TDECQ and SRS

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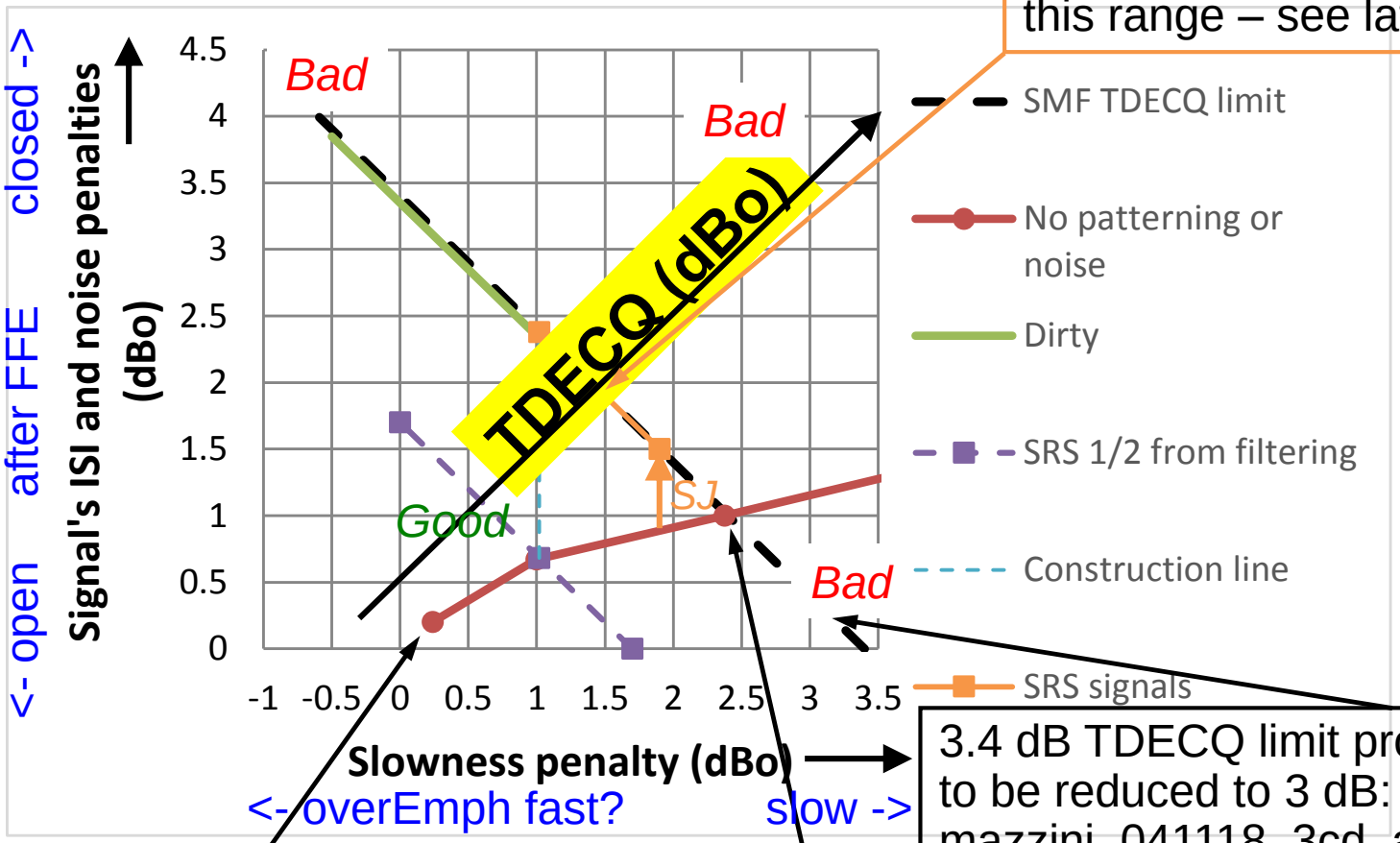
1-dimensional TDECQ is only part of what we need. SRS tweaks can follow

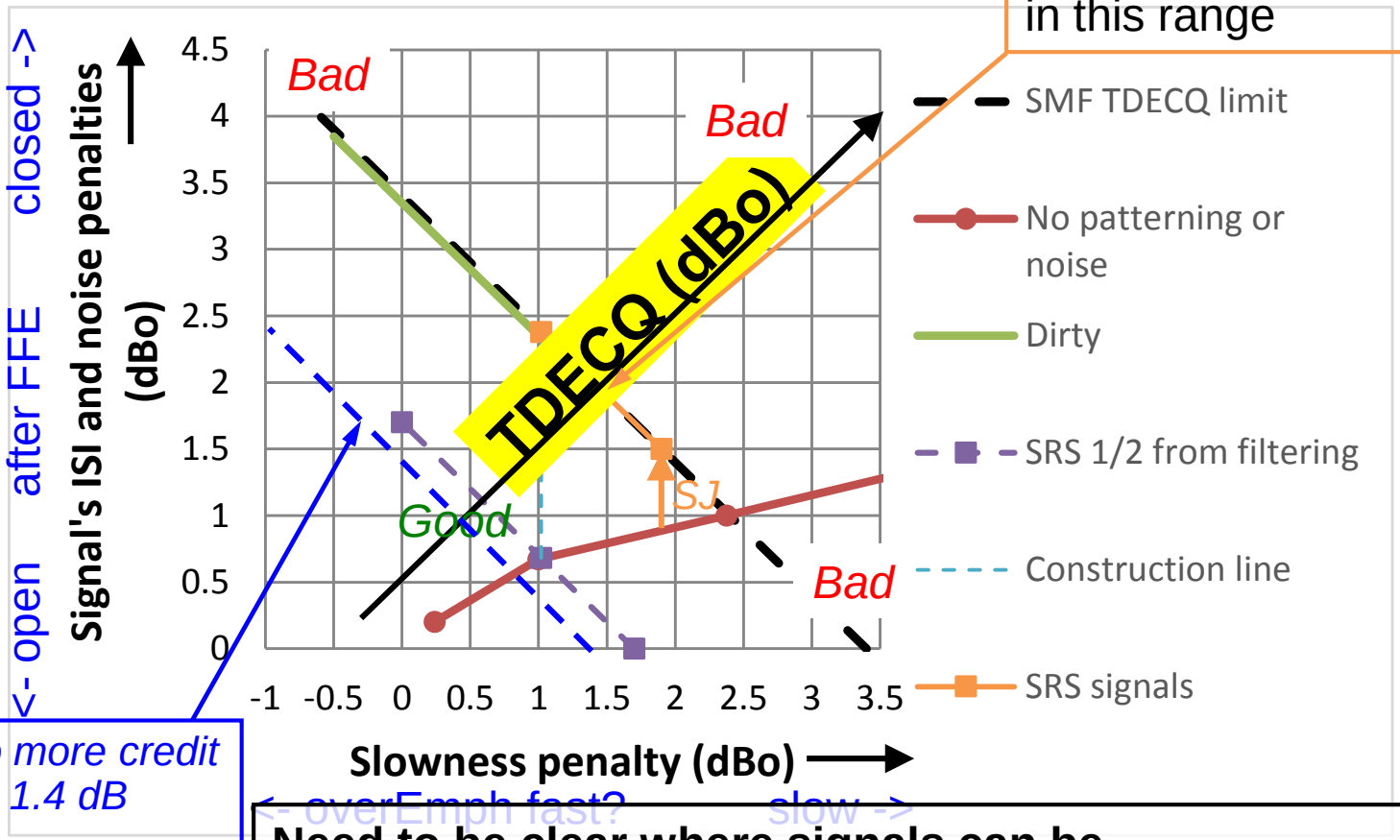
- Continuing to investigate the variety of bad signals (both in-service signals and stressed receive signals), considering where the limits of compliance should be and how to achieve them
- Follows dawe_3cd_01a_0318.pdf , dawe_032118_3cd_adhoc.pdf , dawe_040418_3cd_adhoc , dawe_1_0418 and dawe_041118_3cd_adhoc-v2
- *New this week – more on SRS, and a main tap strength limit. Some latest comments. Clean-up and clarifications. New slides or changes include slides 4, 5, 11, 13, 16-18*

