IEEE 802.3da – RX Model Proposal

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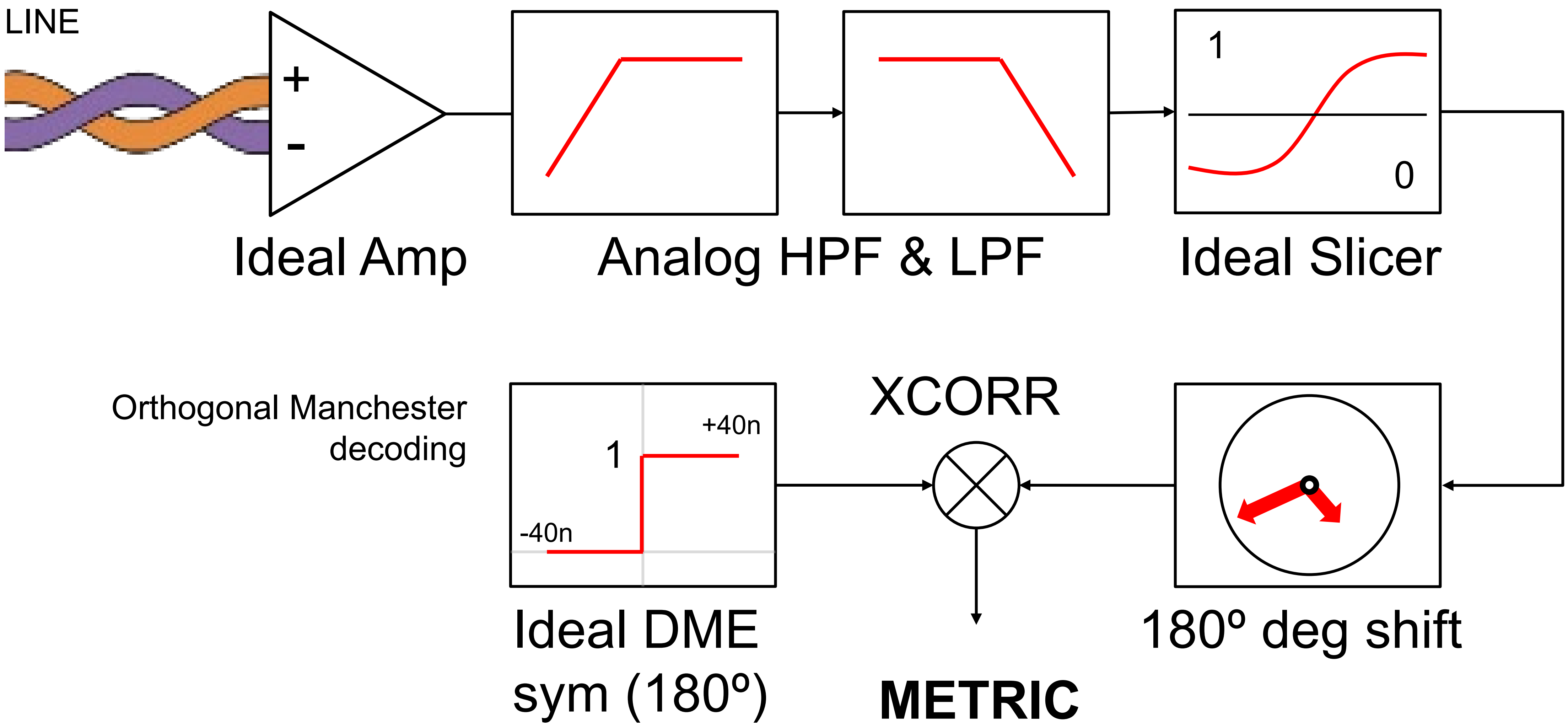
Outline

- A model for the 10BASE-T1M receiver is required to achieve consensus on the PHY performance vs channel characteristics and topology
  - Follow-up presentation of beruto_3da_20220711_noise_env.pdf
- Although an eye diagram provides a rule of thumb to assess the signal quality, it may not represent what a modern PHY can really do
  - In fact, several existing Clause 147 (802.3cg) PHYs can operate with a closed eye
- This presentation is a proposal for adopting a receiver model architecture to be eventually integrated into the existing consensus model
- The end goal of the RX model, along with the channel and TX model, is to find consensus on the trade-offs between the receiver and channel performance
- Additionally, part of this work could be used as a base for defining PHY compliance specifications

