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A Proposed Specification for RFI Ingress Limit in 802.3ch Automotive Links

Ramin Farjadrad

Larry Cohen

Aquantia Corp.

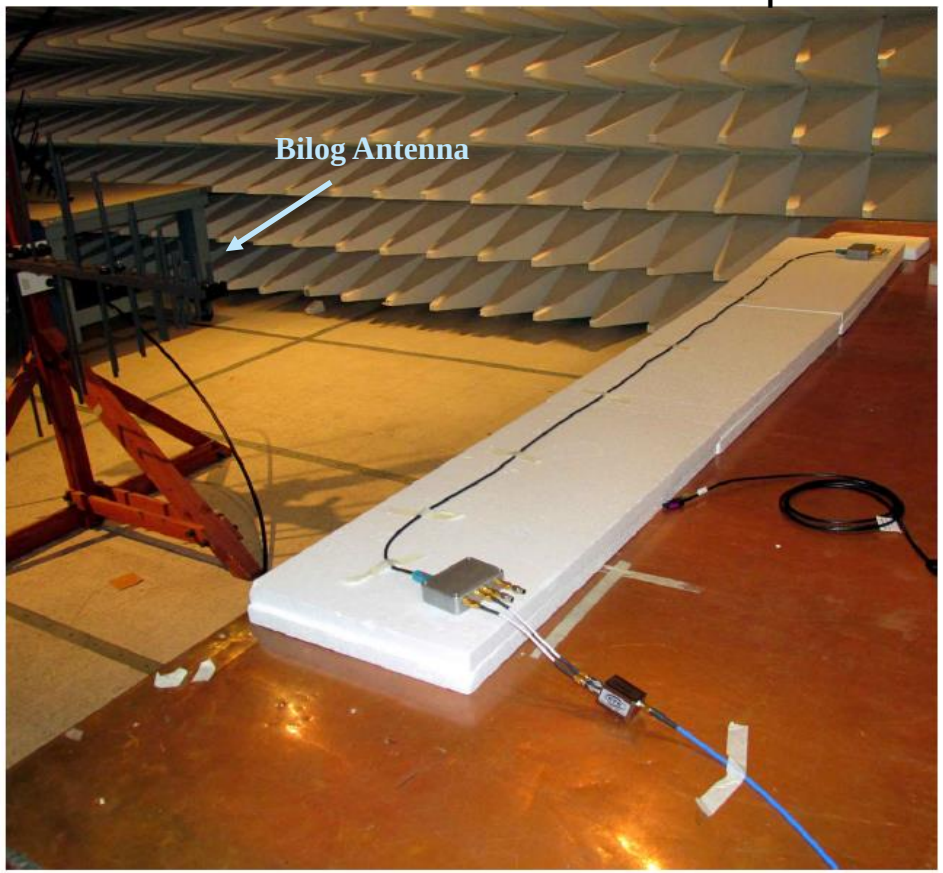
Susceptibility Tests to RF Interference

- RF Interference Coupling to Cable Differential Pairs
  - ALSE 80MHz - 5GHz (ISO11452-2/ OEM specs)
    - Spec is to have an electric field of 50V/m to 100V/m at the cable
    - Use actual antenna radiating an electric field at the cable
  - BCI 1MHz – 400MHz (ISO11452-2/ OEM specs)

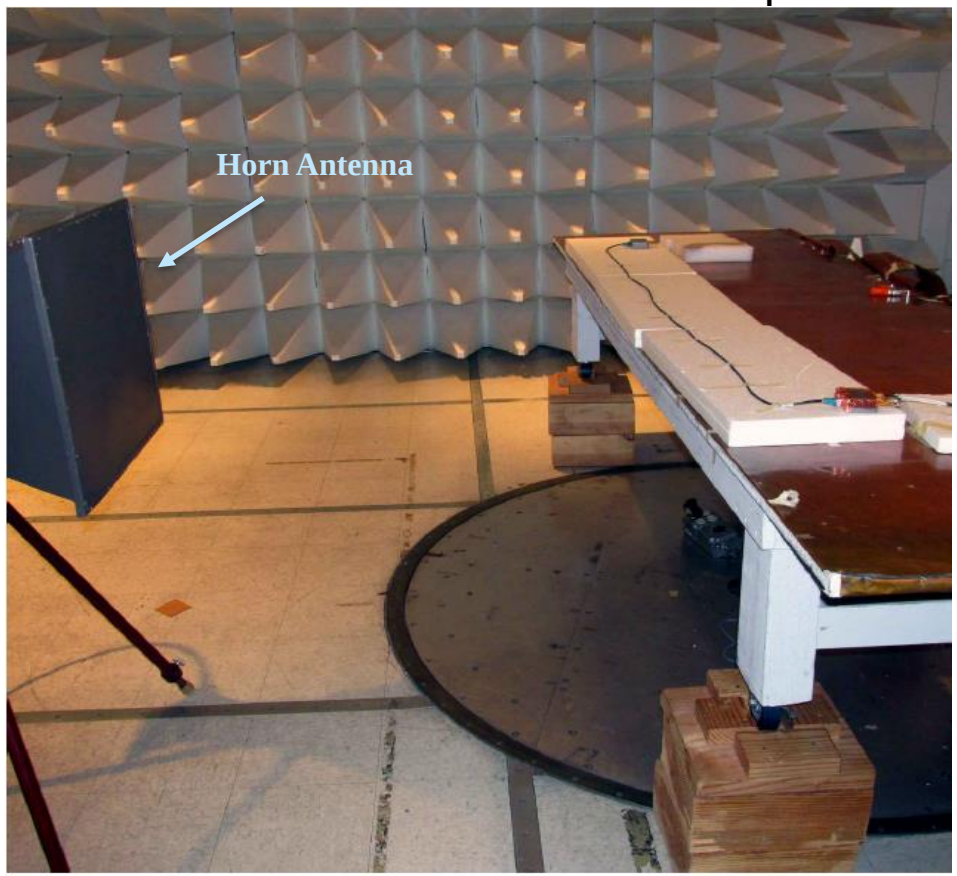
- The RFI tests are meant to determine the tolerance of the whole system/link, including the PHY and the channel, to RF interferences
  - If either PHY or the channel are poorly designed, the link will fail the RFI susceptibility tests
  - Therefore in case of a failure, there needs to be additional tests to determine if the PHY or channel is the problem
  - Simple differences/oversights in building the channel can lead to large RFI coupling to the differential lines
    - Examples: Poor shielding of box breakouts, Type of connectors (inline vs. right-angle PCB), etc
      - Right-angle PCB mount connectors are commonly used in actual products, but they generally have worse EMC characteristics than inline connectors (and cables)