TDECQ map (50GBASE-LR, 100GBASE-DR)



TDECQ map (50GBASE-LR, 100GBASE-DR)

SRS signal must be in this range



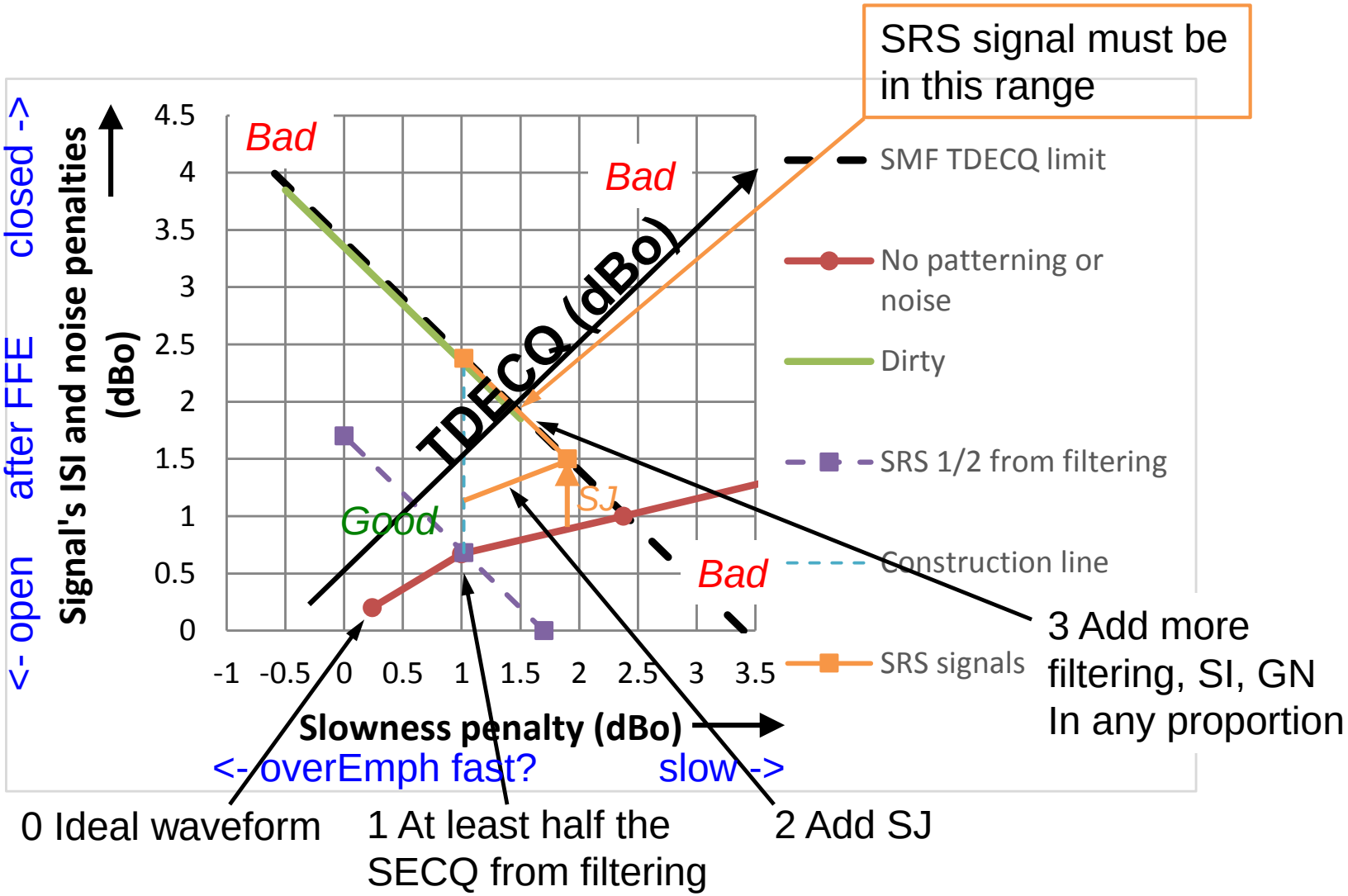
Tx gets no more credit for OMA < 1.4 dB

Signals below the blue line have to provide more power than OMA-TDECQ limit

Need to be clear where signals can be

- √ Bottom: natural limit
- √ Upper right: TDECQ limit
- × Right: vertex where it appears real transmitters aren't
- × Top: no limit
- × Left: no limit

