



Final Assembly for Test

Measurement setup

- The measurements were performed with an Anritsu VNA calibrated up to 70 GHz, using an AutoCal (70kHz- 70GHz) with external Thru.
- Single ended cases and differentials cases were tested.

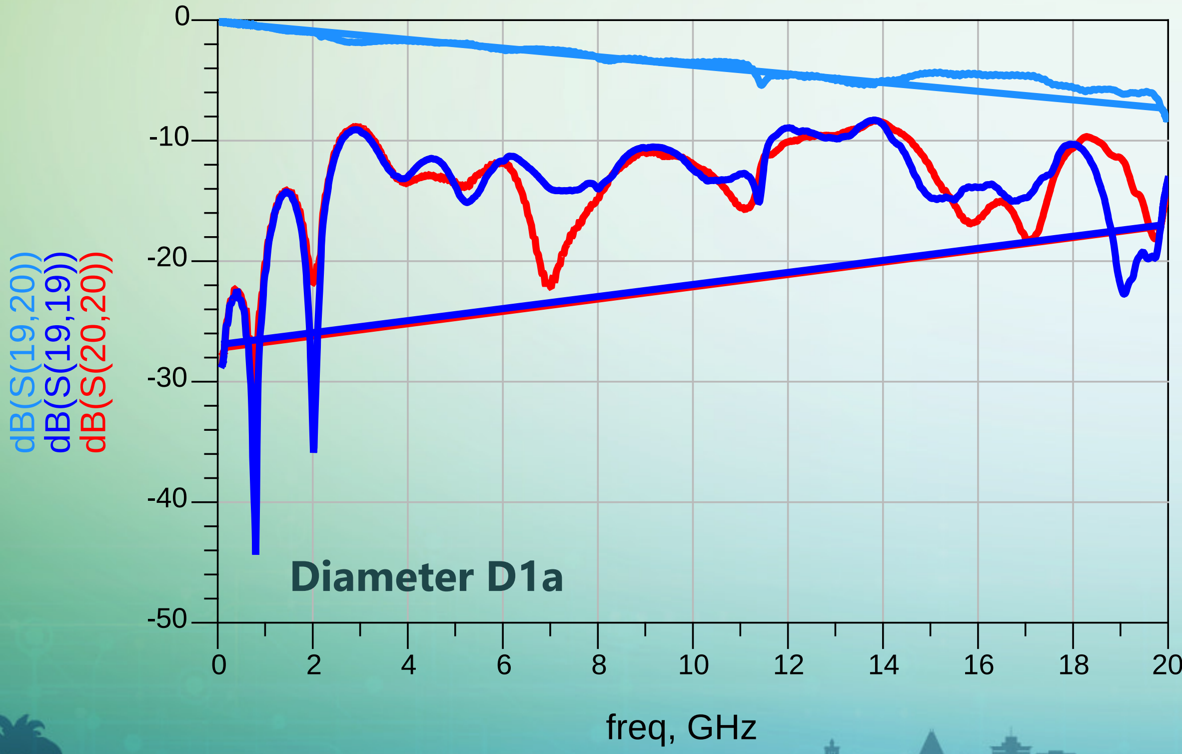


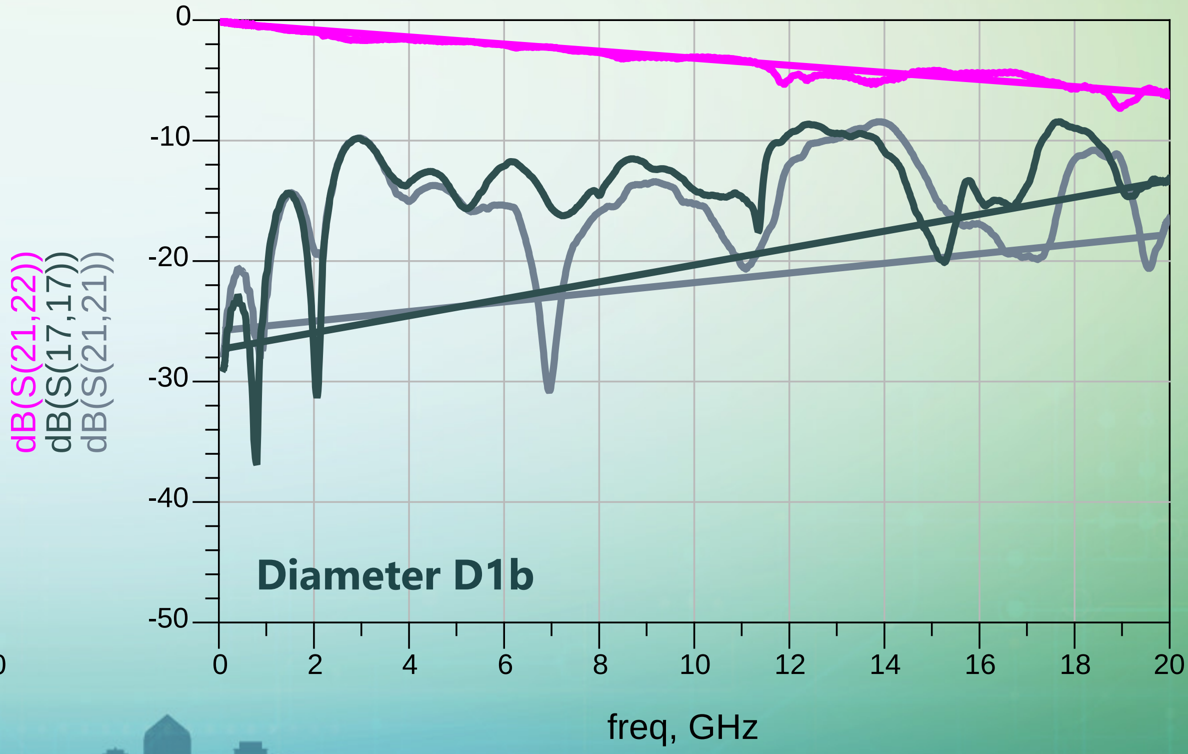
Measurement System

Assessment of the Probe Head

- **Does fabrication tolerance affect the electrical performance?**

Fabrication tolerances do not introduce a significant impact on the S-parameters.