ALSE Test Setup for STP Cable with H-MTD Connector

80MHz – 1GHz EMI Test Setup



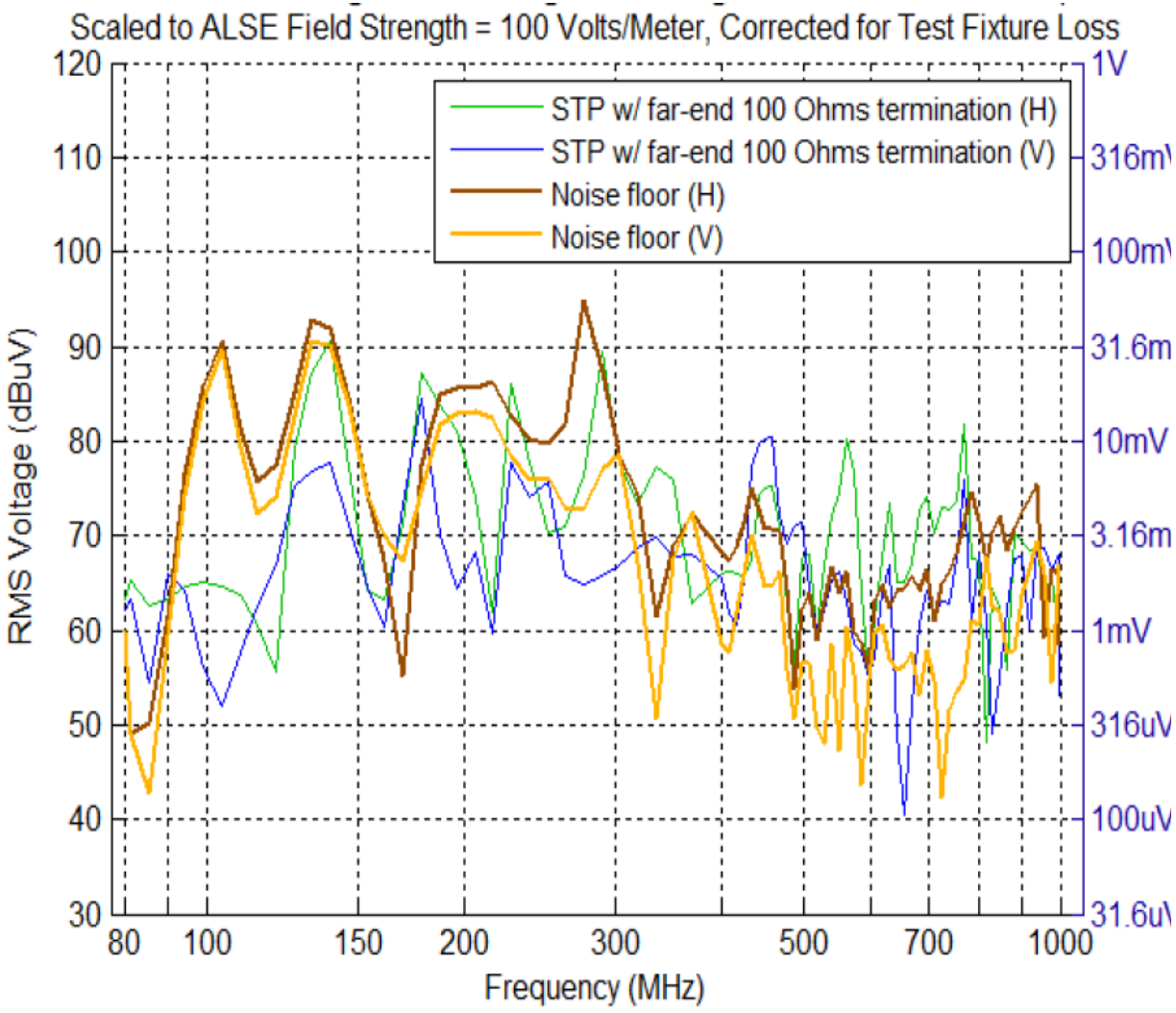
1GHz – 3GHz EMI Test Setup



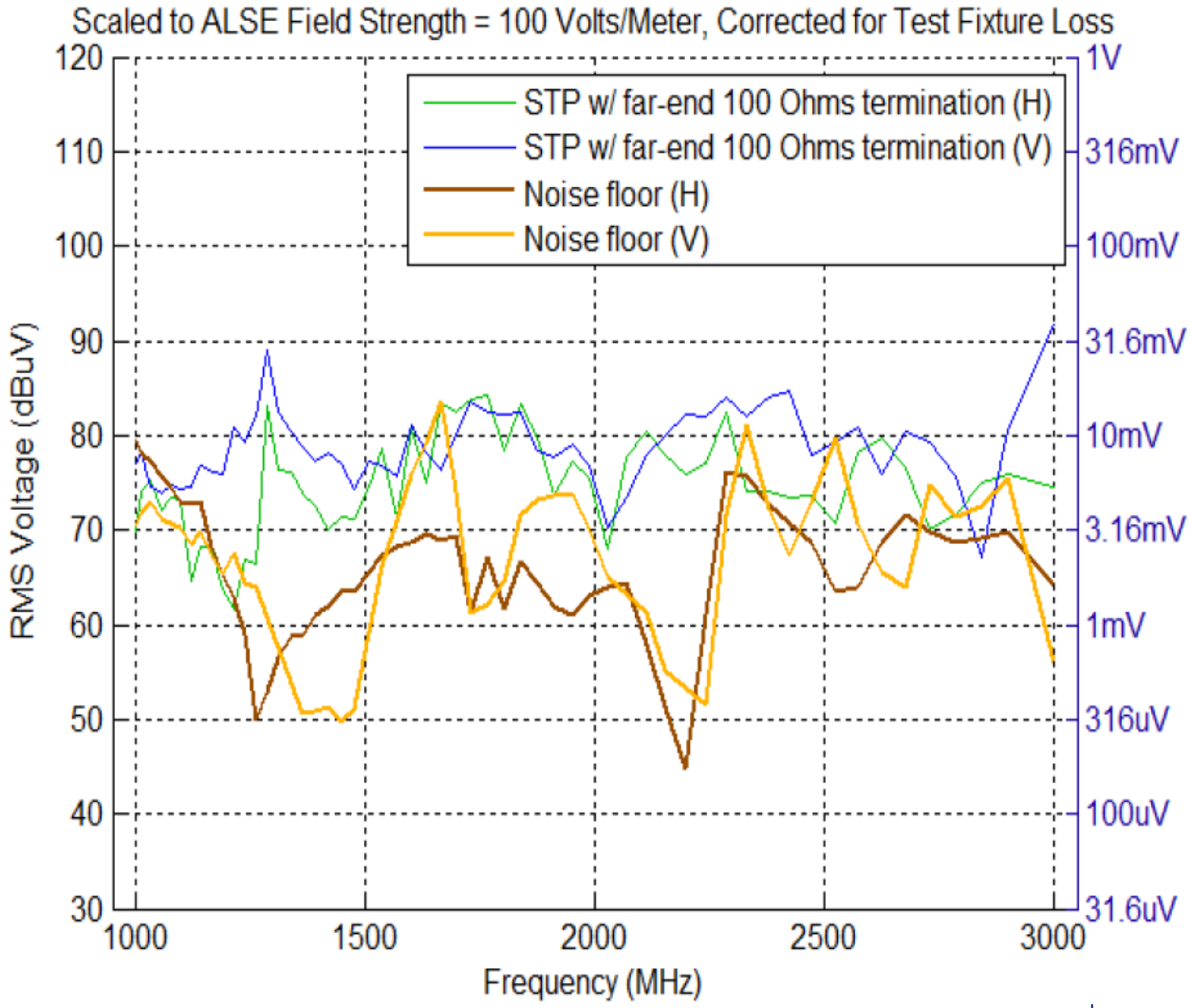
- Measurements were done with both vertical (V) and horizontal (H) waves
- Test fixtures used right-angle PCB mount connectors with a direct connection of the connector shield/ground pins to the test fixture ground plane

