Taming CSRS

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Outline

- **Summary (3 slides)**
- Statement of present situation (4 slides)
- Summary of new material (1 slide)
- Noise loading (3 slides)
- Split stressor (2 slides), noise color (1)
- Monte Carlo method (5 slides)
- Monte Carlo results (3 slides)
- CSRS test & proposed changes (3 slides)
- Conclusions

Margin in Draft 3.1

- Consensus that D3.1 has margin

- Possible uses for some/all of the margin
  - Retain the margin
  - Relax transmitter TWDP
  - Relax the minimum transmitter power (OMA)
  - Relax the symmetric part of the receiver test
  - Relax/remove the noise from the receiver test

- Comment on cases for relaxing transmitter and receiver specs:
  - The necessary transmitter technology is relatively mature and the D3.1 specs can be met.
  - New receiver technology is being developed for 10GBASE-LRM. If we are able to relax the receiver specs, this would have the greater impact in reducing risks and time to market and have the more significant potential to reduce cost.

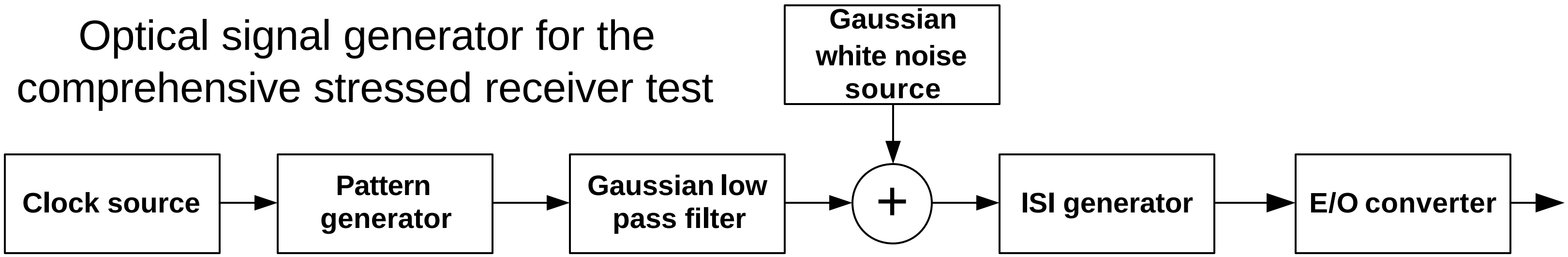
Relaxing transmitter spec

- Relax TWDP
  - Argument made for: Allows lower cost transmitters
  - Arguments made against: Not much cost saving but costs performance; it is not possible to quantify the power penalties for all possible relaxed TWDP transmitters used together with (all) real receivers.*
- Relax transmitted power
  - Argument made for: Allows lower cost transmitters. Predictable consequences.
  - Arguments made against: No significant cost saving; rather late in the process to change the received dynamic range.

*In developing receiver specs, specific transmitted waveform, having rise and fall times of 47ps, was assumed.

Relaxing receiver spec

Optical signal generator for the comprehensive stressed receiver test



- **Implementation of this compliance tester is very complicated.**
  - Good approximations are possible, but testers will not achieve precise agreement. We are repeating the mistake of 802.3ae.
- **The addition of noise prior to the ISI generator adds significantly to the complexity of the tester.**
  - Because it implies a linear implementation of the ISI generator.
  - Otherwise, a simpler tester / better agreement would be possible
- **Noise value in D3.1 is too high** – it should be ?? × smaller
- **ISI generator parameters were selected for a meaningful test - without the added noise**
  - When the noise is added, the symmetric test becomes unreasonably difficult.

- **Recommendation**:
  - Remove the added Gaussian white noise element from the test, or alternatively
  - Reduce the added noise and change the symmetric test

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Comments vs. D3.1 about spec limits and margin

- Consensus that modules per D3.1 spec would have margin against the assumed population of links
  - More detailed statistical analysis (in this presentation) shows a greater gap between spec and application
- Comments in database suggest different ways of spending the margin
  - Relax transmitter TWDP limit
  - Relax receiver test: noise loading
  - Relax receiver test: split stressor
  - Transmitter trade-off OMA for TWDP
  - Other?
- Concerns that some D3.1 specs are too difficult
  - Not representative of application
  - Would cause problems in the future
    - e.g. would not be able to migrate from SiGe to CMOS, or from today's power to lower power, or to equalizers integrated into port ASICs

The story so far 1/3: receiver test

- Noise changes the ranking of the stressors
- Split pulse is most challenging
- The split stressor in the draft is very extreme
- Comprehensive stressed receiver sensitivity and overload tests are very complicated
- It will be difficult to obtain accurate tests
- ***This will hurt the industry. We are repeating the mistake of 802.3ae***
  - So far, had not found a way to simplify

