

Evaluating Power Sensitivity for Channel Impairments

Contribution to IEEE 802.3: NG-BASE-T Study Group Plenary Meeting
March 2013
Orlando, FL USA

George Zimmerman, Ph.D.
CME Consulting

Supporters

- Mabud Choudhury, Commscope
- Kamal Dalmia, Aquantia
- Mike Grimwood, Broadcom
- Paul Kish, Belden
- Wayne Larsen, Commscope
- Gavin Parnaby, Marvell
- Peter Wu, Marvell

Overview

- Motivation
- Analog Front End Power Metrics
- Receiver Dynamic Range
- Impact of Relative Impairment Levels
- Impact of Far End Signal Power
- Conclusions

Motivation

- Modern BASE-T PHYs all cancel internal cable impairment noises
 - NEXT, FEXT, Echo, Insertion Loss, ILD
- Cancellation power is highly architecture dependent
- Impacts on front-end power are more tractable
- Estimates of PHY power based on individual impairments have been proposed
- Continue to build on previous PHY power modeling contributions

Analog Receiver Power Metrics

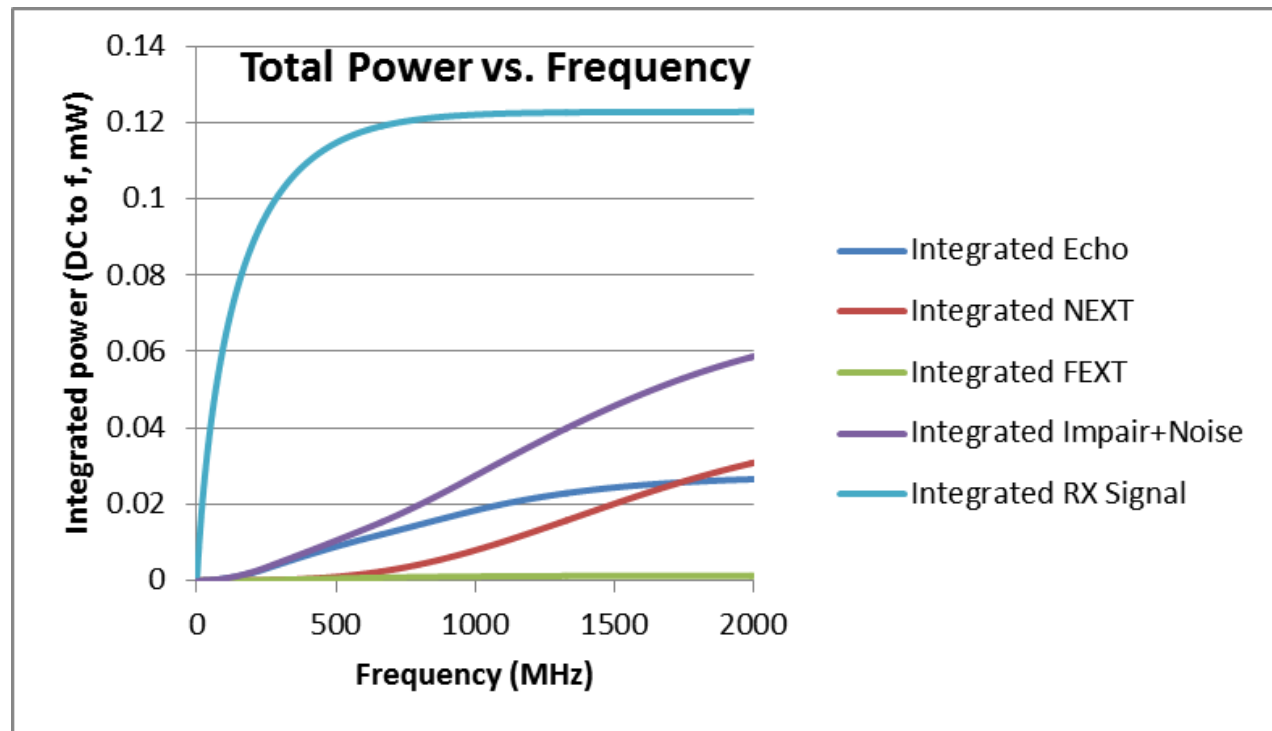
- Uses of ADC figures of merit relating power and SNR/SNDR (ENOB)
 - TIA (Zimmerman)
 - TR42.7-2011-085-40GigPHYcomplexity, $P \sim 2^{\text{ENOB}} * f_s$, with ENOB $\sim \text{SNR}/6.02\text{dB}$ based on receiver margin computations and total impairments
 - IEEE NGBASE-T SG (Bliss, Grimwood, Dabiri)
 - Bliss_01_0912 gives $P \propto \text{BW} * 2^{-\text{No}/6.02}$, No is receiver noise floor required, equivalent to SNR for normalized signal
 - Grimwood_01_0113_NGBT extends this to SNR margin for Return Loss: $\Delta P_{RL} \% = 100 * [2^{-\Delta \text{SNR}_{margin_{RL}}/6.02} - 1]$
 - Dabiri_01_0113_NGBT similarly uses ADC metric to evaluate relative power vs. symbol rate

