FACULTEIT INGENIEURSWETENSCHAPPEN
EN ARCHITECTUUR

ROBUSTNESS AGAINST EMI: NARROWBAND AND WIDEBAND TESTING VERSUS REAL LIFE INTERFERENCE

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ETFA Workshop WS10 – 06/09/2022

MOST RECENT VERSION OF THE PRESENTATION

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CINI4.0

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FE Forschungsvereinigung Elektrotechnik beim ZVEI e.V.

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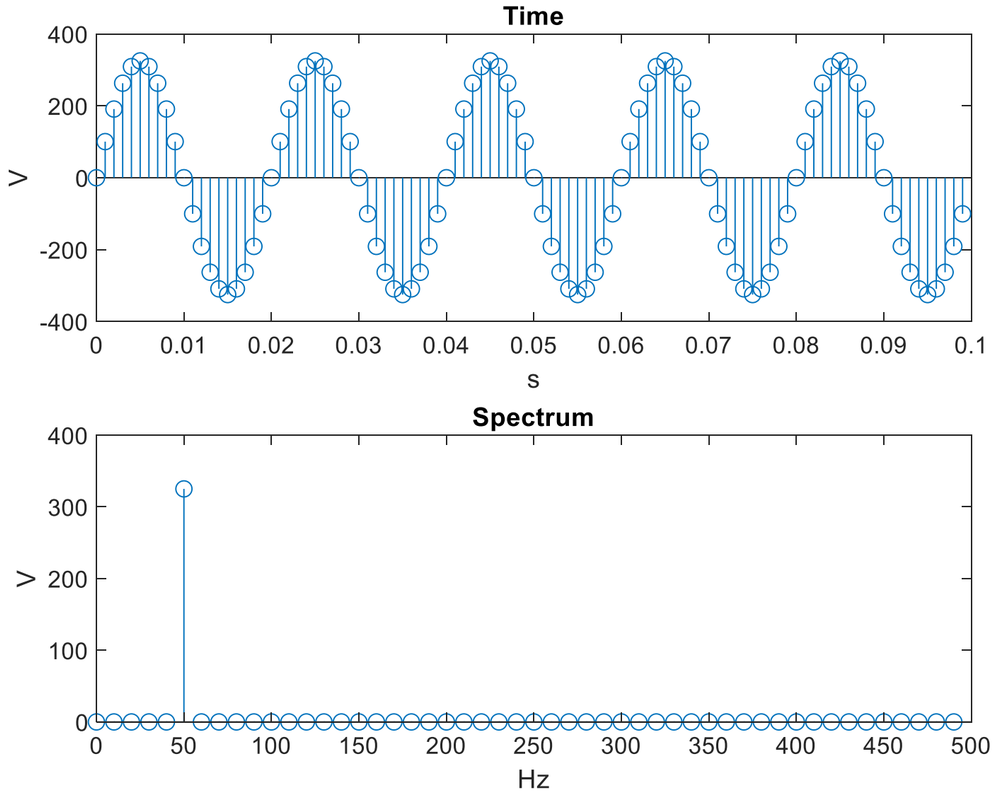
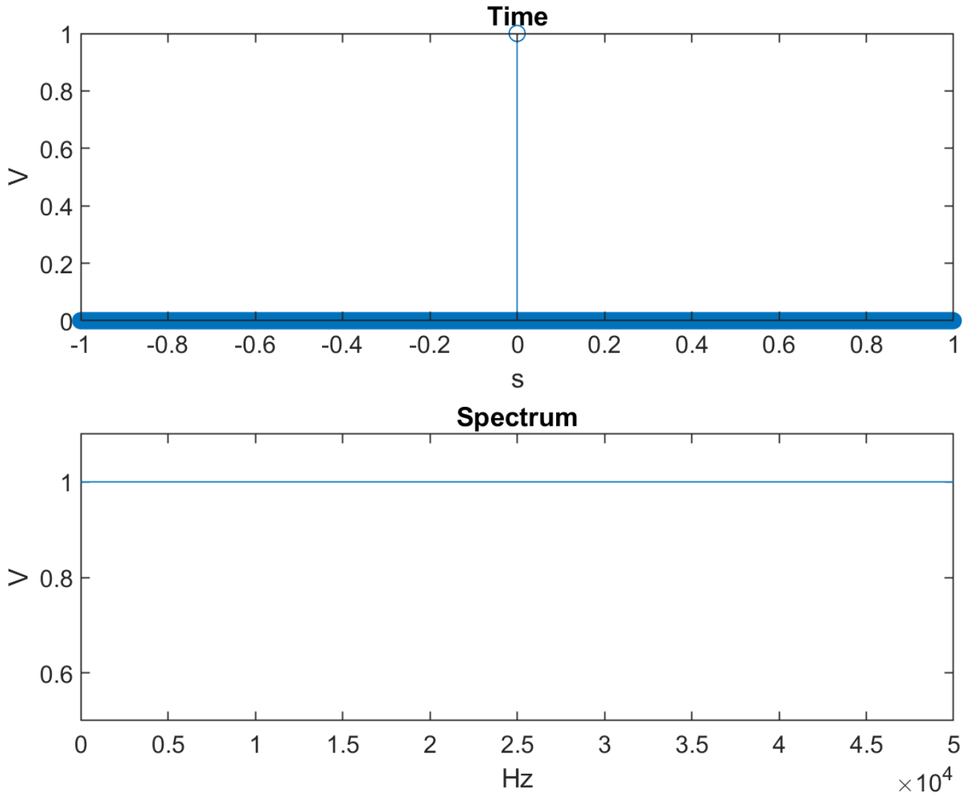
AiF

AGENTSCHAP INNOVEREN & ONDERNEMEN

Supported by: Federal Ministry for Economic Affairs and Energy on the basis of a decision by the German Bundestag

1. Narrowband versus wideband





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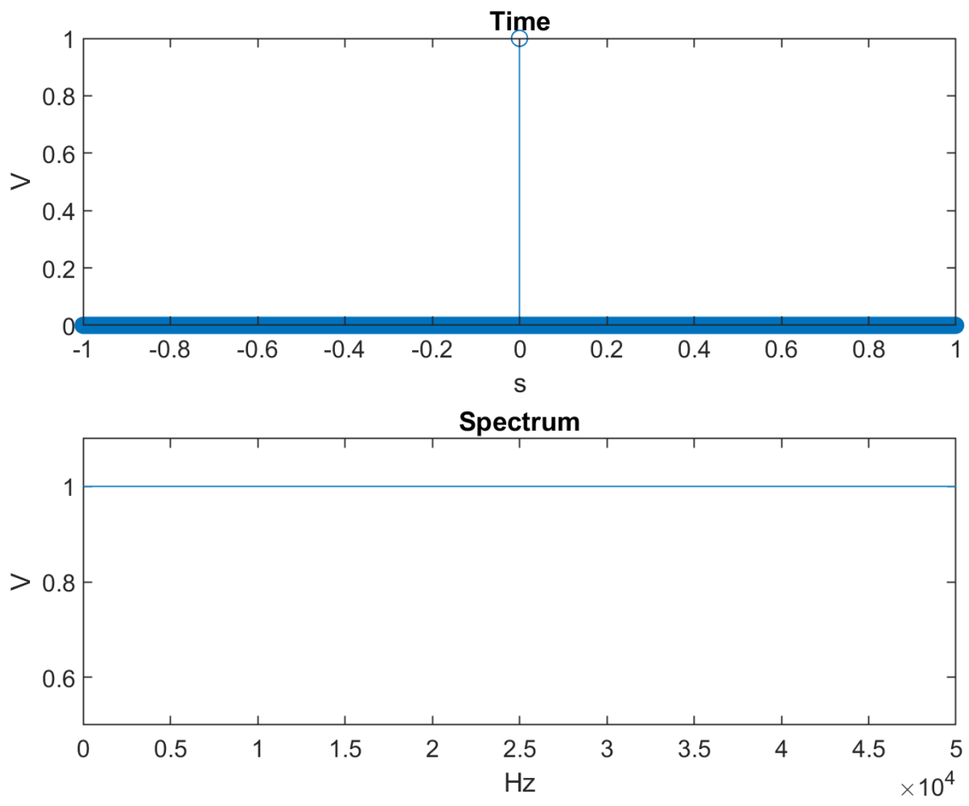
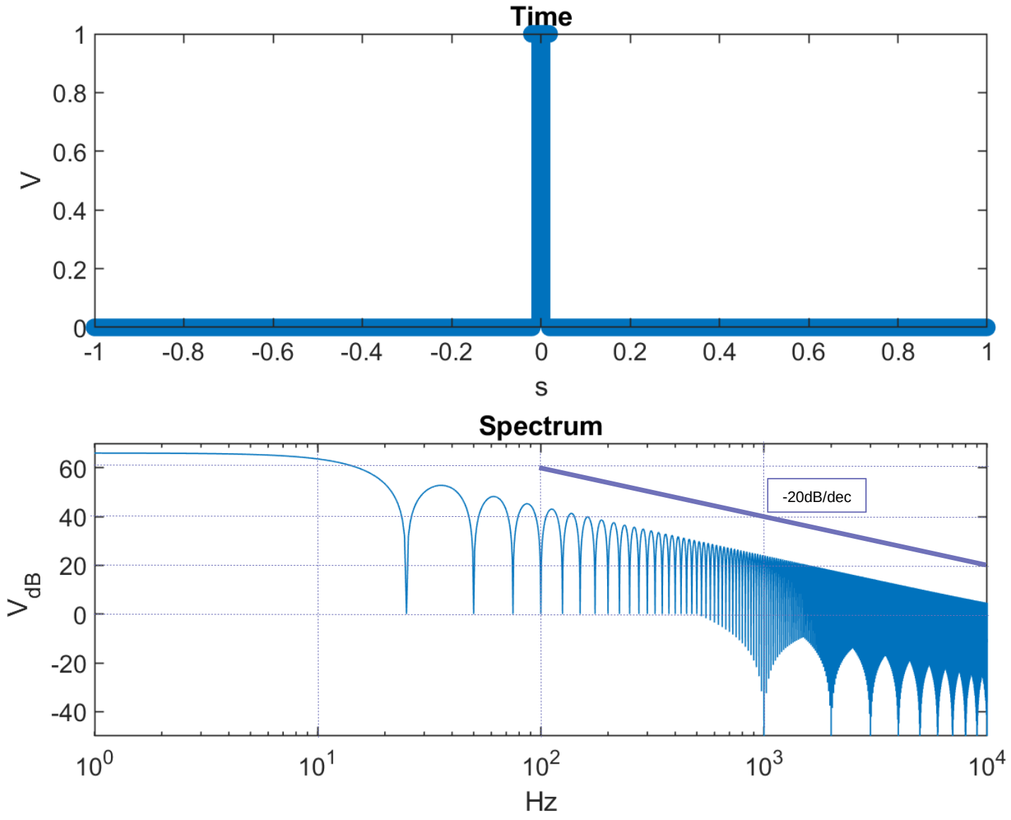
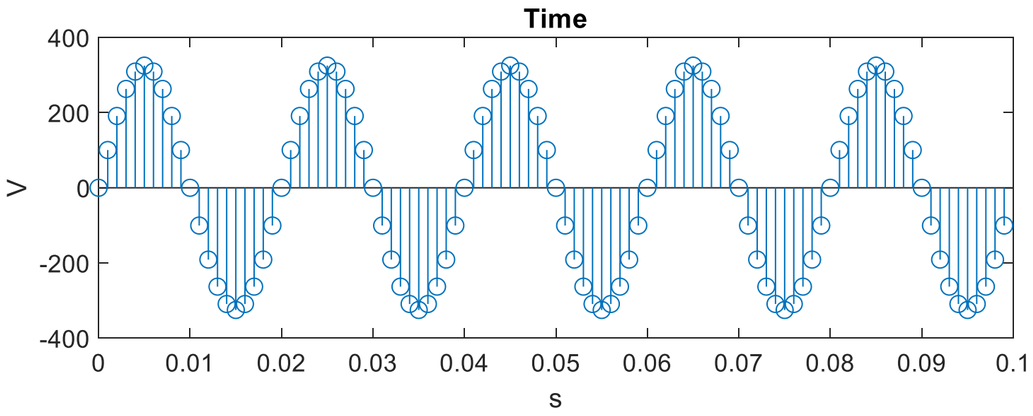
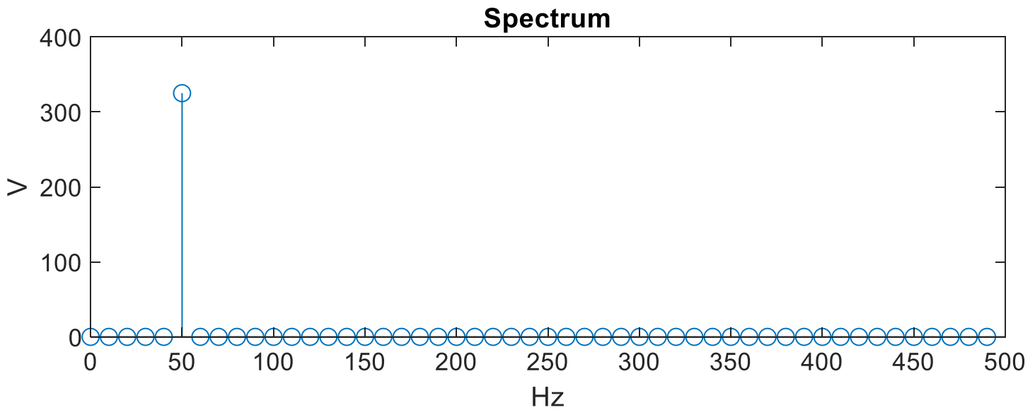
1. Narrowband versus wideband

