RN2483 & RN2903

Crystal Fine Tuning
To Optimise Sensitivity

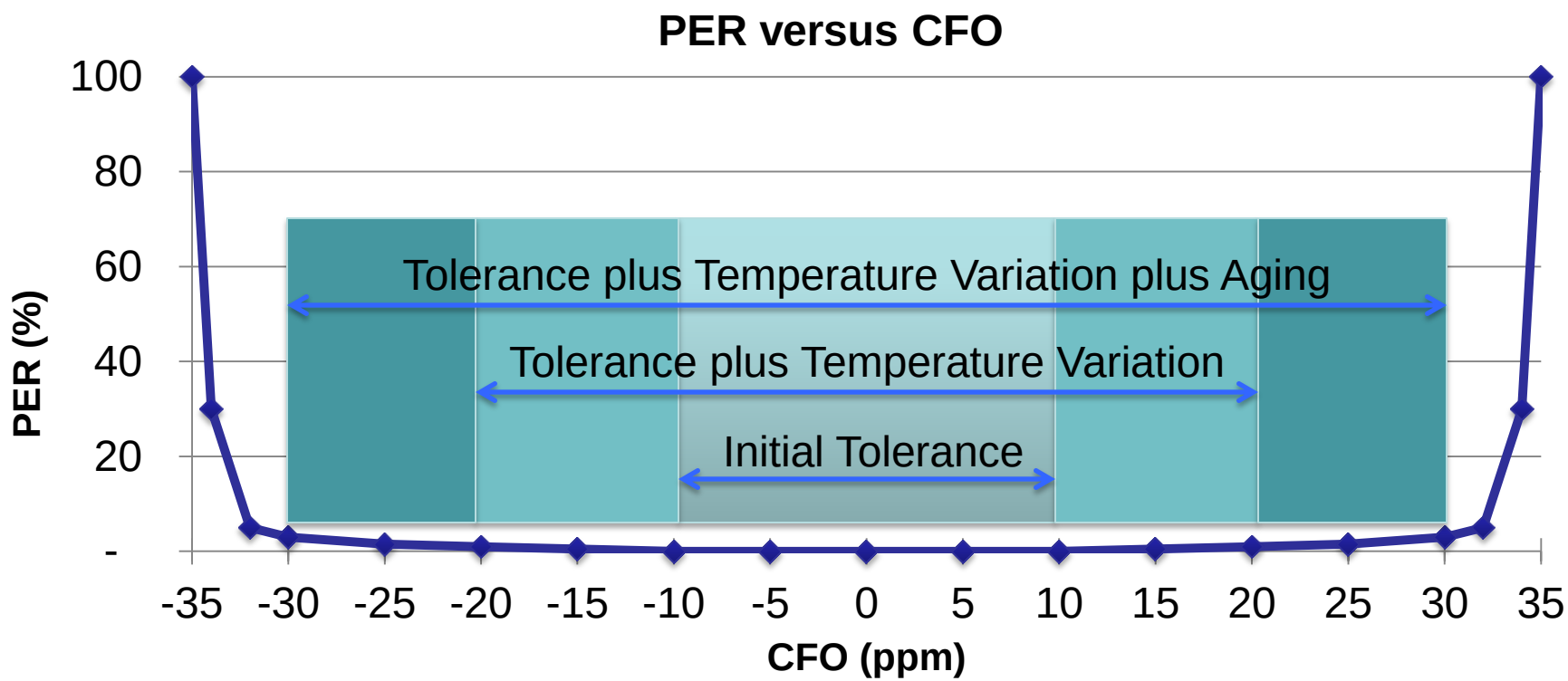
Introduction

Frequency Tolerance in LoRa Systems:

- LoRa physical layer is designed such that the transmitter can have frequency error up to +/-30ppm, and receiver must handle the error
- Actual performance is 34 to 36ppm limit (25% of 125KHz)
- Roughly breaks down to:
  - 10ppm for initial manufacturing tolerance
  - 10ppm for temperature range
  - 10ppm for aging (and some margin)
- Allows for standard low-cost crystals to be used

Why Fine-tune the Crystal?

- If the Carrier Frequency Offset (CFO) of the transmitter reaches the 30ppm limit, then Packet Error Rate (PER) starts to increase
- Seen as excessive packet loss
- Sometimes reported as poor sensitivity



What Can Lead to High PER?

- The CFO can reach the receiver limit through a combination of 5 factors, and occurs in the corner-case:
  - Spreading Factor
  - Payload size
  - Crystal tuning
  - Gateway HAL patch
  - Temperature

SF & Payload (= Time-on-Air)

- Using the longest SF (12) and a full payload (51bytes) results in a very long packet (2.4sec)
- Time-base can ‘slip’. Degradation starts above ~ 1.5sec
- Short-term software workarounds:
  - Dropping to SF=11 halves the time-on-air
  - Reducing the payload reduces time-on-air
  - Many customers avoid this worst case anyway, due to battery drain and network congestion
- RN2903 with NA settings has a specific upper limit of 400ms, so no impact

