Remarks on 2.5G / 5G noise

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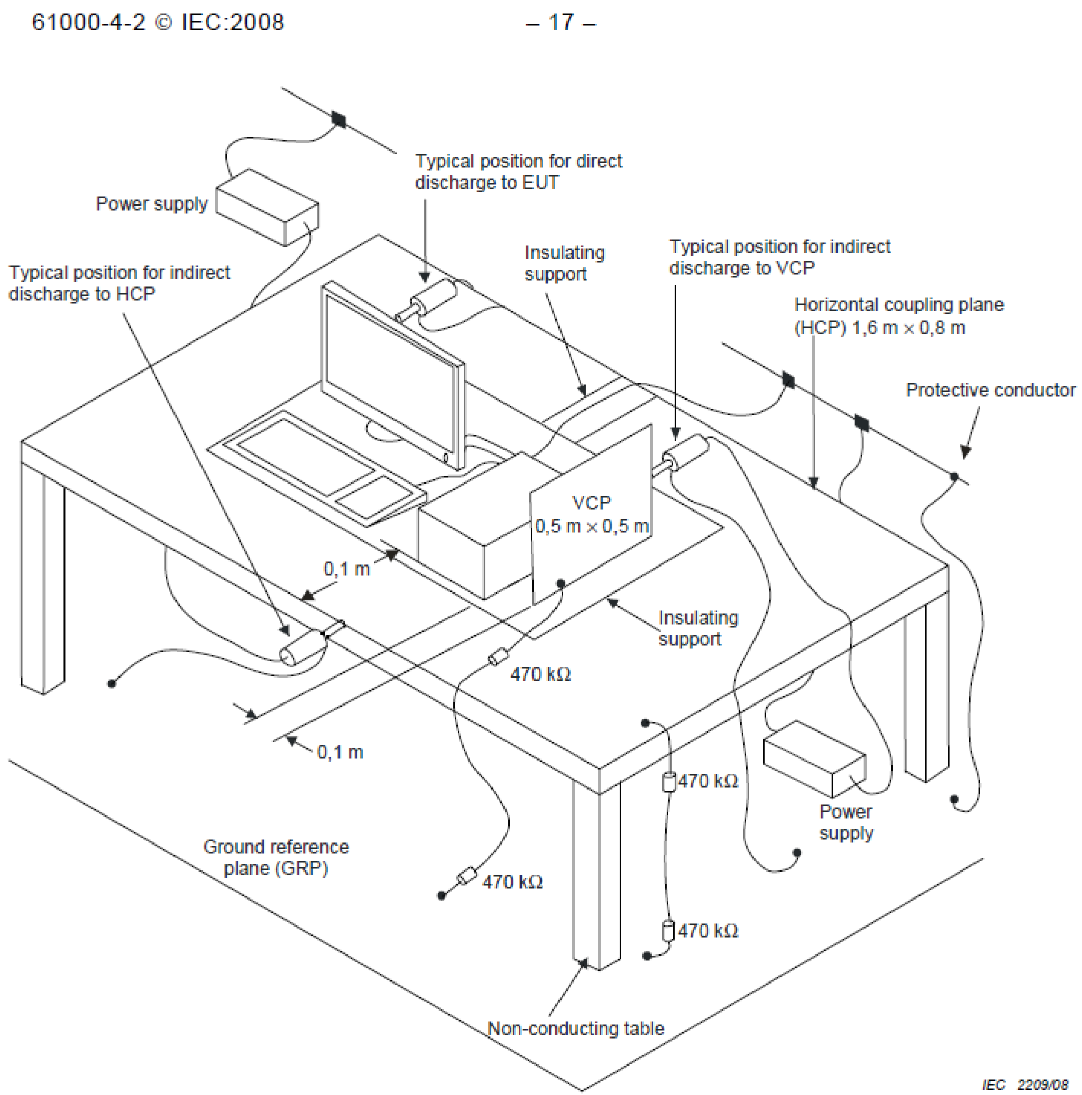
Noise sources

