Echo Cancelling Power For 1Gbps 1TP RTPGE with 15m Category cabling

Will Bliss, Broadcom

IEEE P802.3 RTPGE Study Group

Phoenix, AZ

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Motivation and Overview

- The use of 1TP solutions requires full duplex ‘echo cancelling’
- Echo cancelling is known to be ‘hard’, so the question is raised, “How much implementation power is required for echo cancelling?
- A simple analytic model of the power to cancel echo is introduced
- Results for different cable categories and variable analog bandwidth are given
- Power results are given with respect to the latest design 10GBASE-T PHYs (which everyone has a good idea of total power)
  - The actual ‘echo cancelling’ power must be less than this total PHY power

Channel Assumptions

- Effects due to board, magnetics and associated connectors not considered
  - We will operate at relatively low BW, so these can easily be quite minor
- For a simple first look, we use IL and RL specifications of Class Ea (Category 6a) cable specifications
  - 2-connector (+2 end cords) channel model was used (may be pessimistic)

SNR Margin to Capacity Definition

- See development details in grimwood01_0113NGBT.pdf in www.ieee802.org/3/NGBASET
- Let *BW* be the design analog bandwidth in Hz.
- Let *C′* be the desired capacity for one twisted pair (=1Gb/s)
- From Shannon-Hartley the theoretical min SNR in dB is given by

$$SNR_C = 10log_{10}(2^{(C'/BW)} - 1)$$

- For each cable parameter, define the SNR margin to capacity, $\boldsymbol{SNR\_margin_{cable\_param}(BW)}$, as the required constant change in loss across all frequencies in order to reach SNR_C.

SNR Margin to Capacity Equation

- From Shannon-Hartley,

$$C = \int_0^{BW} log_2\left((S(f)/N(f)) + 1\right) df$$

- For reasonable bandwidths, S(f)/N(f) >> 1 at capacity.
- Express *C'* as a function of $SNR\_margin_{cable\_param}(BW)$:

$$C' = \int_0^{BW} log_2\left((S(f)/N(f)) * 10^{(\,SNR\_margin_{cable\_param}(BW)/10)}\right) df$$

- Solve for $SNR\_margin_{cable\_param}(BW)$ to get the following:

