Far-Field Measurements and Characterization of the Cyclostationary Unintentional Stochastic Radiations from the Digital Electronic Device

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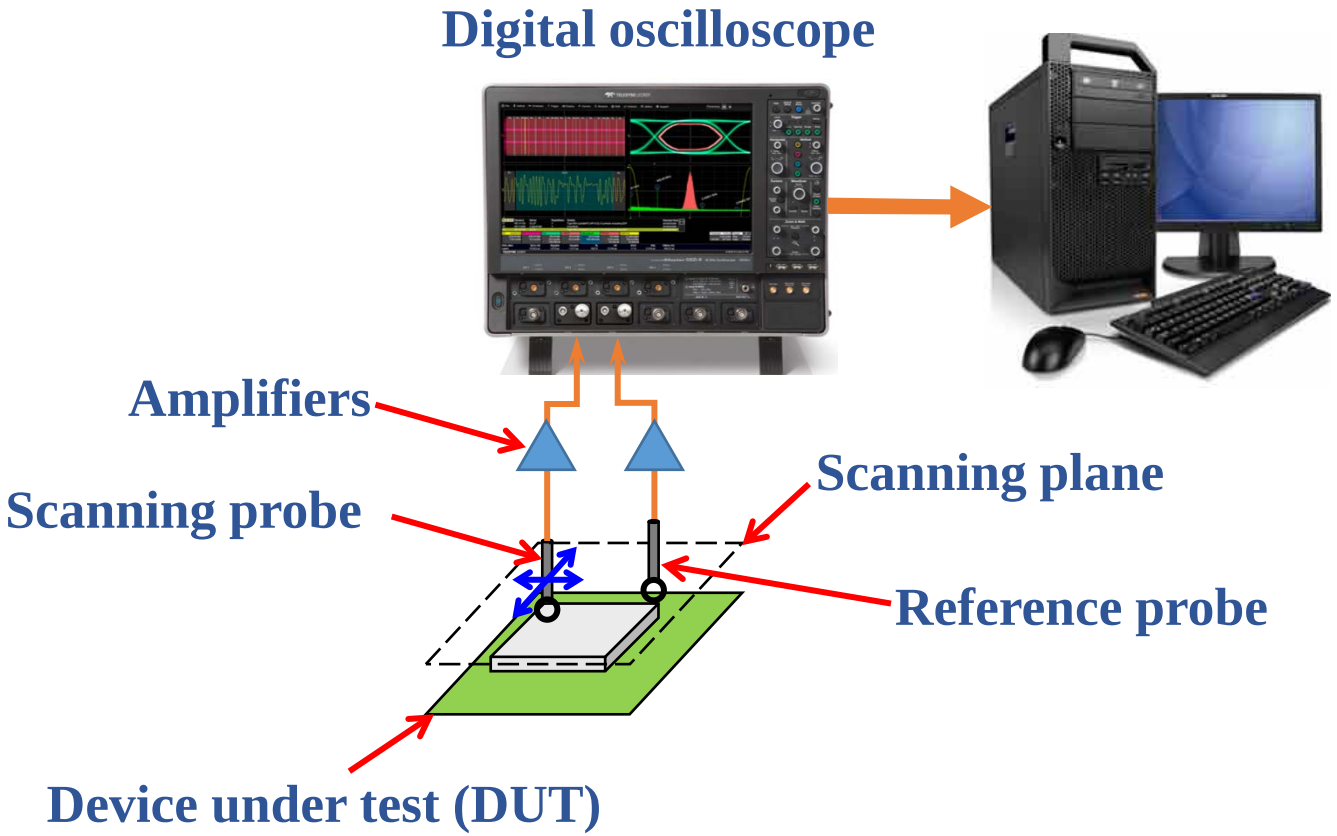
MOSCOW AVIATION INSTITUTE

Outline

- Spatial localization of the pass between the source and the load on the PCB surface
- Characterization of the cyclostationary properties of the PCB pseudorandom emissions
- Characterization of the far-field pattern for the unintentional stochastic emissions of the PCB
- Parametric identification of the ultra wideband near-field probes in time and frequency domains

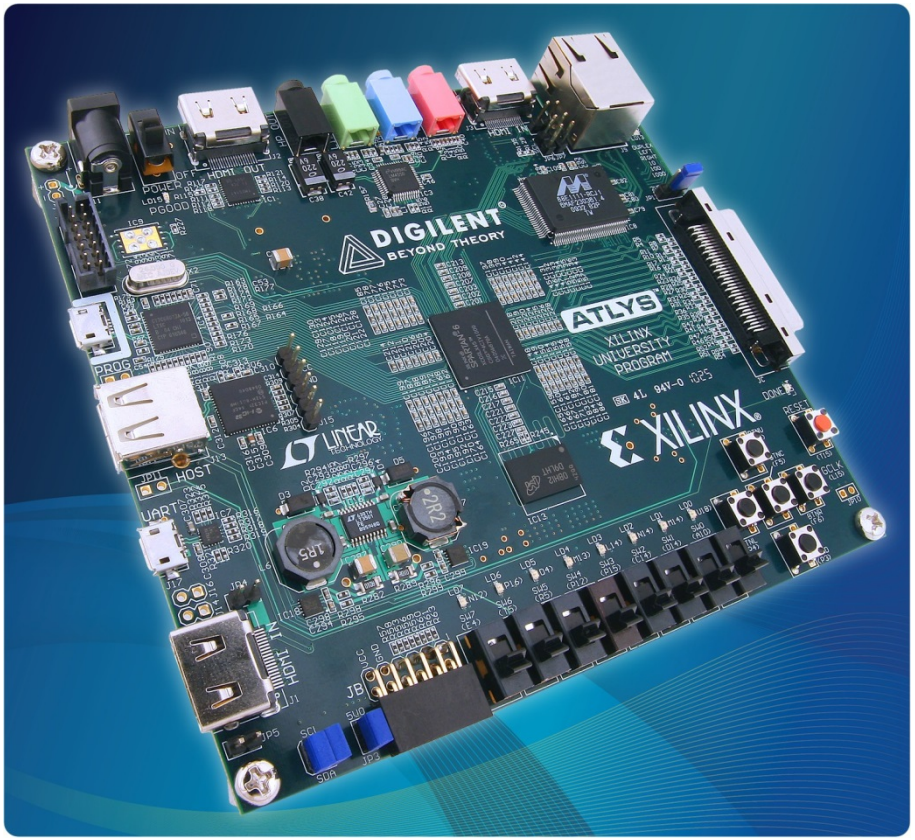
Measurement setup

➢ Time-domain measurement system

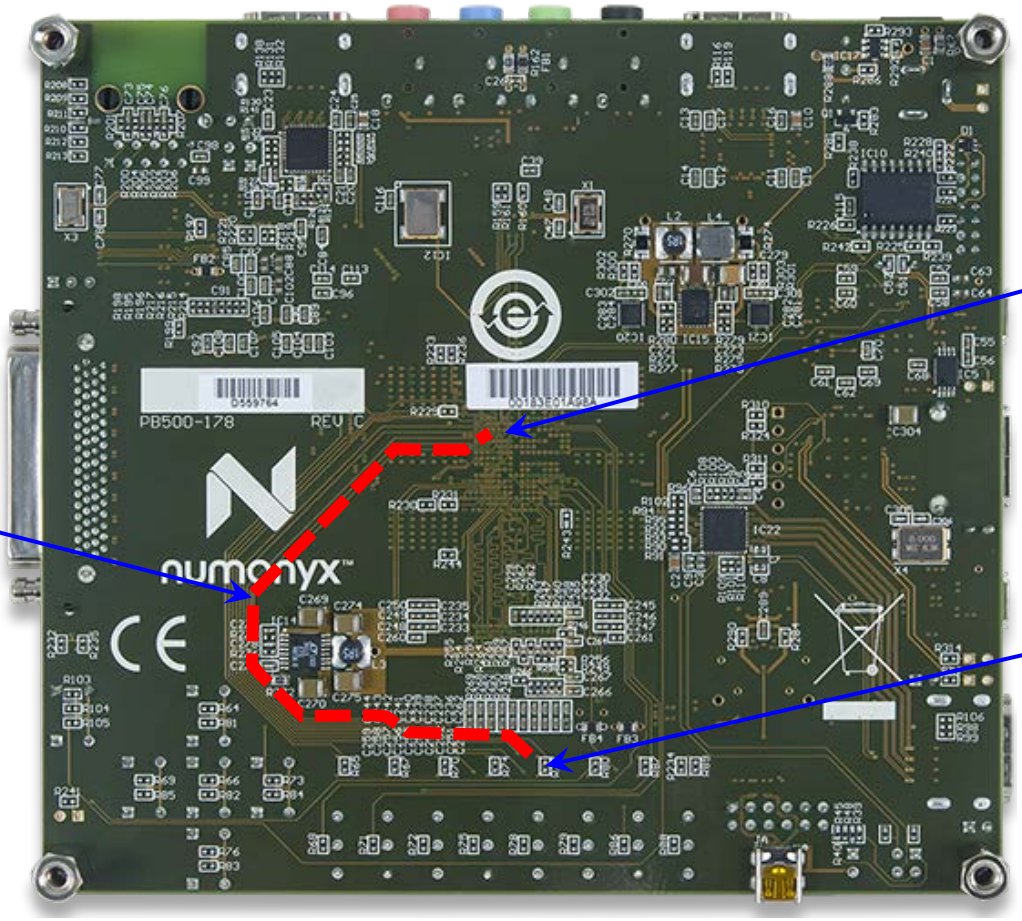


Device under test

- **Atlys Spartan-6 Training Board**

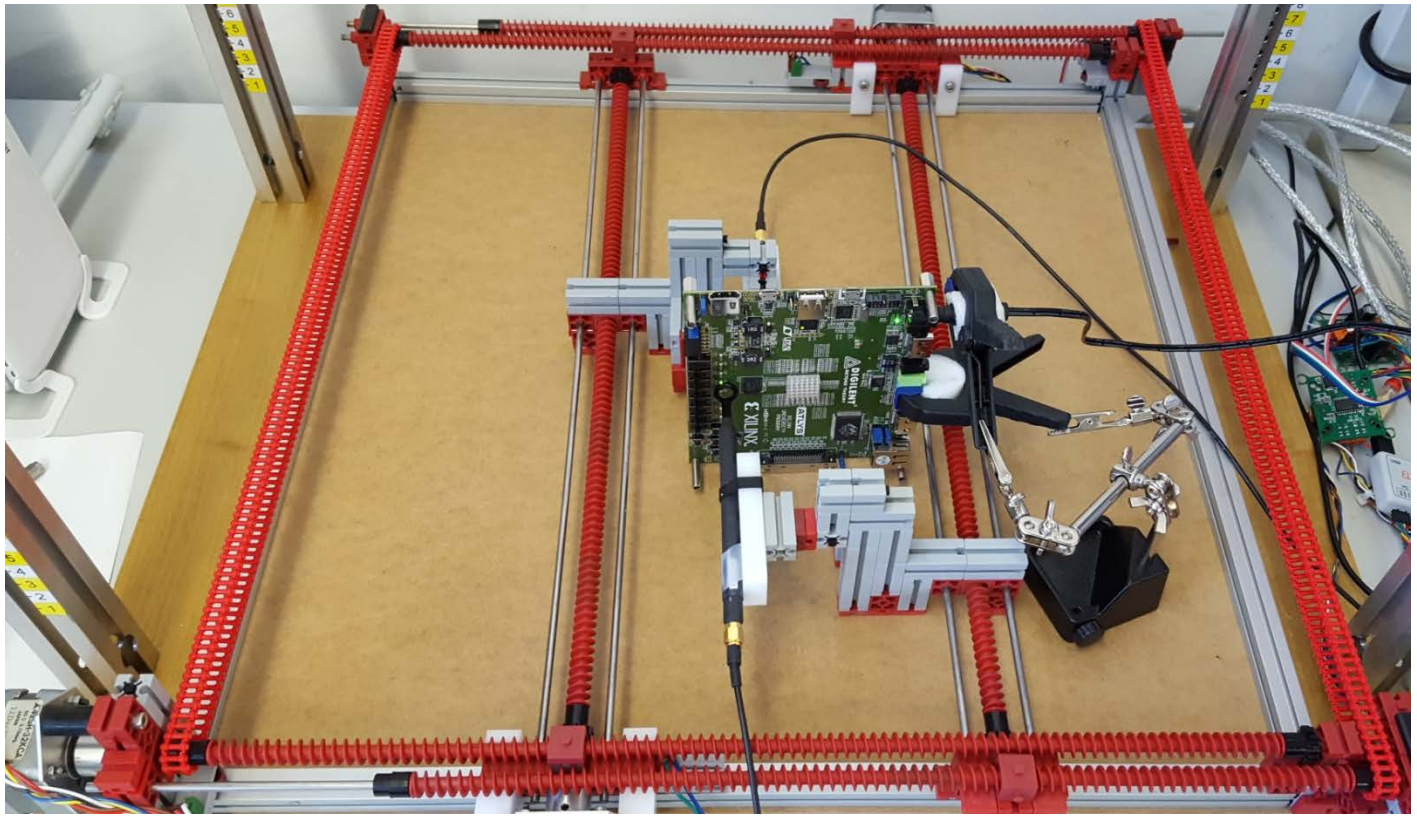


Device under test



✓ Test signal: pseudo random bit sequence (PRBS)

