RF Probe Card Metrology Tool
(Patent pending)

aps Solutions GmbH

BE Precision Technology

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Legal information

German utility model application (recently filed, not yet registered or published)	20 2015 102 364.2
European patent application (unpublished)	15 166 908.2
US patent application serial number (unpublished)	14/707,441

Main index

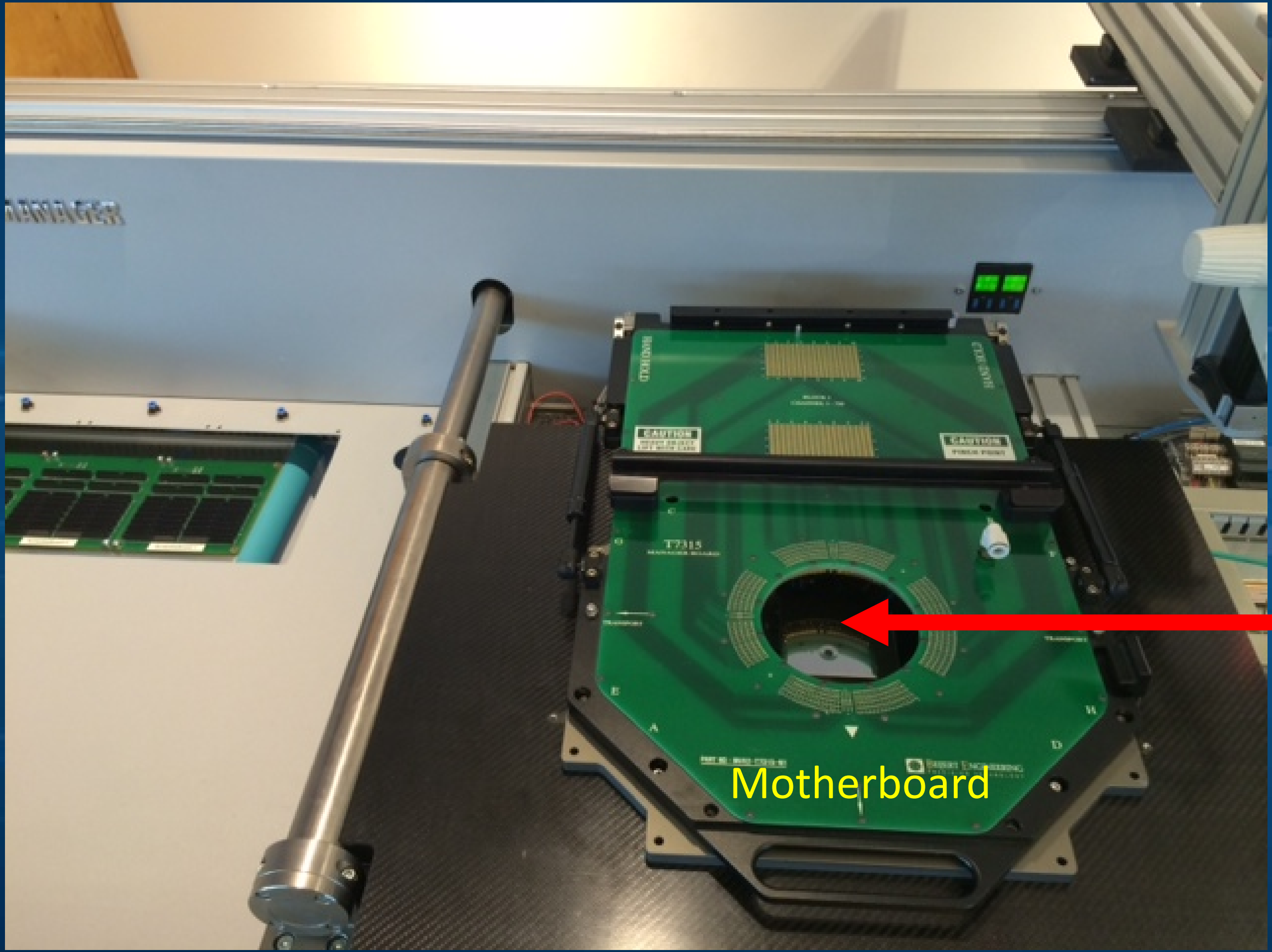
- Existing probe card metrology tools
- Video of the moving chuck
- The need for RF measurement of a probe card
- Why a standard VNA won‘t work
- I have a cunning plan…..
- What the Semiconductor world (Europe at least…) says about it
- Where we are now with the project
- Future things we can do

- Additional: quick tutorial on why a VNA is the wrong solution

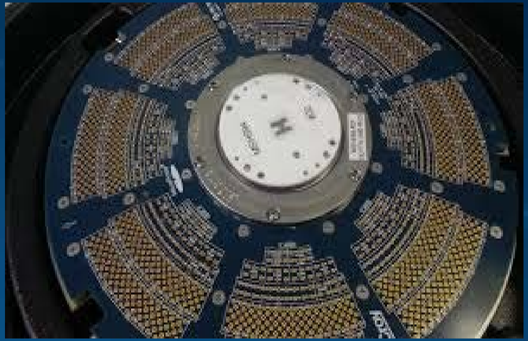
Existing BE M4 Probe Card Analyser

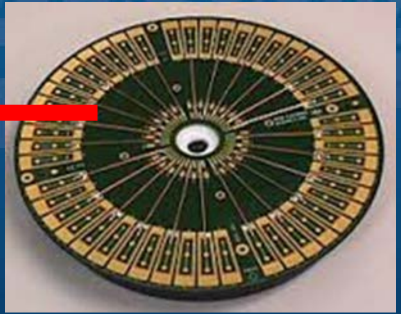
BE Precision Technology

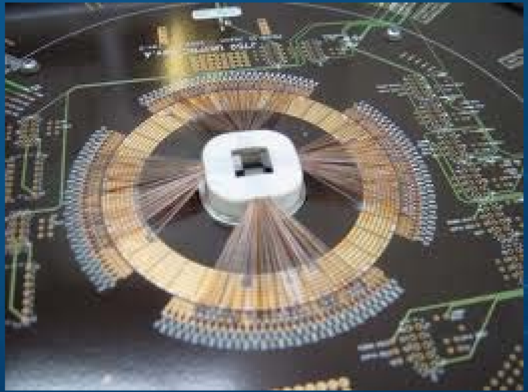
How a Probe Card is measured




RF Probe Card


Vertical Probe Card


Probe Card
(to be tested)


Cantilever Probe Card

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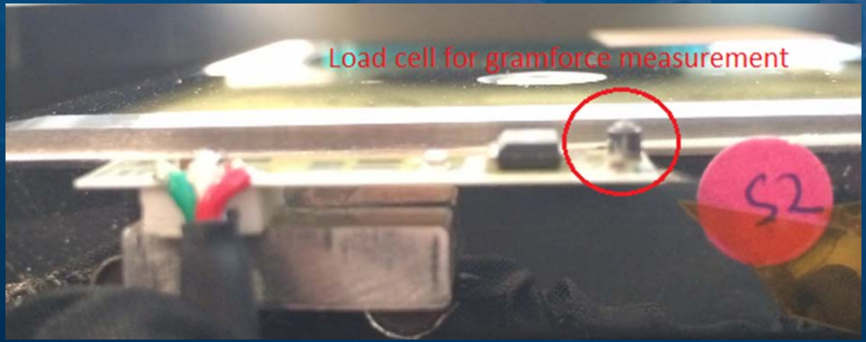
Existing measurements of Analyser

Mechanical or Optical

- Alignment (X & Y)
- Planarity (Z)
- Tip diameter (um)
- Tip scrub (um)
- Gram force (g)

Electrical

- Contact resistance (ohms)
- Leakage current (nA)
- Capacitance (F)



And for RF measurements of Probe Cards........?

- Growing range of devices for RF and HSD applications.
- Requirement to test at wafer level.
- Several Probe Card vendors already offer “RF solutions“ for probing
- No metrology tool exists.
- Can only offer basic simulation data.
- Results will vary with manufacturing tolerances.
- No way to verify RF performance after repair / cleaning / maintenance.
- Makes life difficult for test engineer

The Analog RF Spectrum

800MHz~900MHz → GSM mobile phone
1575MHz → GPS
1700MHz~2000MHz → 2.5G mobile phone
1900MHz~2000MHz → 3G mobile phone / WCDMA
1850MHz~1910MHz → CDMA2000
2400MHz~2500MHz → 802.11b/g (WLAN), Bluetooth
2300MHz~2700MHz → Wimax
2500MHz~2600MHz → 4G LTE (USA & Canada)
5000MHz~6000MHz → 802.11a (WLAN)

And the list grows continuously….

High Speed Digital (HSD) Devices

PCI Express 1.0 ➔250Mbps
PCI Express 2.0 ➔500Mbps
PCI Express 3.0 ➔985Mbps

USB 2.0 ➔480Mbps
USB 3.0 ➔5.0 Gbps

SATA I.0 ➔ 1.5Gbps
SATA 2.0 ➔ 3.0 Gbps
SATA 3.0 ➔ 6.0 Gbps
SATA 3.2 ➔ 16.0 Gbps

Thunderbolt 1 ➔ 10.0 Gbps
Thunderbolt 2 ➔ 20.0 Gbps
DDR II➔ 800Mbps
DDR III ➔ 1.6 Gbps
HDMI 1.3 ➔ 3.4 Gbps
Display Port ➔ 2.7Gbps
Mini-LVDS ➔ 500Mbps
MDDI ➔ 500Mbps

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Why is life difficult for the test engineer?