Calibration of signal for stressed receiver sensitivity



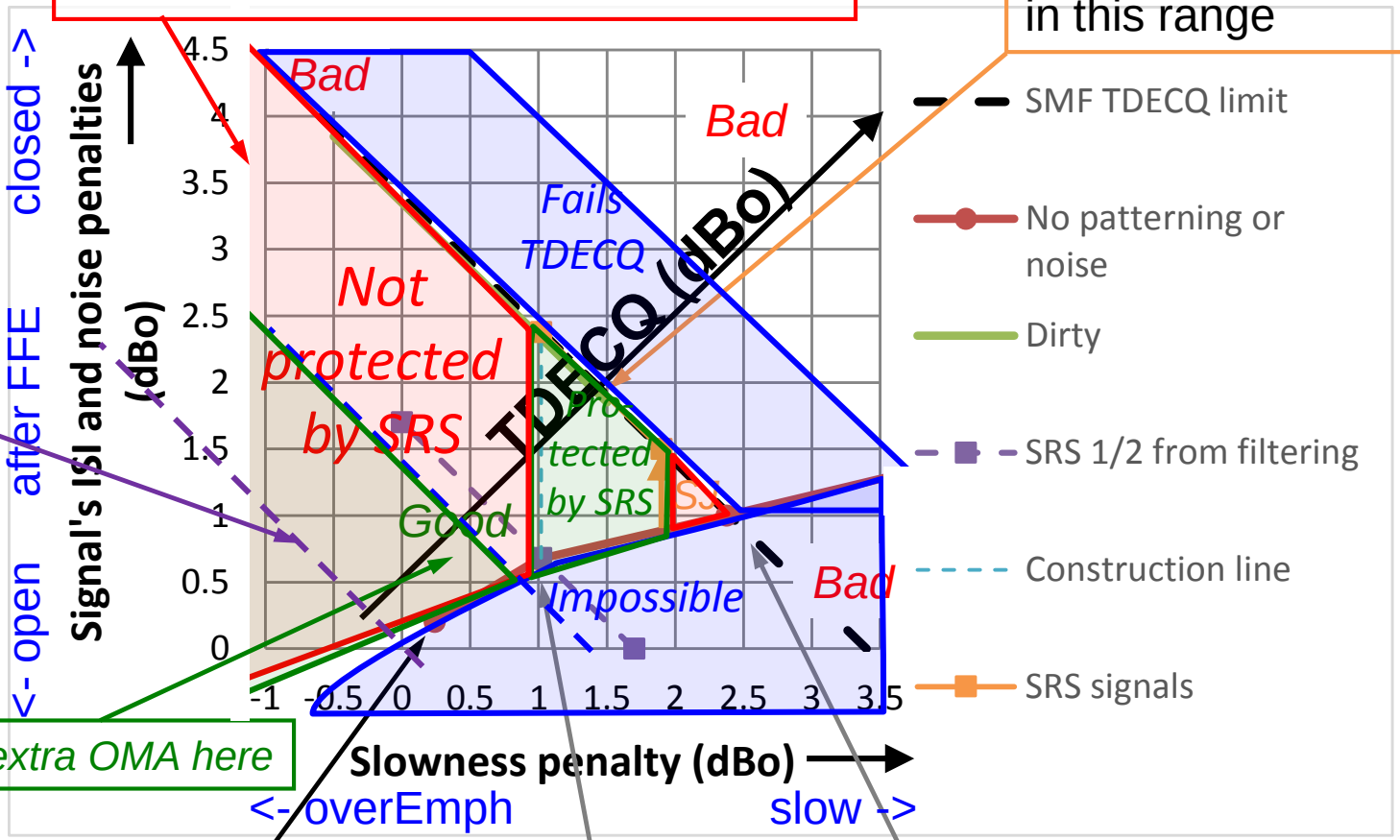
- *Present draft allows unrealistic amounts of Gaussian noise*
- *When we know where acceptable transmitters are (left to right) we can adjust the "at least half the SECQ from filtering" rule to adjust the coverage (comment 55)*

TDECQ map and Rx specs

There's no limit on the left in the draft

SRS signal must be in this range

The "other" receiver sensitivity is defined up to the max for TDECQ, with min. zero, which seems too low



Rx sees extra OMA here

Ideal waveform

Half the SECQ from filtering

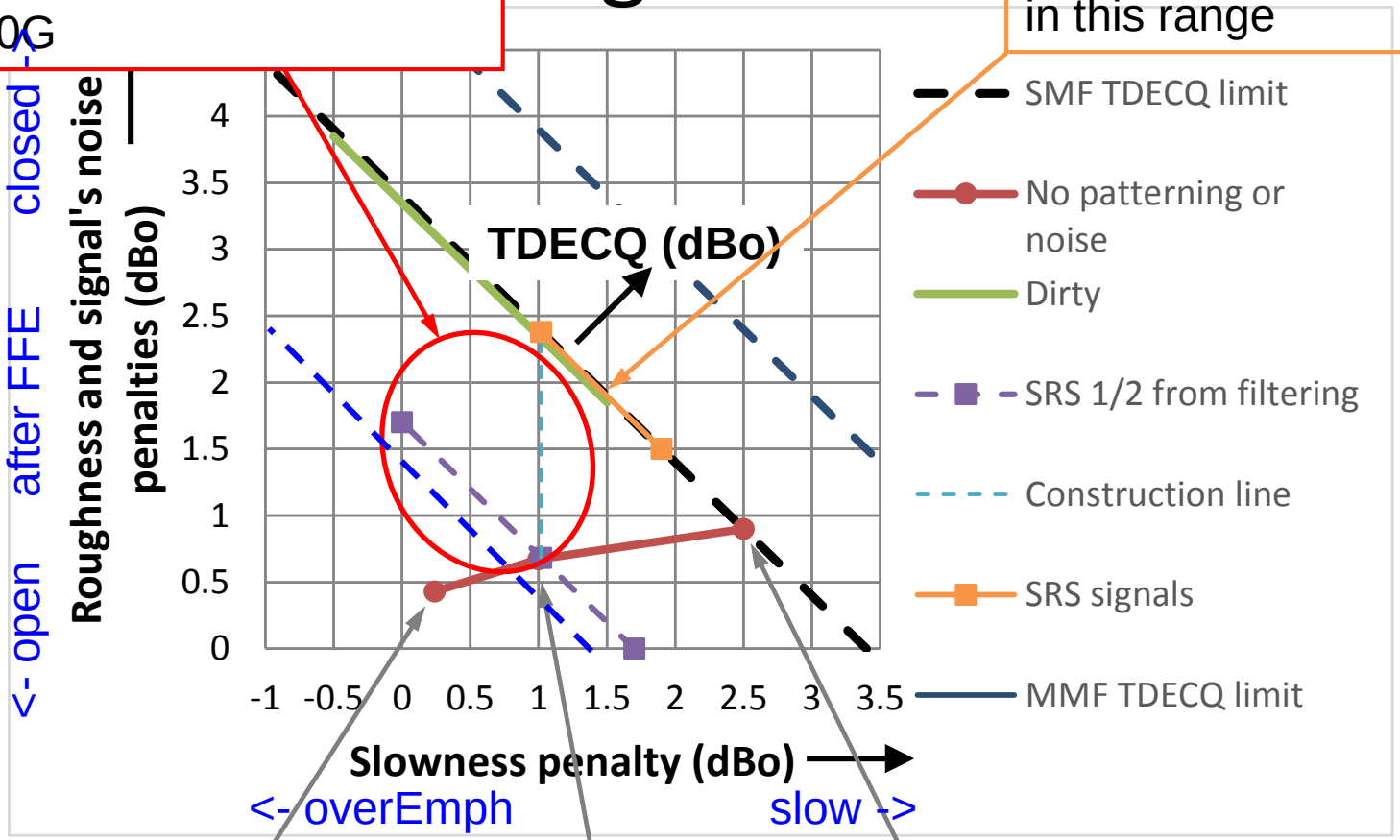
Slowest, as dawe_3cd_01a_0318 slides 2 to 5

Transmitted signals are allowed that receivers don't have to receive (red regions)

Mismatch between SRS and real signals?

