Evaluation of Immunity Aspects in Multidrop Channels

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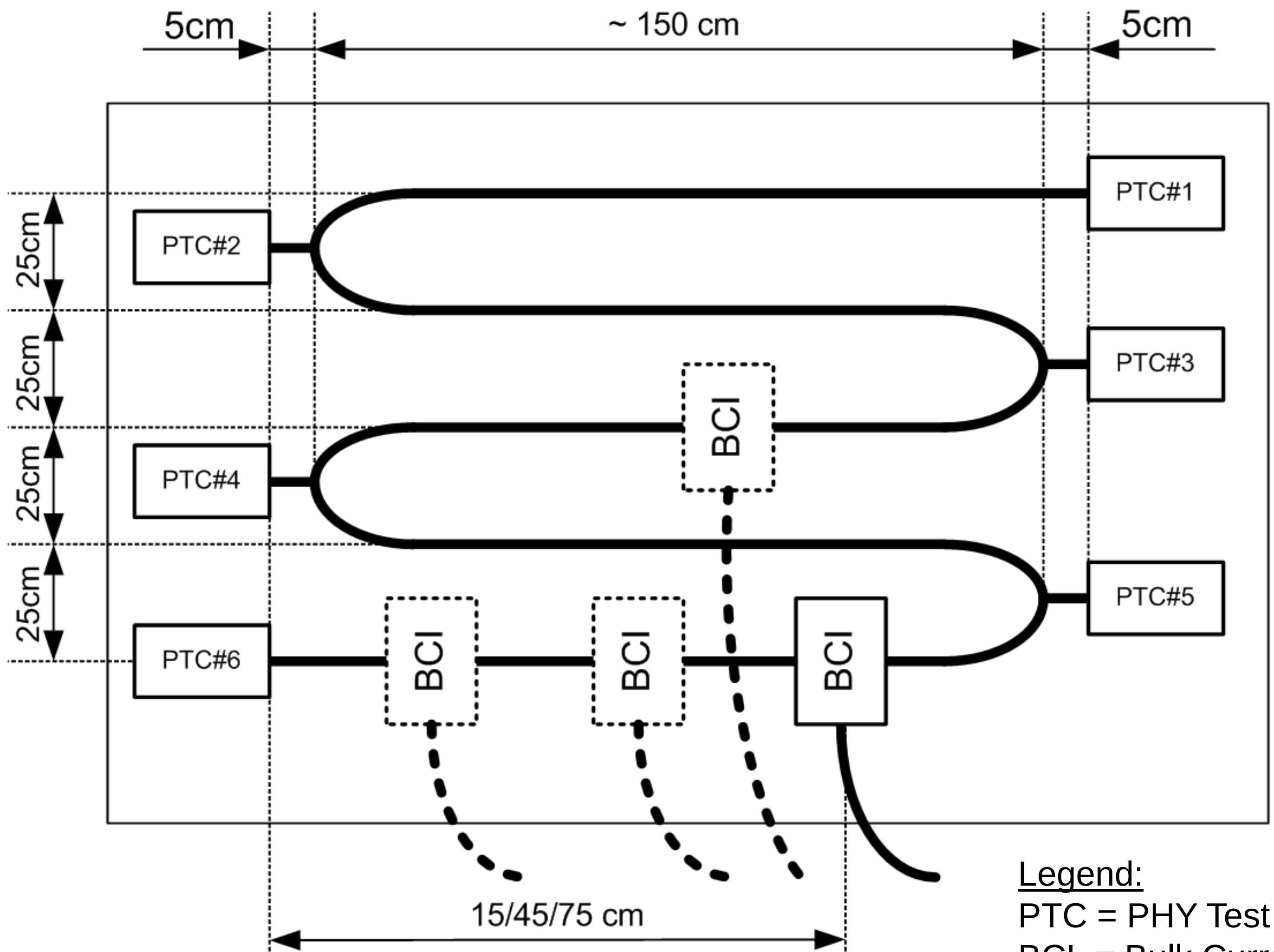
Objectives

