THE GIGABIT ETHERNET INTERFACE UNDER EMC ASPECTS

Adrian Stirn
Technical Lead EMC-Laboratory
+49 7942 945 5737
adrian.stirn@we-online.de

About the speaker

Adrian Stirn
Technical Lead EMC-Laboratory
EMC-Laboratory Engineer
Adrian.stirn@we-online.de

- Get in contact with EMC during apprenticeship and studies on electrical engineering as a company student.
- Responsibility for the EMC-Lab in Waldenburg after receiving engineers degree in 2016:
  - Precompliance EMC measurements.
  - Customer support: measurements, EMC debugging, redesigns, optimizations…

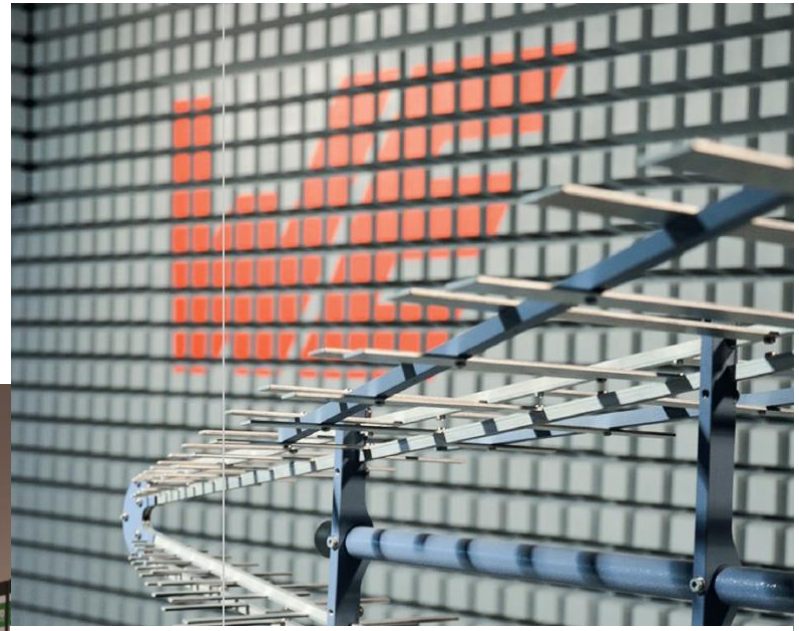
➢ One big topic and question that often came up in the past:
  - How to design a Ethernet frontend?
  - Why is my Design so noisy?
  - What about the connection between the Ethernet shield and the ground plane?

About the speaker

EMC-Lab Waldenburg – Würth Elektronik Headquarters in Waldenburg

Precompliance EMC-Lab:

www.we-online.de/emvlabor
emc.lab@we-online.de



About the speaker

EMC-Lab HIC München/Freiham

- 3 m FAR.
- Shielded Room for commercial conducted and transient testing.

- The Gigabit Ethernet Reference Design
- Test setup and emc issues
- Shielding effects
- Measurement with the scope

Further Information

App Note & Reference Design

- You can find the following information about his topic also on our website:

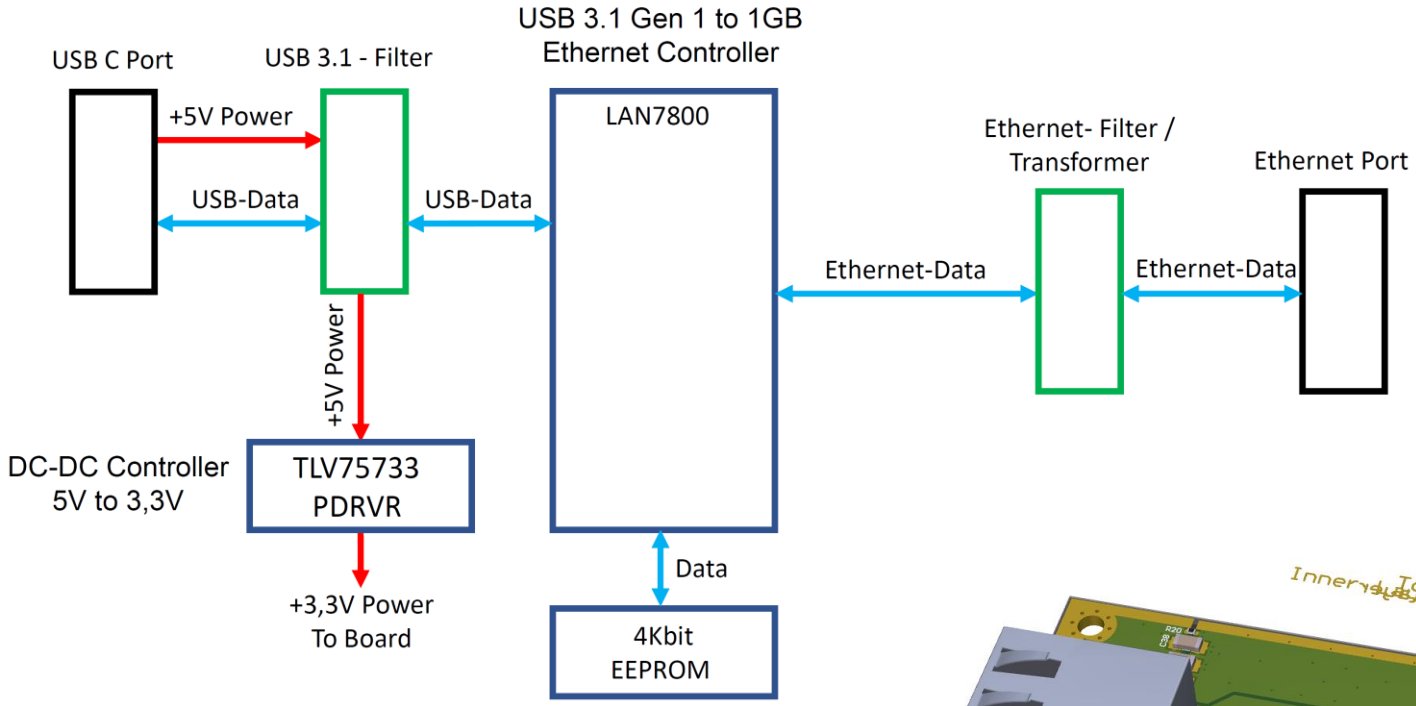
- Reference Design and Reference Design Note of the Boards: RD016 - Dr.-Ing. Heinz Zenkner
- App Note EMC performance of the Ethernet Boards in RD016: ANP116 - Adrian Stirn

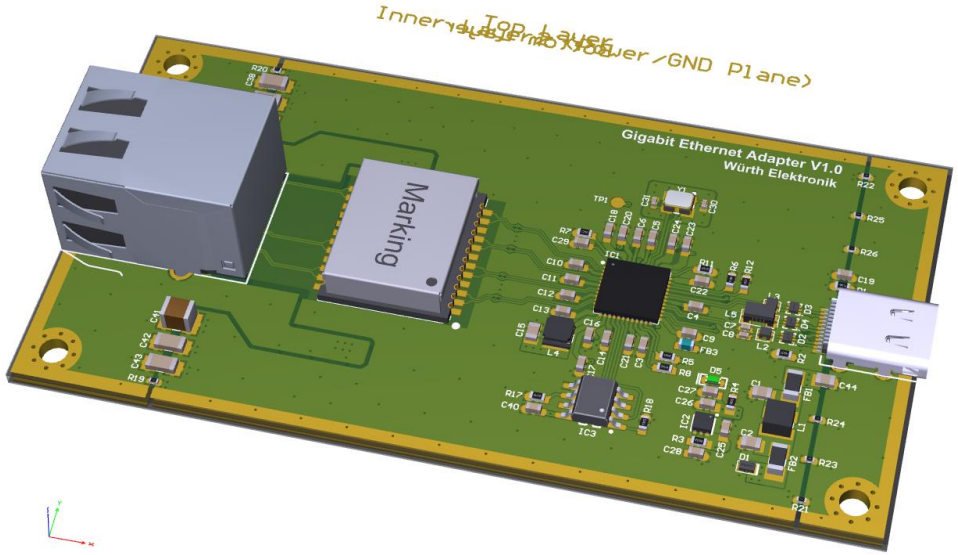
Focus on the emissions and influence of the cable shield in todays presentation.