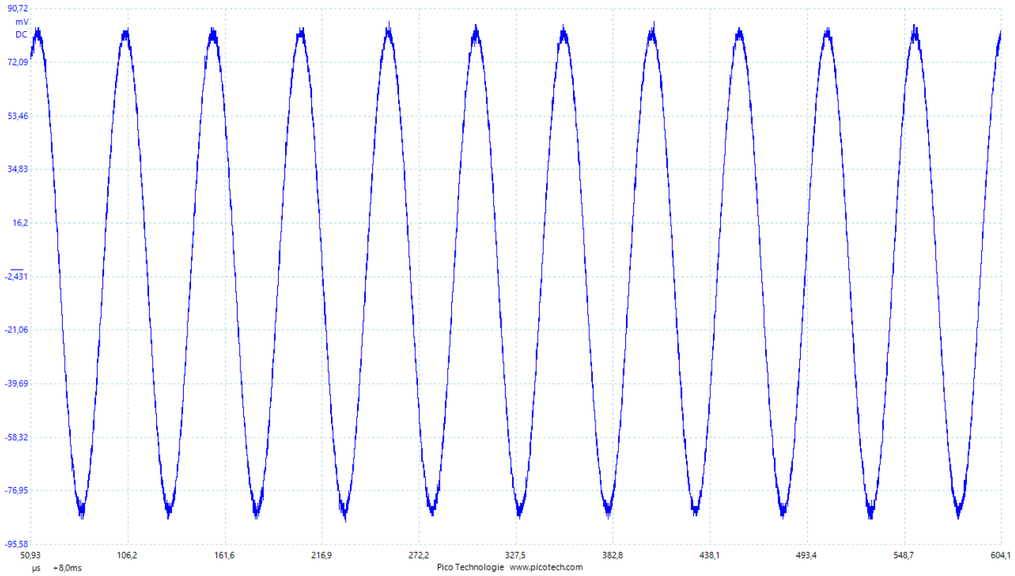




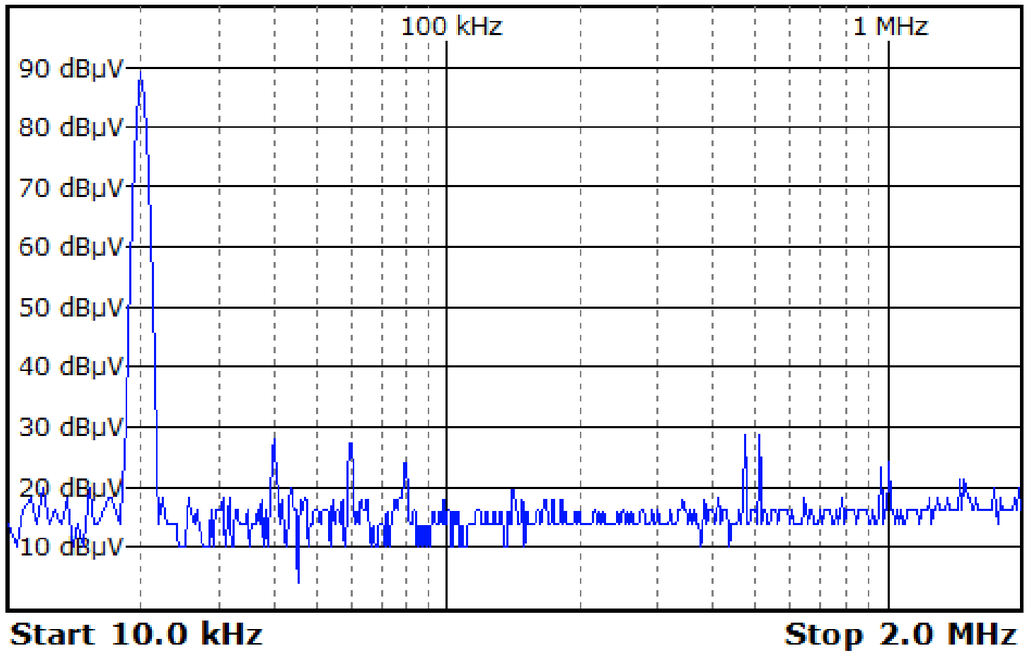
2. Narrowband versus real life







20 kHz



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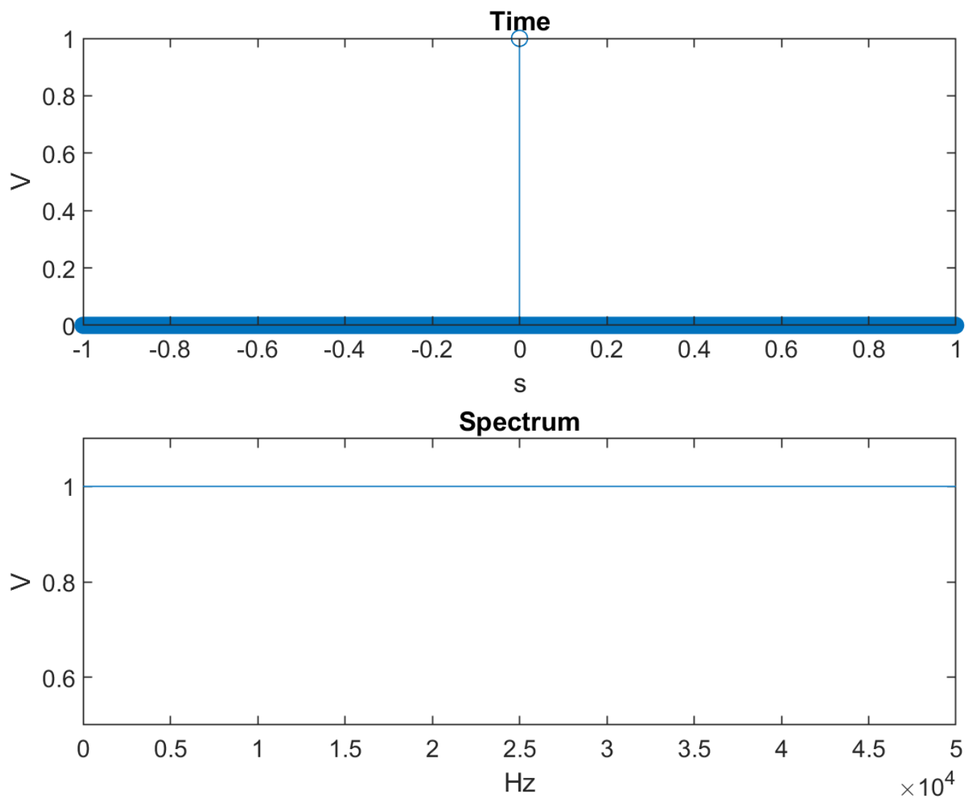
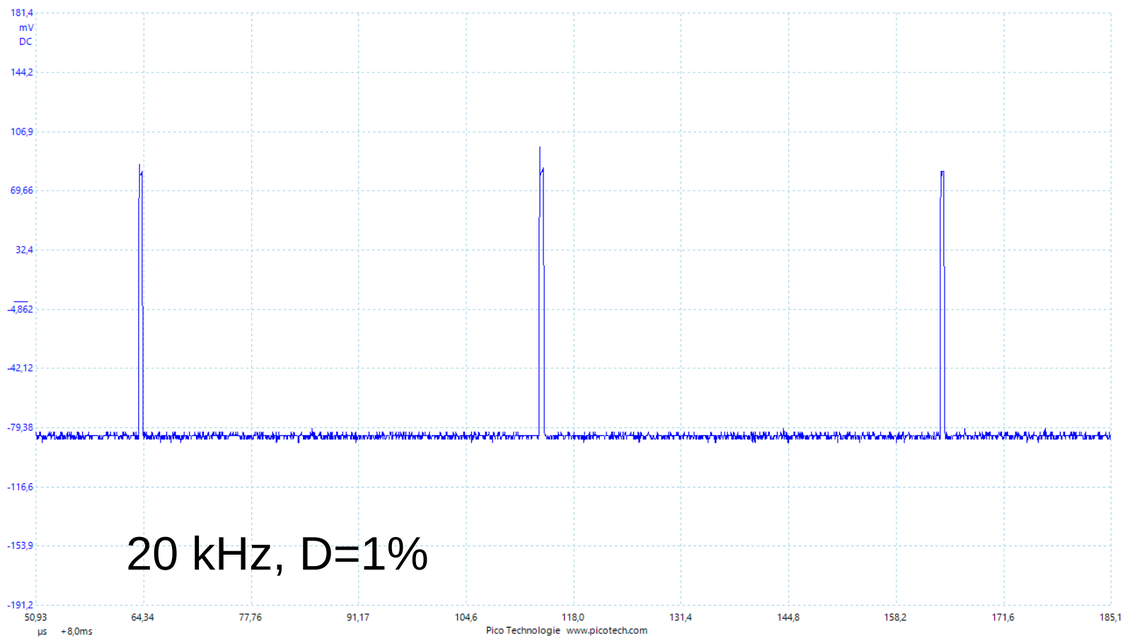
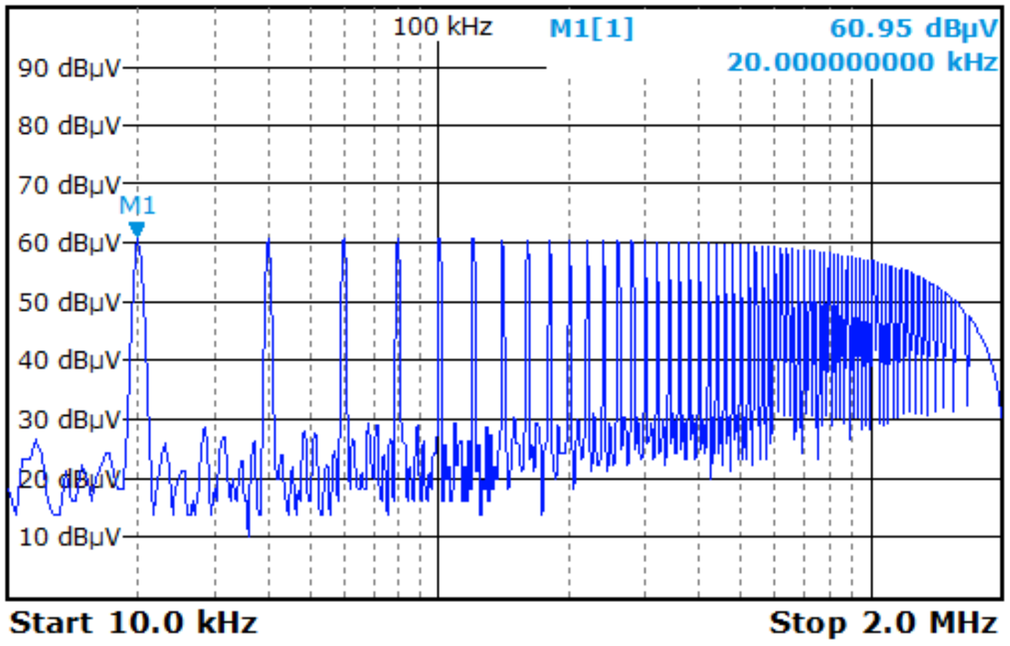
3. Wideband versus real life







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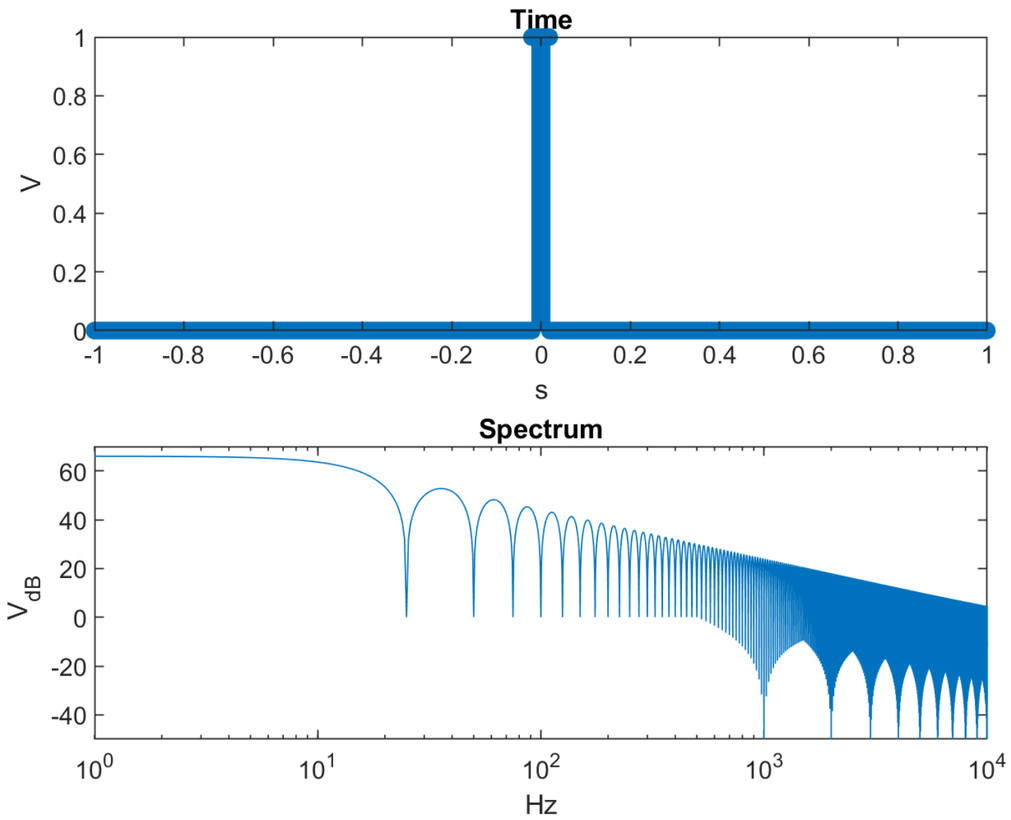
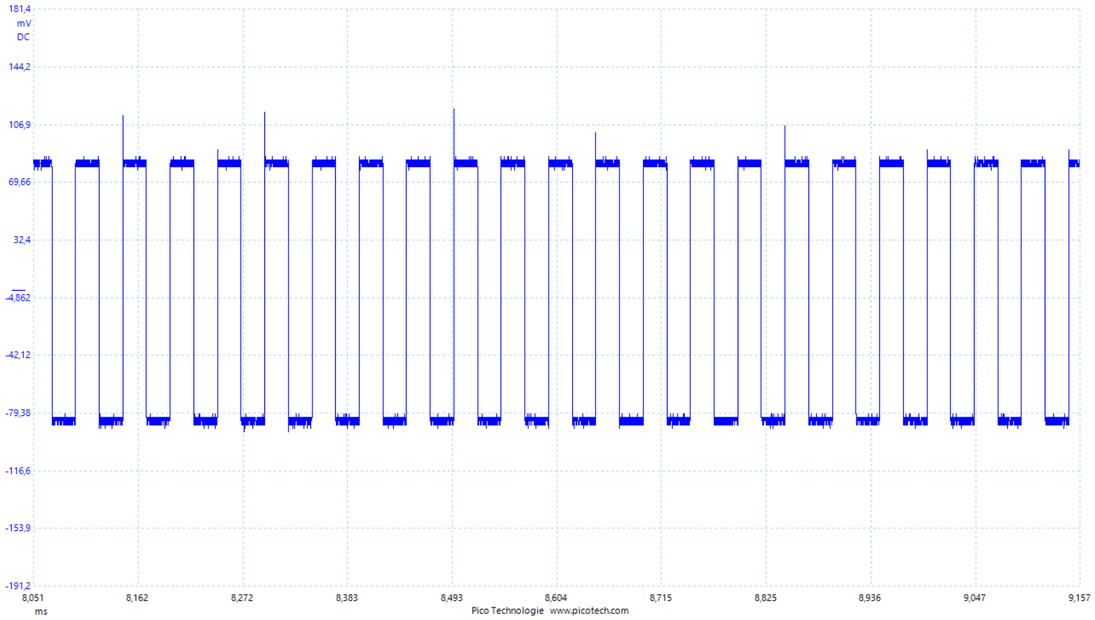
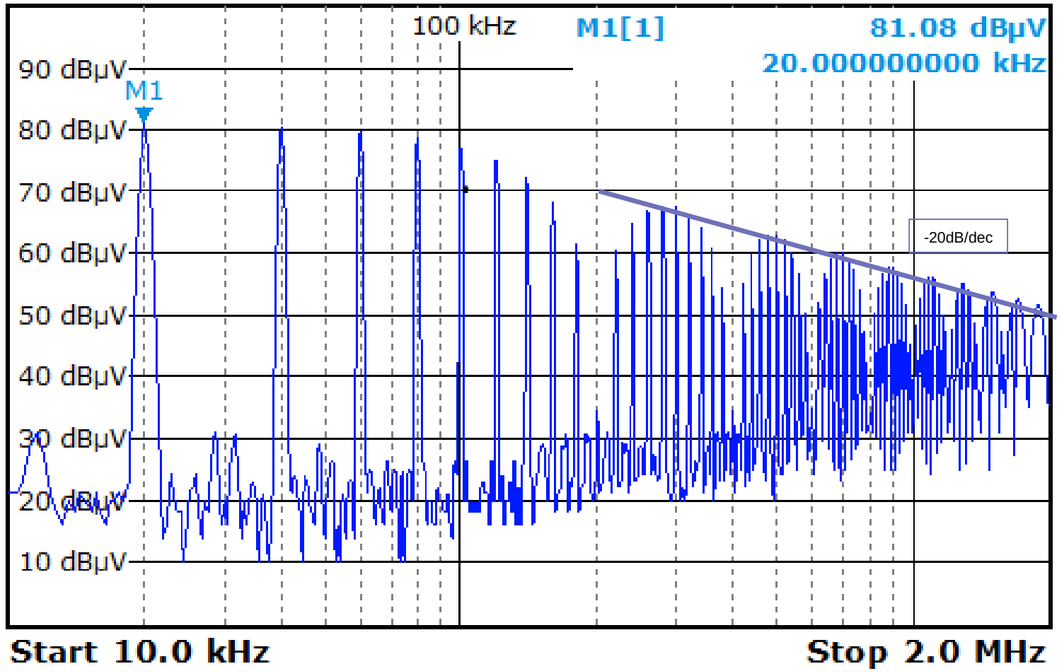
3. Wideband versus real life







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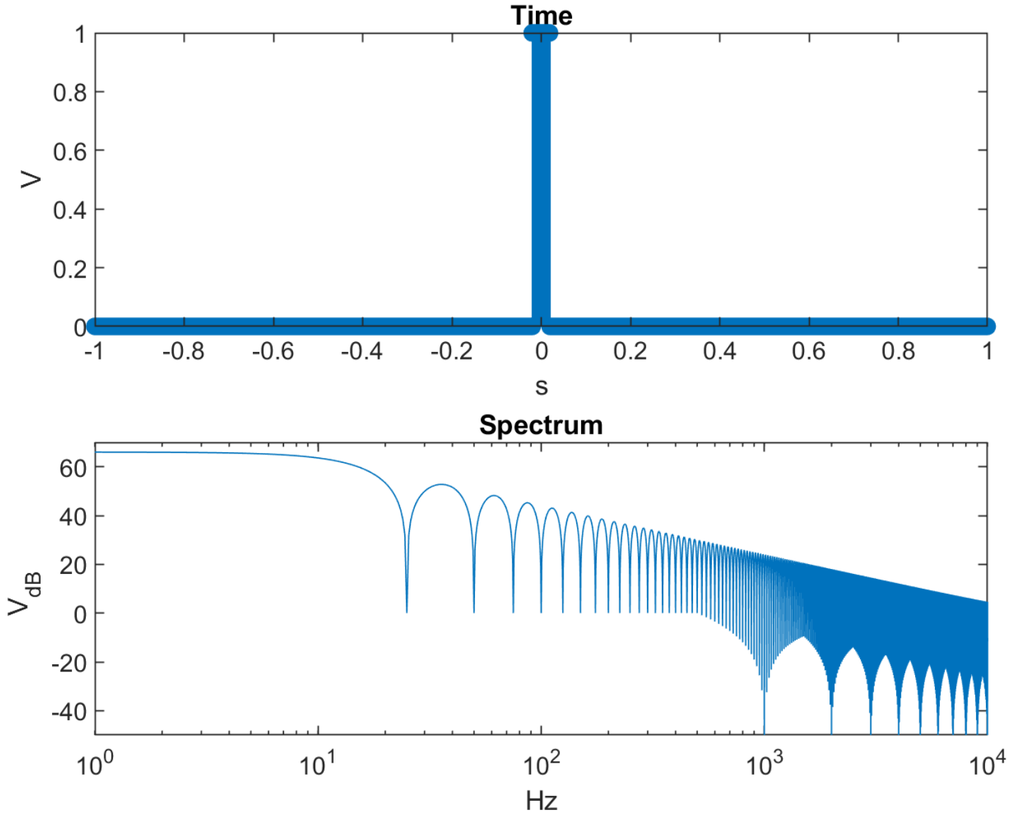
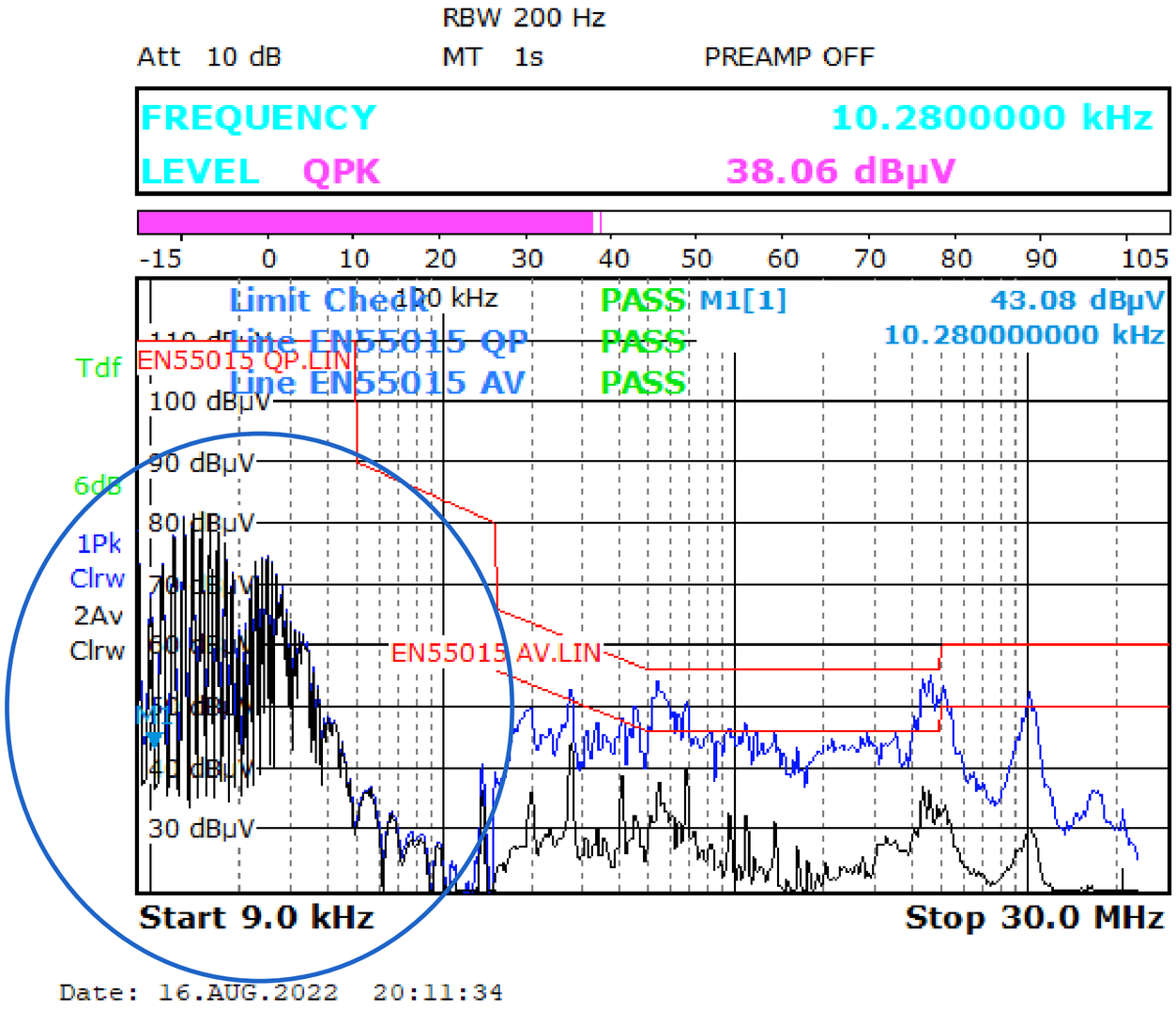
4. Real life