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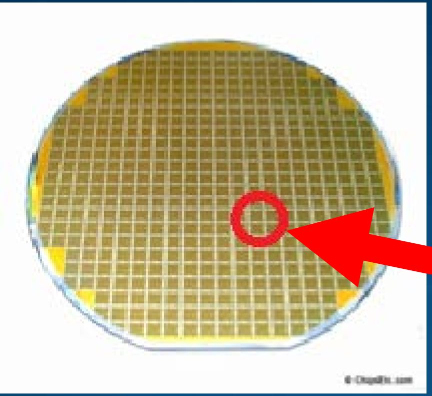
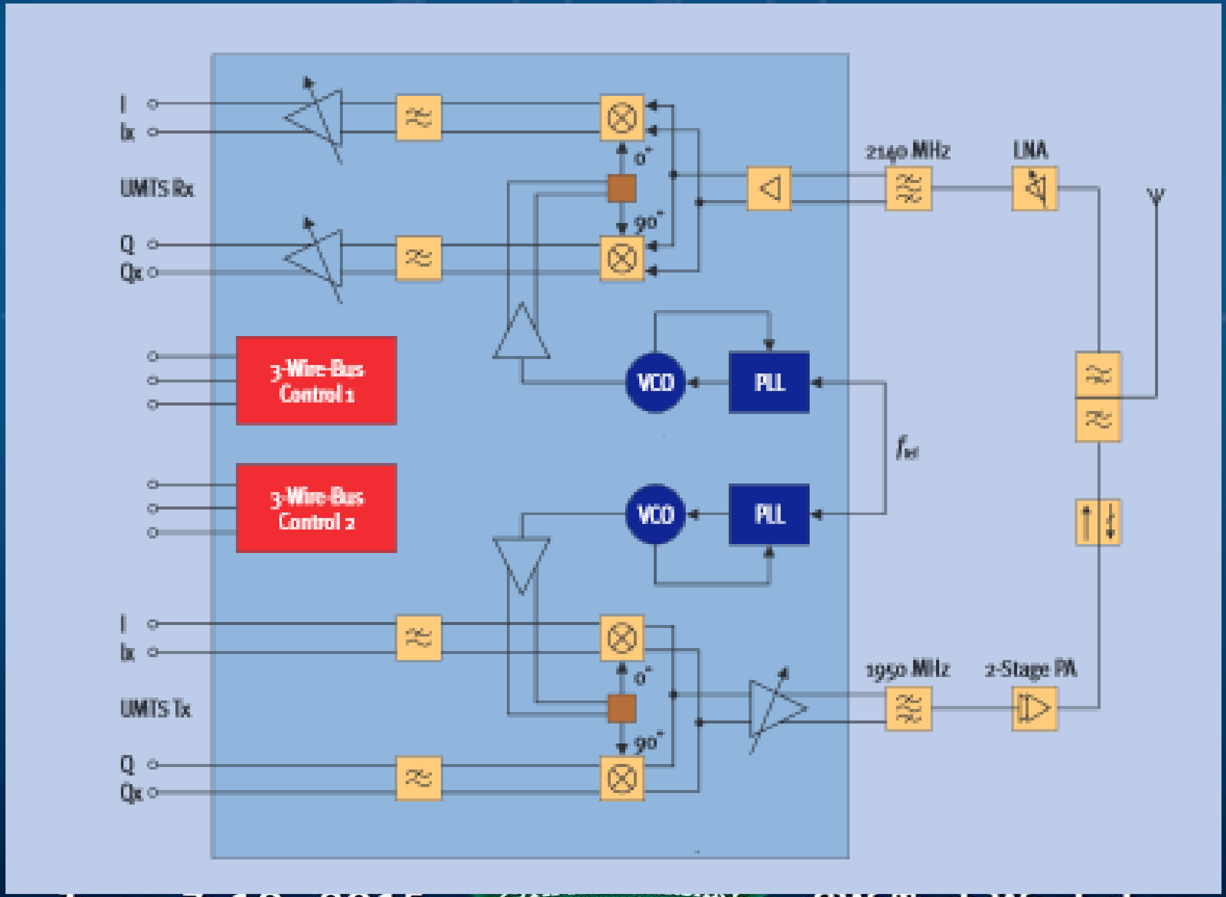


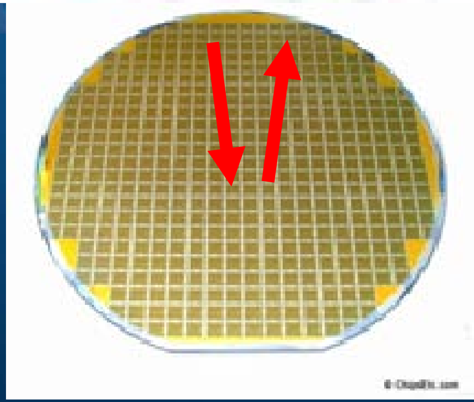


Known level out of the device.

Known level into the device.

Why is life difficult for the test engineer?

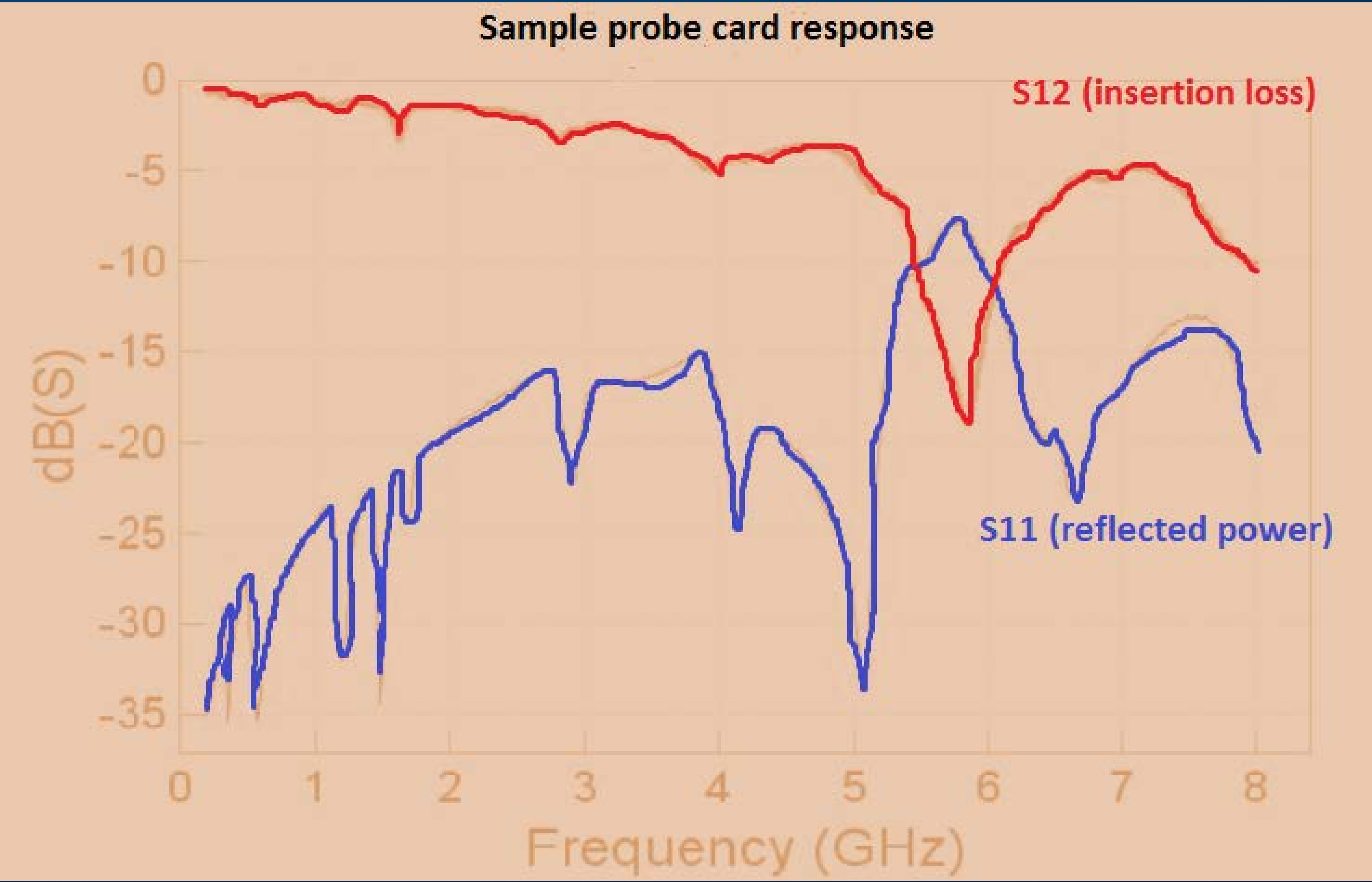
Known
levels here.



So what are the probe card losses w.r.t. frequency?

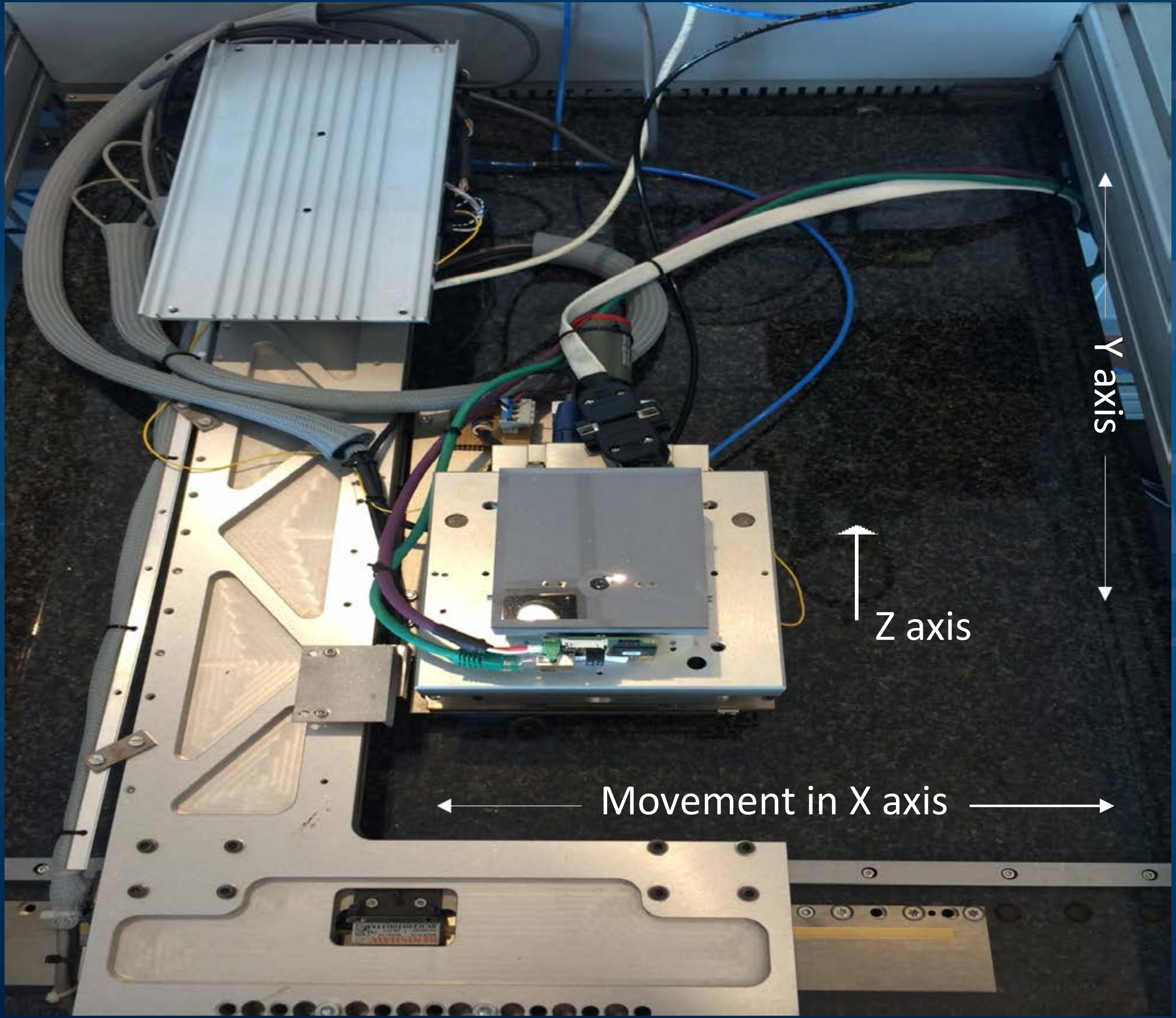
But what about here?