Initial ALSE RFI Measurements on STP/H-MTD

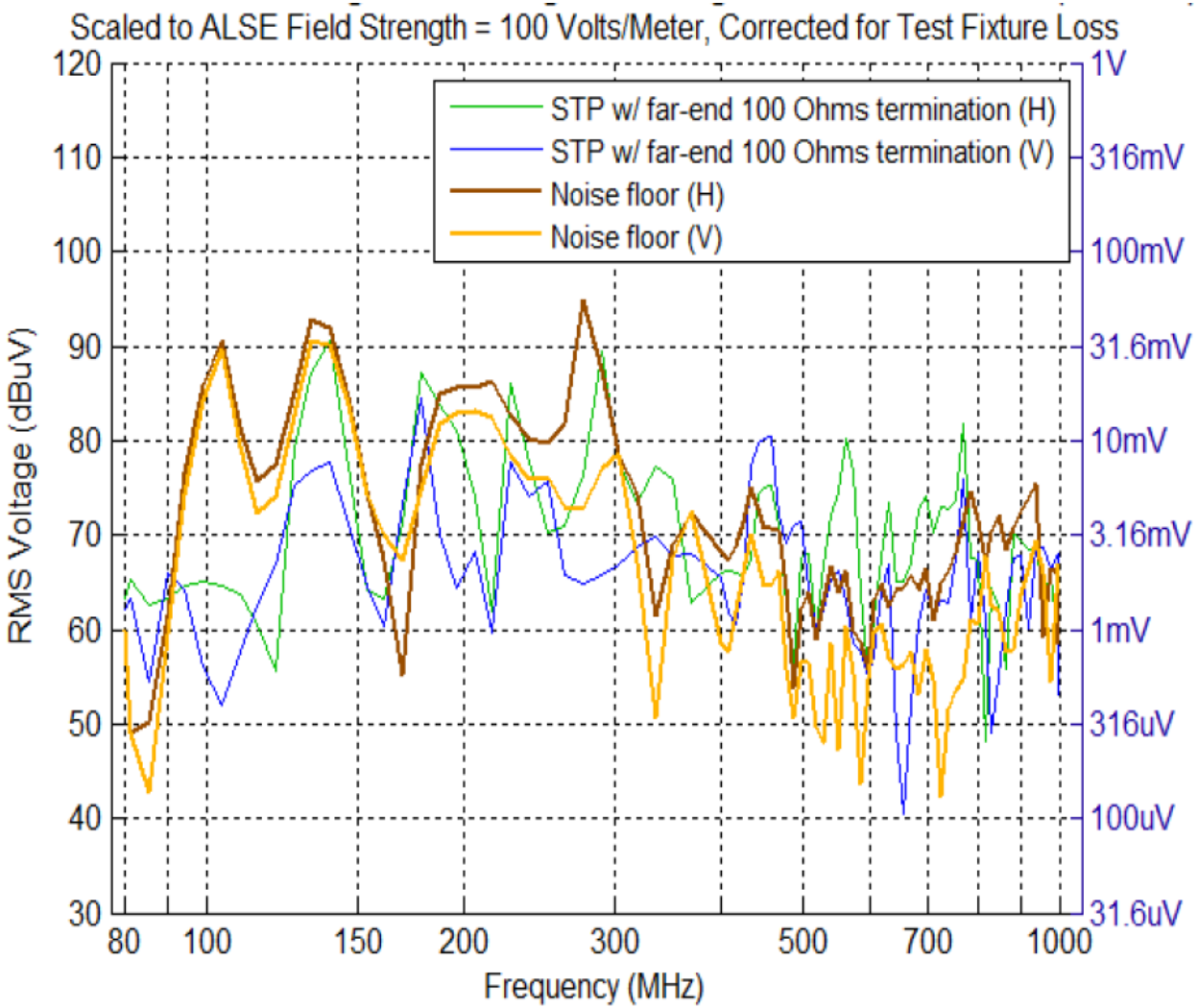
80MHz – 1GHz EMI Test



1GHz – 3GHz EMI Test

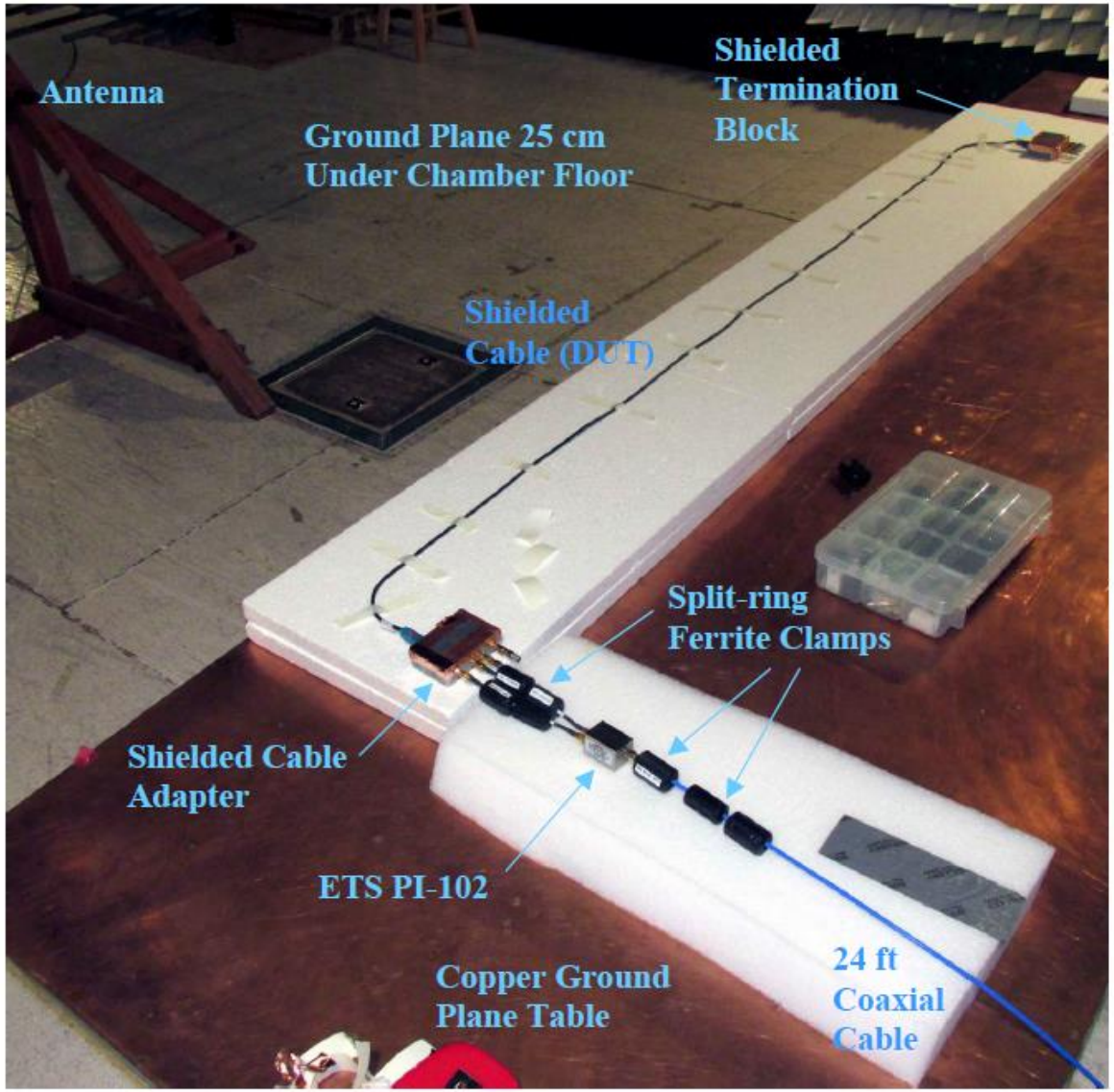


High Noise Floor in Initial ALSE RFI Measurements



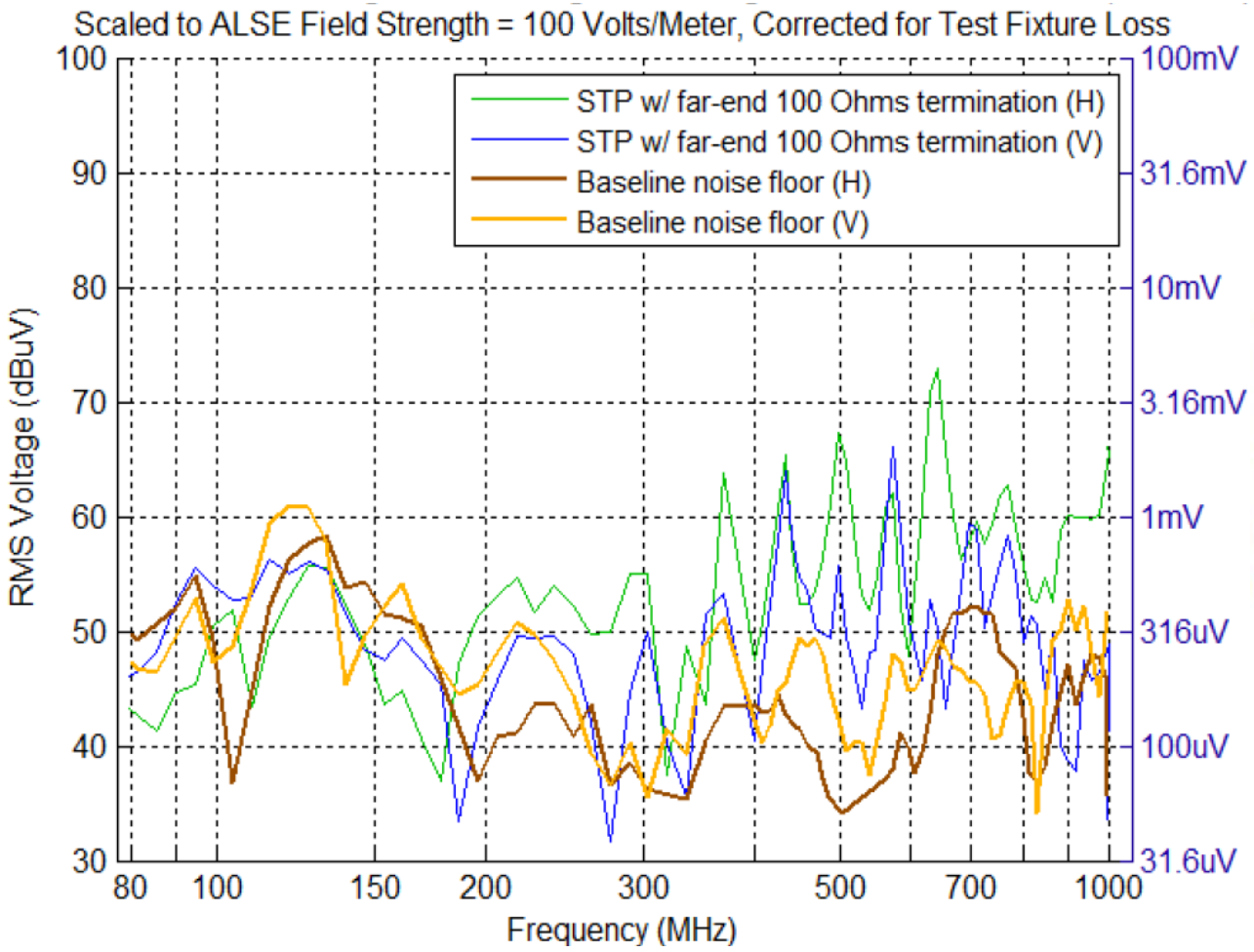
- Noise floor magnitude is the RF signal captured with the cable assembly under test disconnected from the breakout box, and its connector apertures covered with copper tapes
- A very high noise floor was observed in the initial measurements, dominating the RFI measurement with actual cable assembly under test!
- This was caused by RF radiation coupling into unintended paths, specifically through seams in the breakout box and leakage through the coaxial cable shield!
- These leakage signals raised the noise floor above the true ingress level of the attached cable under test, thus significantly affected the measurement accuracy

