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Understanding RF measurements using advanced cantilever technologies

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Main Index

- Spectrum usage
- Main objective of the paper
- Gbps and GHz. Same thing right?
- Modelling of a cantilever probe card
- Modelling of the R+ probe card
- Comparison of results
- Further work
- Useful links and references
- Questions?

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 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

The task……

You are the test manager of a high volume test floor. You have a new high speed digital product operating at 2.5Gbps and need to perform wafer level sort of this part at speed.

You need the most cost effective probe card solution which is fit for purpose.

What are your options?

Option #1

You invite all probe card vendors to submit proposals based on specification, cost etc

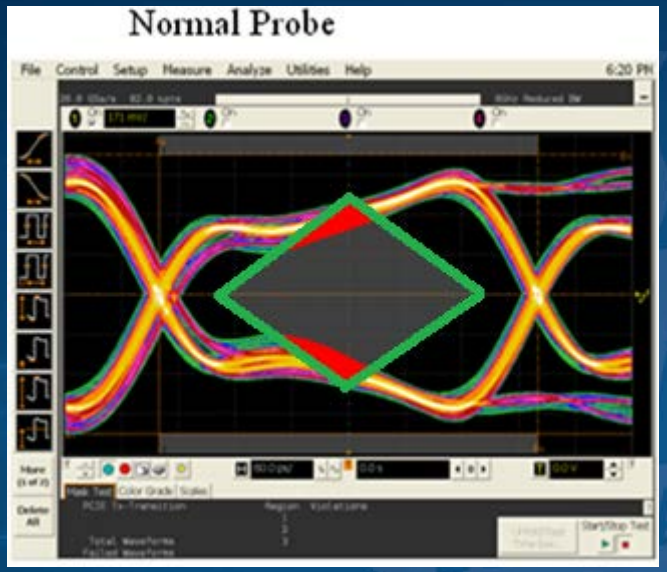
Then you take the cheapest bid.

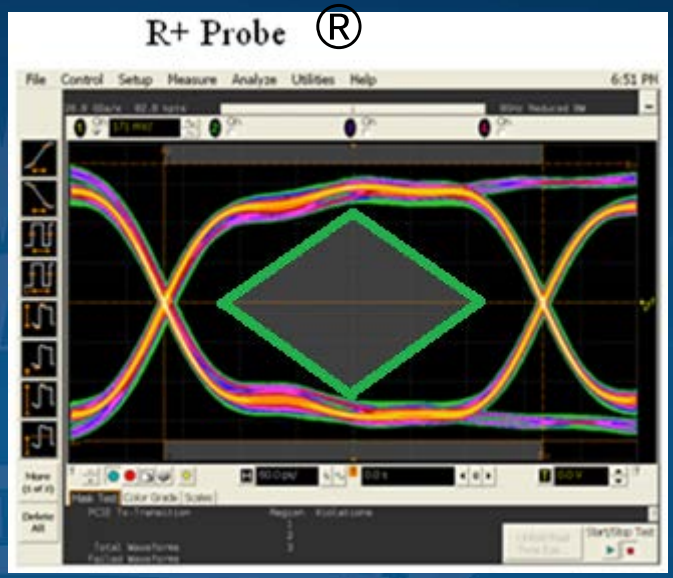
Option #2

You invite all probe card vendors to submit proposals based on specification, cost etc

You then use your knowledge of Engineering to analyse the claims and pick the most cost effective solution which meets your needs.

One vendor shows you this claim..





PCI E-I
Input Data Rate : 2.5Gbps
Input Voltage: +/- 650 mV

The question is: *Can you have confidence in these results?*

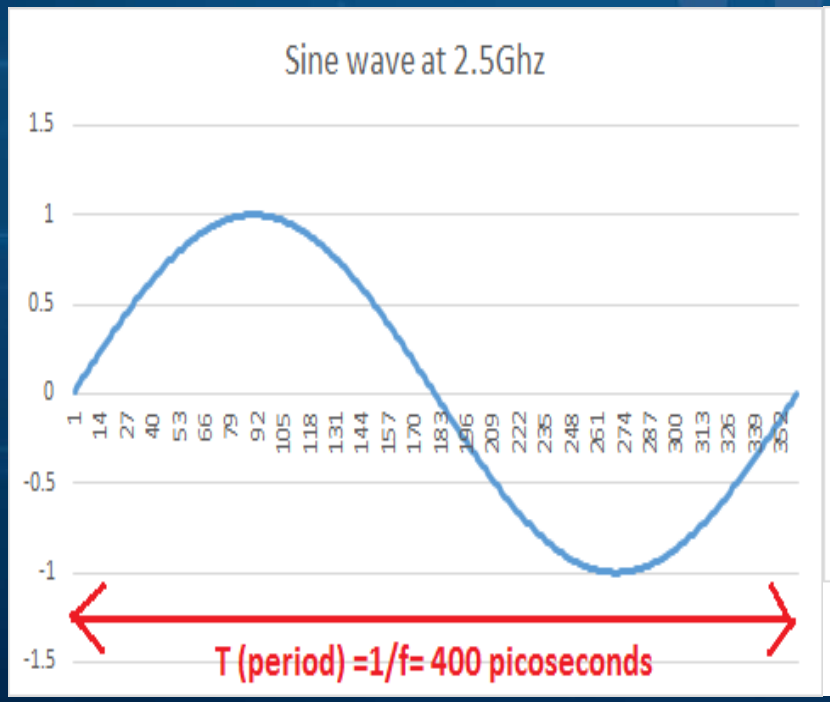
You are now going to use some straightforward freely available engineering tools to analyse the problem and make a decision.

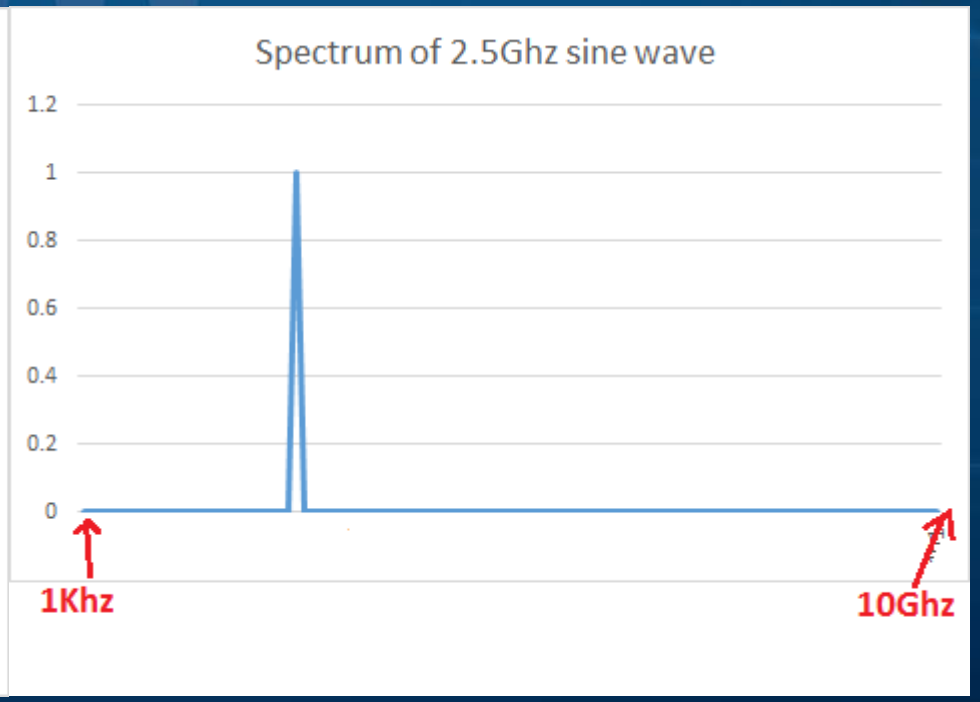
Tools you will use:

- RF Sim 99 (freeware circuit analysis tool)
- S parameter viewer (freeware)
- Basic Fourier series
- Common sense

Gbps and GHz are the same?

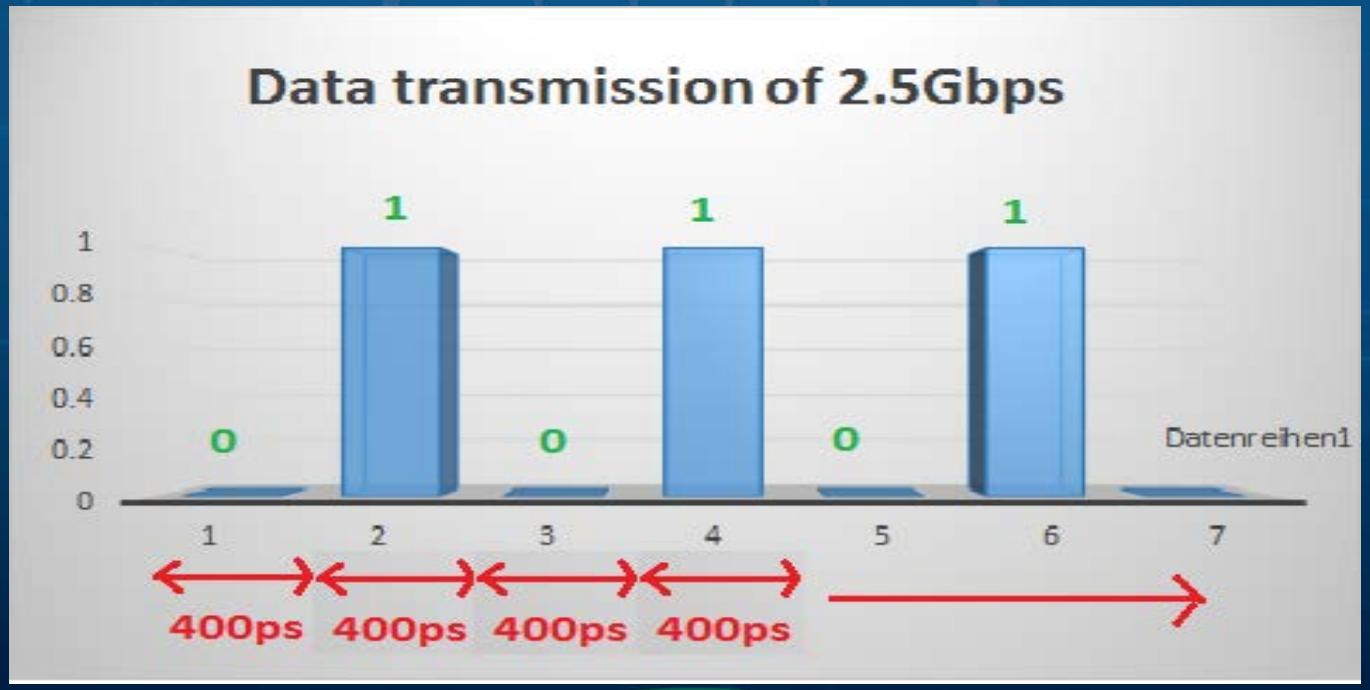
No!! Lets take an example of 2.5 GHz.