- Alien noise
  - Bundled cables
  - Noise created by the signals transmitted in the other cables of the bundle.
- External disturbances
  - Noise created by events external to the cable bundle.
  - Independent of the signals and their strength within the cable bundle.
  - The well-known standards IEC 61000-4-x cover external disturbances:
    - IEC 61000-4-2 Electrostatic discharge immunity test.
    - IEC 61000-4-3 Radiated, radio-frequency, electromagnetic field immunity test.
    - IEC 61000-4-4 Electrical fast transient/burst immunity test.
    - IEC 61000-4-5 Surge immunity test.
    - IEC 61000-4-6 Immunity to conducted disturbances, induced by radio-frequency fields.

Contribution on measurement of external events follow e.g. IEC 61000-4-2 standard

- Measurement technique similar to IEC 61000-4-2
  - Uncontrolled office cube environment.



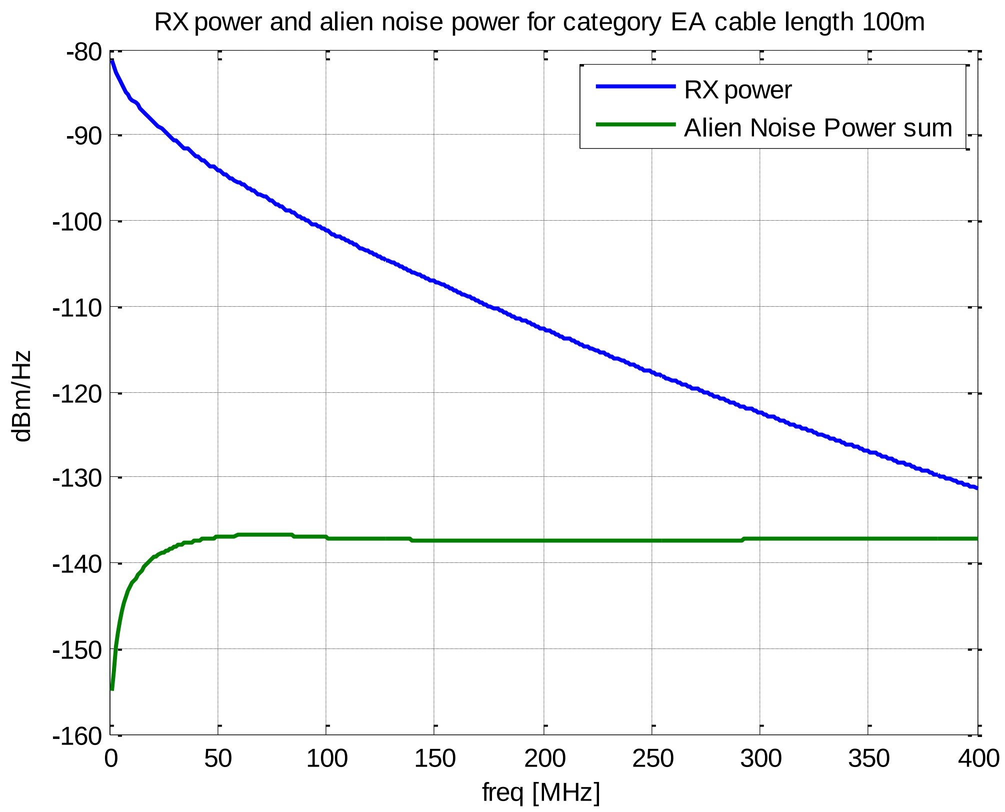
Will NGEA BASE-T duplicate external standard work?