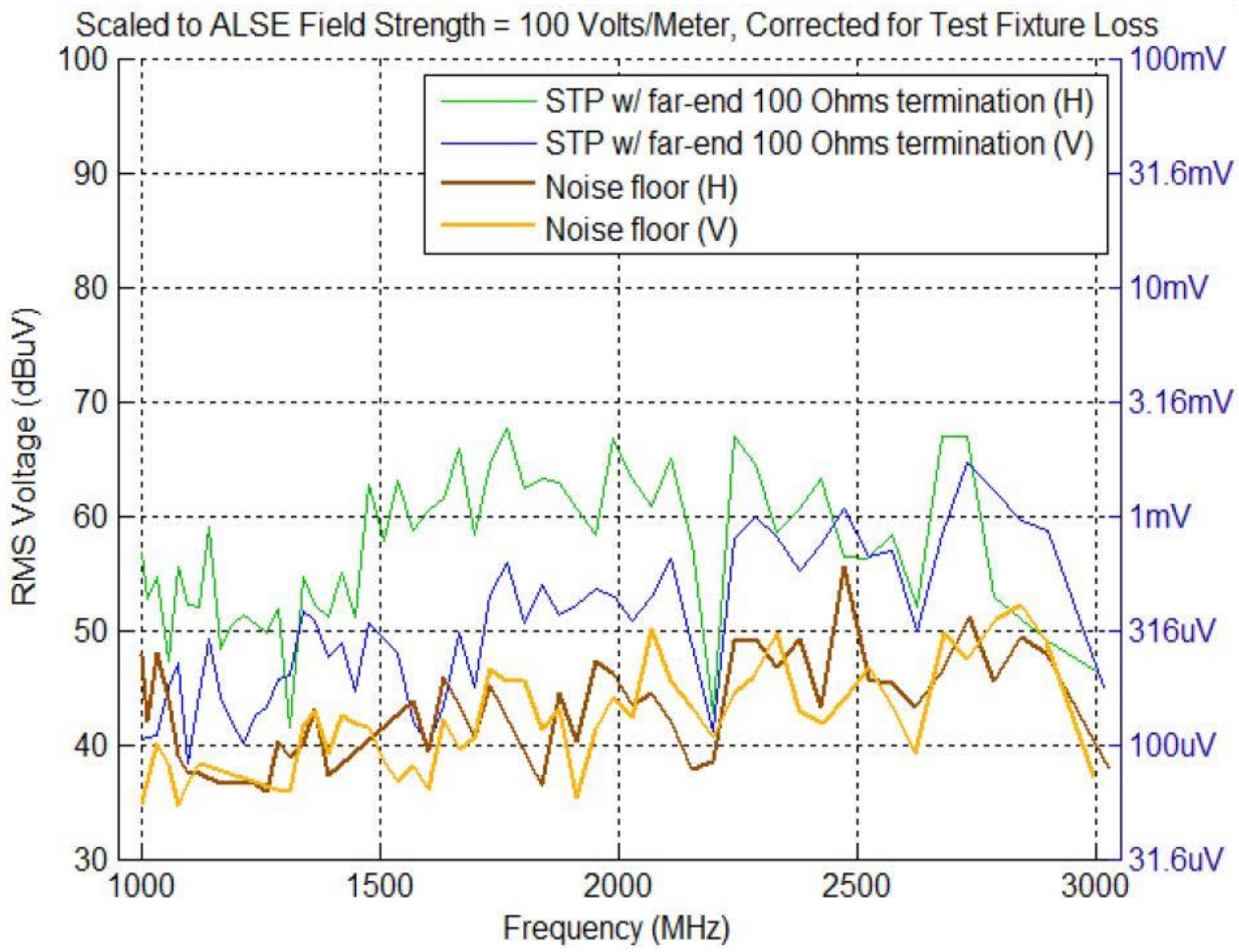
Solution to High Noise Floor in ALSE Measurements Setup



1. The seam problem was solved by placing copper tape over any seams/gaps in the breakout box enclosure.
   - Useful mainly for the frequencies > 500 MHz
2. The coaxial cable leakage problem was solved by adding ferrite clamps to all exposed coaxial cables (box to balun and balun to spectrum analyzer).
   - Useful mainly for frequencies < 500 MHz