Crystal Tuning

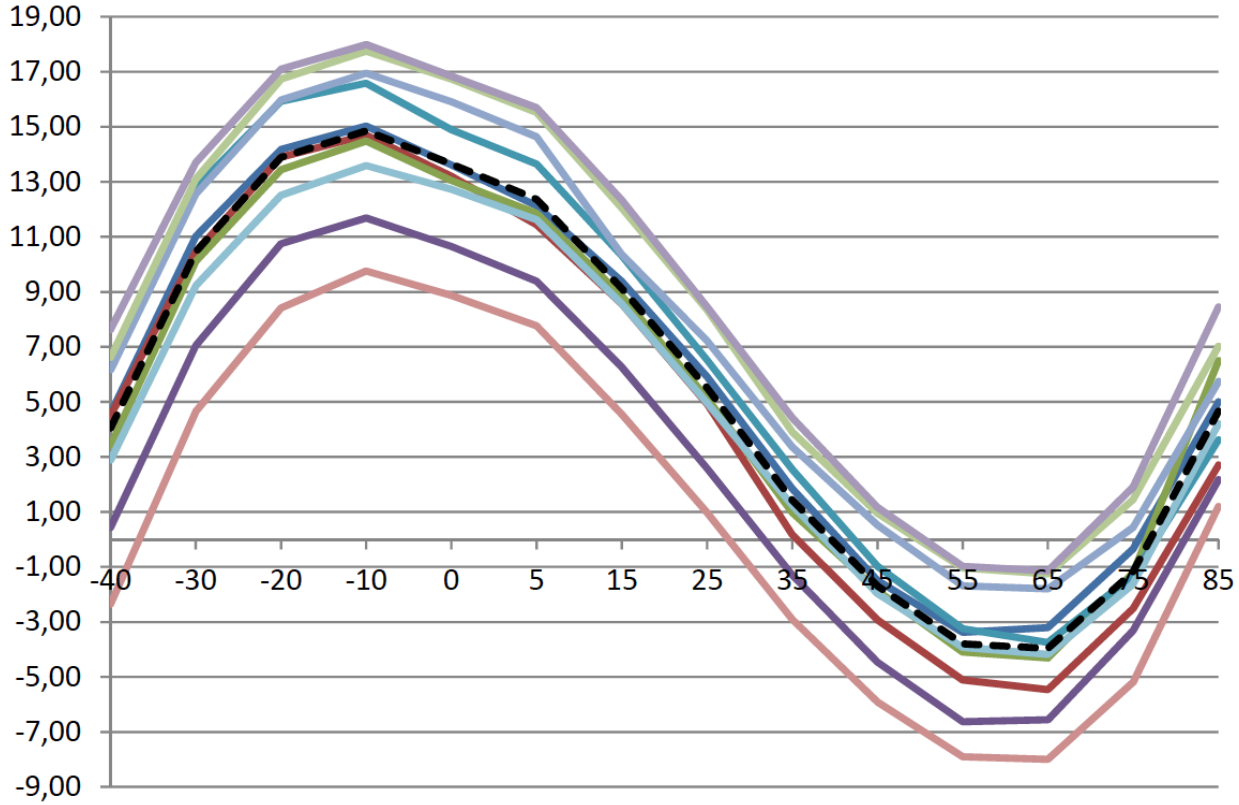
- Crystal is specified to +/-30ppm
- Measurements of a large production batch of RN2xx3 showed an offset due to load capacitor value
- With statistical spread, some are above 10ppm initial manufacturing tolerance
- Still within global 30ppm limit
- Changed load capacitor to re-centre closer to 0ppm
- Provides margin to 30ppm limit
- Denoted by “A” in part number. E.g. RN2483A

SX1301 HAL Patch

- SX1301 drivers in any LoRaWAN gateway are missing a setting which impacts SF12 PER performance due to CFO
- Reduced lower limit from -30ppm to around -20ppm
- Only affects SF12. All other SFs are no problem
- Potentially affects all gateways deployed
- Released a patch to correct this
  - See Semtech PCN-000418, dated 15th Feb 2017
  - Patch available now: https://github.com/Lora-net/lora_gateway see v4.1.3, released 13th Feb 2017
- We will not easily know which gateways are corrected

Variation with Temperature

- Crystal follows a standard “S” curve
- After fine tuning, over industrial temperature range -40 to +85degC, variation is within +18 to -8ppm
- (Spec for tolerance + temperature is +/-20ppm)



Risk Assessment #1

- To experience high PER, many factors must align (a “corner-case” in 5 dimensions):

Factor (estimates)	**Past** (RN2483 / no SX1301 patch)	**Future** (RN2483A / with SX1301 patch)
Using SF12	25%	25%
Payload > ~ 30bytes	10%	10%
High crystal offset	50%	1%
Extreme temperature	10%	10%
SX1301 HAL patch	100%	50%
	0.125%	0.00125%

Sanity Check - Field Feedback

- RN2483 has been shipping for almost 2 years and during that time we have received only a couple of reports of poor sensitivity in SF12, but were unable to recreate the issue
- Previously didn’t understand all the contributing factors needed to cause the failure in the corner-case
- **99.9% of customers have not experienced high PER in SF12**
- Only discovered after upgrading our internal TUV certification test systems to include PER measurements over temperature
- Risk Assessment #1 & Field Feedback are aligned

Risk Assessment #2

- Summary, considering combinations of legacy deployments of nodes & gateways

	RN2483	**RN2483A**
SX1301 no patch	Past 0.125%	Legacy gateways 0.0025%
SX1301 with patch	Legacy nodes 0.0625%	Future 0.00125%

Conclusions

- Does not affect RN2903 (400ms dwell limit)
- Risk of elevated PER is low enough to be a minor contributor to normal wireless reception conditions
- Will be noticeable only in a very specific set of conditions
- Can be avoided by applying simple software constraints
  - Avoid payloads >30bytes at SF12
- Conditions improve as SX1301 patch &/or RN2483A are deployed