Protecting against the error floor

P802.3db Draft 3.1 comment R1-11

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Introduction

- As rates increase, eyes get more closed
  - Even after the equalizer
- We use FEC to run at a higher BER yet still deliver a good link
- We expect to deliver much better than the spec-worst performance
- We expect that an affordable improvement in receiver sensitivity will allow a marginal transmitter to make a good link
- Error floors are observed, particularly with PAM4

As rates increase, eyes get more closed

Lane rate	10G		25G			50G		100G	
BER	1e-12		1e-12	5e-5		2.4e-4			
Qmin	7.03		7.03	3.89		3.41 (×3 = 10.2)			
	TDP	TDP	TDP	TDEC	TDP	TDECQ	K	TECQ, TDECQ	K
DR						3.2+4.8	3.2+4.8	3.4+4.8	3.4+4.8
LR	3.2	2.6	2.2		2.7	3.2+4.8	3.2+4.8	3.4+4.8	–
SR	3.9	3.5		4.3		4.5+4.8	4.5+4.8	4.4*+4.8	–

* In the compliance test: up to 4.5 dB in service

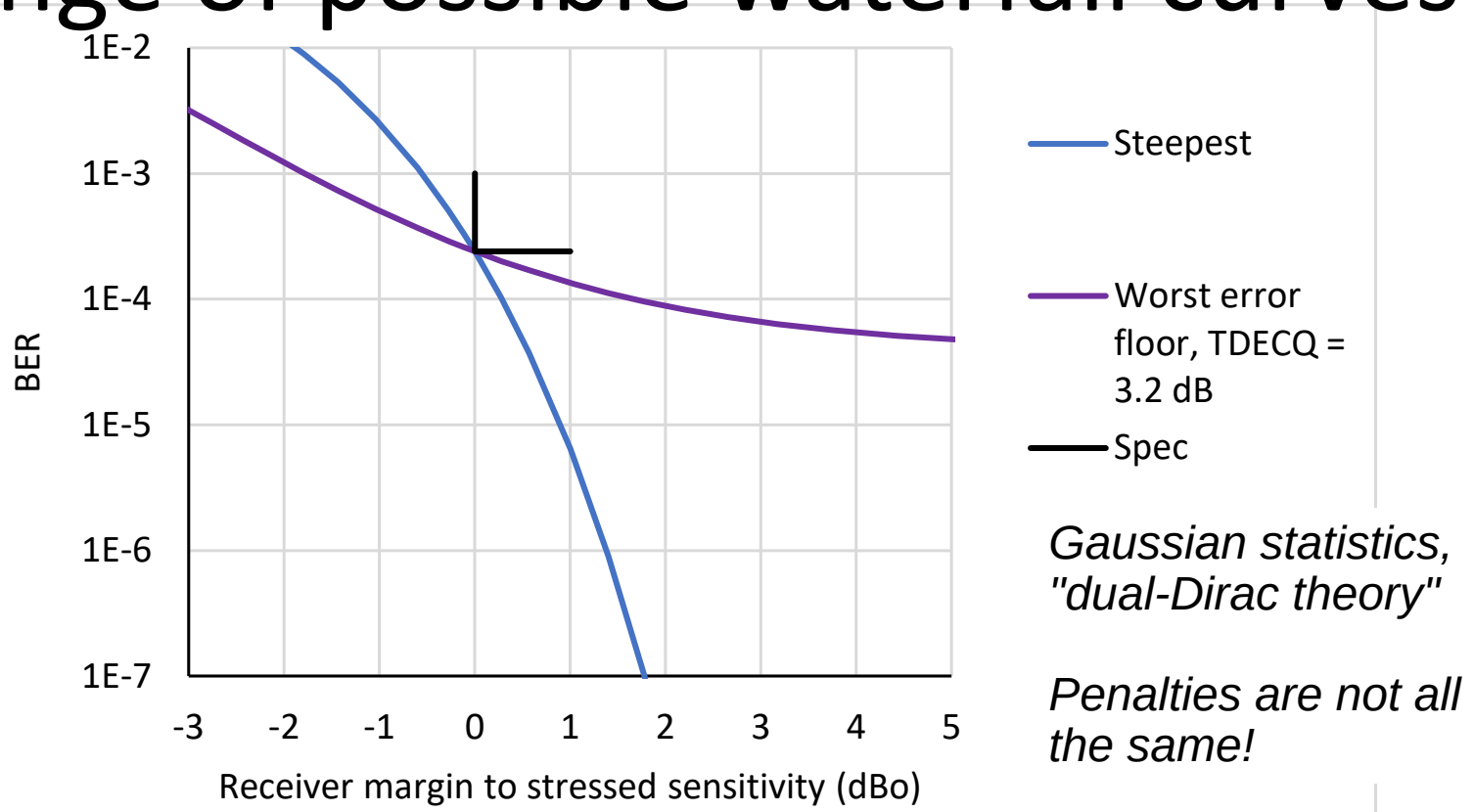
At 10G, a receiver could add noise of (10^-0.39)/(2*7.03) RMS or 2.90% of OMA