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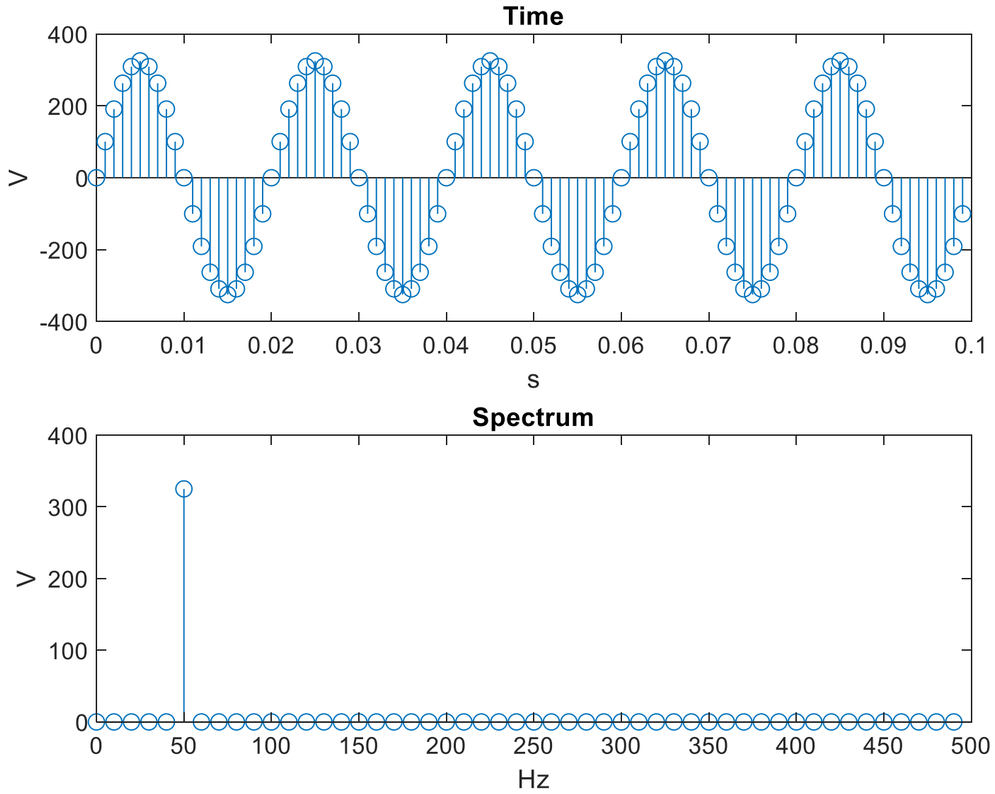
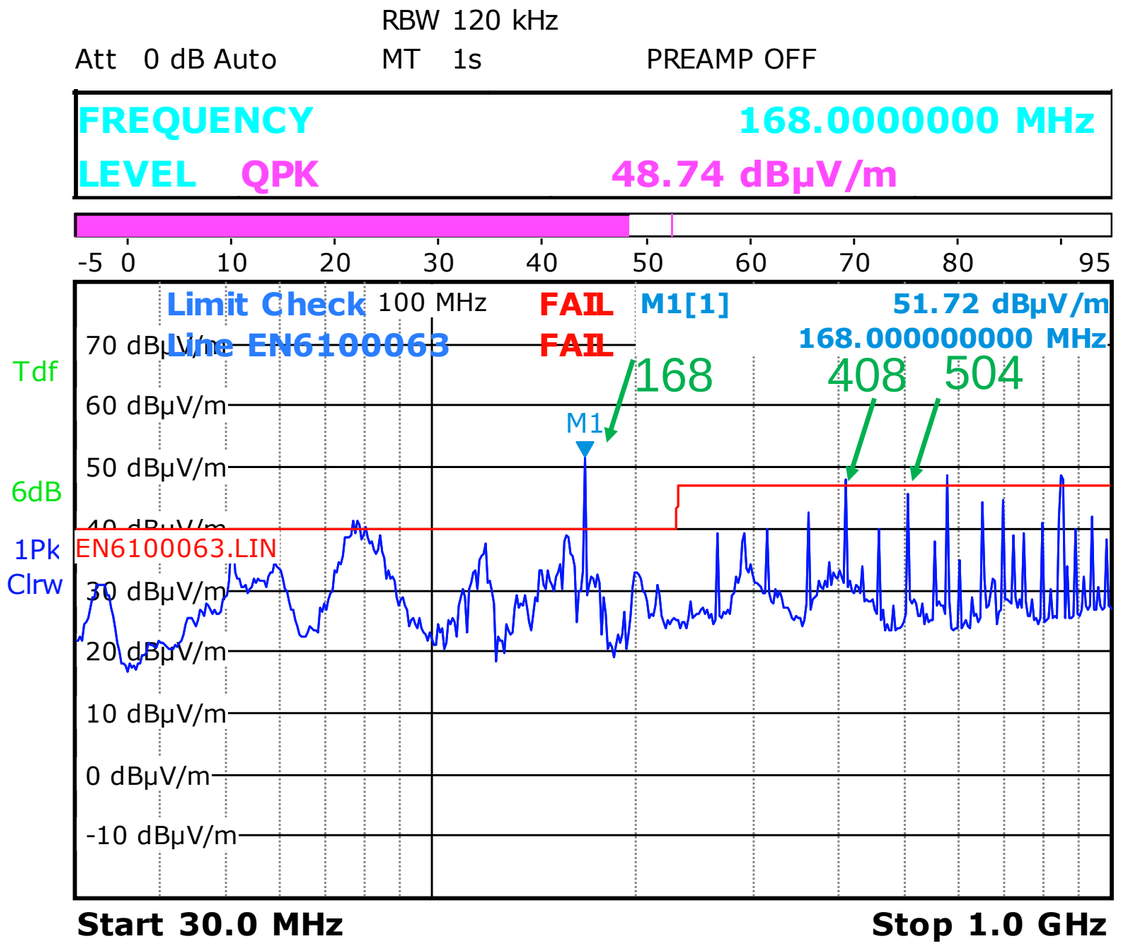
4. Real life





Date: 21.MAR.2022 09:32:32

24 48 72 96 120 144 168 192 216 240 264
288 312 336 360 384 408 432
456 480 504 528 552 576 600 624 648 672
696 720 744 768 792 816 840 864
888 912 936 960

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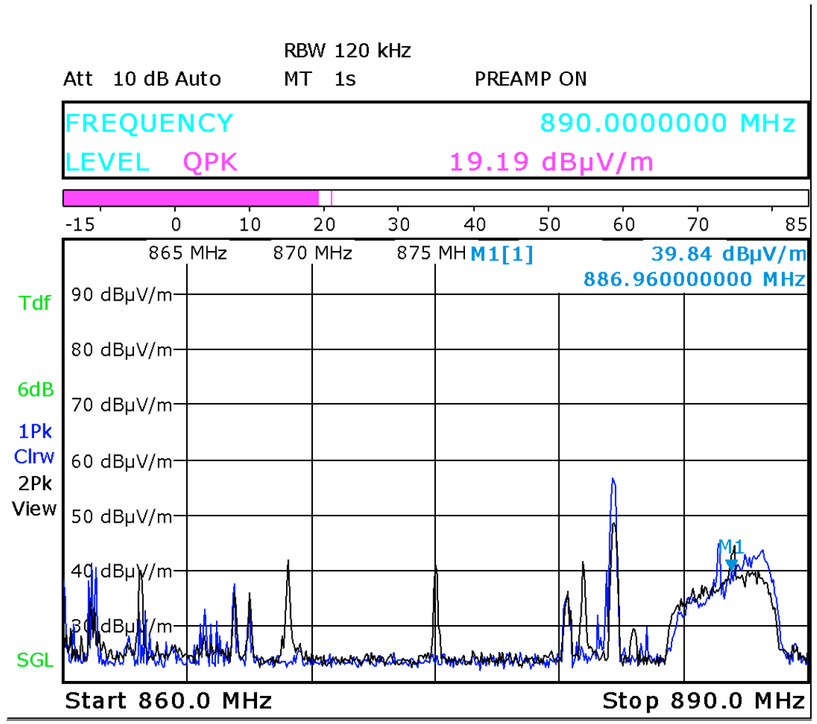
4. Real life

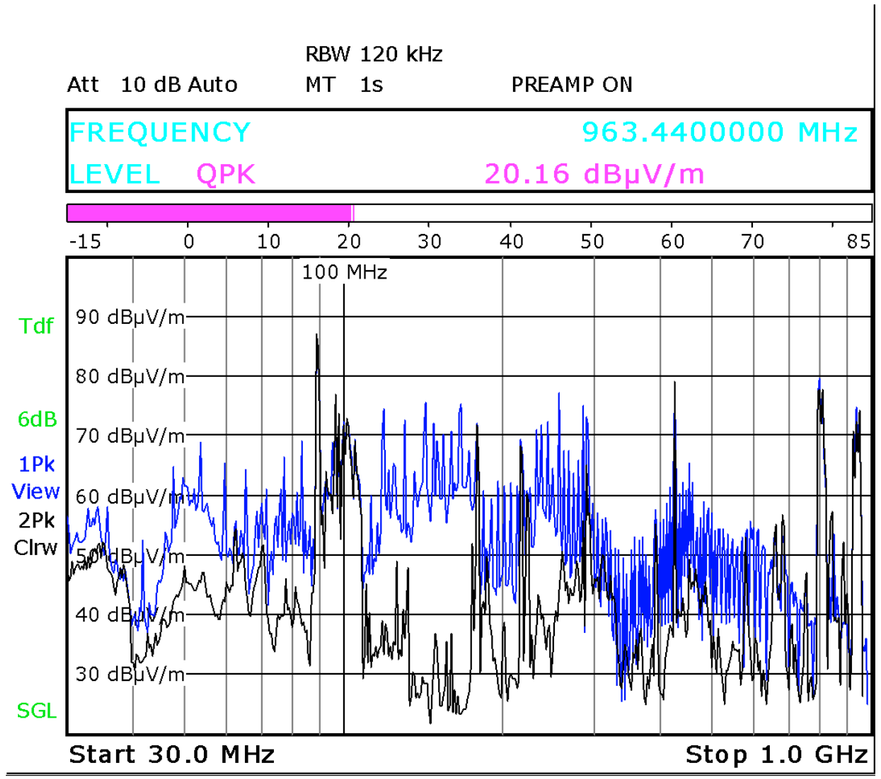
? Question: disturbance of uplink mobile phone at 887 MHz

What is the main source?



Black = disturbing source on

Blue = disturbing source off



Black = disturbing source off

Blue = disturbing source on

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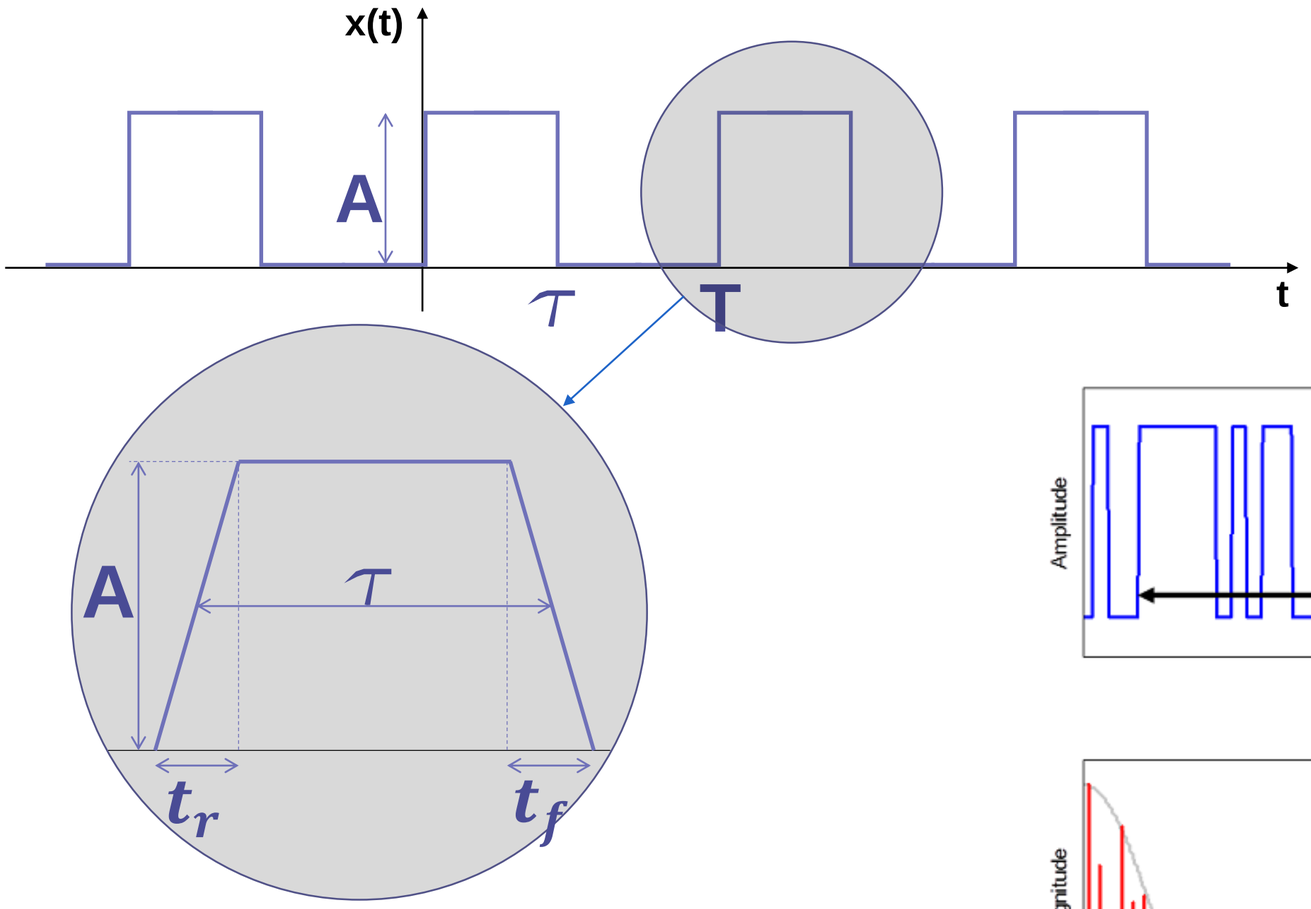
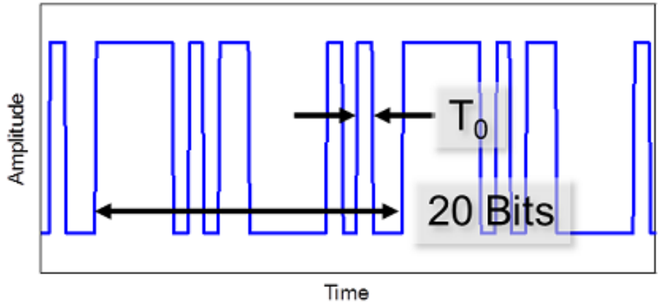
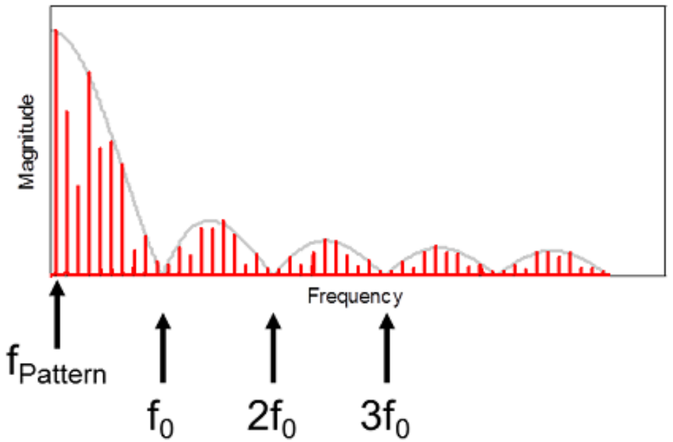
4. Real life

Rectangular signal with finit rise/fall time







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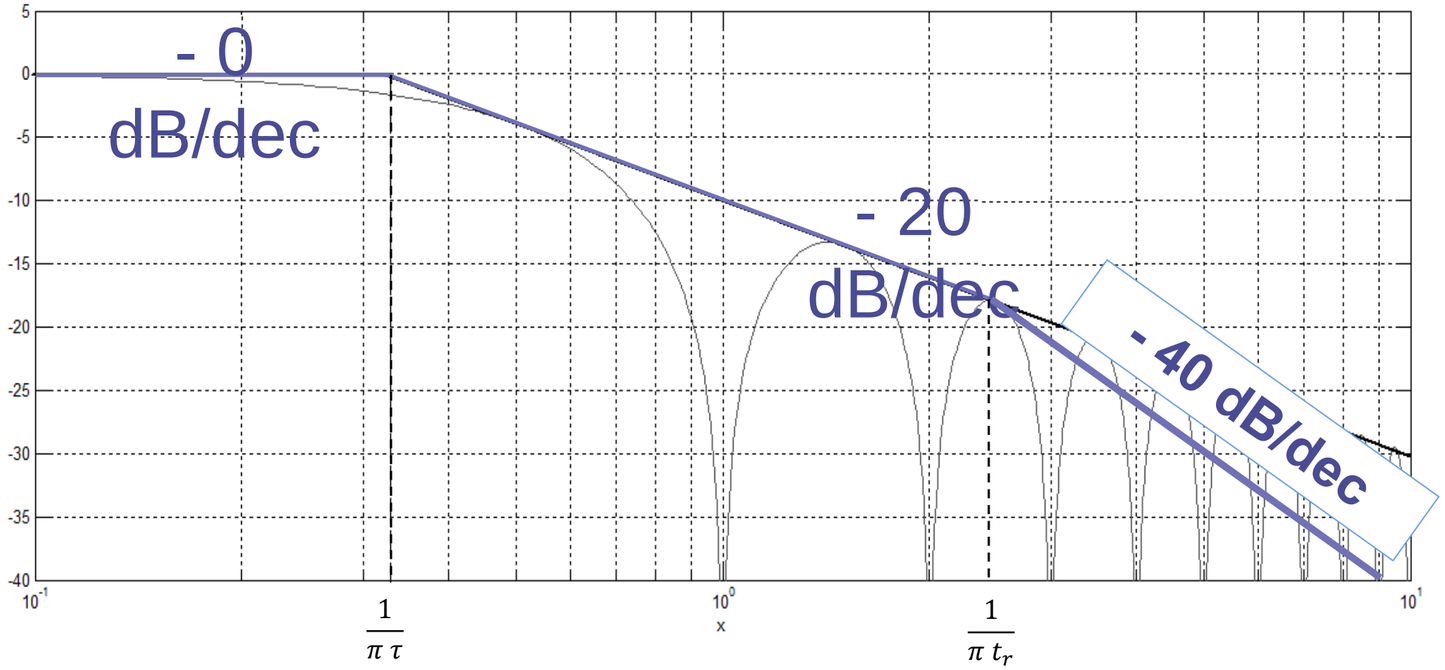
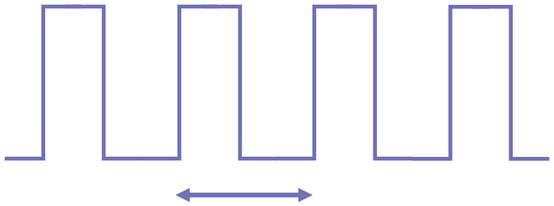
4. Real life