The story so far 2/3: link statistics

- Statistics of link penalties are highly skewed
- Most links are easy, tail (e.g. of dispersion penalty) is difficult
- Most links are very low loss, tail has higher loss
- The combination of these two factors mean the spec has margin
- Believe that it is possible for different mixes of OMA, noise and DMD to be equivalent
  - Some would like trades in the standard, others would not. But this trade-ability shows that there is margin. Trade was not quantified.
- Noise has been worst-cased

The story so far 3/3 : link statistics

- Split pulses are common in single-launch populations of OM1, OM2
- In a "static" joint launch analysis, they are not common (6% split in time)
  - The better launch is usually “smooth” not split
- Because some channels may evolve through time (slowly), proportions in practice would differ from this analysis
- However, the split stressor in the draft is very extreme as compared with splits found “in nature”

Summary of new material here

- Quantifying cost of noise loading to SNR, on particular test stressors
- Modal noise treated statistically in same way as other connector-induced effects
- Effect of different colors of noise loading
- Interplay between dual-launch stats and noise loading
- This analysis shows that
  - Noise loading is an important opportunity for experimental error
  - There much less noise in real links than in current test spec
  - Current spec over-tests receivers, principally with too much colored noise

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Effect of noise loading

- Noise loading affects the relative difficulty of the stressors
  - Split stressor moves from easiest to hardest
    - In fact, to too hard
    - Causes implementers to design to the test not to the application
  - We don’t strictly know that our stressors are “fair”
    - (Current stressors are shown to be fair if without noise)
  - Small(?) effect on “best launch” stats: fewer splits if equalizer doesn’t like them
- Graphs showing PIE(14,5)n, i.e. PIE(14,5) with noise loading, vs. Qsq
- Can translate to graphs of SNR margin
  - SNR margin = PAlloc – PIE(14,5)n
- Graphs showing PIE(14,5)n vs. noise color (from before stressed eye generator’s transversal filter, from after)

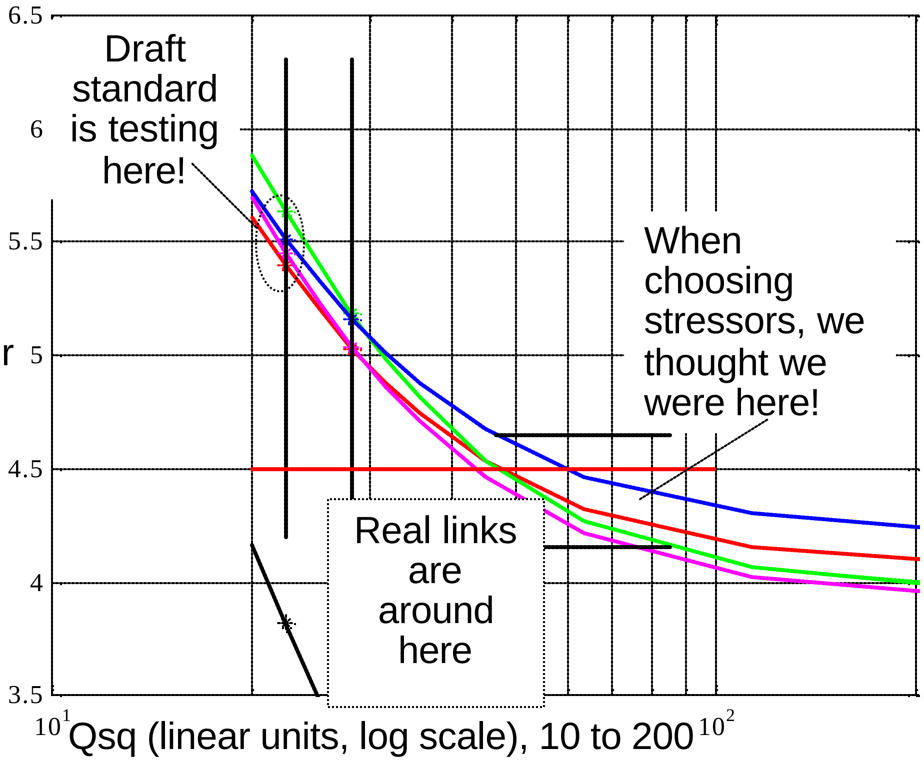
Relative difficulty of stressors with noise loading

Noise loading costs about 1.5 dBo (3 dBe) of SNR

Three D3.1 stressors plus high bandwidth link plus ewen_1_1005.pdf, split-symmetric #1, all at minimum received OMA

D3.1 split-sym (green) is worst affected

Gradient ~0.3 dBo or 0.6 dBe per 1 dBo of stressor noise
- Contributes to test uncertainty



PAlloc = 6.5 dB (sensitivity as assumed in D3.1)