THE GIGABIT ETHERNET REFERENCE DESIGN

1 GB Ethernet front end, hardware design

- Block diagram

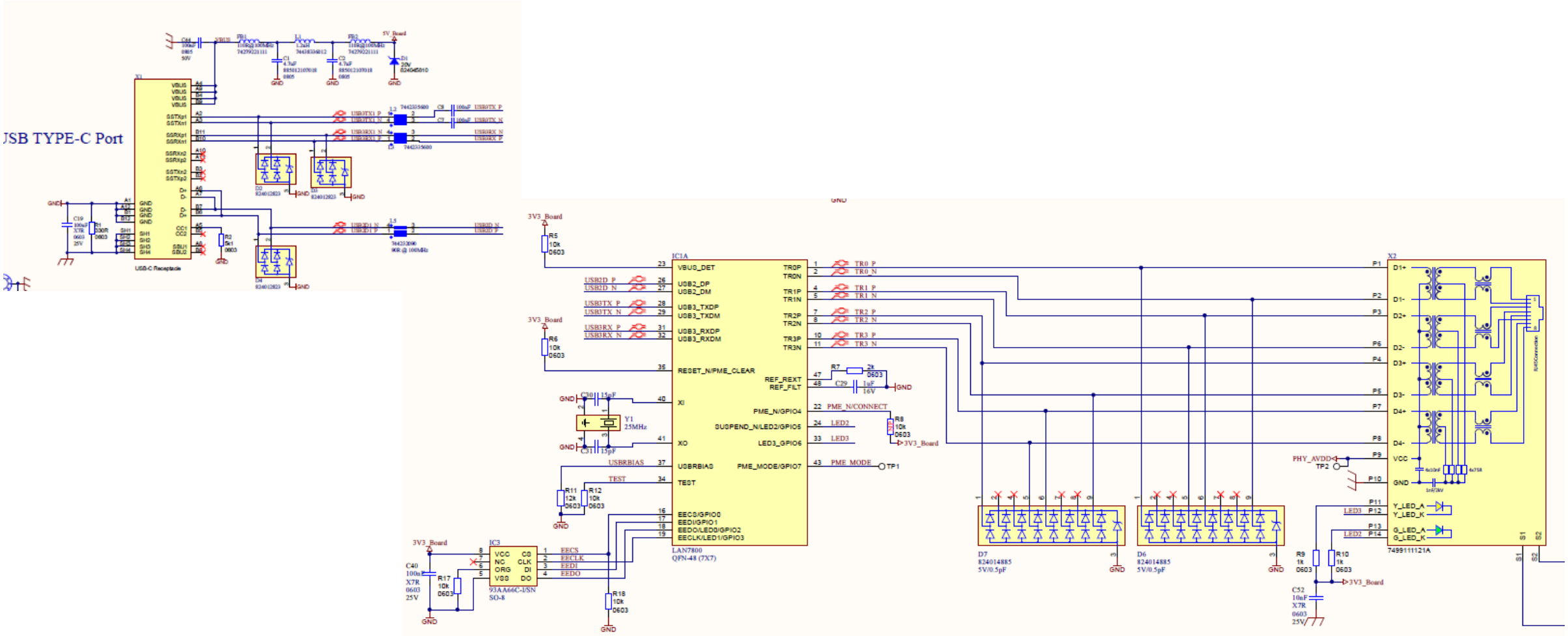




- 1GB Ethernet - USB3.1 converter based on the LAN-Ethernet controller LAN7800 from Microchip Technology.
- Firmware enables real-time measurement of data rate and bit error rate.
- USB side: +5 V and an onboard DC-DC controller (+3.3 V).
- Additional 4 kbit EEPROM for FW.

Board Design

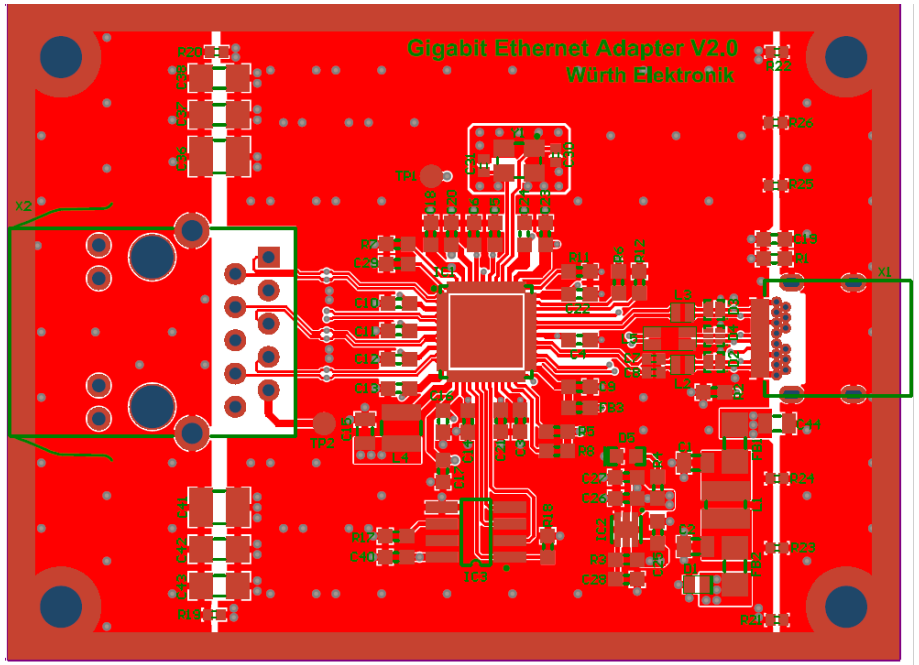
Schematic – integrated Design: USB and Ethernet Interface

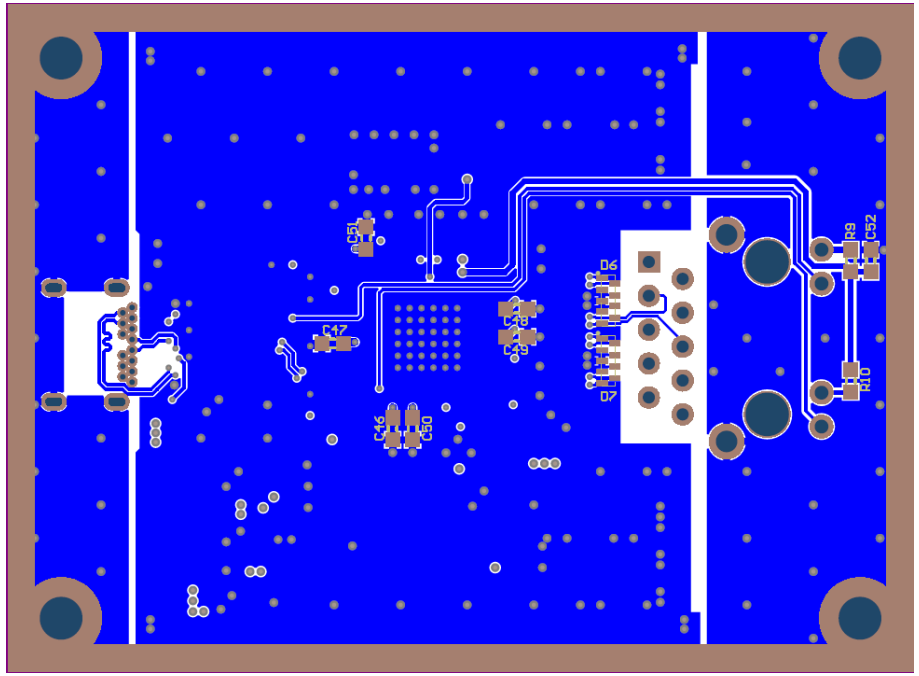


Board Design

Schematic – integrated Design: Top and Bottom Layer

- 4 Layer PCB.
- Inner Layers GND and VCC GND Layer.