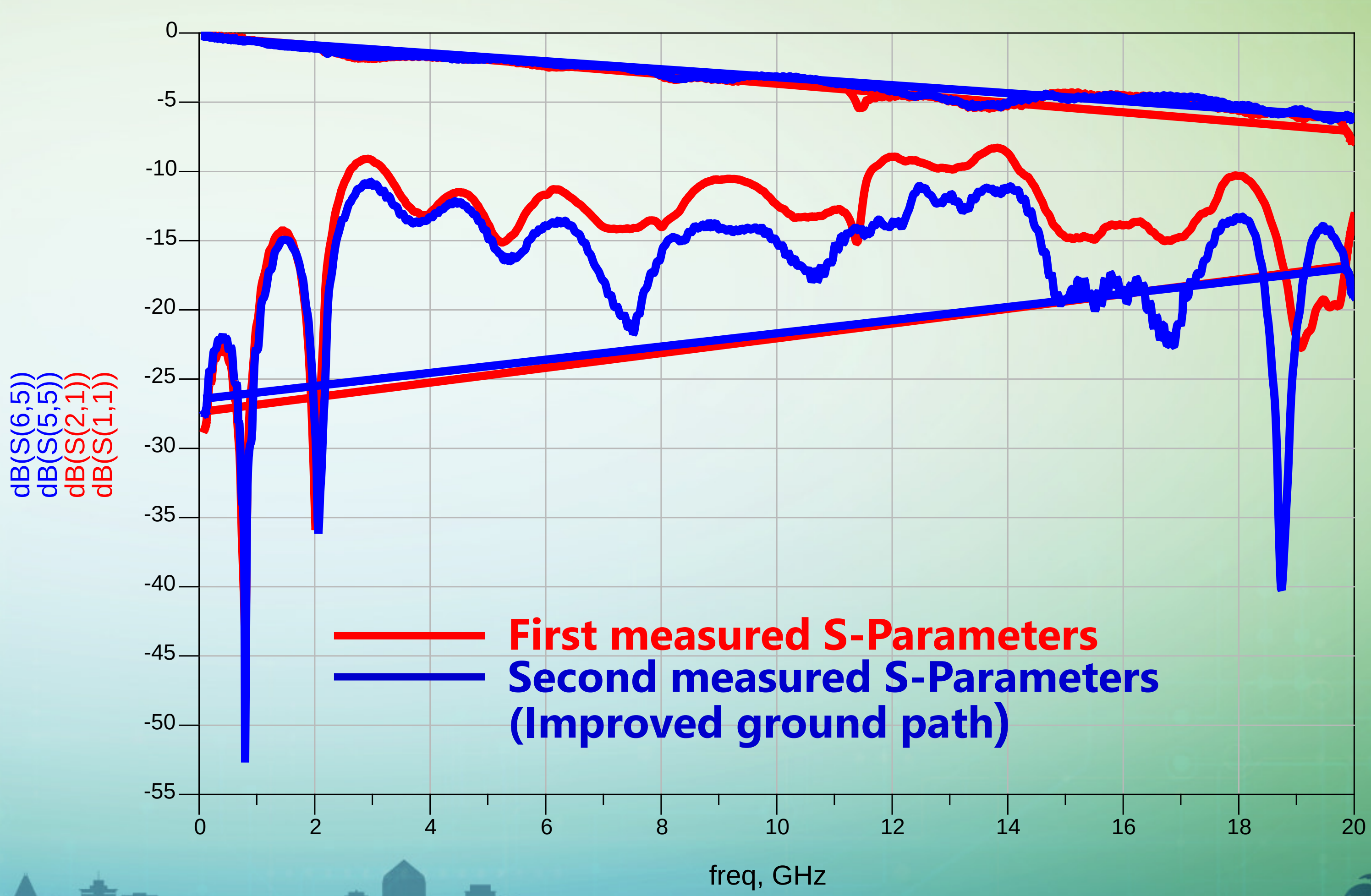




Assessment of the Probe Head

- After the first evaluation of the Probe-Head, the ground path was adjusted to improve impedance.

