Is ~800Ms/s the Optimum Symbol Rate for 10GBASE-T?

IEEE 802.3an Task Force

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Sailesh K. Rao

Phyten Technologies, Inc.

srao@phyten.com

Supporters:

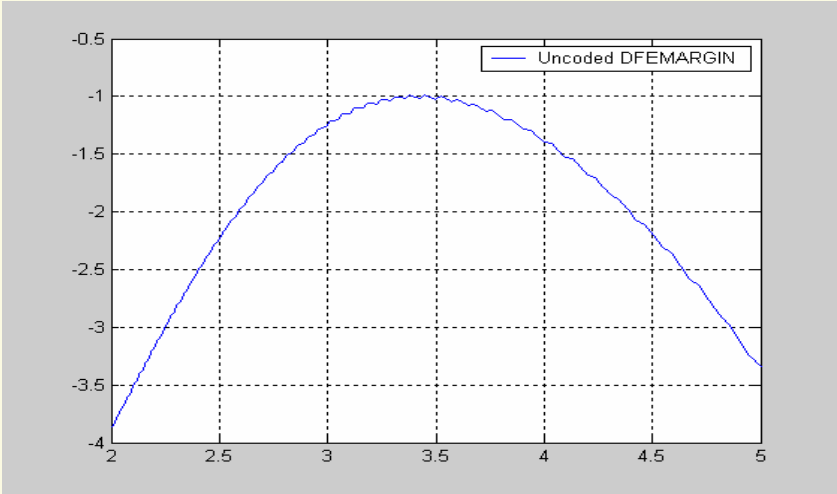
David Srodzinski – Elonics Ltd.
Ze'ev Roth – Mysticom
Joseph Babanezhad – Plato Networks
Sim Narasimha – Ample Communications
Anand Injeti – Krypton Systems
Prof. X. Wang, Raju Hormis – Columbia University
Ignacio Berenguer – Cambridge MIT Institute

Agenda

- Basis of the ~800Ms/s Optimality Claim
- Are all the noise sources "**independent**"?
- Are all the noise sources "**identically distributed**"?
- Are all the noise sources "**additive**"?
- Are all the noise sources "**white**"?
- Are all the noise sources "**Gaussian**"?
- Are all the noise sources "**noise sources**"?

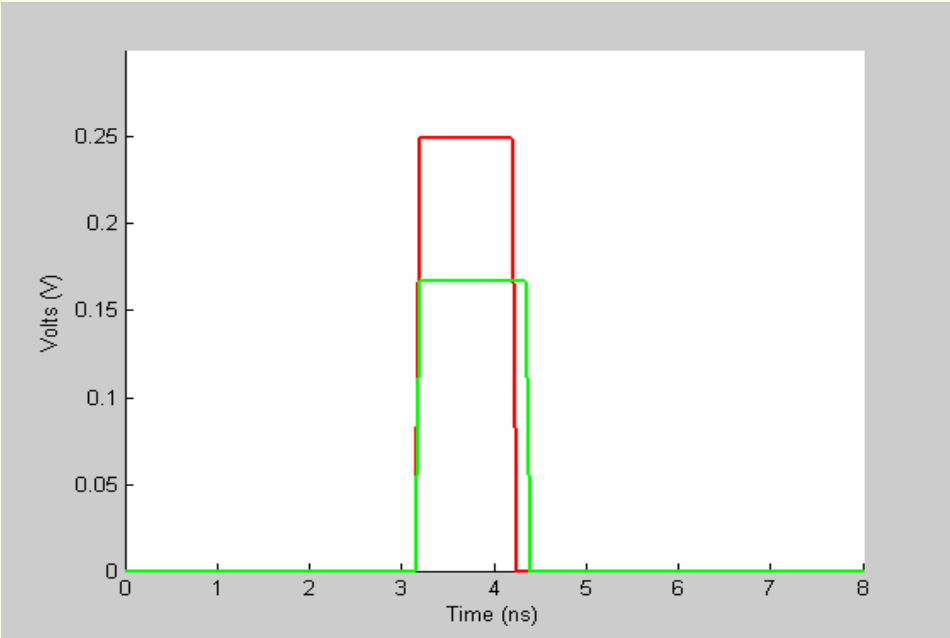
Basis of the ~800Ms/s Optimality Claim: Salz Equation