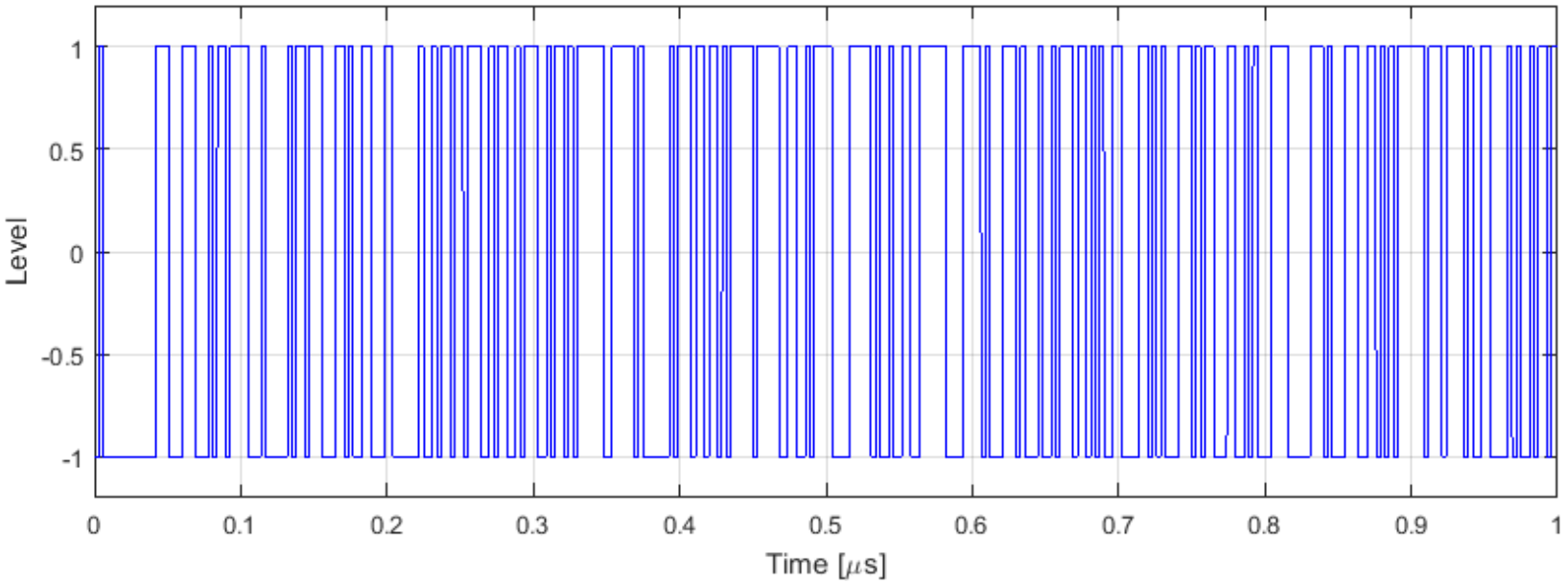
Measurement setup



- ✓ Langer EMV-Technik RF-R 50-1 magnetic field probes
- ✓ Frequency band from 30 MHz up to 3 GHz

Data analysis

➢ Pseudo random bit sequence (PRBS)

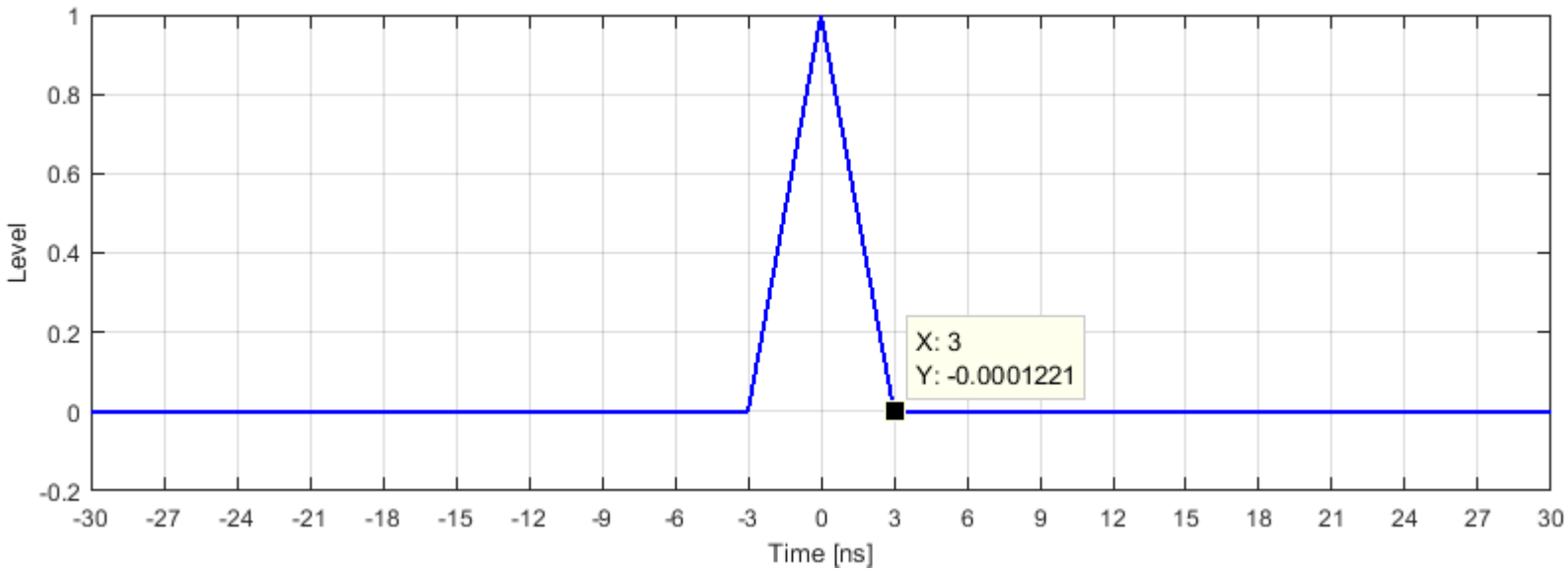


$$s_T(t) = \sum_{n=0}^{N-1} a_n s_0(t - n\Delta) = s_T(t - lT), \forall l = 0, \pm 1, \pm 2, \cdots,$$

✓ $\Delta = 3\text{ns}$; $T = N \cdot \Delta$; $N = 8192$

Data analysis

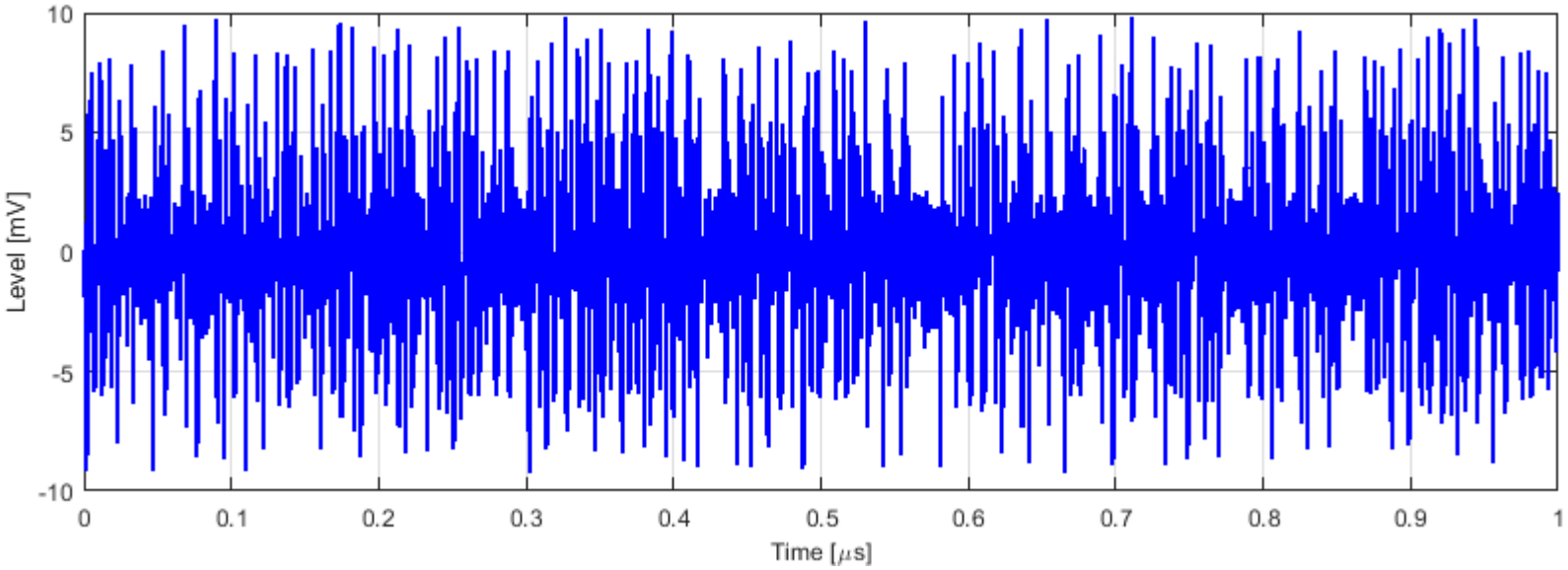
➢ Autocorrelation function of the PRBS



$$R_{sT}(\tau) = \frac{1}{N\Delta}\int_{0}^{N\Delta} s_T(t)s_T(t-\tau)\,dt$$

Data analysis

➢ Averaged signal in the reference probe

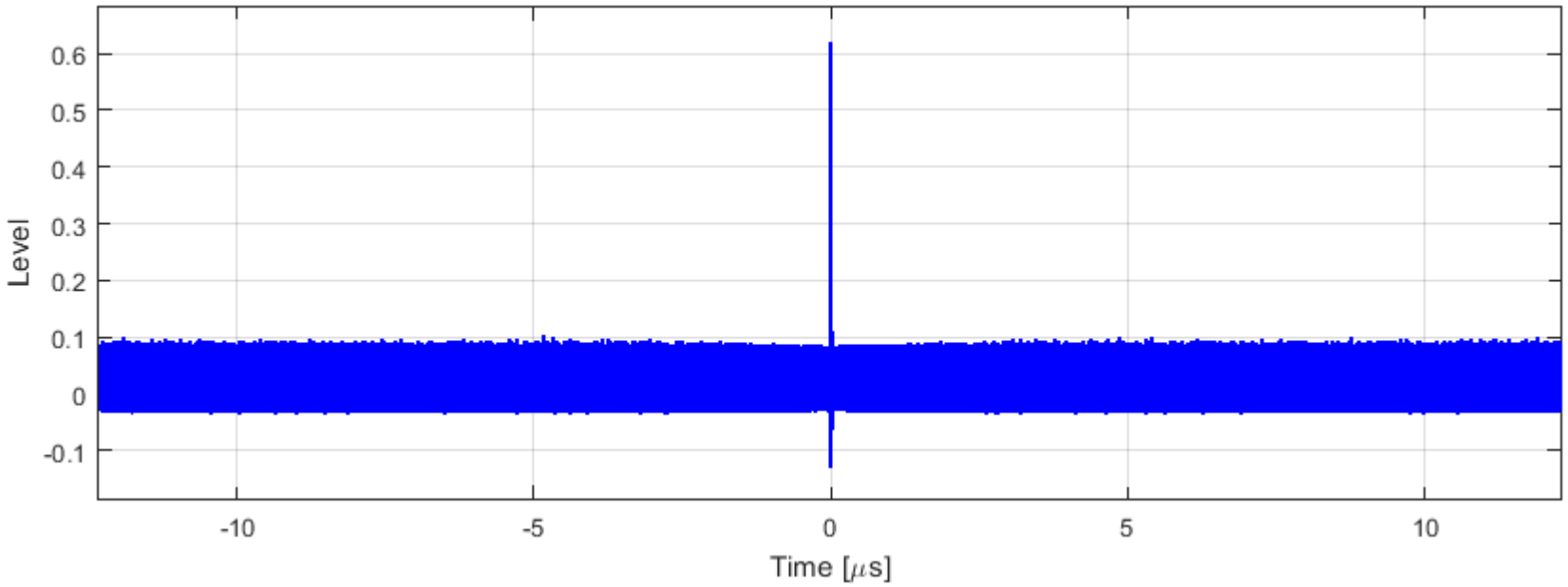


$$\mu_{X_m}[k] = \frac{L}{K} \sum_{j=0}^{(K/L)-1} X_m[k - jL]$$

✓ $L = N \cdot \Delta \cdot F$; $K = 30L$; $F = 10$ GSa/s – sampling frequency

Data analysis

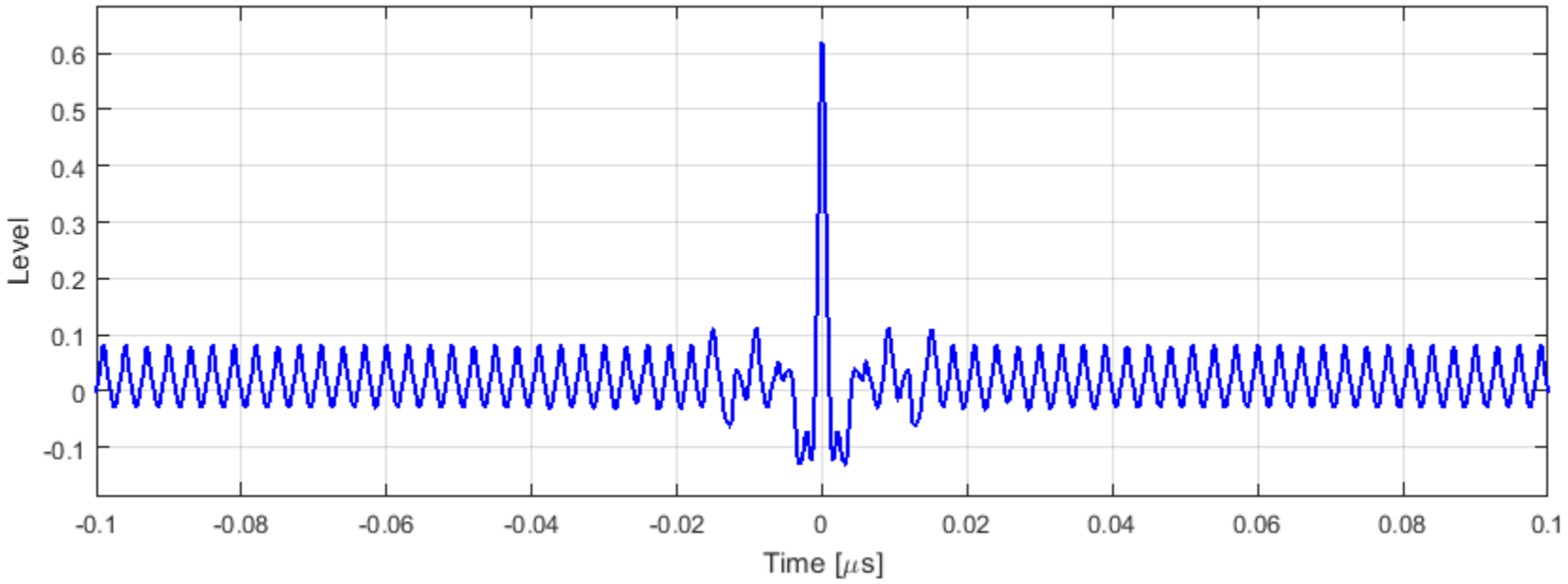
➢ Autocorrelation function of the reference probe's signal



