

# Improved pattern for testing optical transmitters

Piers Dawe

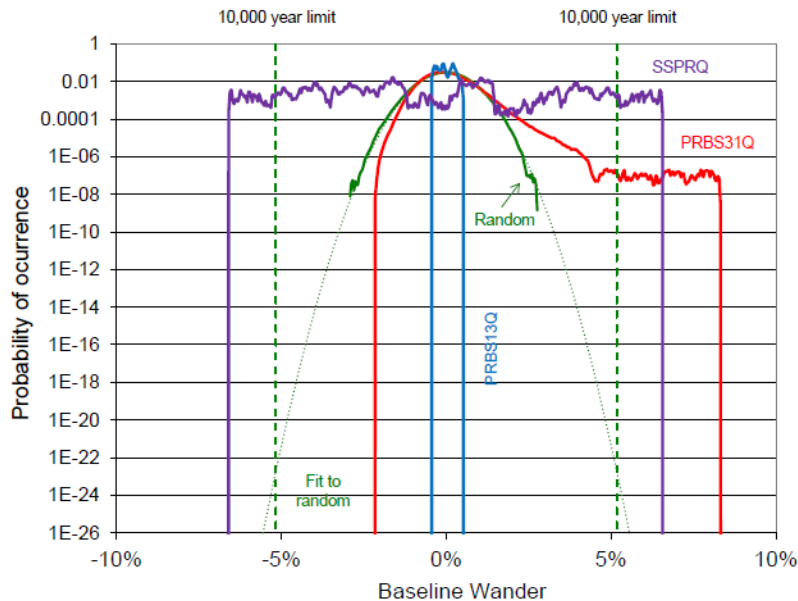
Mellanox

# Introduction

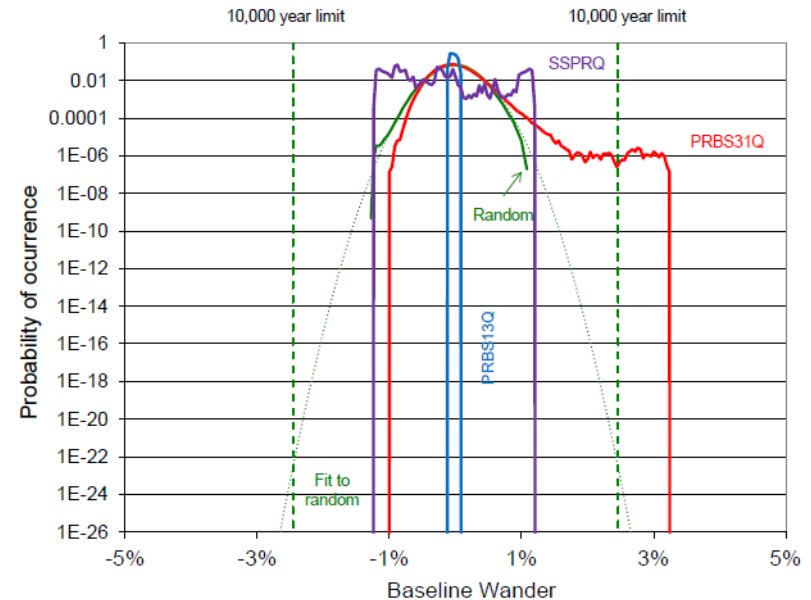
- Recent optical transmitter and receiver specs in 802.3 are defined with long scrambled signals. Measurements are representative of links in use
- For TDECQ, we use a pattern no longer than  $2^{16} = 65,536$  PAM4 symbols so that a soft equalizer in a scope can be used. In most cases QPRBS15, 32,767 symbols long, is enough to capture all but a few hundredths of a dB of the transmitter impairments (as a power penalty relative to  $BER=2.4e-4$ ), including low frequency effects
- P802.3 D2.1 uses SSPRQ ( $2^{16}-1 = 65,535$  PAM4 symbols long), which gives about the same peak baseline wander, twice every 2.5 us, as occurs once in 10,000 years in service. It is too stressful: to pass this test a transmitter has to be much better than necessary
  - Remember the FLR objective allows the link to drop many frames for low frequency effects in 10,000 years! But using SSPRQ with TDECQ effectively doesn't
- This presentation proposes an improved pattern