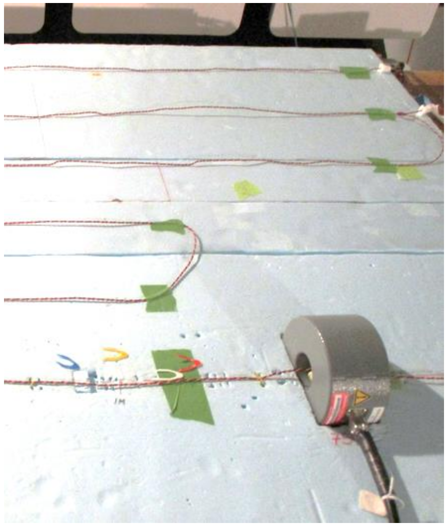
- Generate test setup to effectively evaluate EMI in various multidrop channel configurations
  - Access to End-Nodes and multiple Drop-Nodes locations
  - Minimize effects of measurement fixtures to the channel
  - Minimize RF coupling to the measurement equipment
  - Minimize mode-conversion effects of the measurement equipment
- Evaluate Immunity-related levels
  - Identify and quantify PHY related common-mode voltage (Vcm) and differential-mode voltage (Vdiff) levels
  - Identify major contributors to Vcm
  - Identify mechanisms for Vcm build-up

Test Setup Layout



Legend:
PTC = PHY Test Card
BCI = Bulk Current Injection Clamp

Test Setup Considerations



- Harness with multiple taps
  - Allows study of various multidrop configurations
  - Enables evaluation of the dependencies of Vcm and Vdiff vs. frequency vs. physical location

- More realistic cable used – UTP vs. Jacketed UTP

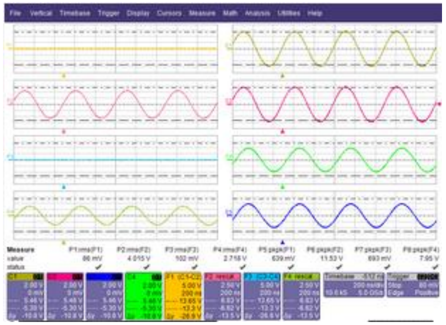
- A specific sub-set matches the setup quoted in [1].
  Used for correlation

[1] “Immunity Measurements and Considerations for 10BASE-T1S”, Cordaro,
http://www.ieee802.org/3/cg/public/adhoc/cordaro_8023cg_Immunity_Measurements_and_Considerations_for_10BASE-T1S.pdf

Test Setup Safeguarding

- PHY Test Cards (PTC#n) designed to minimize effects of measurement fixtures to the channel under test
  - Allow to experiment with various termination configurations
  - Validation tests performed to ensure correct interconnect and correct termination options are installed prior to each test

- Careful setup layout to ensure minimal RF coupling to the measurement equipment
  - Validation test runs performed to confirm the levels are below the measurement resolution



