Relations between the use cases, operational environment and PHY choices in 10GBASE-T and NGEABT.

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Supporters

- (your name here)

10GBASE-T Basics

- PAM-16 modulation
  - Pairs of symbols treated as a 2-dimensional symbol (“DSQ-128”), in a “checkerboard”
- LDPC code protects only a subset of bits
- Optimized for 100m links with additive white Gaussian noise at ~ -142 dBm/Hz
- Several years and lessons learned in the field

10GBASE-T Channel Models

kasturia_2_0304.pdf – culminated months of work on models

Channel Models

Model #	Insertion loss	ANEXT Intercept (X1)	ANEXT margin (dB)
1	100m of Class F	60	2.5
2	55m of Class E	47	2.5
3	100m of Class E	62	2.5
4	55m to 100m of Class E	Given by formula	2.5

ANEXT limit line model:

- $1 \text{ MHz} \leq f \leq 100 \text{ MHz}$ X1 -10*Log10 (fMhz/100)
- $100 \text{ MHz} \leq f \leq 625 \text{ MHz}$ X1 -15*Log10 (fMhz/100)

ANEXT average level (of ripple) to assume in simulations

- $1 \text{ MHz} \leq f \leq 100 \text{ MHz}$ X1+2.5 -10*Log10 (fMhz/100)
- $100 \text{ MHz} \leq f \leq 625 \text{ MHz}$ X1+2.5 -15*Log10 (fMhz/100)

ANEXT intercept X1 as a function of cable length, L

- IL(L) is Class E insertion loss for length L in meters at freq. 250MHz
- Use following formula for ANEXT:

X1 = 62-((IL(100)-IL(L))*15/15.6)

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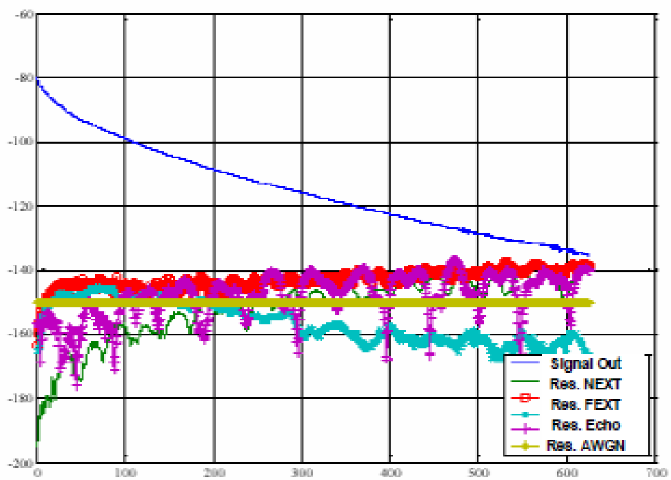
Focus on Achievable Rate (AWGN)

- Shannon Capacity Analysis: (10GBASE-T Tutorial Nov 2003)
  - Assumes stationary noise
  - Assumes bandwidth limited channel