ALSE RFI Measurements with Proper RF Isolation

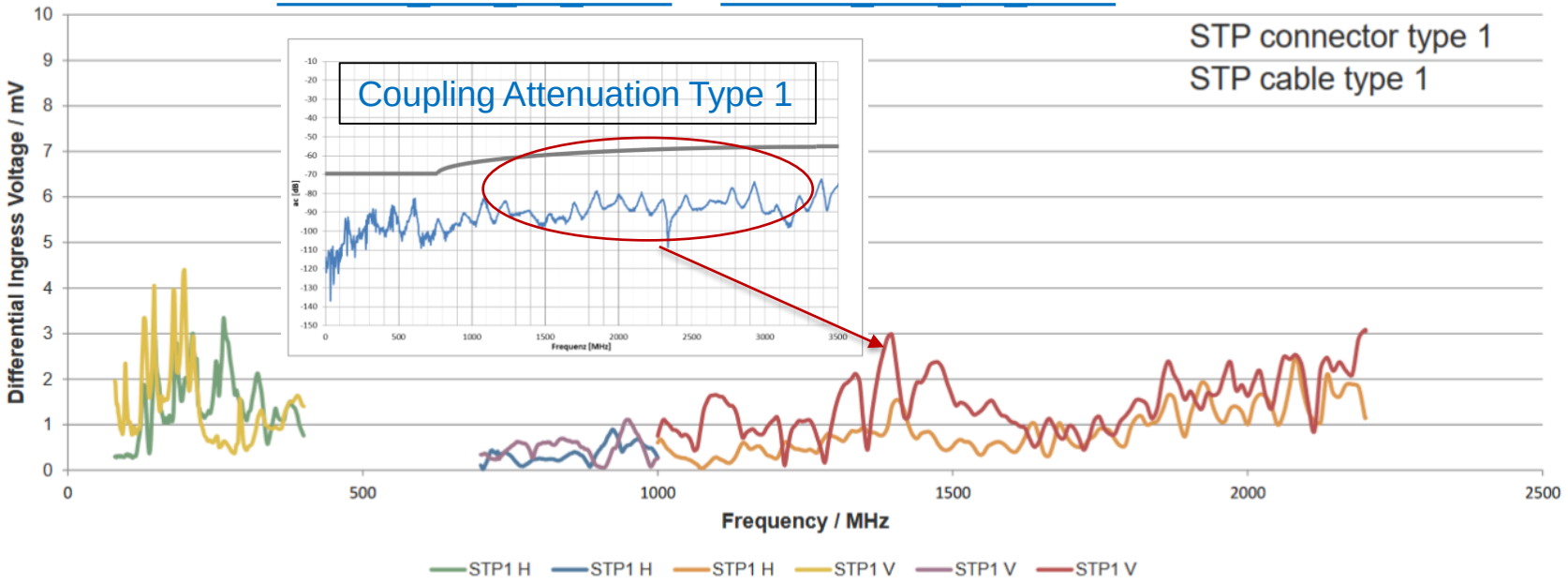


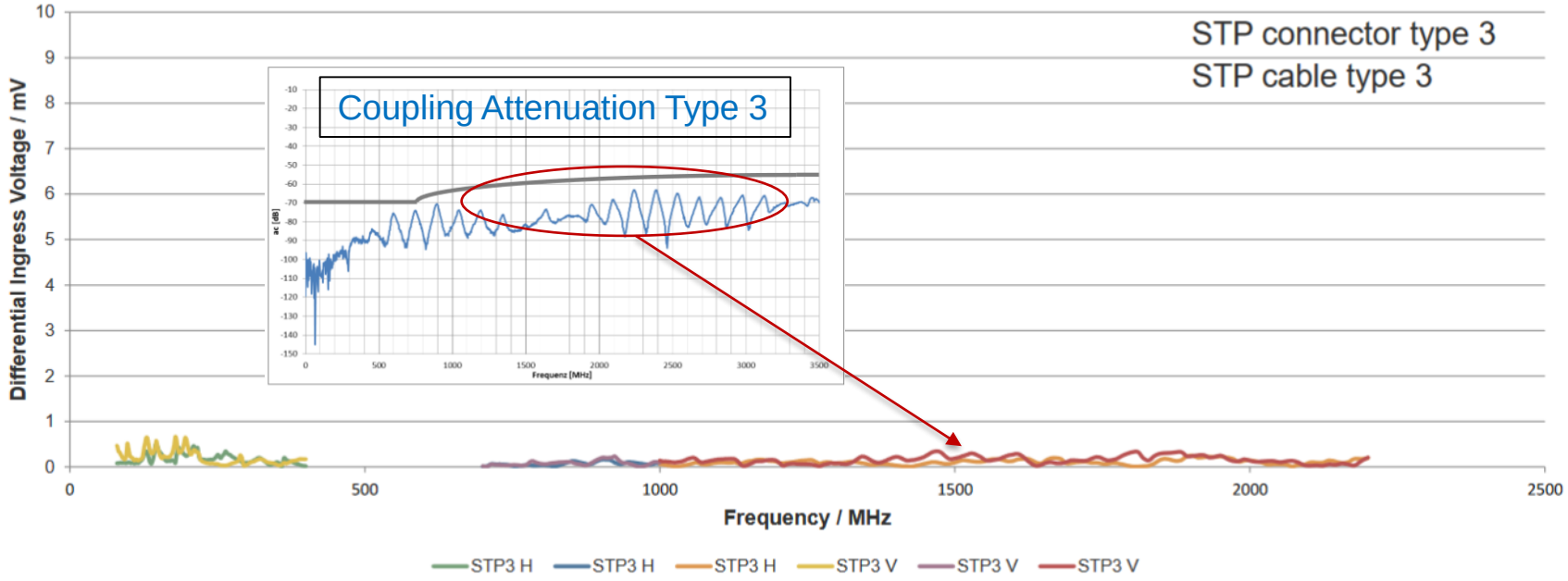


- Baseline noise floor dropped by 20db-30dB, allowing the RFI magnitude with actual cable under test to stand out.