Spectral envelope data

(Consider $t_r = t_f$)



f=6 MHz, D= 50%



T= 167 ns

τ = D.T = 83 ns
3,8 MHz

tr = 0,5 ns
637 MHz

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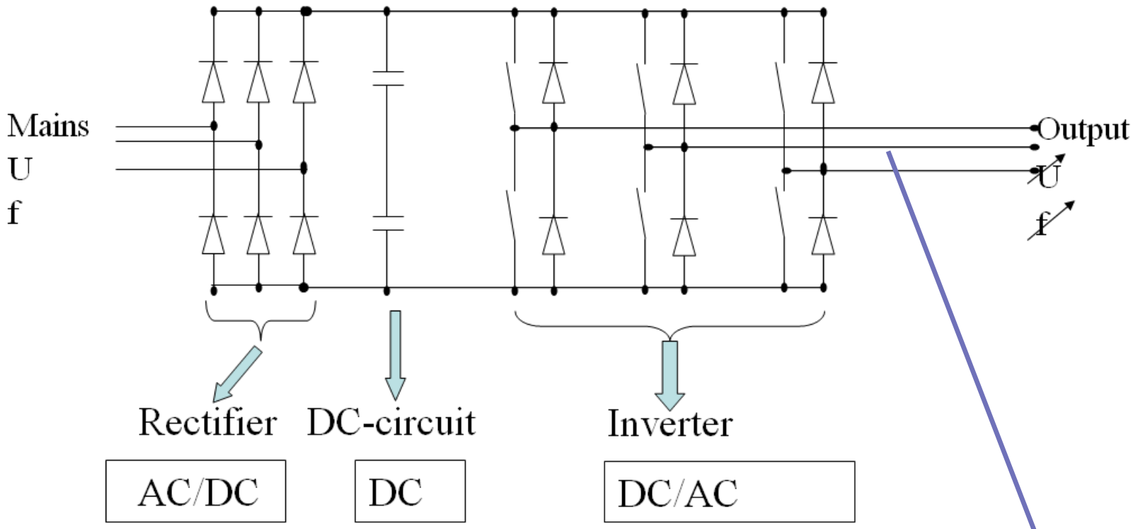
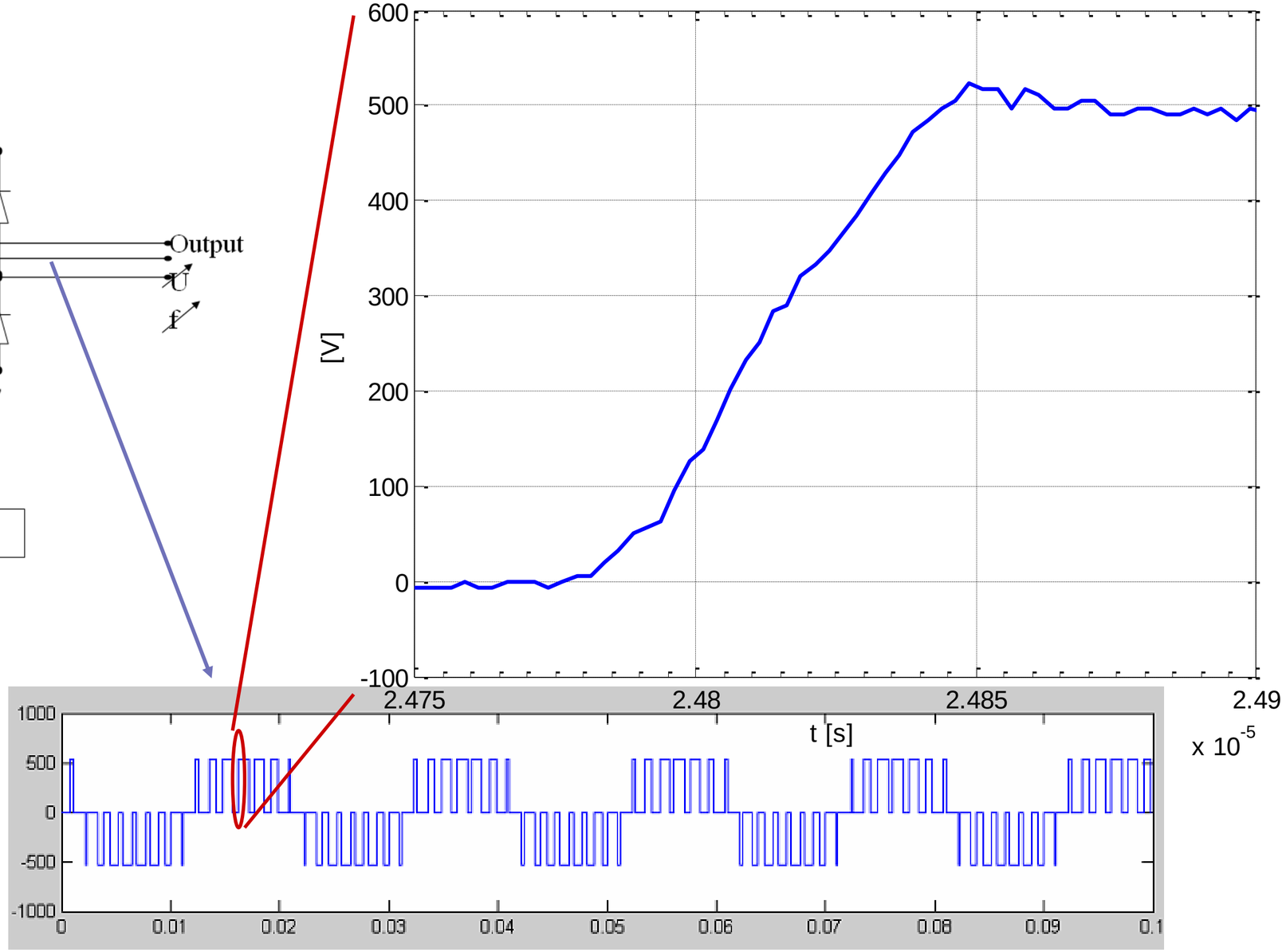
4. Real life

Basic drive:





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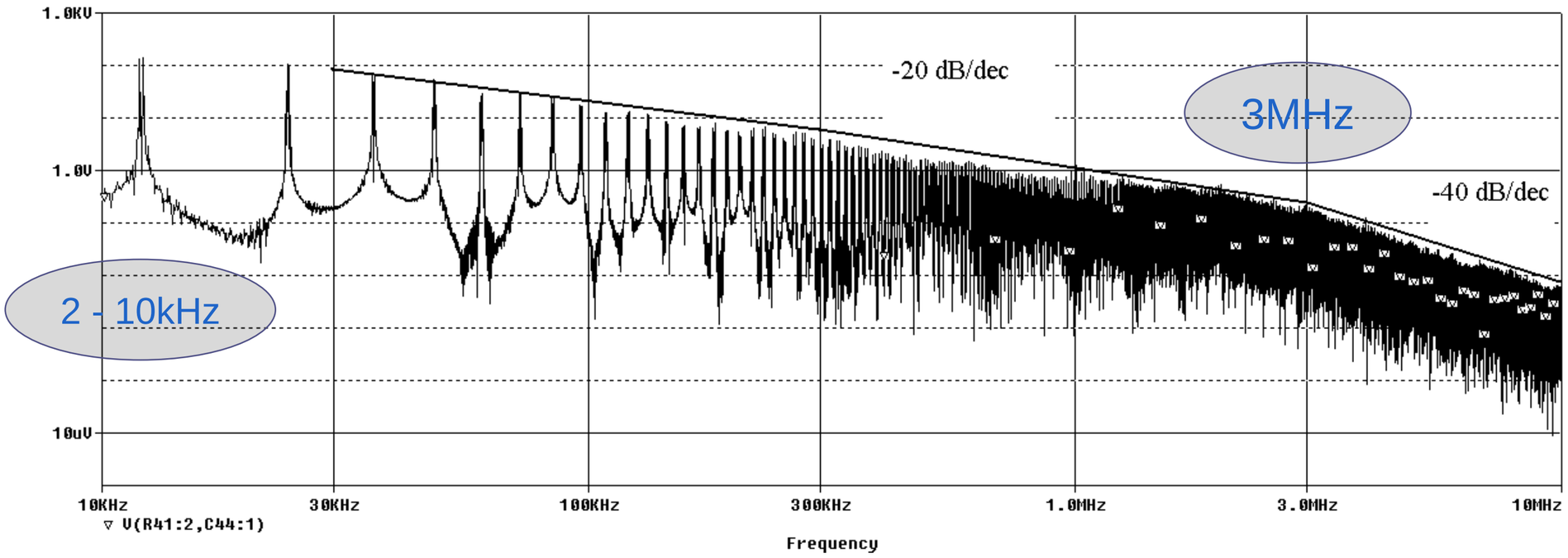
4. Real life

What does it mean for your industrial installation?



10 kHz, D=50% PWM

6,4 kHz

tr = 100 ns

3,2 MHz

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5. Generic cable standards

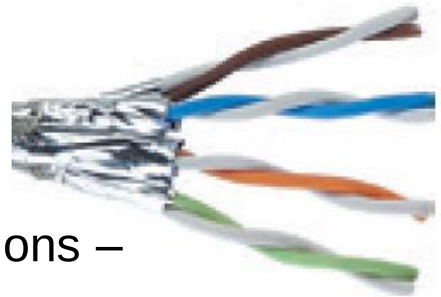
International standards: (selection)

– IEC 11801-x: IT – Generic cabling for customer premises
Links and channels

Table 6 – NEXT for channel

Class	Frequency MHz	Minimum NEXT dB
A	$f = 0{,}1$	27,0
B	$0{,}1 \le f \le 1$	$25 - 15\lg(f)$
C	$1 \le f \le 16$	$39{,}1 - 16{,}4\lg(f)$
D	$1 \le f \le 100$	$-20\lg\left(10^{\frac{65{,}3-15\lg(f)}{-20}} + 2\times 10^{\frac{83-20\lg(f)}{-20}}\right)$ [a]
E	$1 \le f \le 250$	$-20\log\left(10^{\frac{74{,}3-15\lg(f)}{-20}} + 2\times 10^{\frac{94-20\lg(f)}{-20}}\right)$ [b]
F	$1 \le f \le 600$	$-20\lg\left(10^{\frac{102{,}4-15\lg(f)}{-20}} + 2\times 10^{\frac{102{,}4-15\lg(f)}{-20}}\right)$ [b]

– IEC 61156-x: Multicore and symmetrical **pair/quad cables** for digital communications



– IEC 61156-11: Multicore and symmetrical pair/quad cables for digital communications – Part 11: Symmetrical **single pair** cables with transmission characteristics up to 600 MHz

– TIA 568: requirements for cables (including optical, coaxial, …)
Performance tests for cable categories 3 to 7

Category	Max. Bandwidth	Max. Data rate	Max. Distance
Cat 5e	100 MHz	1 Gbps	100 m
Cat 6	250 MHz	1 Gbps (10 Gbps)	100 m (55 m)
Cat 6A	500 MHz	10 Gbps	100 m
Cat 7	600 MHz	10 Gbps	100 m
Cat 7a	1000 MHz	10 Gbps (40 Gbps)	100 m (50 m)
Cat 8.1	2000 MHz	25 Gbps	30 m
Cat 8.2	2000 MHz	40 Gbps	30 m

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5. Generic cable standards

- TIA 568: requirements for cables (including optical, coaxial, …)
  - TIA-568-C.2: balanced twisted pair

    Performance tests:

Mechanical Requirements
- Channels, permanent links, cord, and connectors
- Pair assembly and color code
- Performance marking
- Reliability

Transmission Requirements
- Channels, permanent links, cord, and connectors
- Return loss, insertion loss, NEXT loss, PSNEXT loss, FEXT loss, ACRF, PSACRF, TCL, TCTL, ELTCTL, coupling attenuation, propagation delay, propagation delay skew, PSANEXT loss, average PSANEXT loss, PSAACRF, and average PSAACRF
- DC loop resistance and DC resistance unbalance

- TIA 568: requirements for cables (including optical, coaxial, …)
  - TIA-568-C.0: balanced twisted pair
    - Annex: Environmental conditions

Mechanical	M_1	M_2	M_3
Ingress	I_1	I_2	I_3
Climatic	C_1	C_2	C_3
Electromagnetic	E_1	E_2	E_3
	Commercial	Light industrial	Industrial

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5. Generic cable standards

Electromagnetic	E_1	E_2	E_3
Electrostatic discharge – Contact (0,667 µC)	4 kV	4 kV	4 kV
Electrostatic discharge – Air (0,132 µC)	8 kV	8 kV	8 kV
Radiated RF - AM	3 V/m at (80 to 1 000 MHz) 3 V/m at (1 400 to 2 000 MHz) 1 V/m at (2 000 to 2 700 MHz)	3 V/m at (80 to 1 000 MHz) 3 V/m at (1 400 to 2 000 MHz) 1 V/m at (2 000 to 2 700 MHz)	10 V/m at (80 to 1 000 MHz) 3 V/m at (1 400 to 2 000 MHz) 1 V/m at (2 000 to 2 700 MHz)
Conducted RF	3 V at 150kHz to 80MHz	3 V at 150kHz to 80MHz	10 V at 150kHz to 80MHz
EFT/B (comms)	500 V	1 kV	1 kV
Surge (transient ground potential difference) - signal, line to earth	500 V	1 kV	1 kV
Magnetic Field (50/60 Hz)	1 Am^{-1}	3 Am^{-1}	30 Am^{-1}
Magnetic Field (60 Hz to 20 000 Hz)	ffs	ffs	ffs

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5. Generic cable standards

- EN50173: IT– Generic cabling systems

  European standard based on IEC11801 and TIA568 with additional requirements

– EN 50288-1: Multi-element metallic cables used in analogue and digital communications and control

  European standard comparable to IEC61156

LF testing

EN 50288 series sub-clause n°	Parameter	Test method standard
5.1.1.1	Conductor loop resistance	EN 50289-1-2
5.1.1.2	Conductor resistance unbalance	EN 50289-1-2
5.1.1.3	Dielectric strength	EN 50289-1-3
5.1.1.4	Insulation resistance	EN 50289-1-4
5.1.1.5	Mutual capacitance	EN 50289-1-5
5.1.1.6	Capacitance unbalance	EN 50289-1-5
5.1.1.7	Inductance	EN 50289-1-12
5.1.1.8	Inductance to resistance ratio	EN 50289-1-12

EN 50289-x

HF testing

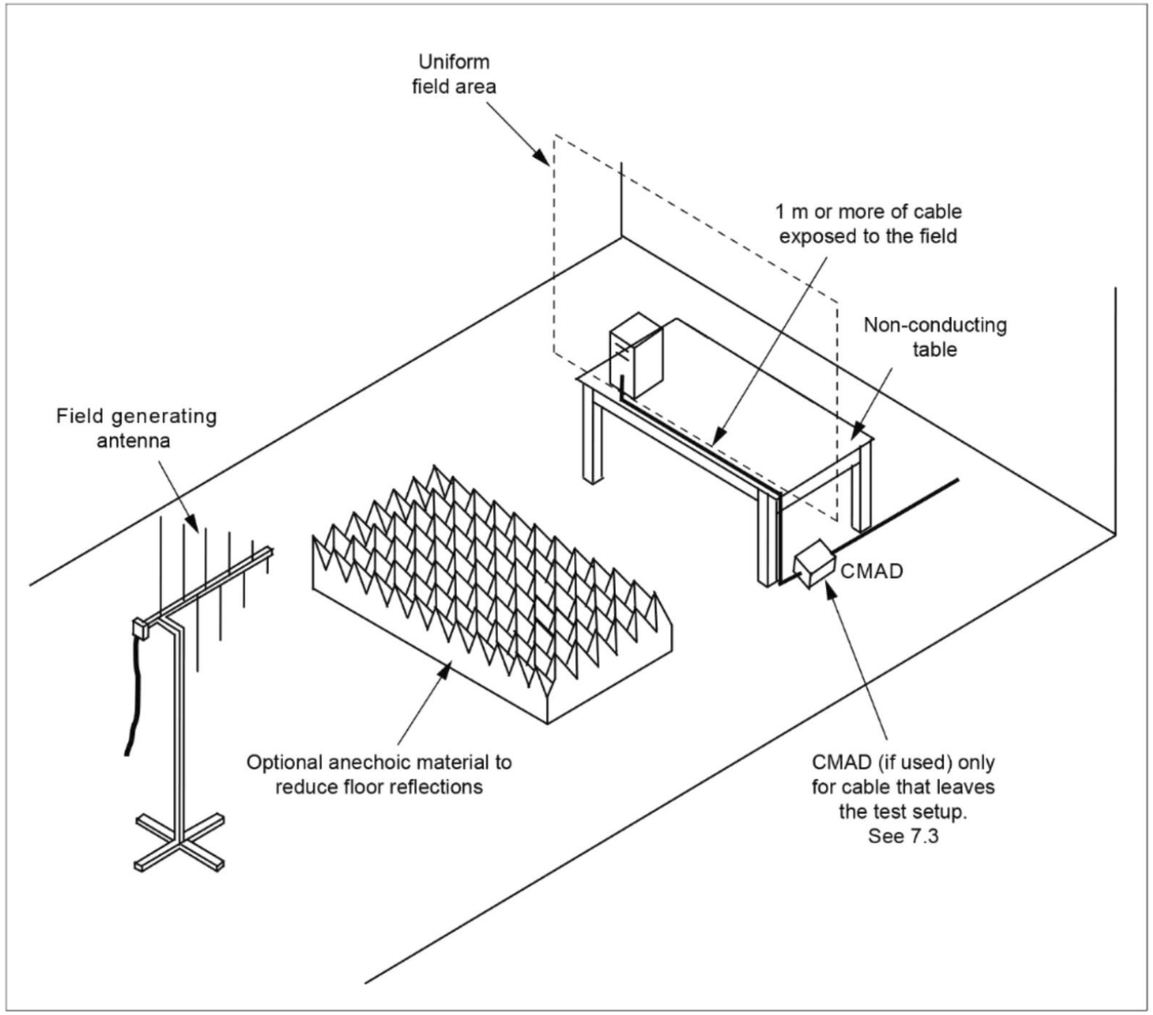
EN 50288 series sub-clause n°	Parameter	Test method standard
5.1.2.1	Velocity of propagation	EN 50289-1-7
5.1.2.2	Propagation delay difference (skew)	EN 50289-1-7
5.1.2.3	Longitudinal attenuation	EN 50289-1-8
5.1.2.4	Longitudinal conversion loss (LCL)	EN 50289-1-9
5.1.2.5	Near-end crosstalk (NEXT)	EN 50289-1-10
5.1.2.6	Equal Level Far-end crosstalk (ACR-F)[1]	EN 50289-1-10
5.1.2.7	Power sum (PS) of crosstalk loss	EN 50289-1-10
5.1.2.8	Characteristic impedance	EN 50289-1-11
5.1.2.9	Return loss	EN 50289-1-11
5.1.2.10	Coupling attenuation	EN 50289-1-6
5.1.2.11	Transfer impedance	EN 50289-1-6
5.1.2.12	Screening attenuation	EN 50289-1-6
5.1.2.13	Exogenous crosstalk	prEN 50289-1-17

[1] Equal Level Far-end crosstalk (ELFEXT) is now re-classified as ACR-F see Annex A for explanation.