$$r_{X_m}[k] = \frac{1}{L}\sum_{l=0}^{L} \mu_{X_m}[l]\mu_{X_m}[l-k]$$

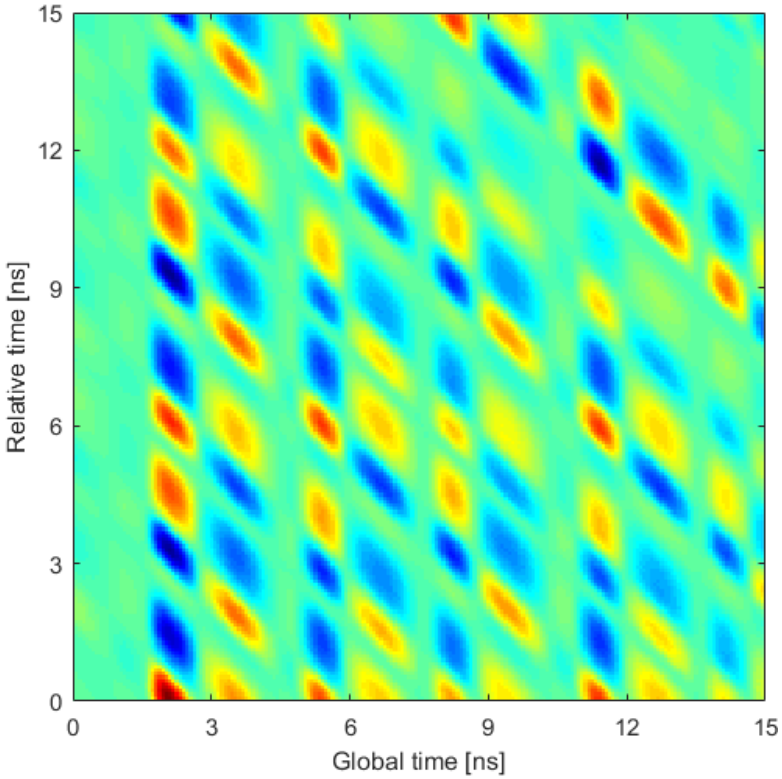
Data analysis

- **Autocorrelation function of the reference probe's signal**



Cyclostationary analysis

➢ Periodic autocorrelation function



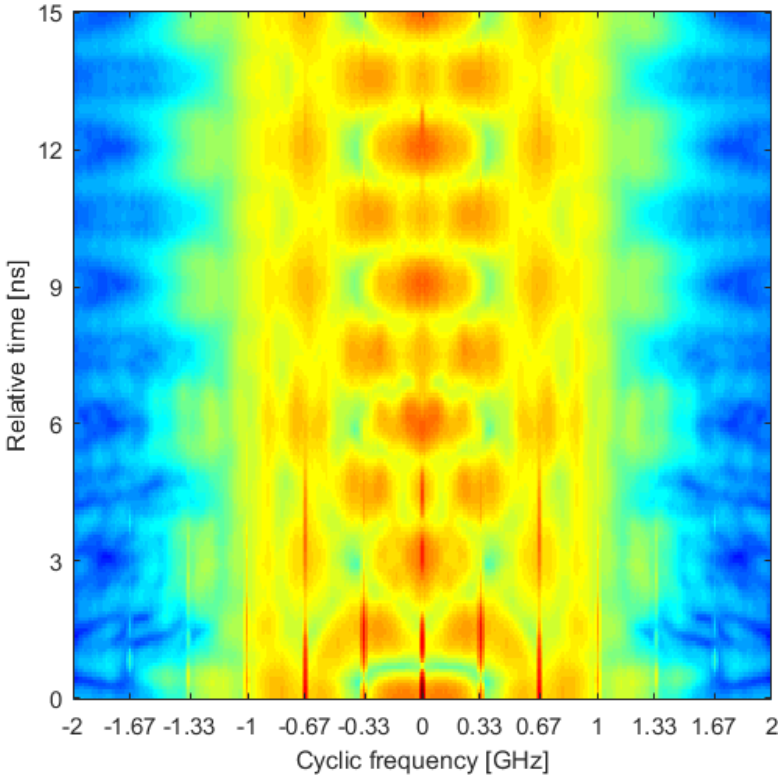
$$\rho_X[i,\nu] = \frac{L}{K}\sum_{j=0}^{(K/L)-1} x\left[i+\frac{\nu}{2}-jL\right]x\left[i-\frac{\nu}{2}-jL\right]$$

i/F – global time

ν/F – relative time

Cyclostationary analysis

➢ Cyclic autocorrelation function

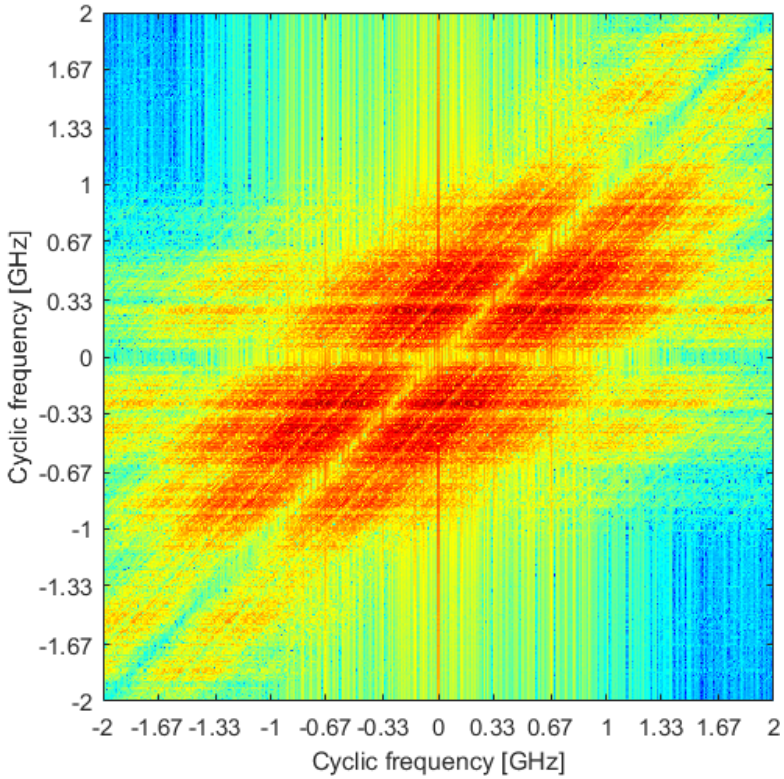


$$R_X^l[\nu] = \frac{1}{L} \sum_{i=-(L-1)/2}^{(L-1)/2} \rho_X[i,\nu] e^{-j\frac{2\pi l \nu}{L}}$$

$l \cdot F/L$ – cyclic frequency

Cyclostationary analysis

➢ Cyclic spectrum

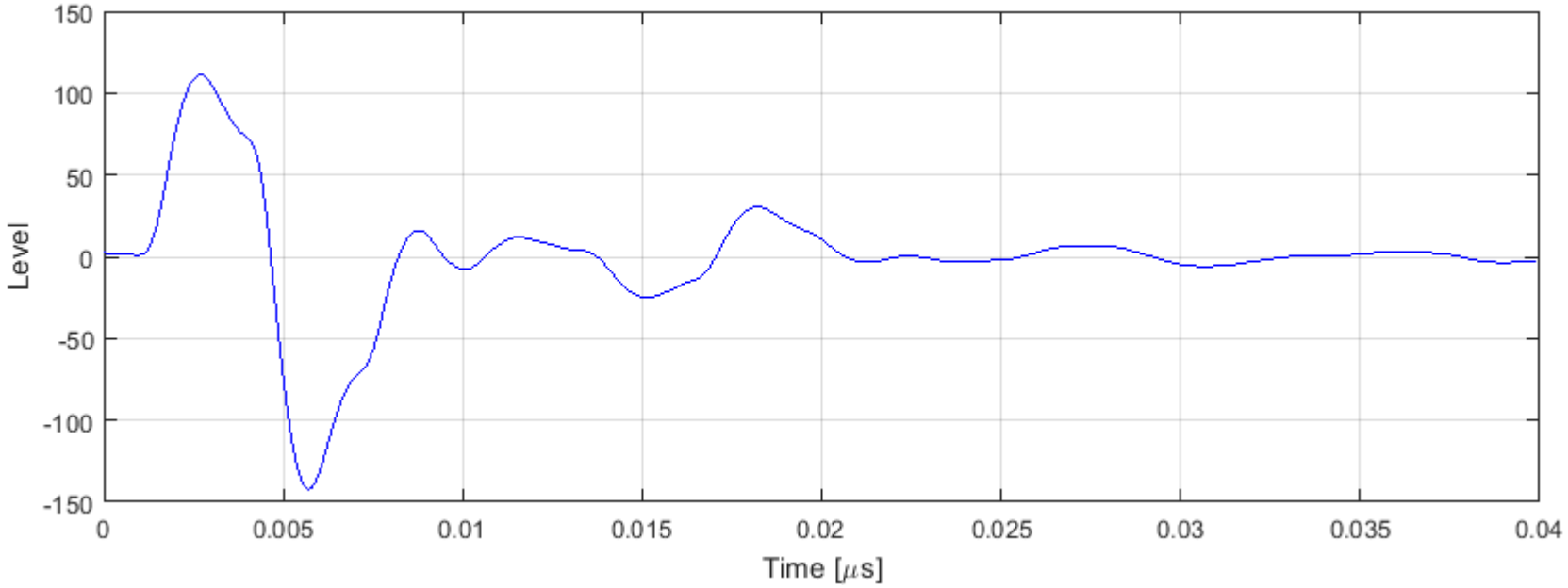


$$S_X^l[m] = \frac{1}{L} \sum_{\nu=-(L-1)/2}^{(L-1)/2} R_X^l[\nu] e^{-j\frac{2\pi\nu m}{N}}$$

$m \cdot F/L$ – cyclic frequency

Data analysis

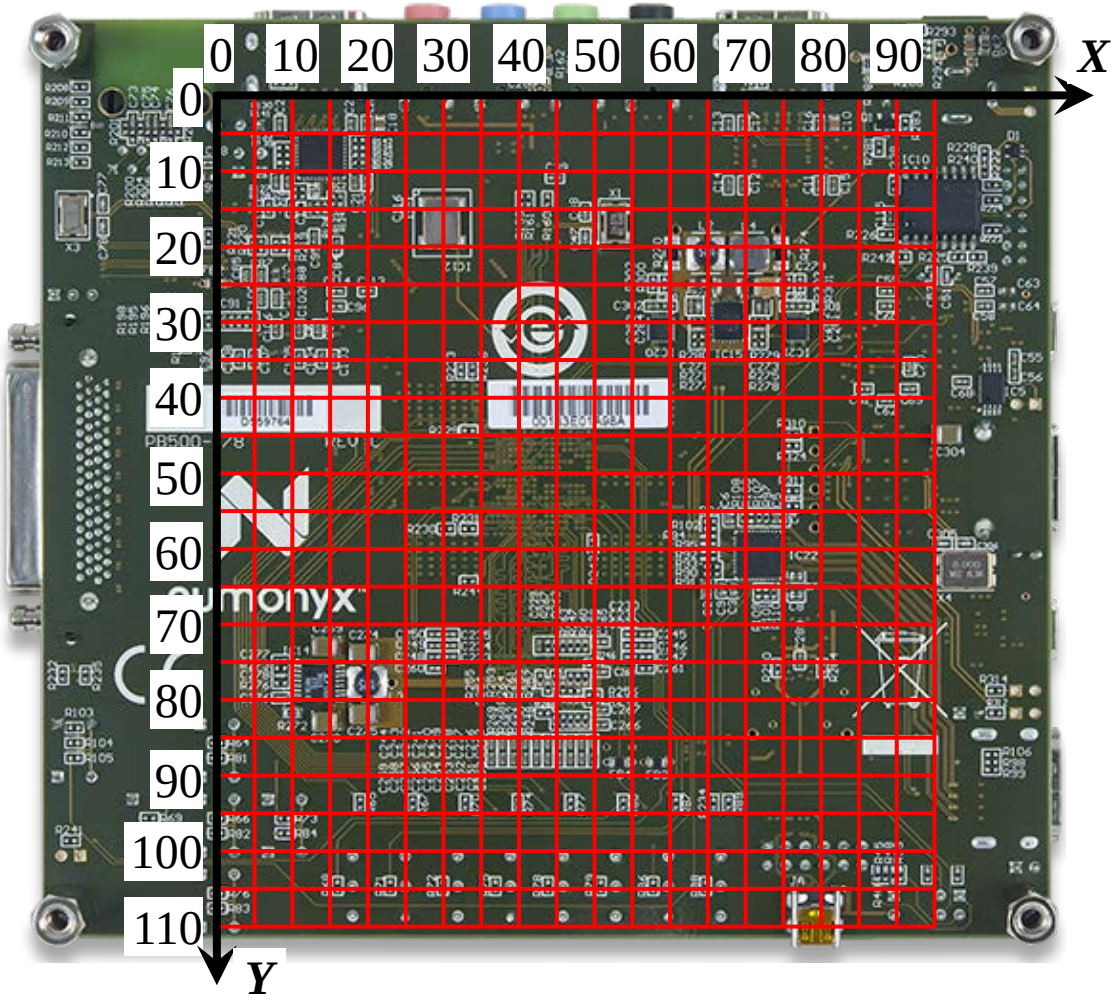
➢Cross-correlation function of the reference probe's signal and PRBS



$$\rho_{SX_m}[n] = E\{S[k]X_m[k-n]\} = \frac{L}{K}\sum_{j=0}^{(K/L)-1}\sum_{k=0}^{L-1} S[k]X_m[k-n-jL]$$

Experimental results

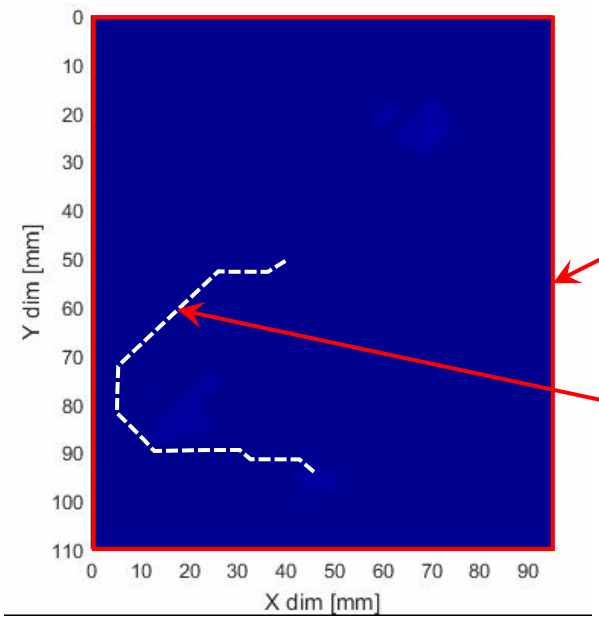
➢Measurement grid



- ✓ 20 x 23 points
- ✓ 5 mm step
- ✓ H_X and H_Y polarization
- ✓ $M = 20 \cdot 23 = 460$
- ✓ $m = 1 \ldots M$