Now for SMF it's (10^-0.32)/(2*3*3.41) to (10^-0.32)/(2*3*3.41) or 2.34% to 2.23% of OMA, even after the reference equaliser has done its best to open the eye

Now it's (10^-0.44)/(2*3*3.41) to (10^-0.45)/(2*3*3.41) or 1.77% to 1.73% of OMA

As we push an increasing burden on the receiver, we need to be careful

Range of possible waterfall curves

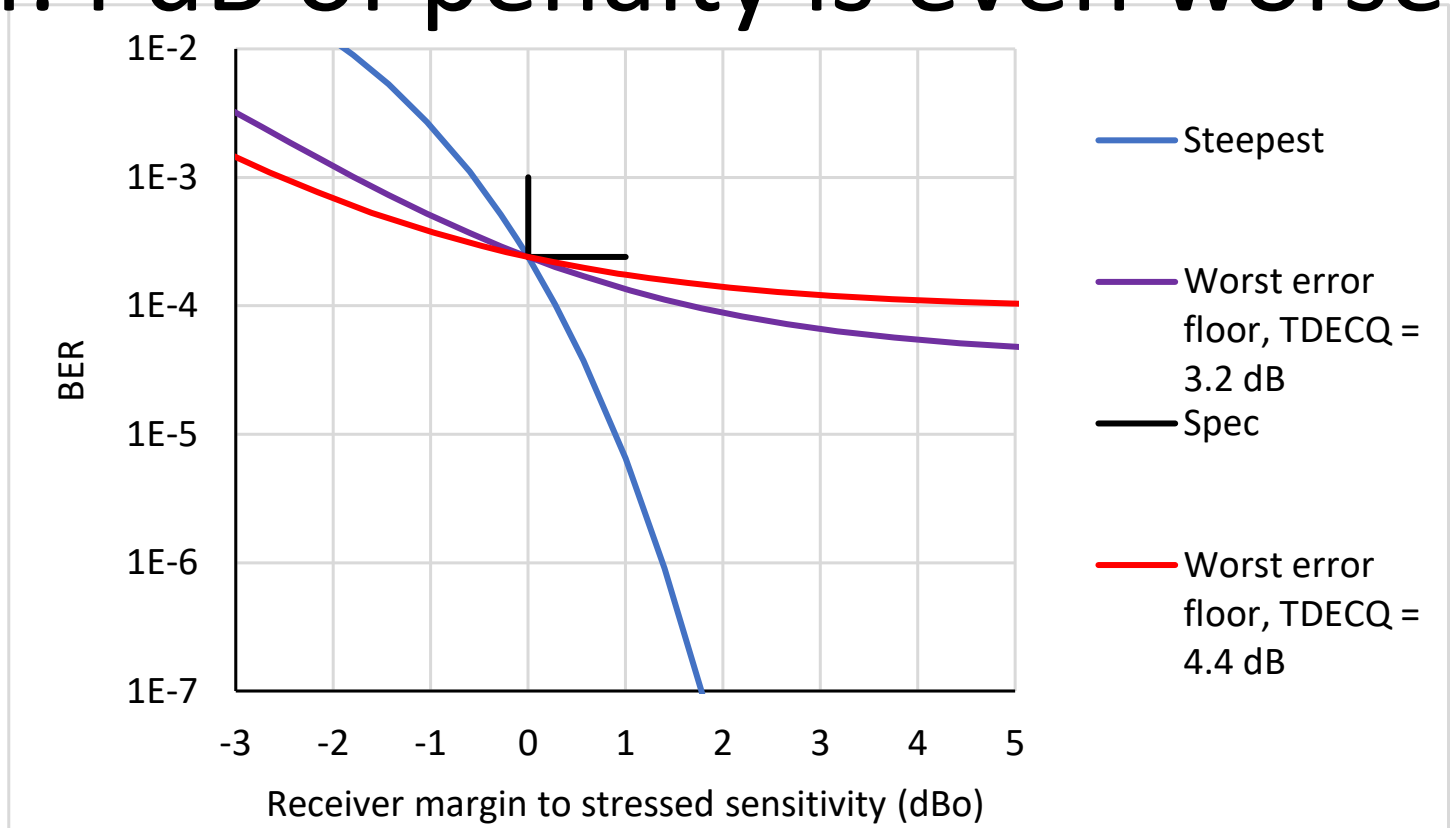


Gaussian statistics, "dual-Dirac theory"