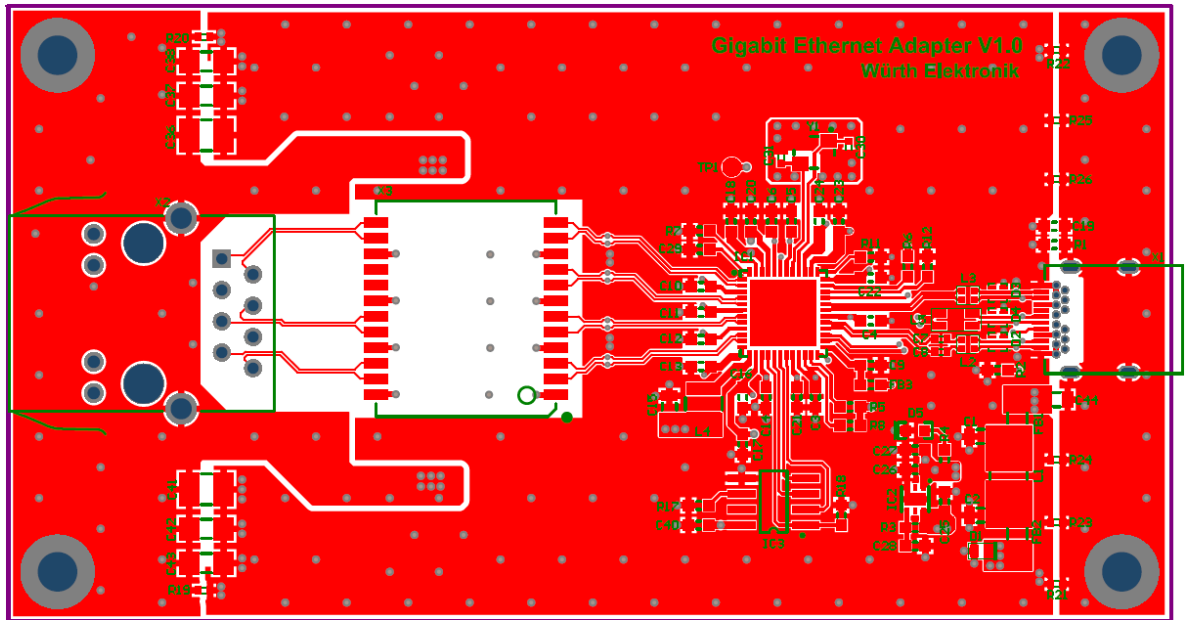


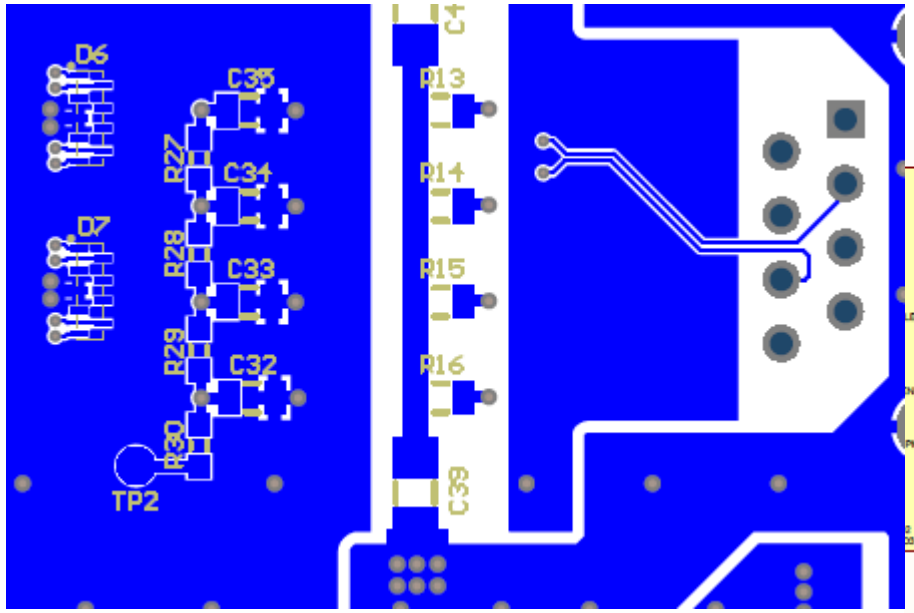


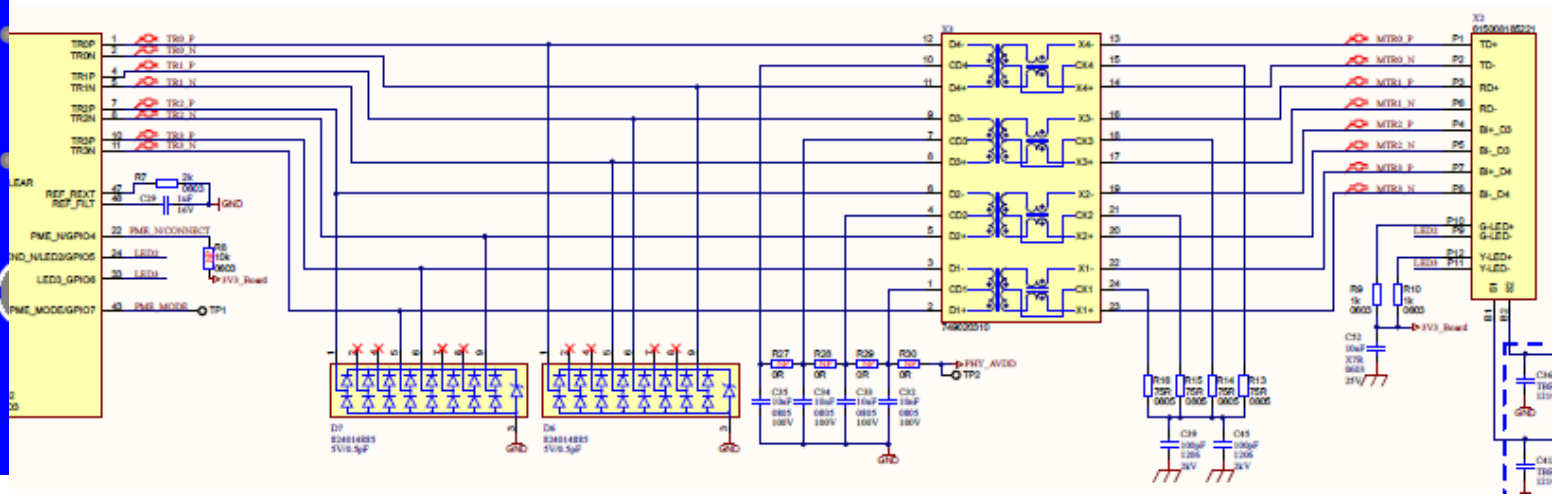
Board Design

Schematic – discrete Design: USB and Ethernet Interface

- Discrete Design: Ethernet Transformer external.
- Discrete Transformer with high symmetry !
- Transformer includes CMC.
- Transient-Suppression below the Transmission Line.
- Bob-Smith externally below the Transformer.





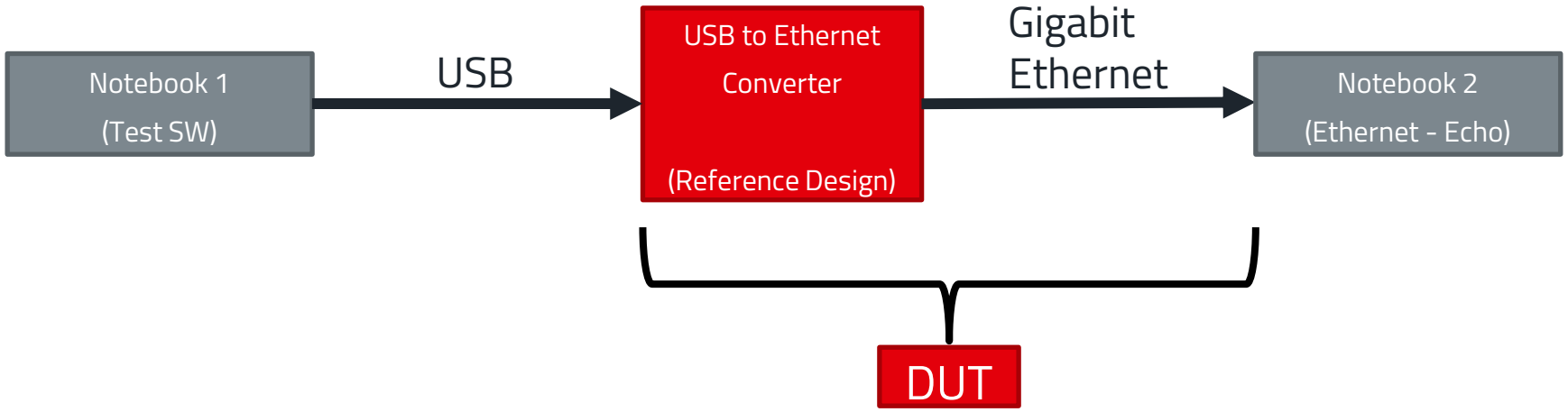


TEST SETUP AND EMC ISSUES

Measurement and test setup

General test setup

- Two notebooks are required to test the function of the reference design.