# Baseline wander

Baseline wander (Baud / 10,000)

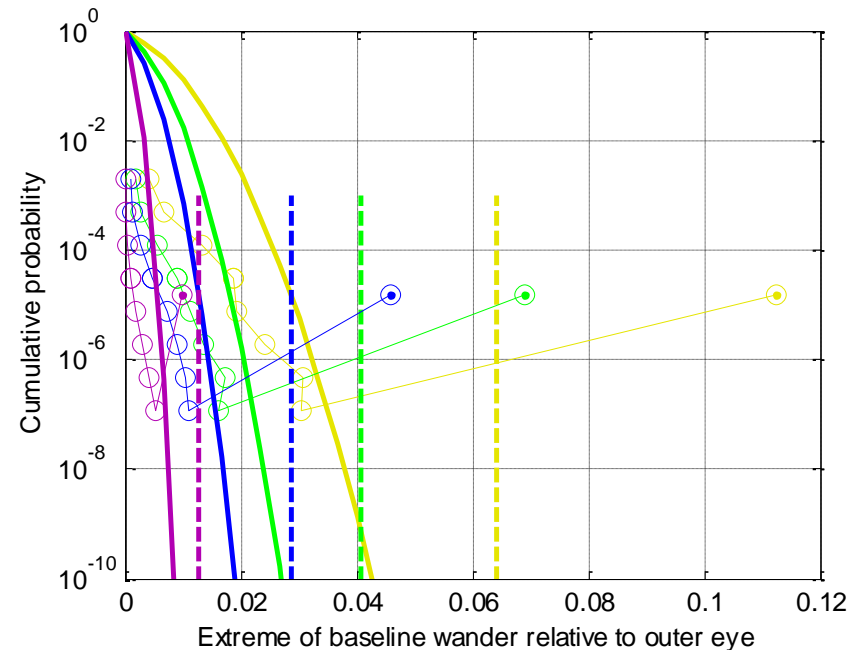
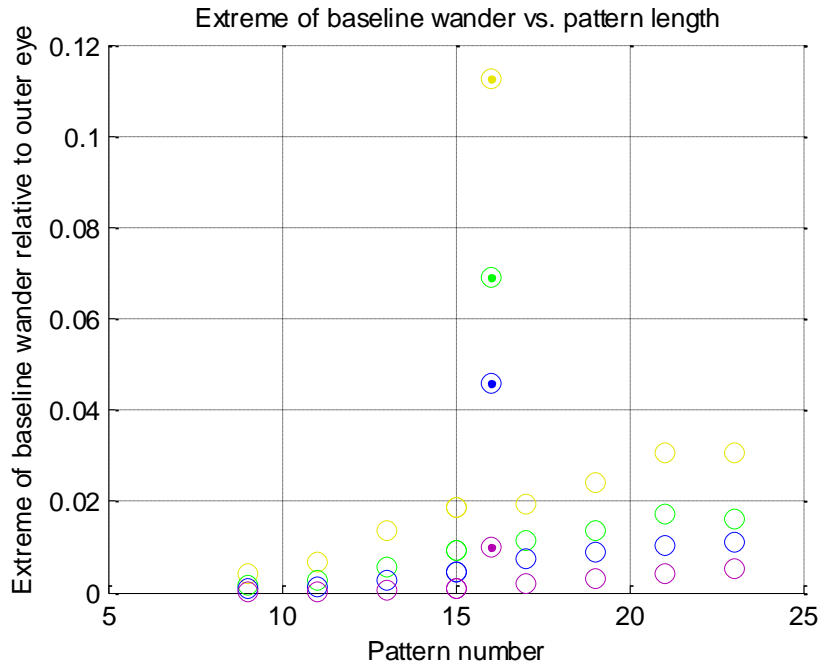