- IEEE standards prefer to reference external standards whenever possible.
  - This avoids
    - Duplication of effort
    - Market fragmentation over the different world wide standards.
  - External standard may have broader and deeper expertise.
- IEEE create liaisons, if external standards need
  - change or
  - updating.
- Are the standards on external disturbances for the NGEA BASE-T application:
  - Non-existent?
  - Deficient beyond hope?
  - Only then would NGEA BASE-T need to develop new requirements

Alien Noise: AFEXT and ANEXT

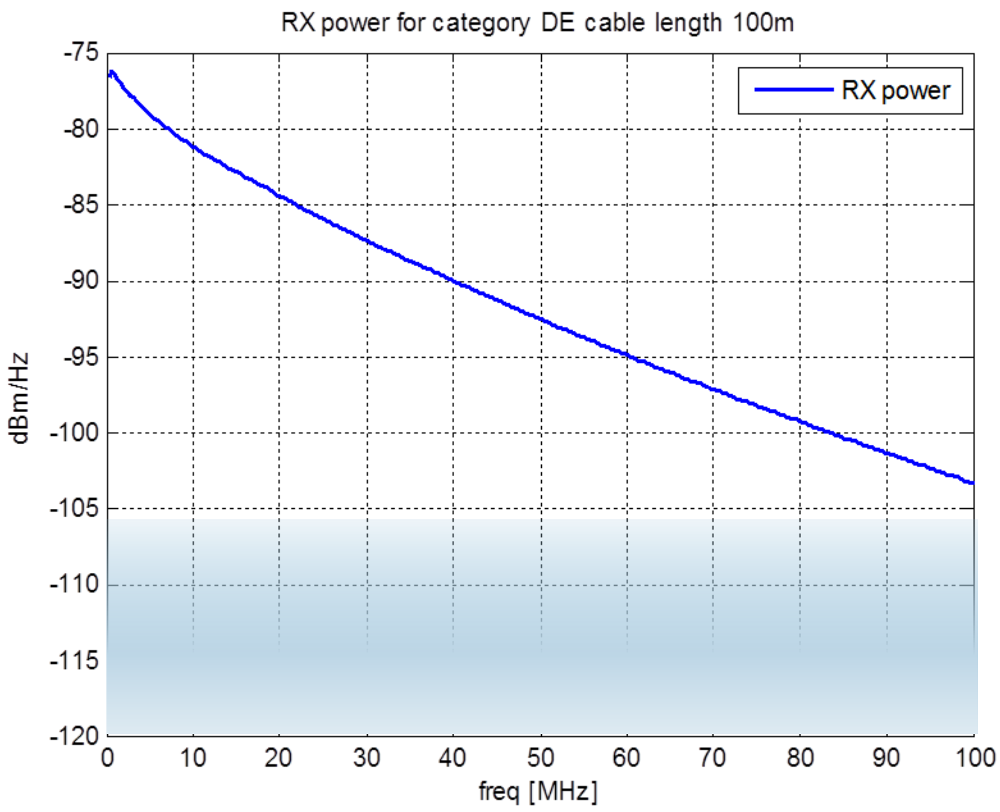
10GBASE-T over CAT6A

- Insertion loss is specified to 500MHz.
  - 125% of Nyquist
- Alien cross talk is specified for CAT6A, such that
- Salz SNR of ~26.5dB is guaranteed.