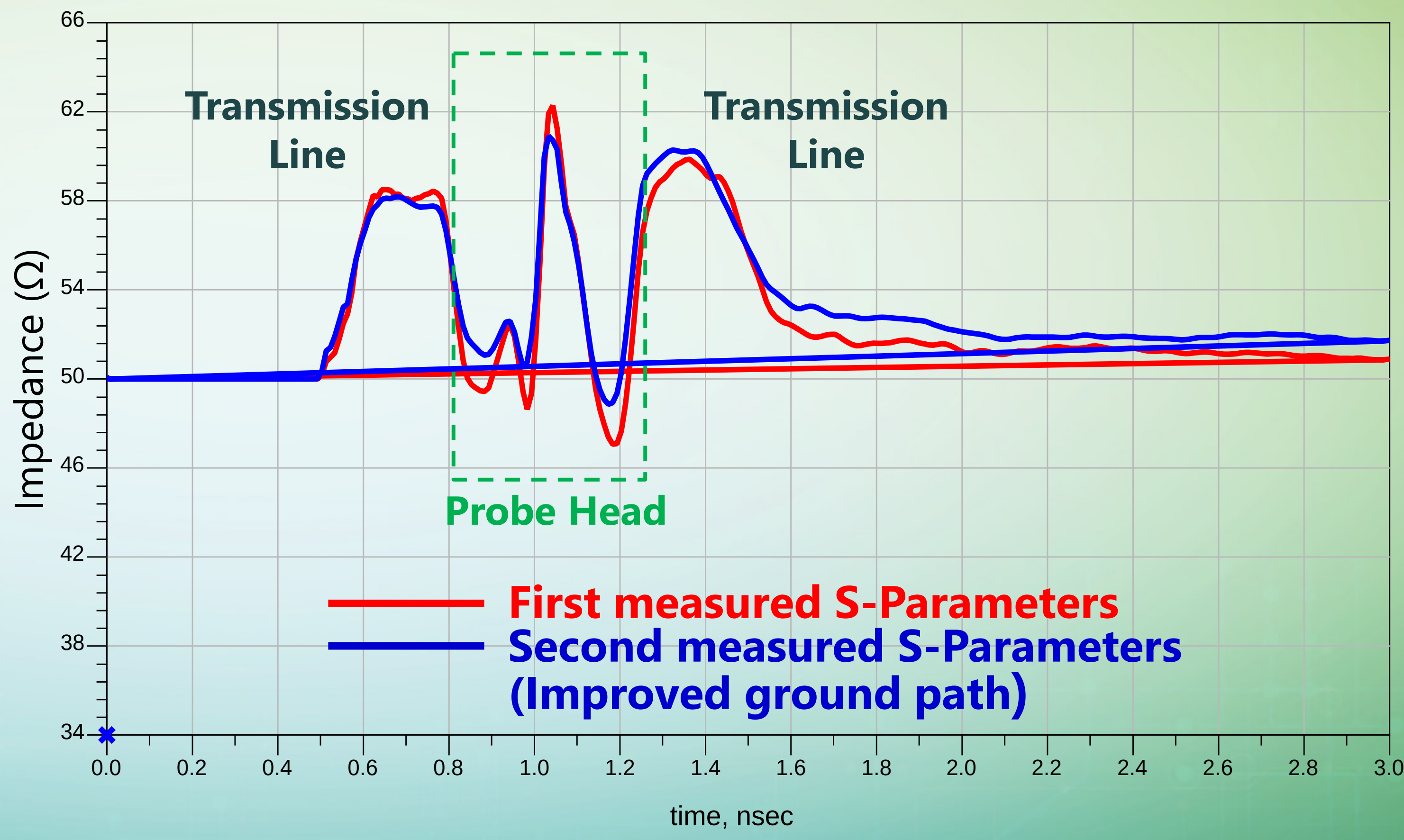
- The measurements show an improvement seen as cleaner transmission and a lower return loss.