We need to know S parameters of the probe card

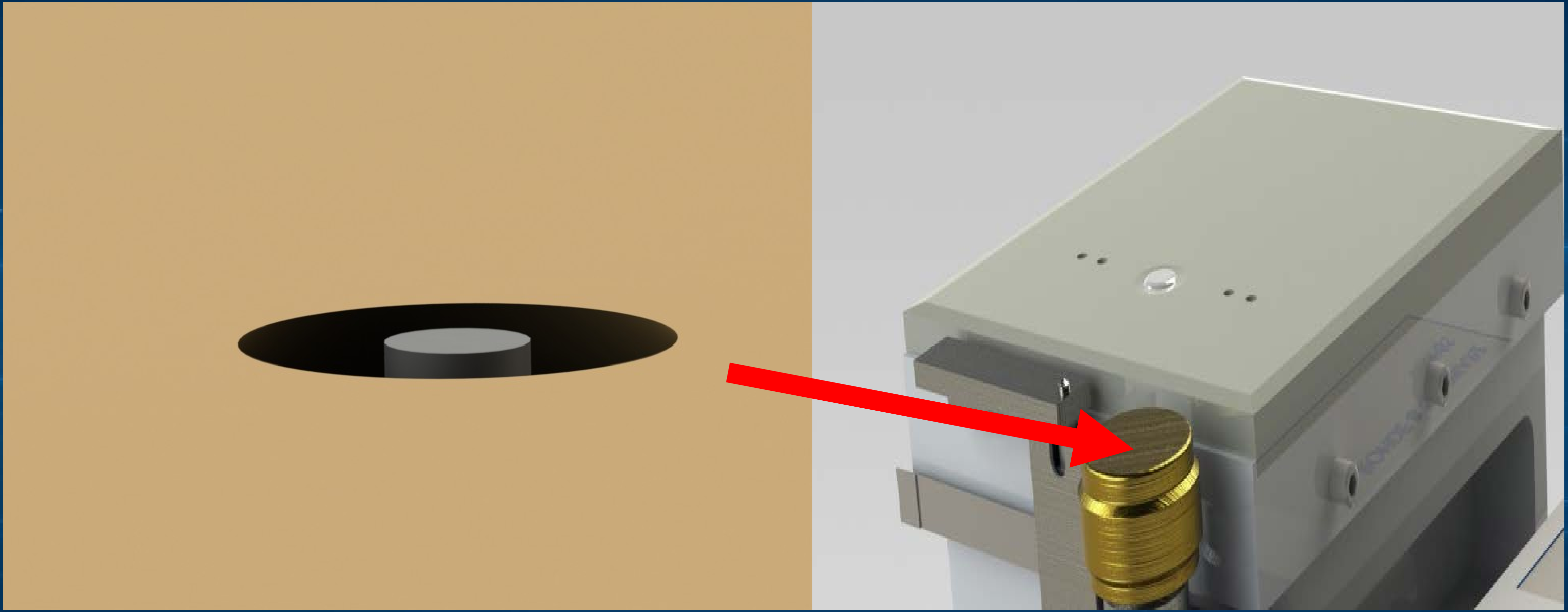


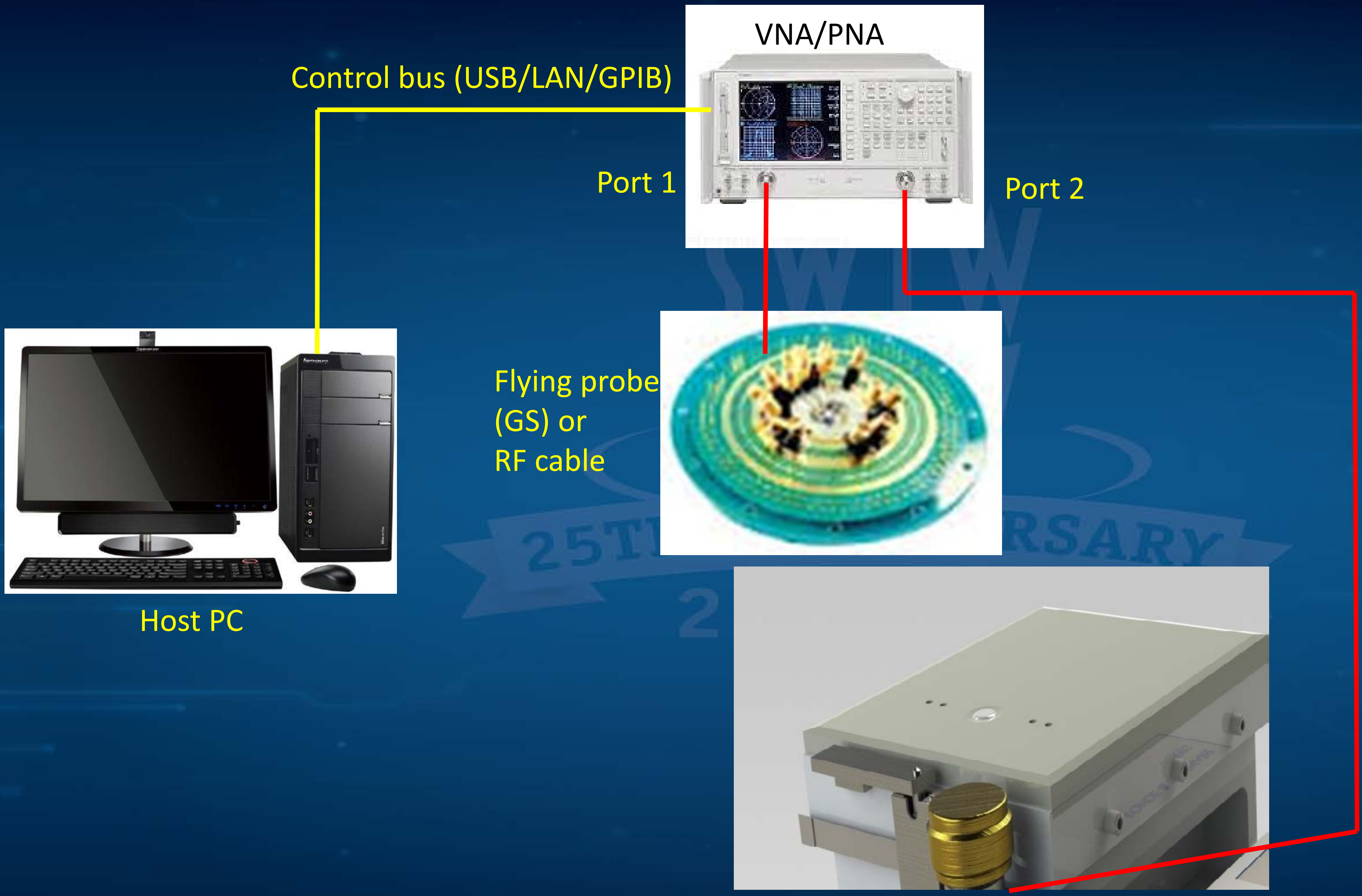
M4RF Probe Card Analyser ??

We need to know S parameters of the probe card



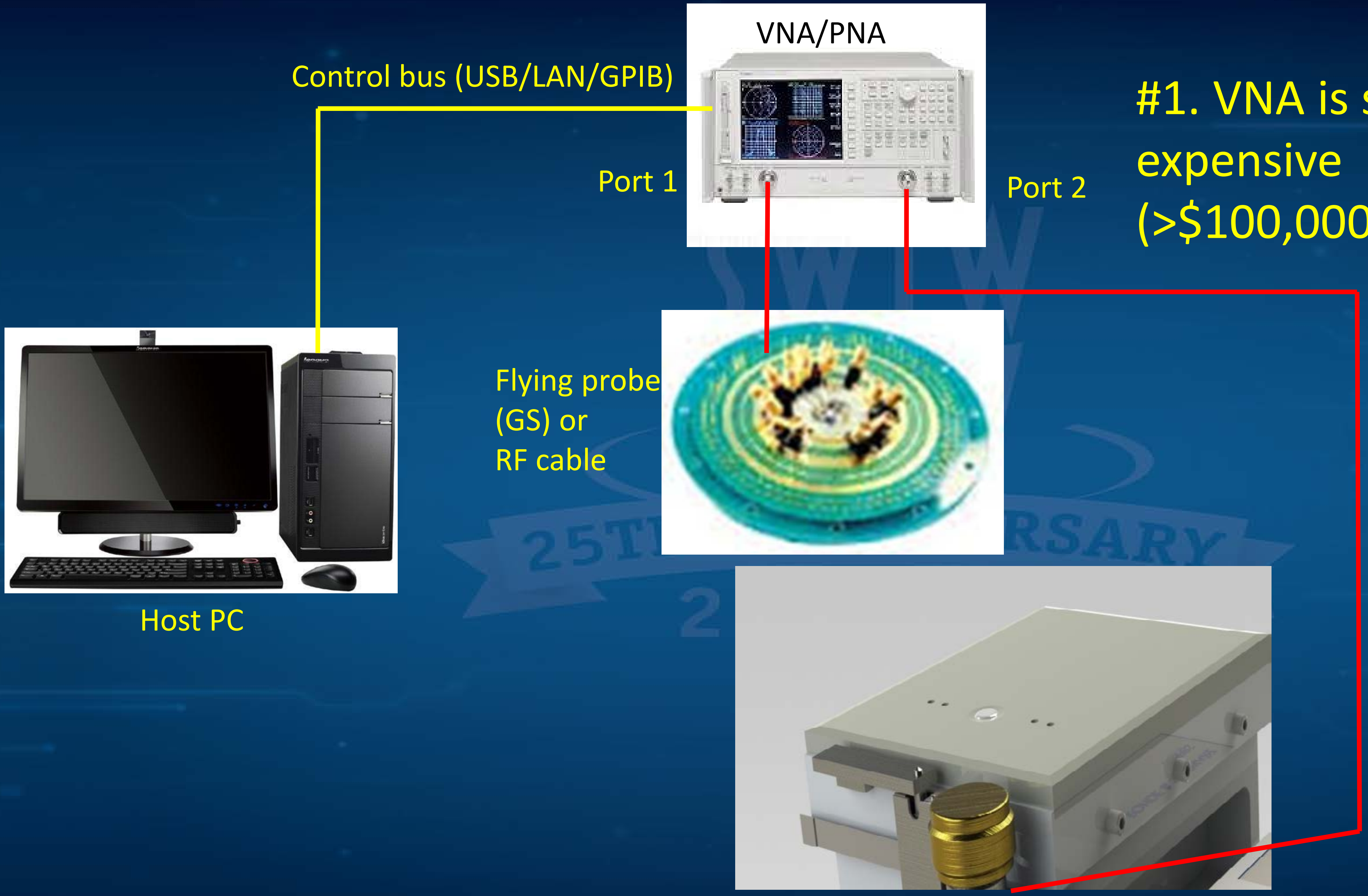
What if we could add an
RF chuck to the original moving chuck?