RX Model Architecture

Proposal

Minimal Architecture Model Overview (Proposal)



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RX architecture basics (1)

- Assumptions / Idealizations
  - Perfect (ideal) clock recovery. Implies perfect phase alignment too.
  - “Infinite” sampling rate
  - Ideal slicer (no hysteresis)
- Using orthogonal Manchester decoding (180º phase shift)
  - The easiest way to decode Manchester is to detect the presence of a data transition between two clock transitions
  - Orthogonal decoding, instead, centers on clock transitions and detects “S” and “Z” symbols
    - Two consecutive identical symbols decode as a logical ‘1’
    - A change from S to Z or vice-versa decodes as a logic ‘0’
  - Yields a +3 dB gain on SNR
  - See also https://www.ieee802.org/3/cg/public/adhoc/cordaro_3cg_06_0418.pdf #19-21

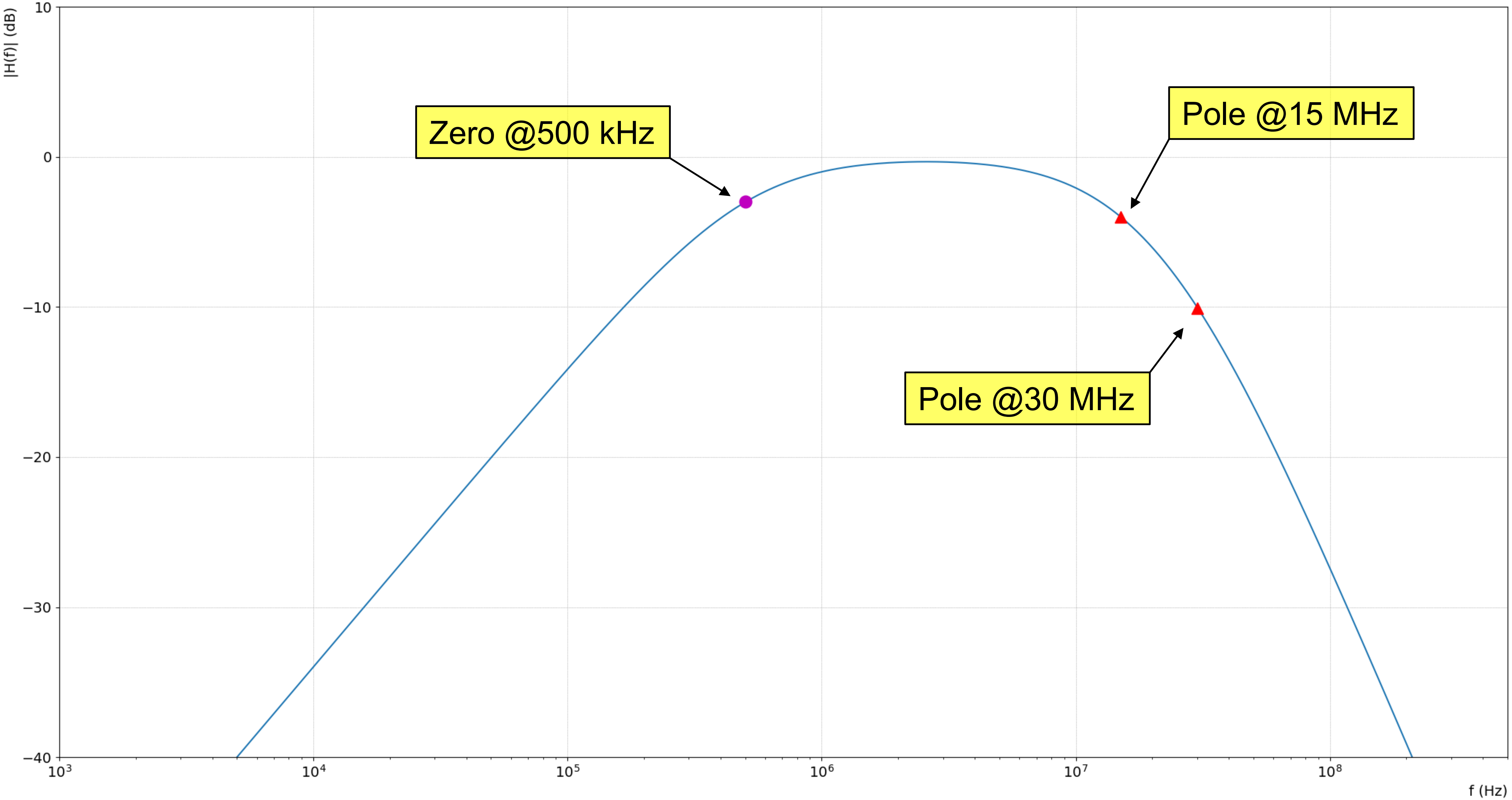
RX architecture basics (2)