Gbps and GHz are the same?

- Now lets take a 2.5 Gbps data stream
- Imagine a continuous sequence of 0101010101010
- We know the period of one BIT is 400ps



Gbps and GHz are the same?

This becomes a square wave with a period of 800ps.

If f=1/t, then f has become **1.25GHz**

Gbps and GHz are the same?

But it‘s not as easy as that……

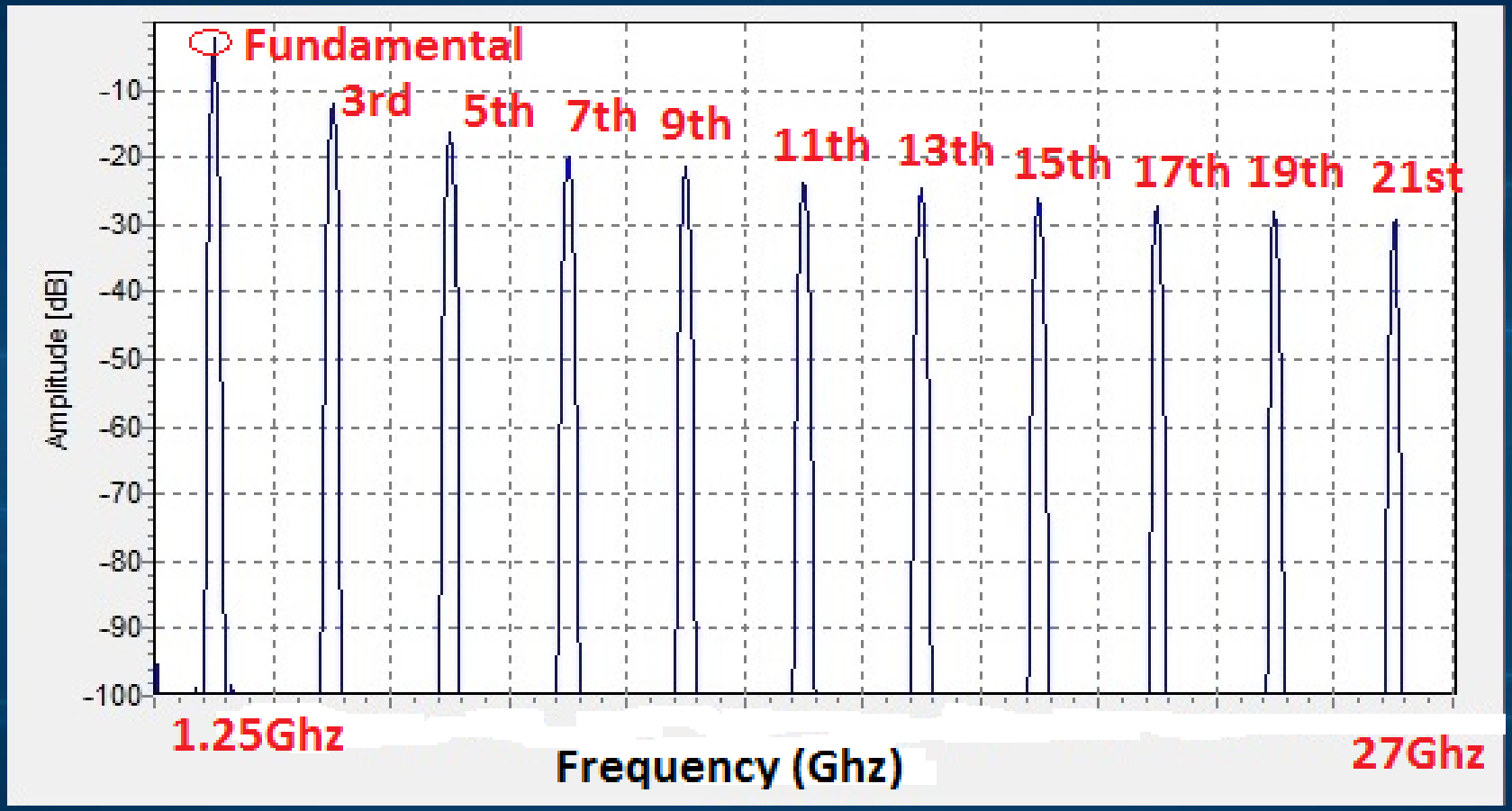
$$x_{\text{square}}(t) = \frac{4}{\pi} \sum_{k=1}^{\infty} \frac{\sin\left(2\pi(2k-1)ft\right)}{(2k-1)}$$

$$= \frac{4}{\pi}\left(\sin(2\pi ft) + \frac{1}{3}\sin(6\pi ft) + \frac{1}{5}\sin(10\pi ft) + \cdots\right)$$

Fundamental	3rd Harmonic	5th Harmonic	.....
1.25Ghz	3.75Ghz	6.25Ghz	.....

These are key frequencies we will be interested in.

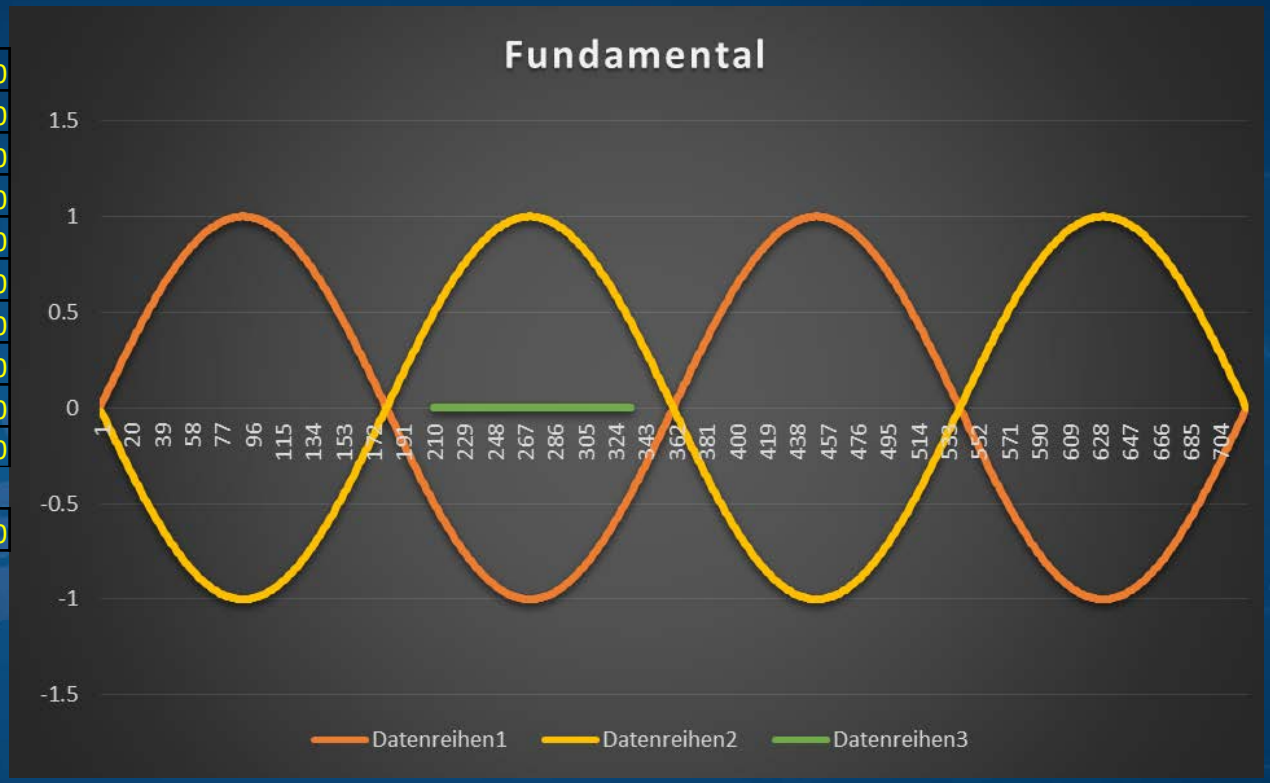
Gbps and GHz are the same?