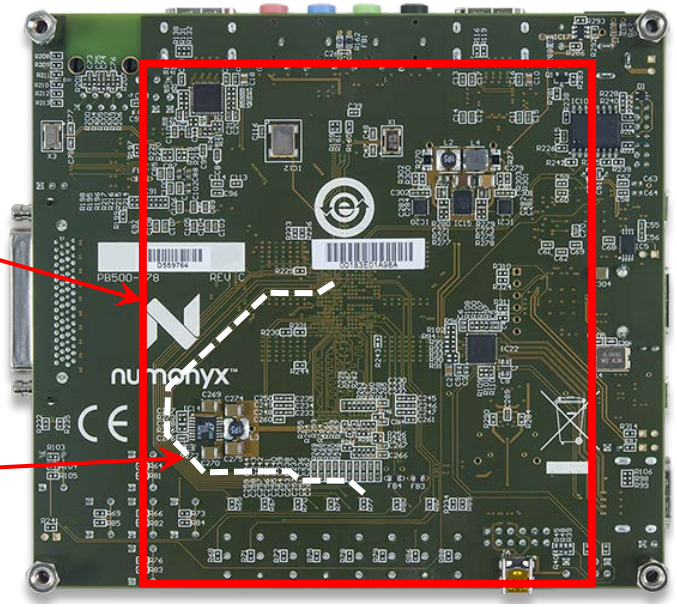
Experimental results

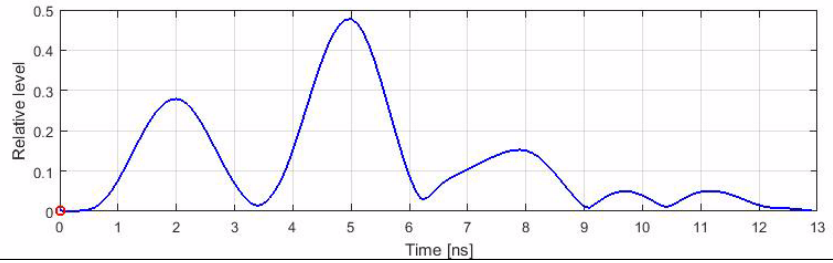
➢ Time evolution of the cross correlation function



scanning area

signal path

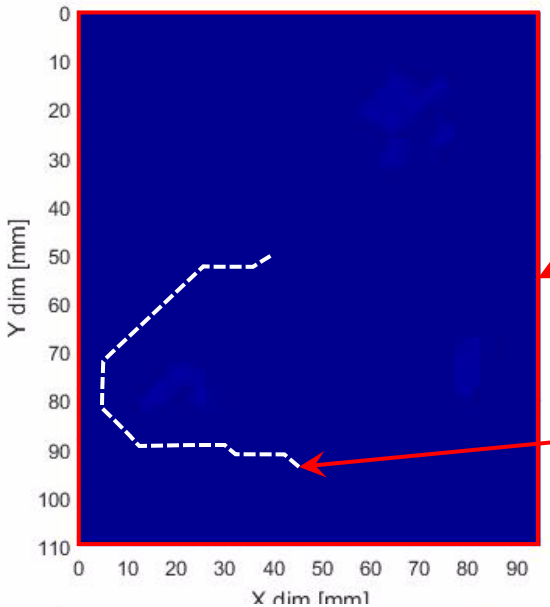




✓ 8192 bit sequence

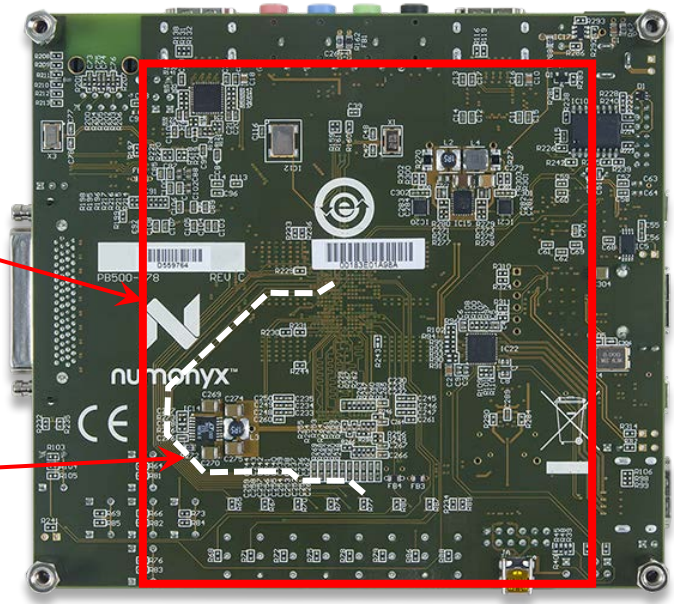
Experimental results

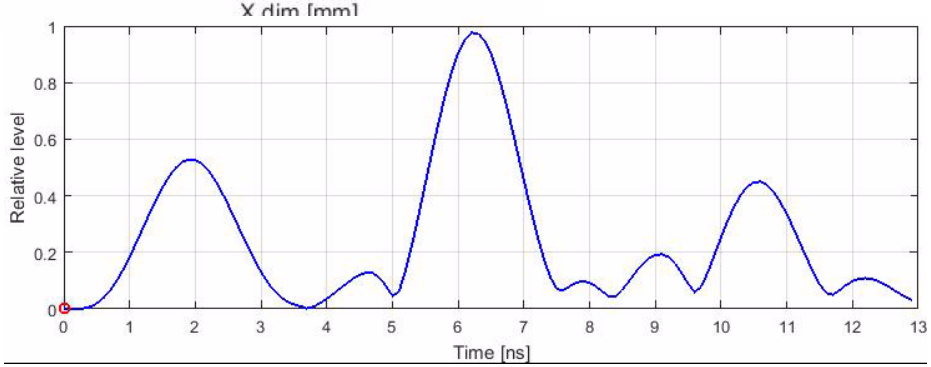
➢ Time evolution of the cross correlation function