$$SNR\_margin_{cable\_param}(BW) = \frac{(C - C') * 10log_{10}(2)}{BW}$$

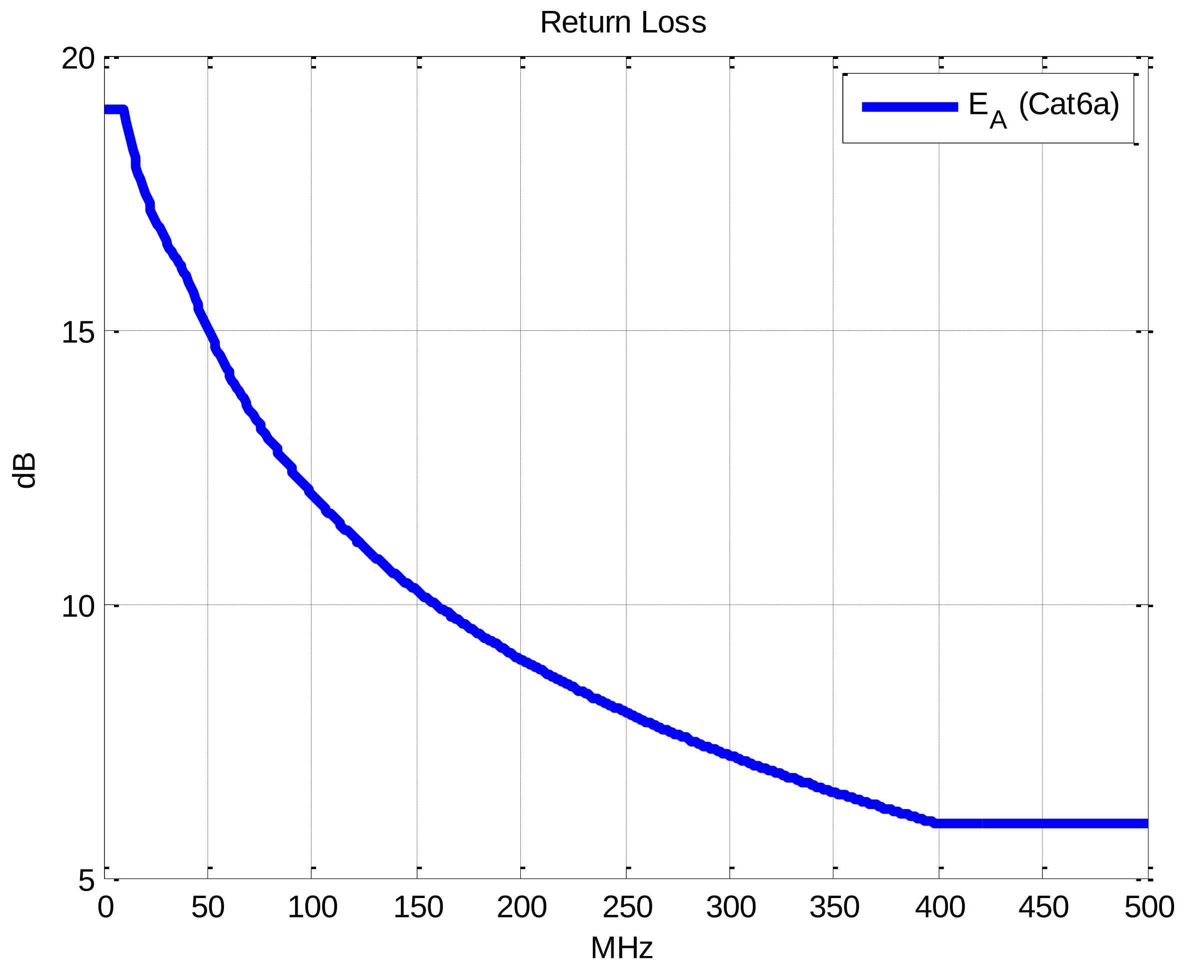
Margin Assumptions for RTPGE

- Allow significantly sub-optimal ‘coding’ that operates 8dB from the Shannon limit
  - 10GBASE-T operates 4.7dB from capacity
  - Current aggressive PHY proposals target <= 4dB
  - Target of 8dB can be met with a relatively modest code with ~6dB coding gain
- Allow another 6dB for Implementation Margin (against the unknown)
  - More than has been allowed for 10GBASE-T
  - More than proposed for some Ethernet PHYs under development
- When calculating ‘allowed impairment’ (for incompletely cancelled echo here) we’ll allow the 6dB implementation margin to be degraded to 5dB