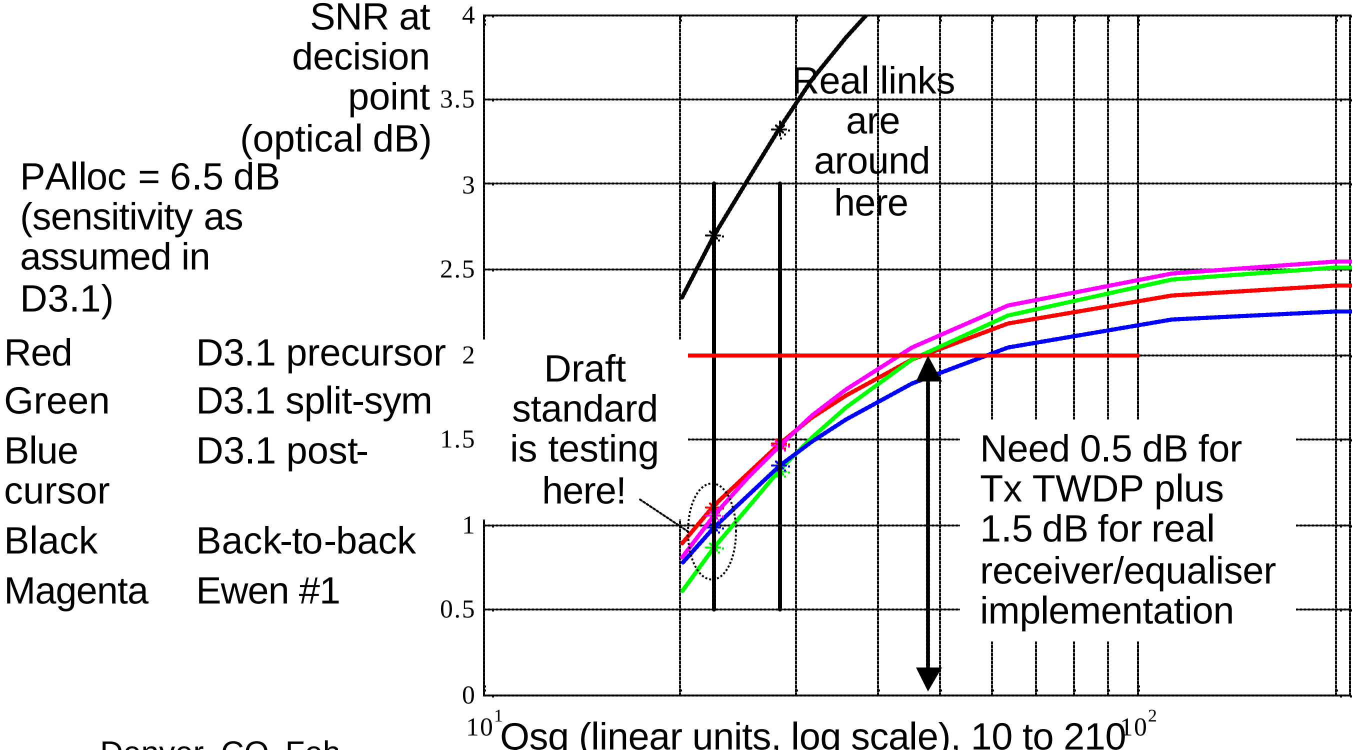
Red	D3.1 precursor
Green	D3.1 split-sym
Blue	D3.1 post-cursor
Black	Back-to-back
Magenta	Ewen #1

(ewen_1_1005.pdf, split-symmetric #1)

SNR margin for stressors with noise loading

After noise loading, there aren't many dB left!
1.5 dBo (3 dBe) of SNR is a big deal

1 dB better receiver sensitivity improves margin after noise loading by very roughly ½ dB