scanning area

signal path

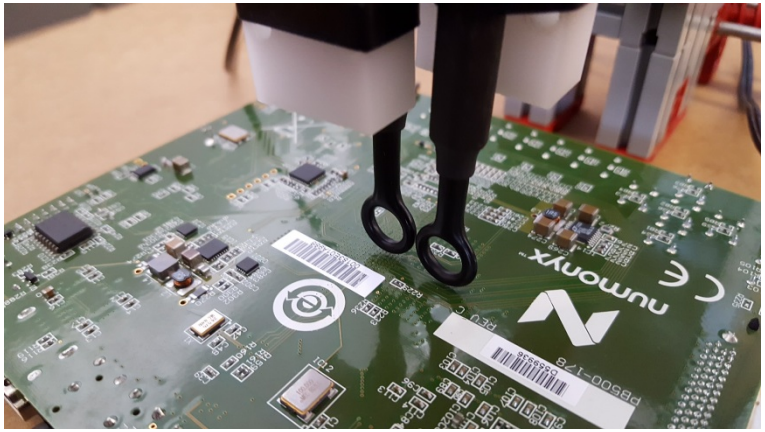


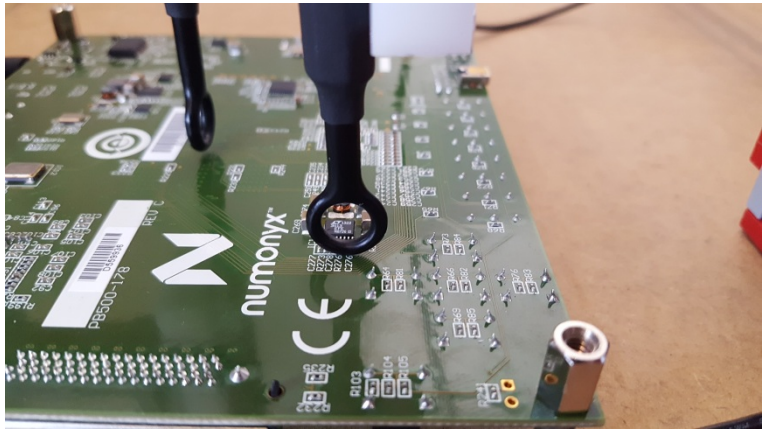


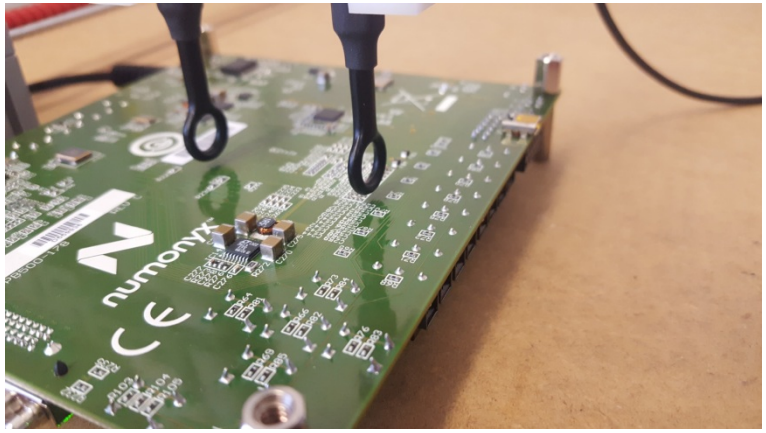
✓1024 bit sequence

Experimental results

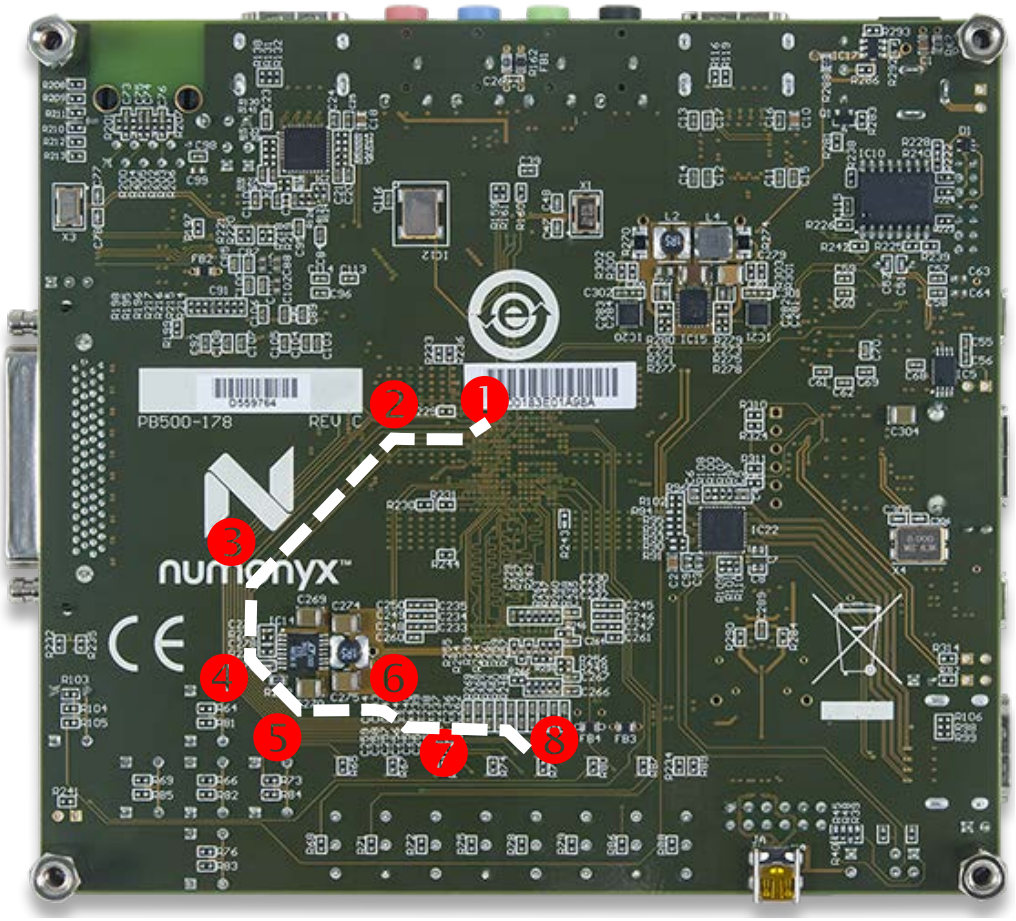
➢ Measurement along the strip line







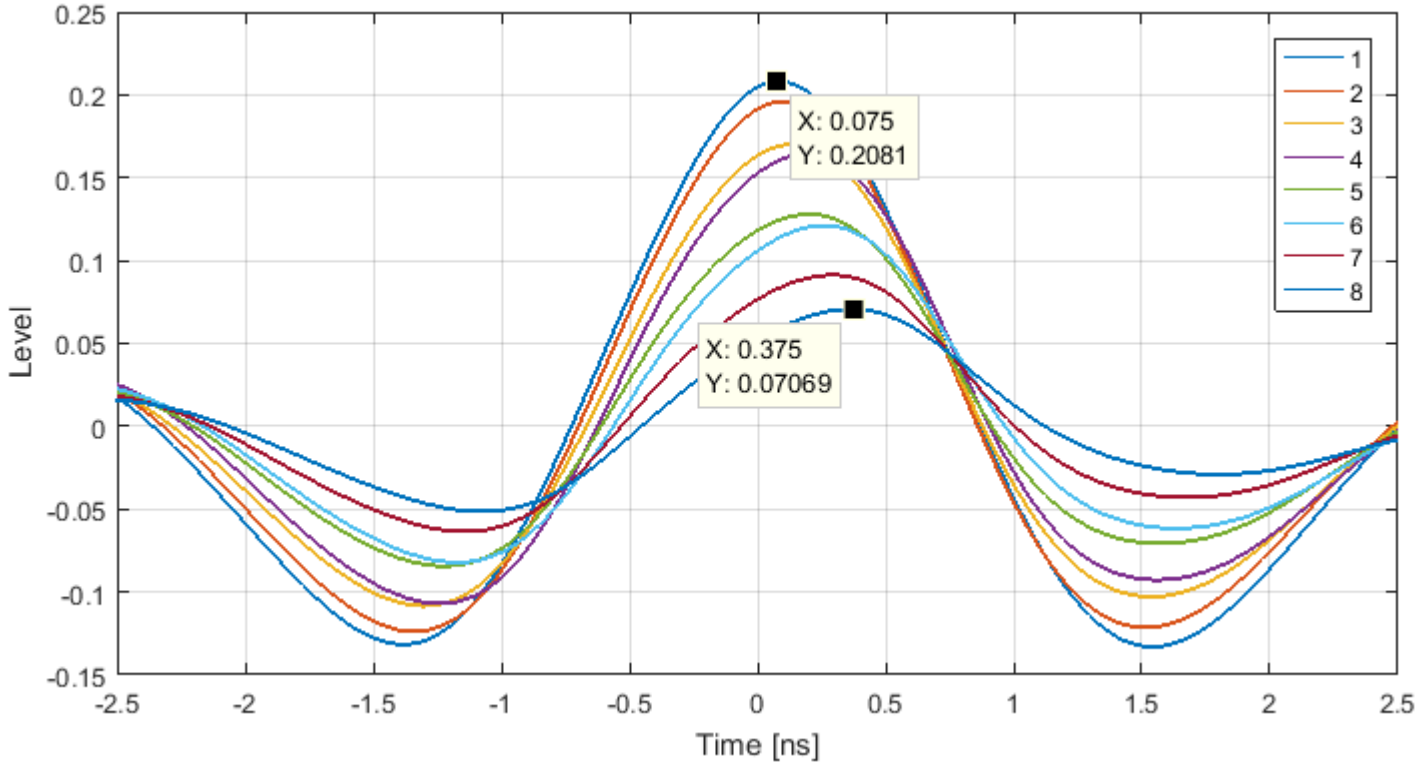
Experimental results



✓ Measurement points along the strip line

Experimental results

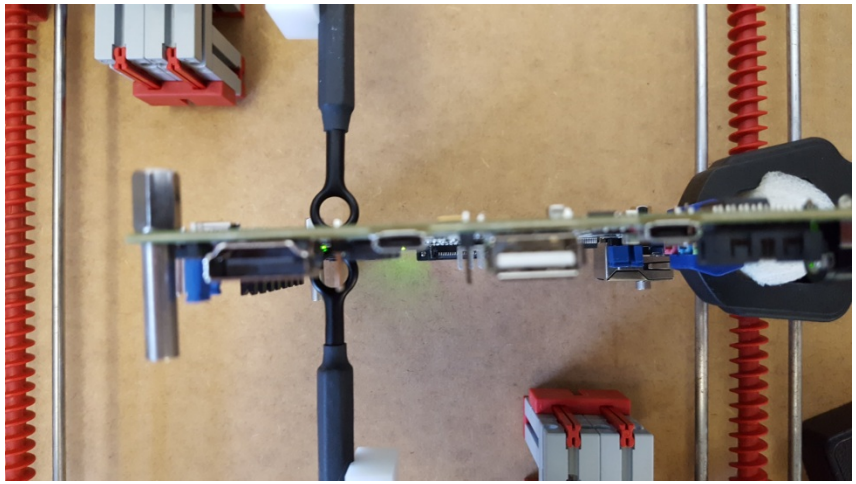
➢ Delay of the cross correlation function

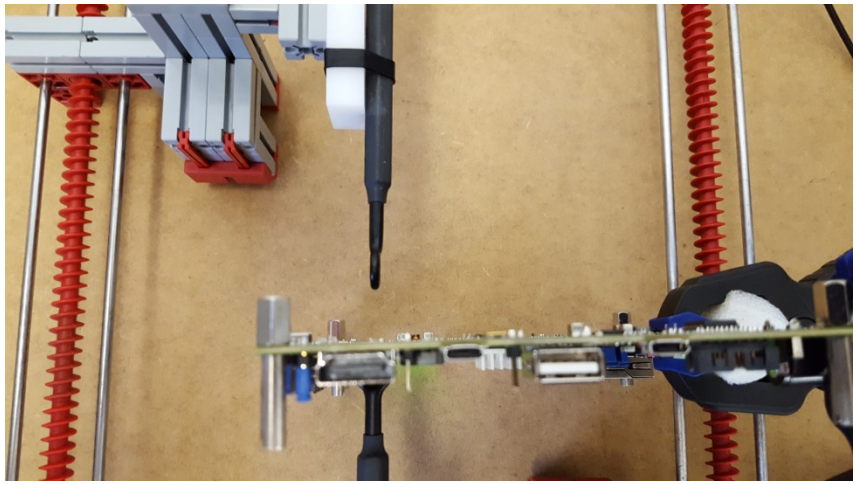


$$\rho_{X_{ref}X_m}[n] = E\{X_{ref}[k]X_m[k-n]\}$$

Experimental results

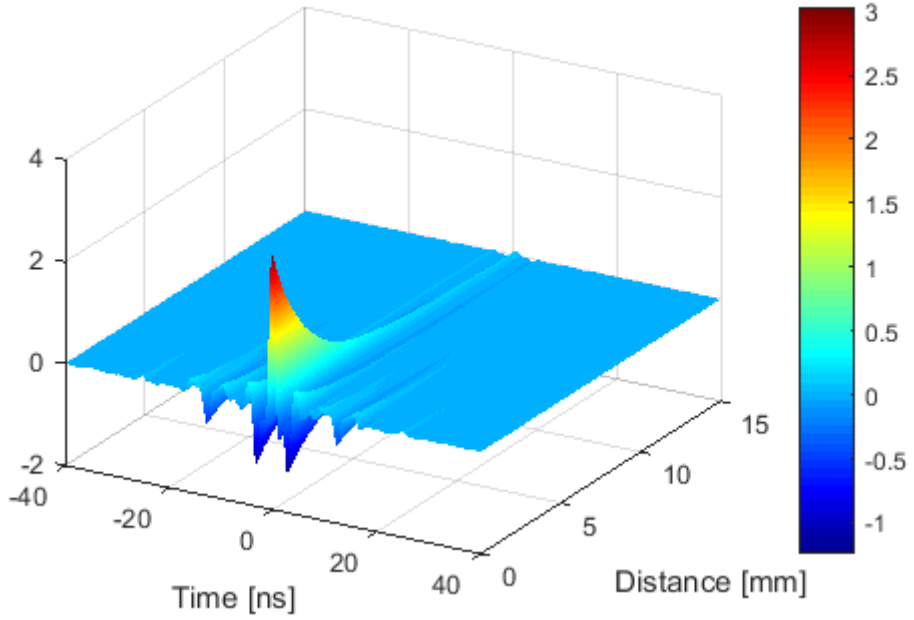
- **Dependence on the distance between DUT and near-field probe**

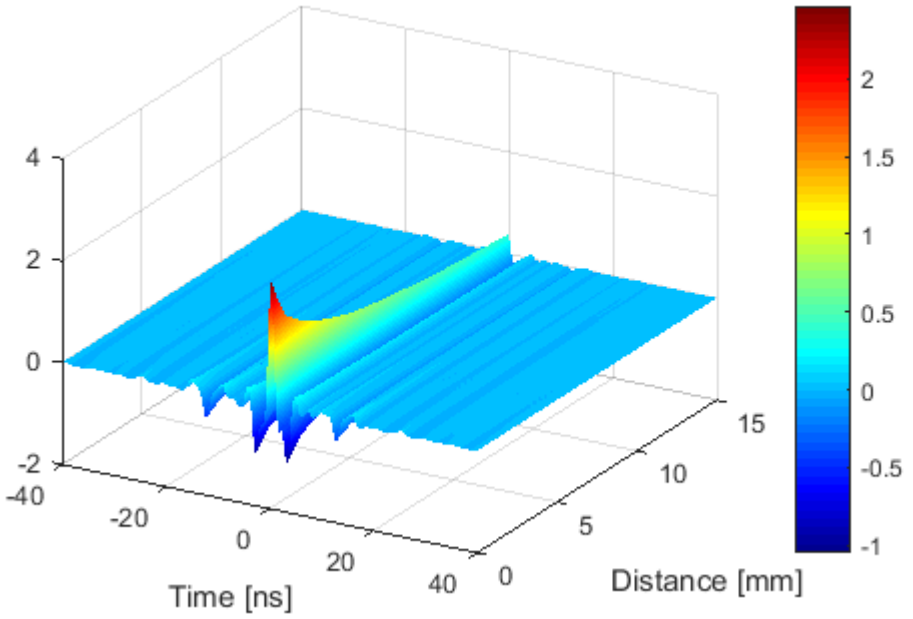




Experimental results

- Vertical polarization
- Horizontal polarization



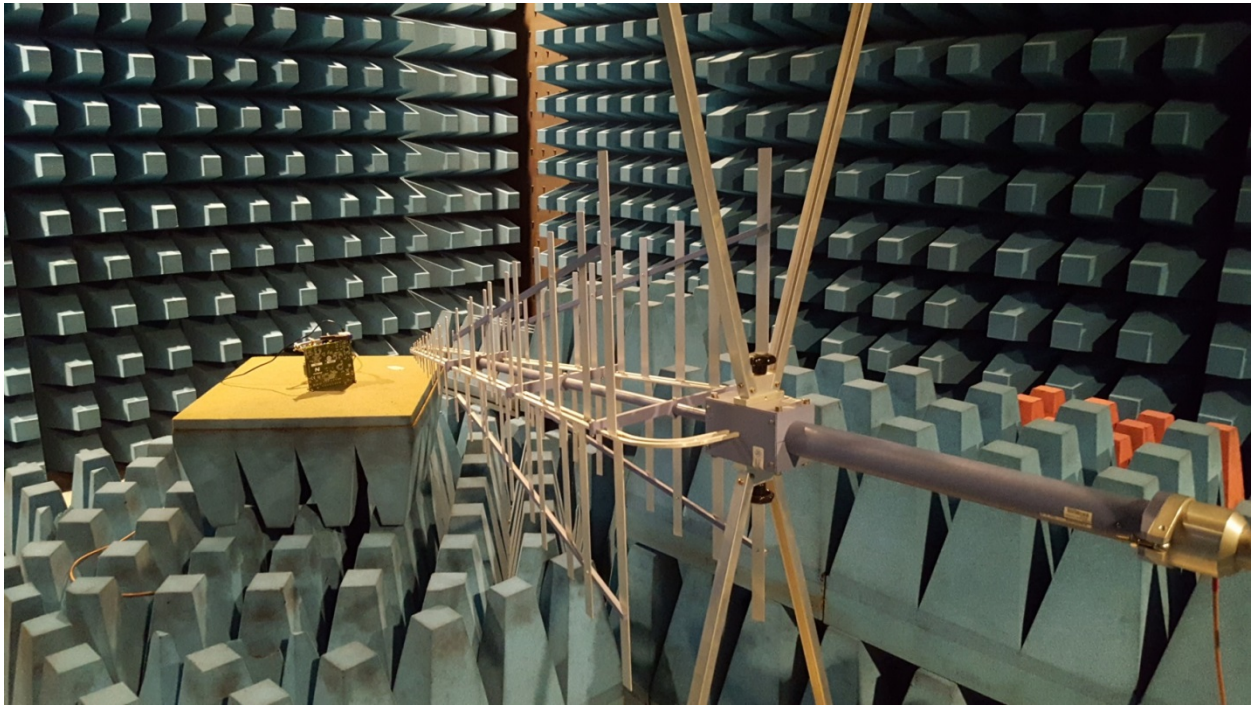


- ✓ distance 1…15 mm
- ✓ step size 1 mm

Outline

- Spatial localization of the pass between the source and the load on the PCB surface
- Characterization of the cyclostationary properties of the PCB pseudorandom emissions
- **Characterization of the far-field pattern for the unintentional stochastic emissions of the PCB**
- Parametric identification of the ultra wideband near-field probes in time and frequency domains