Improved Class E/Cat 6: 100m Capacity & Margin

- (ref cohen_1_0703)
- Capacity > 20.6 Gbps
- >7 dB PAM-10 margin at 1e-12 BER



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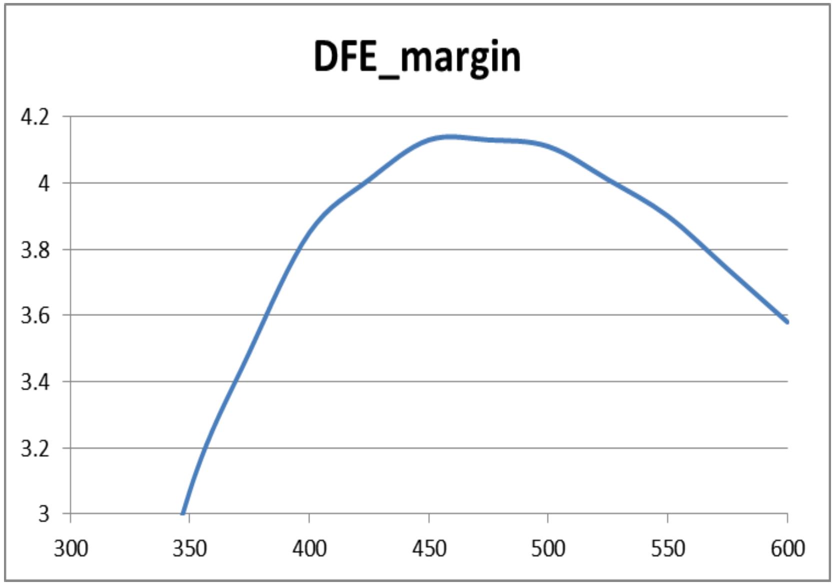
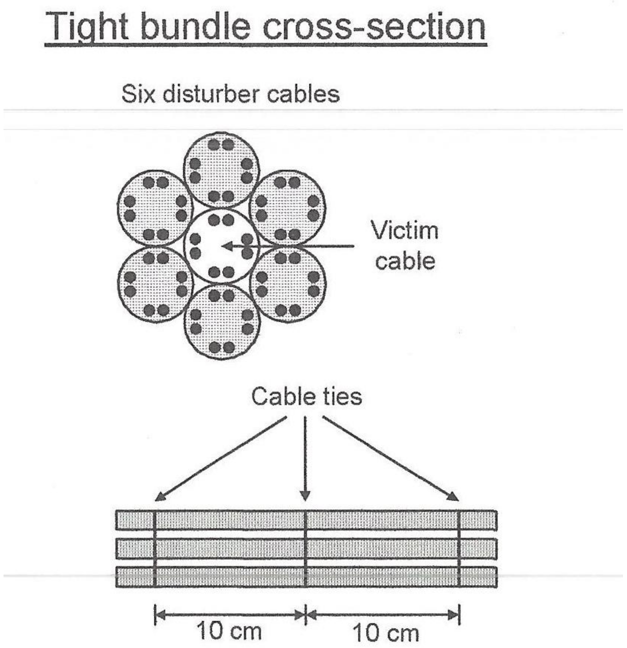
Differences with 5GBASE-T channel

- Lower IL at assumed Nyquist frequency
  - ~ 35dB vs. ~40 dB for 10GBASE-T
  - Not internal noise dominated
- AWGN Optimum Baud higher than 400M
- Potentially impulsive environment



10GBASE-T

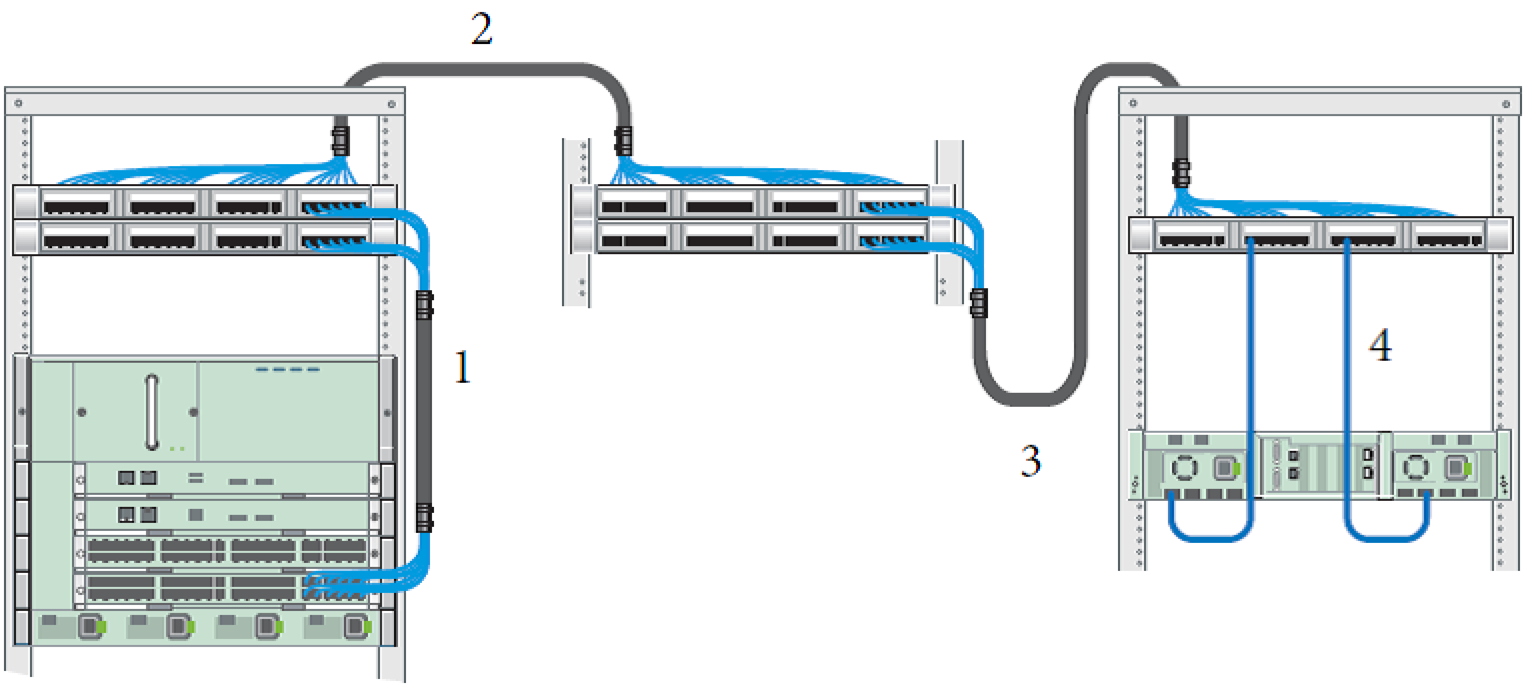
- One configuration:
  - 6-around-1, tightly bound, groomed
  - All disturbers are same type
  - Worst-case length
  - Alien NEXT dominated