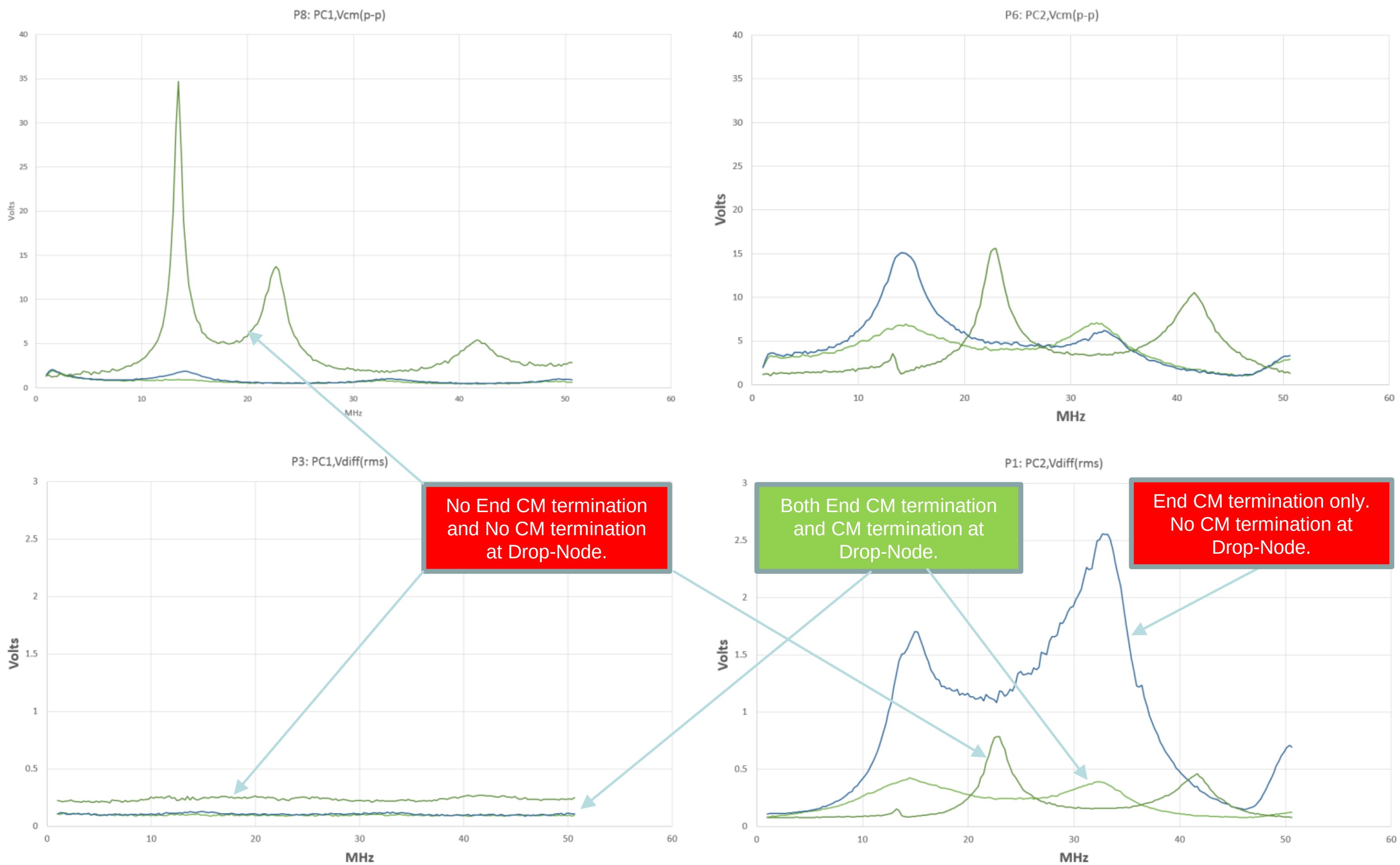
- All interconnects are skew compensated, amplitude and offset matched in order to minimize measurement induced mode-conversion
  - Validation test runs performed to ensure the residual conversion amplitude

