Follow-up to 10BASE-T1S Immunity Measurements
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Objectives and Motivation

• This presentation responds to presentation [1] from Ivanov et al. and is a follow-up to Broadcom presentation [2] on noise.

• 10BASE-T uses Manchester Encoding to transmit 5Vpk-pk (nominal).

• 10BASE-T1S uses Differential Manchester Encoding (DME) to transmit 1Vpk-pk
  – Less transmit swing than 10BASE-T and much higher noise environment.

• Revisit noise topic again using Bulk Current Injection (BCI) clamp method[3].

^ TX Voltage currently TBD in 147.5.3.1
BCI Test Motivation

- Examine the feasibility of implementation of 10BASE-T1S for multidrop automotive configurations.

- Investigate possible immunity-related problems.

- Worst-case EMI-coupling clamp locations are different from testing strictly to ISO 11452-4.
  - Strong resonances will be seen at other clamp locations.

- Long harnesses exhibit in-band resonances at lower frequencies than a 2m cable.

- If a problem does not show at standard clamp locations, it does not mean they do not exist.

→ Must design systems with margin to handle realistic worst-case conditions.
Difficulties with Measurement

• Conversion
  – Peaks at 15 & 30MHz w/o termination in [2] were real but noise radiated out from amp connector.
  – 100BASE-T1 CMC doesn’t have good common to common rejection at low frequency (-20dB).
  – scope converted large common mode voltage to differential noise at 1MHz.

  ➔Eliminate sources of conversion.
  – Use well-shielded differential probe with large CMRR @ 1MHz (Tektronix P6247)
  – Solder short connection directly to PHY-side of CMC.
  – Use coax with low leakage at test frequencies.
  – Add ferrites. Sniff with spectrum analyzer for clean environment with test running.

• Termination – different schemes possible. Each has tradeoffs.
  ➔Utilize termination scheme similar to [1] (except CM term of 250Ω and DM term 1KΩ -- no moat on board)

• All test setup details available on request.
Test Setup

- 100BASE-T1 CMCs at each signal node. CM termination 250Ω to gnd (L0) before CMC.
- 100BASE-T1 cables (26 AWG) in passive linear topology “min” from [4] 5cm above gnd plane. (10cm stubs)
- 100BASE-T1-quality connectors.
- Solder short 2pin connector directly on CMC for noise measurement. Attach differential probe.
- Sniff cable from power amplifier to BCI clamp for any emissions, check connectors. Add ferrites.
- Injection calibrated for 200mA RMS flat level vs. frequency.
- Grounding test conditions:
  - Grounded: all board L0 connected to gnd plane
  - Floating: boards L0 floating 5cm above gnd plane, not connected to gnd plane.

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**Diagram:**

- Signal Generator
- Power Amplifier
- BCI CLAMP
- Probe power supply
- Tek P6247 Diff probe
- Real time scope
- 2.5K Ω to L0 termination (0.5% matching) on PHY side of CMC to protect probe input
- 500Ω (2x1K in ||) (0.1% match) to L0 term on line side of CMC. 250Ω CM term, 1KΩ DM term on each signal node.
- Measurement using differential probe
DM noise, Board Ground Connected to Ground Plane

- DM noise greatly reduced, especially @ 1MHz – due to high CMRR of differential probe
- Note different noise levels at different nodes of the multi-drop configuration.

Note: L0 = Board Ground.
DM Noise, Board Ground Floating Above Ground Plane

- Different clamp location (approx. 1500mm) from node H, all nodes floating.

Note: L0 = Board Ground.
Mode Conversion

- Mode conversion plotted for the tested cable harness and 147.6.3 limit.
  - All CMCs removed, harness 5cm above ground plane, common-mode impedance set to 250Ω on both sides.
  - Clause 147 does not specify setup for common mode impedance for mode conversion.

- Noise measurements need to be scaled, considering the mode conversion of the cable harness.
Scaled DM Noise on Cable Harness

<table>
<thead>
<tr>
<th></th>
<th>16.67 MHz</th>
<th>33 MHz</th>
<th>50 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Node Board L0 connected to ground plane measured DM Noise, mV</td>
<td>50</td>
<td>100</td>
<td>80</td>
</tr>
<tr>
<td>Node Board L0 Floating 5cm above ground plane, measured DM Noise, mV</td>
<td>105</td>
<td>194</td>
<td>132</td>
</tr>
</tbody>
</table>

- Mode Conversion Limit
  - -43.0dB
  - -38.6dB
  - -35.0dB

- Measured Mode Conversion
  - -51dB
  - -46dB
  - -44dB

- DM Scaling Factor
  - 8dB
  - 7dB
  - 9dB

- Node Board Grounded Scaled DM Noise, mV
  - 126
  - 224
  - 225

- Node Board Floating Scaled DM Noise, mV
  - 263
  - 434
  - 372

- Above numbers are for 200mA BCI test level, additional scaling should be done for customers requiring 355mA test level (15-30 MHz band).

- Based on this data, $500\text{mV}_{\text{pk-pk}}$ ($178\text{mV}_{\text{RMS}}$) CW NBI seems like a reasonable design goal.
Summary

- Noise measurements presented with improved measurement setup and common-mode termination.

- CM-DM conversion of 100BASE-T1-based cable harness measured better than 147.6.3 limit.

- Mode conversion data for components is essential in investigating the noise level.

- Differential Narrow-Band Interference is a concern for 10BASE-T1S.

- A robust preamble is essential to improve system performance.

- Use $500\text{mV}_{\text{pk-pk}}$ ($178\text{mV}_{\text{RMS}}$) CW NBI added as basis for comparing preambles & BEACONs.
References


http://www.ieee802.org/3/cg/public/adhoc/cordaro_8023cg_Immunity_Measurements_and_Considerations_for_10BASE-T1S.pdf


[4] “10SPE automotive PHY multidrop topology proposals”, Buntz,
Thank You!