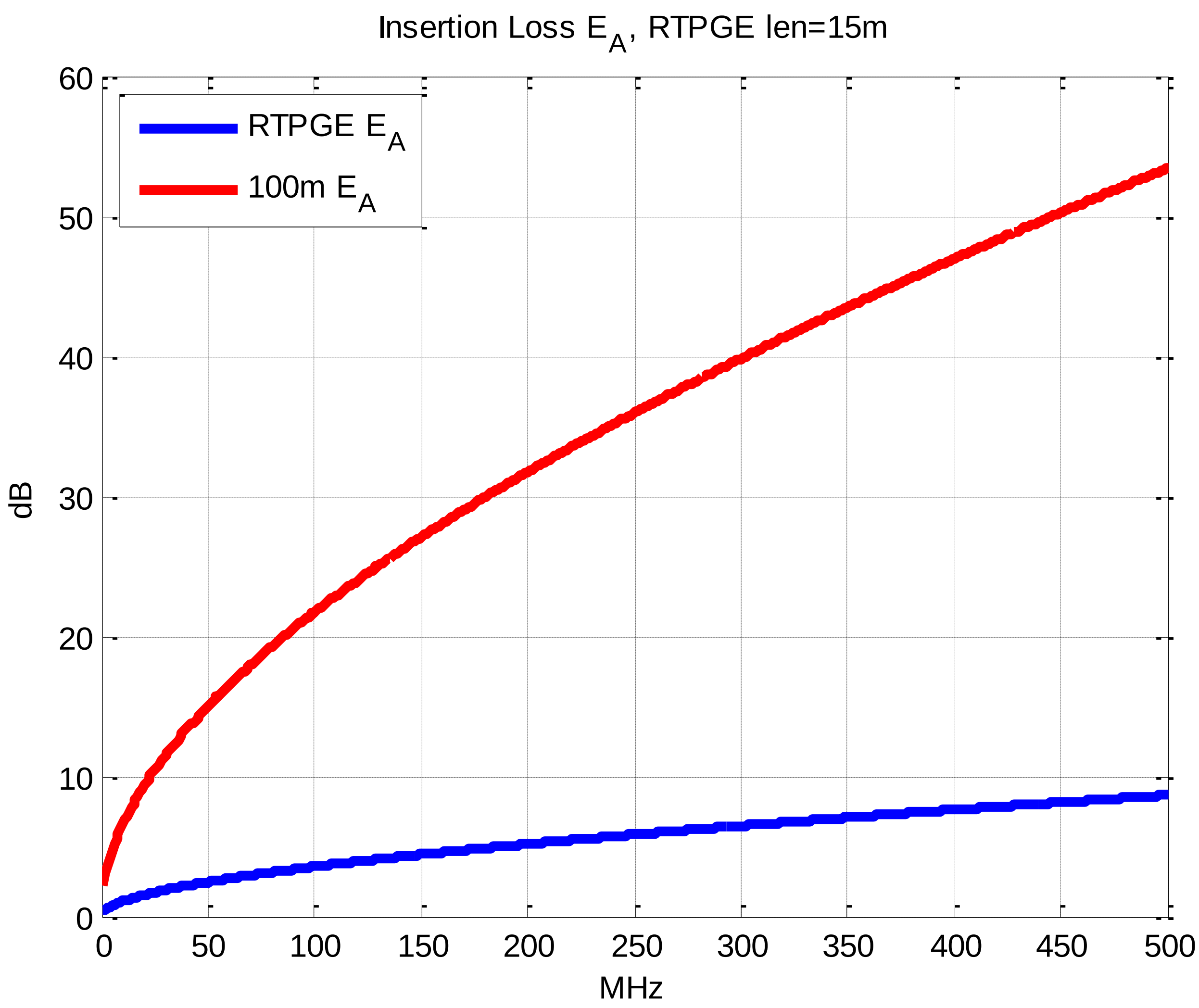
Return Loss Overview

- Analyze combined effect of return loss and insertion loss.
- Determine the margin to capacity, SNR_margin_{RL}, based on the ratio of the far-end signal to the local echo.
- Provide a simple model for the PHY power to cancel echo.
- Estimate gains in power efficiency that can be realized by improving return loss.