Where will real poor signals be? Here? 50G can be better than 100G

SRS signal must be in this range



Ideal waveform

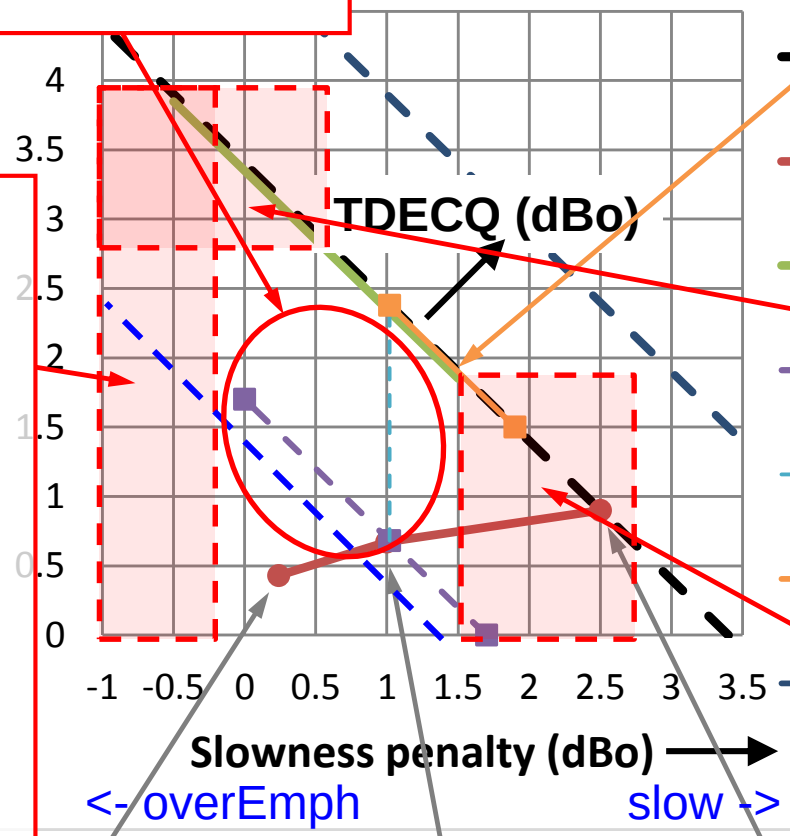
Half the SECQ from filtering

Slowest, as dawe_3cd_01a_0318 slides 2 to 5

Don't support unrealistic bad scenarios

Where will real poor signals be? Here? 50G can be better than 100G

SRS signal must be in this range



A region like this should be excluded because it requires significant tap weights of the opposite sign to normal, could confuse the CDR, no benefit to Tx

A region like this should be excluded because the eye after FFE is very closed, and small amounts of e.g. nonlinearity would cause big additional penalties (cliff edge)
Like VEC issue in C2M

Ideal waveform

Half the SECQ from filtering

Slowest, as [illegible] slides 2 to 5

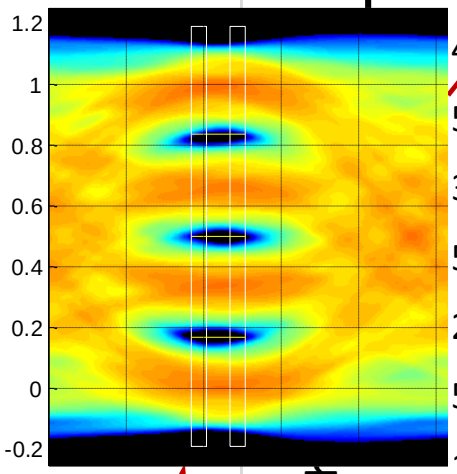
A region like this should be excluded because it requires strong tap weights not useful in practice, would probably have failed T/2-spaced TDECQ

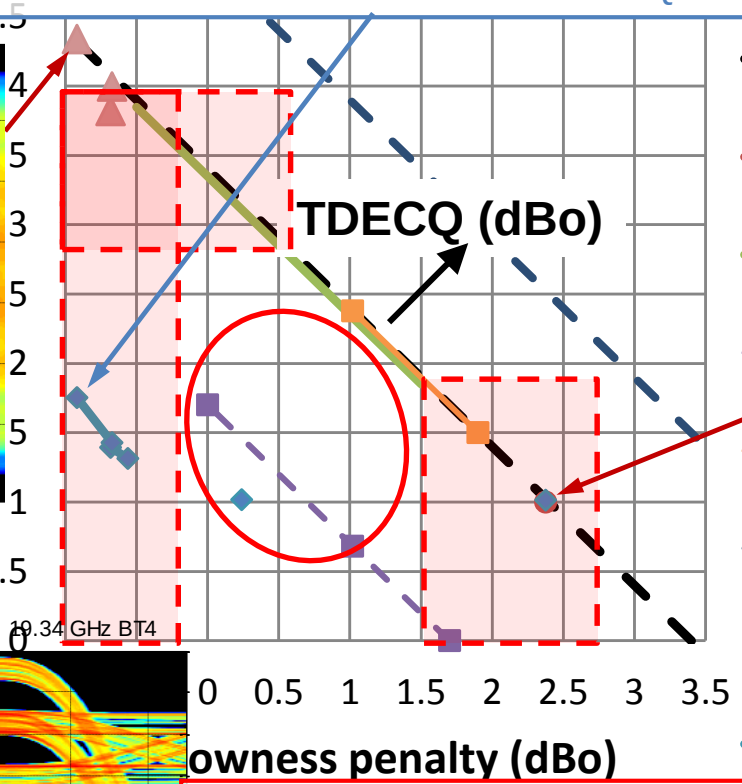
"Exclusion" could be by giving signals in the red boxes worse TDECQ scores, or by "hard" pass-fail rules

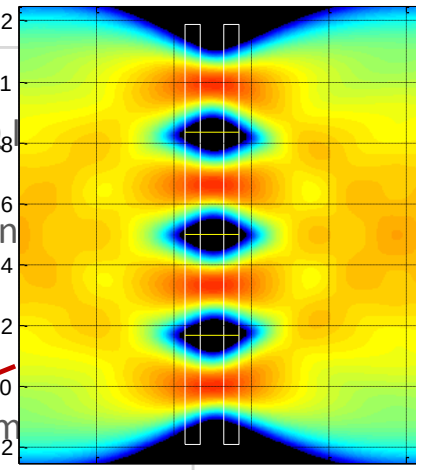
Extremes of worst-case signals

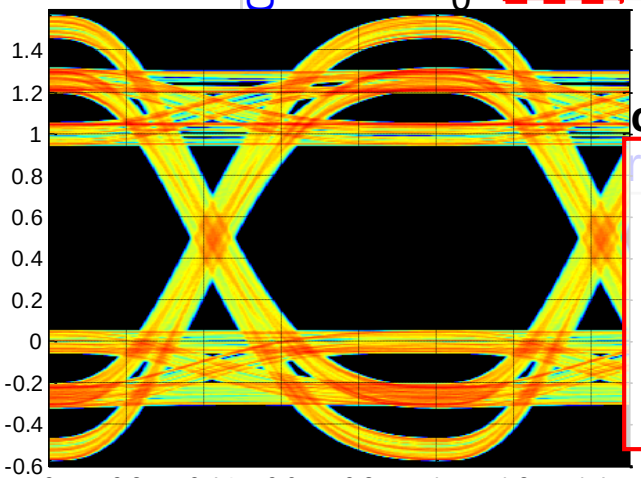
The two upper signals (after reference Rx FFE) are shown with all but 1 dBo of Rx noise