6. EMC testing

– EN61000-4-3

Radiated RF - AM	3 V/m at (80 to 1 000 MHz) 3 V/m at (1 400 to 2 000 MHz) 1 V/m at (2 000 to 2 700 MHz)	3 V/m at (80 to 1 000 MHz) 3 V/m at (1 400 to 2 000 MHz) 1 V/m at (2 000 to 2 700 MHz)	10 V/m at (80 to 1 000 MHz) 3 V/m at (1 400 to 2 000 MHz) 1 V/m at (2 000 to 2 700 MHz)



– Longer cables:
  – Put low inductively
  – Put far from other metallic parts and conductors (shielding)
  – 1 m illuminated ($\lambda/4$ 80 MHz)

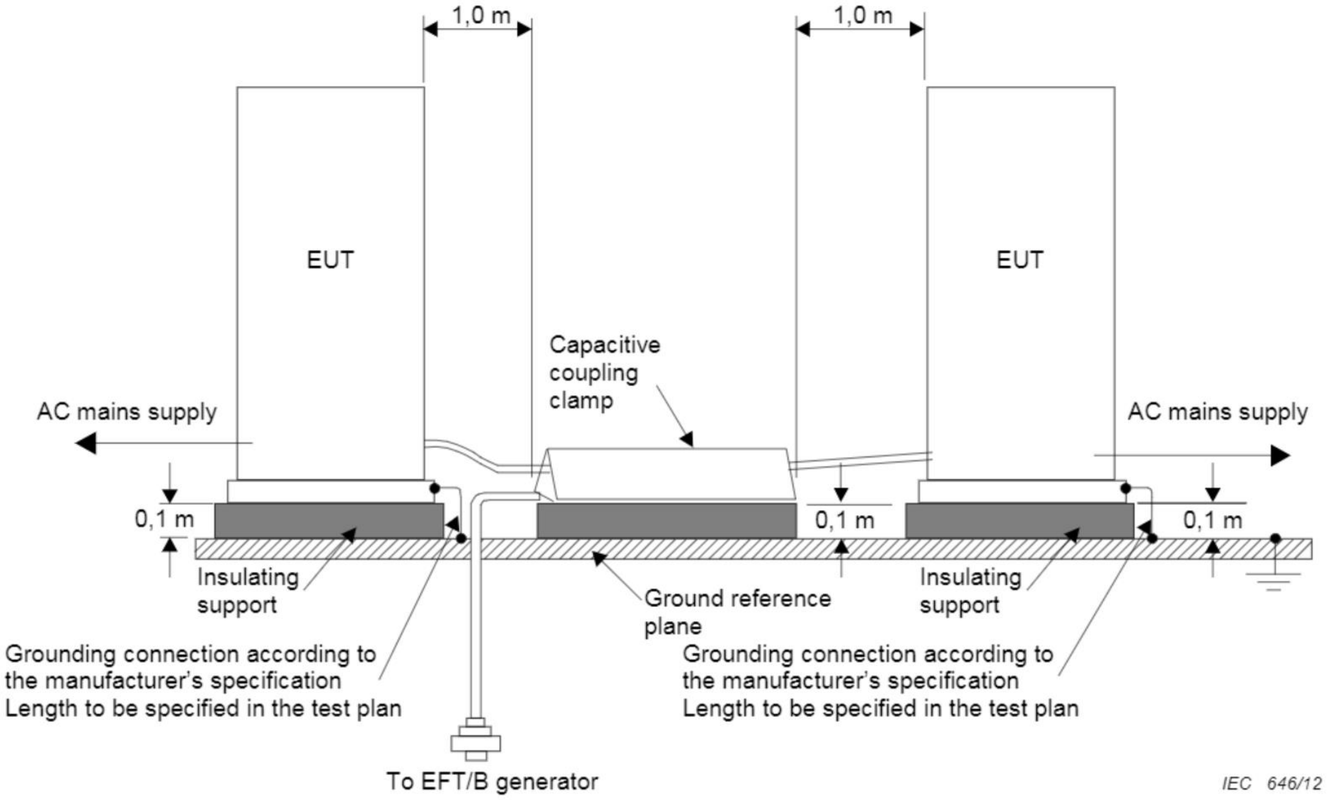
– Continuous wave, narrow band

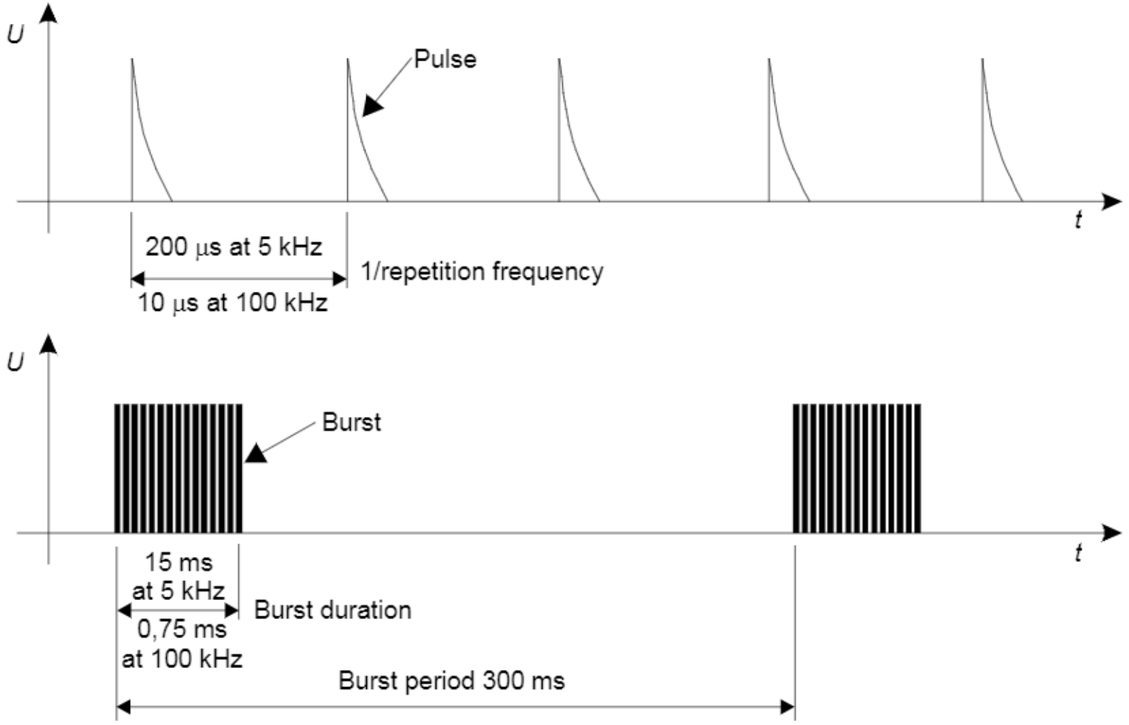
6. EMC testing

– EN61000-4-4

EFT/B (comms)	500 V	1 kV	1 kV

– Impuls, wide band





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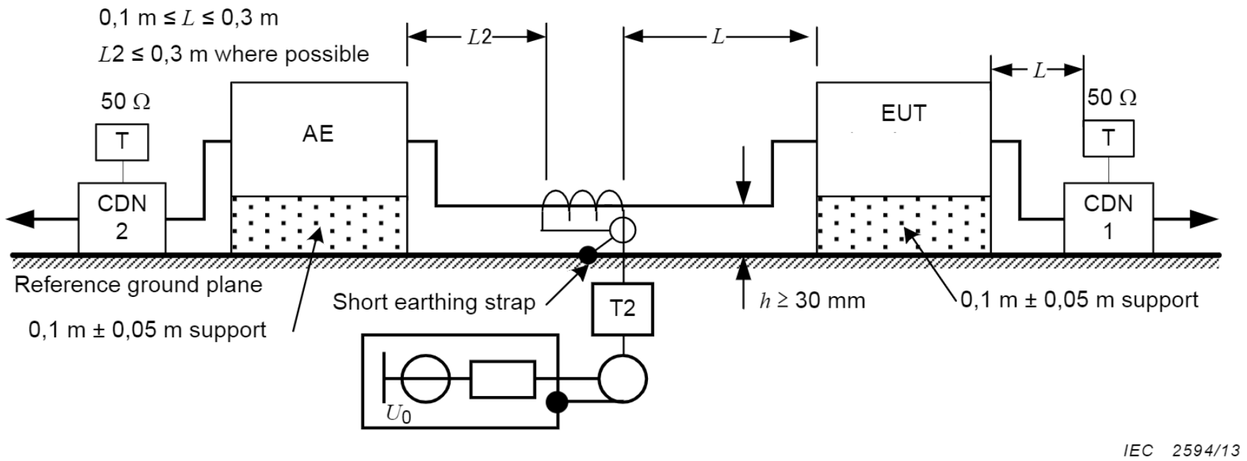
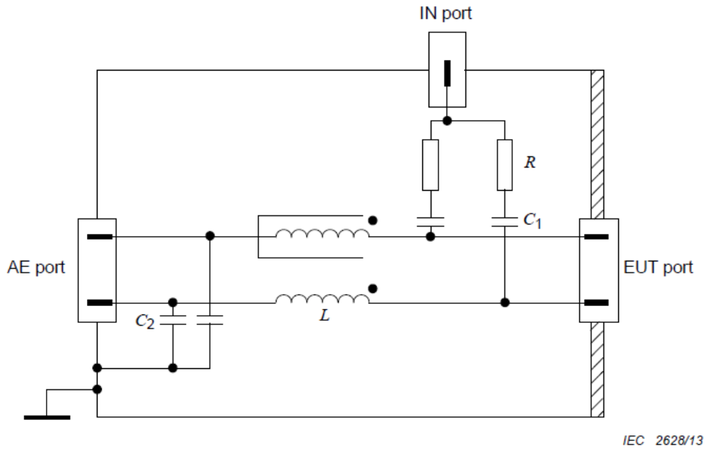
6. EMC testing

– EN61000-4-6

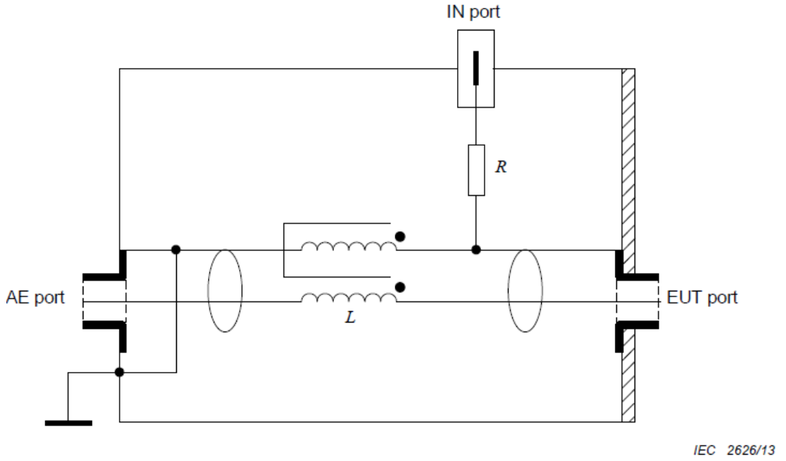
Conducted RF	3 V at 150kHz to 80MHz	3 V at 150kHz to 80MHz	10 V at 150kHz to 80MHz

– Continuous wave, narrow band





CDN for unscreened balanced cable (T2 – T8)



CDN for screened balanced cable (S1 – S8)

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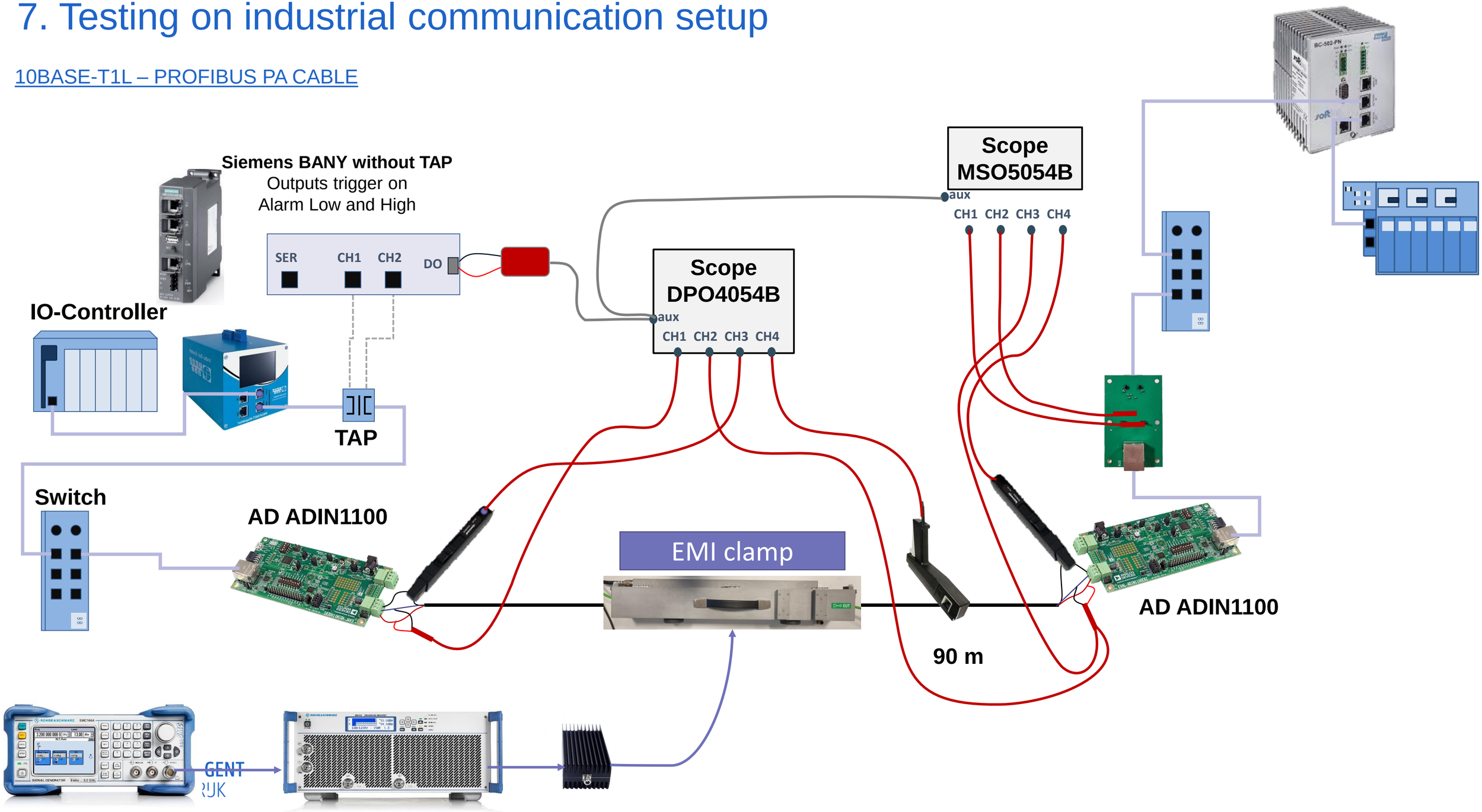
7. Testing on industrial communication setup

10BASE-T1L – PROFIBUS PA CABLE



7. Testing on industrial communication setup

- Large influence of setup:
  - cable length
  - bonding
  - non constant coupling characteristic of clamp (location, coupling, small air gap)
  - modulation (AM, FM)
  - high power needed at some frequencies (linearity?)
- Influence of monitoring components
- Communication failure or system failure: corrupt messages or interference on the boards?

Conclusions:

- reproducibility of failure: difficult for PN (synchronisation?), ok for SPE
- lot of open questions

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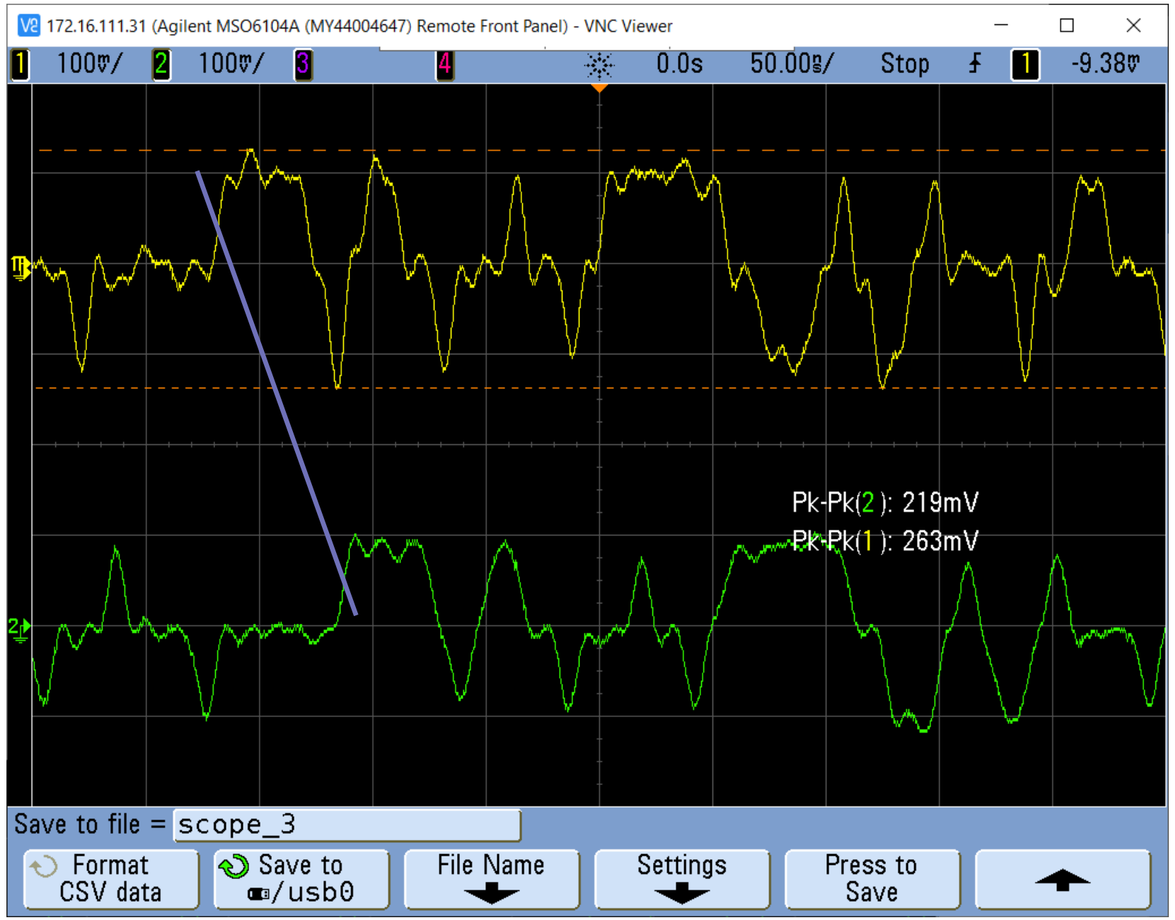
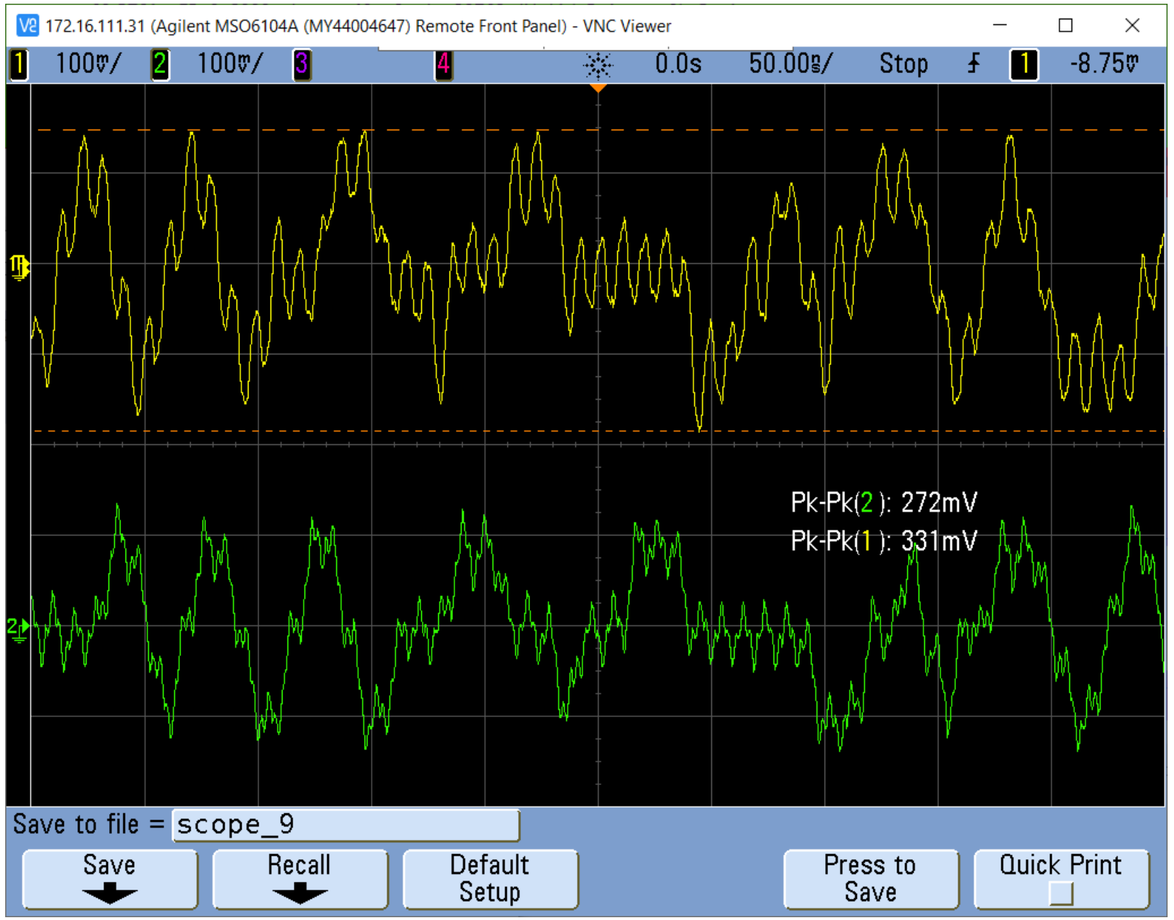
8. Some results