Assessment of the Probe Head

- The TDR shows an impedance improvement after the ground path adjustment.

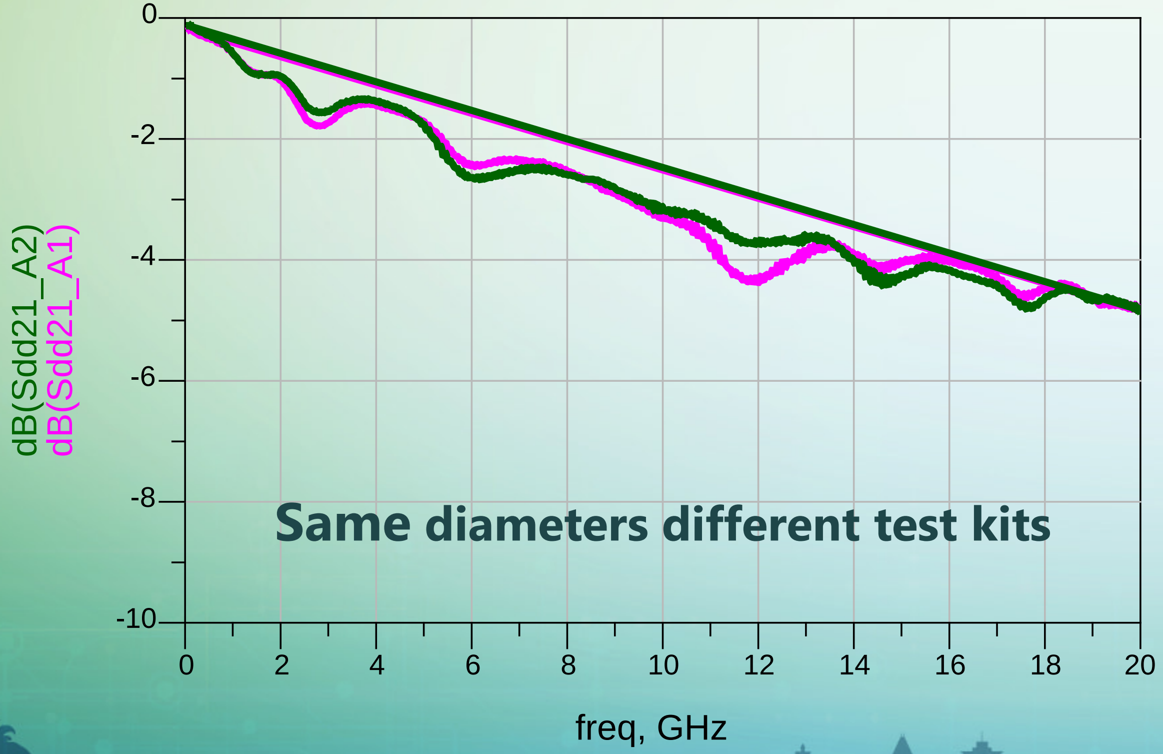
- Parasitic effects are seen that reduce performance, like the high inductance and capacitance depicted by the TDR.