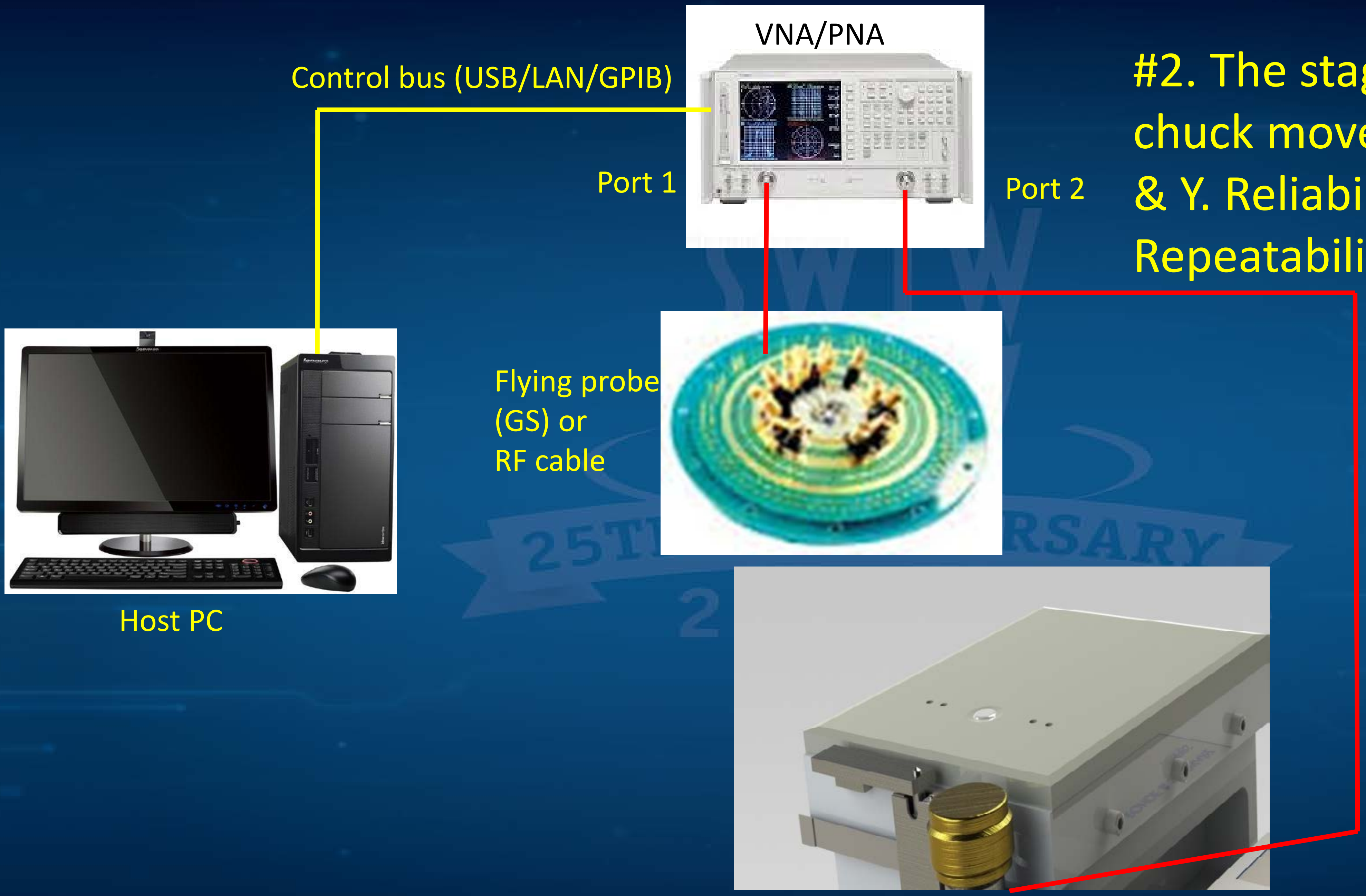
Chuck with sensors moves in X,Y,Z to tip of probe to be measured.

#1. VNA is seriously expensive (>$100,000)!!!!!!



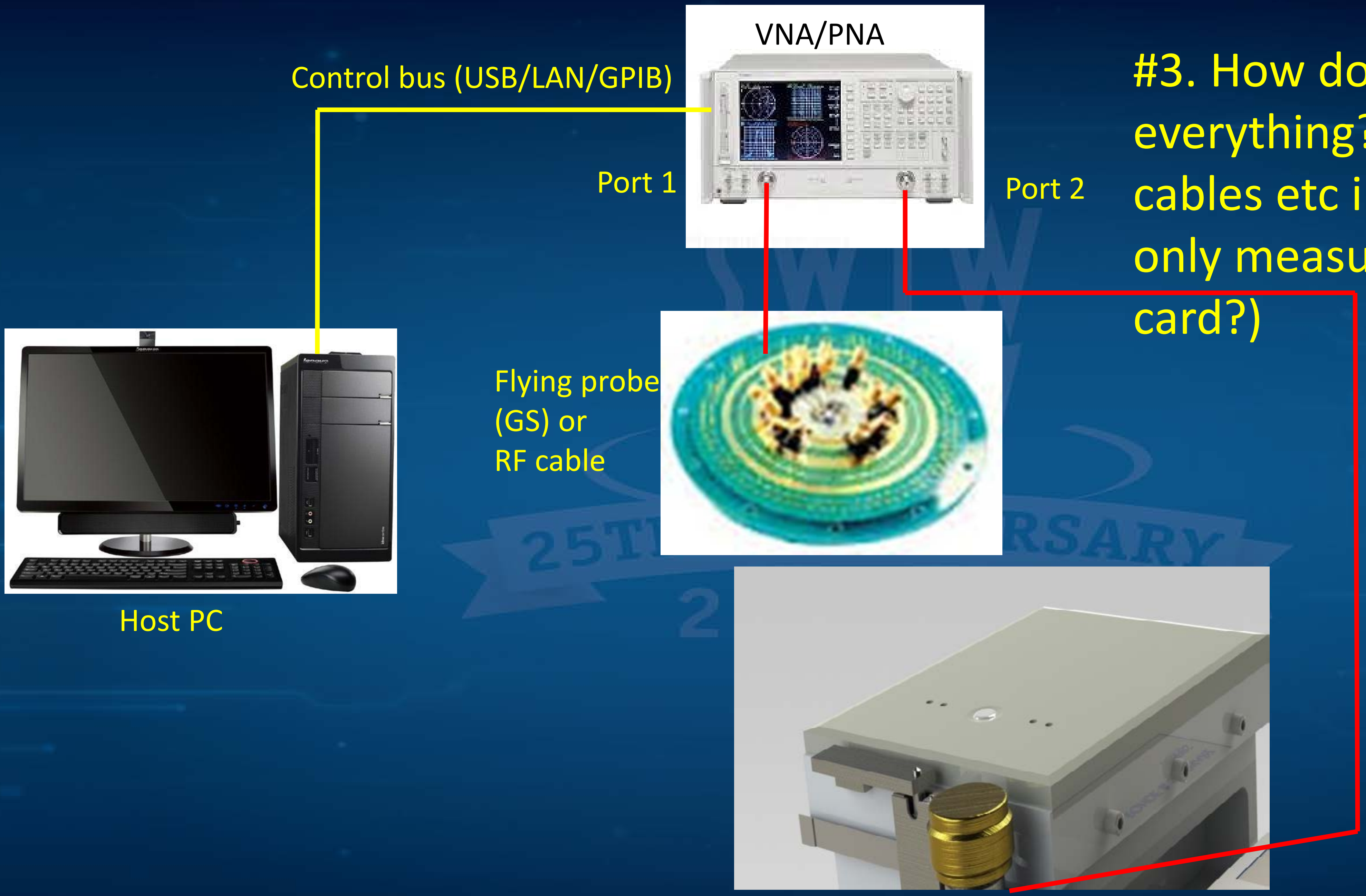
Chuck with sensors moves in X,Y,Z to tip of probe to be measured.

#2. The stage with RF chuck moves 200mm in X & Y. Reliability & Repeatability issues???



Chuck with sensors moves in X,Y,Z to tip of probe to be measured.

#3. How do you de-embed everything? (make the cables etc invisible so you only measure the probe card?)



Chuck with sensors moves in X,Y,Z to tip of probe to be measured.

Problems, Problems, Problems……

1) VNA costs more than a very nice car!!

2) Reliability & Repeatability issues of flexing coax!!

3) How to de-embed everything?

Problems, Problems, Problems……

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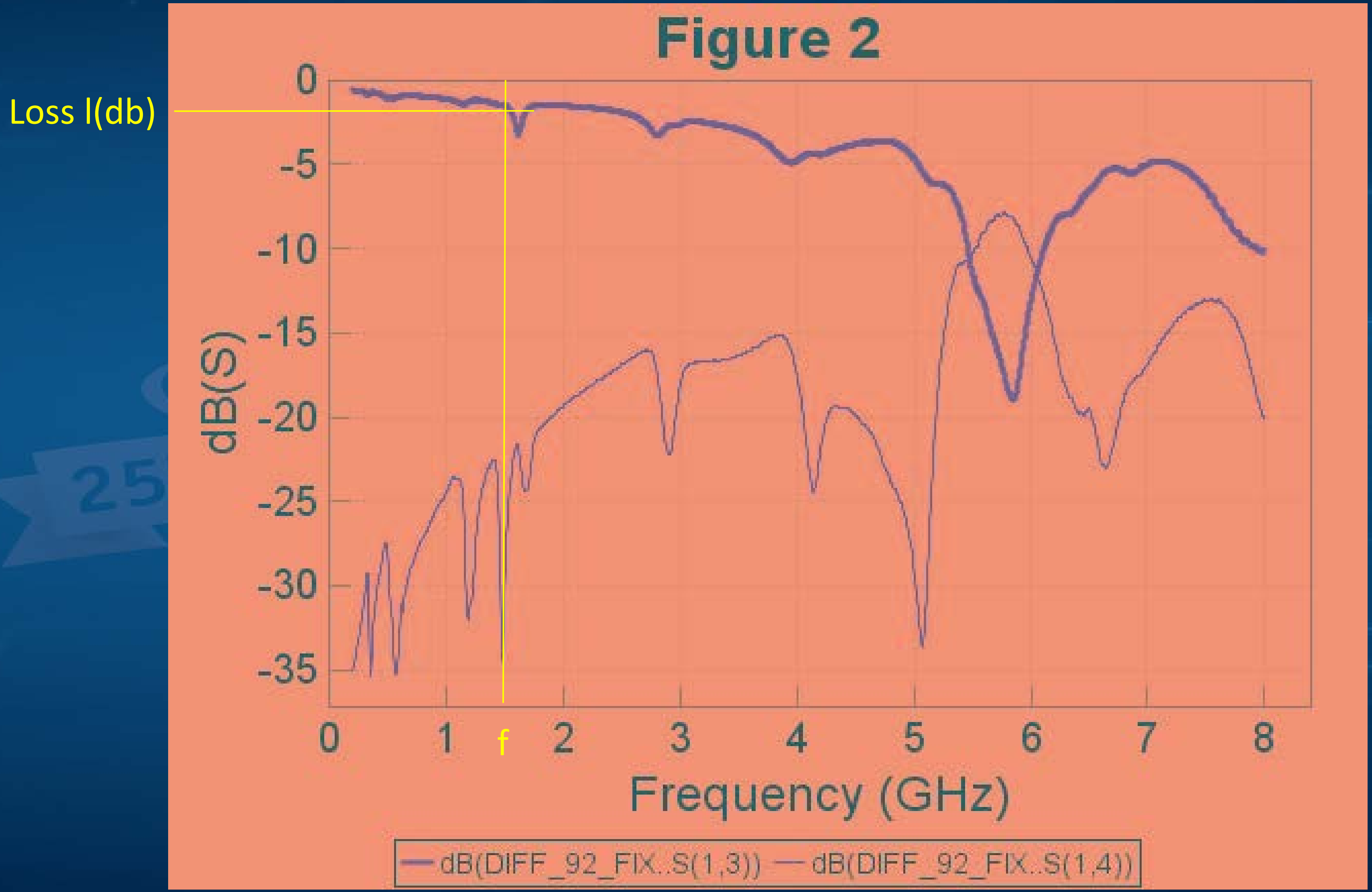
Is there a better way to do this?

What do we need to measure?