View in time domain





- PROFINET without narrowband interference
- Communication ok

- PROFINET with narrowband interference
- Communication ok

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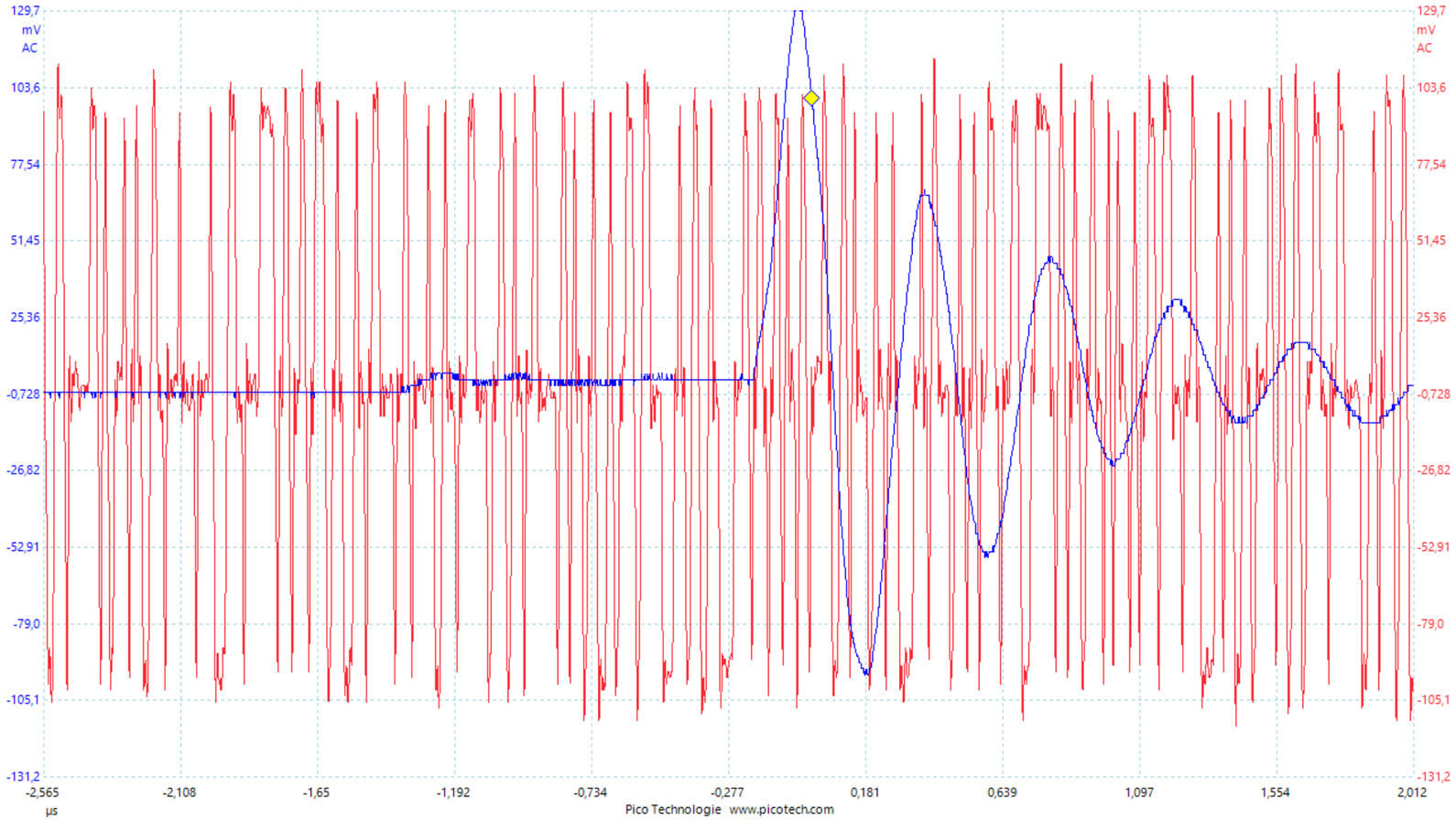
8. Some results

View in time domain

PROFINET



- PROFINET with real interference (frequency inverter ringing due to long motor cable)
- Communication still on

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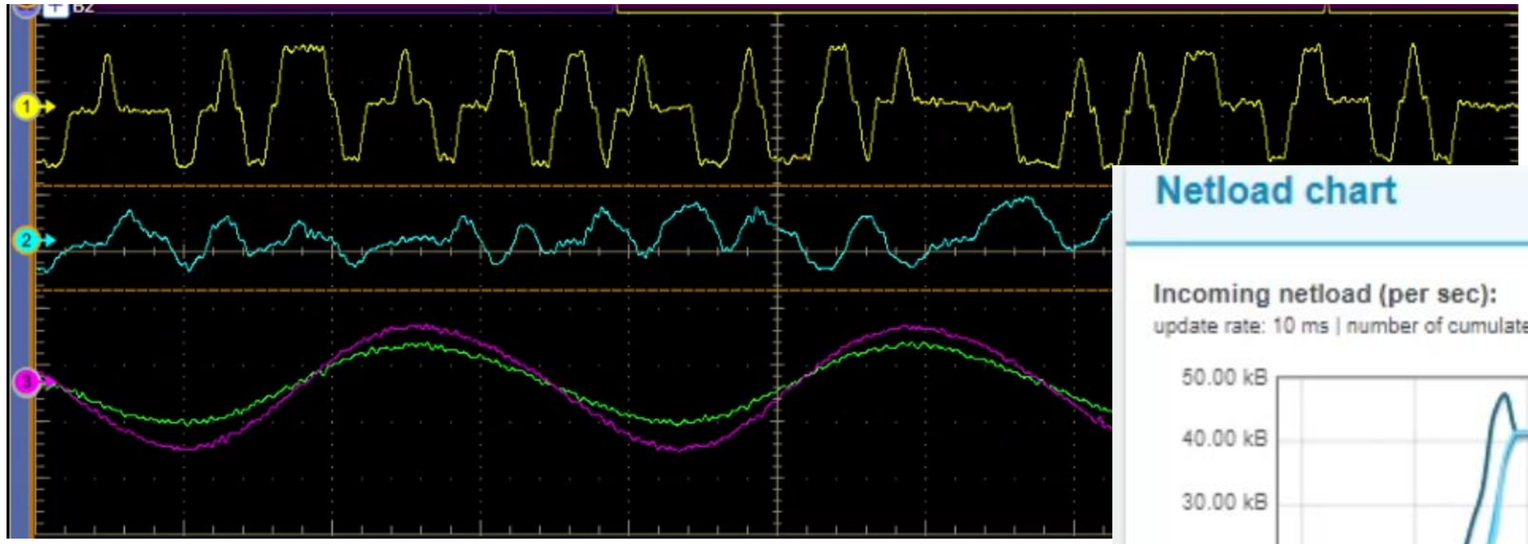
8. Some results

Monitoring

PROFINET



- PROFINET cable 71m
- Interference 3 MHz
- Communication ok
- No bus error

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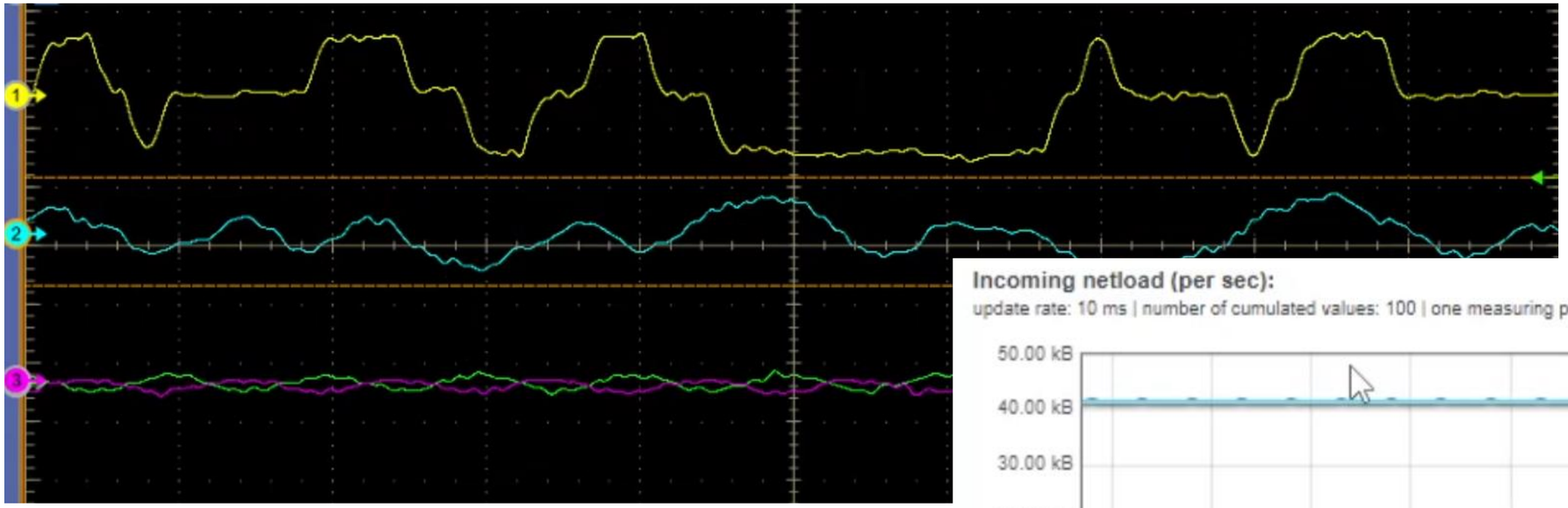
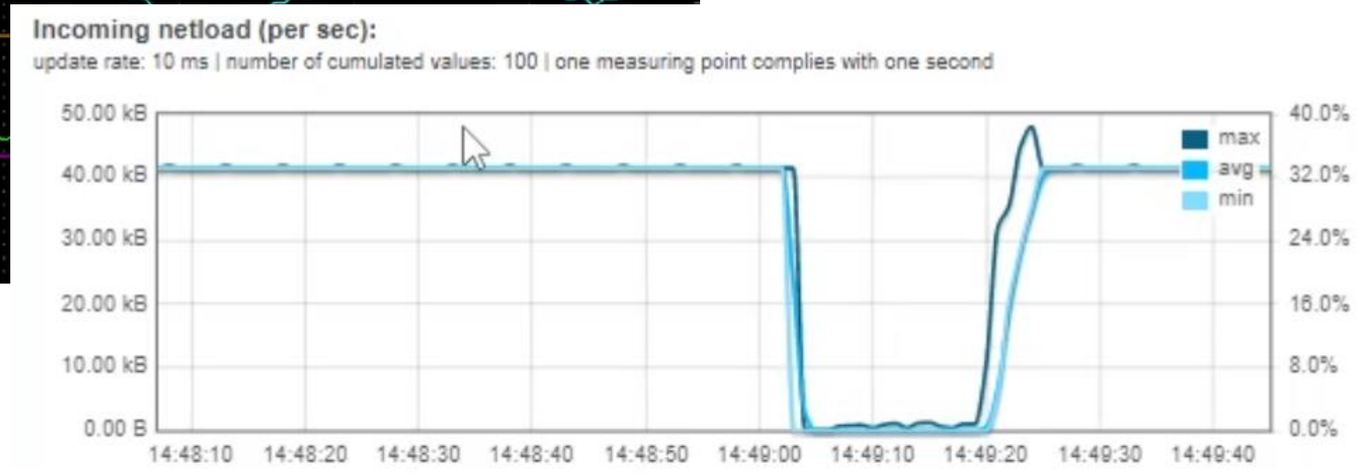
8. Some results

Monitoring





- PROFINET cable 71m
- Interference 25 MHz
- Communication not ok: bus error

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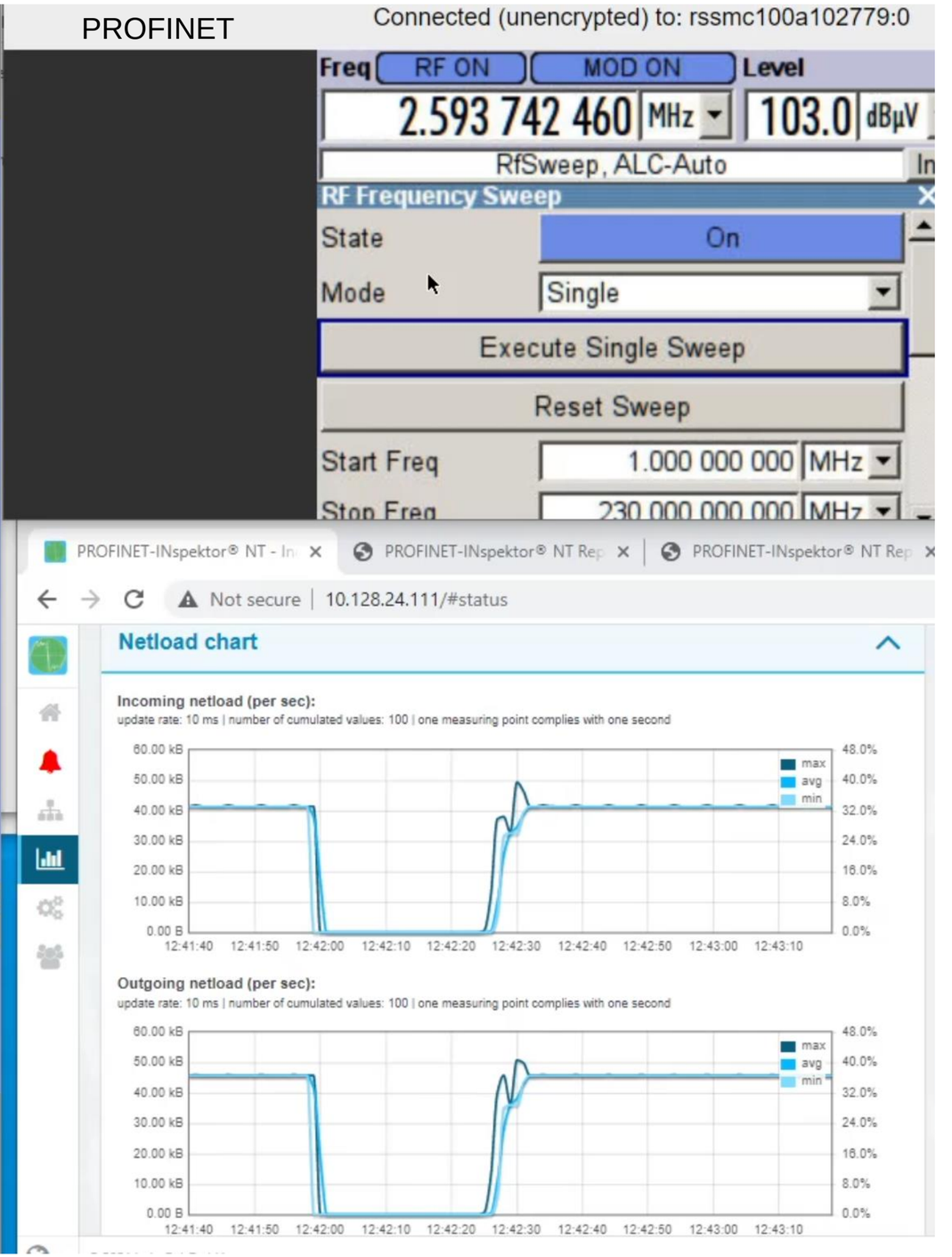
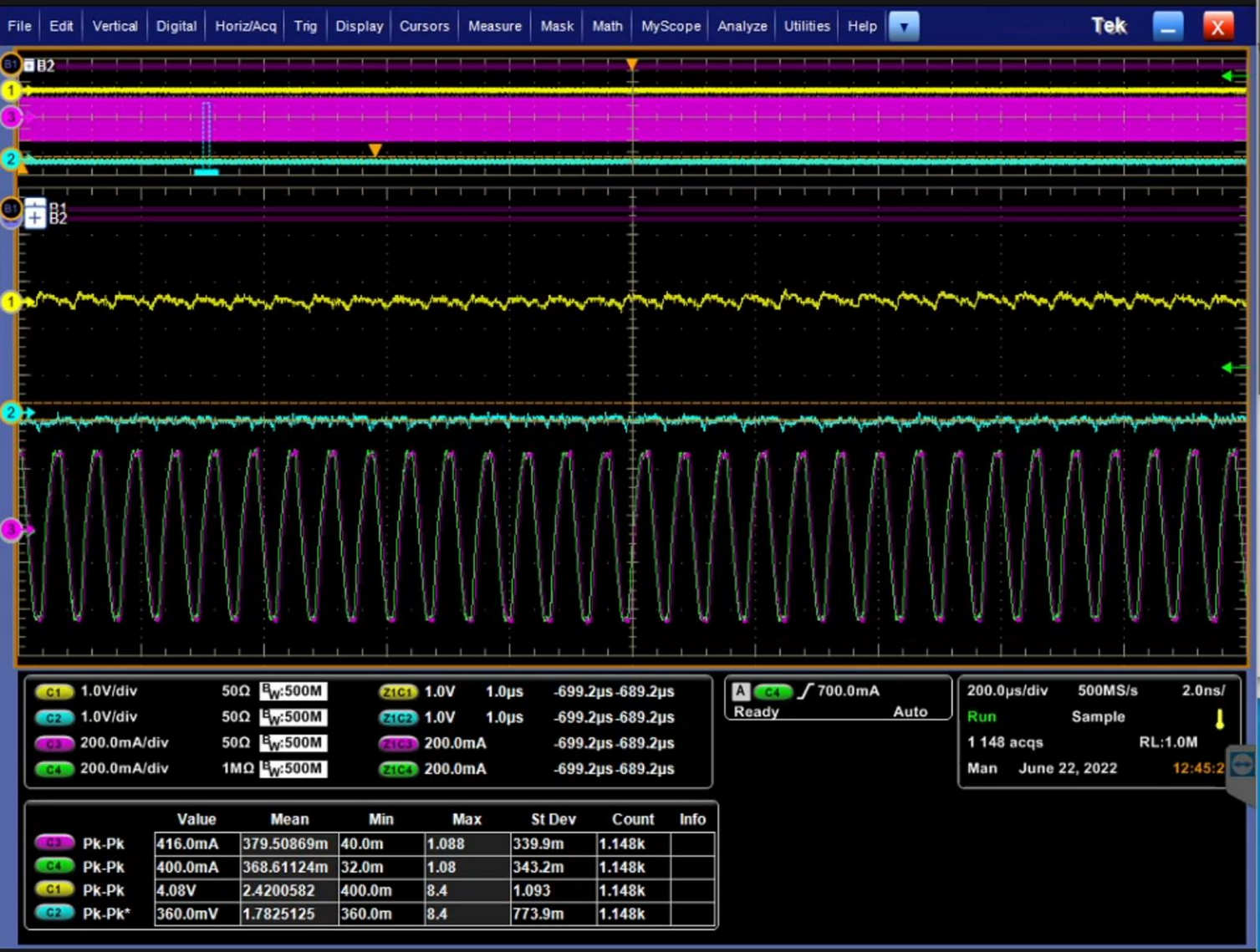
Communication ok