Spectrum of 2.5Gbps square wave

Gbps and GHz are the same?

		attenuation(dB)
fundamental	100.00%	0
third	33.30%	100
fifth	20.00%	100
seventh	14.20%	100
ninth	11.10%	100
eleventh	9.10%	100
thirteenth	7.70%	100
fifteenth	6.66%	100
seventeenth	5.89%	100
nineteenth	5.26%	100
Marker peak		0



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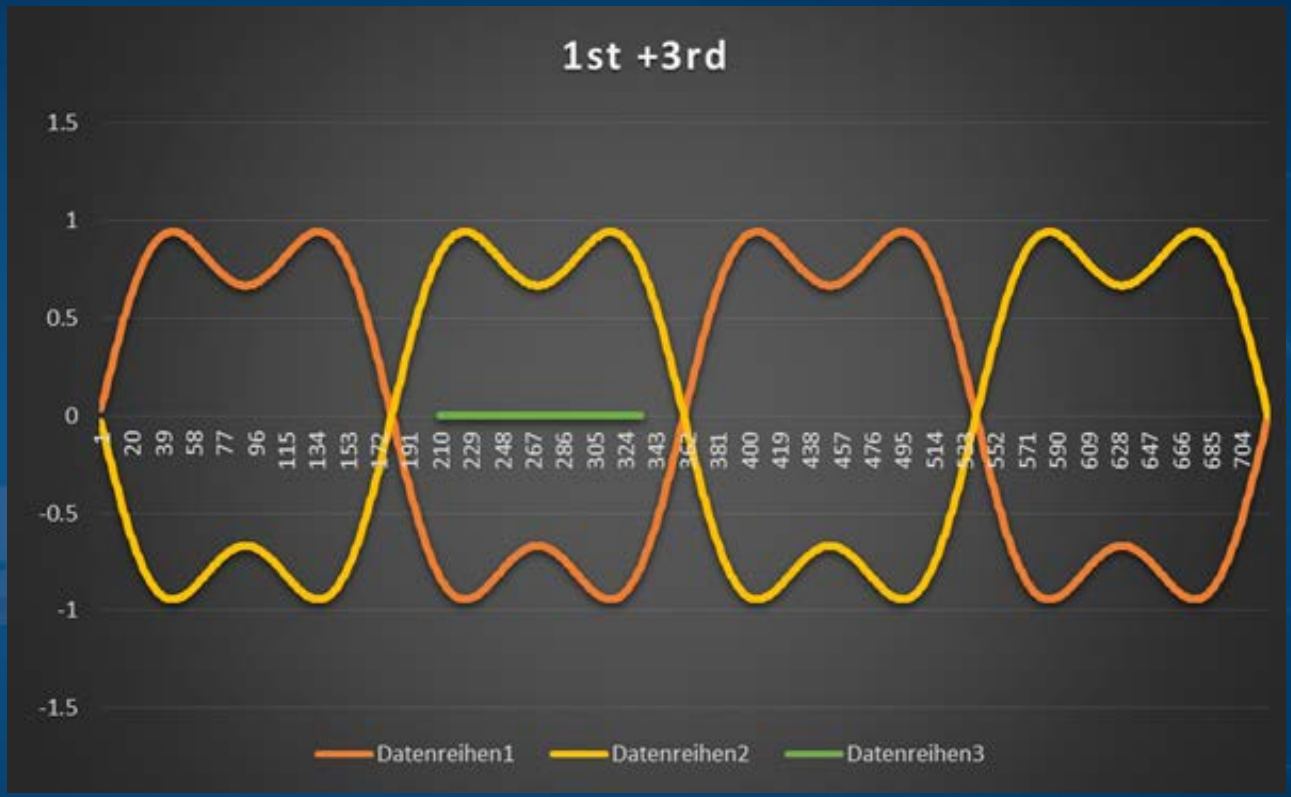
nineteenth	5.26%	100
Marker peak		0



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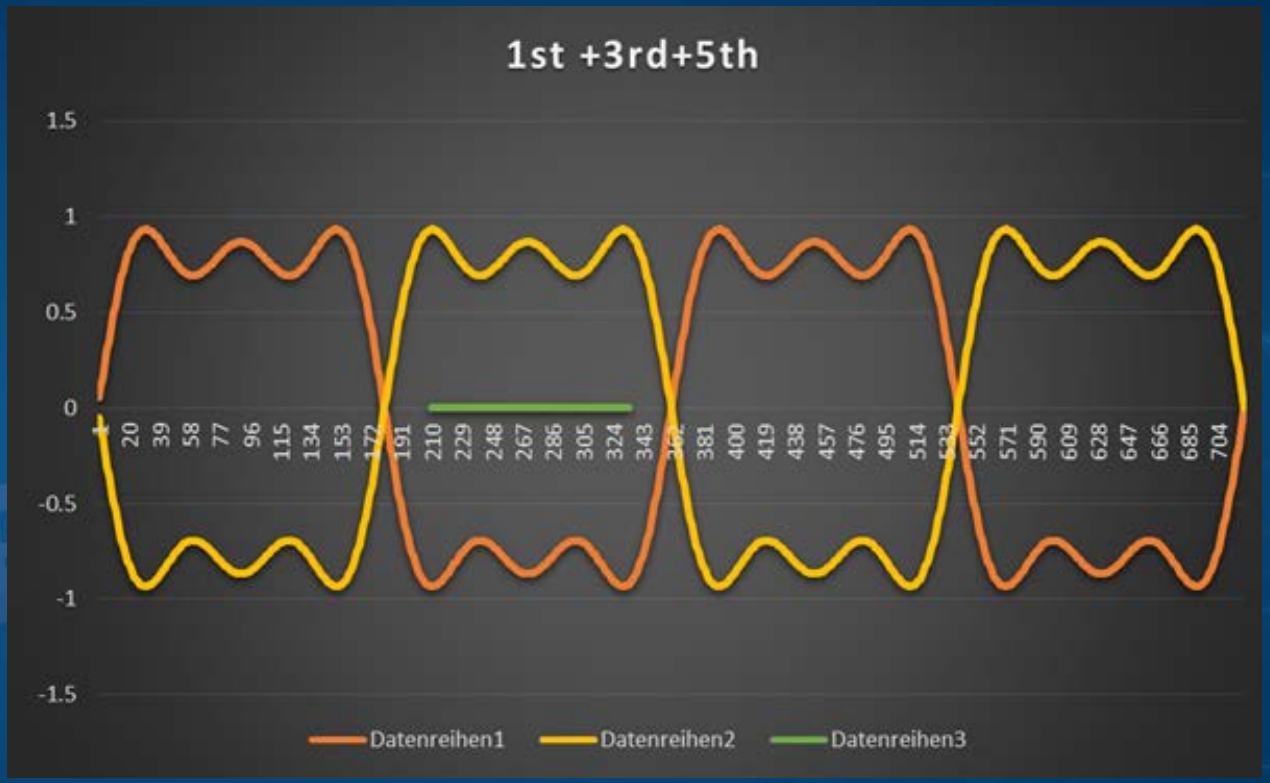

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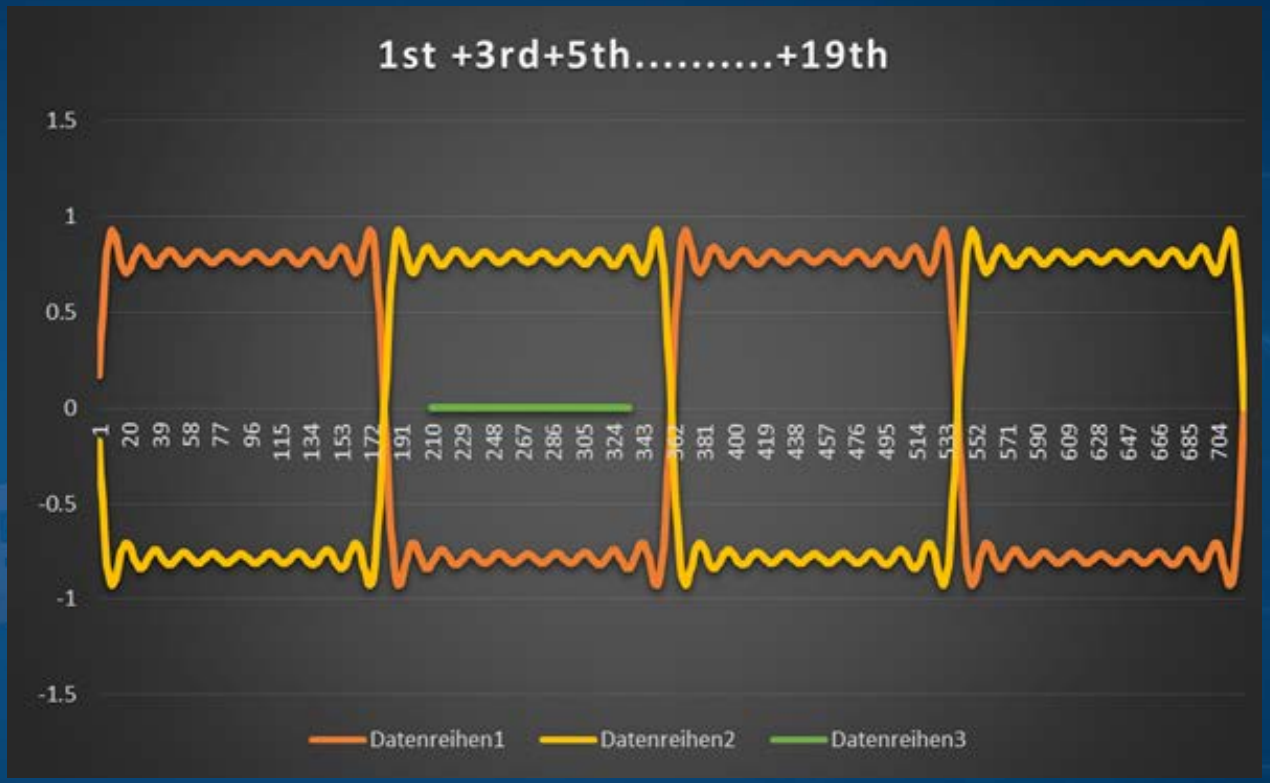
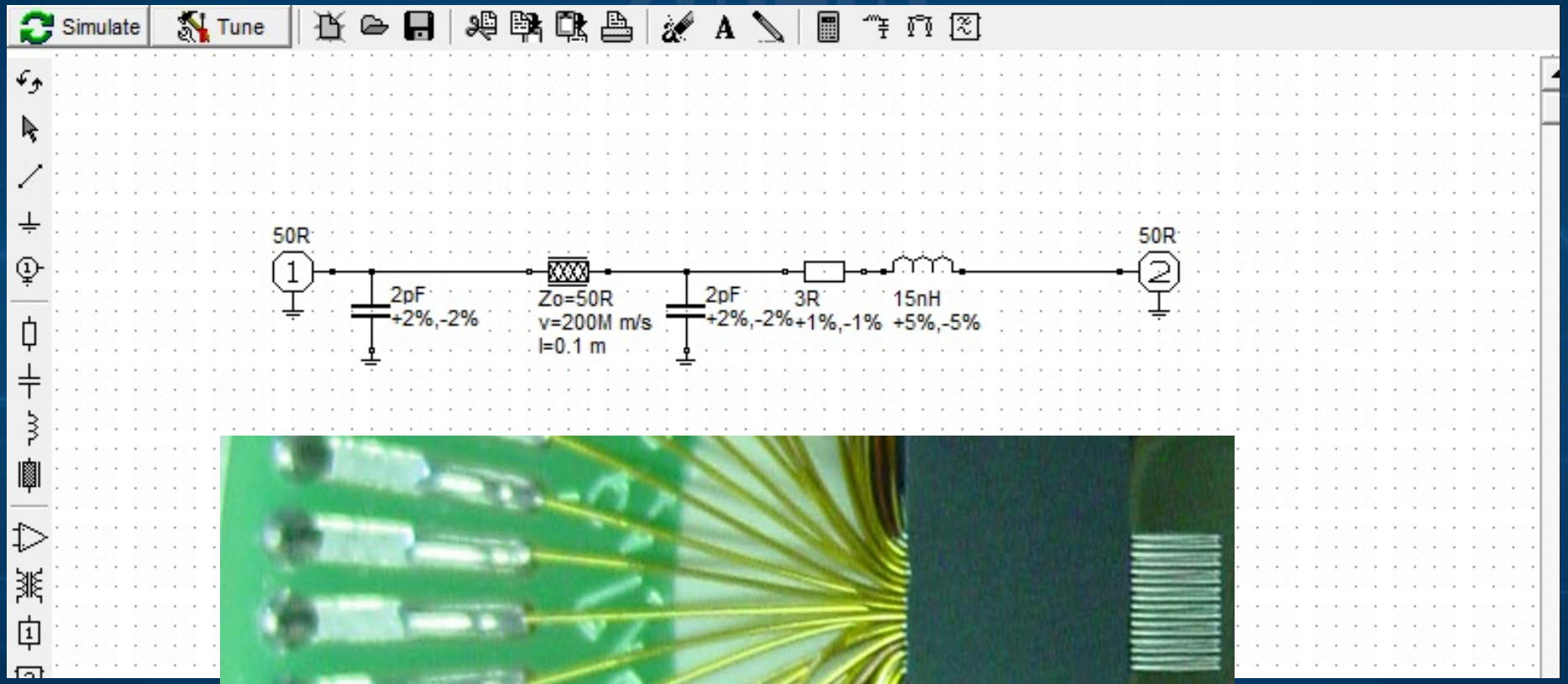
seventeenth	5.89%	0
nineteenth	5.26%	0
Marker peak		0