Penalties are not all the same!

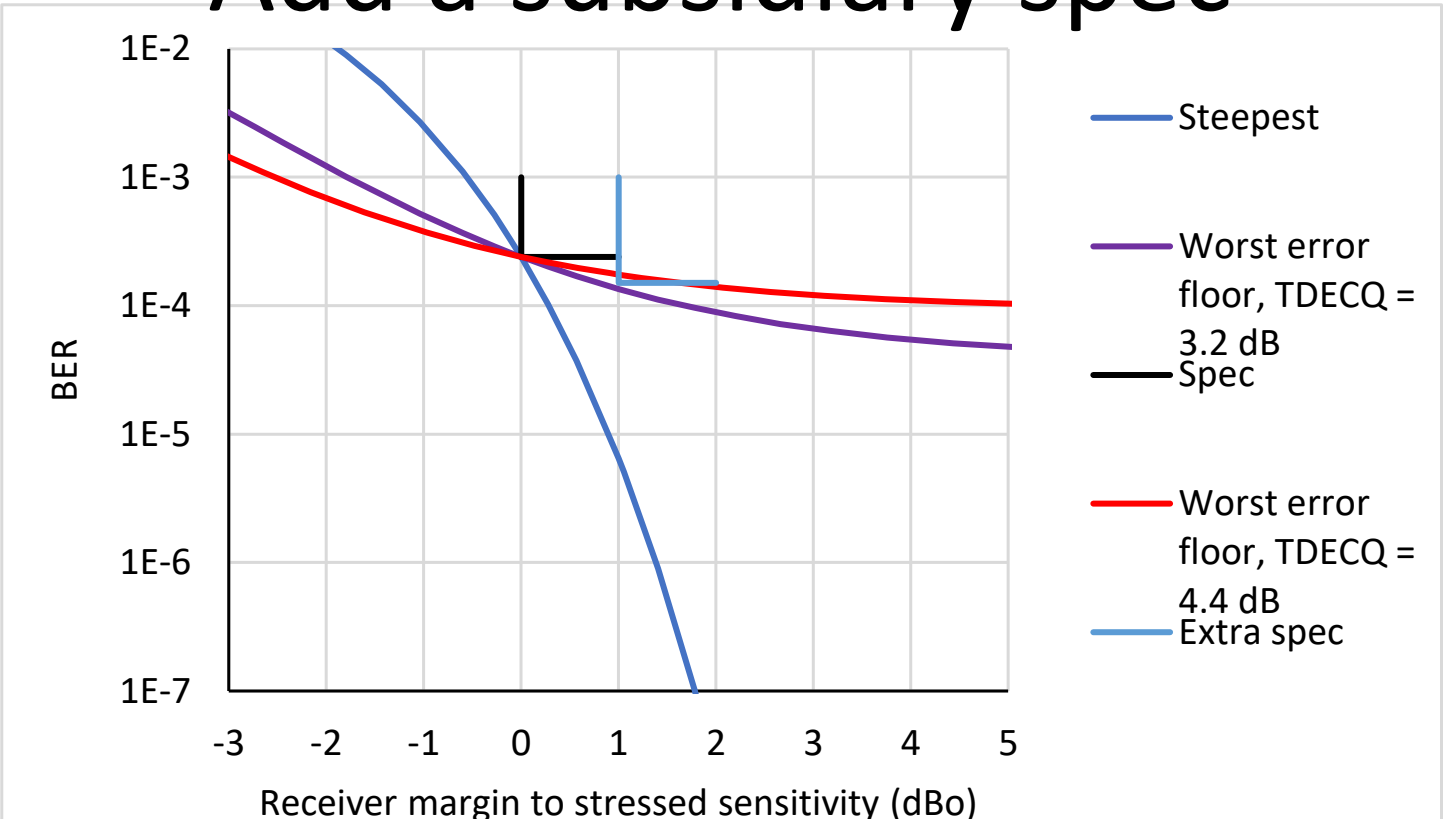
- Two transmitters with the same 3.2 dB TDECQ (the limit finally adopted for the first PAM4 optical PMDs)
  - Blue one has high-probability (narrow distribution) impairments, purple one has Gaussian impairments
- A receiver deals with this with better sensitivity
- The theoretical worst error floor (asymptote) for 3.2 dB of unfortunate K is 3.8e-5