Measured Vcm and Vdiff levels without CMC

End-Node | Drop-Node

Vcm

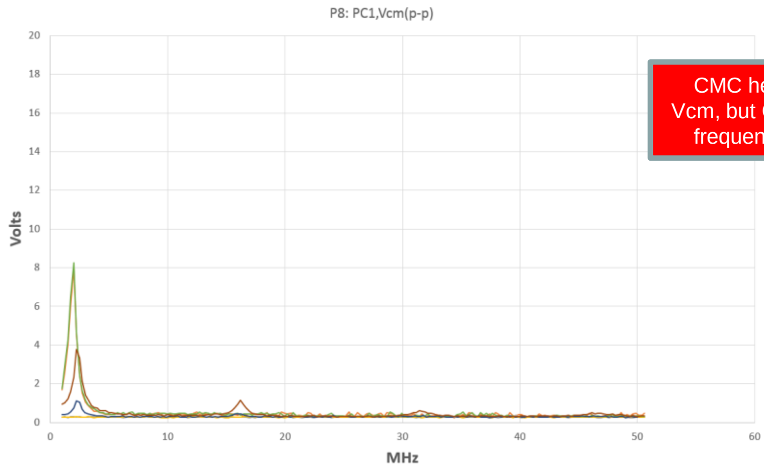
Vdiff

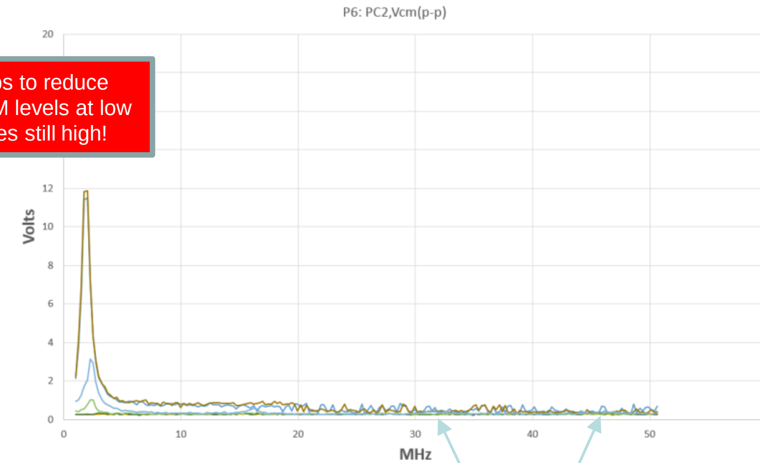


Measured Vcm and Vdiff levels with CMC

End-Node | **Drop-Node**

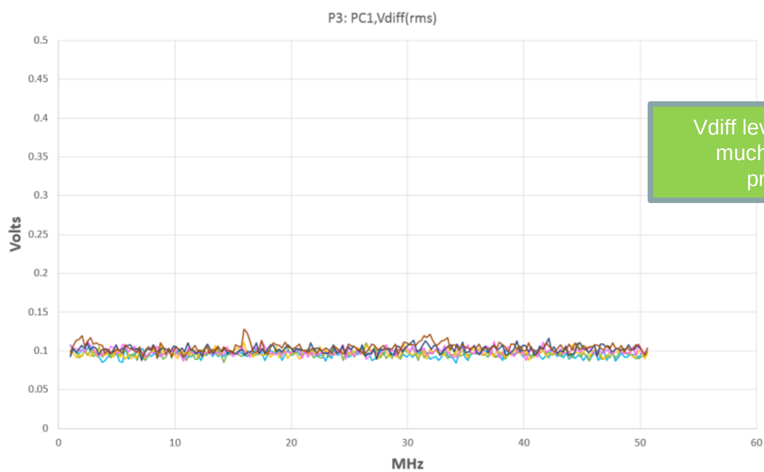
Vcm

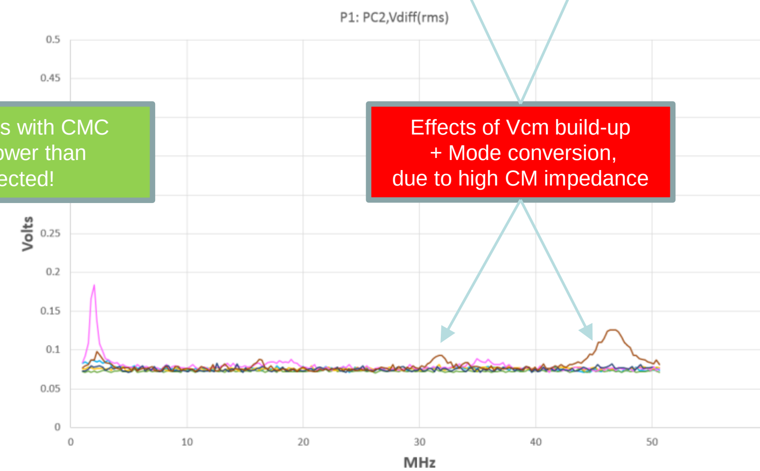




CMC helps to reduce Vcm, but CM levels at low frequencies still high!