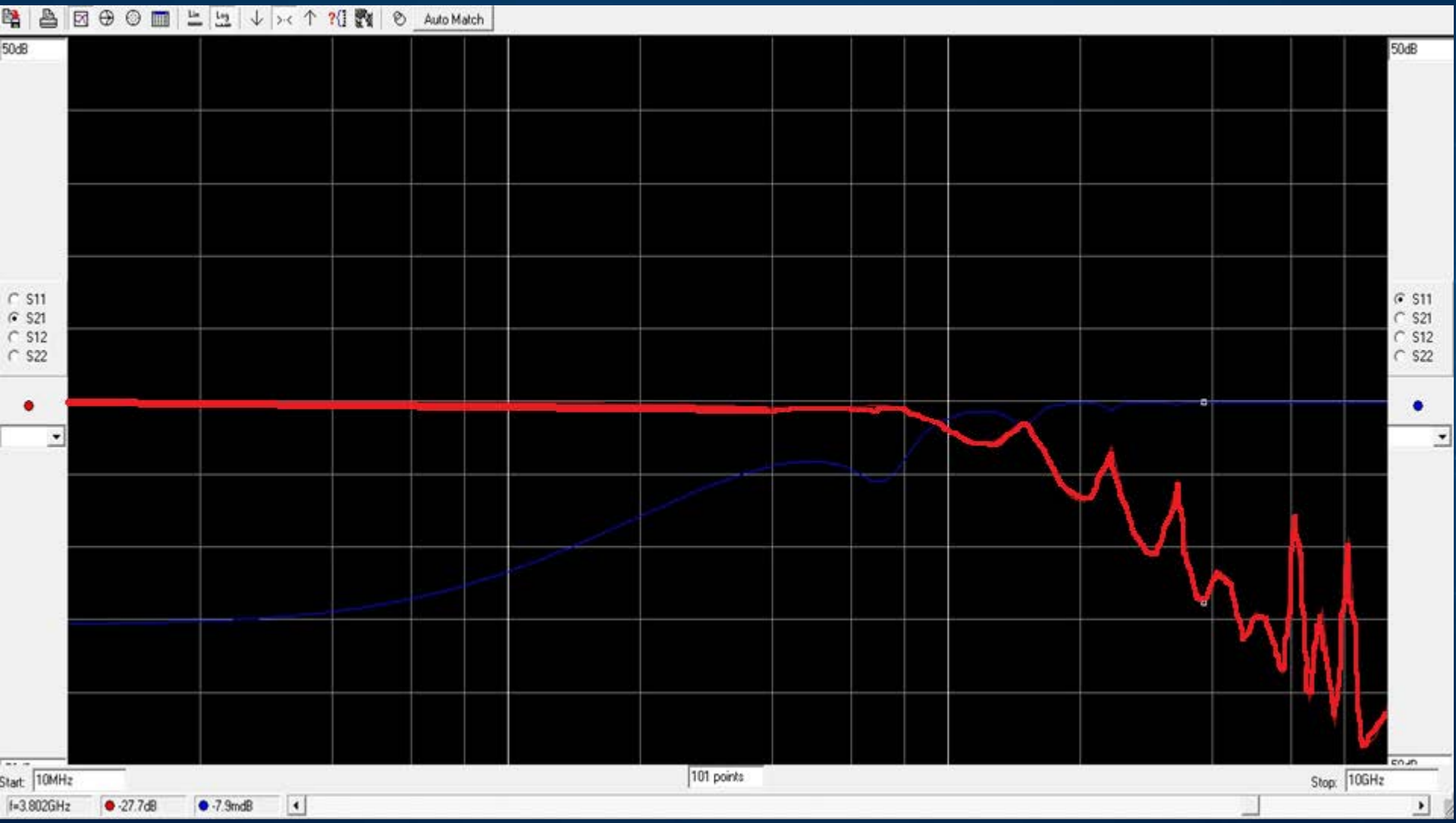


Equivalent model of a cantilever probe card

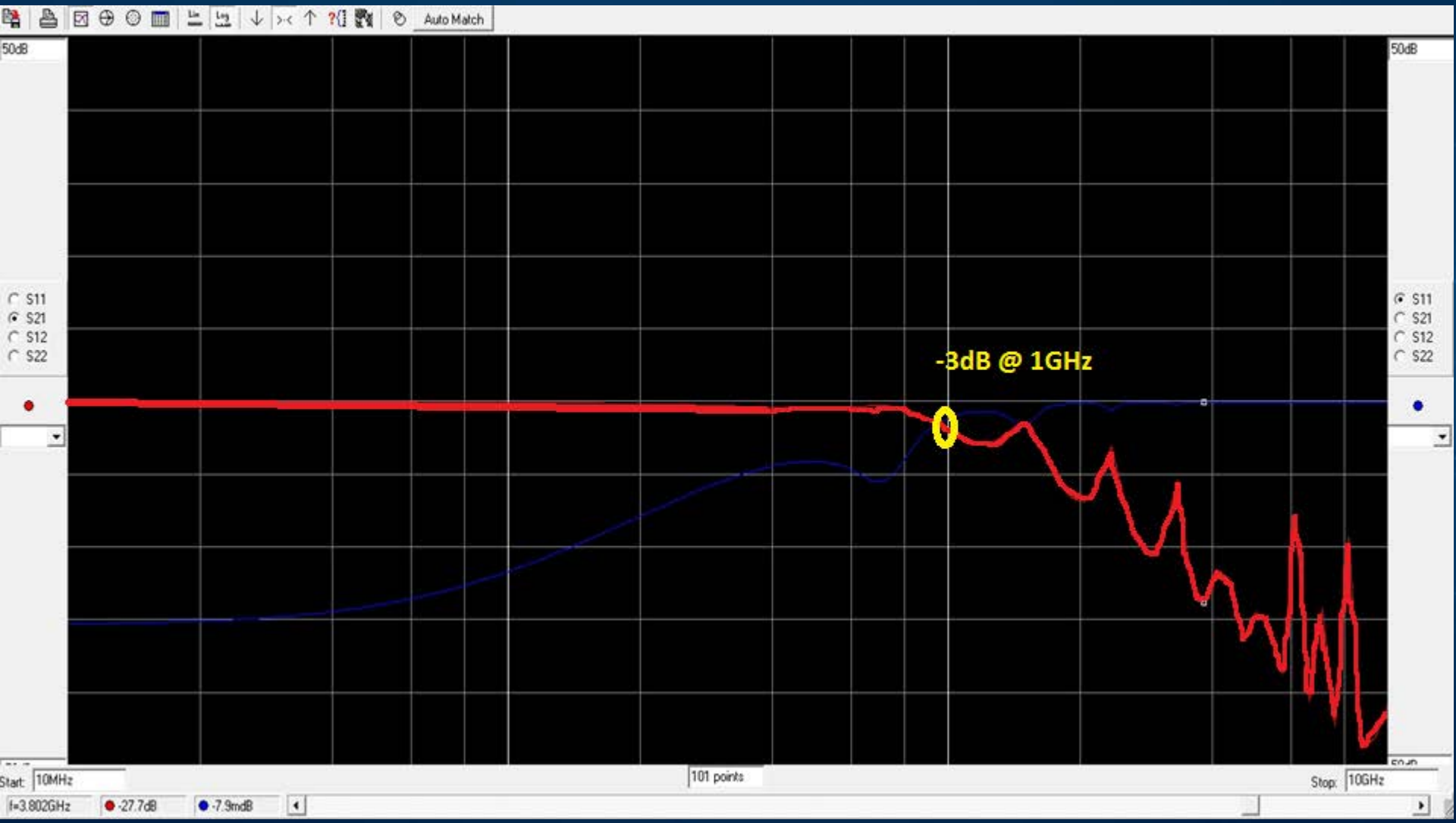
(Software used is RFsim99)