S parameter data contains Amplitude & Phase info

Network Analyzer Impedance:	50					
MAX3550/3553 Input Impedance:	75					
Frequency (MHz)	S11 (in 50Ω)		Impedance		S11 (in 75Ω)	
	Real	Image	Real	Image	Real	Image
1	0.53	-0.12	150.98	-50.17	0.37	-0.14
2	0.53	-0.12	148.11	-52.37	0.36	-0.15
3	0.53	-0.13	145.59	-55.14	0.36	-0.16
4	0.52	-0.14	142.66	-57.44	0.36	-0.17
5	0.52	-0.15	139.69	-59.71	0.35	-0.18
6	0.52	-0.16	136.83	-61.40	0.35	-0.19
7	0.51	-0.17	133.72	-63.43	0.34	-0.20
8	0.51	-0.18	130.63	-65.16	0.34	-0.21
9	0.51	-0.19	127.48	-66.63	0.33	-0.22
10	0.50	-0.19	124.44	-67.89	0.33	-0.23

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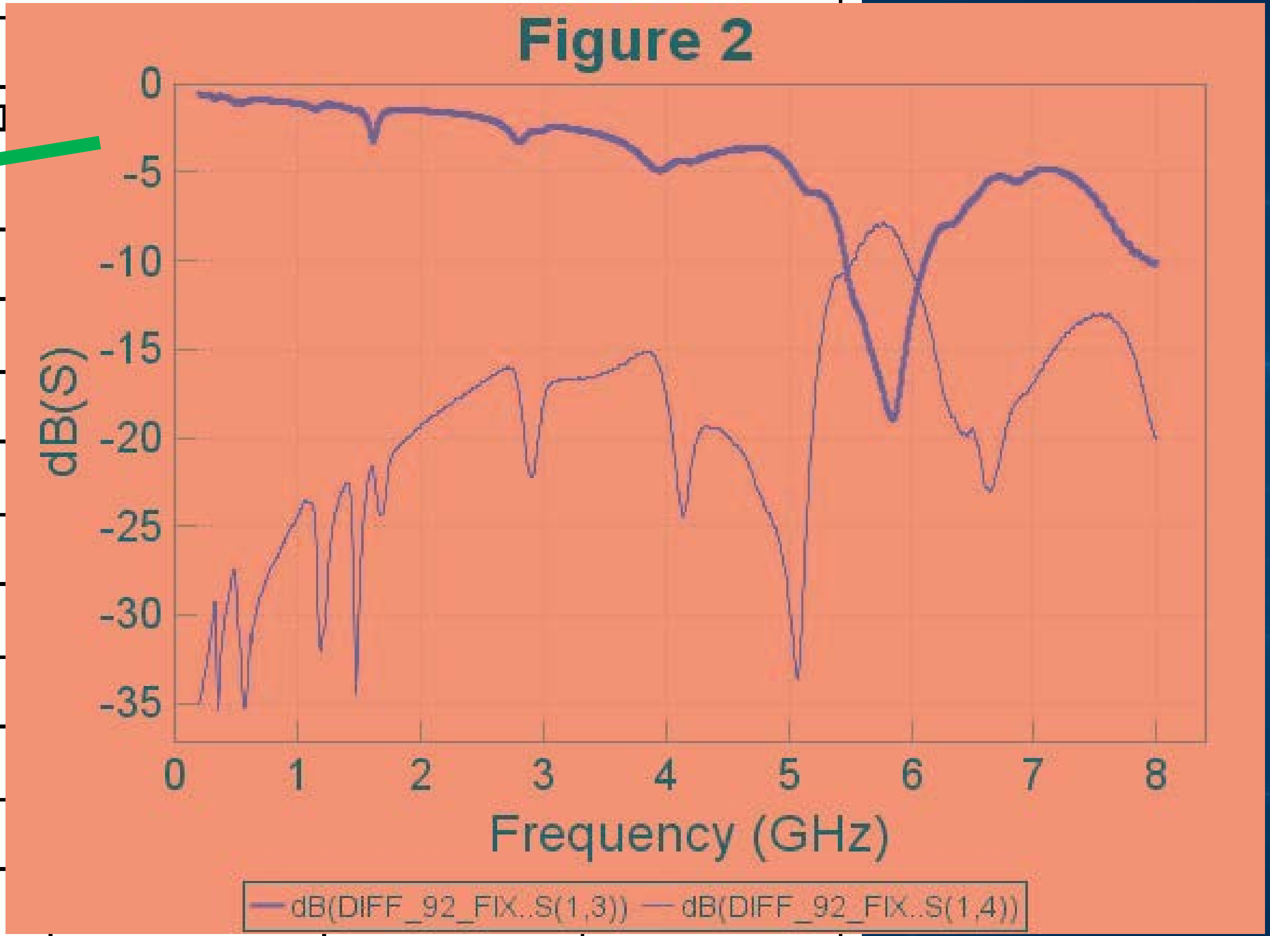

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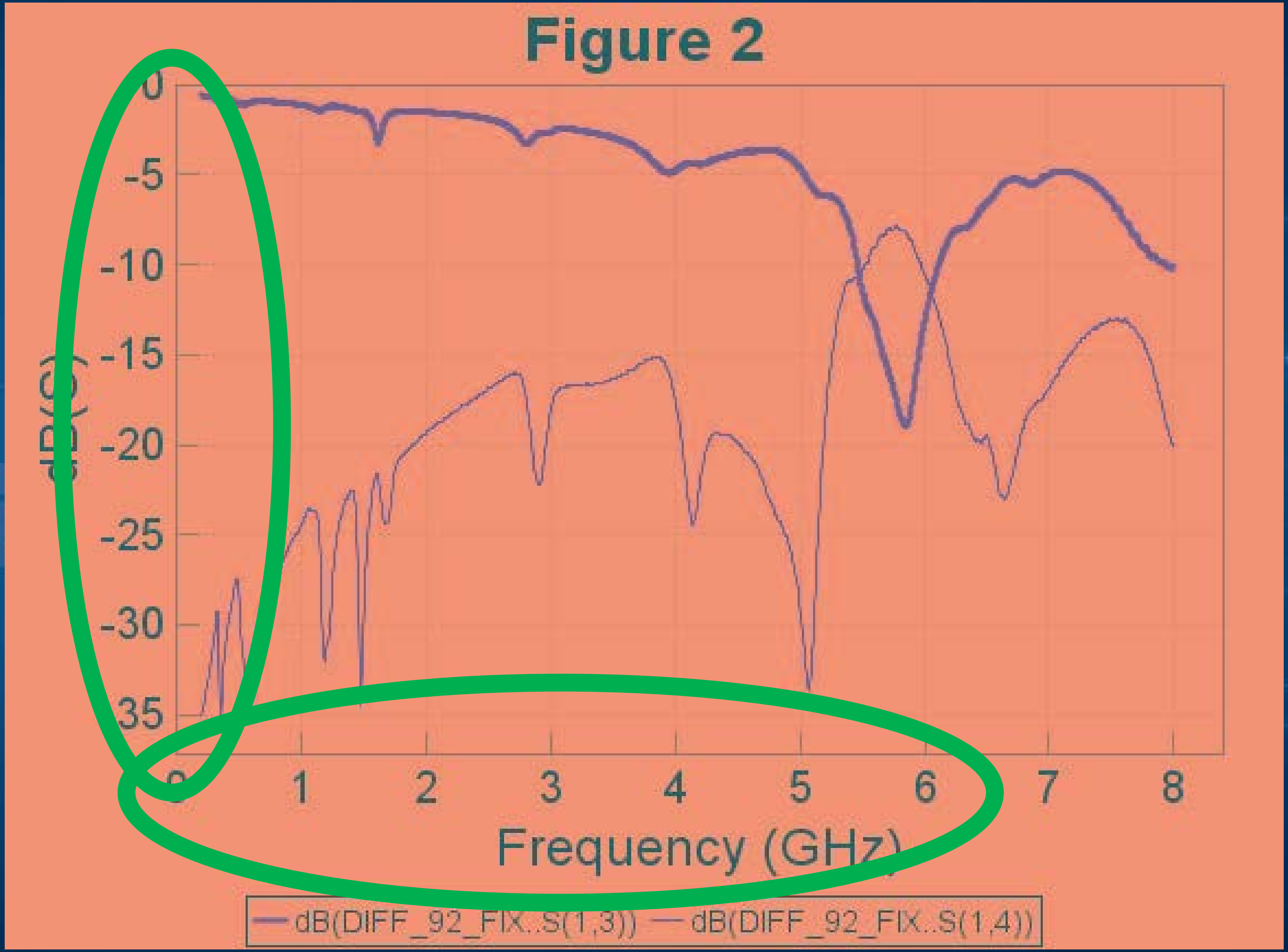
10	0.50	-0.19	124.44	-67.89	0.33	-0.23

Phase information. Not really necessary.

What else do we need to measure?



Only want to measure to 6Ghz

Only want 40dB dynamic range

So we need $100,000+ worth of

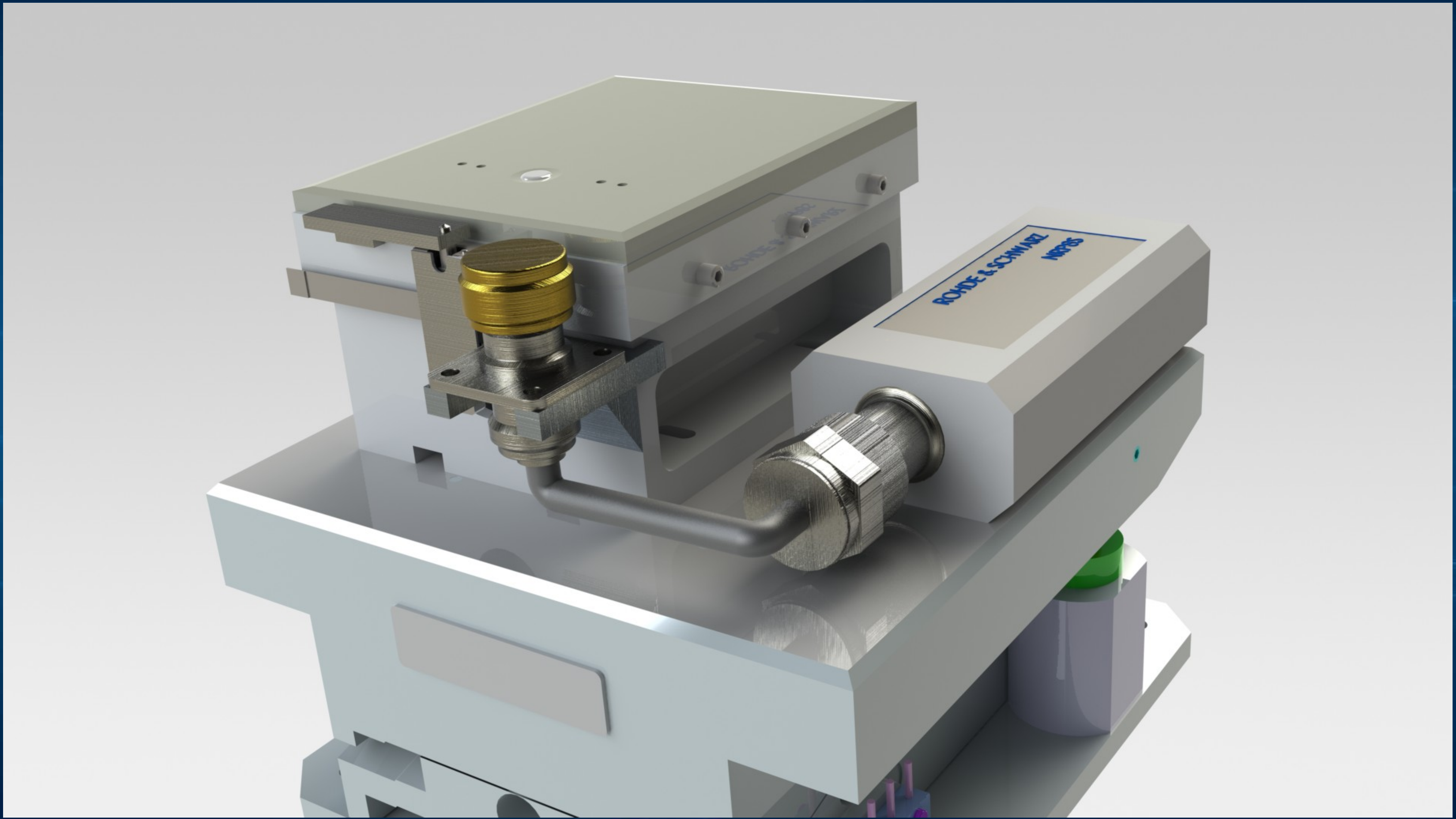
20Ghz, 100dB VNA why exactly?