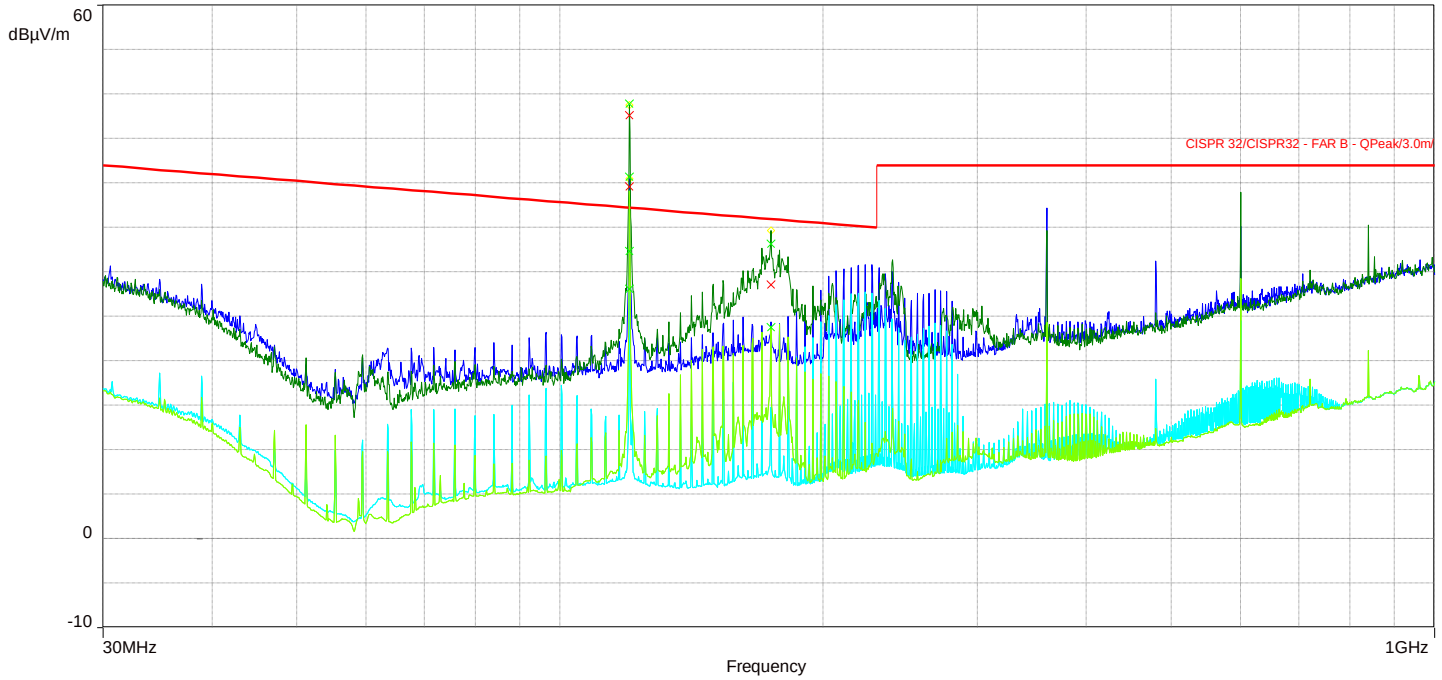


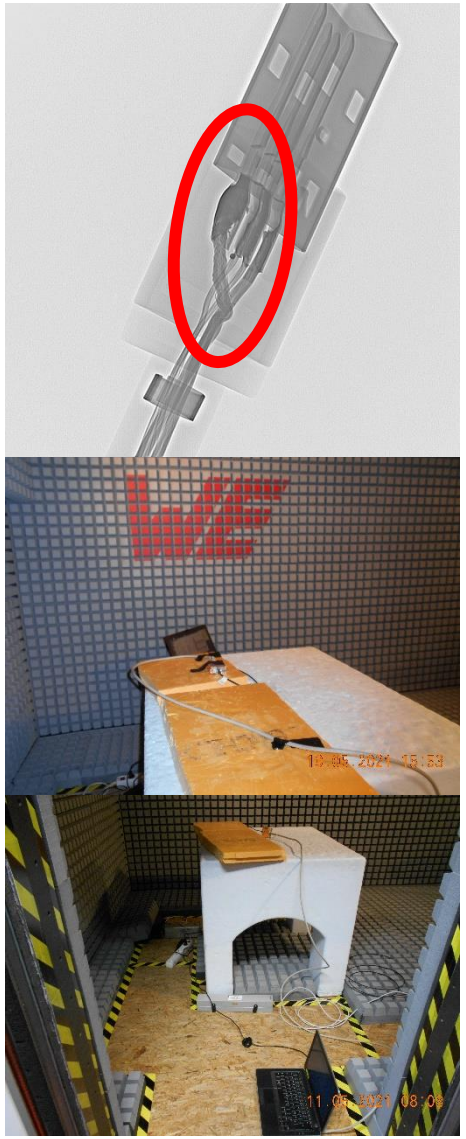
- USB cable and Notebooks are Auxiliary Equipment.
- The Reference Design and the cable on the Ethernet interface are DUT.
- The EMC behaviour is analysed with different cables and shielding connections on the reference design.

Measurement and test setup

Radiated emissions and radiated immunity

- Test according to CISPR 16 Standards in a fully anechoic chamber.
- Both notebooks are placed in the anechoic chamber and are part of the DUT.



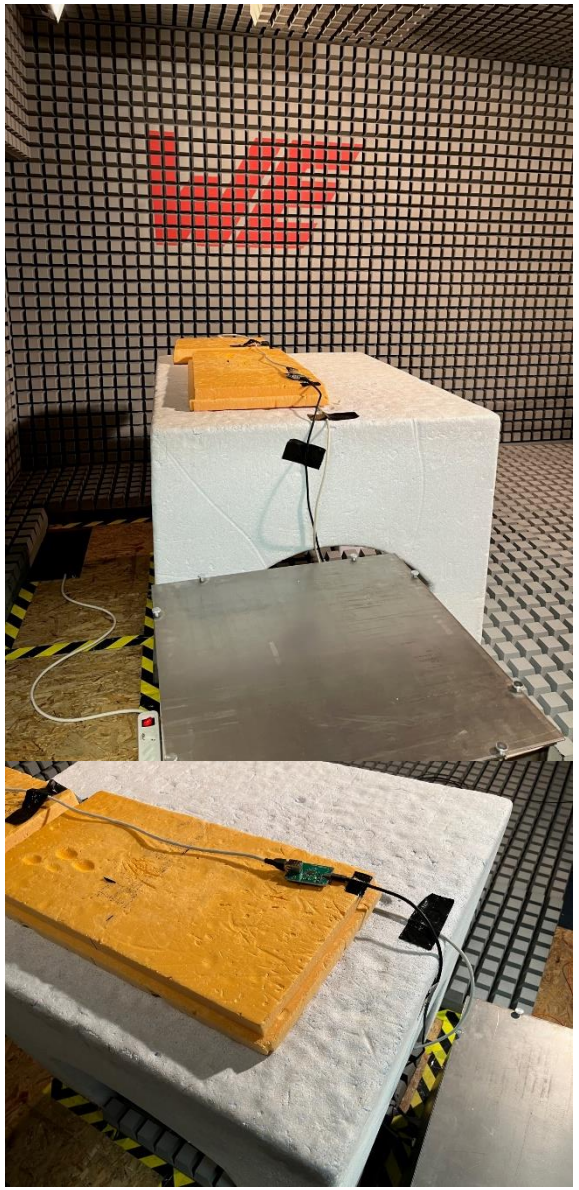


- Noise due to emission of Notebook 1 (test software) and badly shielded USB cable.

Measurement and test setup

Radiated emissions and radiated immunity

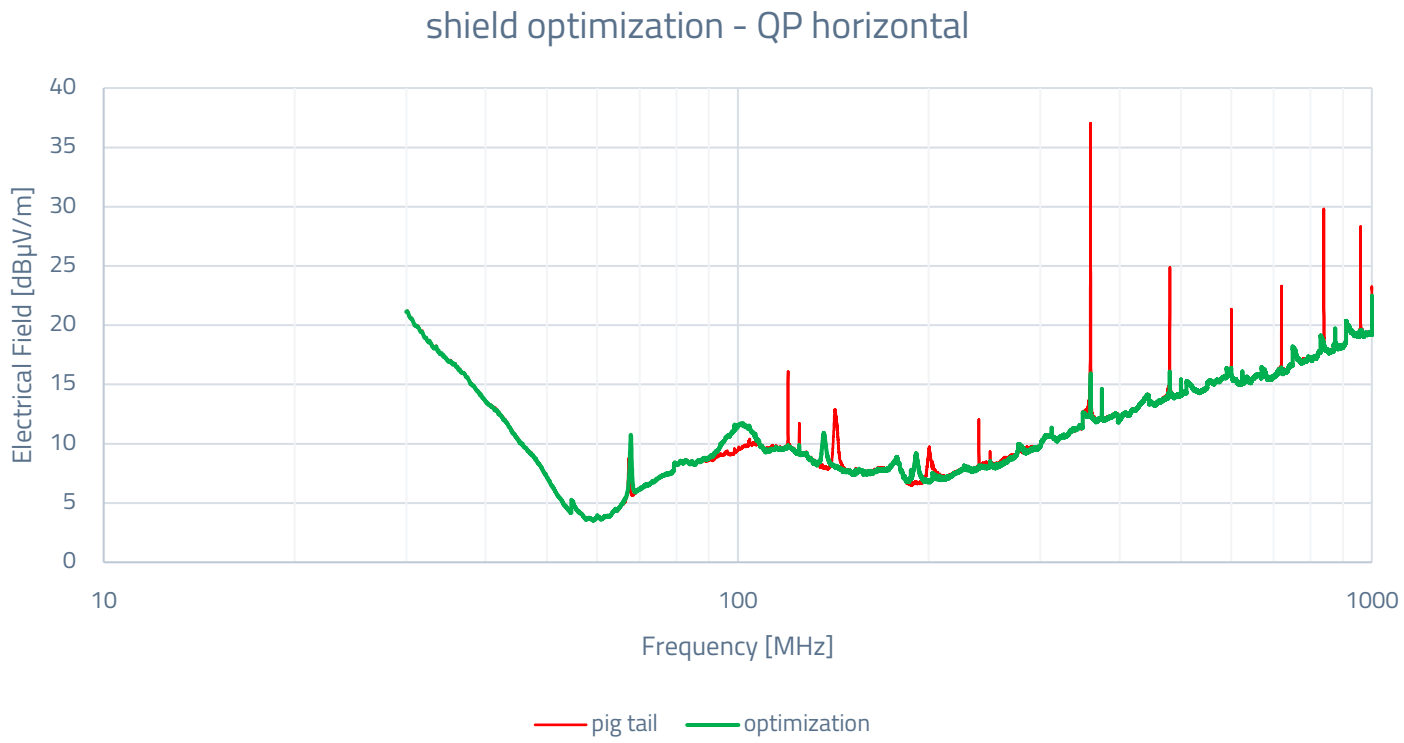
- Test setup with S-Box:
  - The 4 MHz harmonics are not visible anymore.
  - Still 120 MHz noise is prominent.
  - Real time spectrum analysis show, that the noise is radiated during sending of data (1 second signal on and 1 second signal off).
  - Investigation with Near Field Probes and Current Probe.