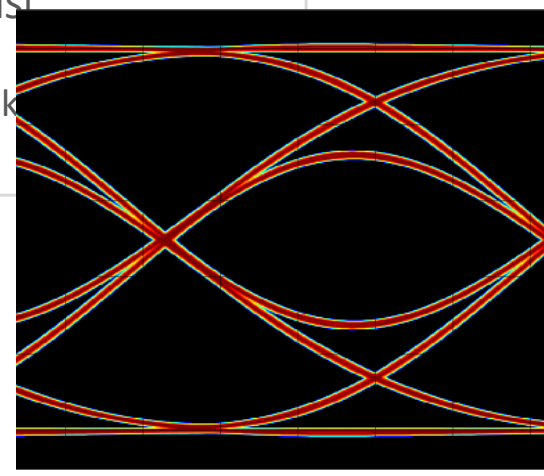
Peak/OMA increases when signal is over-emphasised or slow-but-emphasised
These points are observed in the same fb/2 BW as TDECQ. See later.







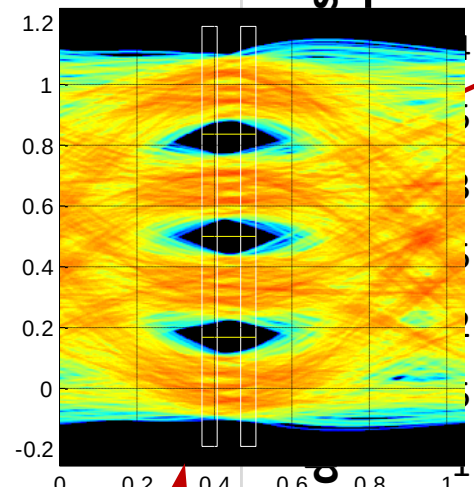


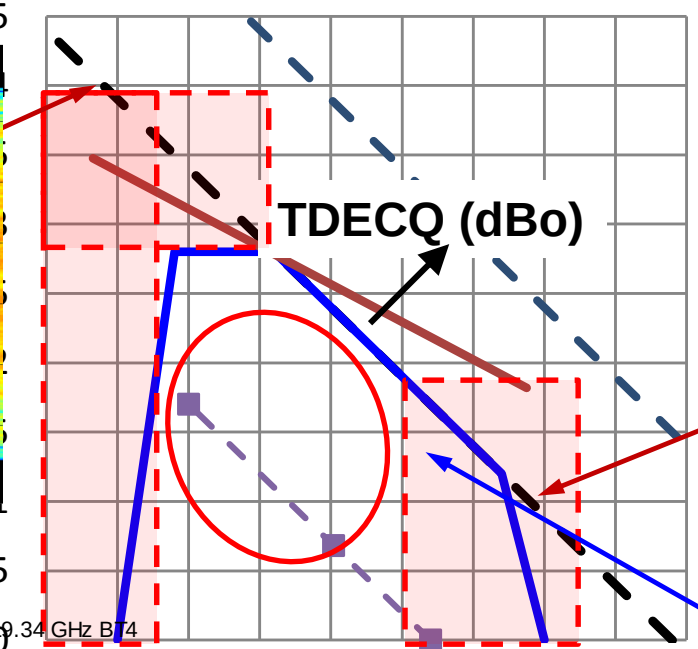


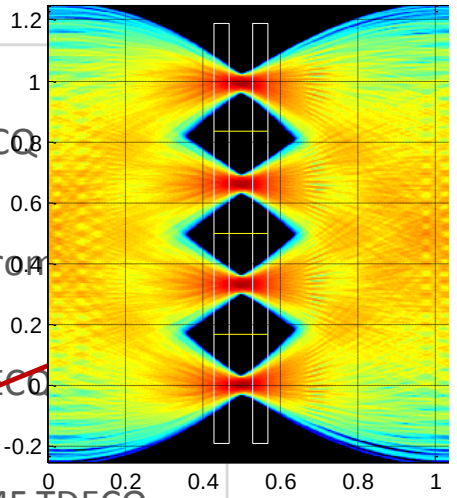
The signal on the left is bad because nothing can be done to improve it – neither sensitivity nor EQ.
Worse is allowed by the draft

Example improved specs

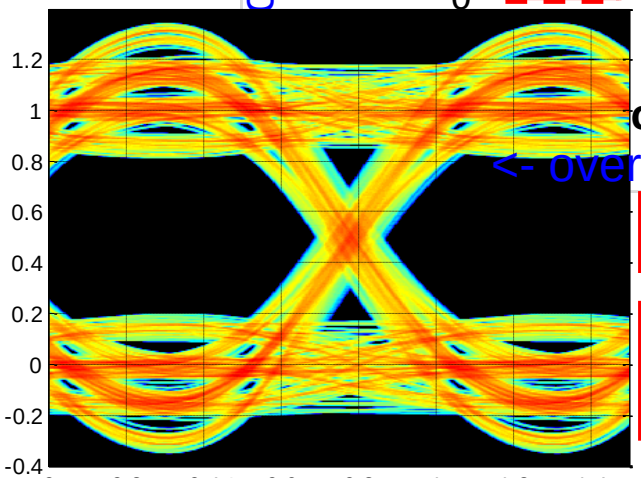
These signals are shown with very little noise