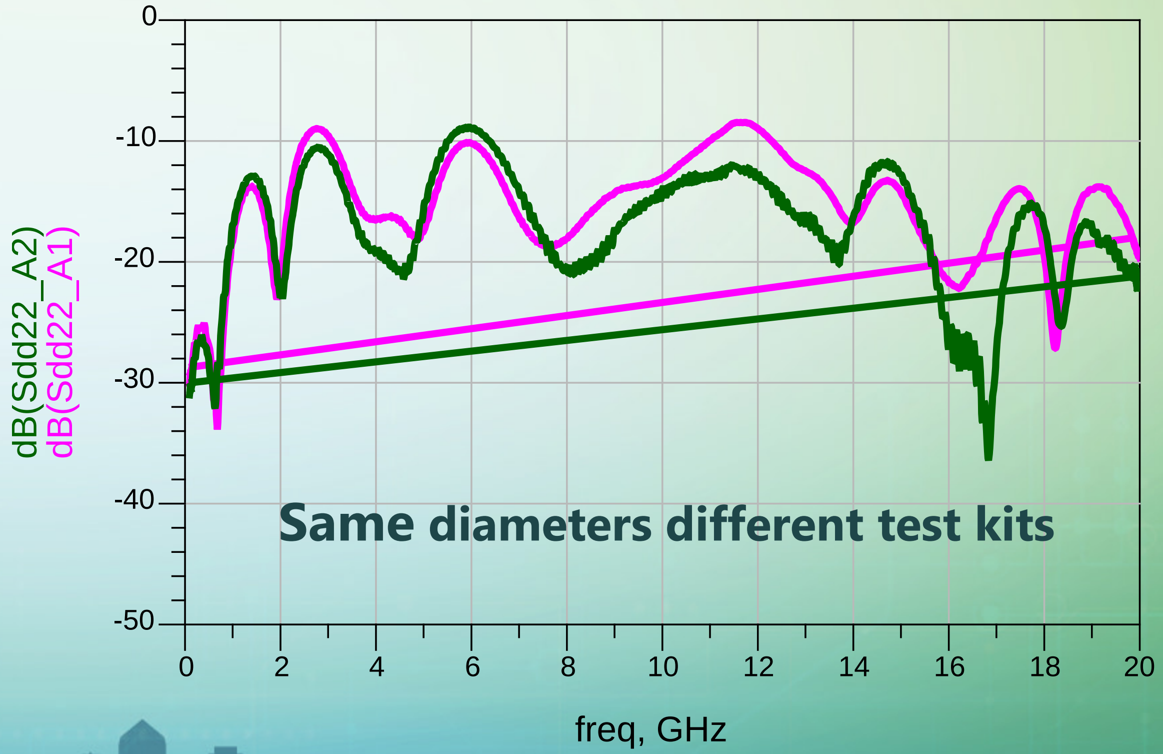


Assessment of the Probe Head

- **Does fabrication tolerance affect the electrical performance?**