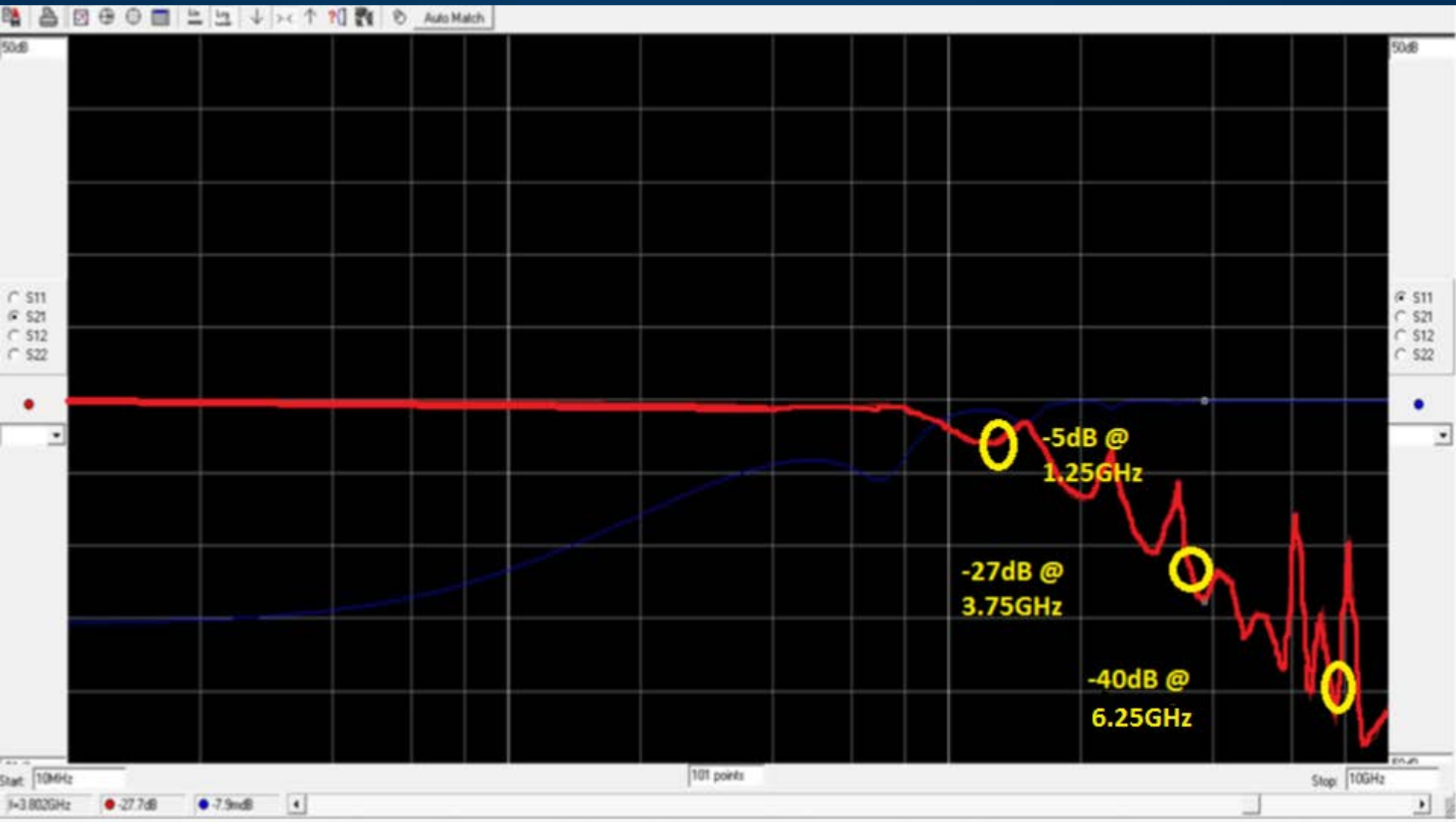
S parameters of a cantilever probe card



-3dB point of a cantilever probe card

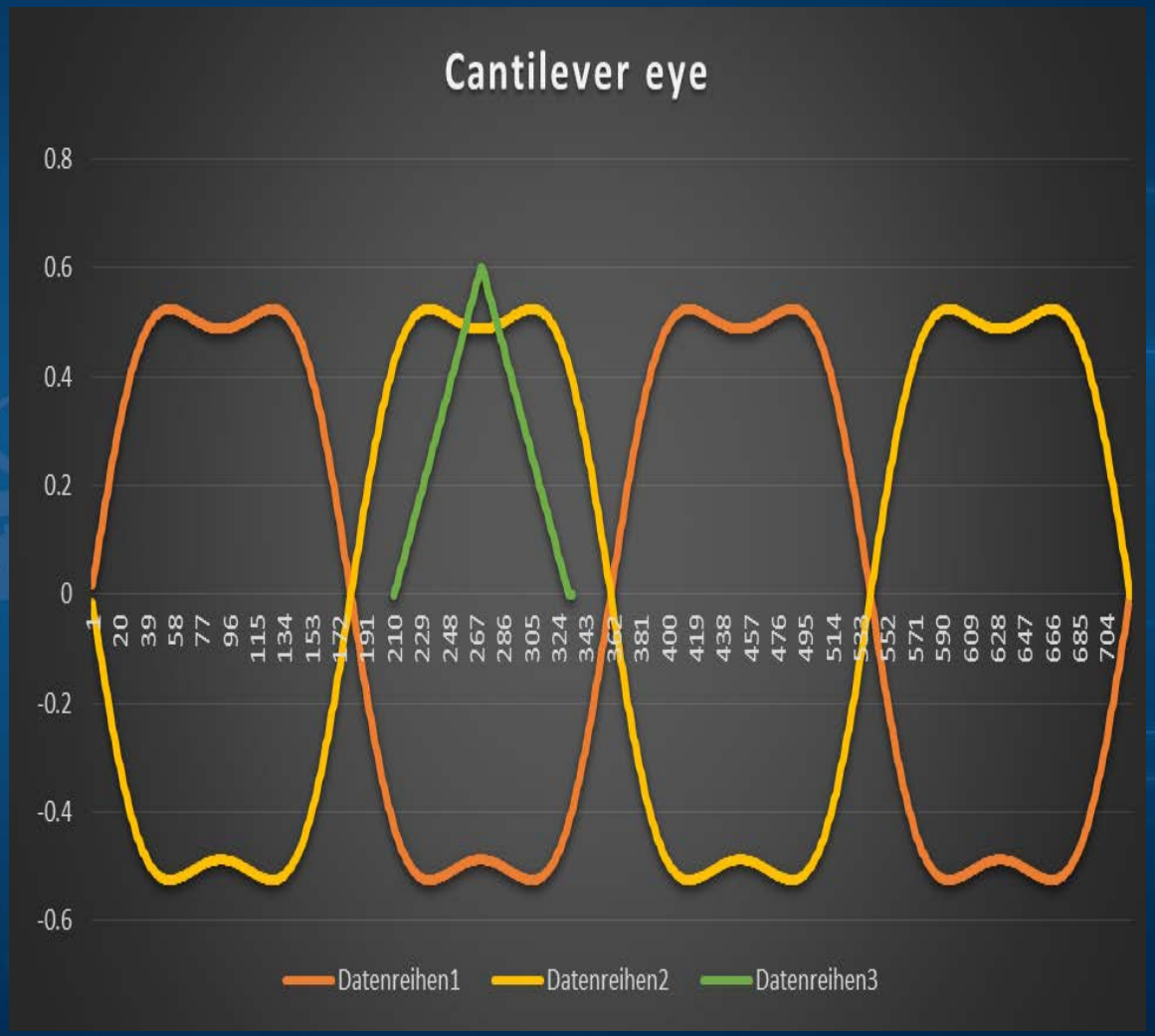


Odd harmonic losses of a cantilever probe card

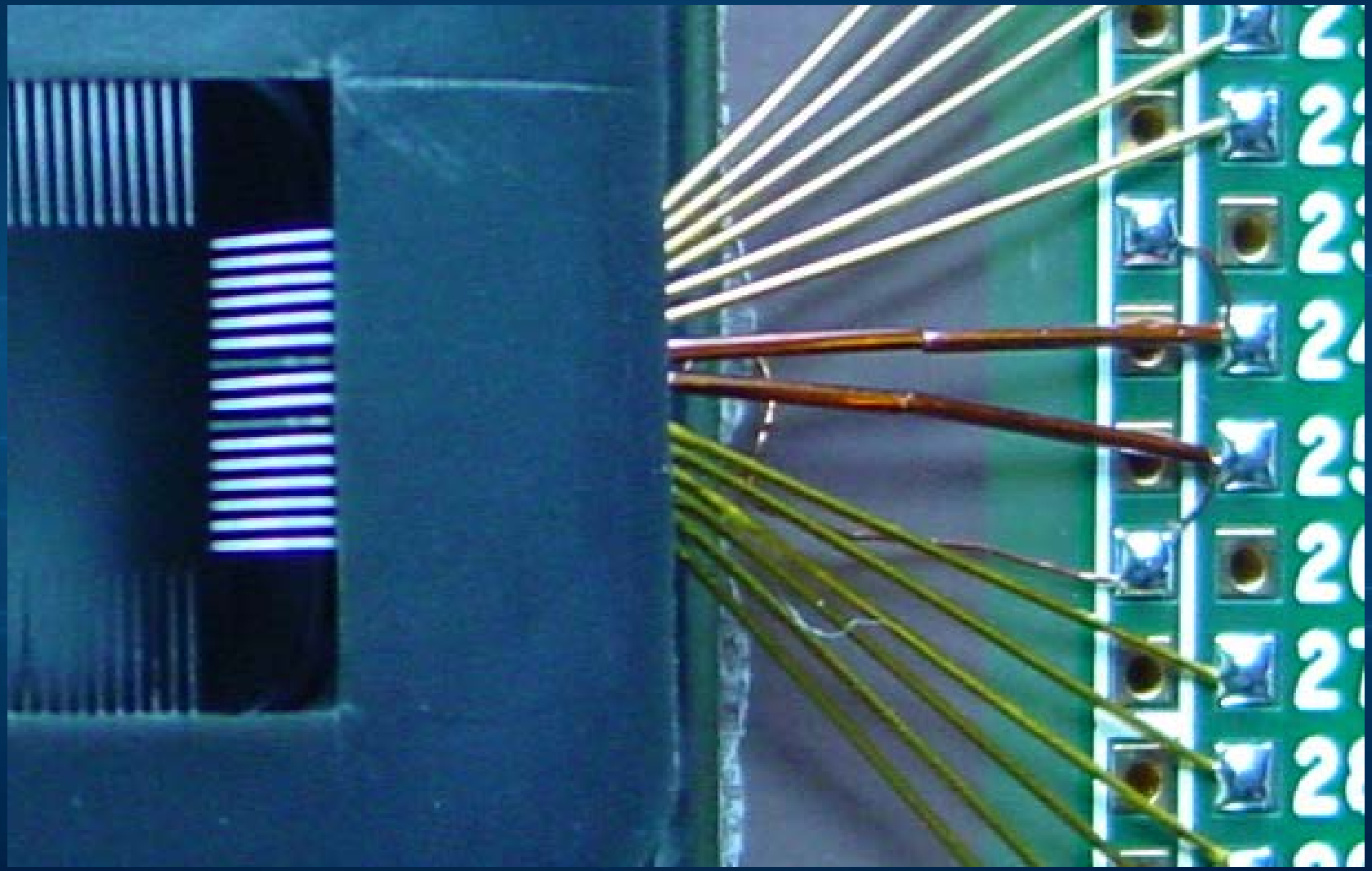


Resultant eye diagram for cantilever