Same transmitter in 25G PAM2 mode, 19.34 GHz BT4

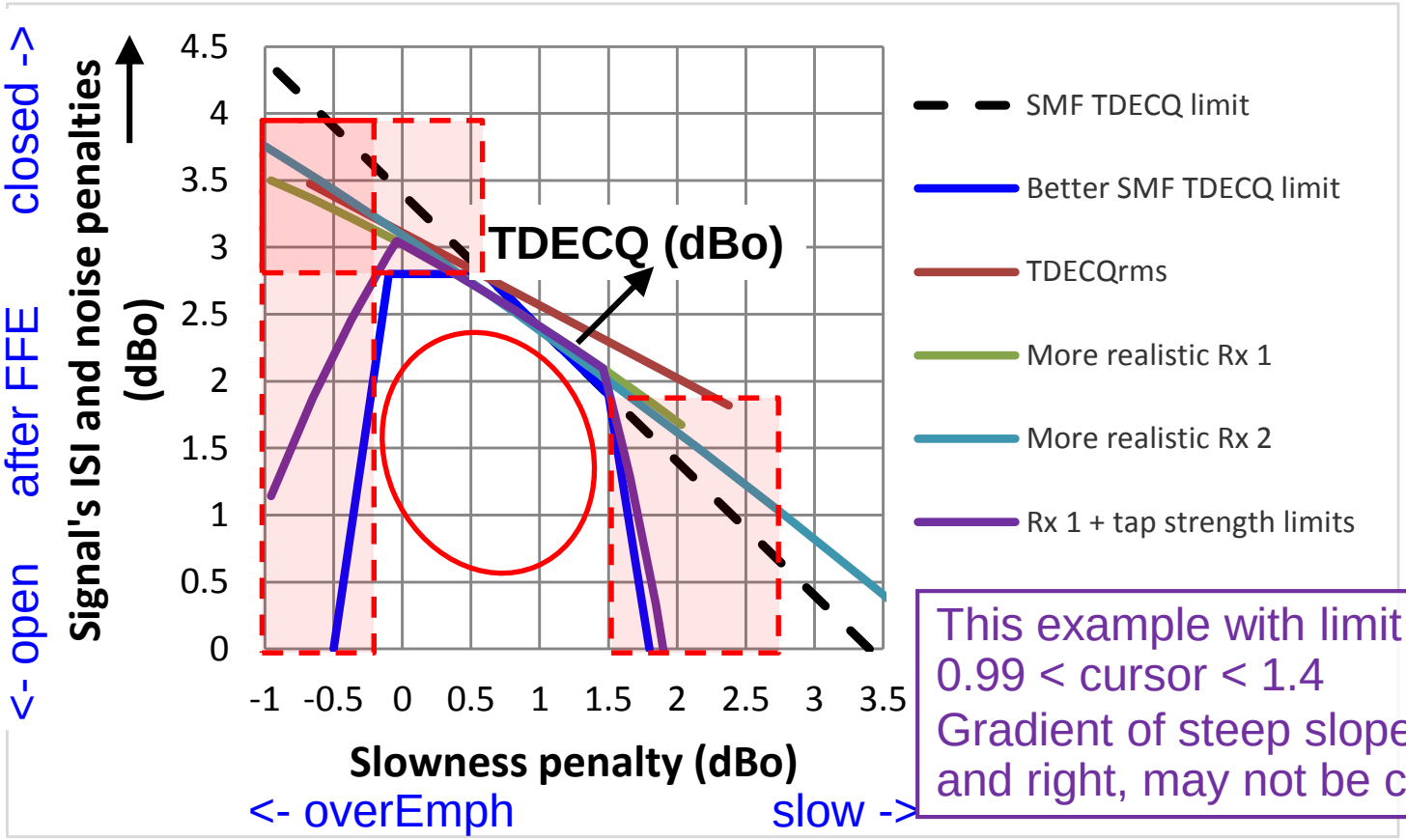


Very slow corner would make more sense for 100G lanes than 50G lanes

Need to come to a consensus on what's reasonable

Upper left: Example of a signal that no reasonable 400GBASE-F/D/LRn should have to receive

More realistic receiver; tap limits

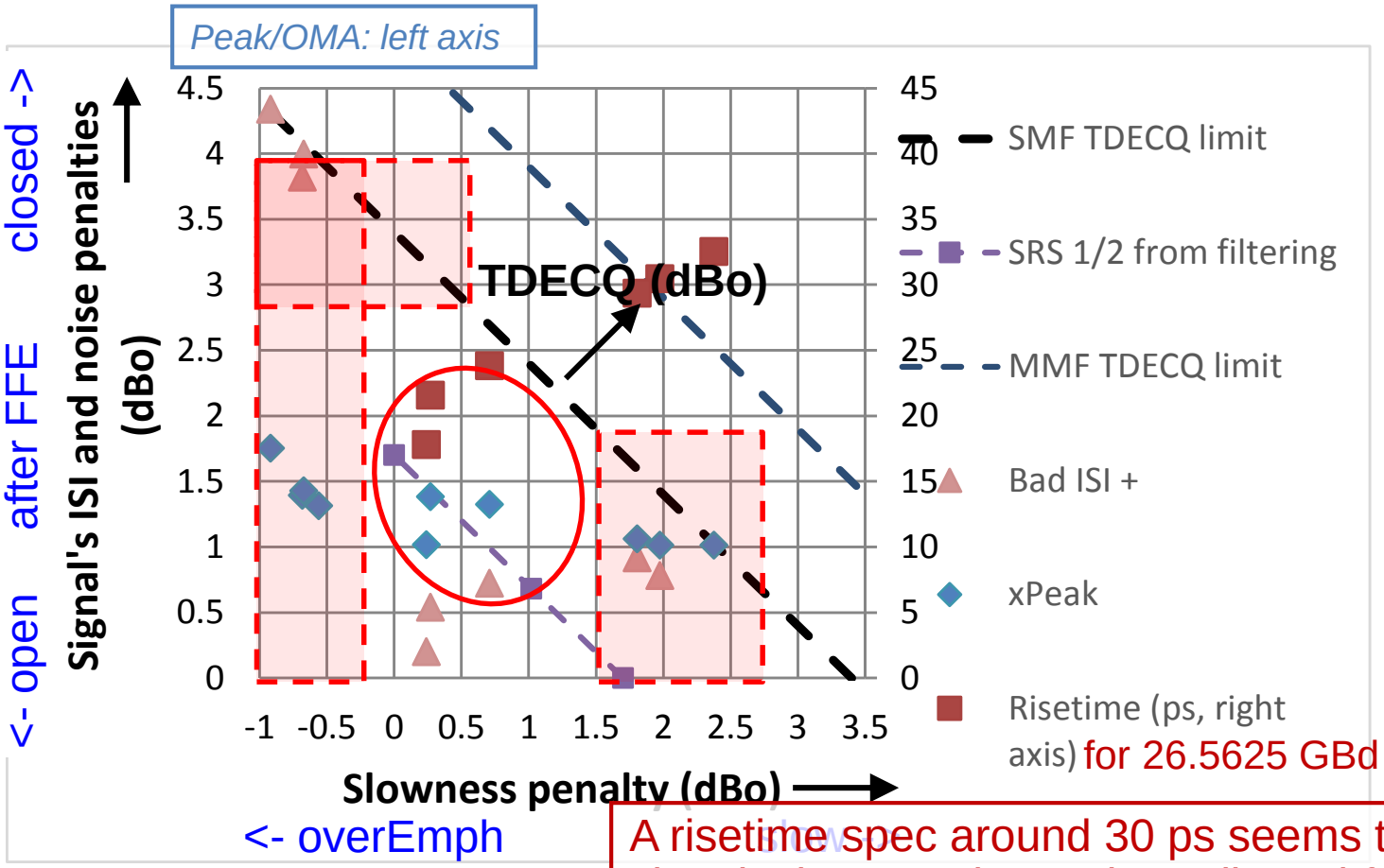


This example with limit
0.99 < cursor < 1.4
Gradient of steep slopes, left and right, may not be correct