Vdiff





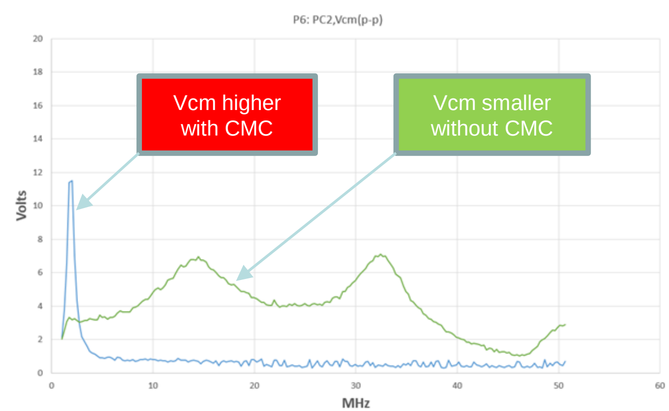
Vdiff levels with CMC much lower than projected!

Effects of Vcm build-up + Mode conversion, due to high CM impedance

Note: RMS valuation used for Vdiff, since p-p results are under the acquisition noise floor

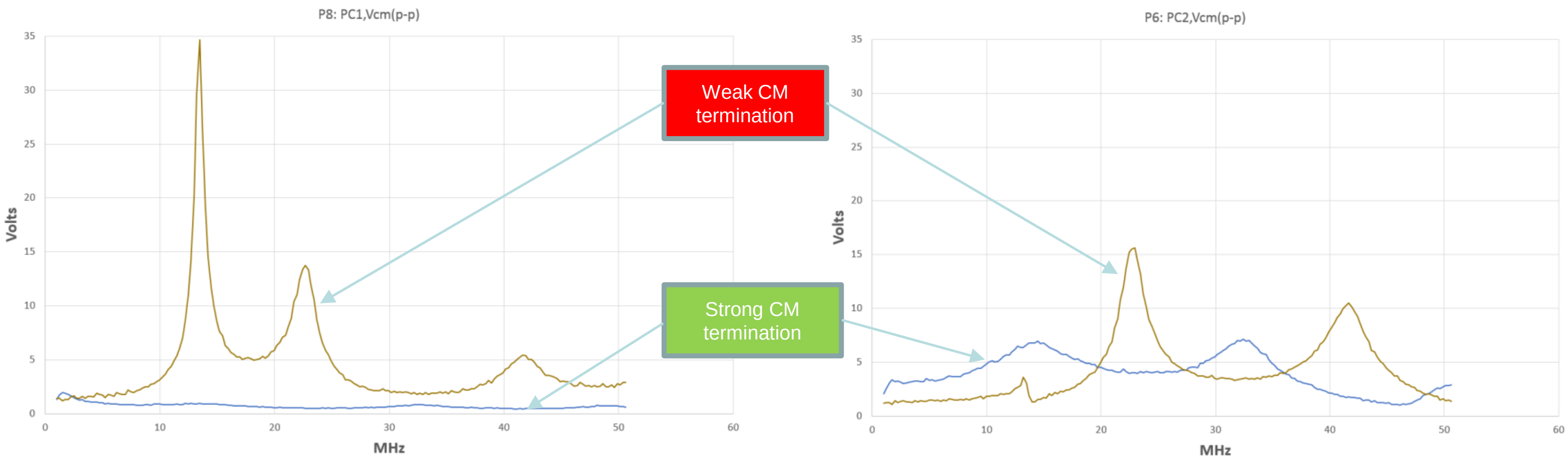
Contributors to Vcm

- **Introducing alien EM energy to the system/channel**
  - As opposed to the Nodes' coupled EM energy – cannot be controlled. Subject to harmonized and vendor-specific EMC.
- **Inductive vs. capacitive coupling**
  - Capacitive coupling – generated voltage can only get as high as the source. Parasitic capacitance typically very small. Total coupled energy small.
  - Inductive coupling – coupled current converted to Voltage at paths with high impedance: such as CMCs(!) and high CM impedance Drop-Nodes
    - The resulting high CM Voltage levels modulated by mode-conversion effects end up as Vdiff noise!
    - Target is to keep CM impedance as low as practical!



Mechanisms for Vcm build-up, #1

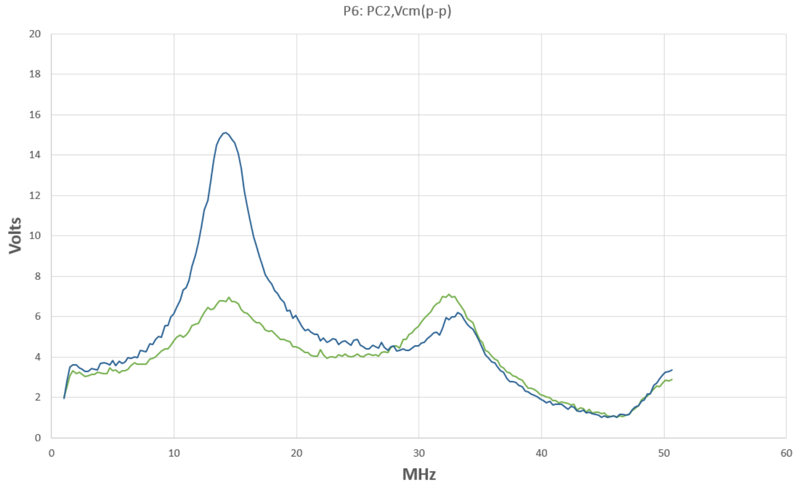
- **Law of preservation of energy dictates, that once EM energy is coupled to the system (multidrop channel), the only ways it may leave the system are:**
  - transferred (i.e. radiated) – may couple back, e.g. to your measurement equipment/device circuits(!) or
  - converted (i.e. dissipated) – happens only in **resistive** components (converted to heat) – the only safe way is to use **strong CM termination**!