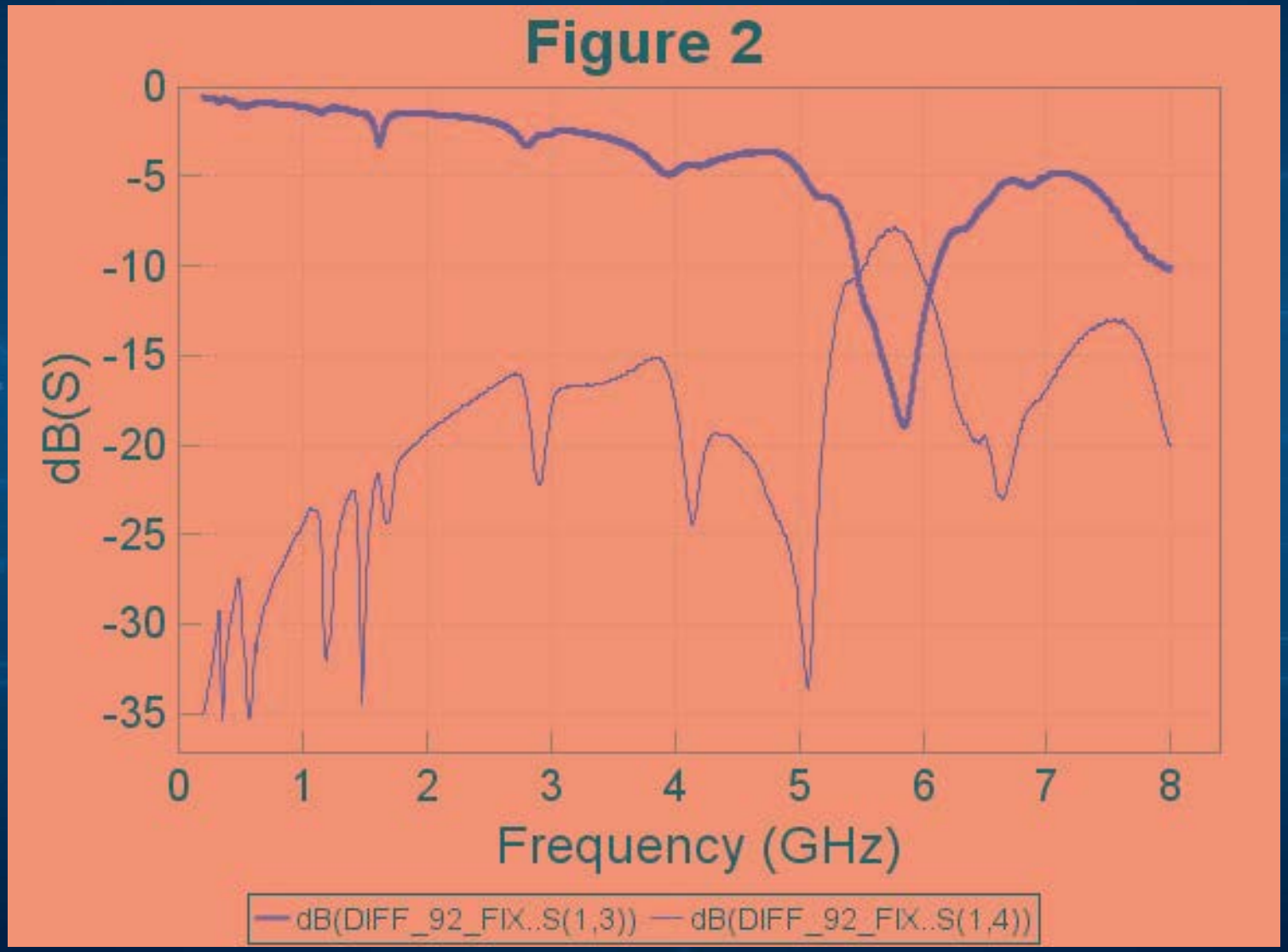
		attenuation(dB)
fundamental	100.00%	5
third	33.30%	27
fifth	20.00%	40
seventh	14.20%	100
ninth	11.10%	100
eleventh	9.10%	100
thirteenth	7.70%	100
fifteenth	6.66%	100
seventeenth	5.89%	100
nineteenth	5.26%	100
Marker peak		0.6