- The metric for recovering data correctly is provided by the cross-correlation of the received signal with the ideal ‘S’ or ‘Z’ symbol
- The received signal is sliced because its amplitude is not really relevant for decoding Manchester. On the contrary, it negatively affects the correlation metric
- The minimum requirement for decoding the correct bit is to have a (normalized) correlation value > 0.5 against the ideal transmitted symbol
  - Rationale: when comparing a received symbol with an ideal “S”
    - a correlation value of 1 means that the symbol matches exactly the “S” shape
    - a correlation value of 0 means that the symbol matches exactly the “Z” shape (which is in fact the opposite of S)
    - a correlation value of 0.5 means that the symbol could be an “S” or a “Z” with the same probability
- Real implementations would also implement energy detection techniques for rejecting alien crosstalk noise
  - Neglected by this ideal model

Analog filtering

- For the purpose of rejecting out of band noise, we need to define a **minimum** acceptable level of filtering
  - Otherwise, we're back to measuring the eye diagram opening at the MDI
    - Could become quite grim when considering the noise environment and the channel MC loss
- The proposed model defines
  - a first-order high-pass filter @500 kHz
  - a second-order low-pass filter with poles at 15 MHz and 30 MHz
- The rationale for this proposal comes from:
  - The noise environment we're considering
  - Minimum low-pass filtering required to compensate resonances when using in-line inductors for parasitic capacitance compensation
    - See https://www.ieee802.org/3/da/public/102021/Koczwara_3da_01_102021.pdf
    - Experience gathered from testing systems based on Clause 147 PHYs (10BASE-T1S)