Baseline wander (Baud / 50,000)



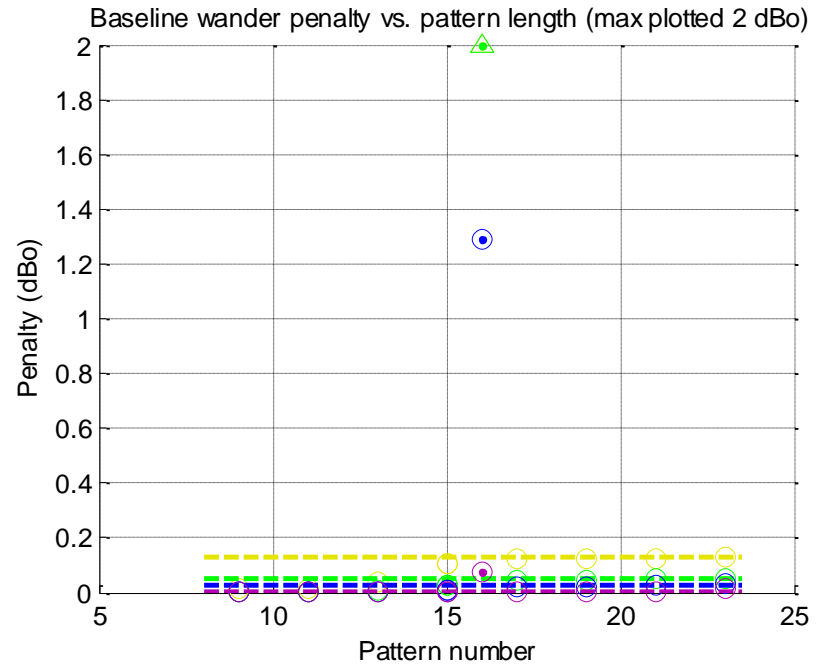
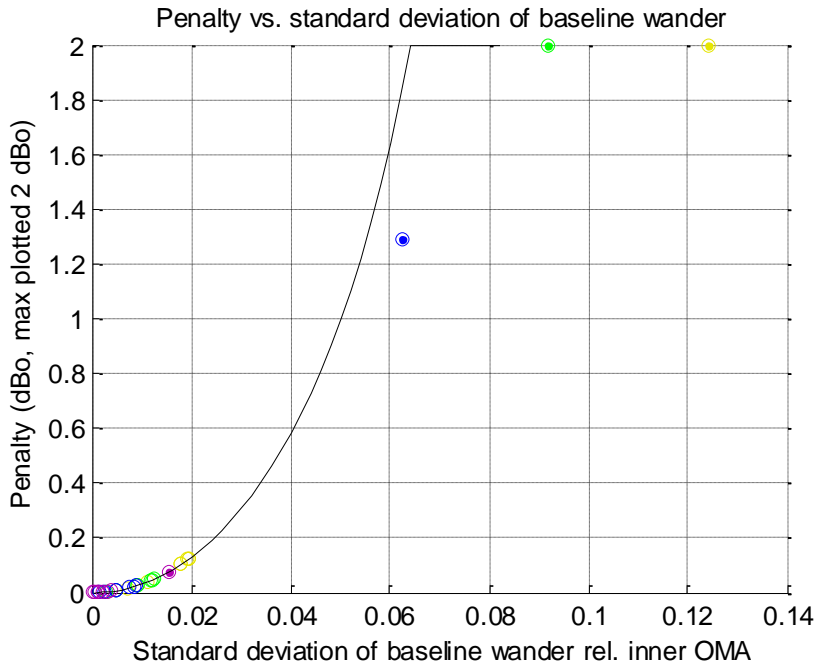
- From [anslow\\_01\\_0416\\_logic.pdf](#)
- The shoulders of the purple line are far above the green curve for a random stream of symbols, and above the BER target
- So SSPRQ is far more stressful: the TDECQ is higher with SSPRQ than it would be with a long representative pattern