PROFINET



Communication failure or system failure



PROFINET

Connected (unencrypted) to: rssmc100a102779:0

Freq RF ON MOD ON Level

3.452 271 214 MHz 103.0 dBµV

RfSweep, ALC-Auto

RF Frequency Sweep

State On

Mode Single

Execute Single Sweep

Reset Sweep

Start Freq 1.000 000 000 MHz

Stop Freq 230.000.000.000 MHz

PROFINET-INspektor® NT - In PROFINET-INspektor® NT Rep PROFINET-INspektor® NT Rep

Not secure | 10.128.24.111/#status

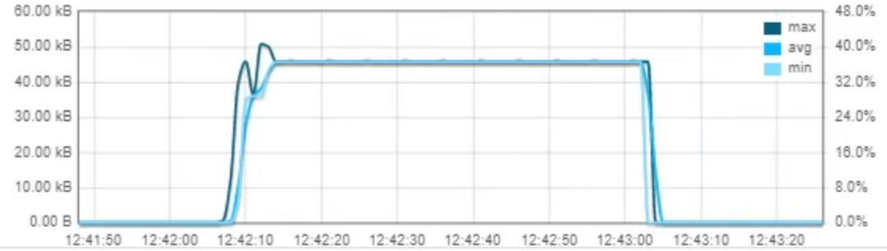
Netload chart

Incoming netload (per sec):

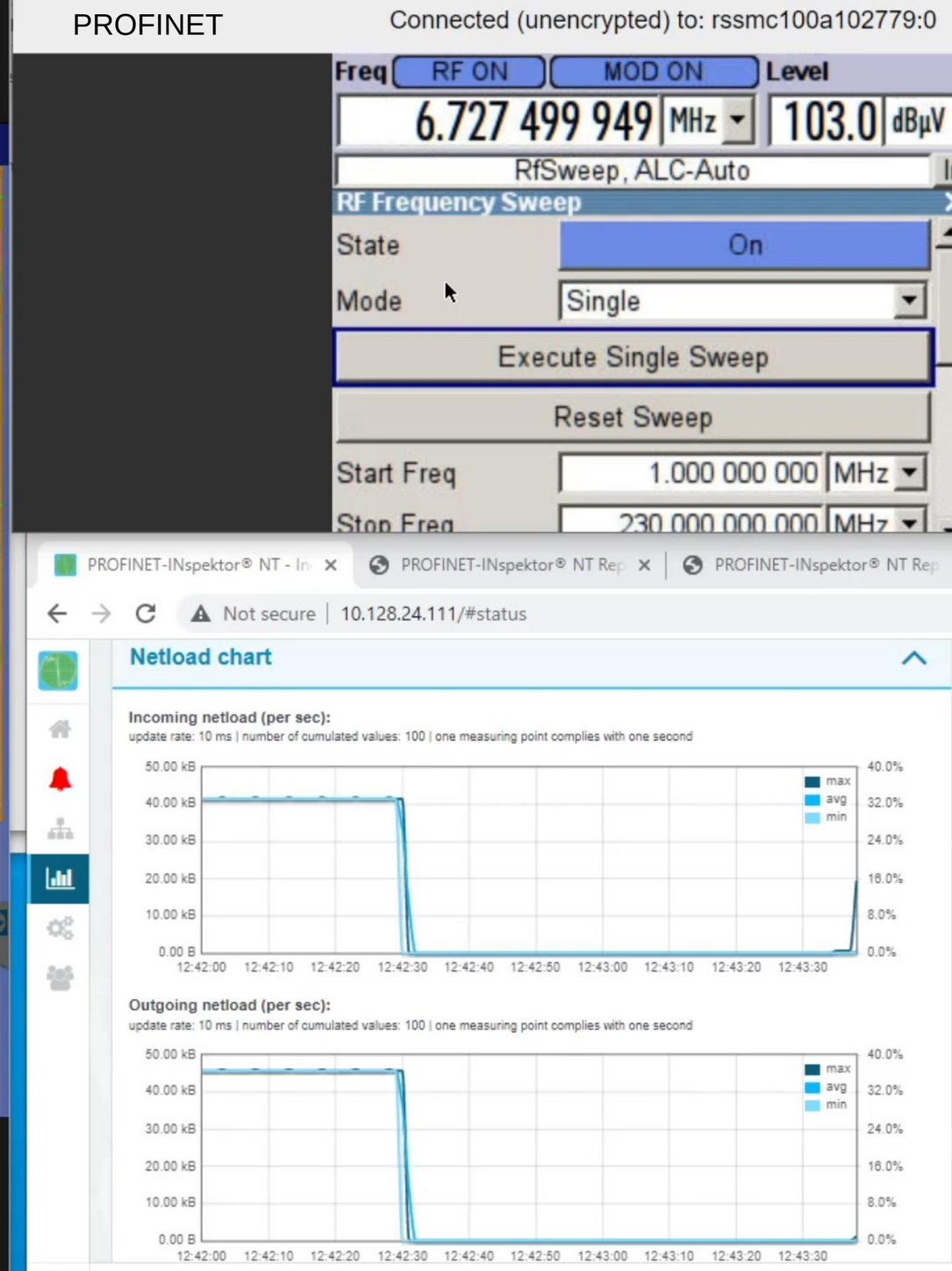
update rate: 10 ms | number of cumulated values: 100 | one measuring point complies with one second

Outgoing netload (per sec):

update rate: 10 ms | number of cumulated values: 100 | one measuring point complies with one second

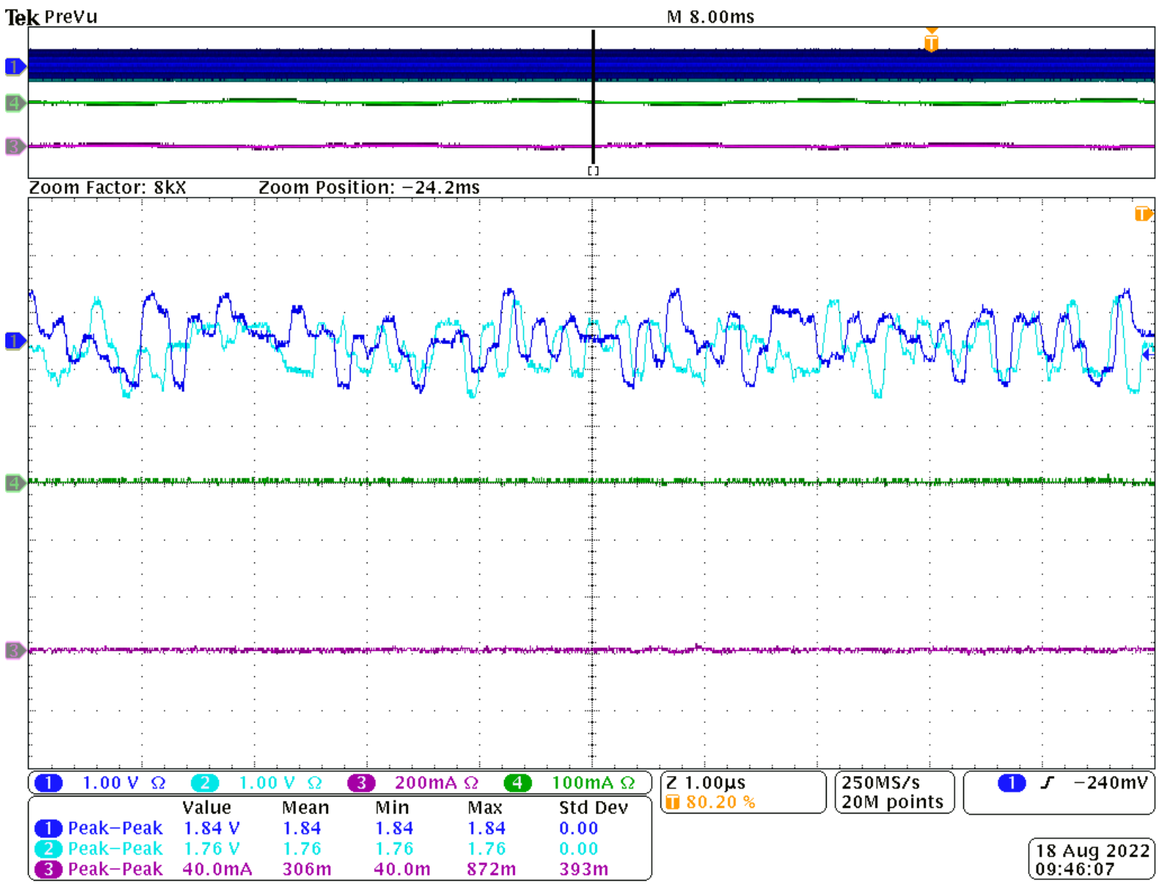


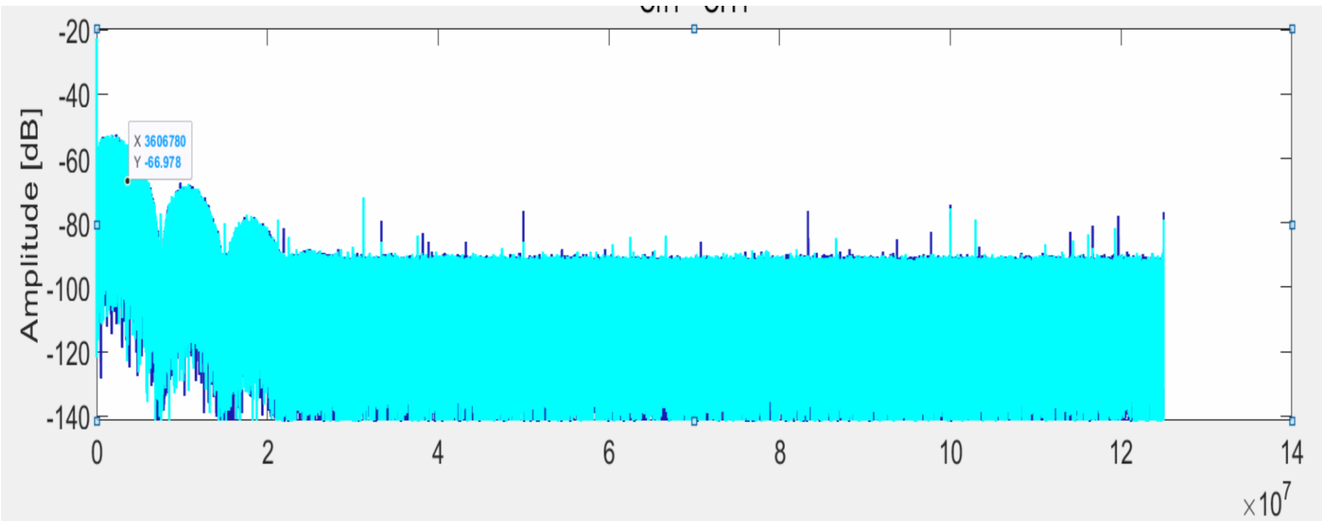
Communication ok



8. Some results

Time and frequency domain





– PB PA cable 100 m, no interference, communication ok

Spectrum of signal (start and end)

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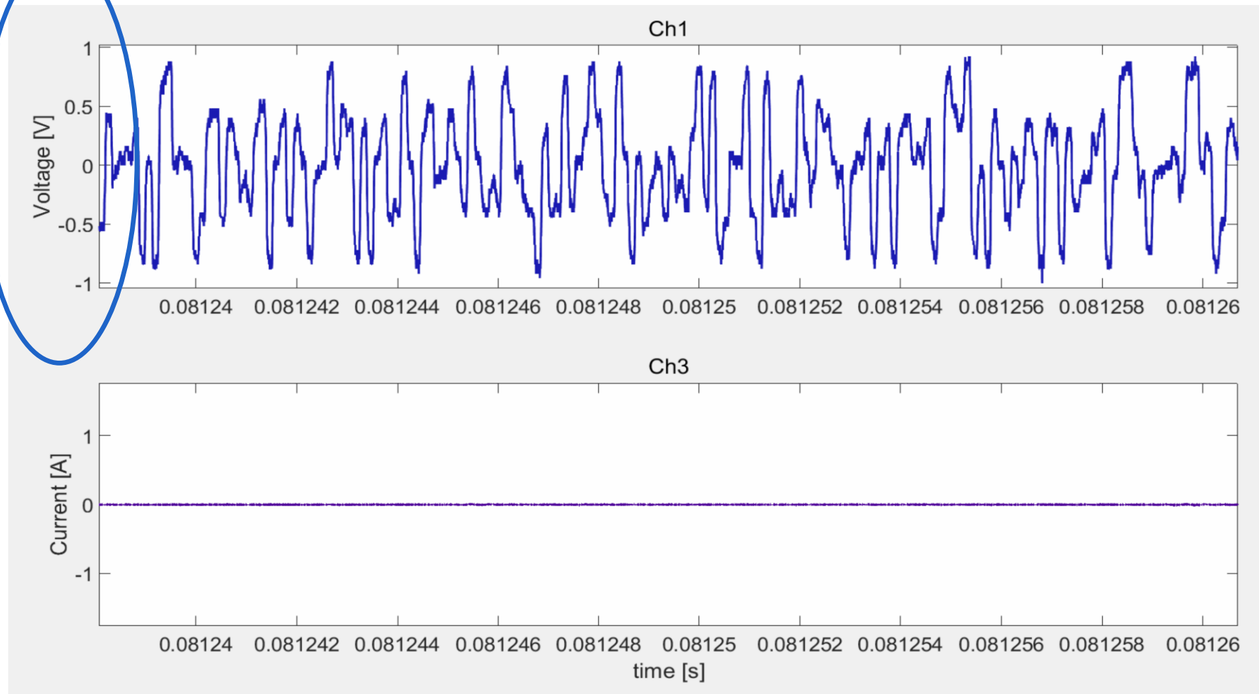
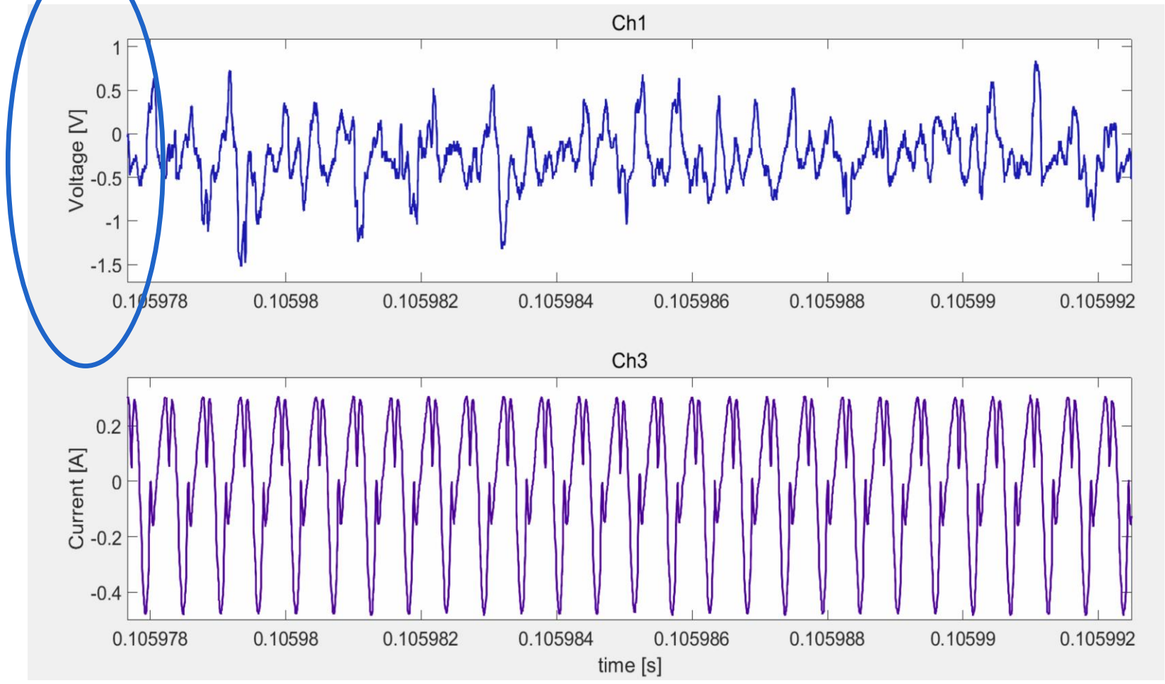
8. Some results

Time domain





– PB PA cable 100 m, no interference, communication ok

Intererence, communication not ok

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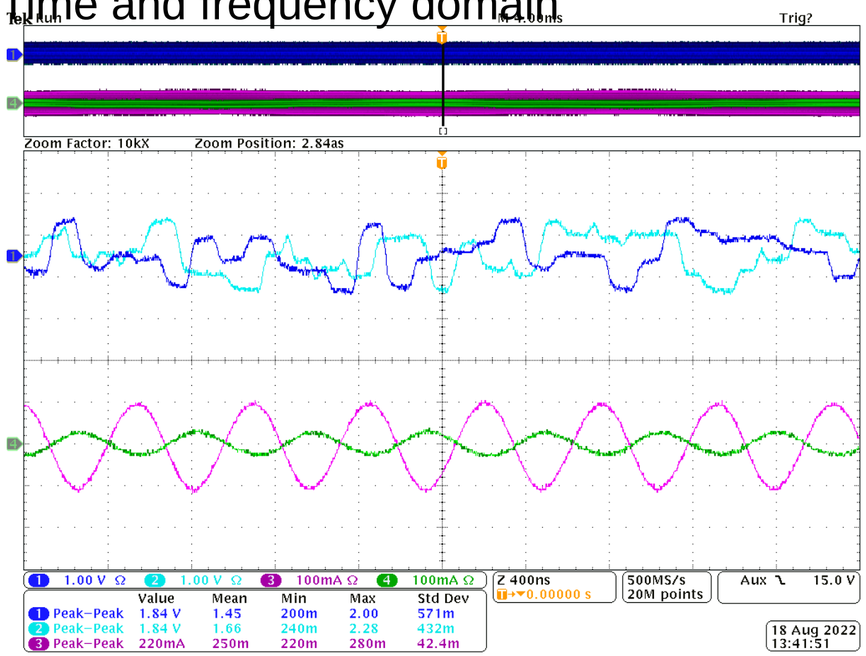
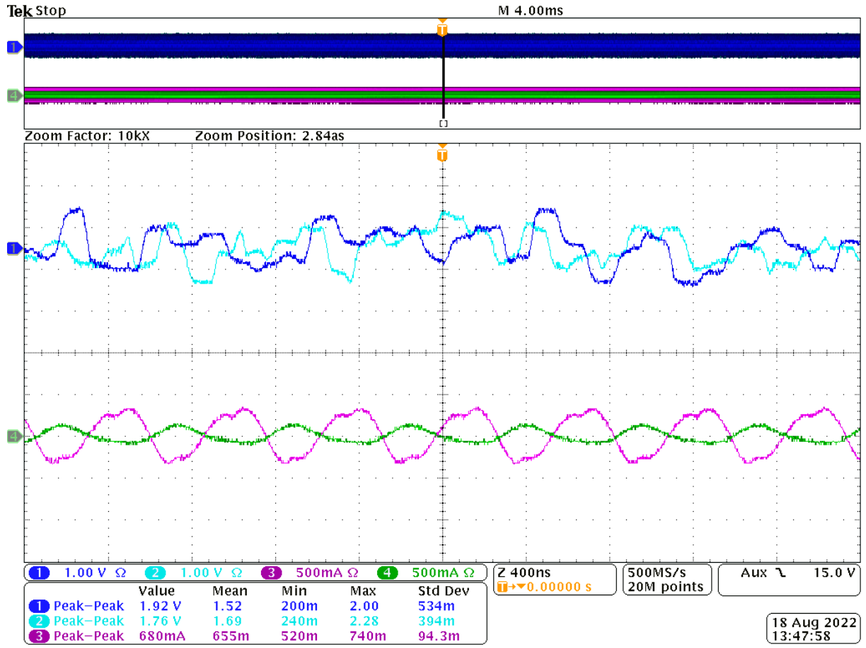
8. Some results