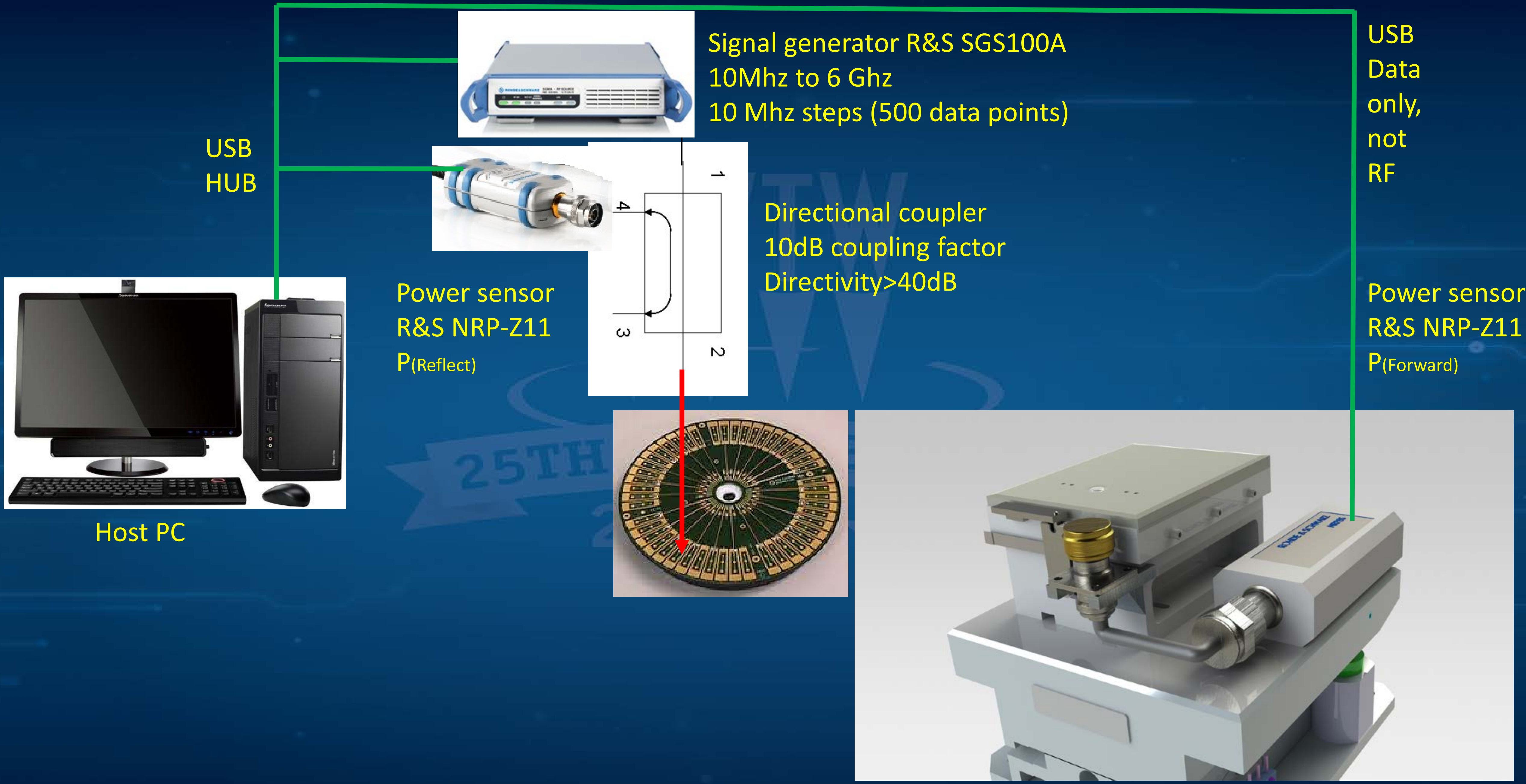
1. We don‘t need a very expensive VNA/PNA.
2. We want to measure to 6Ghz, not 20Ghz.
3. We only need a dynamic range of ~40dB, not 100dB
4. We want all RF paths to be as short as possible.
5. We want no movement in these RF paths.

I have a cunning plan.....

Inspiration!!! Who needs a VNA ?

The new RF chuck-no flexing coax!!




Signal generator R&S SGS100A
10Mhz to 6 Ghz
10 Mhz steps (500 data points)
USB Data only, not RF
USB HUB
Directional coupler
10dB coupling factor
Directivity>40dB
1
2
3
4
Power sensor
R&S NRP-Z11
P(Reflect)
Power sensor
R&S NRP-Z11
P(Forward)
Host PC

USB
HUB

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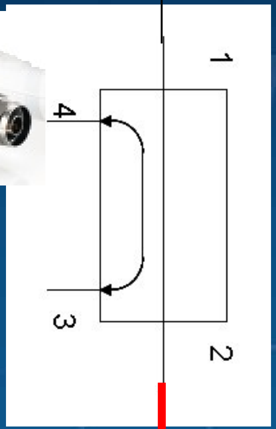
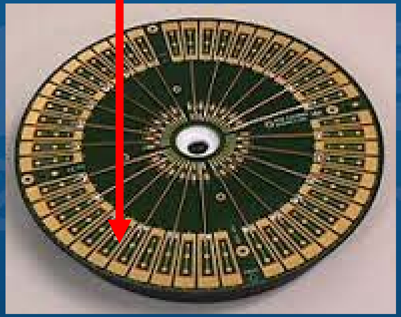


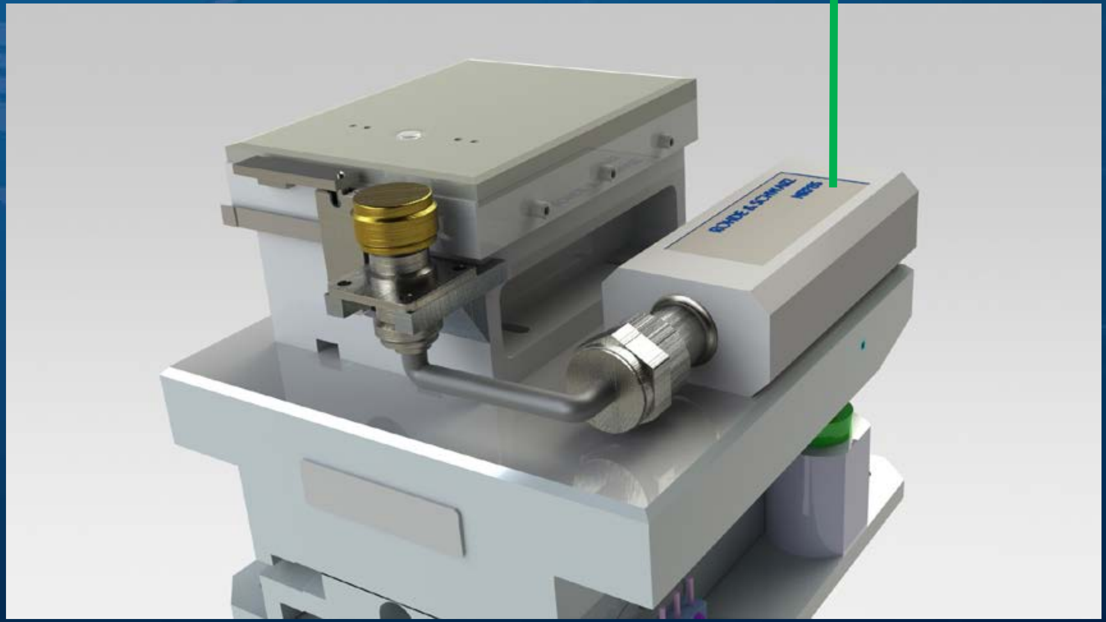
Directional coupler
10dB coupling factor
Directivity>40dB

Power sensor
R&S NRP-Z11
P(Reflect)

Host PC



Power sensor
R&S NRP-Z11
P(Forward)



Test equipment hardware now costs a lot less!!

Solution, Solution, a way forward.....

1) VNA now replaced with cheaper discrete equipment

2) Flexing coax from moving stage now gone-USB only.

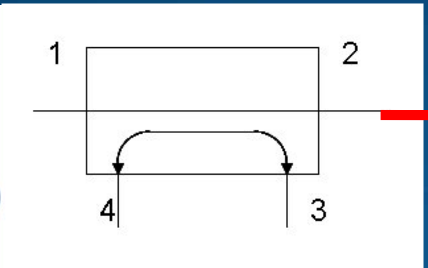
3) How to de-embed everything-*in progress*.

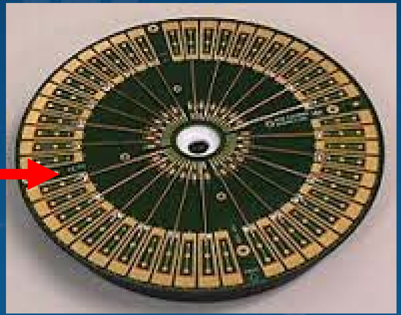
- Modelling of RF chuck by T.U. Dresden
- Building KGPC and modelling its performance.
- Characterisation of all signal paths, connectors etc.