Use cases: Alien crosstalk evolves

- Before 10GBASE-T: Alien Crosstalk? What Aliens?
  - Alien crosstalk only considered for unusual “hybrid cable” situations
- 10GBASE-T: Mostly ‘Virgin Bandwidth’
  - No existing disturbers from 80 MHz to 400 MHz
  - 20% frequency overlap with 1000BASE-T, only at low frequencies where crosstalk coupling is low
    - Minimal impact on DFE SNR which averages SNR in dB’s across frequency
  - Alien self-interference was the single limiting case
    - Could be ‘worst-cased’ as a single disturber-type worst-case bundle.
- NBASE-T: Filling in the Gaps in Occupied Bandwidth
  - Substantial Overlaps
    - 1000BASE-T into 2.5GBASE-T (80% overlap)
    - 1000BASE-T into 5GBASE-T (40% overlap)
    - 10GBASE-T into 5GBASE-T/2.5GBASE-T (100% overlap)
  - Proposed Spectra overlap 50% (2.5G/5GBASE-T)
  - Alien FEXT substantial
  - Mixtures of services is important to consider in use-case planning

4-connector model



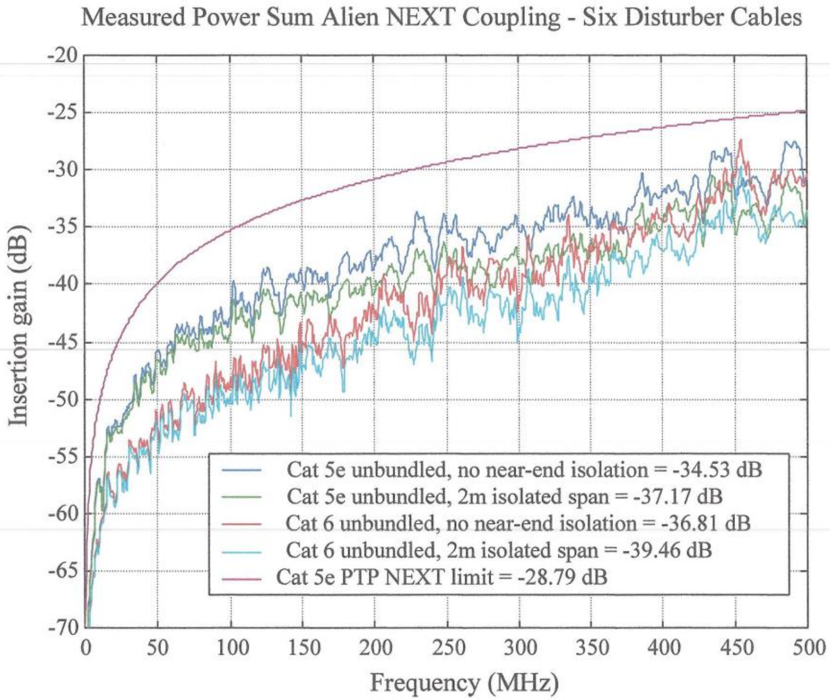
Segments and Crosstalk