Receiver Dynamic Range

- Receiver dynamic range is the ratio of the receiver's (input-referred) noise & distortion to the peak input levels
 - Peak input levels are a sum of the desired (far-end) signal and all the impairments
- On 100m 10GBASE-T, Echo and NEXT were larger than the far-end signal (before any analog cancellation)
 - Receiver dynamic range was set by impairments and noise requirements to receive a weak far-end signal
- Largest component (signal OR noise) usually sets the dynamic range
- On short lines and 30m 40GBASE-T insertion loss is much less resulting in larger far end signal, and therefore sets the dynamic range

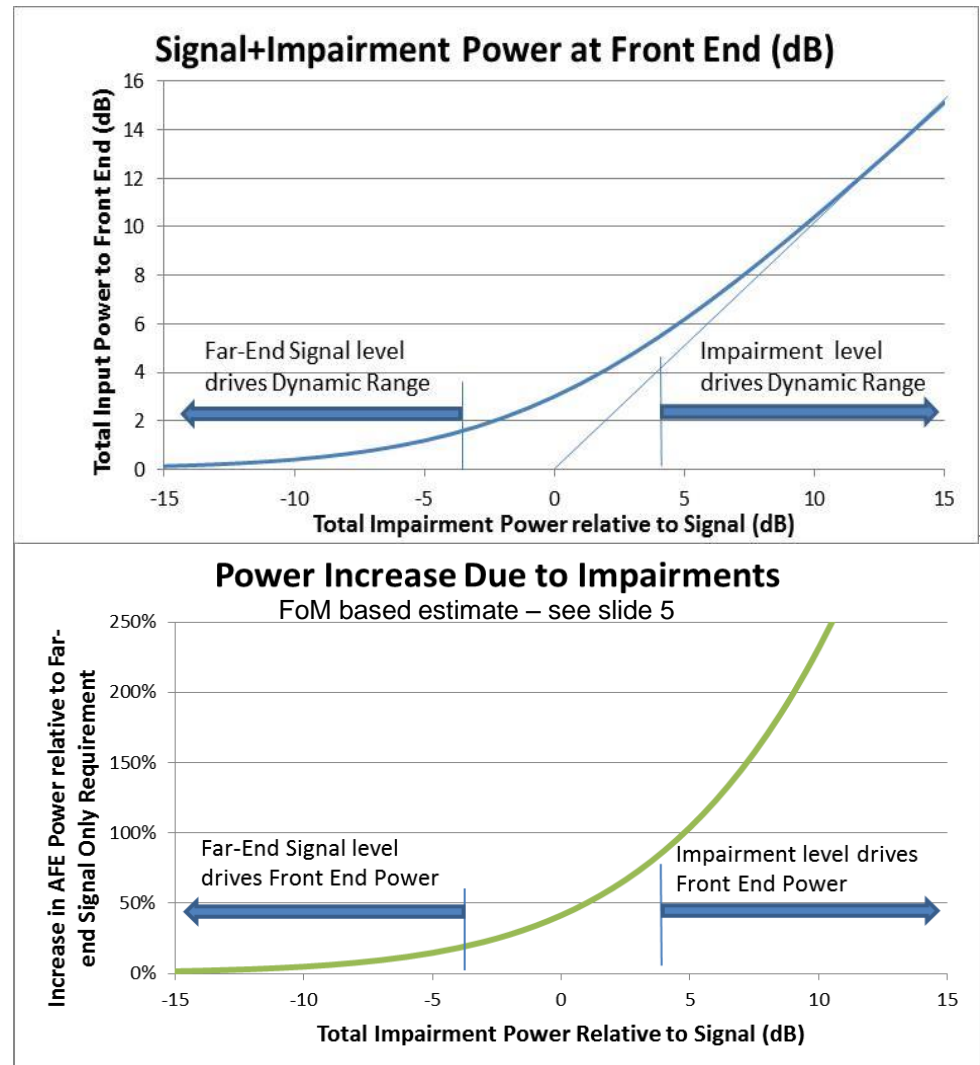
Example of RX Input Power Levels

- 3500 Mbaud PAM spectrum
- 1st order Nyquist receive & transmit filtering
- 30m TIA Cat8 draft 0.6 channel
 - 10dB echo reduction prior to analog front end via hybrid