The green and blue-green lines represent receivers with some internal impairments such as finite tap and threshold setting accuracy

The purple line ***(preliminary – needs confirmation)*** shows how a finite range of tap weights affects things, with either a real receiver or the reference FFE in TDECQ

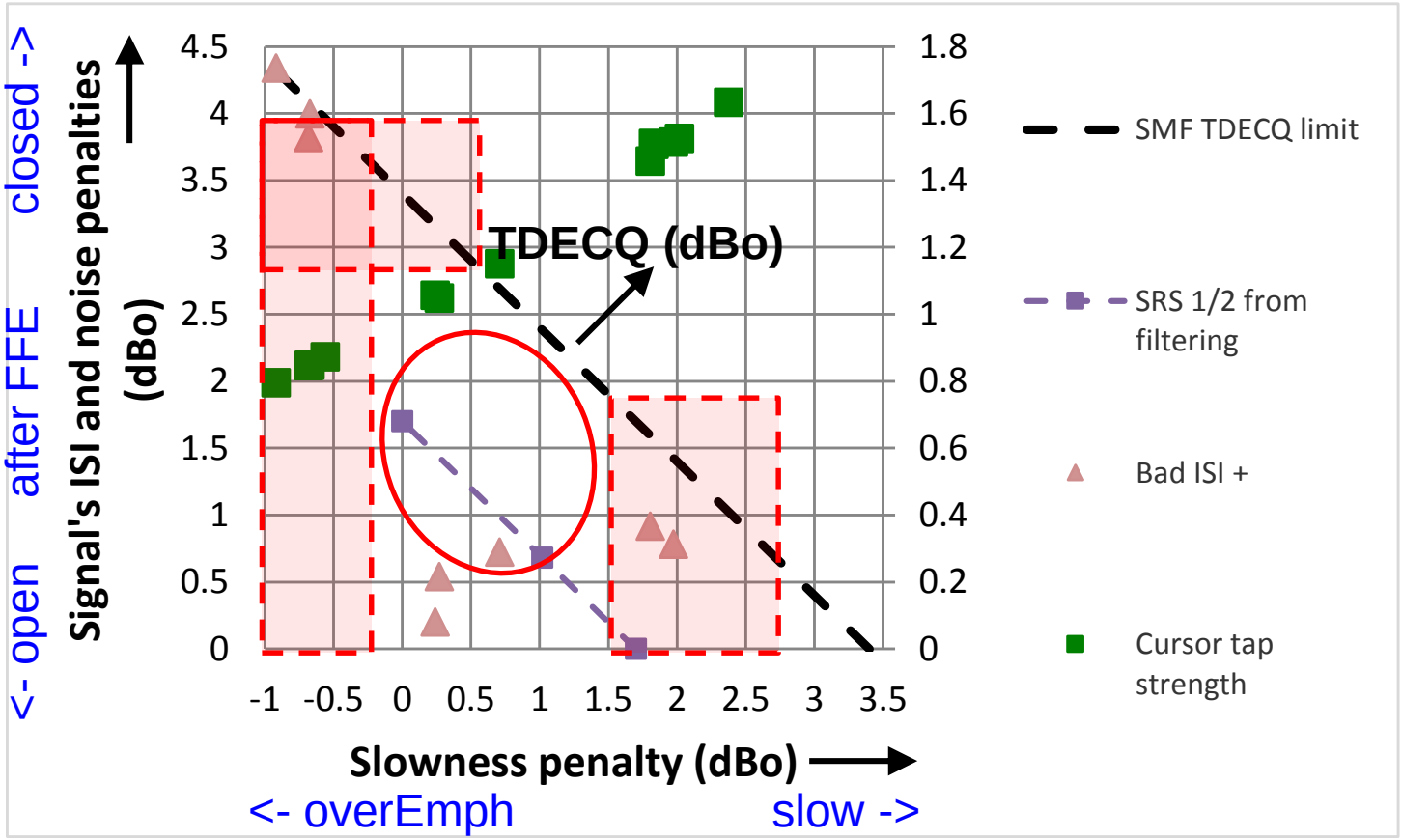
Possible peak/OMA and risetime specs



A peak/OMA spec would exclude signals that have too much "dynamic range", but does not seem to control over-emphasis unless very bad

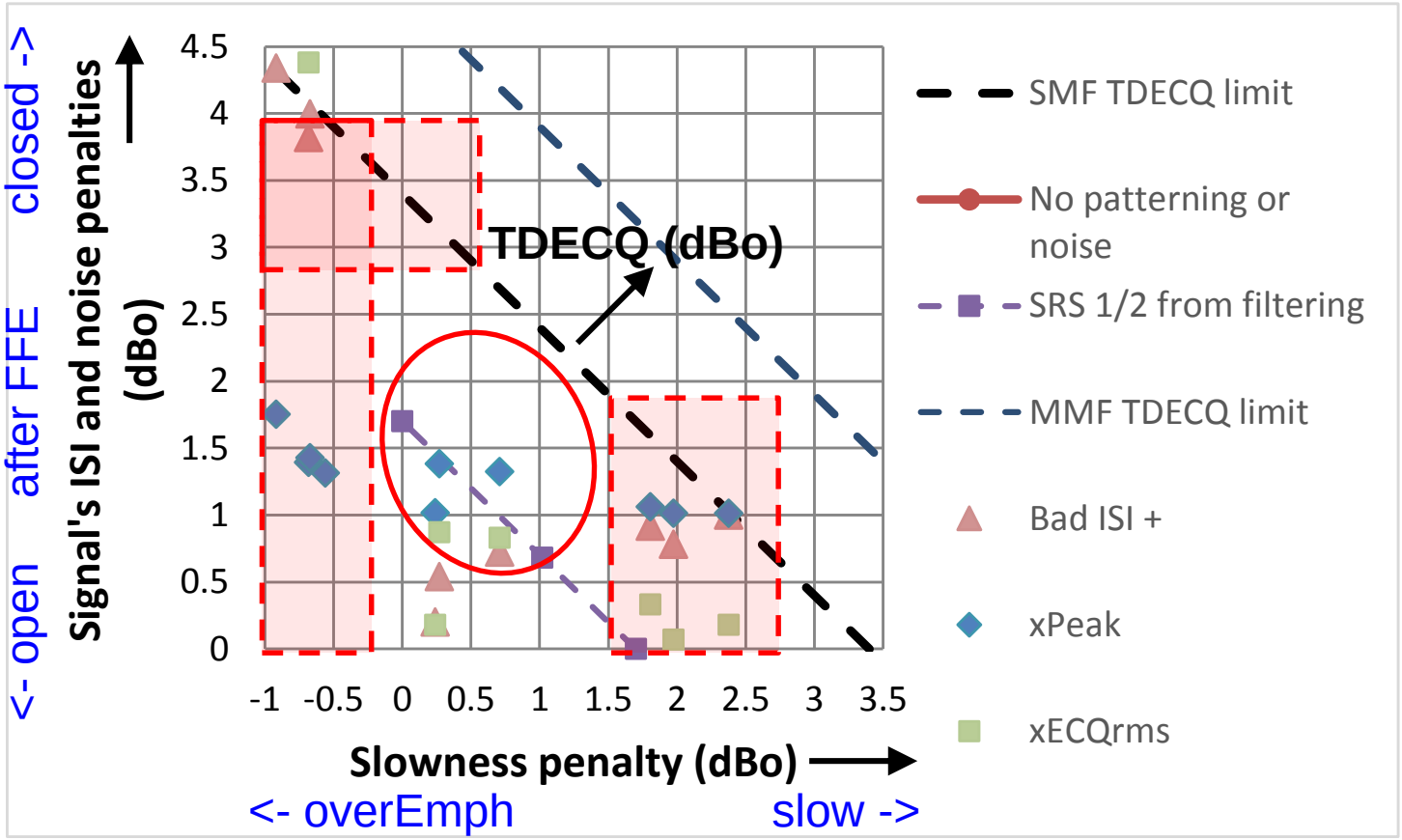
A risetime spec around 30 ps seems to screen signals that are slower than allowed for PAM2
Limit for 50G lanes should be a bit tighter than that
This is 20-80% observed in the usual fb/2 BW
Scatter needs more investigation, but promising for right side, not so for left side