Measurement and test setup

Radiated emissions and radiated immunity

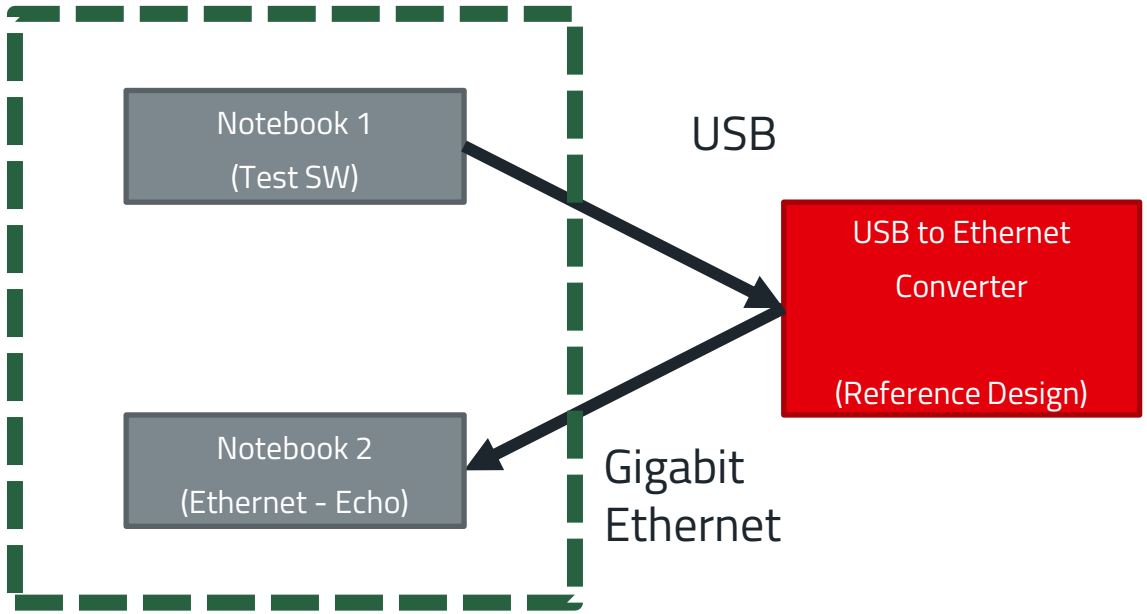
- 120 MHz noise coming from the USB-cable: pigtail or issue with USB-feedthrough connection in S-Box.
- Connect the USB-cable shield directly and 360 ° to the S-Box with shielding tape reduces the noise emission.

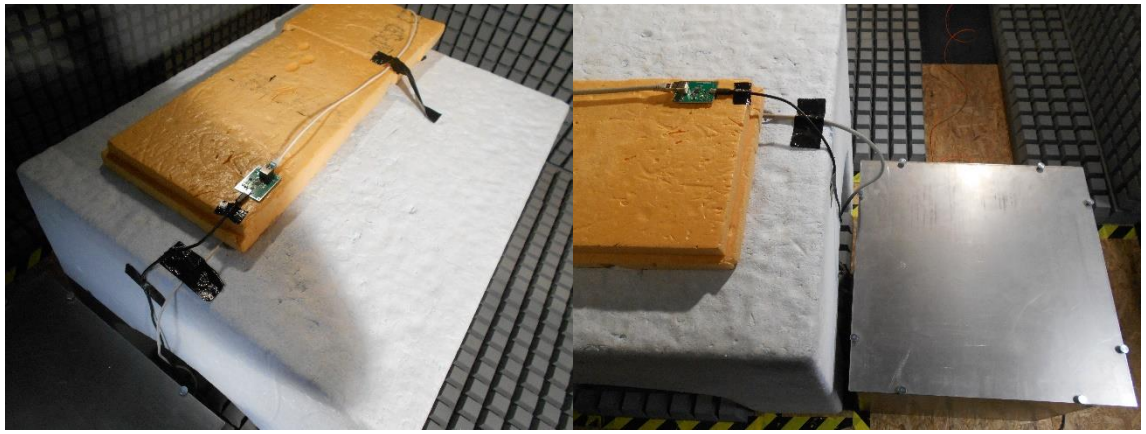


Test setup –radiated

Radiated emissions and immunity – different cables and designs. General test setup

- Two notebooks are required to test the function of the reference design. The notebooks are placed inside a shielded box.





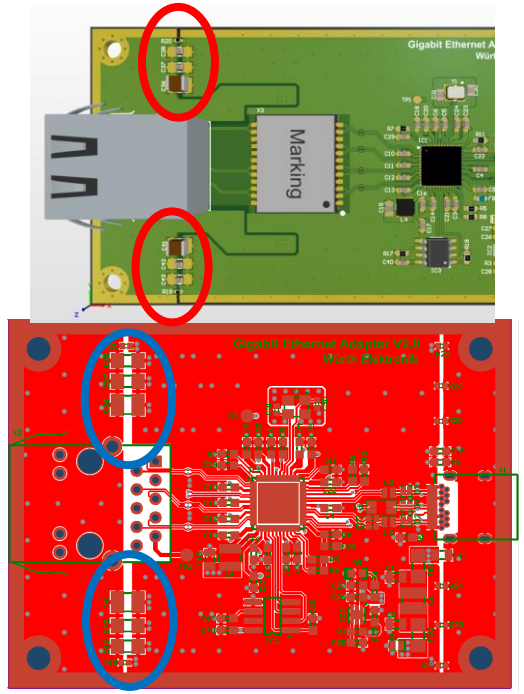
- The shielded box is reducing the noise of the notebooks below the noise floor level of the emc test equipment, so the noise of the notebooks is not visible in the results and the functionality of the notebooks is not disturbed during immunity testing.

SHIELDING EFFECTS

EMC test results – integrated HW

Different shielding connections

- Transient voltages can be on the Ethernet cable.
- Caps need to have a high voltage resistance or protection against transients.