# Extreme of baseline wander



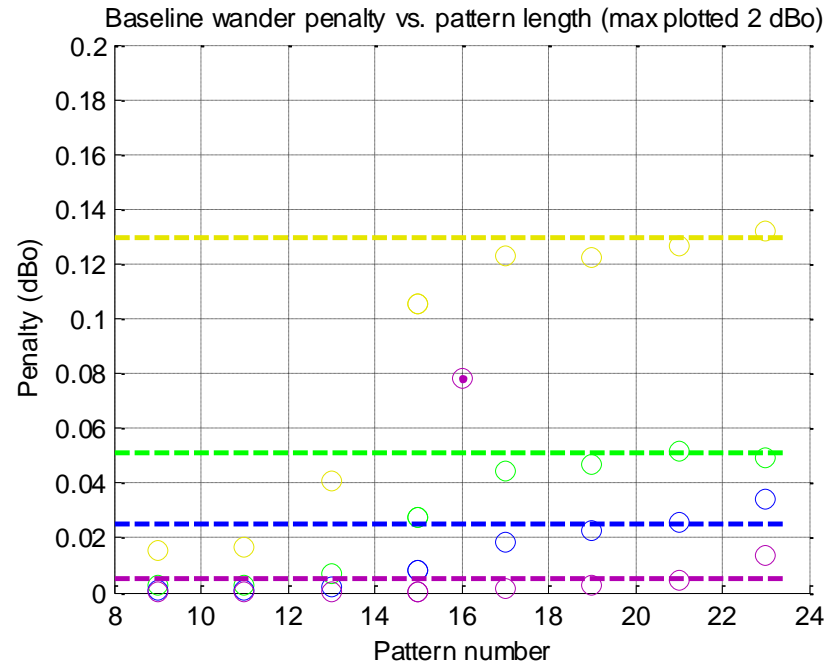
- SSPRQ gives a much greater maximum baseline wander than short to medium QPRBSs
- Longer QPRBSs approach the Normal curve for random symbols (lines, right plot); SSPRQ is extreme
- Dashed vertical lines represent 1 in 10,000 years (9.7 standard deviations). For some cases, SSPRQ gives a greater maximum baseline wander than would be seen in 10,000 years – twice every 2.5 us