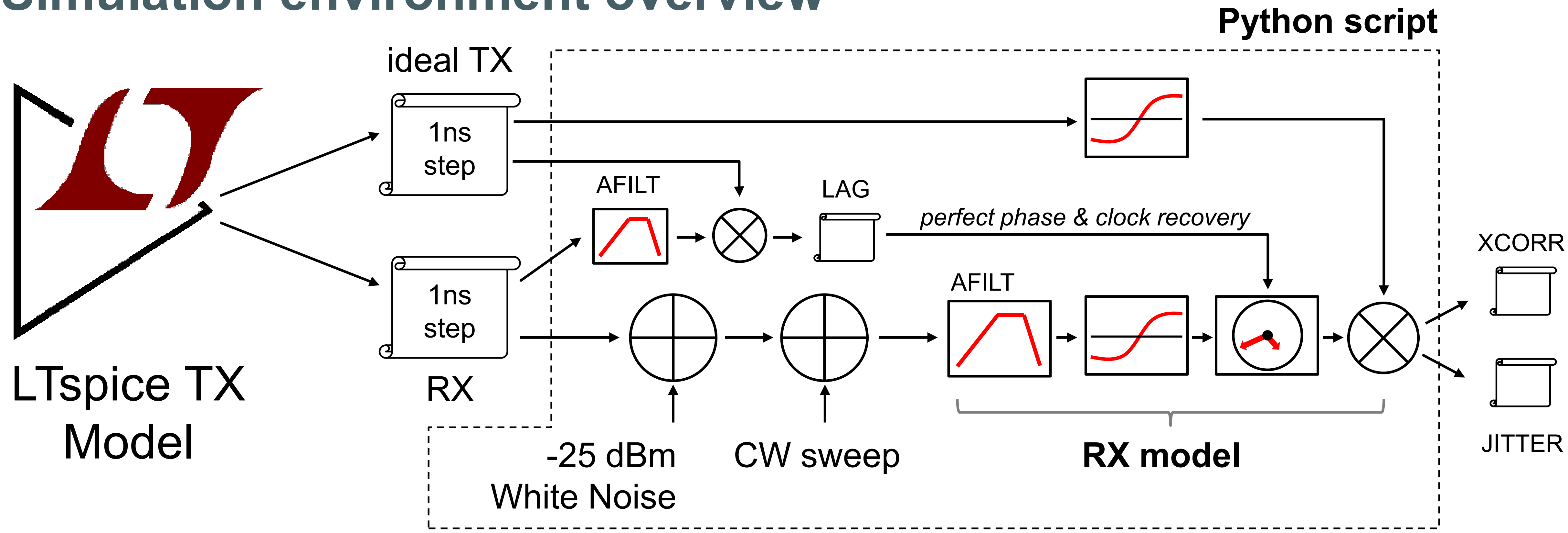
Analog filter model Transfer Function



Model Validation

Python elaboration of LTspice generated data

Simulation environment overview



- The simulation purpose is to evaluate how well the proposed metric follows the noise