Impact of Far End Signal Power

- Two regions – one dominated by far-end requirements, one by impairments
- Diminishing returns for impairment power below signal
 - Impairments 6dB or more below far-end signal, add <1dB to dynamic range
 - Less than 12% more front end power

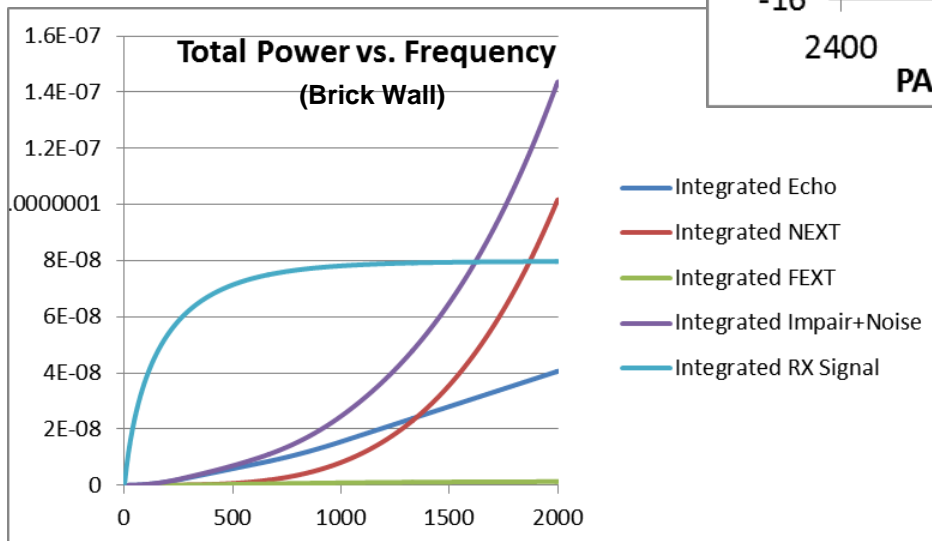
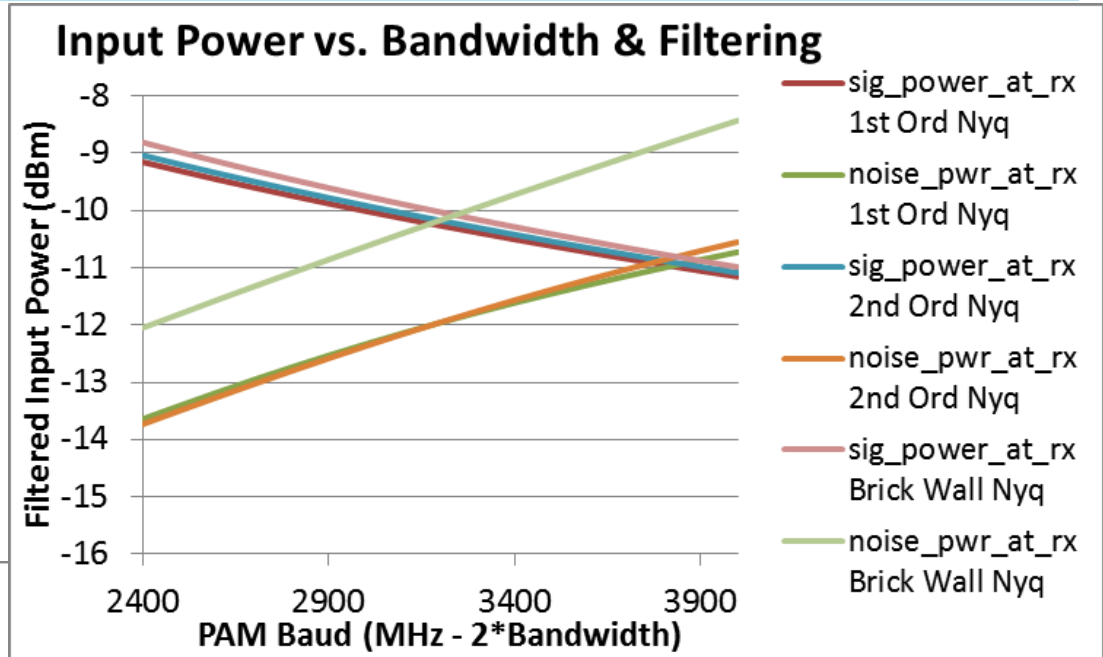


Impact of Bandwidth, Spectrum and Relative Impairment Levels

- Relative levels of impairments is important
- “Dilutive” effect is more pronounced when the impairment is not the largest
 - Relative impairment levels may be dependent on bandwidth, tx/rx filtering or pre-front end cancellation
 - Below 1GHz, Echo is generally the dominant impairment