Coupling Attenuation & RFI Ingress

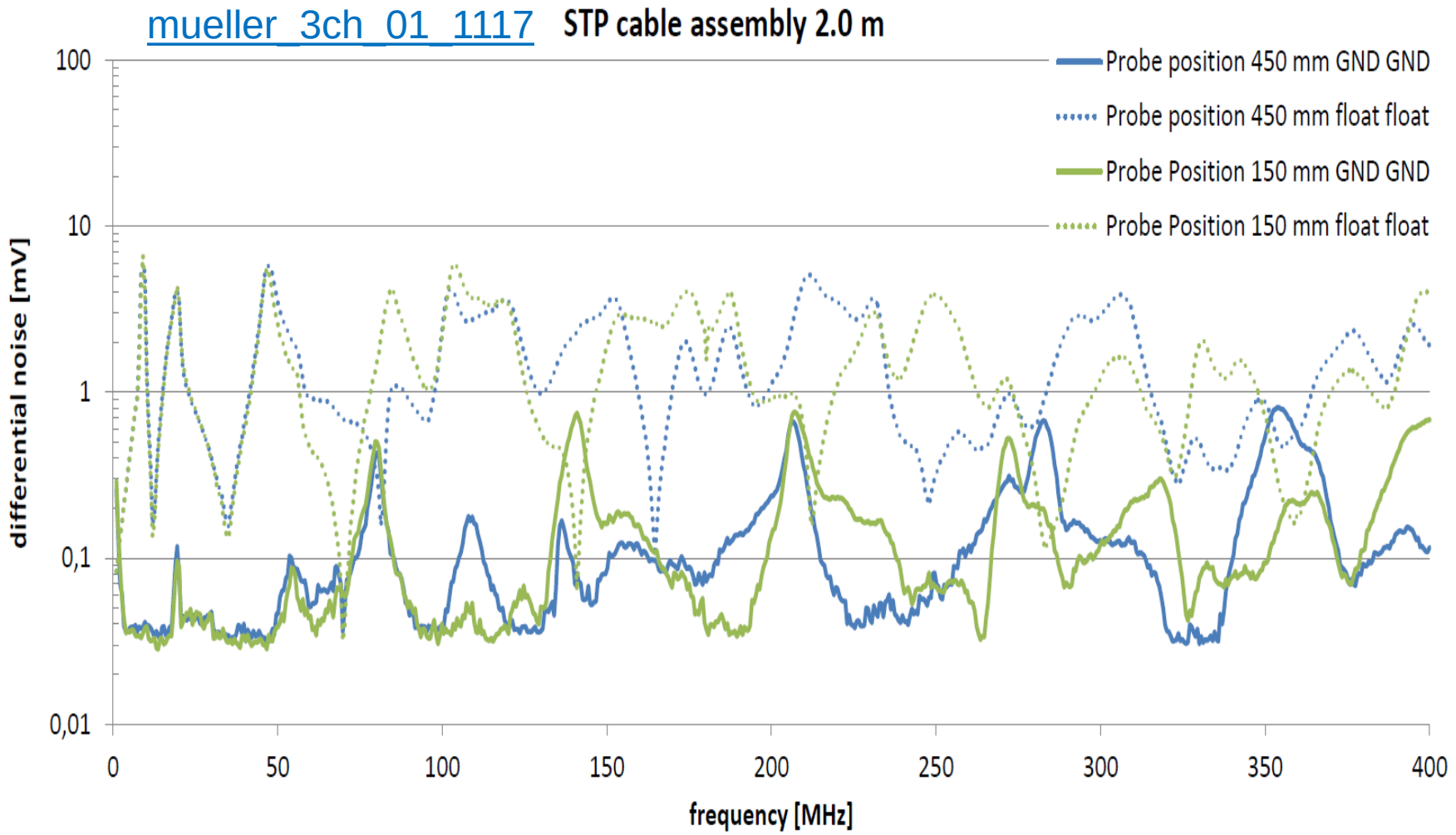
mueller_3ch_02_0518 & mueller_3ch_03_0518





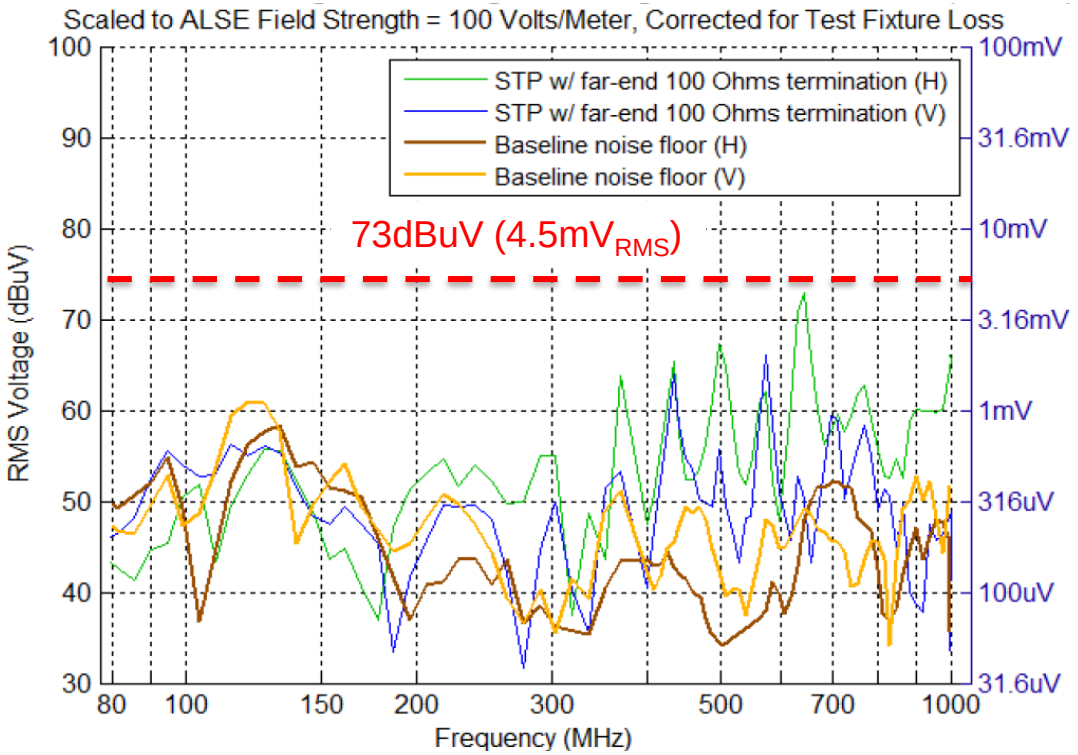
- As a result of RFI leakage into the other units used in the complete system setup, we cannot solely rely on Coupling Attenuation specification of cable assembly to define the actual RFI Ingress magnitude
- A cable assembly can have very good Coupling Attenuation, but poor EMC characteristics at the end connections can significantly increase PHY exposure to RF ingress
  - Internal connector C-to-D conversion and/or high RF impedance in the cable shield ground connection