Forward path gain distribution

Probe card forward loss X(dB)

Measured level out (dBm)





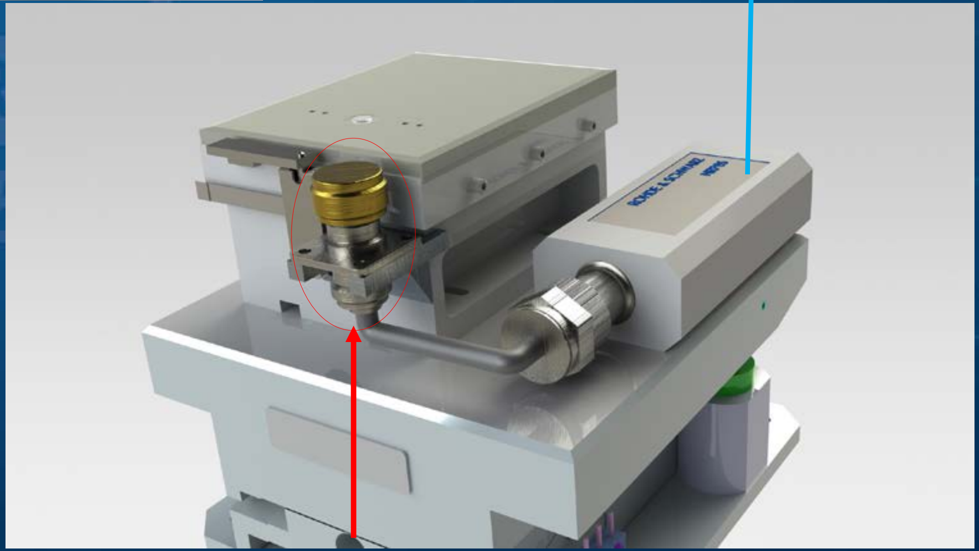
P(Gen)

Set frequency and
Power level (dBm)
Typically 10Mhz to 6Ghz
At 0dBm (1mW)

Coupler
loss L(cp)

Connection to Probe card
Loss L1

Could be Coax
Or GS probe
Still L1 just different L1



Loss L2, characterised by TU Dresden

For any given frequency ƒ…….

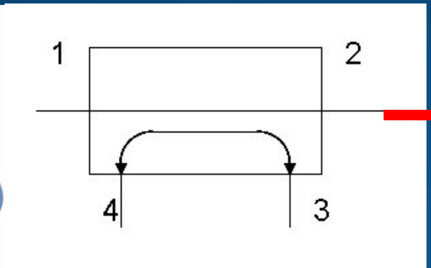
Probe card loss $X_{(db)}$=:

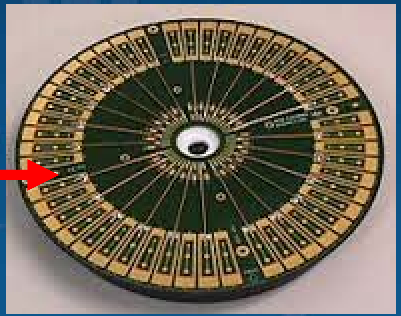
{Gen output $(_{0dBm})$-P$(_{forward(dBm))}$}+{L_{cp}+L_1+L_2 (dB)}

So you can determine X(db) w.r.t. ƒ

Probe card forward loss X(dB)

Measured level out (dBm)





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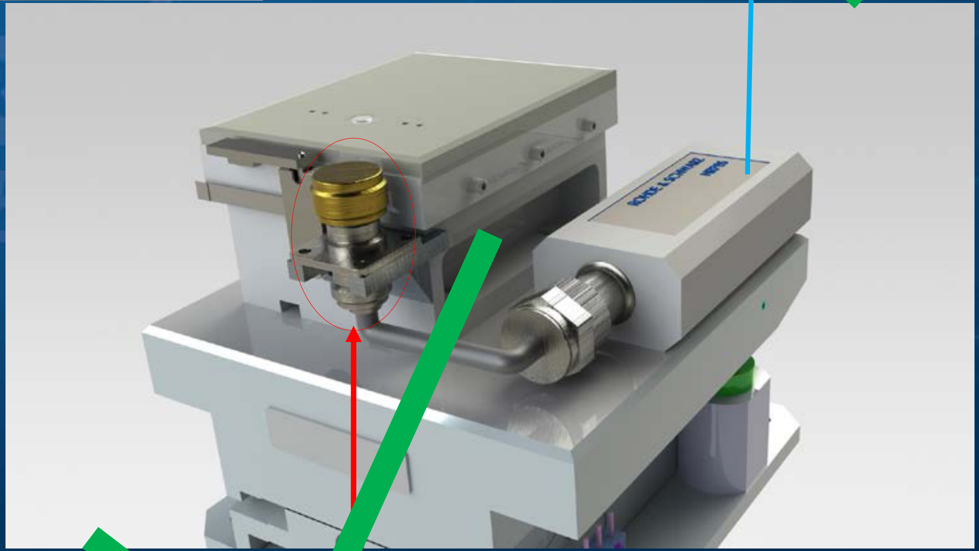


Loss L2 characterised by TU Dresden

A nice little trick learned from experience using Rohde & Schwarz test equipment

$$\{\text{Gen output }(_{0dBm}) - P(_{forward(dBm)})\} + \{L_{cp}+L_1+L_2\ (dB)\}$$

This data (w.r.t. f) can be uploaded as S parameters (set Ø to zero) directly into the power sensor head via USB port to reduce PC number crunching And hence speed the measurements up!!

We can also do the same for reflected power data.

Target specifications

- 10Mhz to 6Ghz (future model 12Ghz)
- +/- 1dB accuracy.
- Operator driven menu with graphics.
- Easy calibration routine (using a known good probecard)
- Verification against simulation data.
- Not S parameter data, just loss versus frequency (Scalar network analyser)
- Calculation of -3db point.
- Go / No Go verification for operator.

Benefits

- **Metrology tool to measure RF performance of probe card**
- **Can be driven by an operator, not an expensive RF engineer**
- **Test engineer now a happier person.**
- **Provides a benefit to the Semiconductor test industry.**

Intel Mobile Communications

In the modern chip industry structures accompanied by technology nodes as well as chip size are dramatically shrinking. On the other hand the implemented chip functionality is increasing from design to design step. In the RF area the number of integrated RATs (radio access technology) is following the increasing demand of bandwidth in terms of transmitted and received data. Thus the chips are nowadays able to transmit on multiple channels as well as receive data in a broader bandwidth like "carrier aggregation". To test this MIMO (multiple in multiple out) functionality a detailed knowledge of the whole chip surrounding environment (i.e. PCB, contactor etc.) is essential.

Intel Mobile Communications is highly interested in analyzing its high volume production DUT – boards (device under test) as well as probe cards to gain excellent knowledge about detailed technical parameters like frequency response, rise / fall time, X-talk inter and intra contactor area, impedance and losses. Moreover this tool allows us to monitor in a standardized and repeatable way the aging, wearing out of our tester interface boards in volume production. This helps to maintain and repair those units in an inexpensive way without encountering yield losses.

Stephan Fuchs, RF test development engineer at Intel Mobile Communications, Munich
Stephan.Fuchs@intel.com

GLOBALFOUNDRIES®

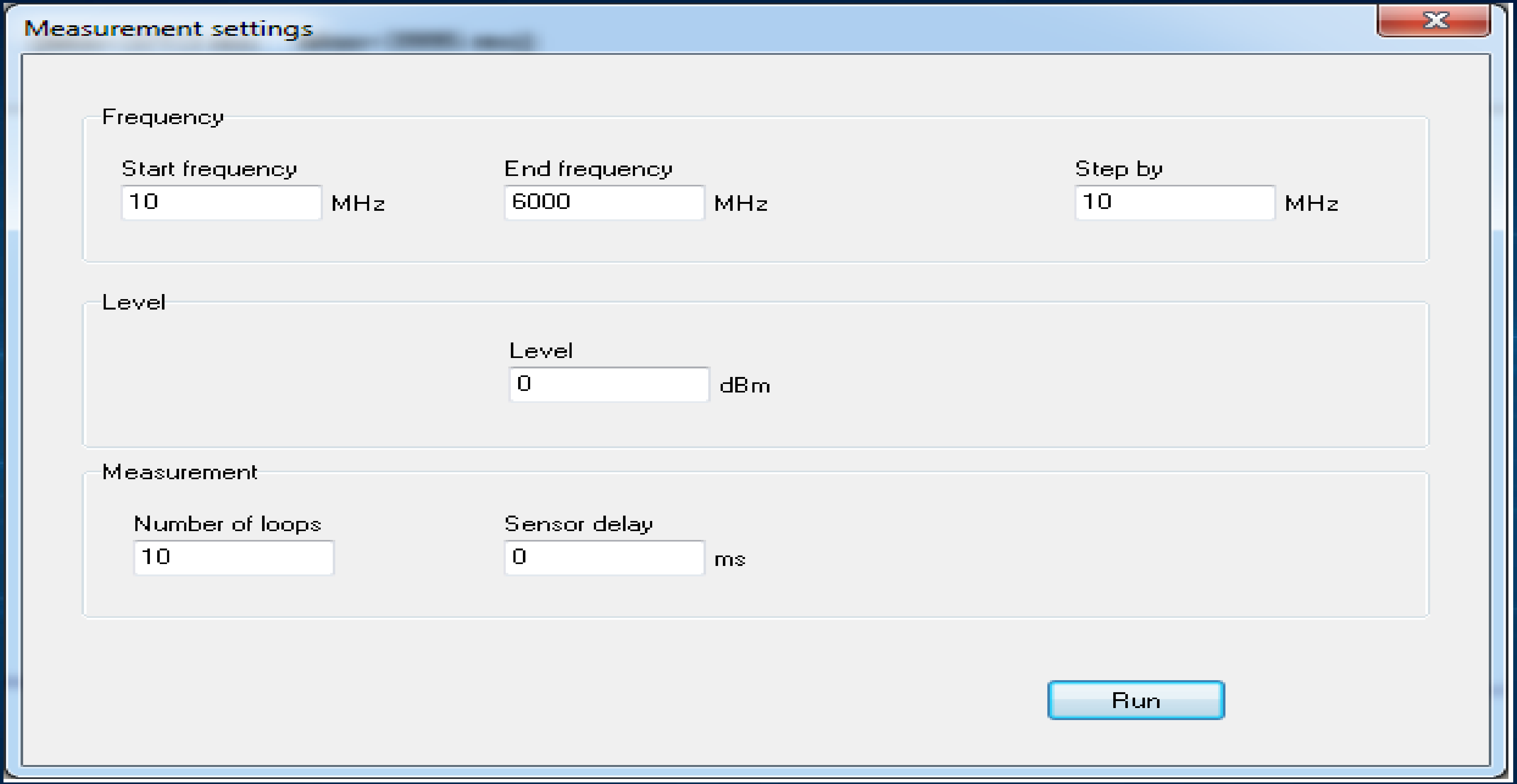
In the silicon foundry business fabless customers have a strong desire to fully characterize RF-type probe cards at the earliest possible stage and at the lowest cost. Performing the probe card characterization at the tester level is too expensive and time consuming. This approach also limits the test cell utilization and wafer throughput in a foundry world.
Having a probe card analyzer tool that performs in depth RF probe card characterization will solve all aspects – that are missing at this point in time:

- Low cost characterization approach using a probe card analyzer and RF measurement equipment connected to the probe card analyzer at the foundry locations and OSATs (out sourced assembly and test facilities)
- Low cost characterization capability for probe card suppliers (no probe card supplier can afford to have testers and probers installed at the supplier site in order to fully characterize RF type probe cards)
- Parallel engineering activities possible – offline by using a probe card analyzer connected to RF measurement equipment & online by using testers and probers
- Faster development and verification times of RF type probe cards (probe card suppliers can do full in-house verification instead of waiting for feedback from the test floors)
- Standardized and repeatable check out and characterization methods for RF type probe cards