- Segment 1 will probably have the worst ANEXT from like-sources (2.5G or 5GBASE-T), but won’t likely be longer than 10m – AFEXT on this segment can probably be ignored.
- Segment 2 will have a mix of services, but is also likely short . Needs an attenuated ANEXT model, may not need AFEXT (depends on the length).
- Segment 3 will be the long segment, definitely has AFEXT, but is driven by the mix of services distributed out to the enterprise floor fan out.
- Segment 4 will have separated cabling & minimal crosstalk in itself, but provide attenuation of ANEXT/AFEXT disturbing other services, into itself.
- Mitigation techniques can change the crosstalk levels & frequency shape

Small changes matter

- (cohen_1_0103.pdf)

Effect of Near-end Cable Isolation



- Add extra physical isolation (> 10 cm separation) between disturber and victim cables on short span between equipment and patch panel.
- Produces attenuated NEXT behavior
- Reduction better than 1 dB attenuation per meter isolated span length.

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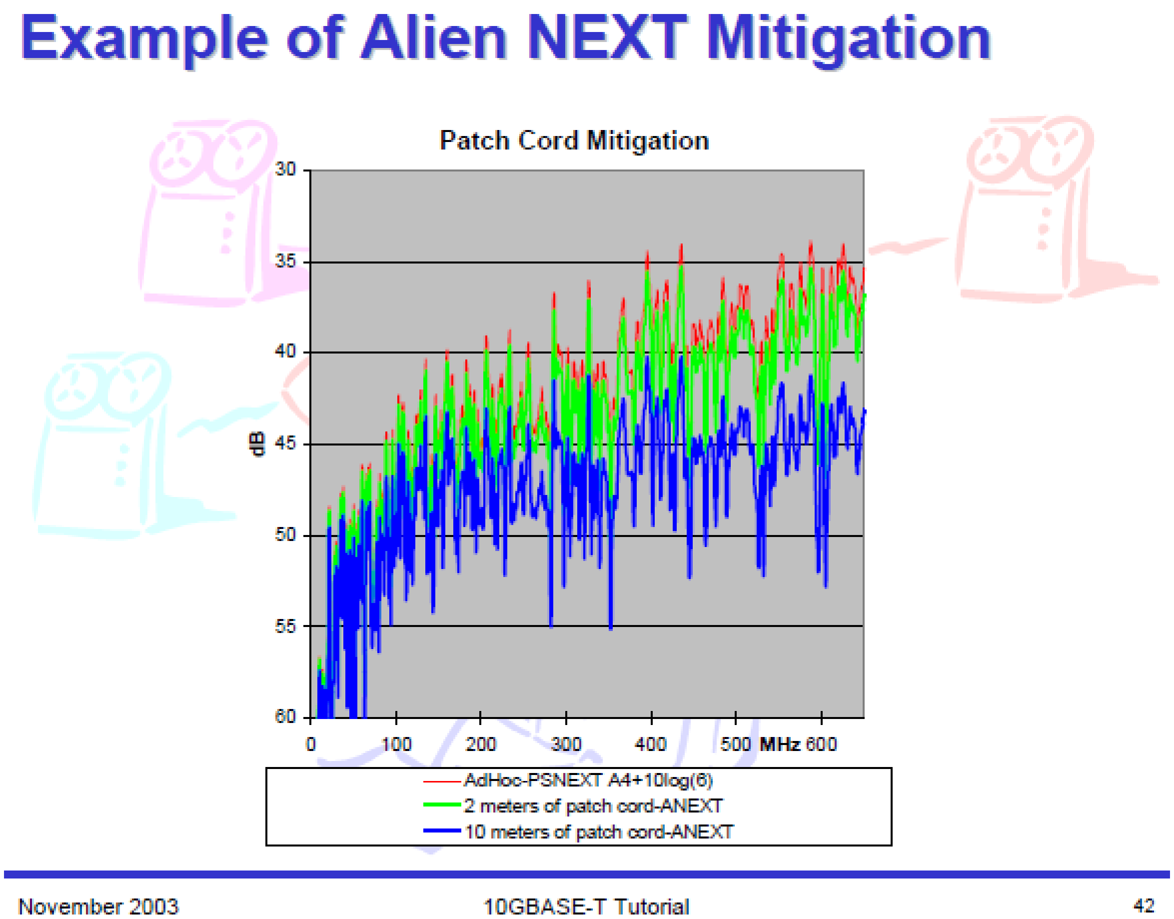
Alien Crosstalk & Use Cases