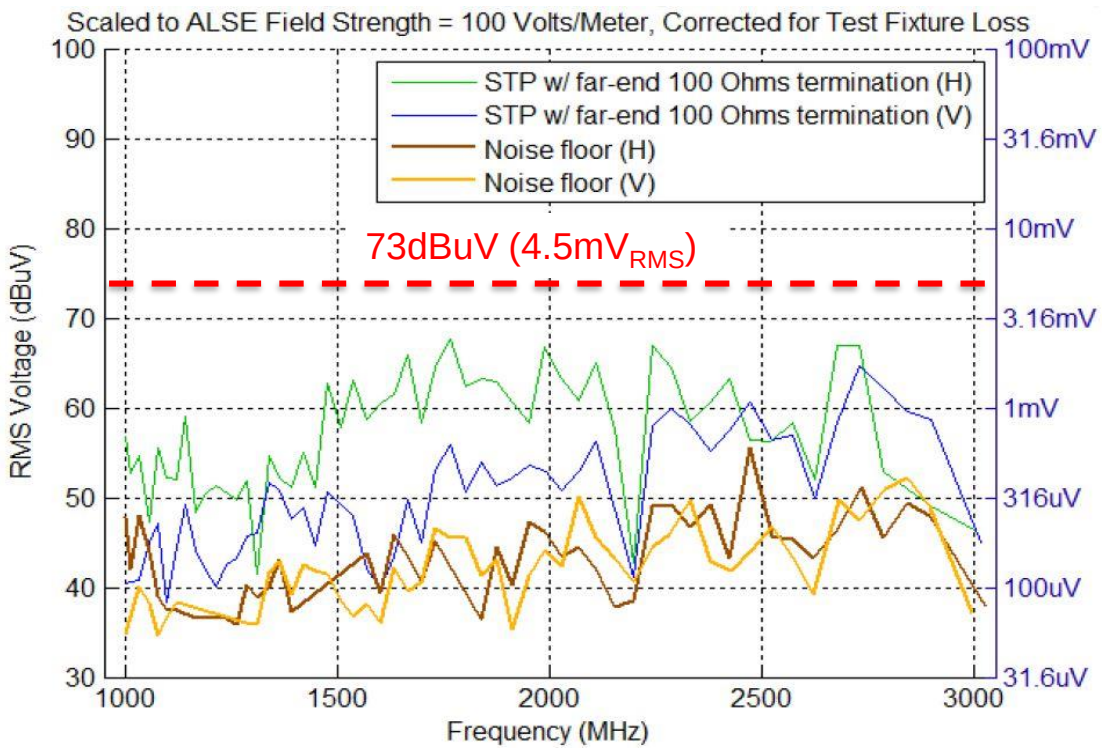
BCI Measurements for STP Cable with/without Grounded Shield



- A similar problem can be observed in BCI test depending on whether the cable shield is properly grounded or not
- The differential noise coupled to the cable terminal can vary by an order of magnitude for the same cable (with same coupling attenuation)

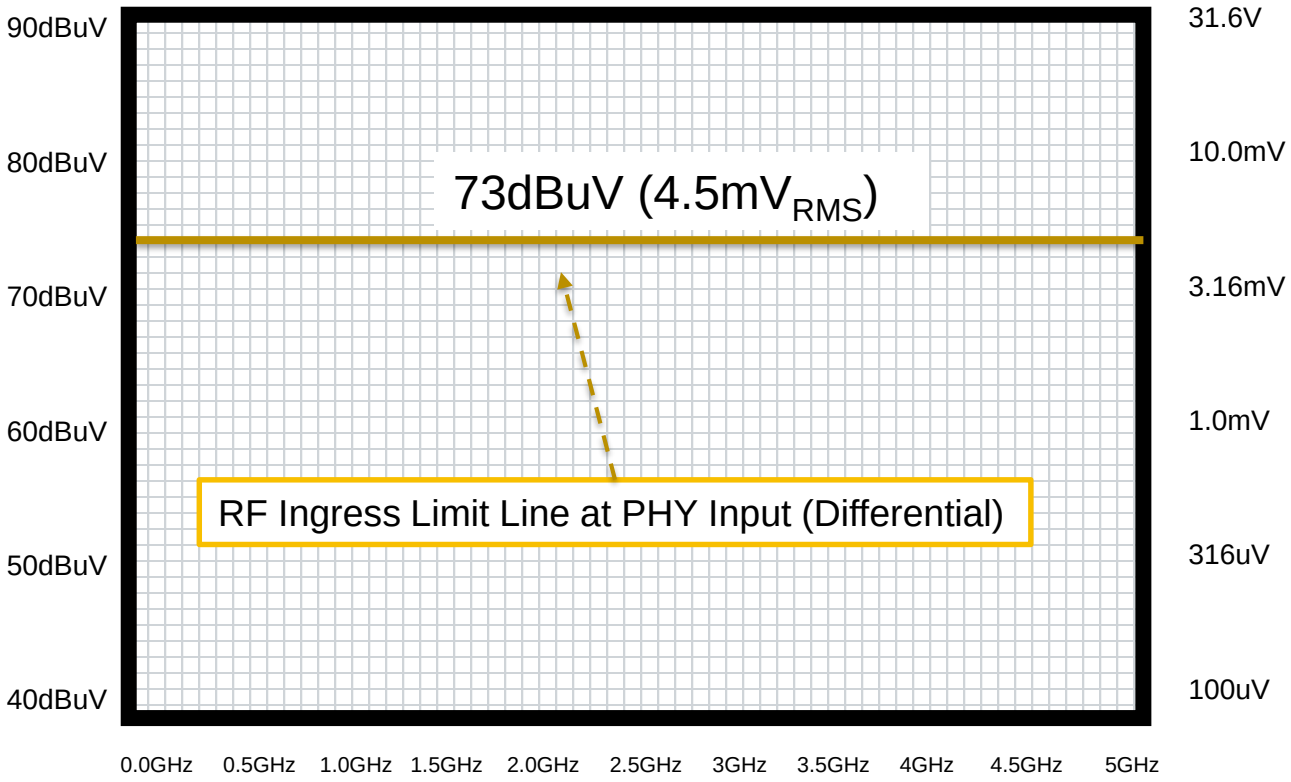
Define a Spec for RFI Ingress under ALSE Test





- In order to design an automotive PHY with properly calculated RF exposure tolerance, we need to ensure the whole link (not just the Cable + Connectors) meet a certain RFI attenuation spec
- The proposed spec line should set a limit line for RFI ingress voltage measured at the PHY differential inputs for the full link/system under ISO/ALSE test condition

Proposed Limit Line for RFI Ingress under ALSE Test



- Proposed limit line for RFI Ingress voltage measured at the PHY differential inputs for the full channel under ISO/ALSE test condition:

RF Ingress at PHY Input ≤ 73dBuV (Differential)

Frequency Range 100kHz-5GHz

- All the RFI Ingress measurements using STP/H-MTD Cable Assembly under ISO/ALSE test condition with 100V/m of radiated field meets the proposed RFI Ingress Limit Line with a margin

Thank you.

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