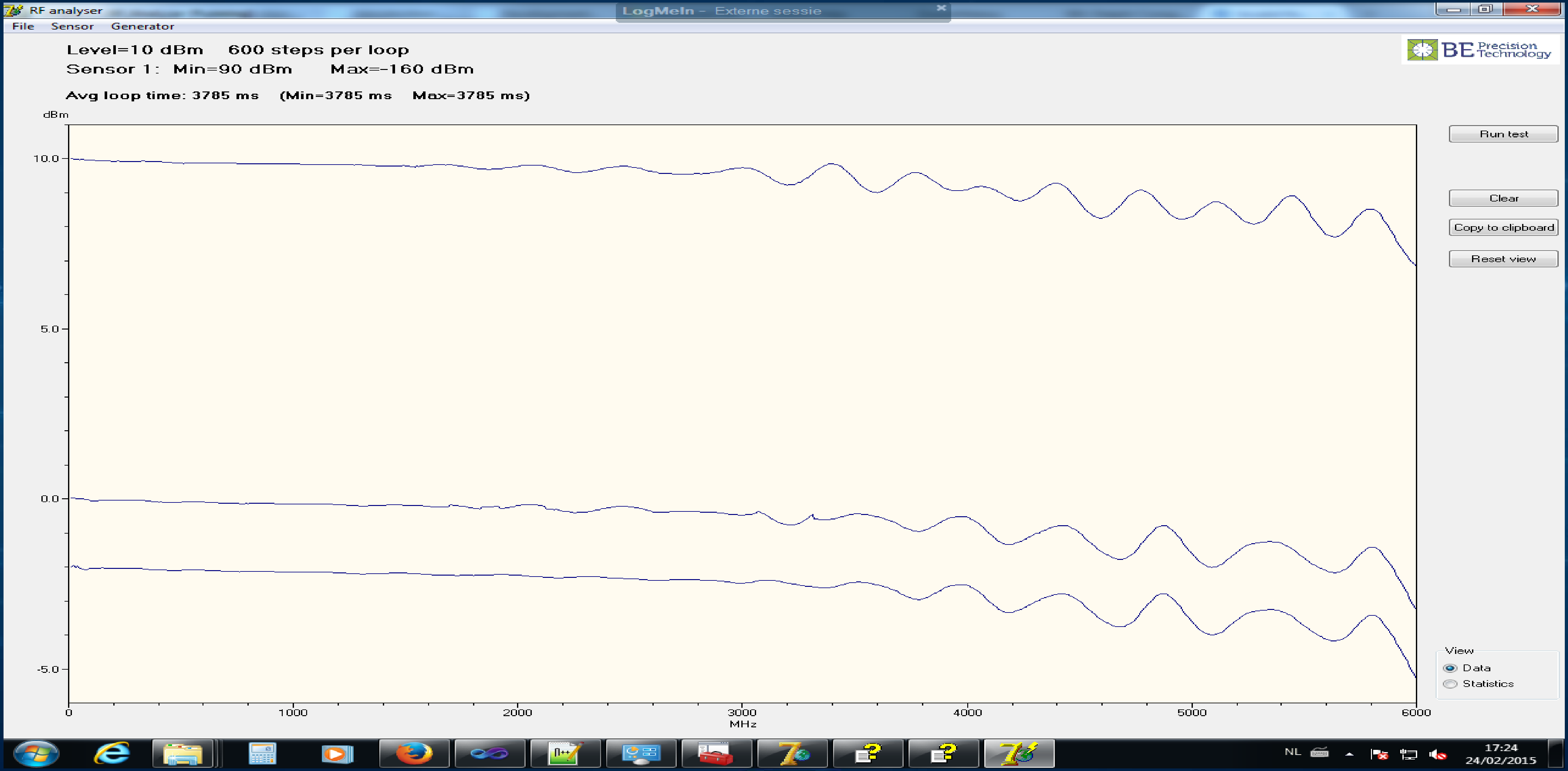
GLOBALFOUNDRIES and their customers would be very interested in having a technical solution that allows the complete check out and characterization of RF type probe cards at a lower cost, fast turnaround time and standardized repeatable approach.

Jens Kober

Sr. Manager Test Engineering, GLOBALFOUNDRIES Dresden
Jens.Kober@globalfoundries.com


Measurement settings
Frequency
Start frequency
10
MHz
End frequency
6000
MHz
Step by
10
MHz
Level
Level
0
dBm
Measurement
Number of loops
10
Sensor delay
0
ms
Run

First results (sensor direct to generator: N›BNC›SMA connectors)



Future work

- Improve spec to 12GHz. Should be a simple equipment upgrade.
- Allows probe card manufacturers to measure / tweak / improve their designs.
- Measurement of probe tip contamination in the RF domain.
- Measurement of effectiveness of cleaning media in the RF domain
    - Maybe contact capacitance or contact impedance will be future buzzwords?
- Differential signal measurement? Chuck design will get „interesting“
- Insert your idea here. We want to work with you and solve problems.

Acknowledgements

- **Mr Hanns-Georg Ochsenkuehn,** Managing Director, aps Solutions GmbH

- **Mr Ulrich Eckenberger**, Director of Global sales operations, Rohde & Schwarz GmbH

- **Mr Hans-Joerg Strufe**, Director Product Managagement Signal generators & power sensors, Rohde & Schwarz GmbH

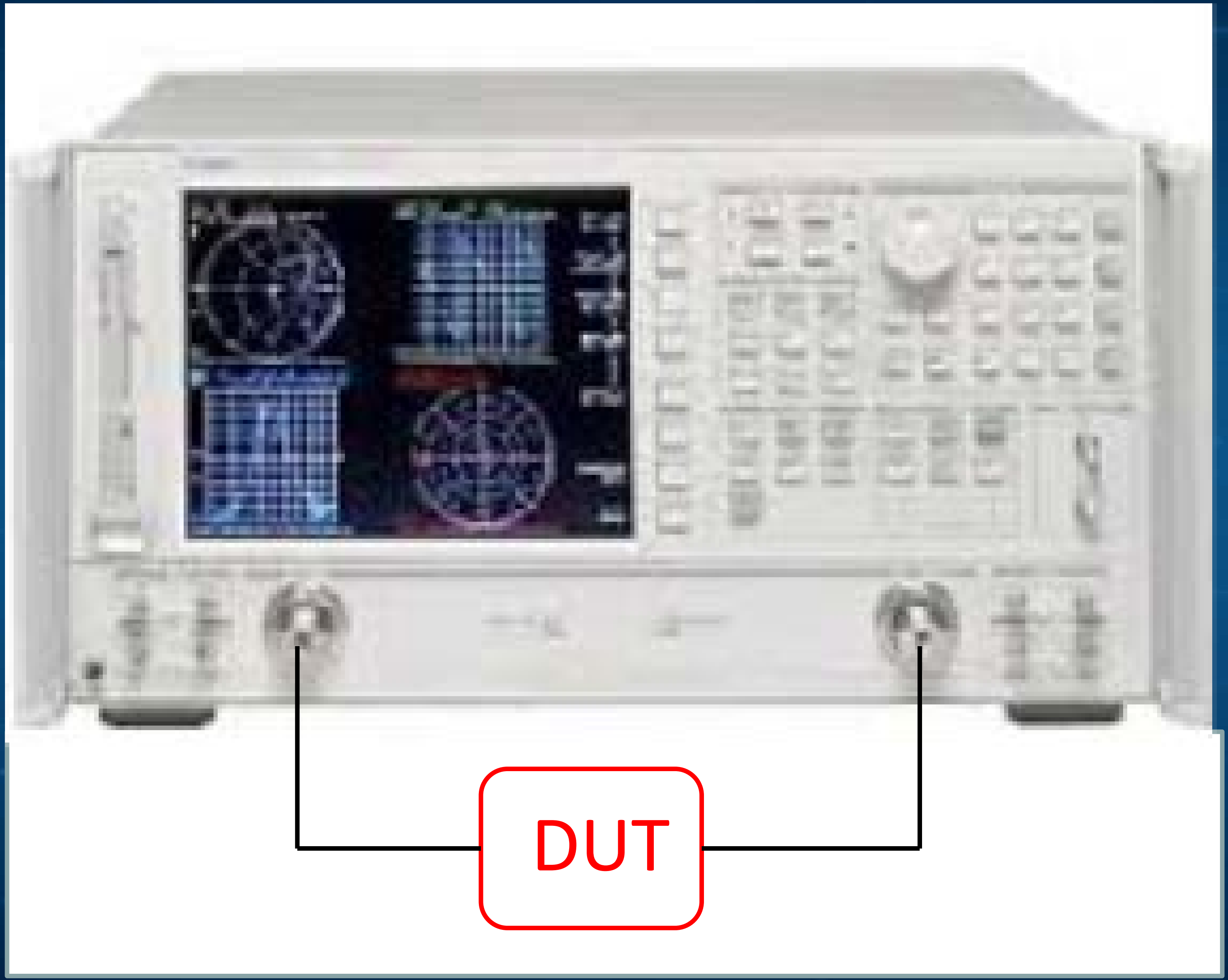
- **Dr.-Ing. Niels Neumann**, Group leader microwave photonics T.U. Dresden

- **Prof. Dr.-Ing. Dirk Plettemeier**, Chair for RF Engineering, T.U.Dresden

Any questions?

Thank you for your attention

Standard VNA SOLT Calibration



Now with a probe card.

Standard VNA SOLT Calibration

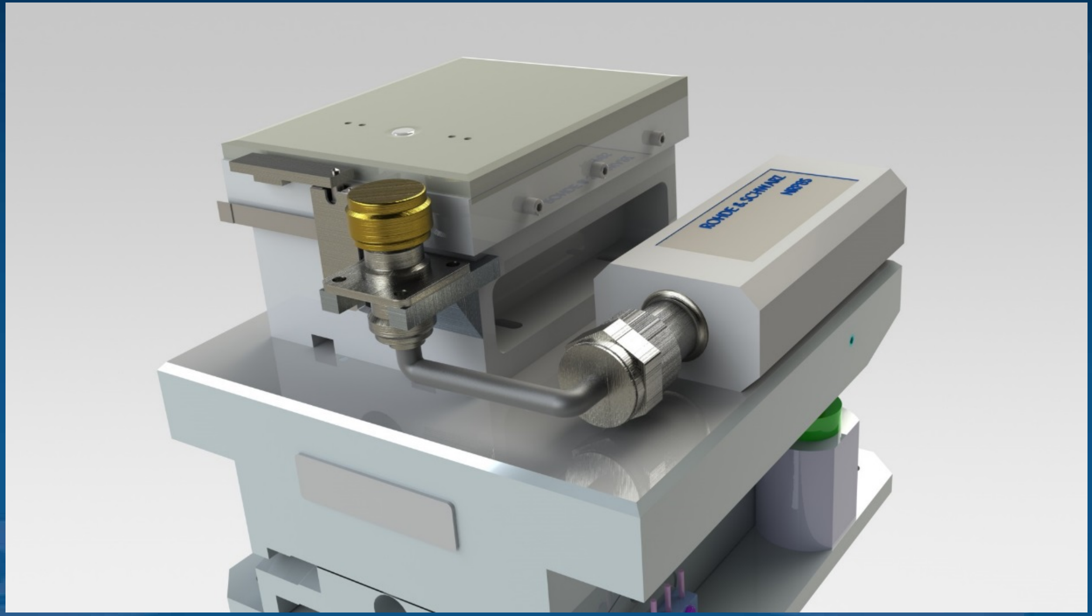
Short P1,P2

Open P1,P2

Load P1,P2

Thru P1 to P2

If Port 2 is the RF chuck?



No possibility for Load (P2), Short (P2) or Thru (P1P2)

We need a cunning plan……