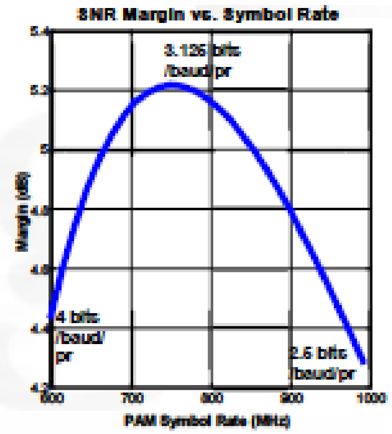
- 10GBASE-T Study Group discussed impact of simple mitigations like separating patch cords (ref: 10GBASE-T Tutorial, Nov 2003)

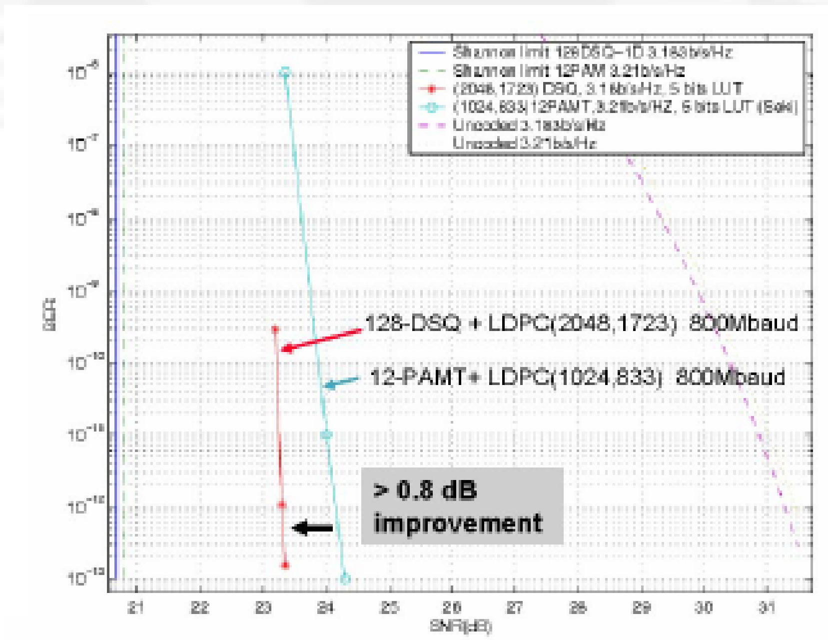


Result: 10GBASE-T Line Code

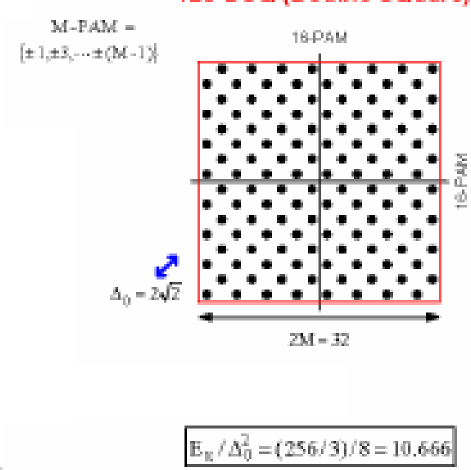
10GBASE-T line code optimized baud and then jointly picked constellation & coding for bandwidth-limited AWGN channel

- 800 Mbaud signaling, near optimum rate
- (2048, 1723) LDPC code, 12 dB partition
- Tomlinson-Harashima Precoding