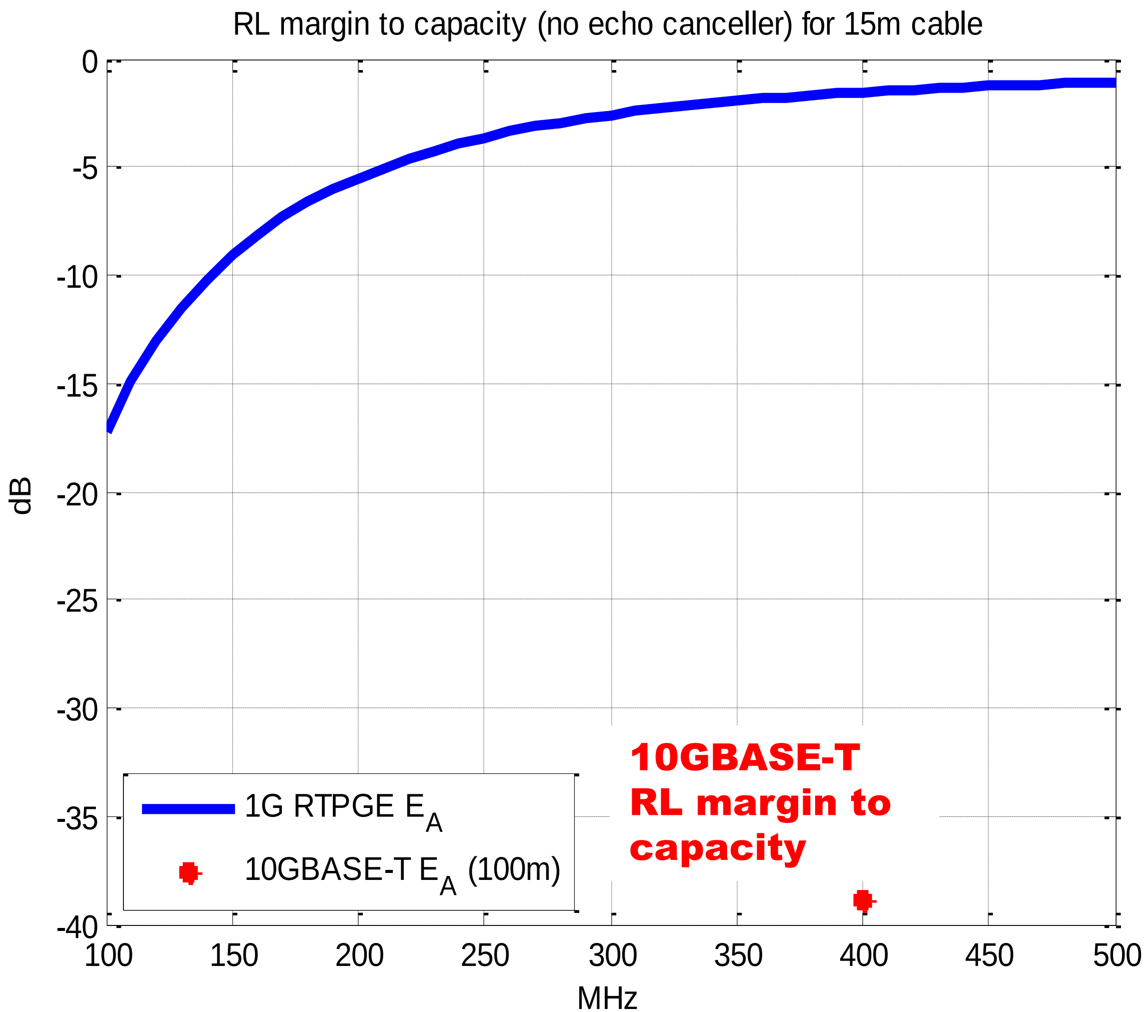
Return Loss Specifications



Insertion Loss Specifications 15m



Return Loss Margin to Capacity



- Required Echo Cancellation = *code_margin* + *impl_margin*$_{RL}$ – *SNR_margin*$_{RL}$.
- 55 dB for 10GBASE-T
- For >= 250MHz analog BW, the echo cancellation required for RTPGE is reduced by over 39-4 =35 dB compared to 10GBASE-T
- And only 1TP to cancel vs. 4TP