Example: Bandwidth and Spectrum Effects

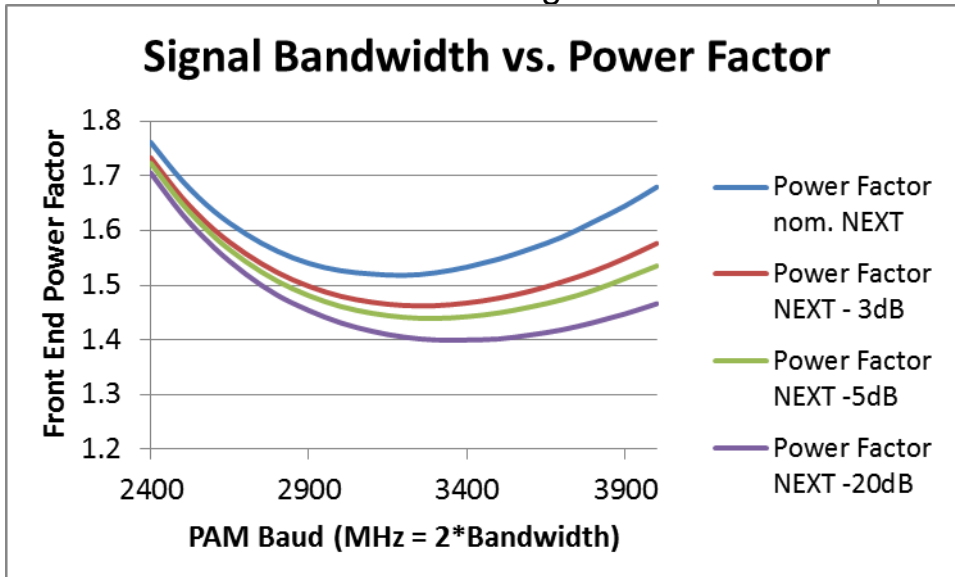
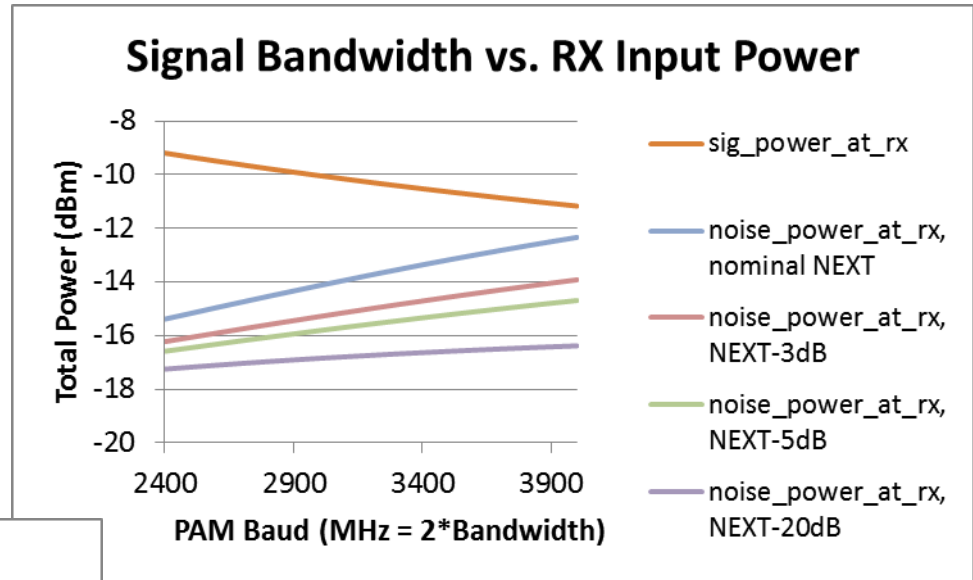
- Brick-wall spectra approximations overemphasize high frequencies
- PAM spectra + filtering reduces noise more than signal



- Reasonable filtering (1st or 2nd order) keeps noise from dominating
- Likely to get from parasitic effects

Example: Power/NEXT Sensitivity

- TIA Cat 8 draft 0.6 NEXT
 - Adjusted at all frequencies, 0, -3, -5, -20 dB
- Required RX ENOB computed for 8dB Margin Target
 - Assumes other impairments cancelled in back-end processing
 - 1st ord Nyquist TX, 2nd ord RX filter
 - -155 dBm/Hz background



- Diminishing returns as NEXT drops below echo
 - More than 3 to 5 dB improvement relative to TIA Cat8 draft 0.6 NEXT provide little benefit

Observations/Conclusions

- At short reaches, far-end signal drives front end power, at long reaches, dominant impairments do
 - Usually echo
- At 30m we are at the high end of the range driven by far-end signal
 - Validates choice of distance target
- Power impacts of individual impairments must be considered in view of the total power received
 - Improvements in impairments sufficiently below the far-end signal + the dominant impairment do not necessarily improve front end power