environment compared to the receiver model performance
- The Python script implements the RX model and the noise environment
  - Outputs correlation data & jitter (also a good metric for DME)

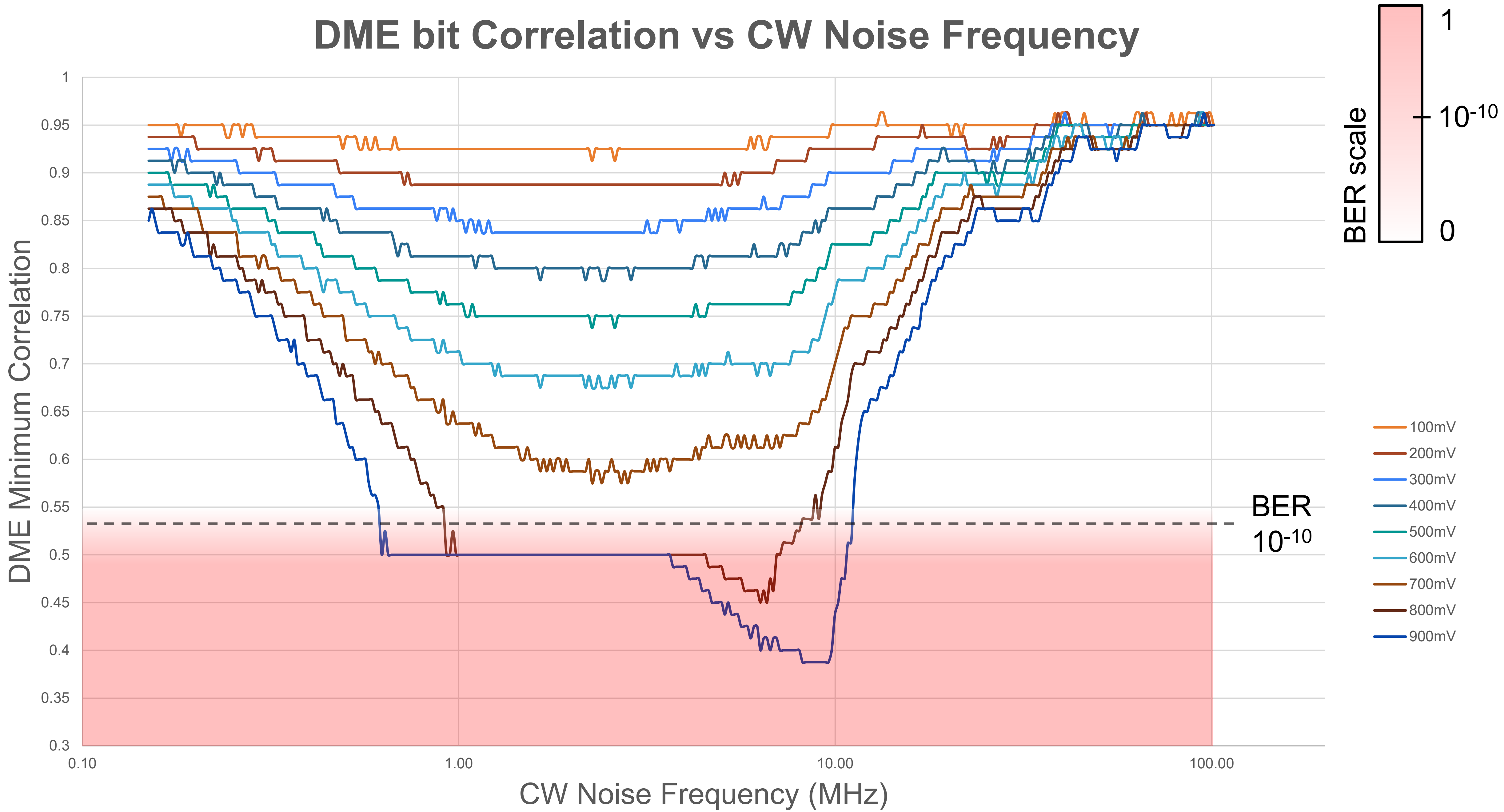
Simulation Environment details (1)