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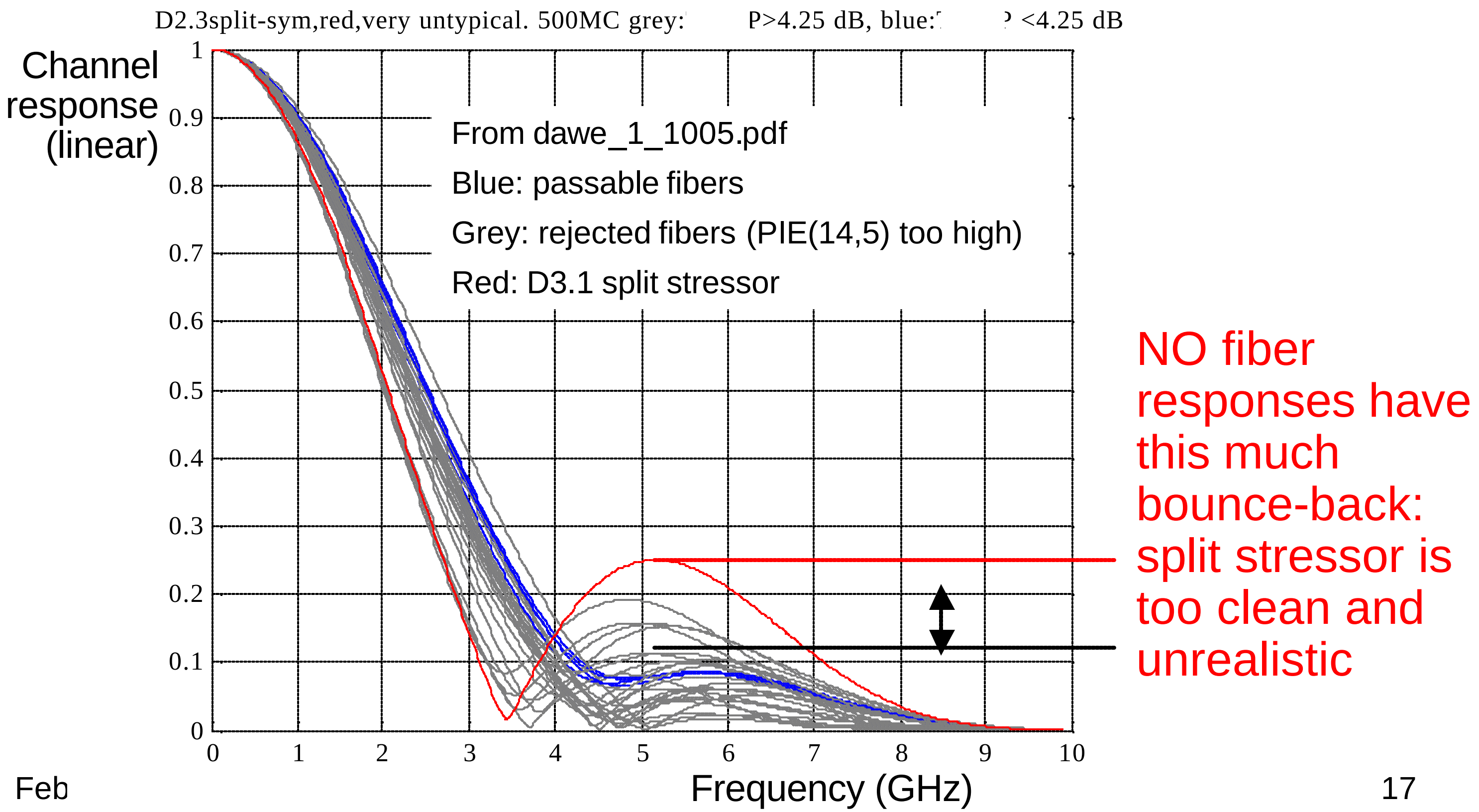
Current split-sym (red) very unrealistic: notch too deep, bounce-back too high

Plot shows the responses with notch deeper than 11 dBo up to 5.15625 GHz

FDDI, 1-1-220, dual launch

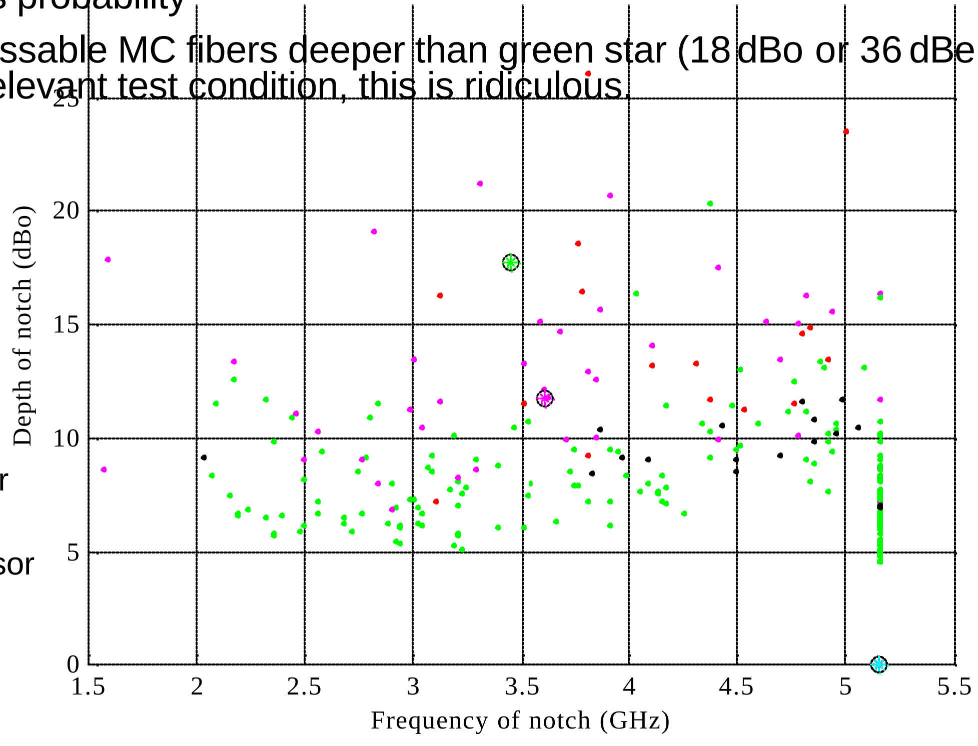
Note how unusual frequency notches like this are