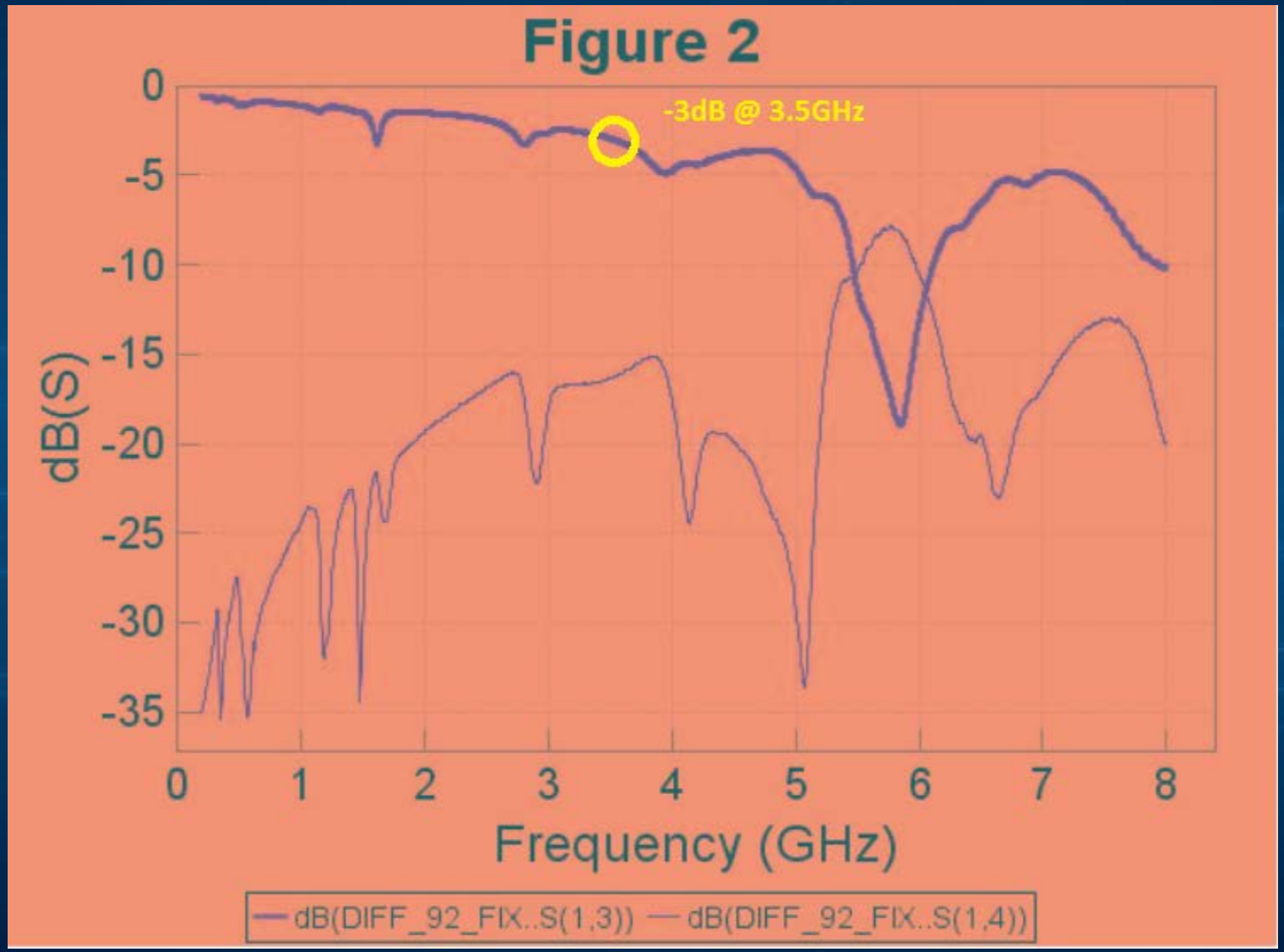
The R+ cantilever probe card



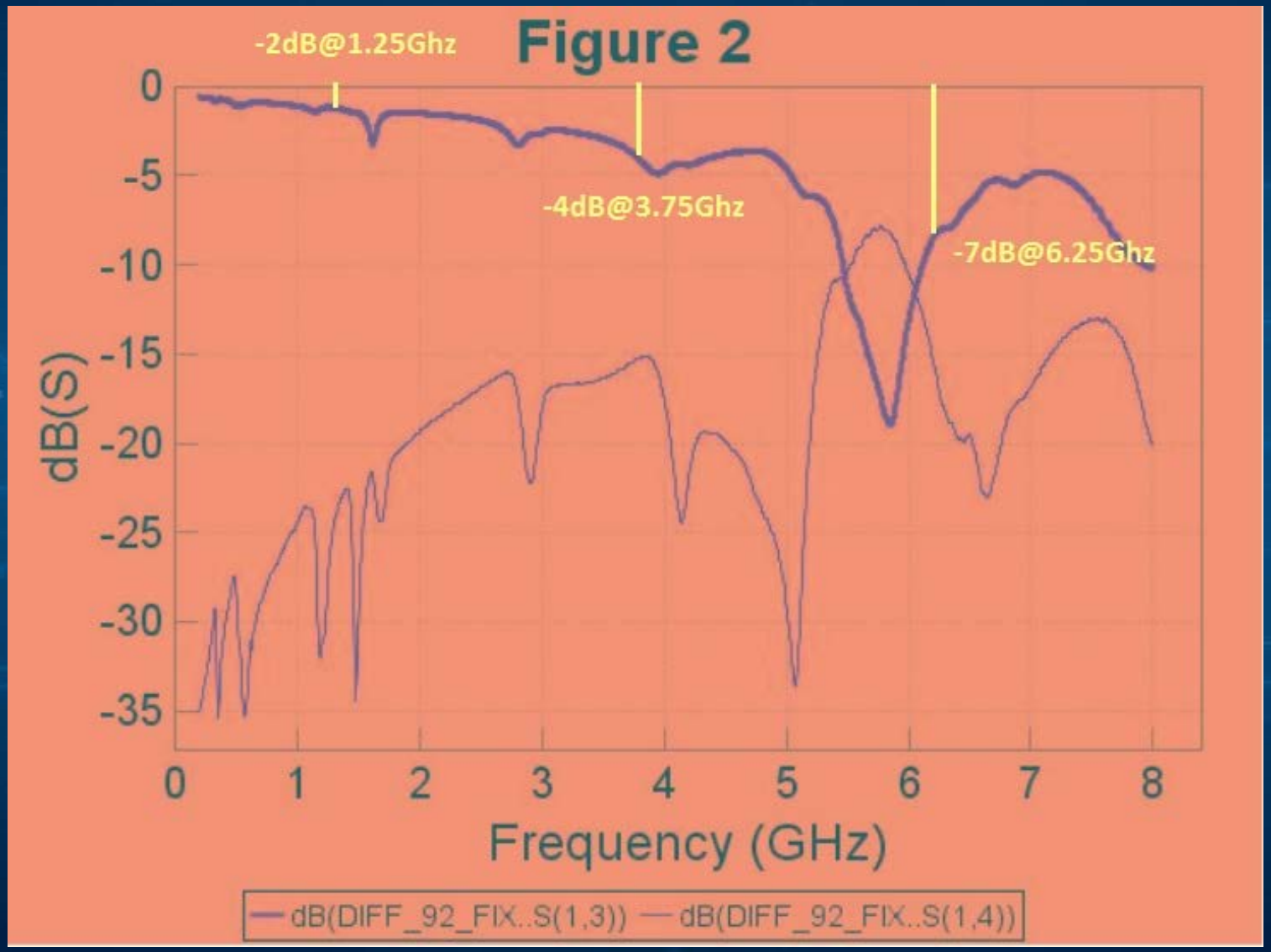
R+®S parameters (as measured)



-3dB point of R+ cantilever card

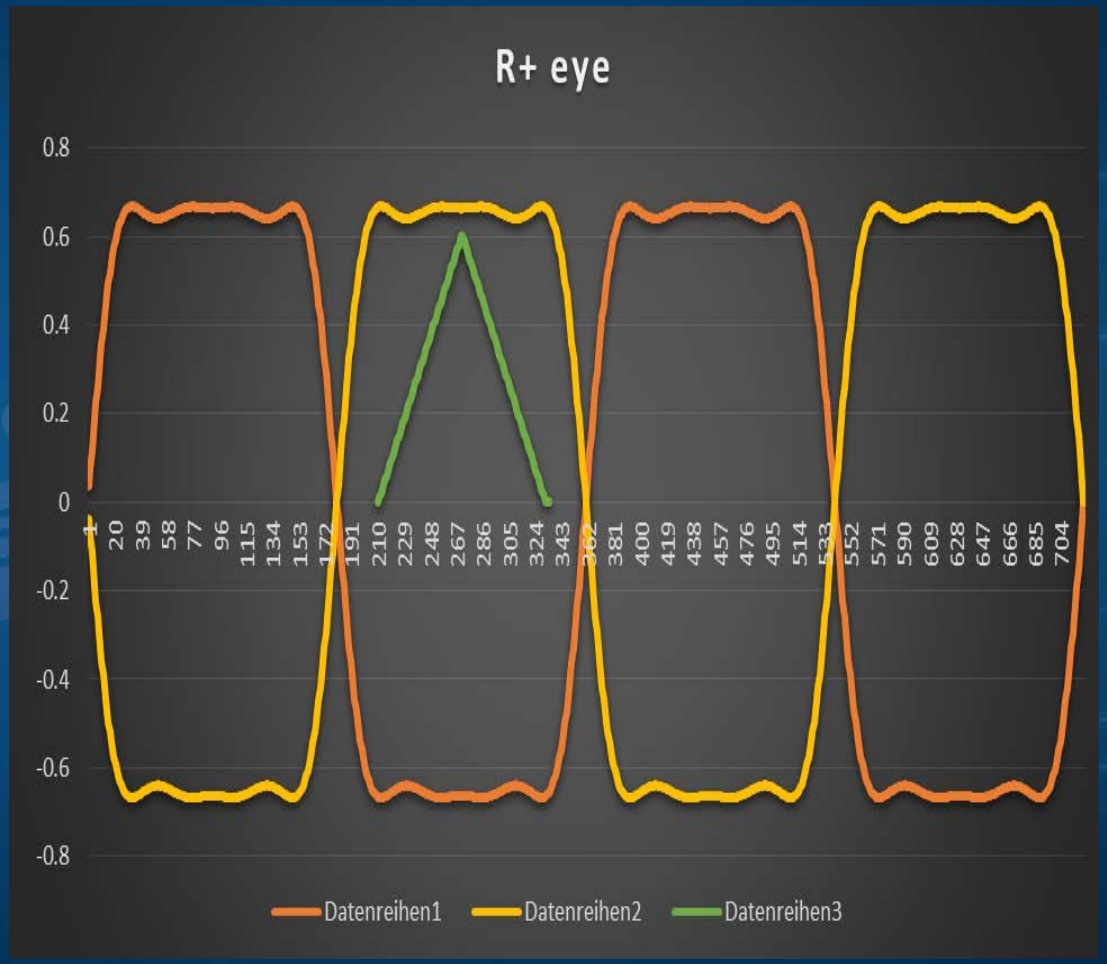


Odd harmonic losses of R+ probe card

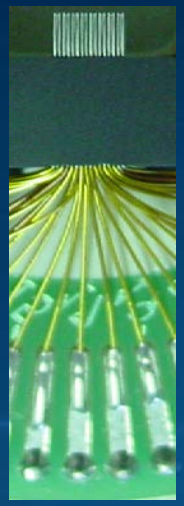


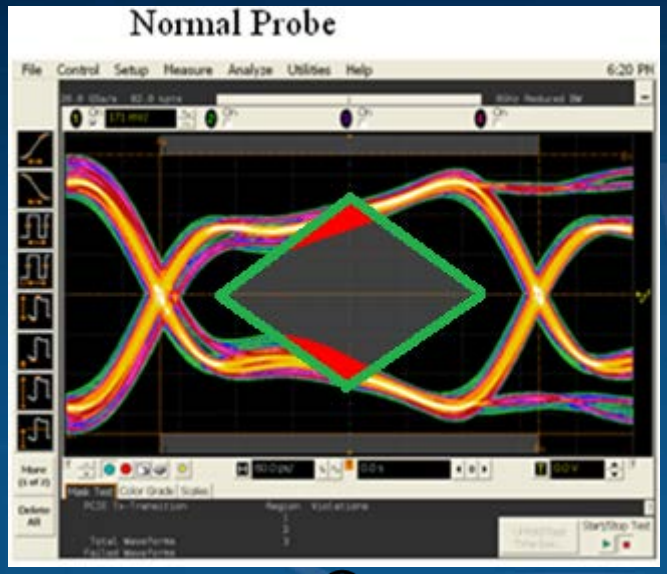
Resultant eye diagram for R+

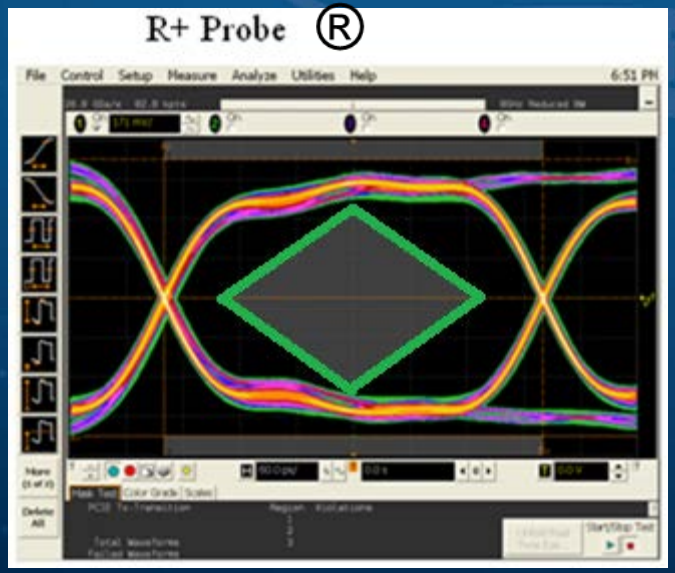
		attenuation(dB)
fundamental	100.00%	2
third	33.30%	4
fifth	20.00%	7
seventh	14.20%	100
ninth	11.10%	100
eleventh	9.10%	100
thirteenth	7.70%	100
fifteenth	6.66%	100
seventeenth	5.89%	100
nineteenth	5.26%	100
Marker peak		0.6