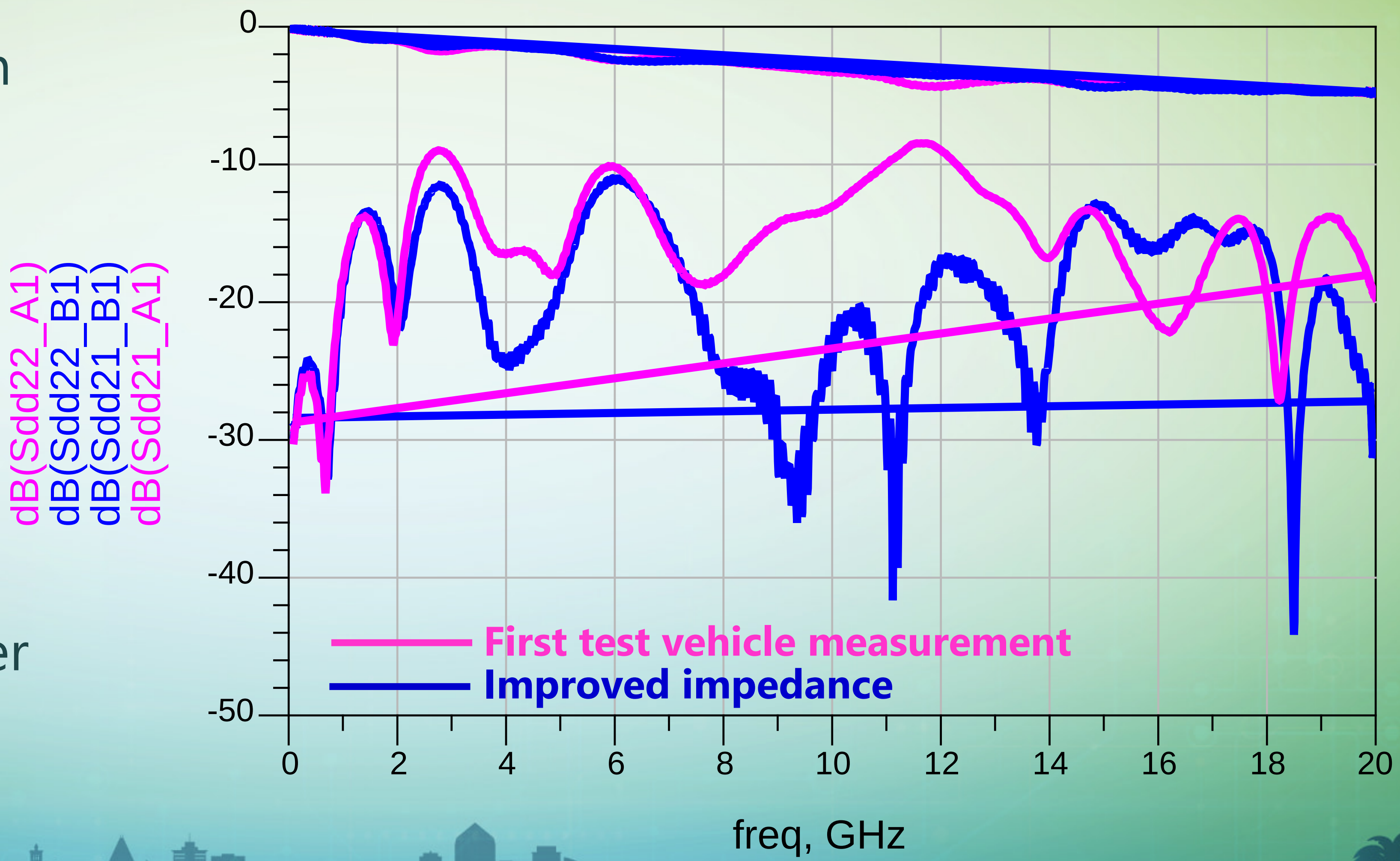
Fabrication tolerances do not introduce a significant impact on the S-parameters.





