Multi-level PAM Study for M-Gig Automotive PHYs

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PAM scheme in Automotive PHYs

- PAM3 for 100BASE-T1 (802.3bw)
- PAM2/PAM3 + FEC for 1000BASE-T1 (802.3bp)
- Multi-Gig PHY (802.3ch)
  - Simple Scale from 1000BASE-T1 means big bandwidth, 937.5Mhz for 2.5GBASE-T1 (375Mhz for 1GBASE-T1)
  - Multi level PAM scheme beyond PAM3 should be considered.
- Higher PAM levels Vs. Baud rate
  - benefits: lower baud rate, smaller bandwidth used, less channel insertion loss
  - issues: smaller eye, higher SNR required, more complicated DSP, more susceptible to noise/NBI
  - Emissions concerns with higher TX amplitude

PAM scheme with EMI noise at MDI

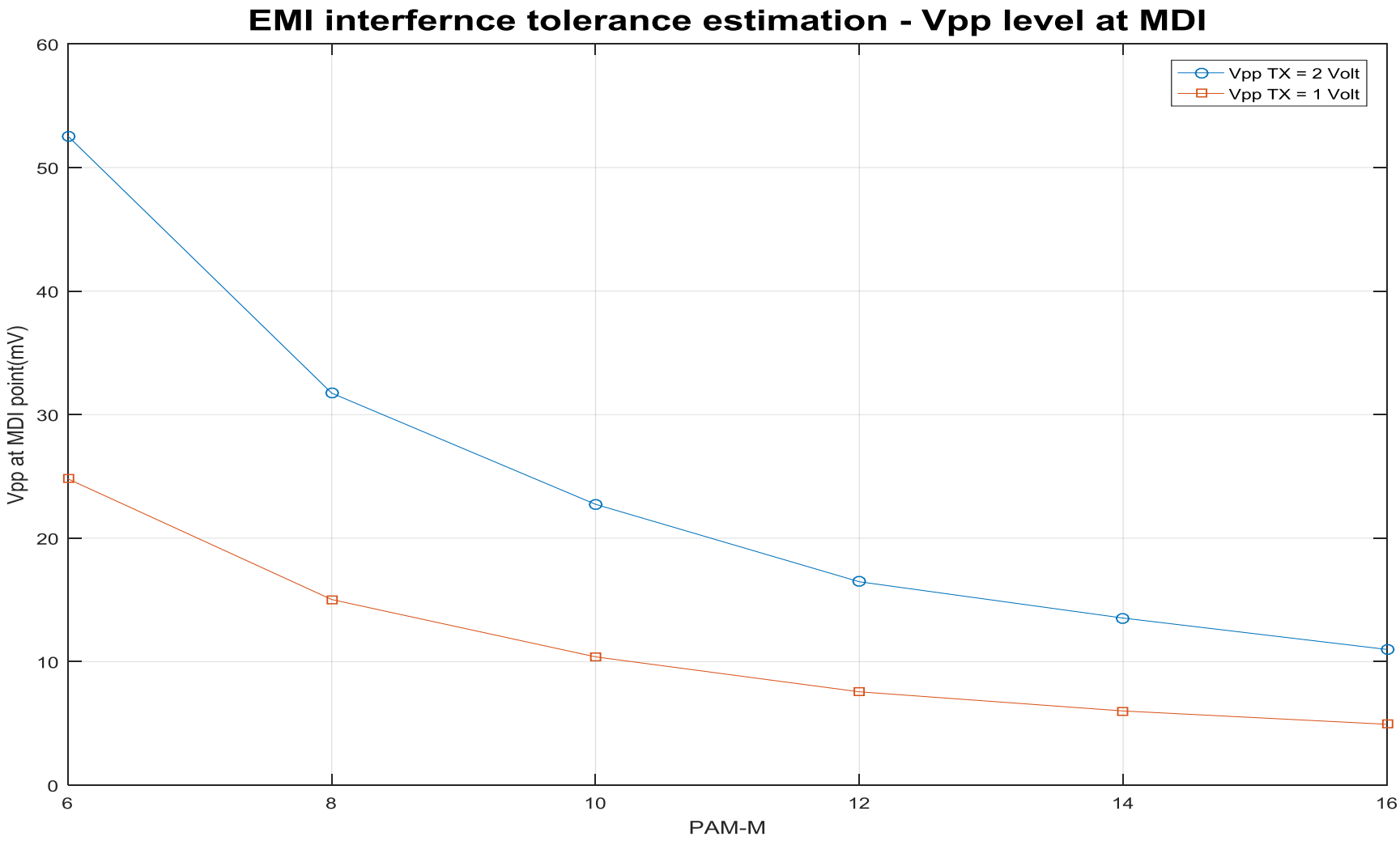
- EMI noise shown at Slicer
  - EMI noise at MDI
  - Insertion Loss of total channel
- The Symbol error rate of PAM-M can be estimated at worst case.
  - $\boldsymbol{V_{emi}}$ is the V_{pp} of EMI noise shown at Slicer, it is related to EMI noise level at MDI, channel Insertion loss, and detailed receiver design
  - M is PAM level
  - V is the peak level of Transmit signal
  - $\boldsymbol{\sigma}$ is the noise variance, deducted from SNR without EMI noise

$$\boldsymbol{P_e \approx Q\left(\frac{\frac{2V}{M-1} - V_{emi}}{2\sigma}\right)}$$

PAM level study for 2.5GBASE-T1

- Simulation Setup
  - Automotive One Pair Channel
    - 15meter cable with Insertion Loss (10dB at 350MHz,12.5dB at 500MHz)
  - EMI levels
    - Added differential EMI tone (NBI) at MDI
  - FEC: RS(450, 406, 2^9), coding gain 6~ 7dB (PAM8 and PAM16)
  - TX transmit Vpp = 2Volts (Vpp = 1Volts for 1000BASE-T1)
  - Other noises
- Case Study PAM8
  - Baud rate ~ 990MHz
  - Tolerance of V_{pp_emi} at MDI is around 25 mV EMI at MDI
- Case Study PAM16
  - Baud rate ~ 700Mhz
  - Tolerance of V_{pp_emi} at MDI is around 10 mV EMI at MDI

EMI Differential Signal tolerance for 2.5GBASE-T1



Conclusions

- Emission and Immunity will be more challenging beyond 1000BASE-T1
- Higher PAM level needed with Higher TX signal level
- With FEC, the immunity tolerance at MDI is around 25 mV_{pp} level
  - BCI test reports around 6.4mV_{pp} under 400MHz from one contribution (http://www.ieee802.org/3/ch/public/jul17/cohen_shirani_3ch_01_0717.pdf)
- PAM8 has ~10dB more margin vs. PAM16
- PAM16 is very challenging for immunity

Recommendations

- At 802.3bp, EMC channel analysis and noise conditions have been intensively studied for UTP, and they should be done for STP at this group
  - http://www.ieee802.org/3/bp/public/mar14/EMCnoise_ad_hoc_3bp_01_0314.pdf
- EMC channel analysis over STP
  - Stripline test for Emission Transfer Function -> TX PSD Mask
  - BCI test for immunity
  - Measurements correlations
- Link segments characteristics
  - Insertion loss/Return Loss
  - Mode conversions/Coupling parameters/Alien Crosstalk

- PHY study correlations
  - BCI Measurements done on STP was at range less than 400MHz
  - Study 2.5BASE-T1 first, then extend to higher speeds