- See Ungerboeck_1_0504.pdf
- Salz equation predicts DFE SNR in the presence of ISI and **independent, identically distributed additive white Gaussian noise** (i.i.d. AWGN)
  - For 100m Cat-6 (Model 3), 3bits/Hz has 0.9dB higher "SNR margin" in Salz equation than 2.5bits/Hz



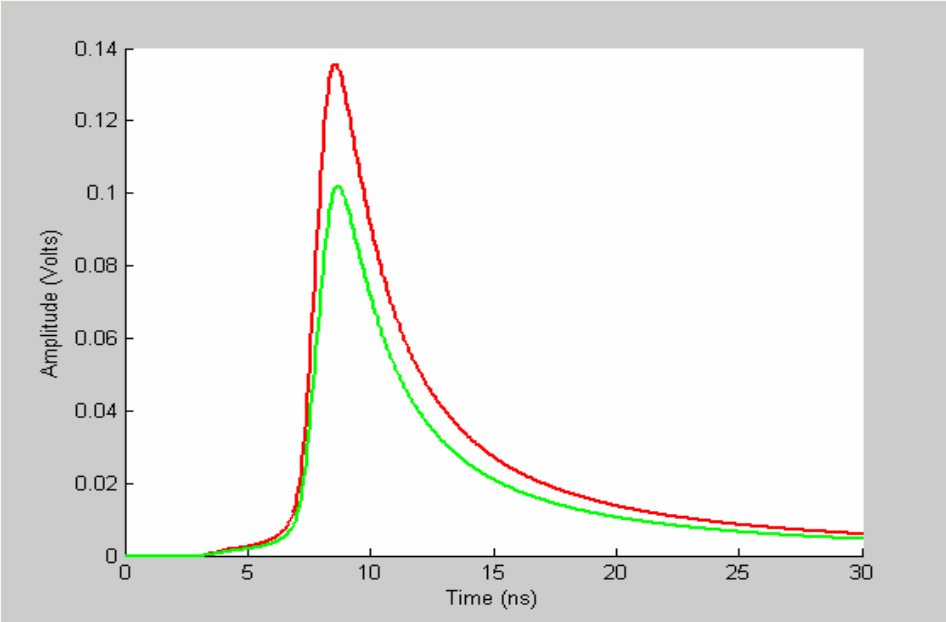
Caveat #1

- Salz equation measures relative noise margins.
  Real world noise hits are absolute events: **3.5dB improved separation of levels at 0m is ignored!**