Weak vs. Strong CM termination – End-Node **Weak vs. Strong CM termination – Drop-Node**

Mechanisms for Vcm build-up, #2

- **Antenna effects on non-uniform transmission line**
  - CM impedance cannot be tightly controlled
  - Reflections and resonances inevitable
  - Standing-wave patterns build-up implications:
    - Voltage maximums (function of frequency and location) expected to be most significant for the Drop-Nodes
    - Can mitigate those by adding CM termination to the Drop-Nodes – the drafted 10 kOhm input impedance requirement needs to be revised!



Vcm at one example Drop-Node (PCT#2):
blue trace - with no CM path to GND and
green trace - with 500 Ohm
(1 || 1 kOhm resistors) to GND

Note: No CMC – direct connection

Conclusions

- Common-mode termination is a must – at minimum at the end-termination
- Common-mode termination at each Drop-Node improves significantly the system EMC behavior. The drafted 10 kOhm minimum input impedance requirement needs to be revised.
- External CM suppression is most likely needed. CMC may not be the optimal solution though (still high CM levels).
- Measured EMI contributed Vdiff noise significantly smaller than projected by [1]. Based on those we see no justified need for special preamble.

[1] "Immunity Measurements and Considerations for 10BASE-T1S", Cordaro, http://www.ieee802.org/3/cg/public/adhoc/cordaro_8023cg_Immunity_Measurements_and_Considerations_for_10BASE-T1S.pdf