Unshielded cable

1 nF Y-Cap + 1 MΩ

2 times 10 nF MLCC + Varistor

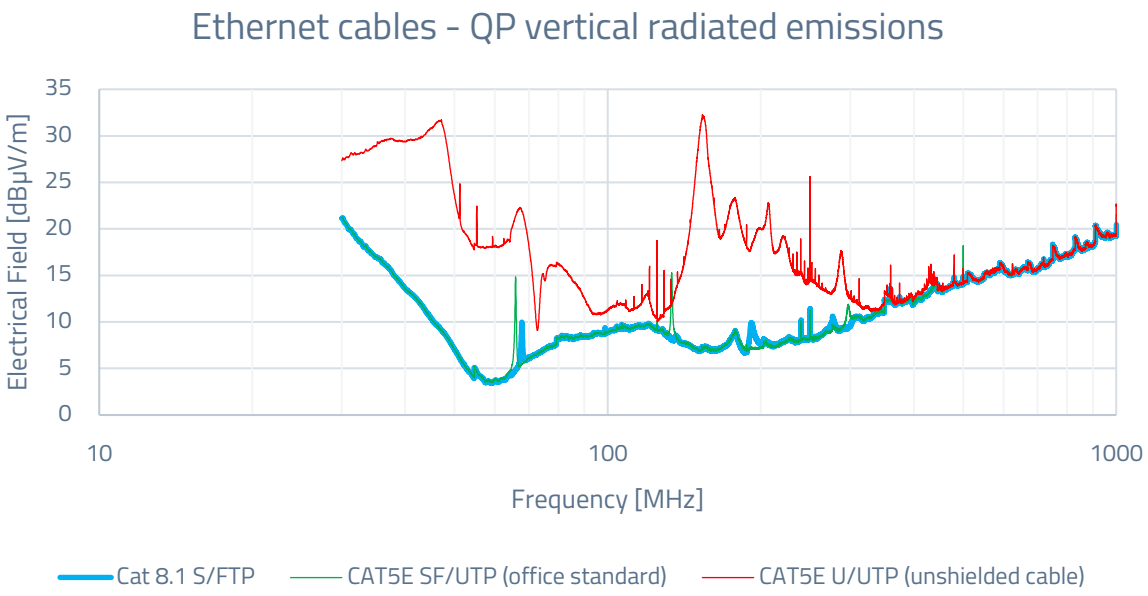
Full and direct connection

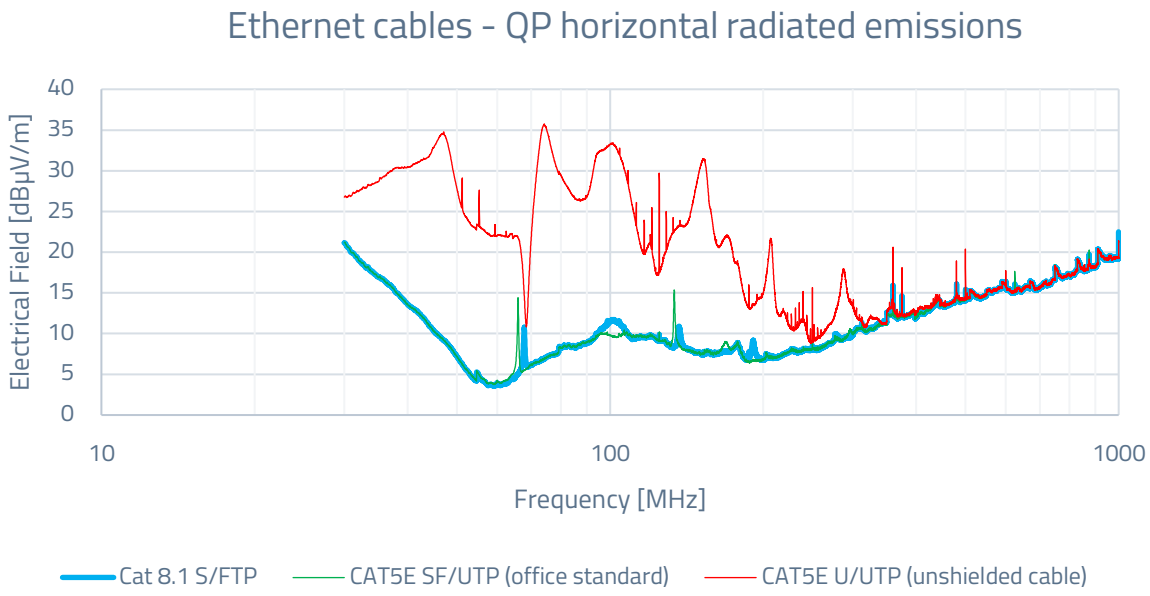
- Not safety relevant.
- Capacitance to stop 50 Hz leakage currents.

EMC test results – integrated HW

Radiated emissions – different cables. Investigation with integrated Design

- The radiated emissions of different cables on the Ethernet reference design with integrated Transformer and Filter is investigated.
- The Shield of the Ethernet connector is directly connected to the GND-Plane of the PHY.



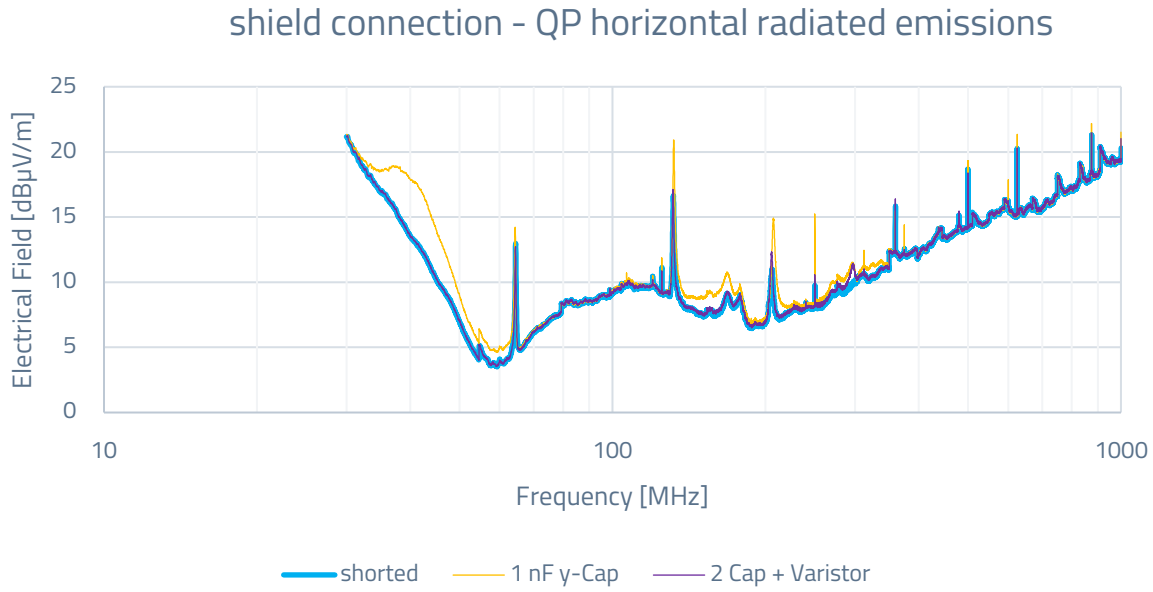


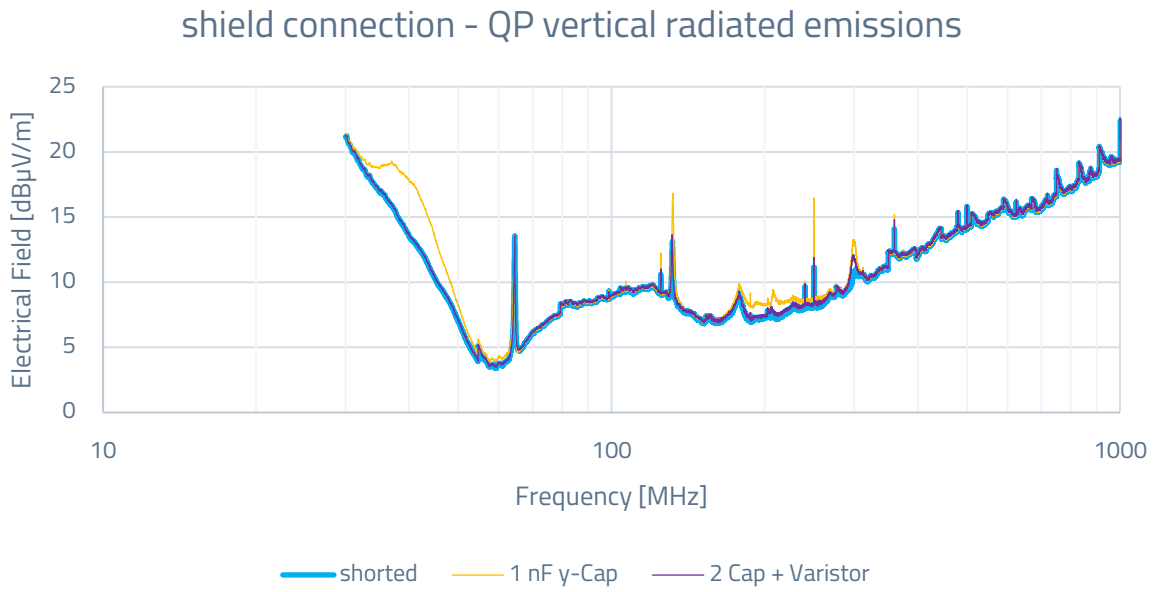
- 5 dB difference between CAT8.1 and CAT5E SF/UTP. Unshielded cable causes a bad performance.

EMC test results – integrated HW

Radiated emissions – different shield terminations. Investigation with integrated Design

- The Shield of the Ethernet connector is connected to PCB GND with different options.