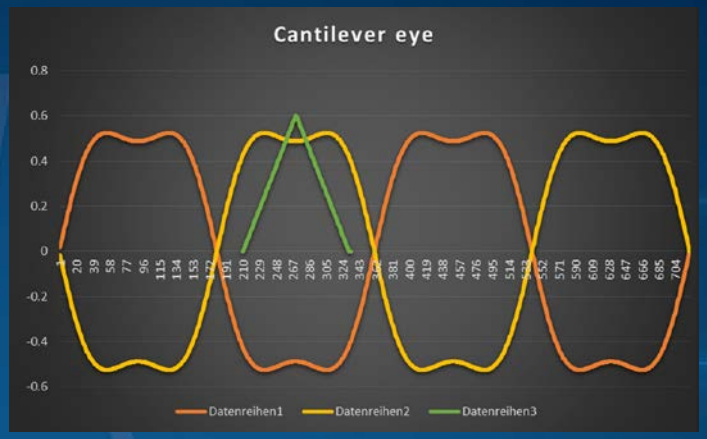


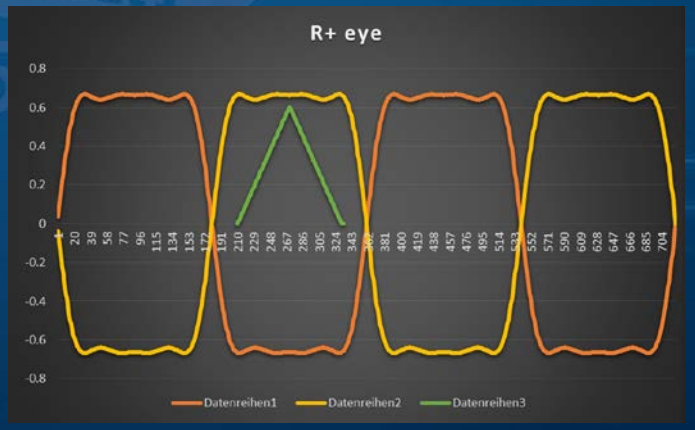
2.5Gbps result comparison











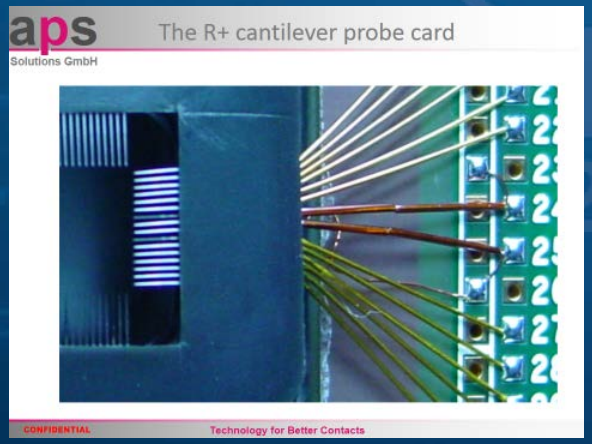
Claimed

By Simulation

2.5Gbps result comparison

Freq	Cantilever(dB)	R+(dB)
1.25GHz	5	2
3.75Ghz	27	4
6.25GHz	40	7

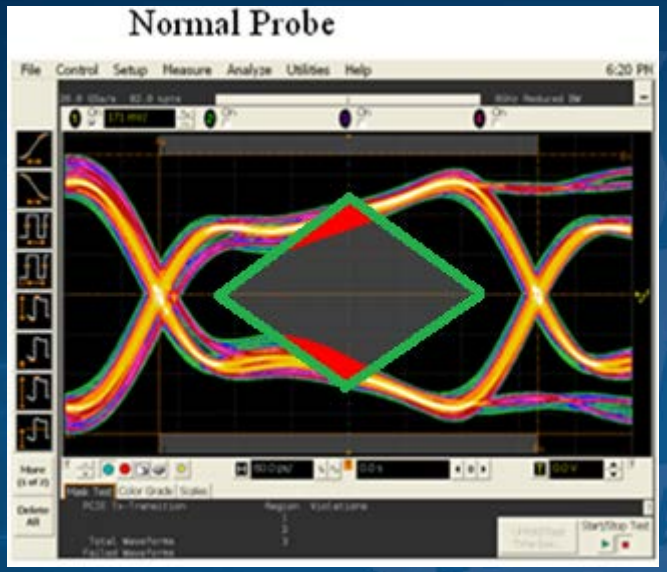
-3dB point	~1GHz	~3GHz

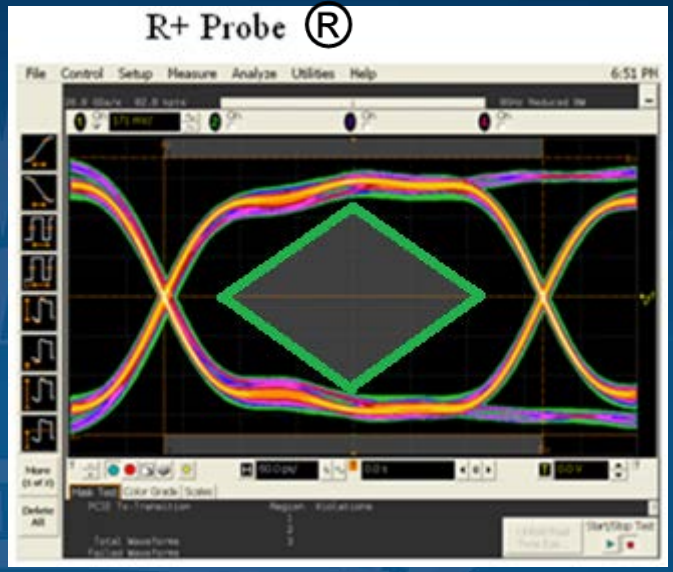


So, R+ technology brings significant RF improvements

Yet mechanically it acts like a regular cantilever needle. No special PTPA algorithm, standard online cleaning, no specific operator training,cantilever tolerance to debris etc

Back to the problem in hand





PCI E-I
Input Data Rate : 2.5Gbps
Input Voltage: +/- 650 mV

The question was : *Can you have confidence in these results?*

The answer is : *A fairly confident YES!!*

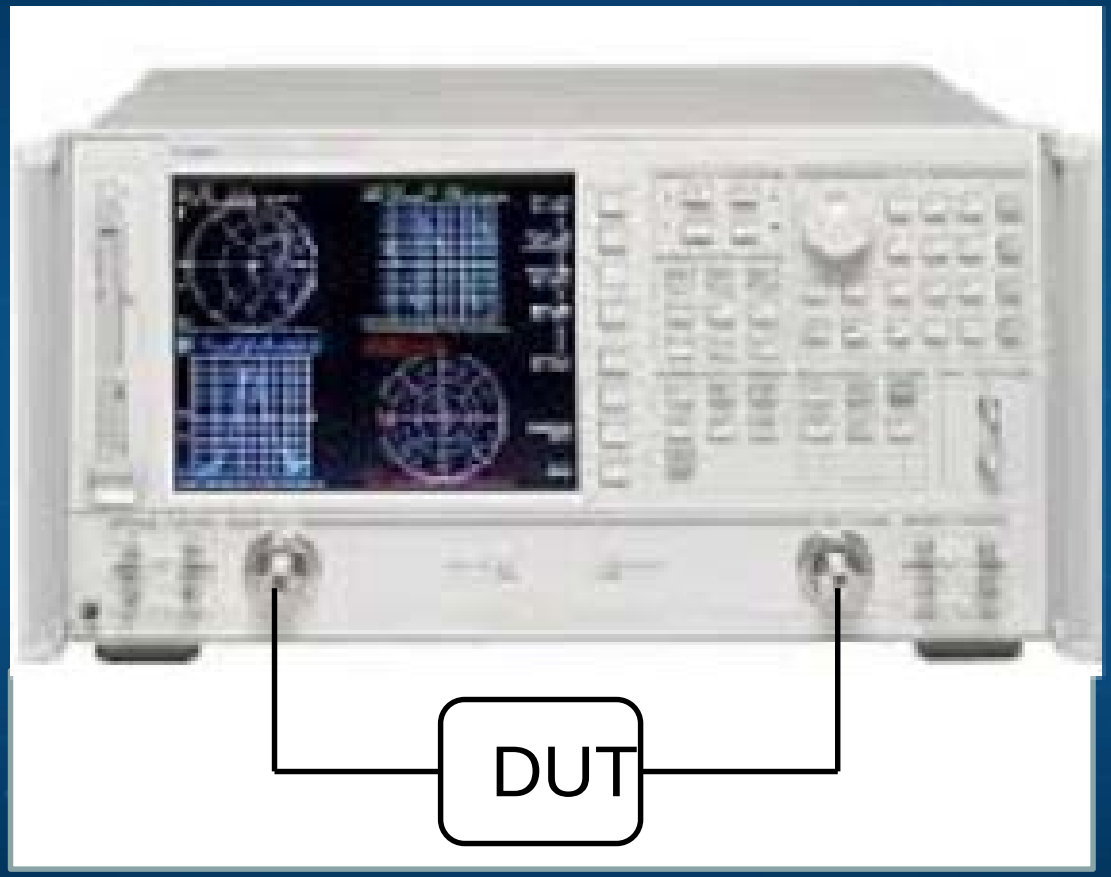
Further work at aps Solutions GmbH

- Acquire test equipment and probes to provide a measurement service for probe cards and load boards at aps.

Further work at aps Solutions GmbH

- Provide a measurement service for customers
- More research on contamination and their effect on measurement.
- Build a tool to measure the S parameters of a probe card.

Standard VNA SOLT Calibration



Standard VNA SOLT Calibration

Short P1,P2

Open P1,P2

Load P1,P2

Thru P1 to P2

Now with a probe card.

Spoiler alert!!

If Port 2 is an RF chuck?

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

I have a cunning plan…..

Useful links and references

- RF Sim 99 http://www.electroschematics.com/835/rfsim99-download/
- S parameter viewer http://www.eecircle.com/downloads/spex.html
- Square wave fourier series http://en.wikipedia.org/wiki/Square_wave
- Common sense: If only a website existed?

Acknowledgements

- Mr Hanns-Georg Ochsenkuehn aps Solutions GmbH

- Engineering team at MPI for the R+® S parameter data.

Thank you for your attention

Questions?