# Using SSPRQ gives the wrong penalty



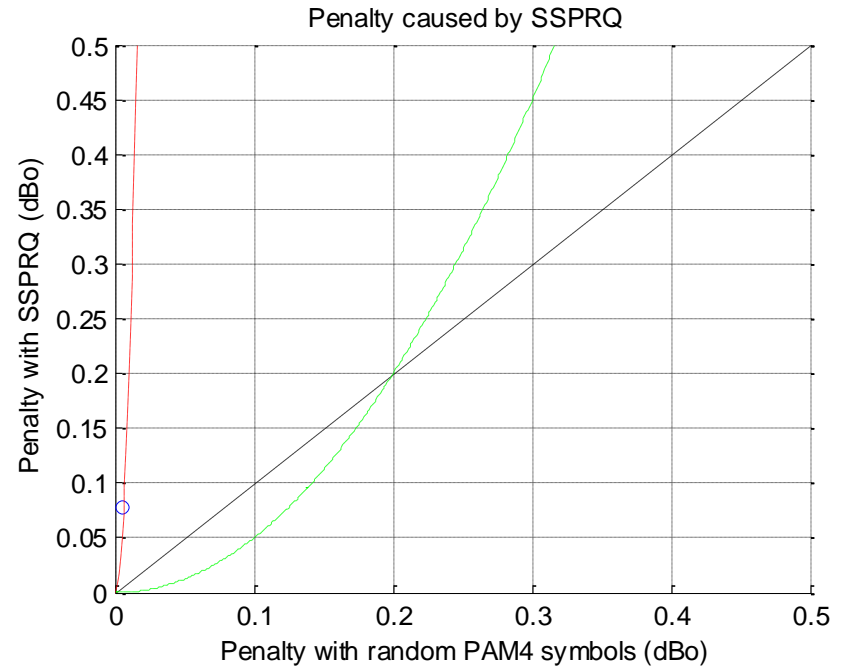
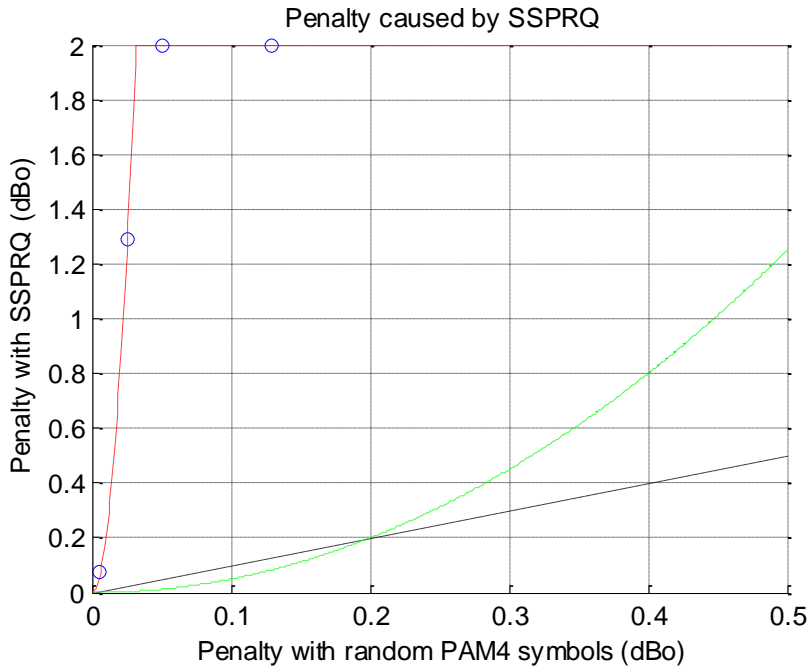
- Pattern numbers: QPRBS9 to QPRBS21
- 16 means SSPRQ (identified with dot): RMS baseline wander and penalty are both far too high
- Solid lines are from link model theory for random PAM4 symols
- Four transmitters with 2.5 dB penalty in addition to four different high-pass filters – four colours
- Yellow has the worst low frequency performance; blue and green are "interesting" – penalties should be determined accurately for the  $OMA_{outer}$  minus TDECQ trade-off but are not; purple has very good low frequency performance but SSPRQ penalises even this