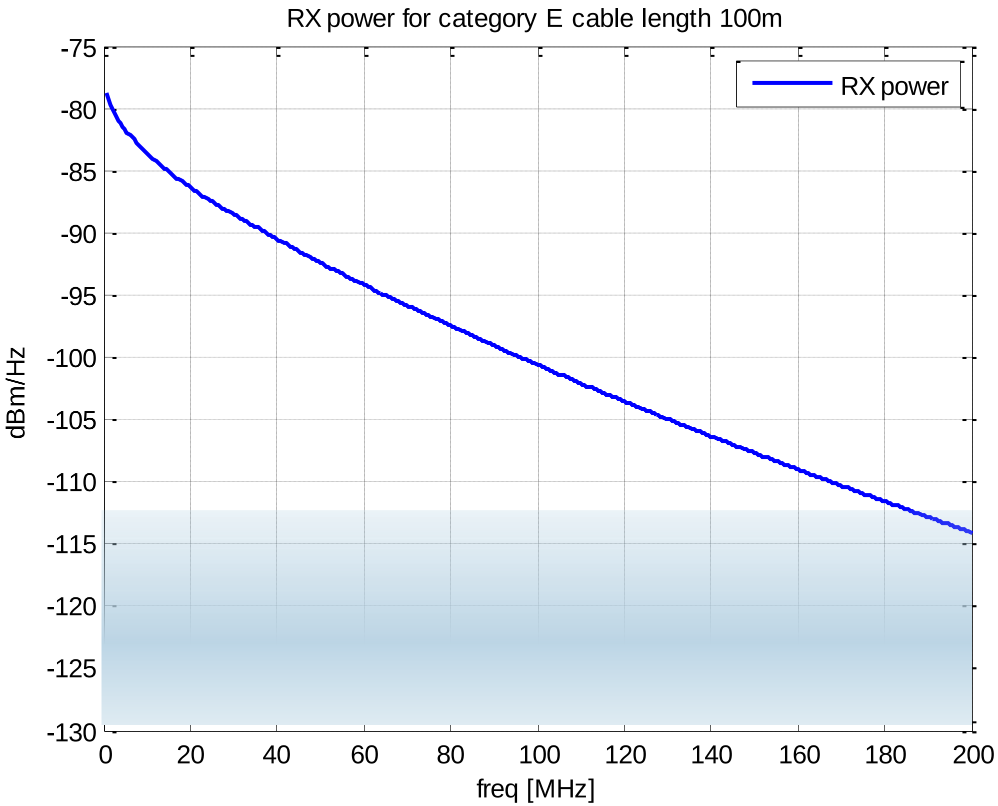
2.5GBASE-T over CAT5E: Alien Noise Limited

- Insertion loss is specified to 100MHz.
  - 100% of Nyquist.
- Alien cross talk is specified as a peak to peak signal for GPHY.
- Salz SNR on measured cables is good.
  - Cables are used in the frequency range, where insertion loss is low.
- No guarantees for the alien noise.
  - How bad are the bad cables and connectors?