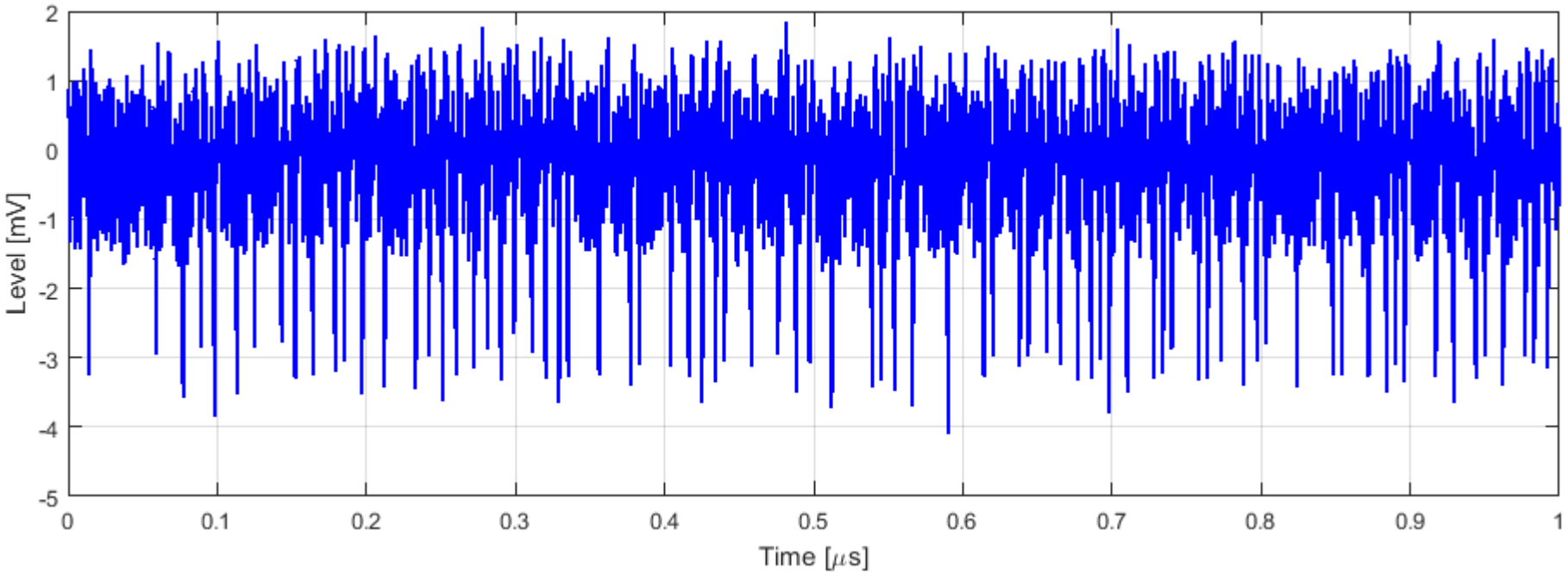
Anechoic chamber



- ✓ **Antenna R&S HL 562E**
- ✓ **30 MHz … 6 GHz**
- ✓ **Amplifier 30 dB**

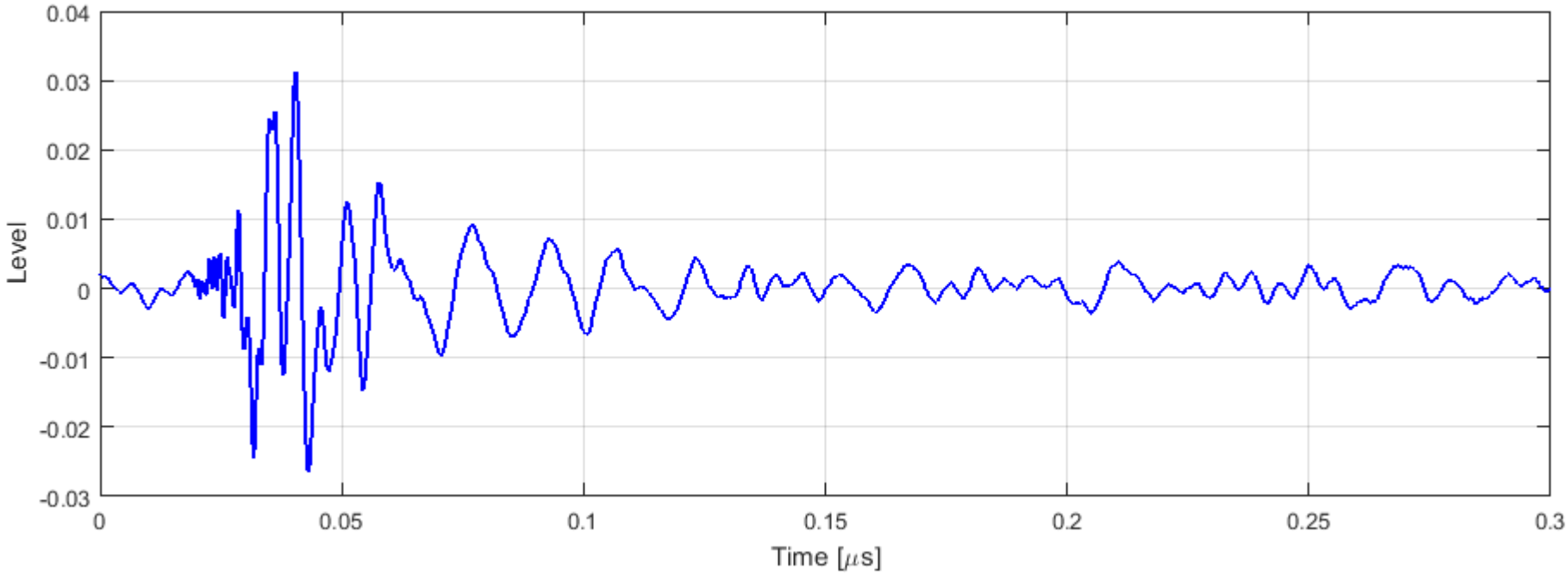
Data analysis

➢ Measured signal



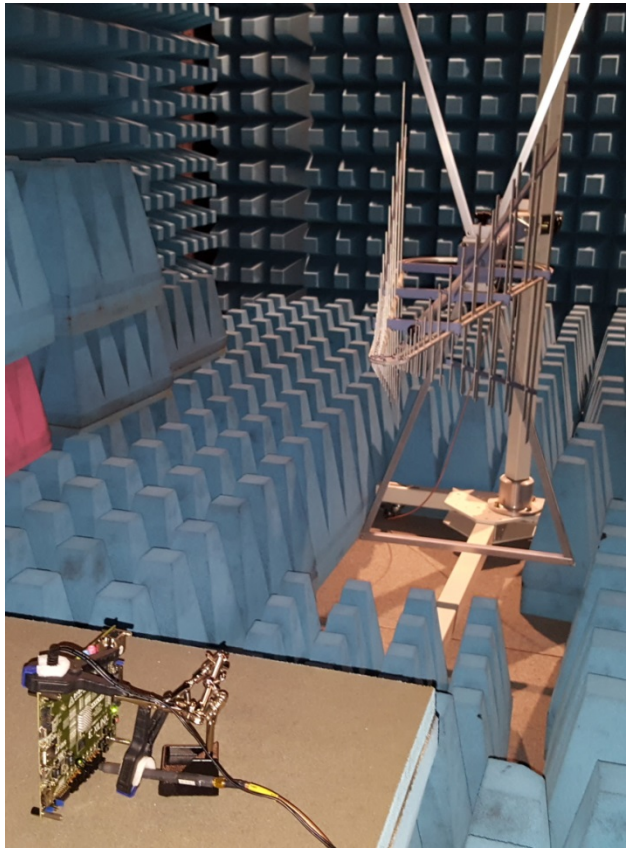
Data analysis

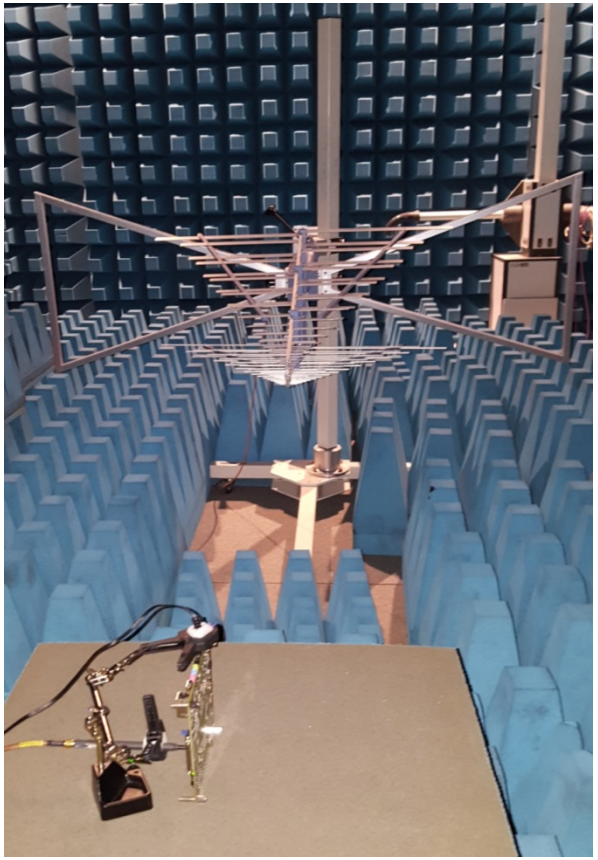
➢Cross-correlation function of the antenna's signal and PRBS