# Zooming in



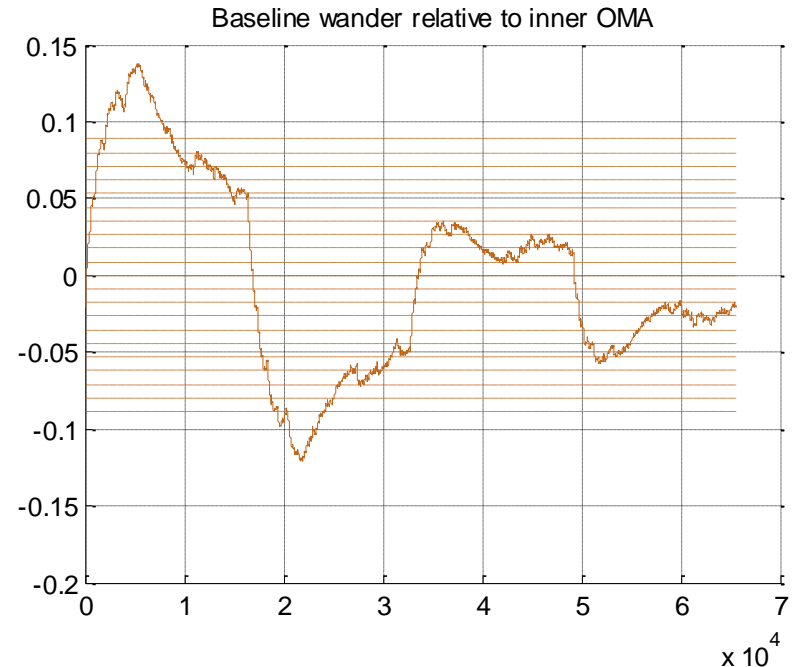
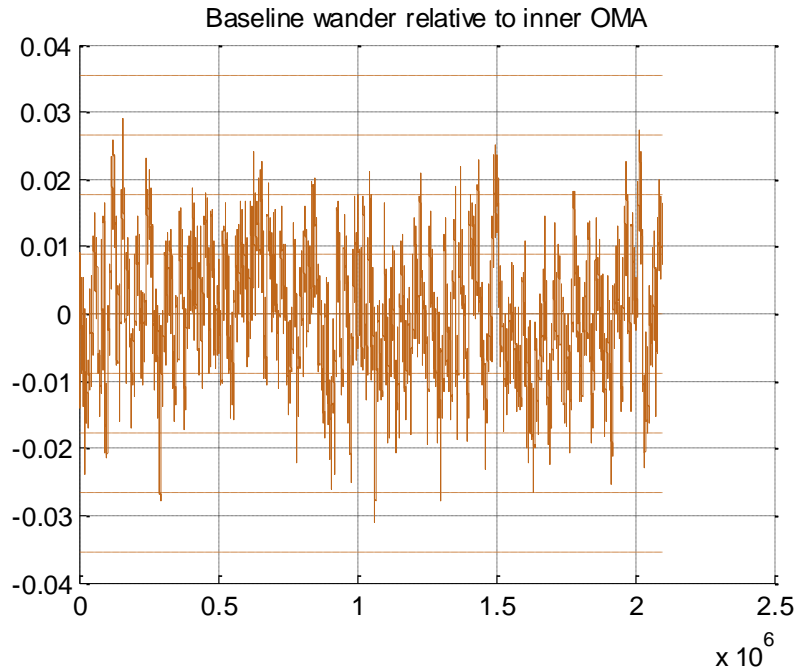
- Looks like QPRBS21 generates approximately the baseline wander penalty
- Just lucky? These sequences are not ideal pseudo-random sequences
- Purple dot is 0.07 dB (or several times) too high; other dots are off scale

# Penalty caused by SSPRQ



- Black dashed line: 1:1, target
- Red dashed line: parabola drawn through second point
- Green line: target: what an optimised short test pattern could do
- Transmitters that have negligible baseline wander penalty for random PAM4 symbols suffer a large penalty with SSPRQ