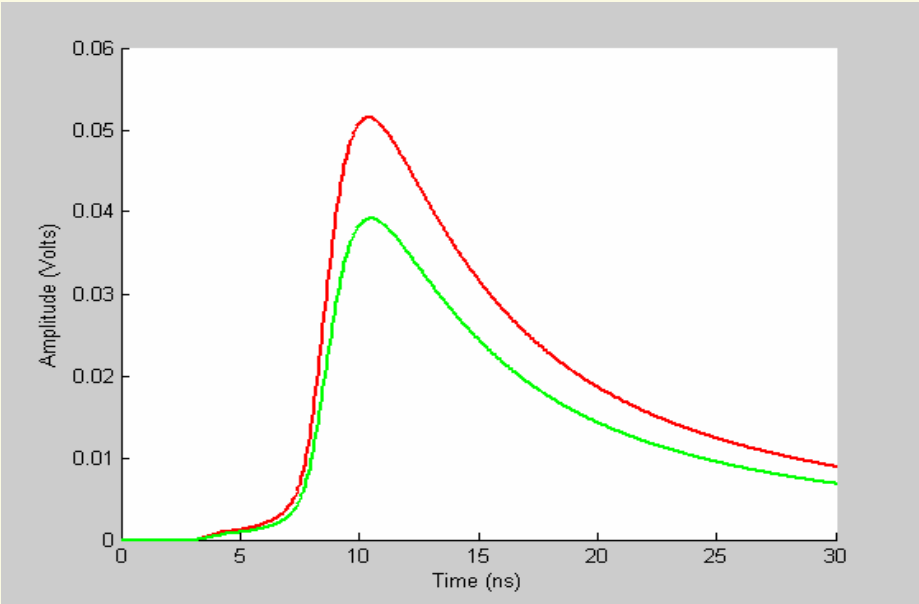
Caveat #1 - cont'd

- Salz equation measures relative noise margins.
  Real world noise hits are absolute events: **2.6dB improved separation of levels at 55m is ignored!**



Caveat #1 - cont'd

- Salz equation measures relative noise margins.
  Real world noise hits are absolute events: **2.3dB improved separation of levels at 100m is ignored!**



Caveat #2

- Salz equation measures theoretical performance.
  Reality for 3bits/Hz system requires 2D coupled LDPC code vs. 1D LDPC code for 2.5bits/Hz system
  - Log likelihood ratios used in LDPC decoder for “donut” PAM12 constellation depends on a 2D received symbol vs. 1D received symbol for PAM8
  - Gap to Capacity for simulated PAM12 system is 5.0dB vs. 3.9dB for a simulated PAM8 system
  - 1.1dB SNR margin loss for PAM12 system due to “practical considerations”.
- In addition to these caveats, let’s check if the noise assumptions are valid for the 10GBASE-T system.

Are all the 10GBASE-T noise sources independent?

Note: LDPC code spans across all 4 wire pairs.

- All four wire-pairs are in the same bundle!
- All four wire-pairs are connected to the same RJ-45 connectors!
- All four wire-pairs come into the same chip!
- In a Master-Slave clocking arrangement, the transmitters on all four wire-pairs are clocked by the same clock!

In the presence of dependent noise a 952Ms/s system works better due to the increased separation of levels.

Are all the 10GBASE-T noise sources identically distributed?

- In 7 years of lab experience with 4-pair 1000BASE-T systems, there were ZERO systems that exhibited identical noise statistics on all 4 pairs.

In the presence of non-identically distributed noise sources, a 952 Ms/s system works better since it doesn't use a 2D interlocked LDPC code.

Are all the 10GBASE-T noise sources additive?

- Analog front-end distortion is NOT additive.

A 952Ms/s system is more robust towards AFE distortion since the required SNR at the receiver output is 3.9dB lower.

Are all the 10GBASE-T noise sources white?

- Real world residual noise events, especially the noise events that cause errors, are never, ever white. “White” noise is a theoretical invention, designed to make all our integrals easier to compute.

In the presence of colored noise, a 952 Ms/s system is more robust due to the increased separation of levels.

Are all the 10GBASE-T noise sources Gaussian?

- If this is the case, then the FCC wouldn't be requiring compliance tests with narrow band interferers.

In the presence of narrow band interferers, a 952 Ms/s system is more robust due to the increased separation of levels.

Are all the 10GBASE-T noise sources “noise” sources?

- Analog Front End distortion is not noise.

A 952Ms/s system is more robust towards AFE distortion since the required SNR at the receiver output is 3.9dB lower.

Conclusions

~800Ms/s system is NOT optimum for 10GBASE-T for all the practical reasons outlined below:

- 2.3dB to 3.5dB worse separation of levels than 952Ms/s system at ALL line lengths
- 1.1dB Worse Simulated Gap to Capacity.
- Higher order dependency of LDPC LLR calculations.
- 2.3dB to 3.5dB worse performance in the presence of colored noise.
- Up to 3.9dB worse performance in the presence of Analog Front End distortion.