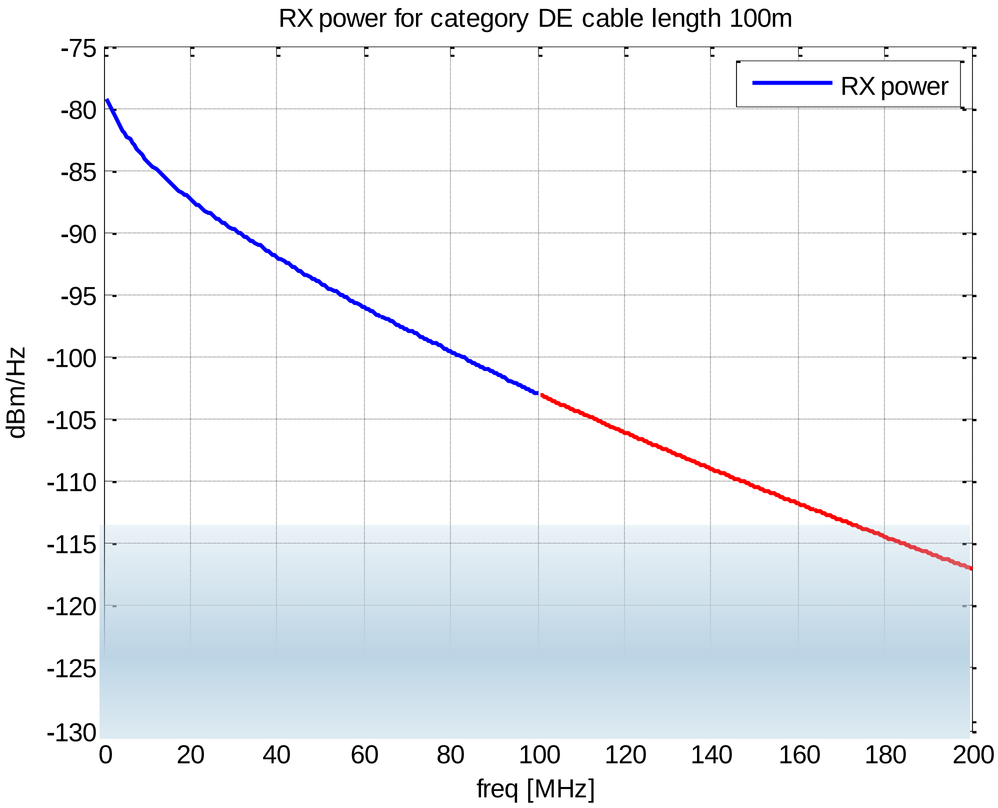
5G over CAT6: Very Alien Noise Limited

- Insertion loss is specified to 250MHz.
  - 125% of Nyquist.
- Salz SNR on measured cables is marginal at best.
  - Higher baud-rate of 5G results in higher insertion loss.
- No guarantees for the alien noise.
  - How bad are poor cables and connectors?



5G over CAT5E: Extremely Alien Noise Limited

- Insertion loss is specified to 100MHz.
  - 50% of Nyquist.
- Salz SNR on measured cables is abysmal.
  - Higher baud-rate of 5G results in higher insertion loss.
  - Measured CAT5E cables have higher ANEXT and AFEXT than CAT6 cables.
- No guarantees for the alien noise.



Alien Noise Conclusion

- Challenge: Alien noise worse than 10G
  - 2.5G over CAT5E
    - Measurements show comfortable SNR
    - But: no alien noise spec = no guarantees!
  - 5G over CAT6
    - Marginal SNR
    - No alien noise spec = no guarantees!
  - 5G over CAT5E
    - Abysmal SNR
    - Insertion loss specification covers only half the transmission band
      - Half a spec = no guarantees on insertion loss!
    - No alien noise spec = no guarantees!

- Scaling 10G will provide the optimal performance against alien noise.