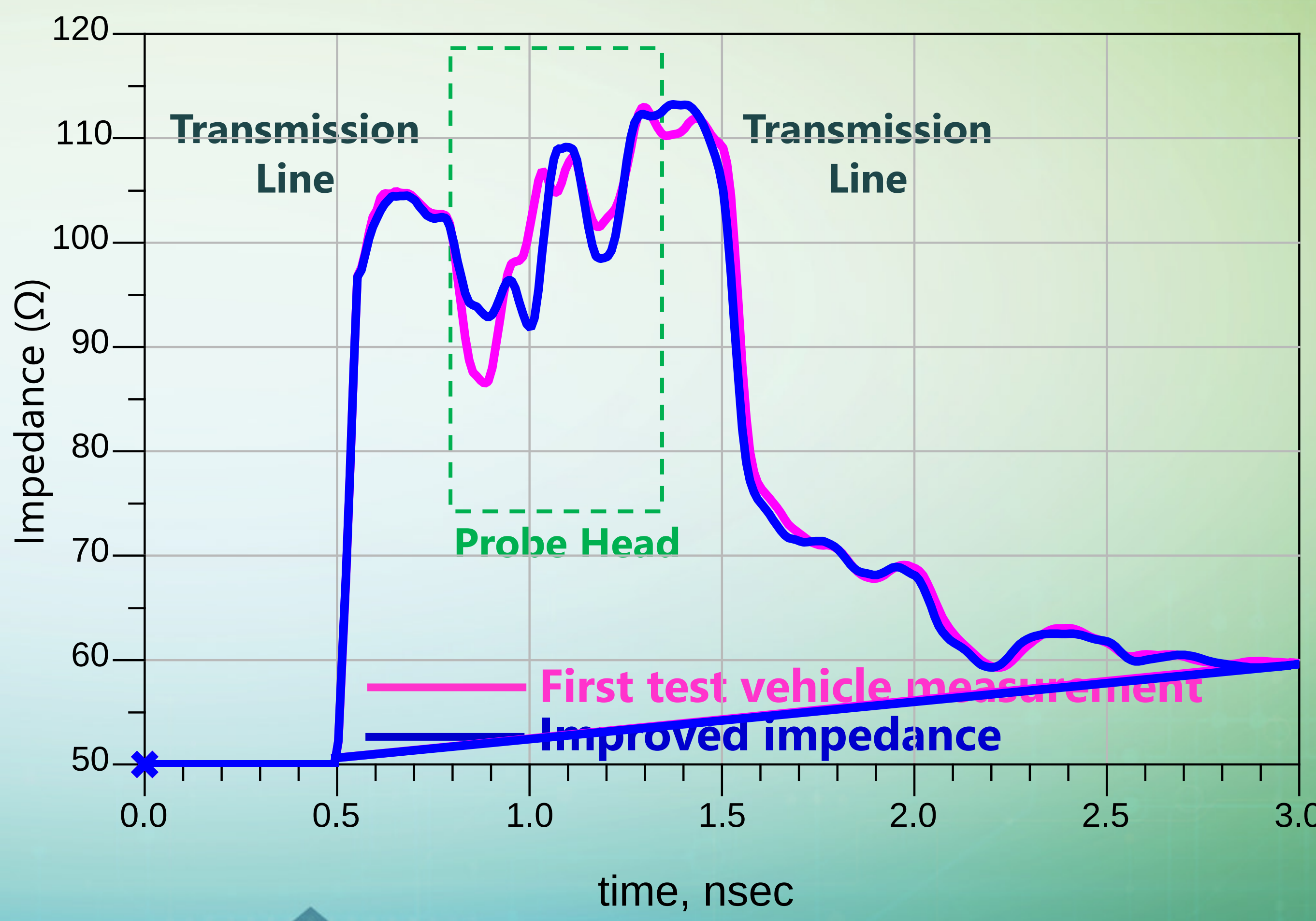
Assessment of the Probe Head

- After the first evaluation of the Probe-Head the ground path was adjusted to improve impedance.
- The measurements of the improvement showed a cleaner transmission and a lower return loss.



Assessment of the Probe Head

- The TDR shows a slight
- Improvement on the impedance; this could be because the differential transmission is more robust to imperfection of the signal path.
- Parasitic effects are seen like the high inductance and capacitance depicted by the TDR.



Summary

- **P**roposed the advanced contact solution probe card for high bandwidth
- **A**dopted the 3D MEMS coaxial shield technology for the metal coaxial shield
- **A**nalyzed the performance of the coaxial contact using the simulation study and the experimental measurement.
- **V**erified the RF contact probe card both in frequency-domain and time-domain method

Acknowledgement

- **Special thanks** for the management of their work & the dedication in preparing data and the review of this paper.

Microfriend Inc.

- **Jooyong Kim**
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Nidec SV TCL

- **Merlin Dudley**
- **Son Dang**

"Thank you for your attention"

If you have any questions, please let us know.

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