Anechoic chamber

- Vertical polarization
- Horizontal polarization

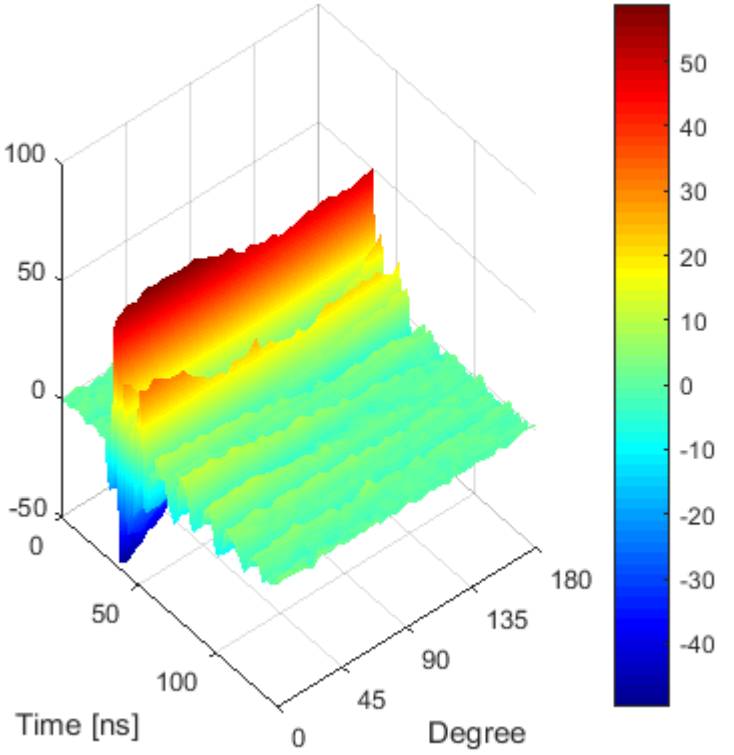


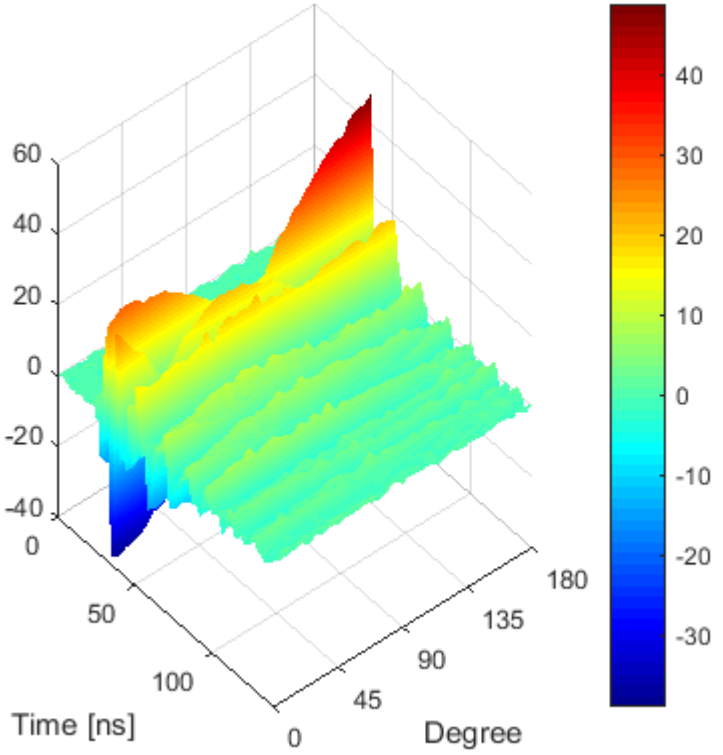


✓ distance 1 m

Experimental results

- Vertical polarization
- Horizontal polarization

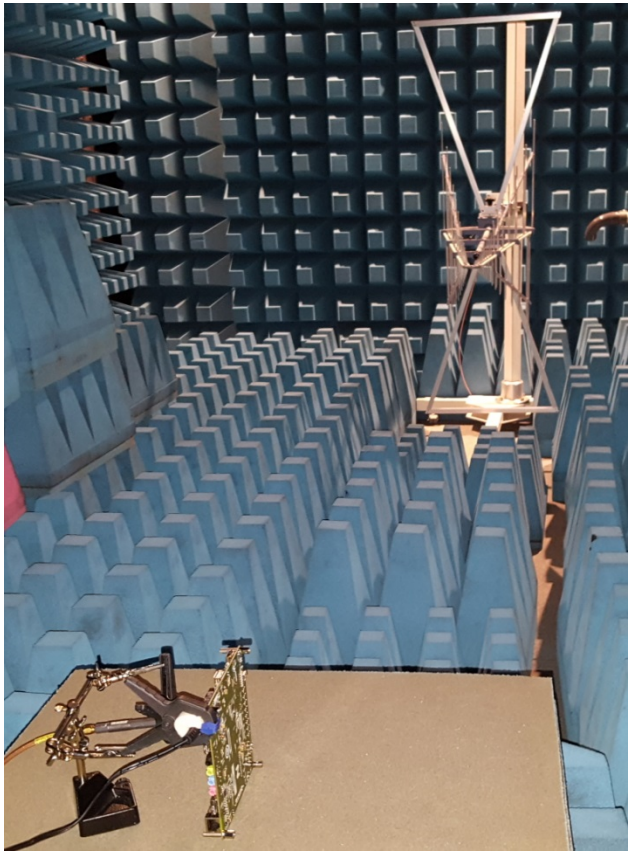




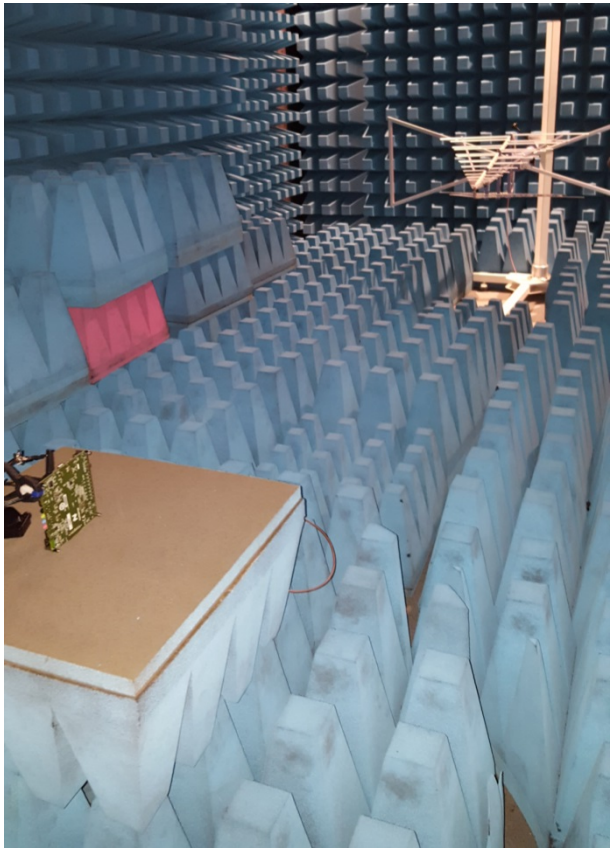
✓ distance 1 m

Anechoic chamber

- Vertical polarization



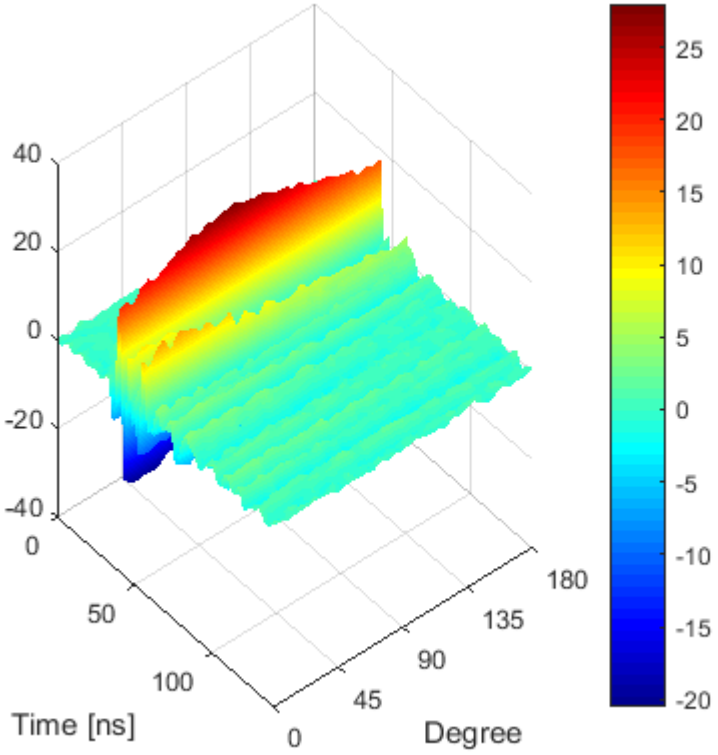
- Horizontal polarization

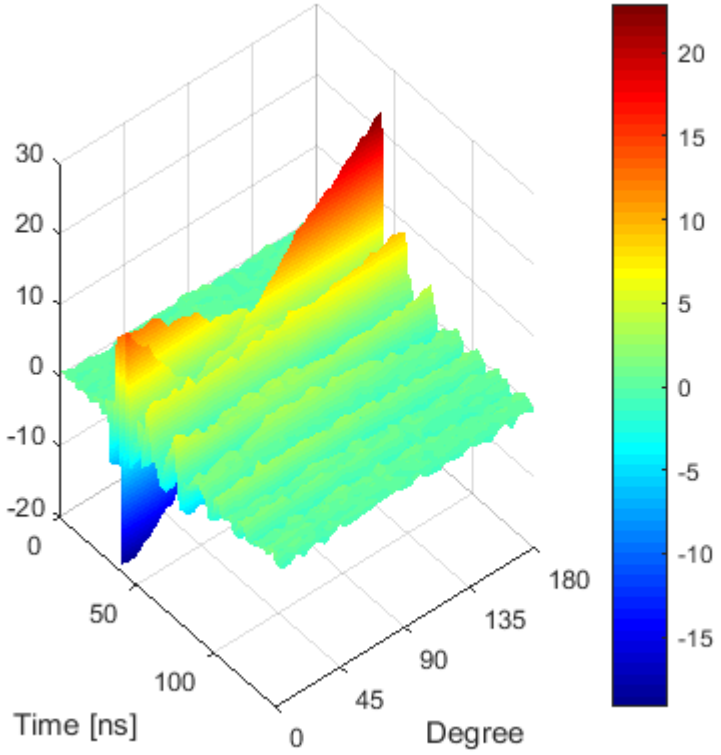


✓ distance 3 m

Experimental results

- Vertical polarization
- Horizontal polarization





✓ distance 3 m

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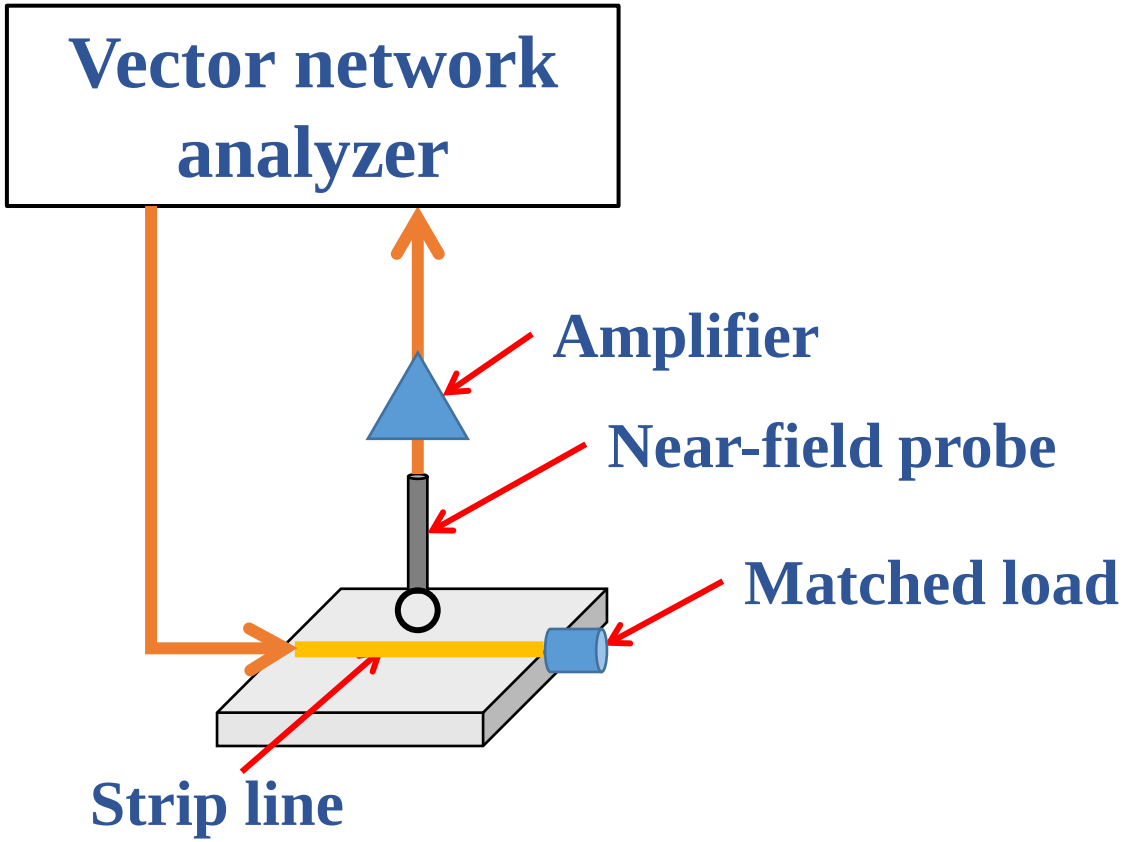
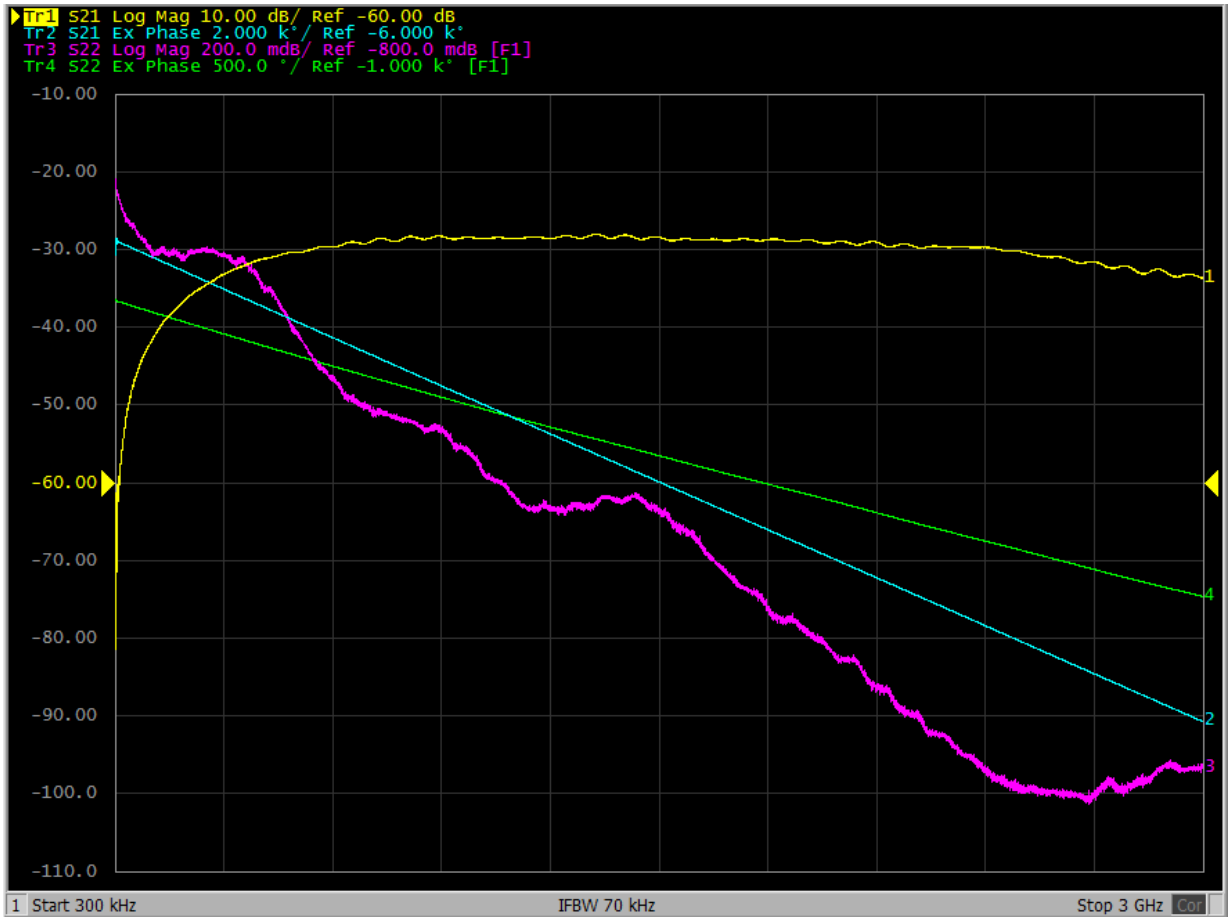
Measurement setup