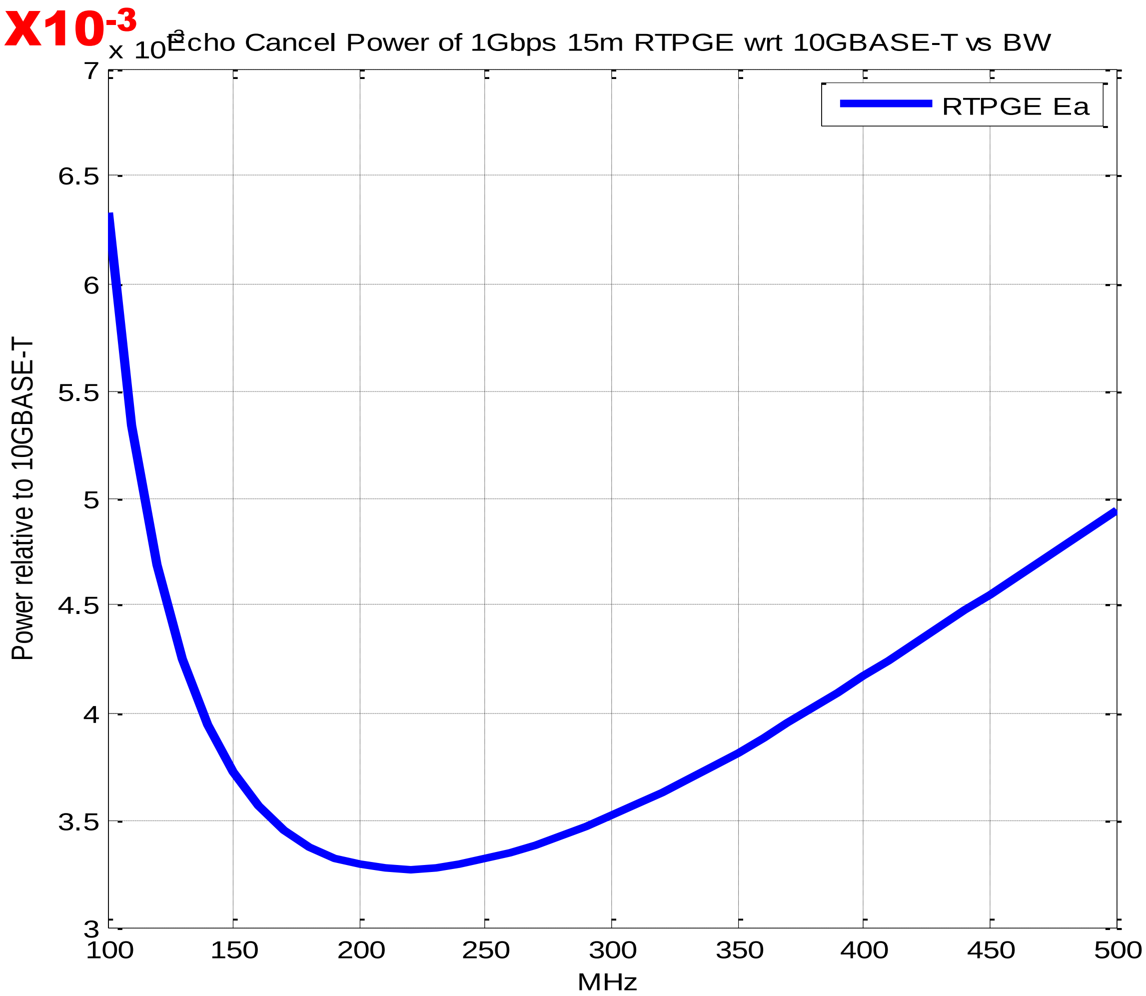
Echo Canceling Relative Power Model

- Define a new power model that reflects the relative power consumption due to echo cancellation:

$$P_{RL} \propto BW * 2^{\left(\frac{code\_margin+impl\_marginRL\ -SNR\_margin_{RL}\ (BW)}{20*log10(2)}\right)}$$

- The term (*code_margin* + $impl\_margin_{RL}$ – $SNR\_margin_{RL}(BW)$) reflects the dynamic range of cancellation required
- The dynamic range required is closely related to the required ENOB for ADC and DAC and noise floor
- The above equation very effectively captures the power of well designed analog circuits achieving this BW and the effective 'ENOB'
  - Add reference
- The above equation has been argued as a good first order prediction for the total PHY power
- We don't explicitly consider the power breakdown for the electronic hybrid function

1TP RTPGE Echo Canceling Relative Power vs. Bandwidth



- The power plotted is relative to the echo cancelling power calculated for 10GBASE-T
- The minimum occurs for analog BandWidths between 200 and 250MHz
- The worst cable still achieves power < **3.5 thousandths** of 10GBASE
- IF we say all the 10GBASE-T PHY power is spent on echo cancelling, then using published numbers of 3W PHY power, this puts **RTPGE echo cancelling power = 10mW**

Conclusions

- The overall complexity of sending 1Gbps on 1TP over 15m of CAT6a (class Ea) like cabling is trivial compared to 10GBASE-T
  - The ‘communications complexity’ is reduced by over 99%!
  - The industry may wish to consider using cables with less copper, as the low frequencies and short reach makes the Insertion Loss rather trivial
  - As an aside (not proven here), the industry may also wish to consider using more plastic (spacing) to control proximity to other wiring and thus control ‘Alien’ (not studied in this presentation)
- The added complexity of ‘Full Duplex’ (only 1TP for bi-directional traffic) is very low under these conditions, estimated less than 10mW
  - Market users need to decide whether ~10mW power is worth eliminating half the cables and connections

Thank you