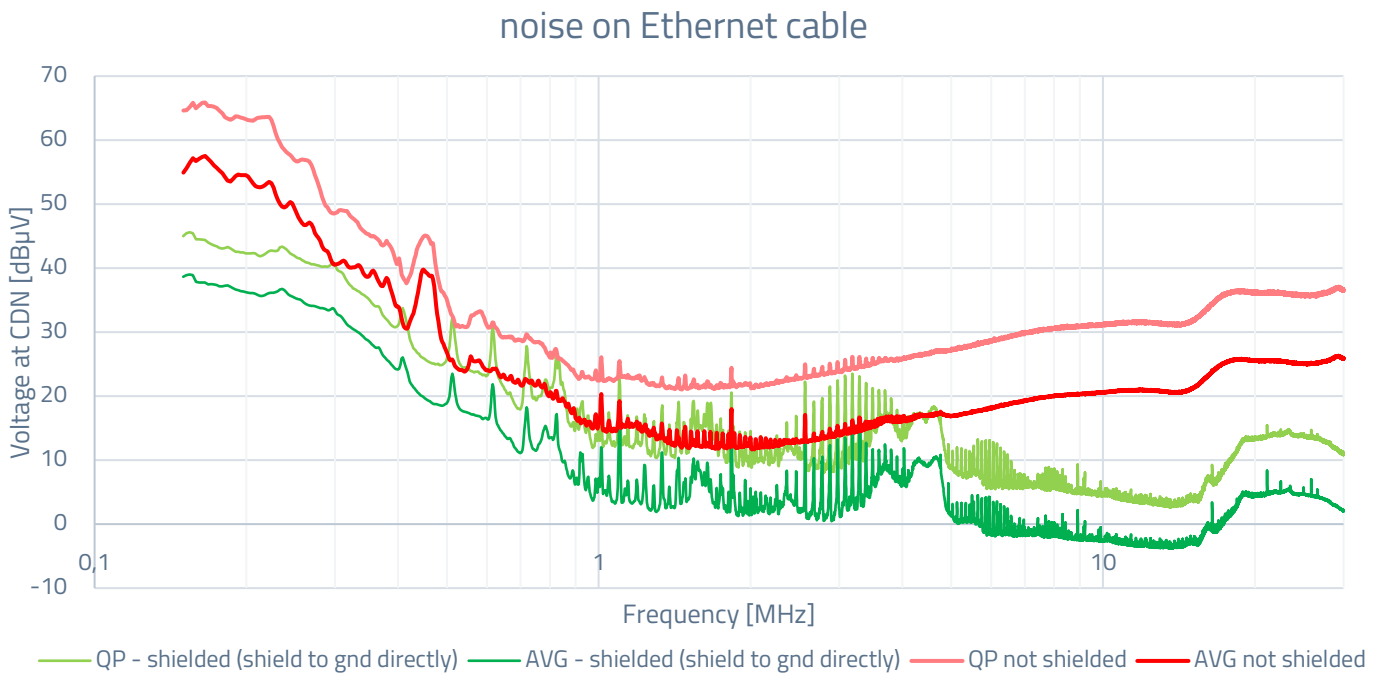


- Connecting the shield with the classical well known internet method (1 nF y-Cap + 1 MegOhm) is working, but the termination with 2 times 10 nF + Varistor is better.

EMC test results – integrated HW

Conducted emissions – shielded (green) and unshielded (red) Ethernet cable. Investigation with integrated Design

- The integrated test board is used to compare the noise on the CAT5E SF/UTP and CAT5E U/UTP cable.

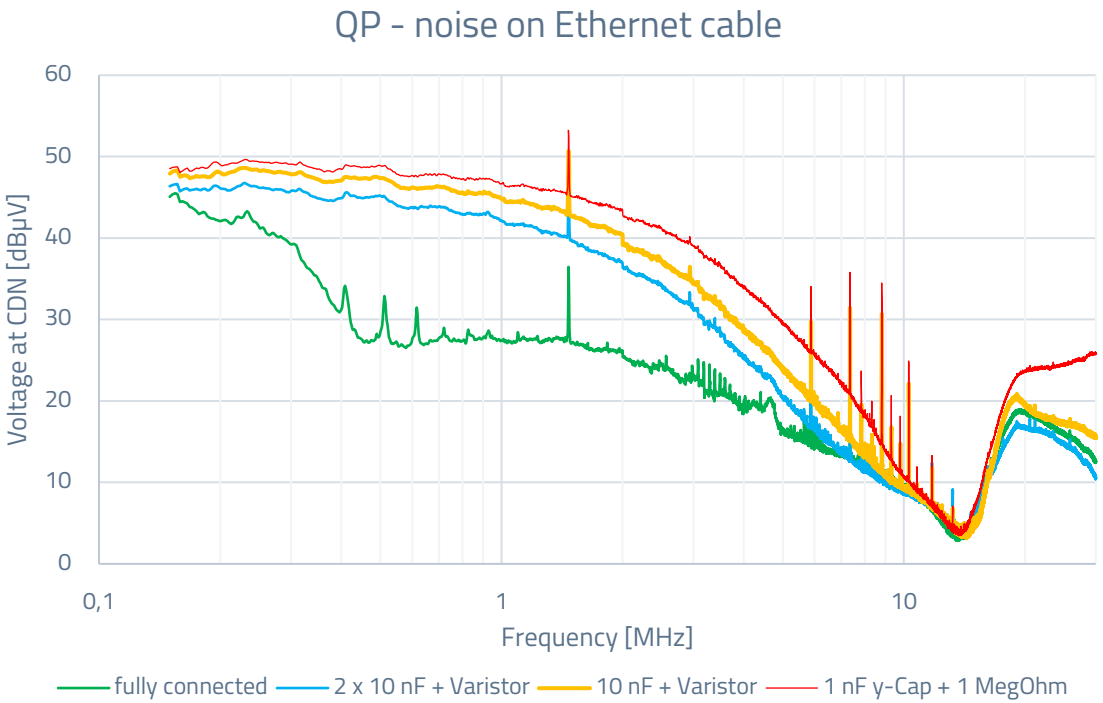


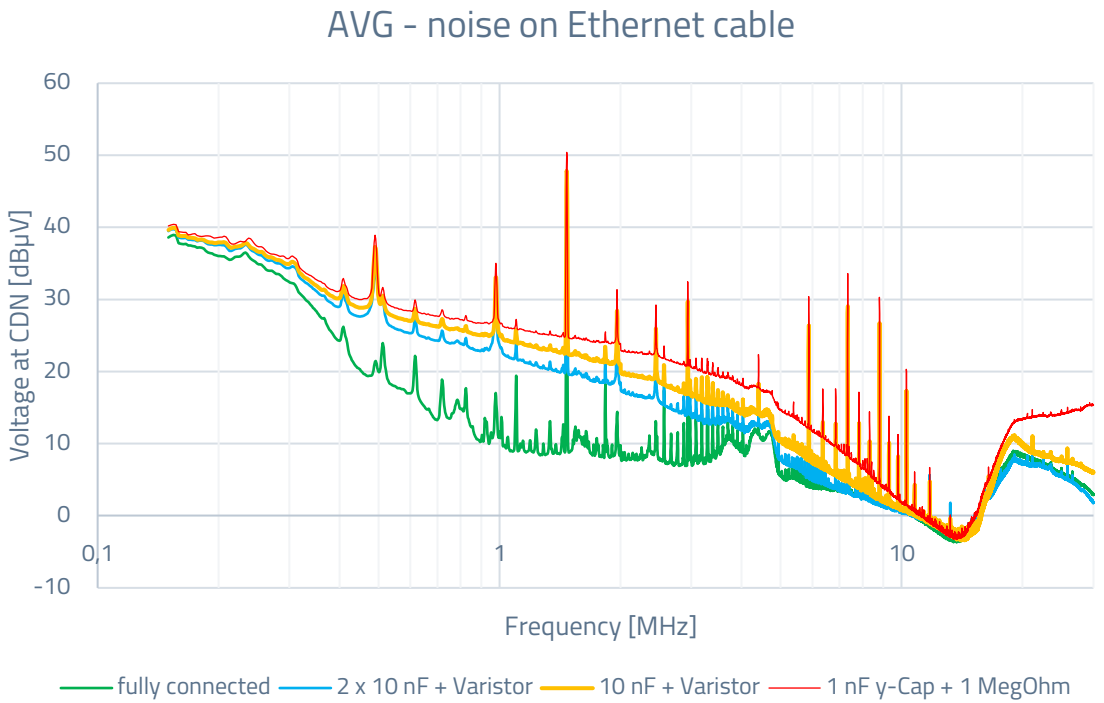
- The noise un the U/UTP cable is (10 to 20 dB) higher than on the shielded cable.

EMC test results – integrated HW

Conducted emissions – termination of shield from connector to pcb ground plane. Investigation with integrated Design

- Different shield termination options are compared – measurement with CDN on shielded Ethernet cable:





- 2 x 10 nF or direct connection recommended for the best results.