Possible largest tap spec



- So far, the correlation between slowness penalty in dB and largest tap coefficient looks promising
- This might be just luck
- This is a simplification of a previous proposal that used the sum of the other four taps

TDECQrms



TDECQrms is below TDECQ on the right, above on the left – goes with a TDECQ limit having a shallower slope on this plot, as on slide 8

Most serious gaps

- The most serious gaps are on the left and top
- To address over-emphasis, either

1. Constrain cursor, or
2. Constrain Ceq in TDECQ, or
3. Reject signals with Ceq < limit, or
4. Reject signals with (peak-mean)/OMA > limit

- 1 and 2 are more lenient to otherwise good signals
- All are "free": by-product of TDECQ measurement, or part of it
- Option 4 can be done without the full TDECQ analysis
  - but may not work so well
- See next two slides for example remedies

Bound the left side (too much emphasis)

Cl **138** *SC* **138.8.5.1** *P* **273** *L* **41** # r02-47 *Comment Type* **TR**

In this draft, it is possible to make a bad transmitter (e.g. with a noisy or distorted signal), use emphasis to get it to pass the TDECQ test, yet leave a realistic, compliant receiver with an unreasonable challenge, such as high peak power, high crest factor, or a need to remove a lot of emphasis from the signal, contrary to what equalizers are primarily intended to do ("gaming the spec": D3.1 comment 70). Note the receiver is tested for medium to slow signals only, not for any of these abusive signals. This is an issue for all the PAM4 optical PMDs, although it may be worse for MMF because of the high TDECQ limit and because the signal is measured in a particularly low bandwidth. On the TDECQ map (see e.g. dawe_041818_3cd_adhoc-v2) we need to stop signals that are too far to the left, which would be outside the range of what a typical equalizer would be designed to cope with (e.g. would need strong tap weights of the opposite sign to normal) and provide no practical benefit in a system. At present there is no boundary on the left.

D3.0 comment 116, D3.1 comments 70, 71.

SuggestedRemedy

To protect the receiver from having to "invert" heavily over-emphasised signals, change "largest magnitude tap coefficient" to "largest magnitude tap coefficient, which is constrained to be **at least 0.95**."

Similarly in clauses 139, 140.

It may make sense to have a higher limit (1 to 1.1) for MMF because the transmitter is not tested without the filter emulating a low-pass fibre.

- *Slide 12 shows that 0.99 might be suitable, for SMF*
- *The remedy doesn't directly outlaw over-emphasised signals, but gives them worse TDECQ scores*
- *Alternatives considered: peak-peak/OMA limit, minimum Ceq limit, minimum risetime limit*

Bound the top (irreparably bad)

- Cl **139** SC **139.7.5.3** P **297** L **52** # r02-52 Comment Type **TR**
- In this draft, it is possible to make a bad SMF transmitter with emphasis (e.g. with a noisy or distorted signal) that even an equalizer better than the reference equalizer won't be able to improve. Note the receiver is tested for a slow signal only, not for such signals.
- On the TDECQ map (see e.g. dawe_041818_3cd_adhoc-v2) **we need to stop signals that are too high up the page**.
- D3.0 comment 116, D3.1 comment 71.
- SuggestedRemedy
- For a SMF TDECQ limit of 3.2 or 3.4 dB: **Either:**
- **1. Limit TDECQ -10*log10(Ceq) to <=2.8 dB for SMF PMDs.**
- **or:**
- 2. Define **TDECQrms** = 10*log10(A_RMS/(s*3*Qt*R)) where A_RMS is the standard deviation of the measured signal after the 13.28125 GHz filter response (before the FFE), Qt and R are as already in Eq 121-12. s is the standard deviation of a fast clean signal with OMA=2 and without emphasis, observed through the reference Bessel-Thomson filter response but before the reference equalizer (0.6254 for 13.28125 GHz).
- **Limit 3 dB for SMF PMDs.** This could be added to the transmitter tables.
- *Either is a free by-product of a TDECQ measurement*
- *Is there an alternative?*

Bound the right (slower than expected)

- *Cl* **139** *SC* **139.7.5.4** *P* **298** *L* **6** *#* r02-54 *Comment Type* **TR**
- The draft transmitter spec allows signals that are slower than the receiver is tested for in SRS, slower than the equivalent SMF PAM2 spec, and I believe slower than were allowed when the draft had a T/2-spaced equalizer. I have seen no evidence that implementers want to make super-slow transmitters. Yet receiving such a signal would place an extra burden on the receive equalizer e.g. better linearity and/or finer AtoD or tap resolution. This is one kind of "abusive signal" mentioned in D3.1 comment 71. See e.g. dawe_041818_3cd_adhoc-v2. The first option more directly protects the receiver and allows more trade-offs in transmitter design; both are free by-products of a TDECQ measurement and are at about 1.7 dB slowness penalty.
- *SuggestedRemedy*
- Limit the signals on the right of e.g. dawe_041818_3cd_adhoc-v2. **Either:**
- **Set a maximum cursor strength limit,1.4**
- **or:**
- **Set a maximum 20-80% transition time limit as observed after the reference Bessel-Thomson filter response but before the reference equalizer, 28 ps.**
- For Clause 140, the limits would be 1.5 and 15 ps (allowing relatively slower signals).
- For Clause 138, the transmitters would have similar speed to Clause 139, but the signals are observed in a lower bandwidth, so a limit in between 1.4 and 1.5 should be used.
- *Either is a free by-product of a TDECQ measurement.*
- *Comments 57 and 58 also propose a maximum rise time specification*
- *The cursor strength limit allows a trade-off, more representative of receiver's needs: otherwise better Tx can be a little slower*