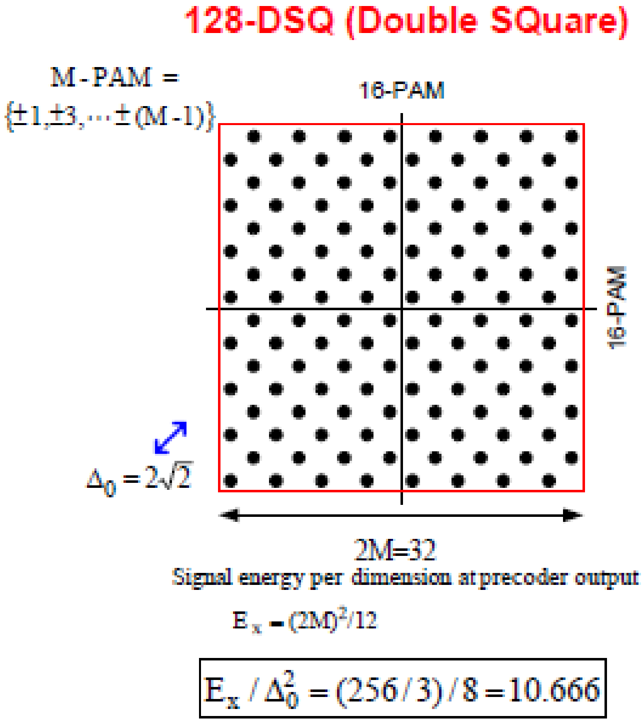


128-DSQ (Double SQuare)



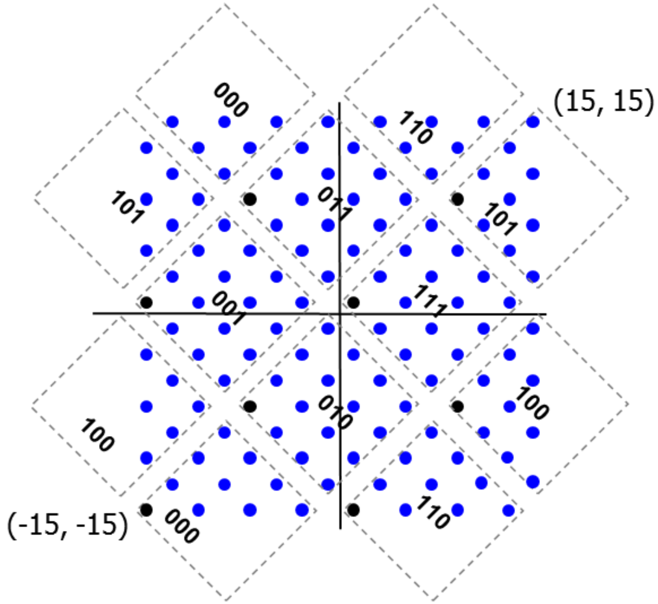
10GBASE-T constellation

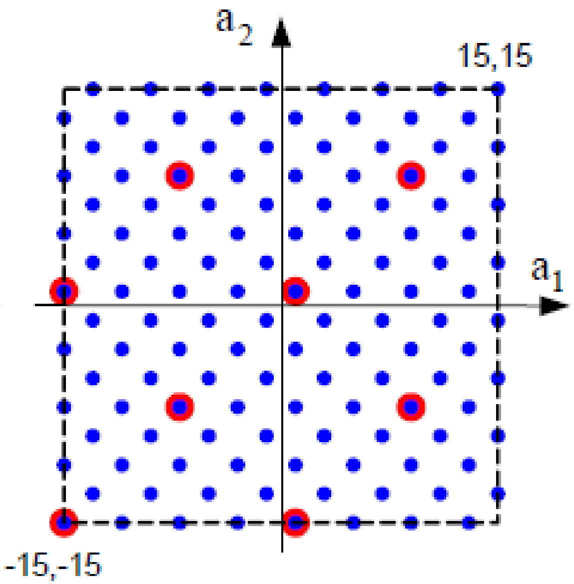
- 10GBASE-T uses a 12dB partition into LDPC coded and unprotected bits
  - LDPC coded bits are protected from Gaussian and impulsive noise
  - 12 dB “parallel transitions” are unprotected
  - CRC8 detects errors



Impulse Noise: Unprotected thresholds

- DSQ code point distance rel to Vrms = $^1/_{\sqrt{10.666}}$ = 0.306
- 12dB partition -> distance is 1.225 rel. to Vrms
- Single Error threshold is 0.612 Vrms
- Double Error threshold is 0.433 Vrms





Non-Stationary Noise has impacts

- EM Susceptibility
  - Fast Retrain added in 802.3az
- Excess clip range in AFEs
- Impulse noise known to cause errors

Where does this leave us

- 10GBASE-T is a good starting point, but it isn’t the end
- We’ve learned a lot from deployment
- Enterprise environment has differences
- Use cases and noise matter!