- The input to the simulation is the analog RX signal at the PMA input
  - Since the model is not yet integrated in the full consensus model, for the sake of this presentation I’ve used the data produced by the LTspice TX+MDI model that was presented in https://www.ieee802.org/3/da/public/050422/beruto_3da_20220502_tx_model.pdf
- The simulation digitalizes the analog signal working on 1 ns samples
  - 1 GHz should be a fair approximation of “infinite” sampling rate in this context
- The clock frequency is fixed → the script assumes the RX data is generated by a nominal 25 MHz clock ± 0 ppm
- The sampling phase (lag) is calculated from the correlation of the filtered input signal (w/o the noise environment contribution) with the ideal TX signal
  - The lag is used to chunk the RX DME signal in bits to correlate against TX

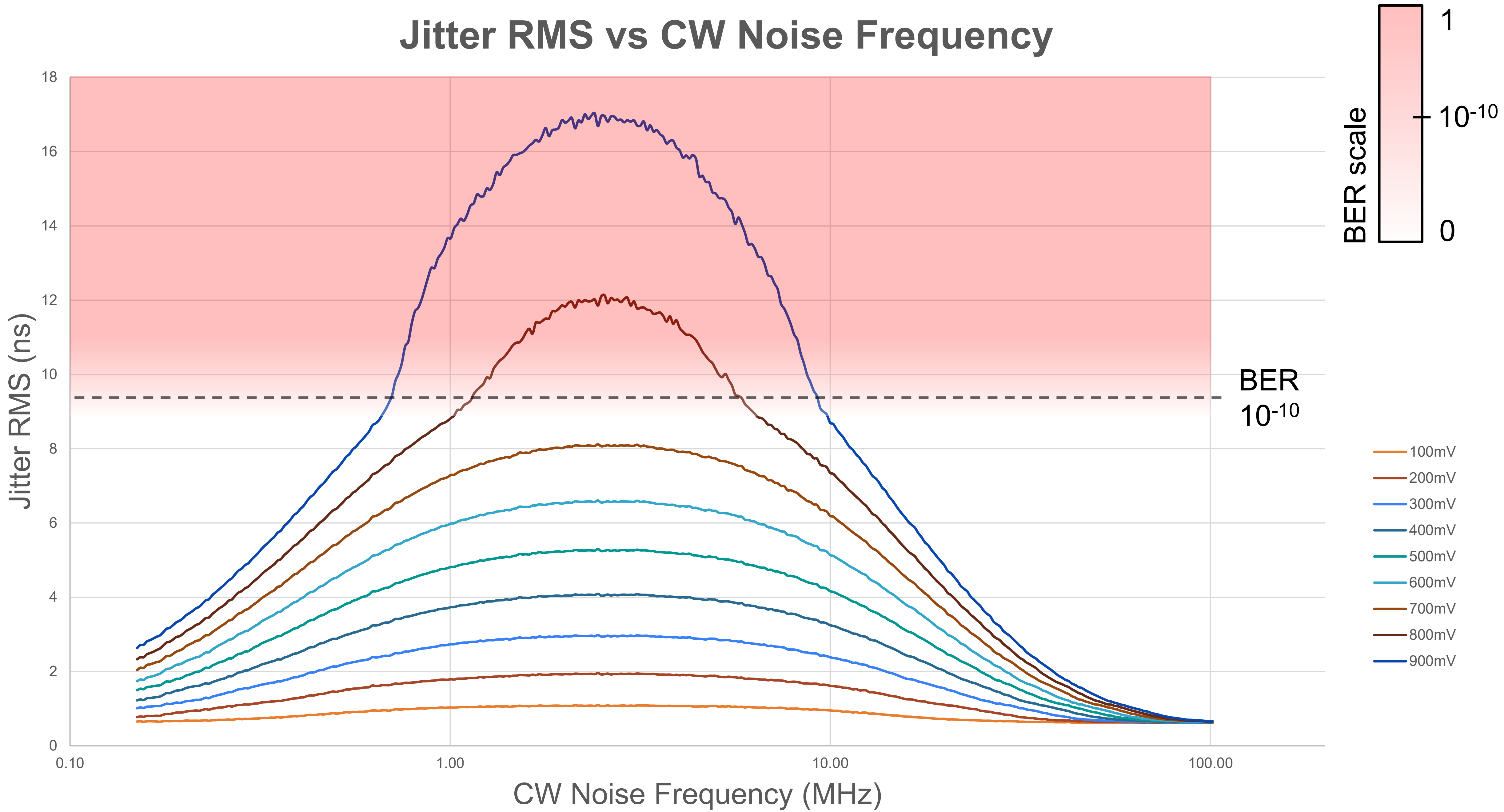
Simulation Environment details (2)

- The Python script adds the CW noise (as defined by the noise environment) to the RX signal, sweeping all frequencies from 150 kHz to 100 MHz with 1% steps, and amplitudes from 100 mV_{p-p} to 900 mV_{p-p} with 100mV steps.
  - This is way above the requirements of the noise environment under consideration
  - But we need margin for adding the channel/topology contribution, eventually
- The simulation calculates the bit correlation value and the output jitter of the model as a function of the CW amplitude and frequency
  - The jitter may be a useful metric for the purpose of defining compliance tests