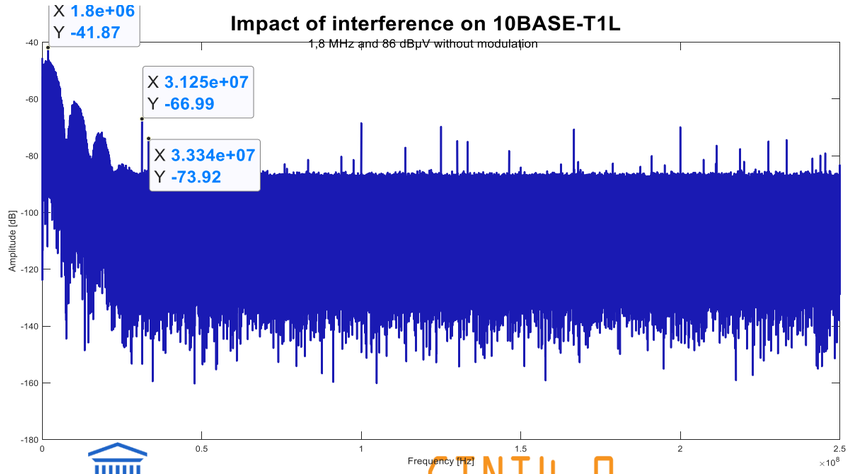
Time and frequency domain

SPE

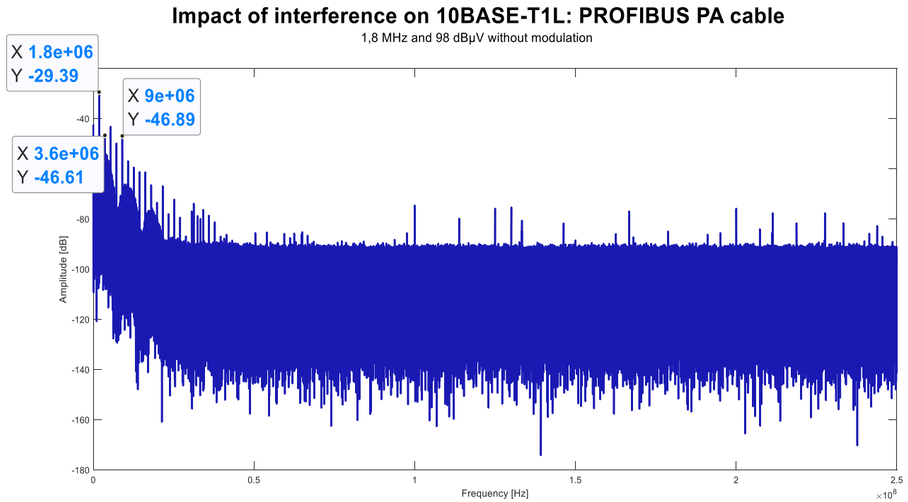


– 86 dBµV, communication ok





– 98 dBµV, communication not ok



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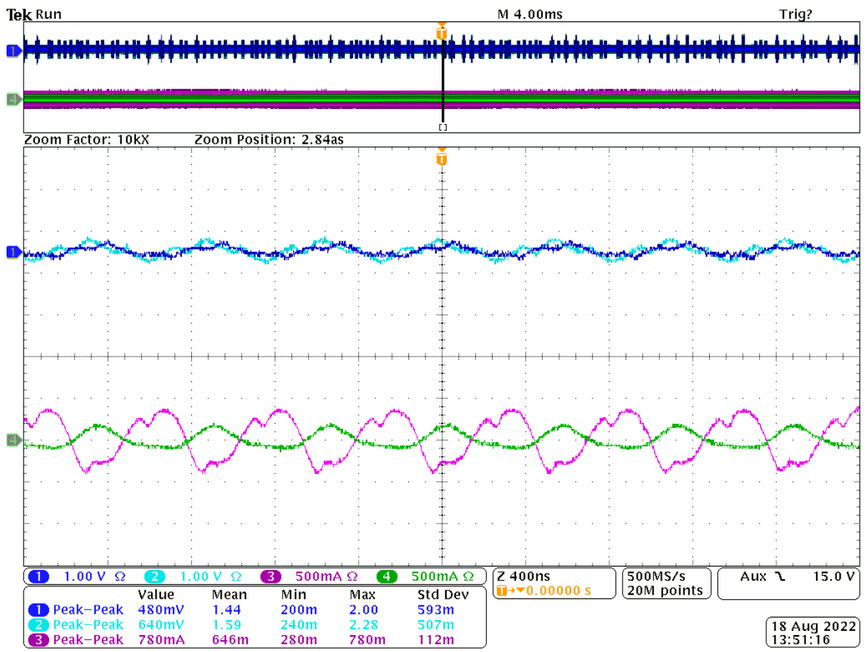
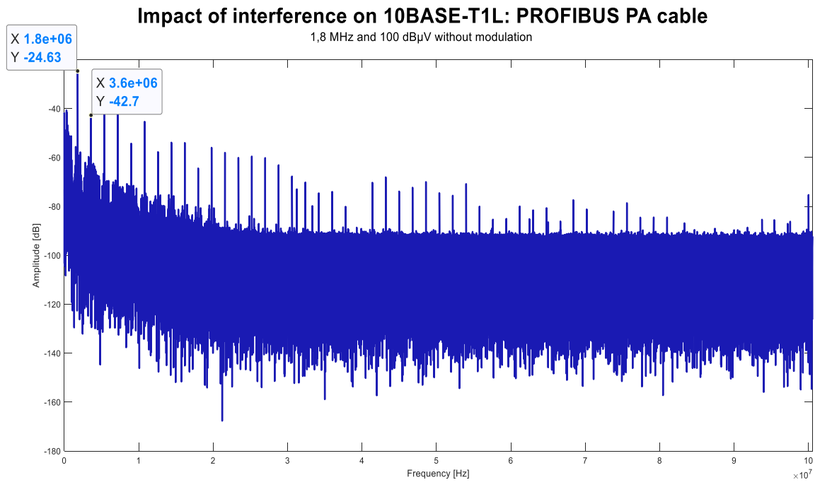
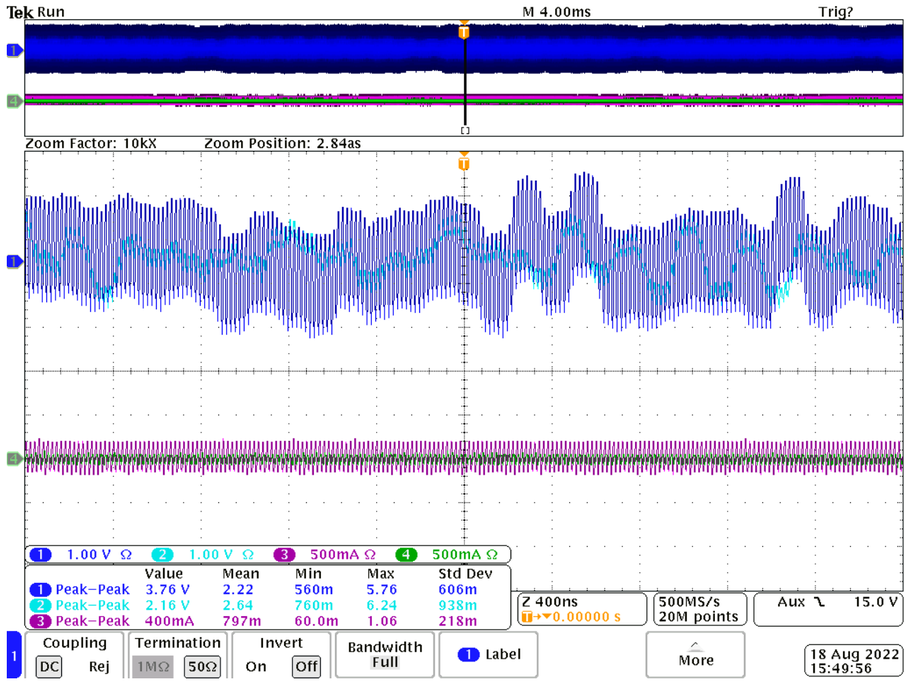


– 1,8 MHz, 100 dBµV, device failure



– 50 MHz interference, 98 dBµV, communication ok



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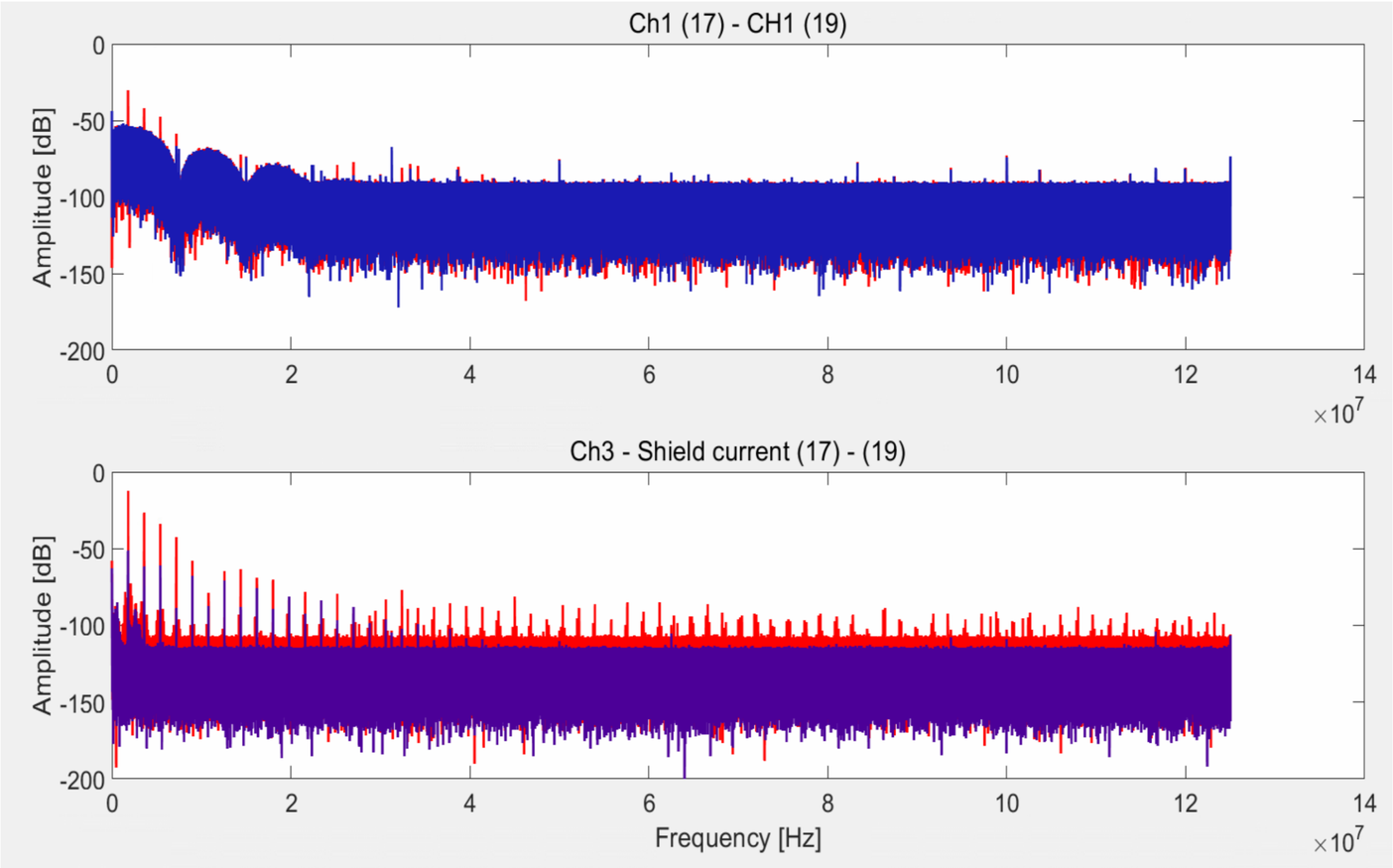

– Influence of litze between setups:

Red = with litze

- higher shield current
- higher interference at lower frequencies, but equal at higher frequencies
- communication is ok

Blue = without litze

- lower shield current
- lower interference at lower frequencies
- communication is not ok

Conclusion: shield current should flow to oppose the interference

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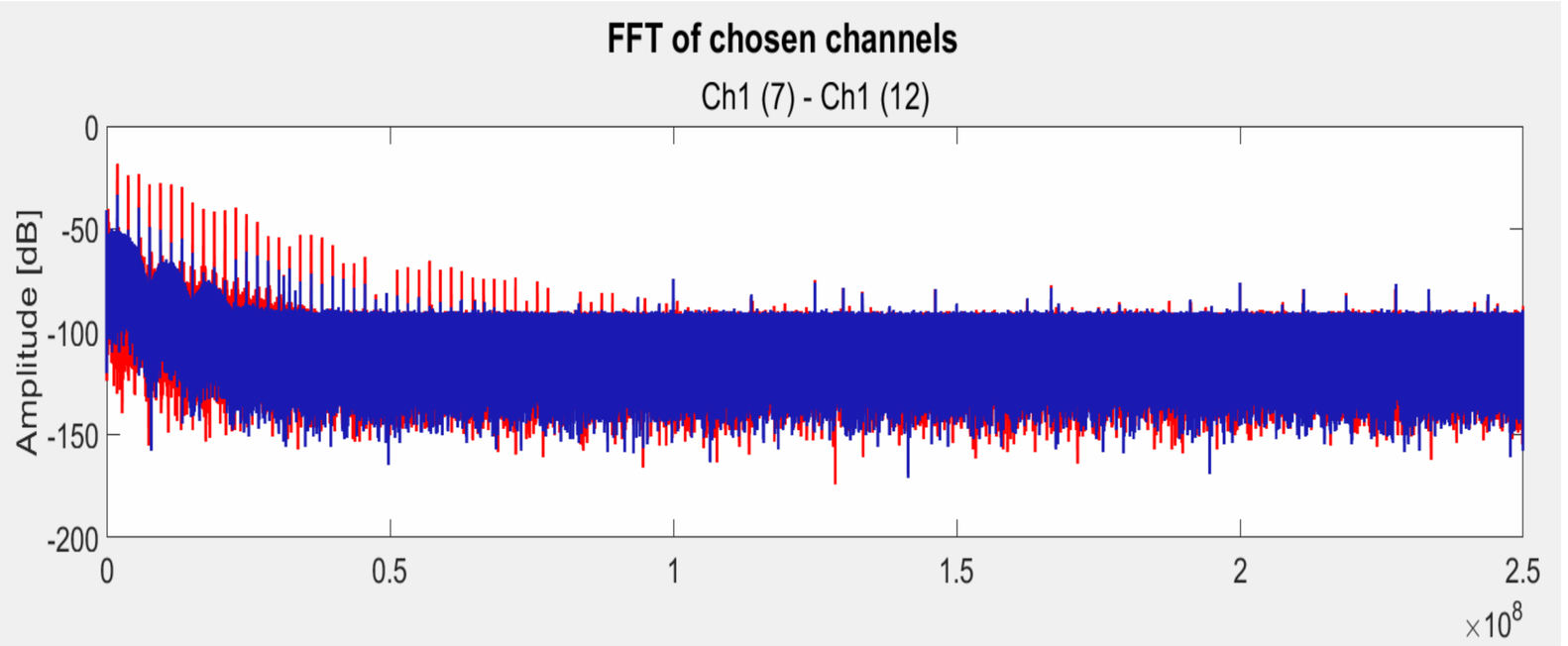
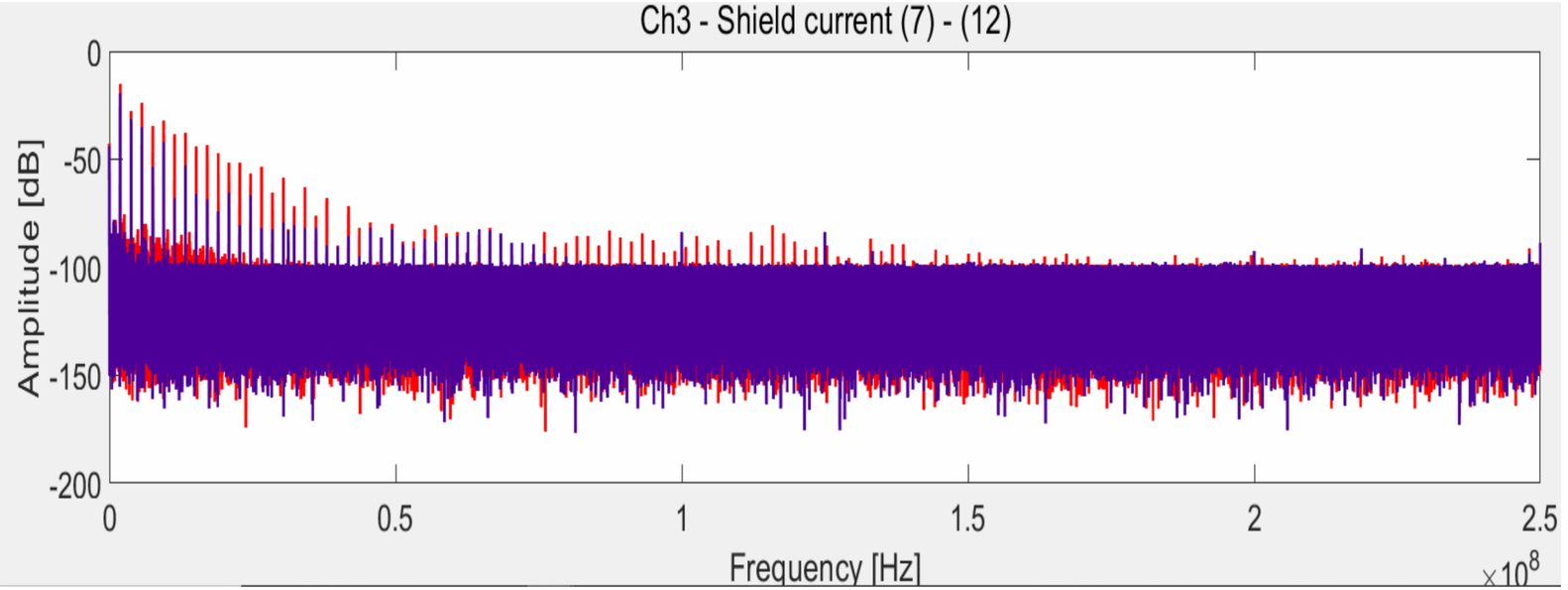
- Same setup 100 m cable
- CAT6a (blue) versus PB PA (red)
- Shield current 3 to 10 dB higher in PB PA
- Interference 20 dB lower in CAT6A





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9. More results?

Visit us at the demo

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EN ARCHITECTUUR

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