Only 4% have notches (of any depth) < 5.15625 GHz: 3.5% CL, 0.7% OSL



Quantifying the rarity of a very deeply notched channel

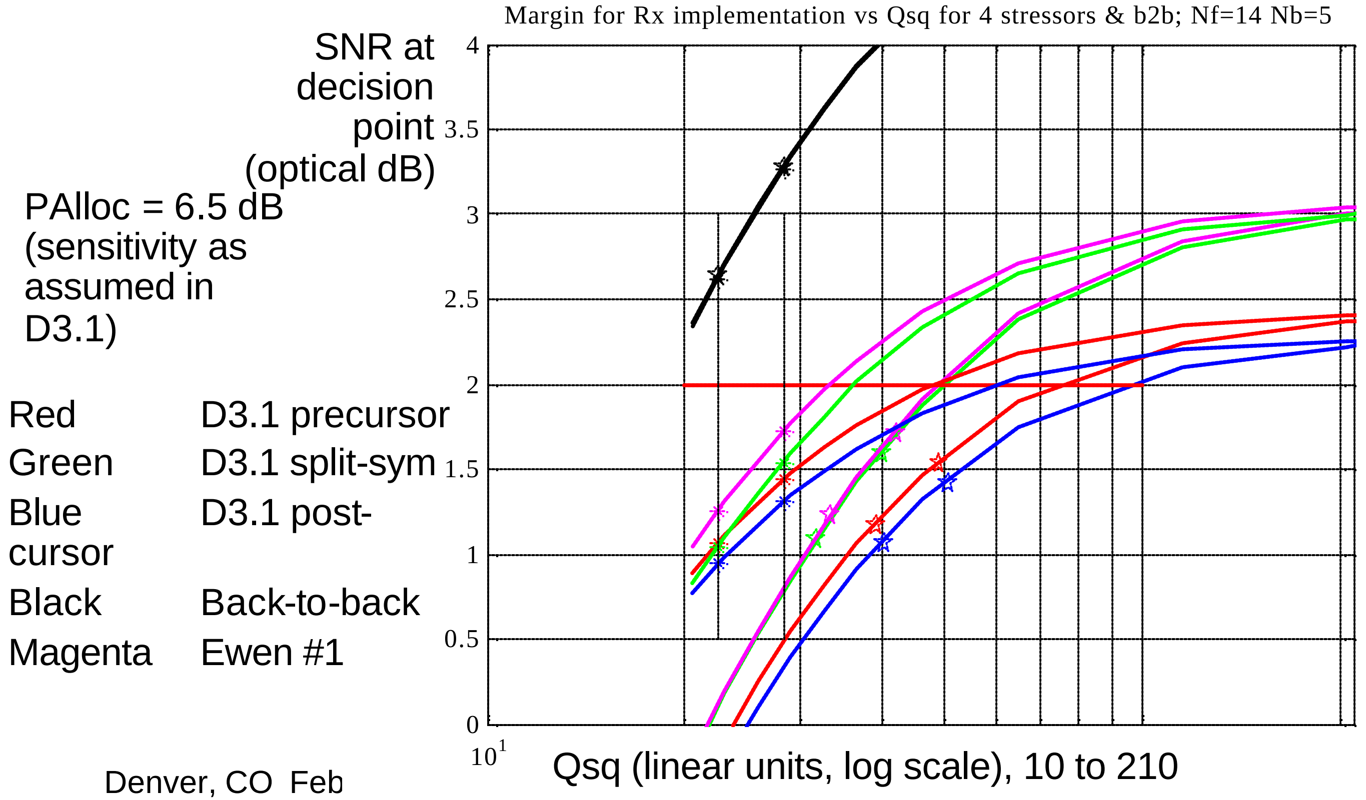
- Result of **more than 4000** Monte Carlo fibers
- Green & black: PIE(14,5)n < 5.5 dBo: OK to marginal fail, called "passable " below
  Red and magenta: PIE(14,5)n > 5.5: We weren't expecting to pass this fiber anyway
- Red and black: offset launch was best (the more common case in general: 67%)
  Green and magenta: center launch was best (the more common notched response: 5% of cases are CL, split in time domain, 1% are OSL, split in time domain)
- Asterisks circled in black: stressors
- Deep notches for passable MC fibers absent below 2 GHz
- Only 8 in 4000 passable MC fibers deeper than pink star (12 dBo or 24 dBe notch) and PIE(14,5)n < 5.5 dBo: all above 4 GHz. These are rare enough to ignore. Any evolution of center launch through time may raise this probability
- Only 1 in 4000 passable MC fibers deeper than green star (18 dBo or 36 dBe notch) and PIE(14,5)n < 5.5 dBo. As a relevant test condition, this is ridiculous.