DME bit Correlation vs CW Noise Frequency



Jitter RMS vs CW Noise Frequency



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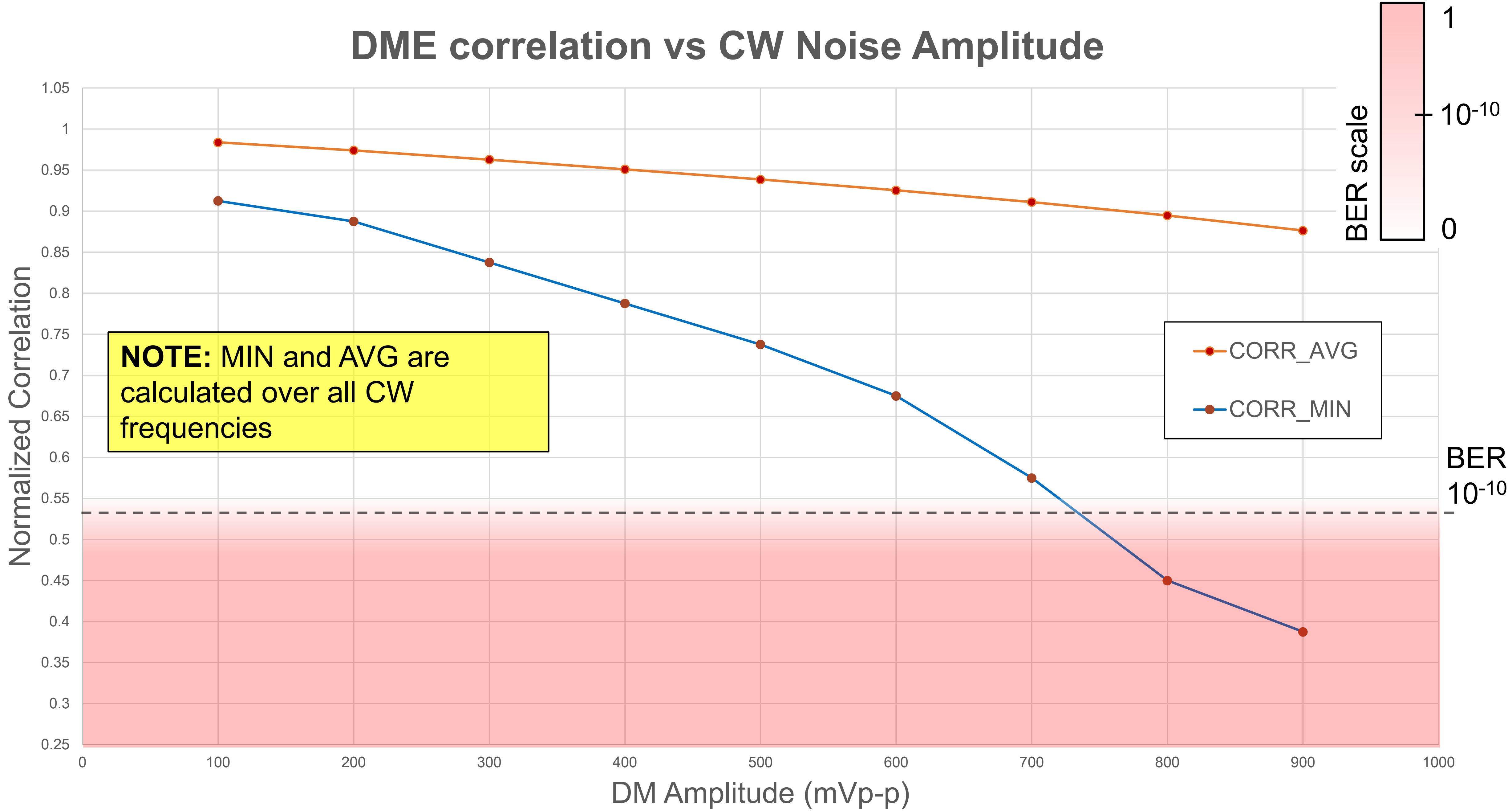
DME correlation vs CW Noise Amplitude