- Frequency-domain measurement system



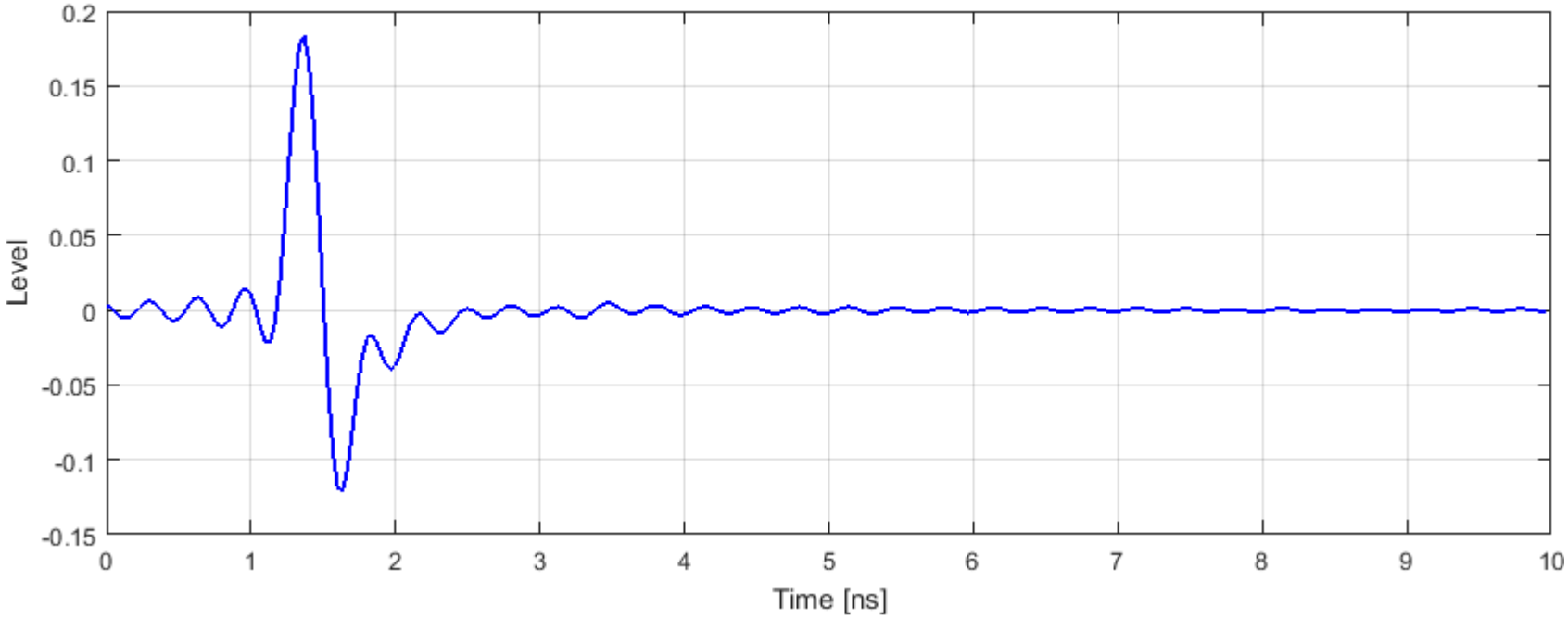
Probe identification

➢ S-parameters of Langer RF-R 50-1 probe



Probe identification

➢ Impulse response of the near-field probe

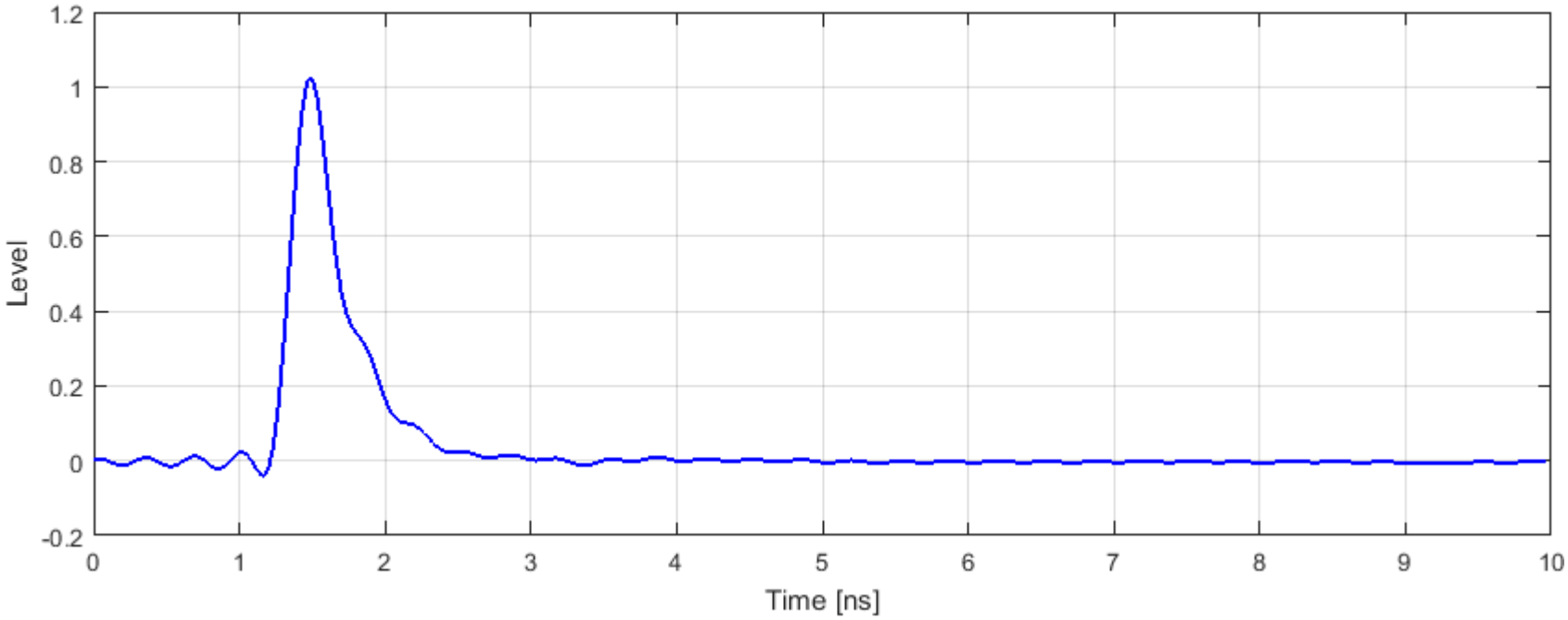


✓ RF-R 50-1

✓ ∅ 10 mm

Probe identification

➢ Step response of the near-field probe

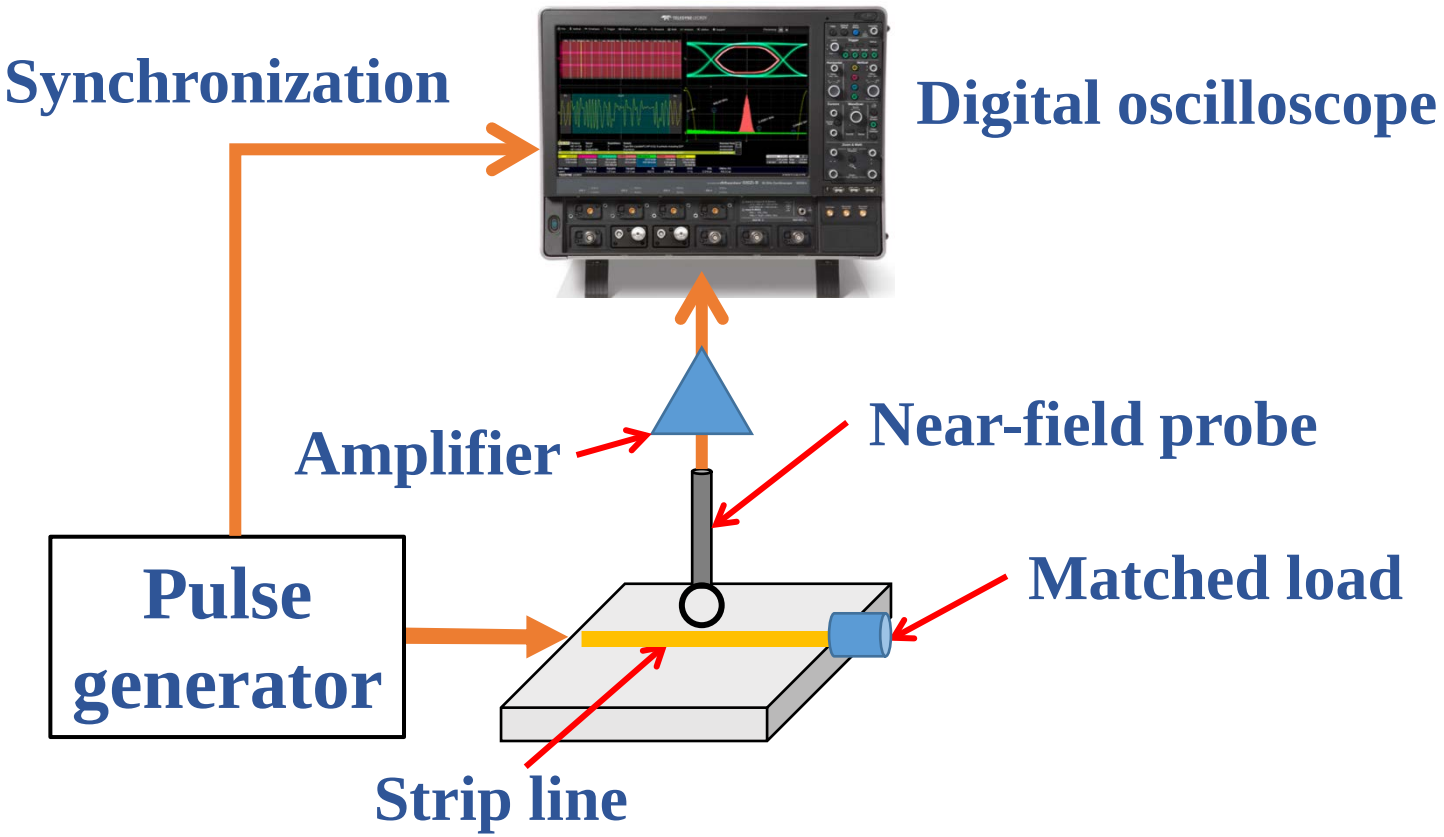


✓ RF-R 50-1

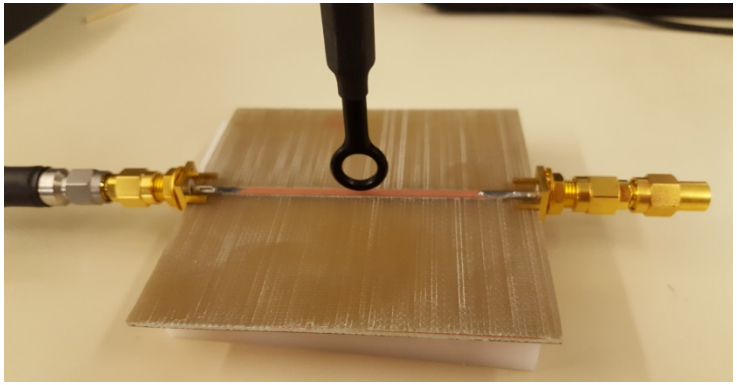
✓ ∅ 10 mm

Measurement setup

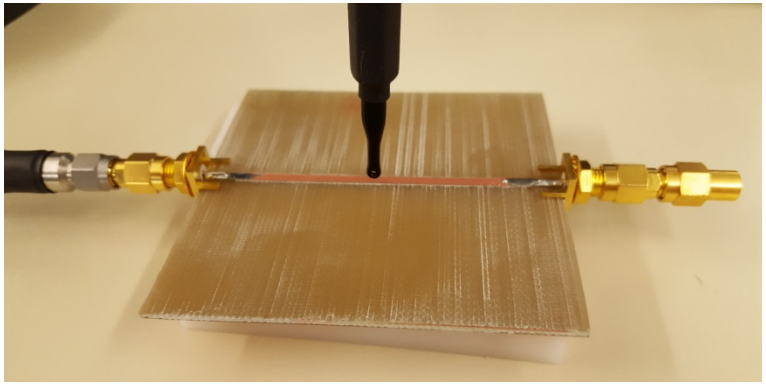
➢ Time-domain measurement system



Probe identification



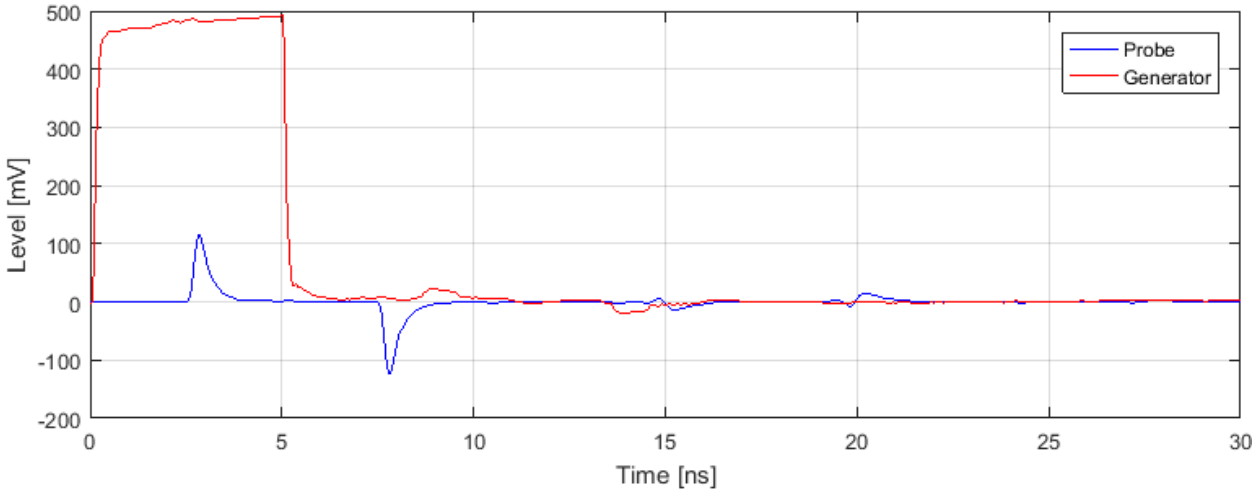
✓ Langer RF-R 50-1
✓ ∅ 10 mm



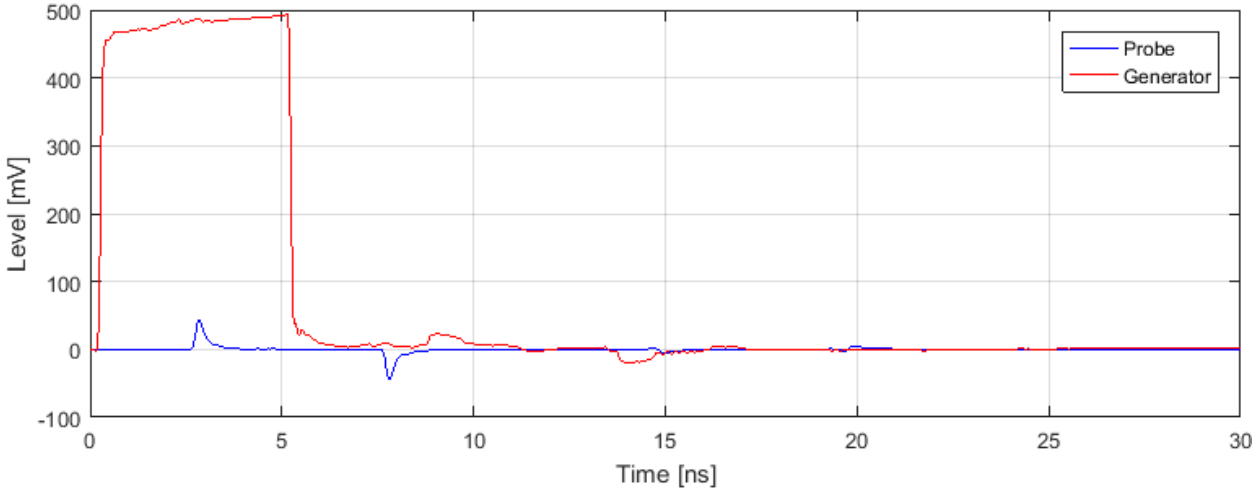
✓ Langer RF-R 3-2
✓∅ 3 mm

Probe identification

➢ Step responses of the near-field probes



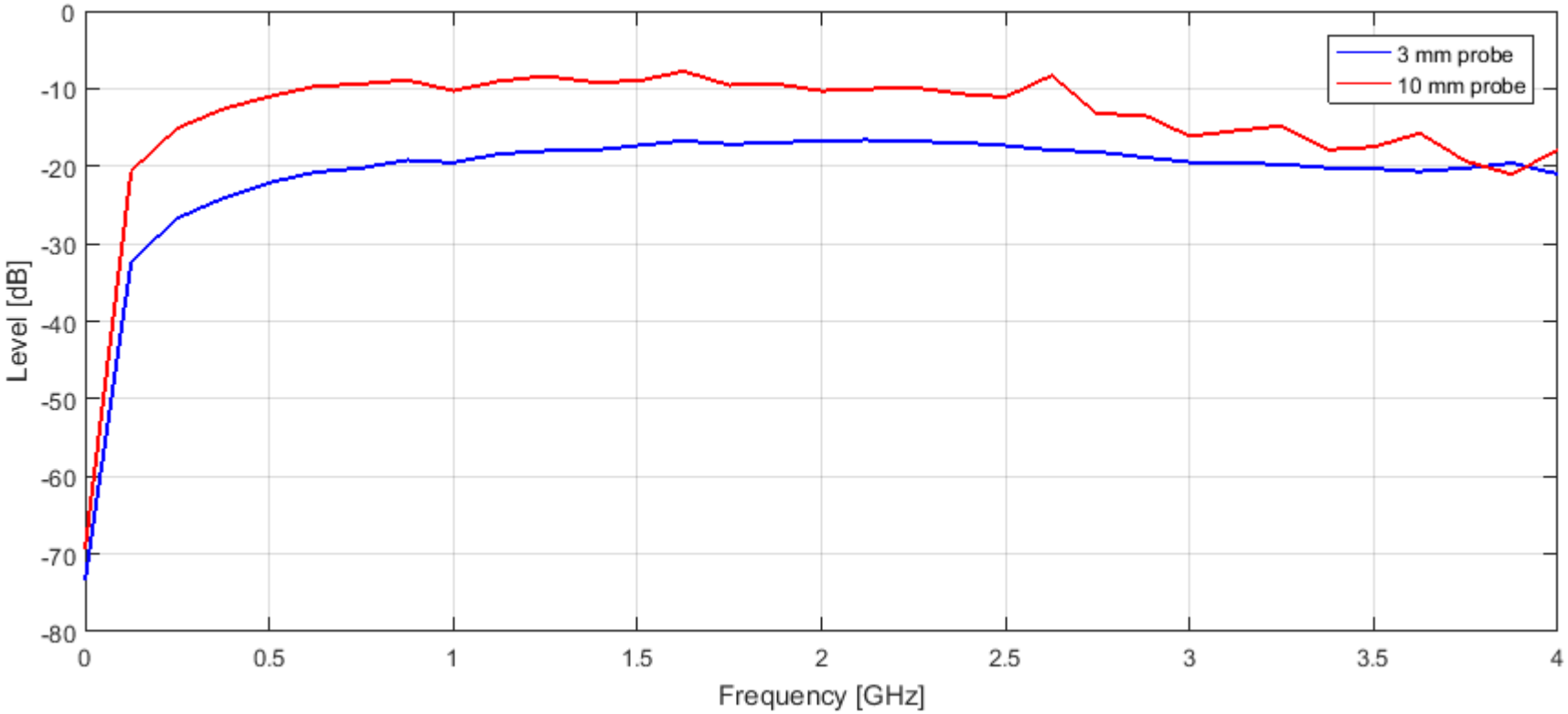
✓ RF-R 50-1
✓ ∅ 10 mm



✓ RF-R 3-2
✓ ∅ 3 mm

Probe identification

- **Frequency characteristic of the near-field probes**



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