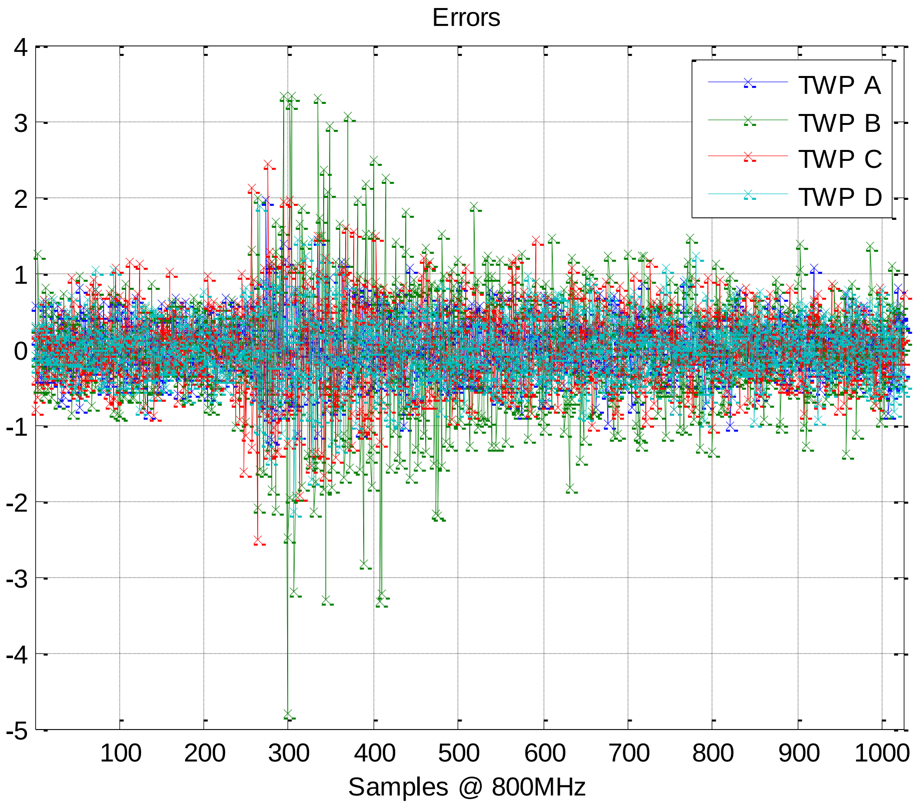
External Disturbances

Sizing up the problem: model, quantify and relate

- Two-state channel model
  - “good” state, where noise is additive colored Gaussian noise.
  - “bad” state, a noise burst plus the “good state” additive colored Gaussian noise. Noise burst is characterized by:
    - Amplitude,
    - Onset and Duration,
    - Frequency content or time domain shape.
  - Memoryless transition probability matrix between the states.
- 5G throughput per hour: 5.625e9 LDPC frames vs.
- Disturbances: 6
  - 5x chair noise
  - 1x light
- 800 octet frames error ratio ≤ 9.6e-9 is equivalent to BER ≤ 1e-12
  - 800 octet frame = 2 LDPC frames
  - ½ 9.6e-9 * 5.625e9 = 27 LDPC frames
  - From: xxx.5.4.1: Receiver differential input signals

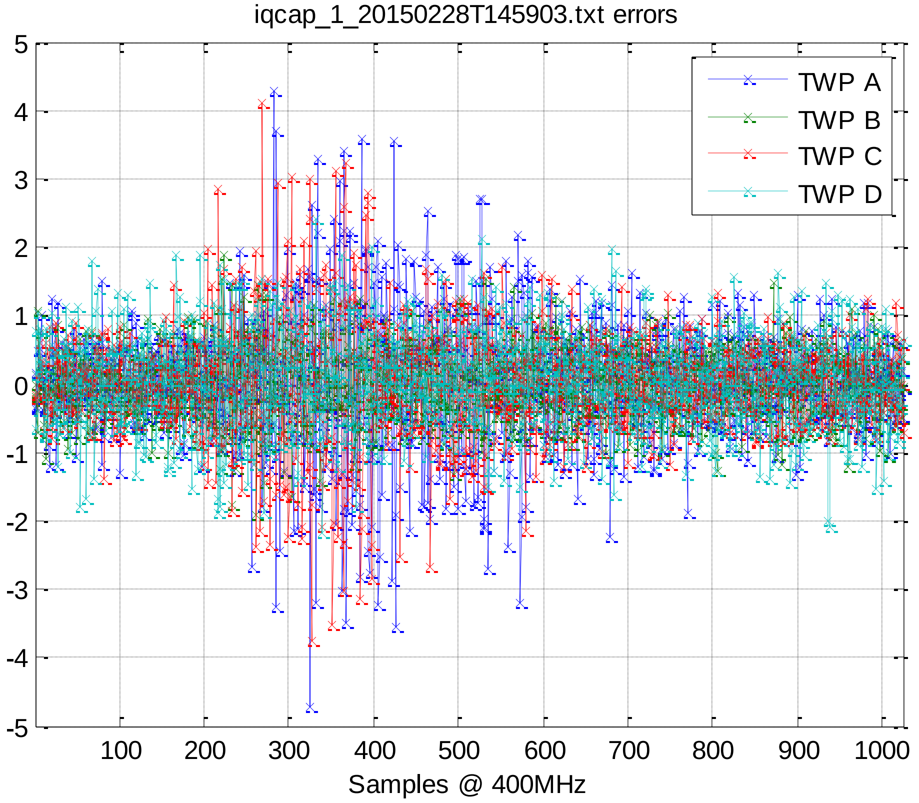
External disturbance: 10G

- 5G and 10G on same cable tray
  - 5G produces less error events than 10G
- 10G external disturbance at detector
  - Attack: time constant of low pass filter
  - Decay: add time constant of high pass filters.
    - Magnetics
    - AFE
- Event duration:
  - 350 symbols.
  - LDPC protection overrun.