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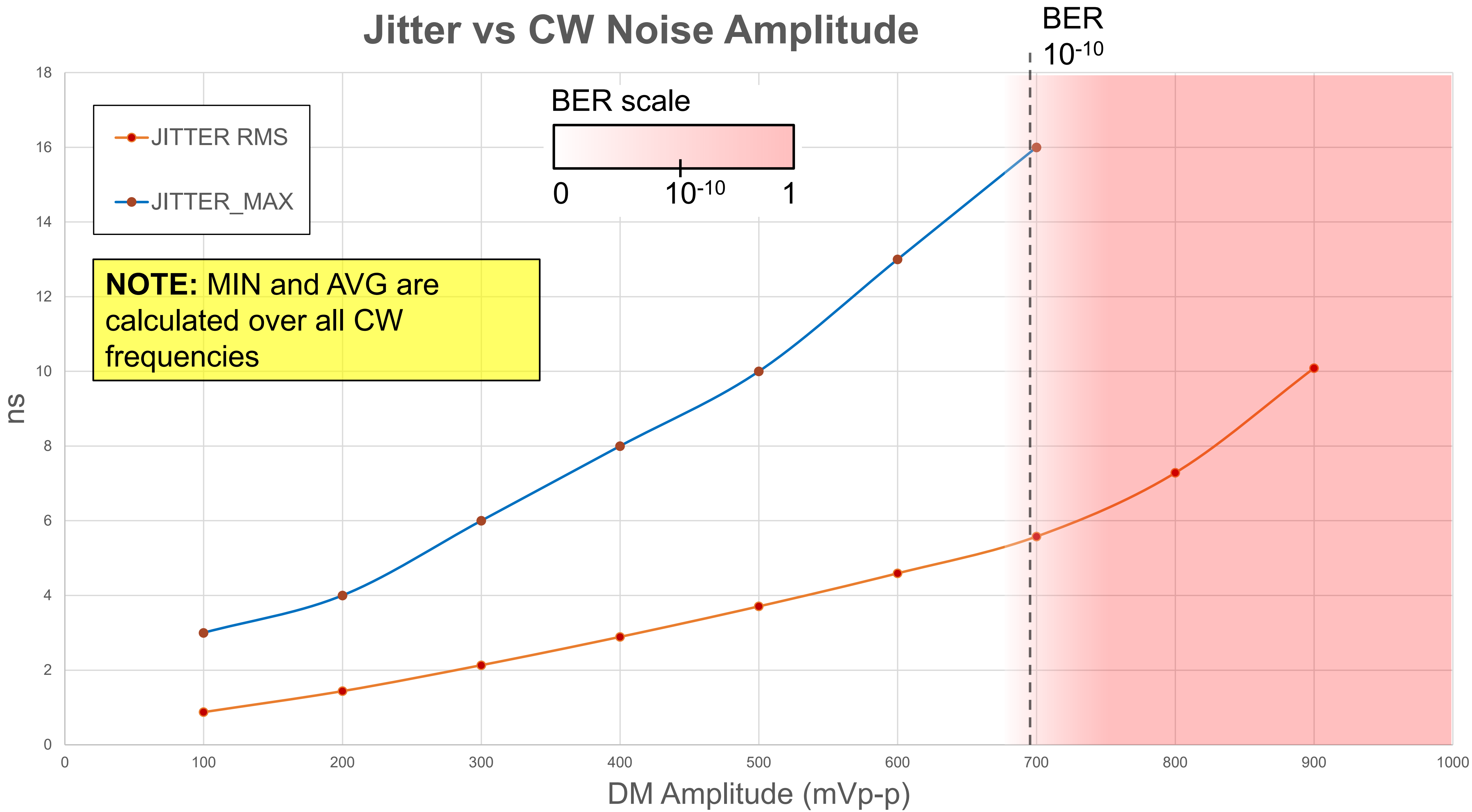
Jitter vs CW Noise Amplitude



NOTE: MIN and AVG are calculated over all CW frequencies

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Comments on simulation results

- The proposed metric shows a good linearity vs the CW noise amplitude
- Both the jitter and the correlation get worse between 2 MHz and 5 MHz
  - Compatible with the pass-band region of the defined analog filter
- The metric works well up to 700 $mV_{p\text{-}p}$ of CW
  - should give enough margin for adding the channel and topology contribution
- The jitter also copes well with the CW noise, but the correlation value is a better indication of the actual receiver capability of decoding bits successfully

Conclusions

Conclusions

- This presentation proposes an RX model architecture to adopt for completing the consensus model
  - Relies on “simple” analog filtering, slicing and orthogonal Manchester decoding
- The RX model produces a metric to evaluate the receiver performance vs noise
  - Based on the cross correlation of the received signal with ideal DME symbols
  - Linearity verified by simulating the target noise environment
- The metric can be used to specify the minimum requirements of a receiver implementation
  - We could define different performance classes to allow different trade-offs between noise immunity complexity of PHY implementations for different applications
    - As suggested by IEC61000-4-6 (see TODO)

Next steps

- If there is consensus on the receiver model architecture…
- Integrate it into the consensus model
  - Some help would be appreciated!
- Use the complete consensus model and the related output metric to specify the minimum receiver performance and trade-offs with the channel characteristics

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