Red	D3.1 precursor
Green	D3.1 split-sym
Blue	D3.1 post-cursor
Black	Back-to-back
Magenta	Ewen #1

Effect of noise color

- Comparing adding noise before transversal filter per D3.1 (asterisks, upper lines) or after (5 pointed stars, lower lines)
- Meeting the filtered Qsq values but getting the color wrong makes ~0.1 dBo difference!?! (This is not what I expected – can others confirm or correct?)
- Gradient for noise after transversal filter is steeper
- Some noise after transversal filter is probably unavoidable. How much? Need to be sure what our test is doing!



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Predicting SNR margins

- SNR margin = PAlloc – PIE(14,5)n
  - where PAlloc depends on received OMA: less loss means more PAlloc
  - and received OMA depends on channel loss (function of launch and connectors)
- Can calculate scattergrams of SNR margin from Monte Carlo model
  - With noise loading, case by case

Parameter mismatch loss in Monte Carlo model

- Parameter mismatch loss arises at a connector if e.g. the two fibers have different sized cores
- Believe worst case for 3 connectors is 0.5 dBo
- Last time, I assumed 0.5 dBo for all links
- John Ewen assumed 0 dB
- This time, I have used a uniform distribution from 0 to 0.5 dBo
- Still a conservative analysis

Modal noise in Monte Carlo model

- Modal noise caused by loss due to connector offsets
- Can find an upper bound to the modal noise as function of loss
  - See David Cunningham's presentation
- Actual modal noise could be significantly lower than this
  - Depends on individual modes rather than mode-groups – too complicated for my MC model
- Analysis assumes:
  - full visibility of speckle pattern
  - no filtering of modal noise frequency spectrum
  - and that equalizer has no idea how to adapt for it
- Pessimistic assumptions

RIN in Monte Carlo model

- Any population of transmitters won't have worst case RIN
  - RIN has a significant spread in manufacture
  - Cannot afford to throw away a lot of transmitters on test
- RIN spec is defined with worst amount and polarization of back reflection: must be lower or (with a good isolator) same in service
- Analysis assumes a uniform distribution of RINxOMA, from –130 to –128 dB/Hz
- Compare spreadsheet link model, uses a RIN coefficient of 0.7 or ~-1.5 dB of RIN
  - The uniform distribution is more conservative than this
- RIN in MC modelling is larger than expected in real life: conservative

Monte Carlo method summarized

- Varied realistically
  - Fiber DMD
    - Affects link's frequency response
  - Launch offset
    - Affects link's frequency response, loss and modal noise
  - Connector offsets
    - Affect link's frequency response, loss and modal noise
- Varied pessimistically
  - Transmitter RINxOMA
  - Parameter mismatch loss
- Not varied
  - Transmitter OMA
  - Transmitter waveform
  - Transmitter wavelength
  - Fiber attenuation (1.5 dB/km, worst case per spec)
  - Slow changes such as speckle changing with temperature
  - Number of connectors in a link (3)
  - Length of link (220 m)
  - Receiver sensitivity (noise floor)

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Monte Carlo results

- Histogram of SNR margin
- Scattergrams of margin vs Qsq overlaid with margin-Qsq contours of three stressors & Ewen #1