External disturbance: 5G

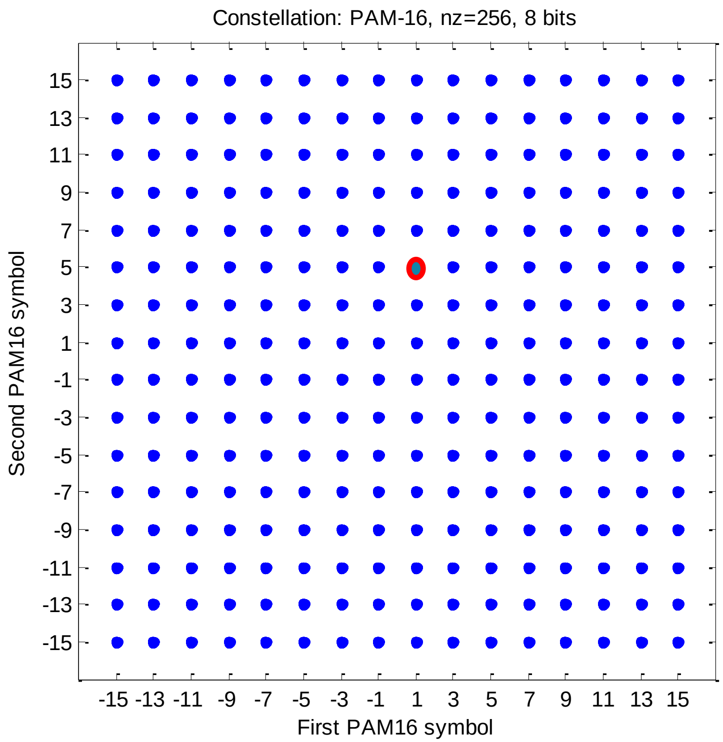
- CAT6 cable:
  - 6 around 1,
  - 100m,
  - 4 connectors.
- Victim error shown:
  - Detector input captured.
  - Decoded error.
- Duration ~350 symbols
  - 0.9us
- 5 day run:
  - Not a single error,
    - where only the Euclidean distance protected bits were in error, **and**
    - LDPC decoding succeeded.