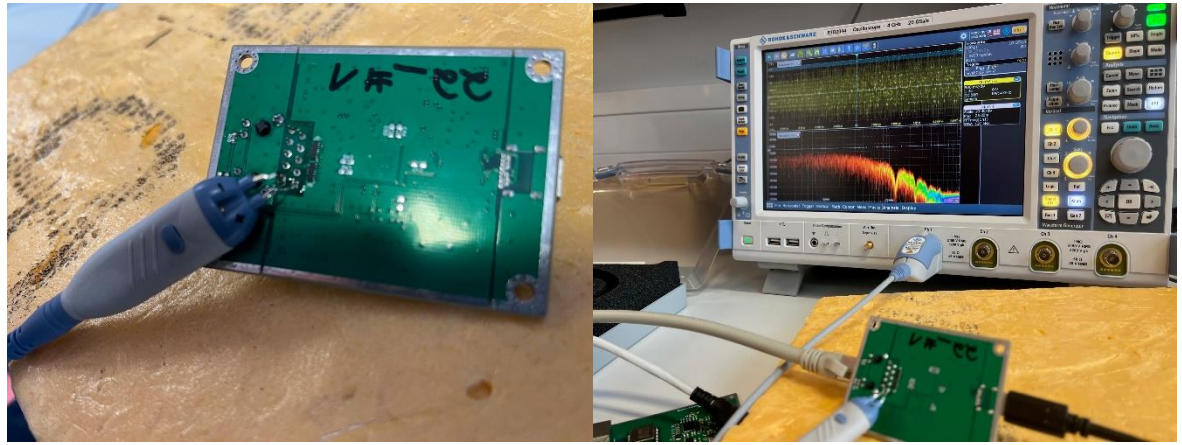
MEASUREMENT WITH THE SCOPE

Measurement and test setup time domain measurement

General test setup

- The Ethernet-Signal is measured with a Scope between PHY and Signaltransformer.
  - 4 GHz Scope; 20 GSa/s; R&S RTO.
  - R&S RT-ZD40 active probe: 4,5 GHz; 0,4 pF.

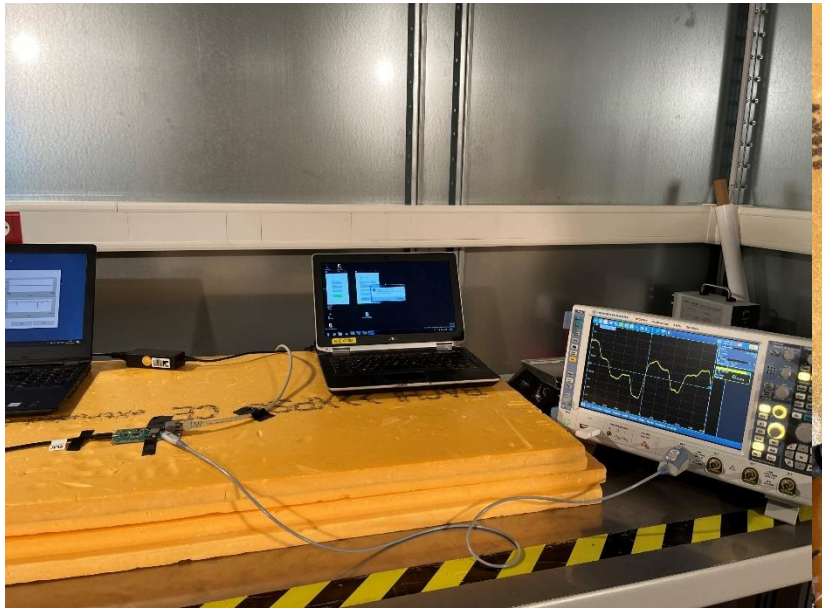
➢ Rule of thumb in University measurement curse: bandwidth of the measurement chain should be 10 times higher than the frequency of the measured signal to get a satisfying signal sampling.
➢ Only small probe capacitance allowed, due to transmission line disturbance by external capacitance.

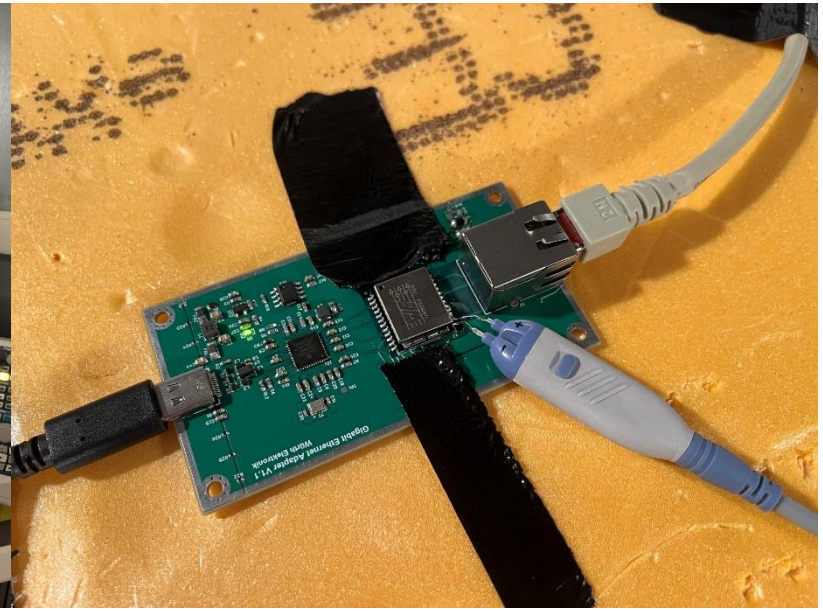


Measurement and test setup

Test on Signal Line 1 – between Ethernet transformer and connector

- Measurement with discrete test board.

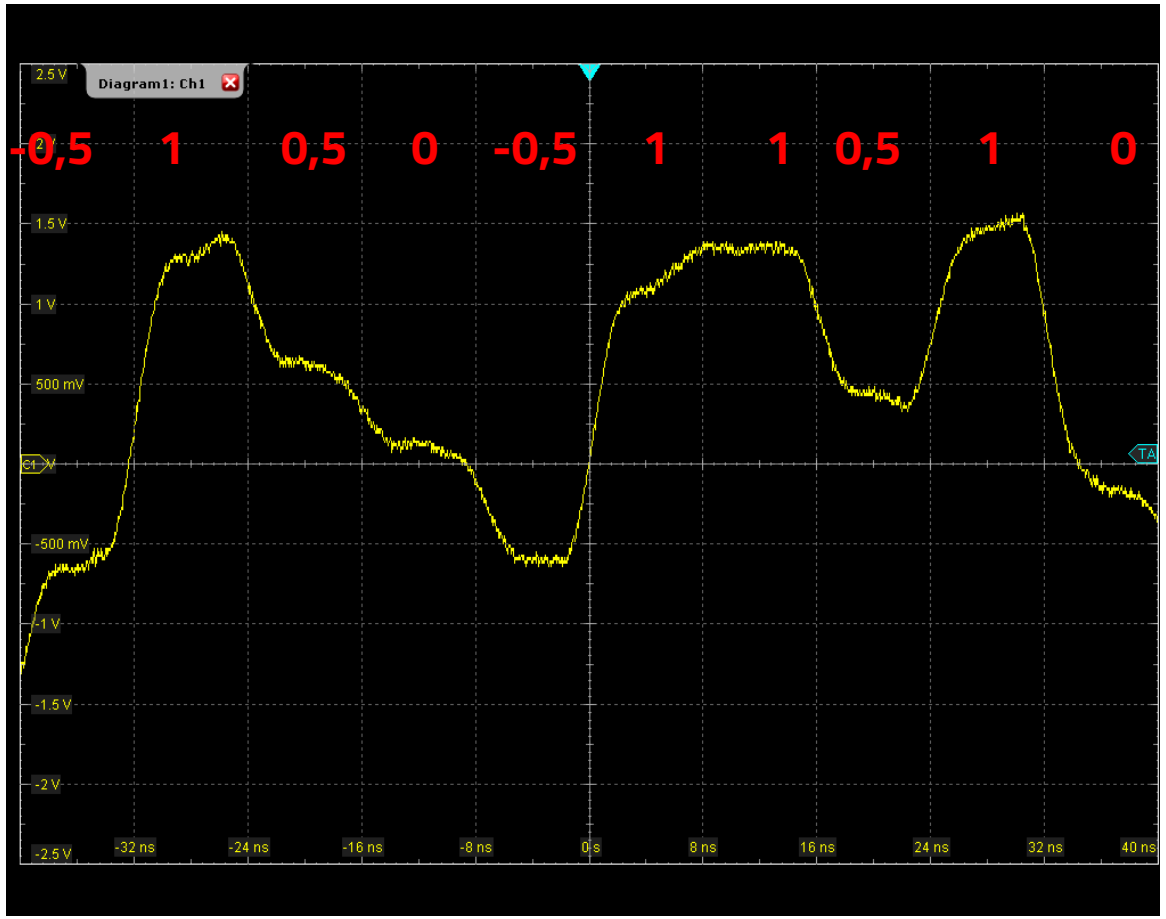




Measurement and test setup

Test on Signal Line 1 – between Ethernet transformer and connector

- Signal on Dataline with reduced reflections and noise.
- Measurement with discrete test board.
- Measurement with scope: 8ns/div.
- PAM-5 Modulated Signal.



- Reduced reflections behind transformer.
- PHY needs / has correction for reflections.

Thank you for your attention!

You can meet EMC and RF everywhere…