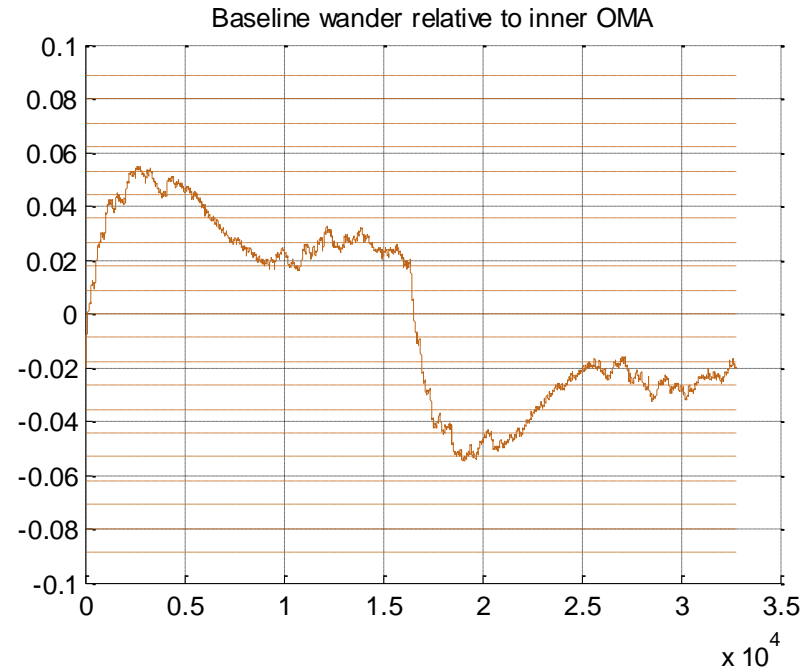
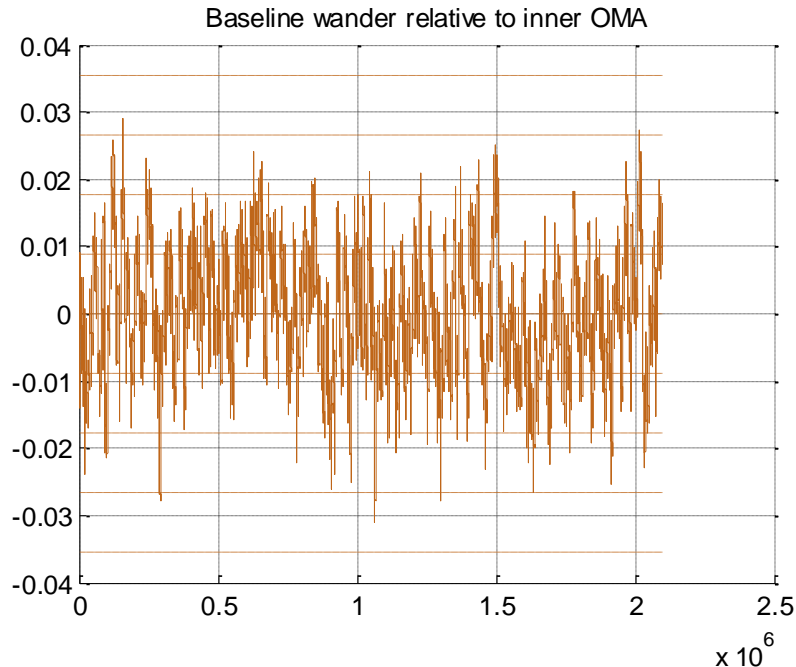
# Time-domain comparison



- Left: PRBS21 extends beyond +/- 3 standard deviations of a random signal, occasionally
  - Penalty for PRBS21 and for random signal ~0.025 dB
- Right: SSPRQ extends beyond +15.5/-13.6 standard deviations of a random signal, frequently!
  - Penalty 1.29 dB!



# Removing the first section of SSPRQ



- Right: The later parts of SSPRQ extend  $\pm 6.2$  standard deviations of a random signal, frequently
  - Penalty 0.32 dB
  - Better, but still too extreme

# Changing SSPRQ

- The first part of SSPRQ, made from extreme sections of PRBS31Q, takes the baseline wander to a very high then very low value
- Choosing a different seed / starting condition moves these peaks partly out of an improved SSPRQ
- The pattern can be tuned to give the right penalty at one value that we choose
- Propose 0.2 dB
  - Transmitters with more baseline wander are inaccurately graded as having a high penalty, but the cost of avoiding them is believed to be small
  - Transmitters with less baseline wander get an inaccurate grade as having a low penalty, but the error is small
- As the later parts of SSPRQ generate more penalty than desirable by themselves, the first section can be deleted
  - The later sections should be toned down also