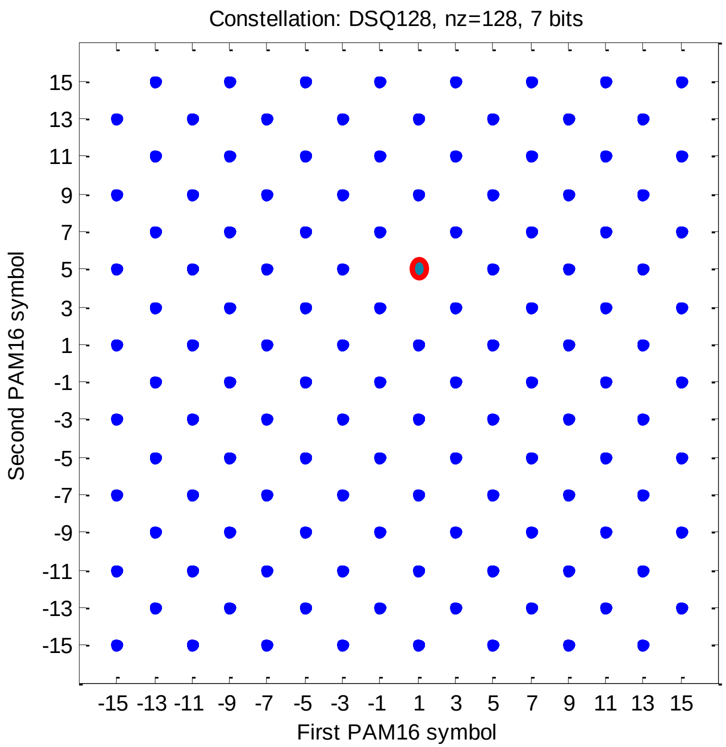


Coding Options

Option 1: Higher Order Modulation

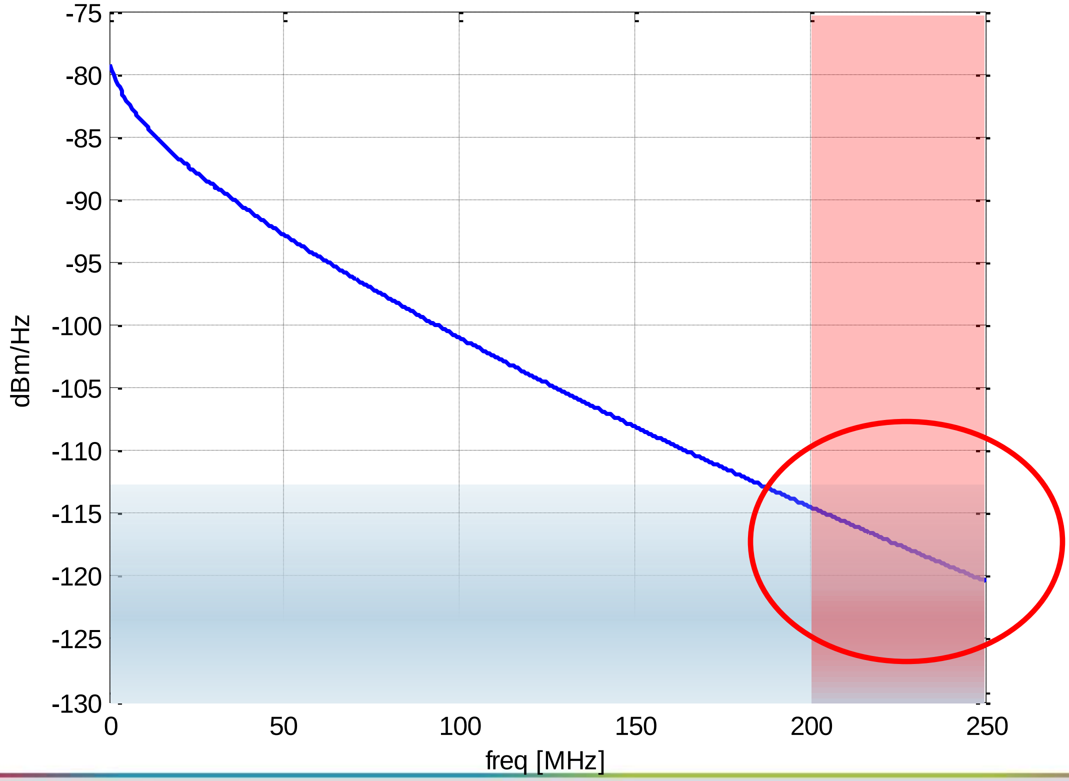
- Baud-rate kept the same.
- Extra bits for coding from constellation density increase.
  - Extra credit: find point (1, 5) in both constellations.





Option 2: Increase in baud-rate

- Constellation density kept the same.
- Extra bits for coding from baud rate increase.
  - Raise Nyquist frequency.
- Use of the transmission channel in the low SNR region.



Option 3: Rob Peter to pay Paul
Option 4: Increase latency

- Keep constellation density and baud rate the same.
- Weaken base LDPC code by taking some parity bits away.
- Encode the already Euclidean distance protected bits.
- Base LDPC protection will fail more often.

- Option 4: Lengthen LDPC code word
- Higher encoding/decoding delay.

Re-evaluate DSQ128 and LDPC(1723,2048)

DSQ128 and LDPC(1723,2048)

- Euclidean distance protected bits are protected by a factor of 4x (12dB) of the Euclidean distance of the LDPC protected bits.
- Field testing results:
  - No known occurrences of
    - LDPC decoder succeeds, but
    - CRC protecting LDPC and Euclidean distance protected bit fails.
  - External disturbances (examples were shown above):
    - Duration of external disturbances is in excess of the available base LDPC protection.

Conclusion 2.5G and 5G

- Alien noise limited.
- External disturbances in field have long time duration compared to LDPC frame.
- Best match:
  - 128DSQ Euclidean distance and
  - LDPC(1723,2048) protection.