4.4 dB of penalty is even worse!



- With 4.4 dB of TDECQ receiver needs more than twice the better sensitivity to get to a reasonable BER
  - To be more precise, it's an unfortunate transmitter with 4.4 dB of K
  - TDECQ = K + Ceq, all in dBo
  - The theoretical worst error floor (asymptote) for 4.4 dB of unfortunate K is 9.3e-5
- As what we care about is to the right of the nominal spec, put another spec there

Add a subsidiary spec



- We can't spec far to the right because of instrument noise
- Proposing a limit of 1 dBo less added noise R in TDECQ than the spec (not the transmitter under test's R), for a predicted BER of 1.5e-4
- Like a (OMA_{outer} – T(D)ECQ) limit at a better BER
- The implied ~TDECQ at 1.5e-4 for a Tx with min. OMA, max TDECQ at 2.4e-4, with worst error floor, is 5.16 dB. Raising the OMA by 0.76 dB buys this out. Other passing combinations are possible

Further information

- In terms of error floor, this makes MMF transmitters (high TDECQ limit) perform similarly to SMF ones (not so high TDECQ and K limits)
- To make this spec a free by-product of TECQ and TDECQ, don't search for different tap weights at the lower noise value R, just use the ones already found for regular TECQ and TDECQ
- The target noise R in the draft is: min(OMA_{outer} – T(D)ECQ) divided by Q_t, divided by 6 for PAM4
- min(OMA_{outer} – T(D)ECQ) = -4.4 dBm or 363 µW
- 1/(6*3.414) = 17.7 µW or -17.5 dBm RMS
- This extra spec: 14.1 µW or -18.5 dBm RMS
- Transmitters can easily pass this by various combinations of avoiding the worst kind of penalty and/or keeping off the minimum OMA

Conclusion

- As penalties are far from all the same,
- and error floors are a concern with PAM4 and exacerbated by the high TDECQ limit for MMF,
- and better-than-nominal performance is commercially necessary,
- Add a quick side calculation to T(D)ECQ that looks more directly at a transmitter's ability to deliver a somewhat better-than-nominal BER
- No additional measurement required