Histogram of SNR margin

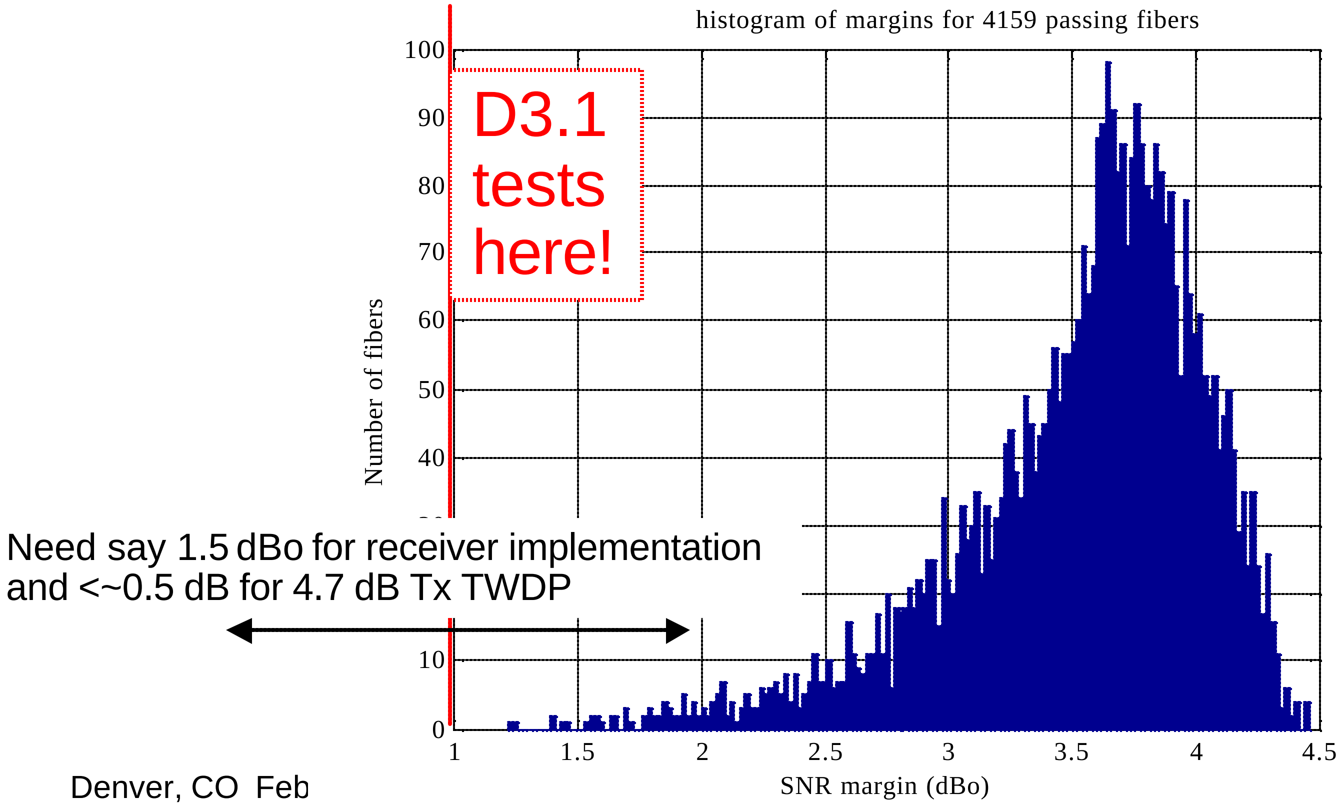
Histogram based on >4000 MC fibers

14+5 ideal equalizer

Note: some of the margin is needed for Tx TWDP 4.7 vs 4.2

Predicted yield is fine

Tests and real links are out of alignment



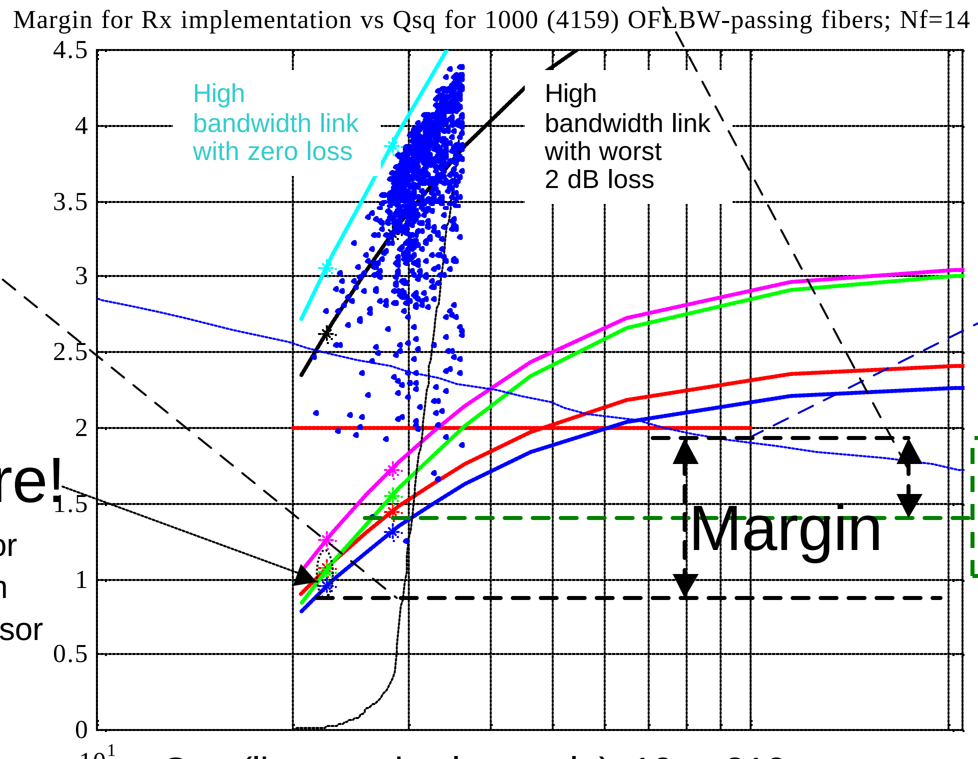
Monte Carlo simulation of DMD, loss, RIN and modal noise shows margin

Cumulative histograms based on >4000 MC fibers

14+5 equalizer

Plot shows 2000 fibers

Note: some of the margin is needed for Tx TWDP 4.7 vs 4.2



Cumulative histogram of Qsq, on vertical scale 0=0, 4=100%

Cumulative histogram of margin on Qsq axis

1% vs. model here

MC sims say test about here

D3.1 tests here!

Red	D3.1 precursor
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Qsq (linear units, log scale), 10 to 210

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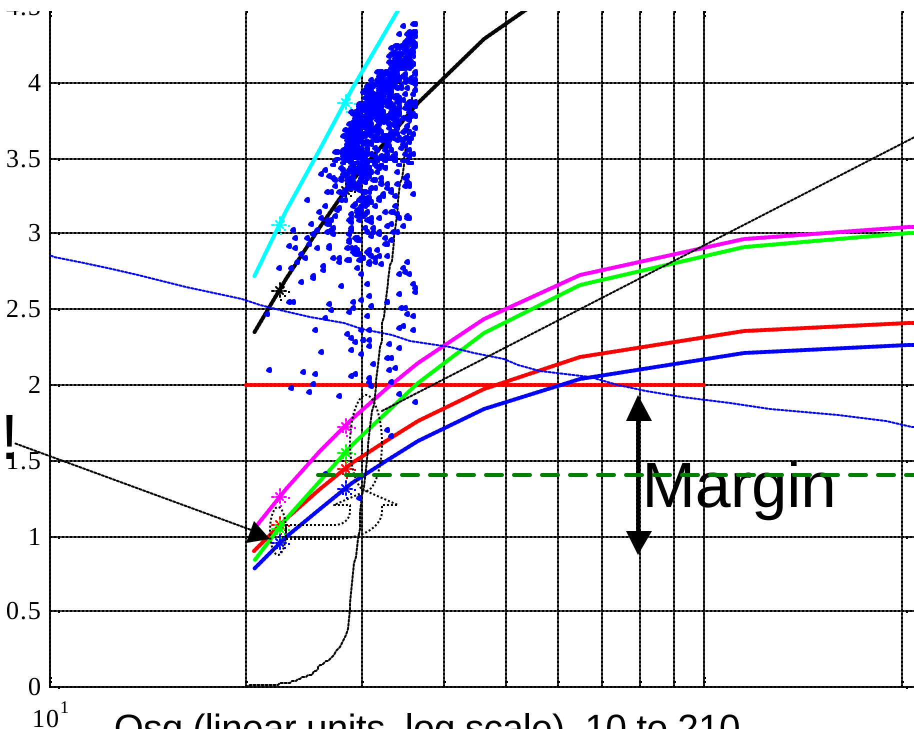
Proposed lower-noise test points

- Propose moving Qsq to 30 and changing split stressor to “John Ewen #1”
  - Gradient of penalty vs Qsq is less: reduced errors
  - Effect of noise color must be less: reduced errors
  - Smooth stressors (pre and post) at the right margin vs MC sims – these stressors are more like the majority of real channels and define coverage
  - Unnatural green split stressor replaced by more moderate magenta “John Ewen #1” – tests for receiver’s versatility rather than defining coverage



D3.1 spec vs implementation

- Implementers' design choices are confidential, but some say that
- D3.1 noise loaded spec restricts the EDC IC choices available to module builders
- And restricts the EDC IC technology choices choices available to IC builders
- Reasons…
  - Test is not representative of application
  - Would cause problems in the future
    - e.g. would not be able to migrate from SiGe to CMOS, or from today's power to lower power, or to equalizers integrated into port ASICs
- Costs yield, excessive margin
- Current noise level excessive, restricts choices, fails good receivers
- Removing the noise addresses these issues

D3.1 spec constrains CSRS implementation choices

- Requirement for 2 shaped noise levels and their importance makes CSRS test very complex
  - 6 test conditions is too many
  - Forces a very linear (difficult) analog implementation
  - Rules out clocked delay lines that may be more accurate
  - Raises calibration problems that most will ignore
  - Needs (electrical) spectrum analyzer (as well as scope) to verify
- This will cause very poor agreement between compliance testers
- Removing the noise addresses these issues
- How much residual noise do testers have anyway?

Conclusions

- Reduce the noise loading significantly
- Use one noise loading level rather than two - simplification in tester
- Consider defining test "as if without noise" or with the noise expected "naturally" from the tester
- Either: change the split stressor to a representative one
  Or: remove it