Common Mode (CM) Noise: Next Steps

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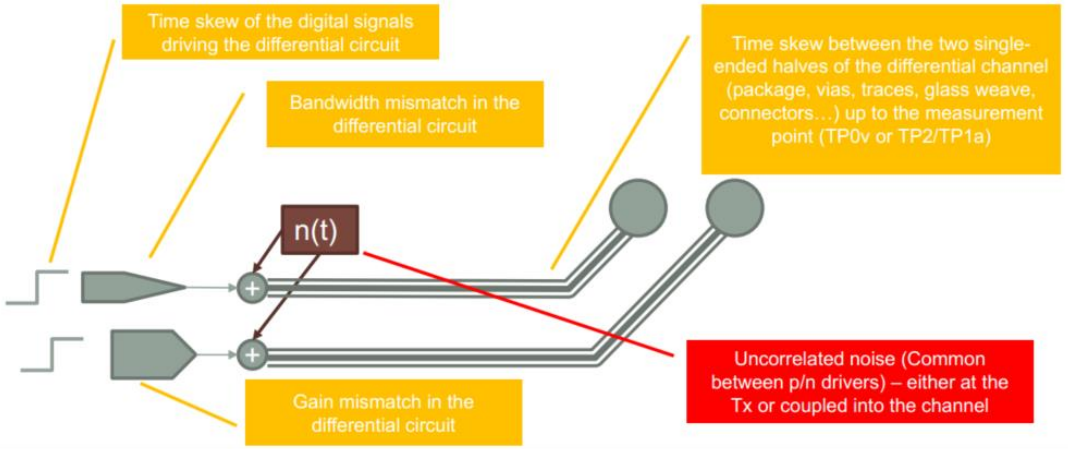
ran_3ck_04_1020 suggests sources and impact of common mode (CM) noise

Common mode AC output – sources

- Tx for electrical interfaces is typically a fully differential circuit whose output should have constant common mode voltage.
- Typical causes of common mode AC signal in the TX are:



Common mode AC output – impact

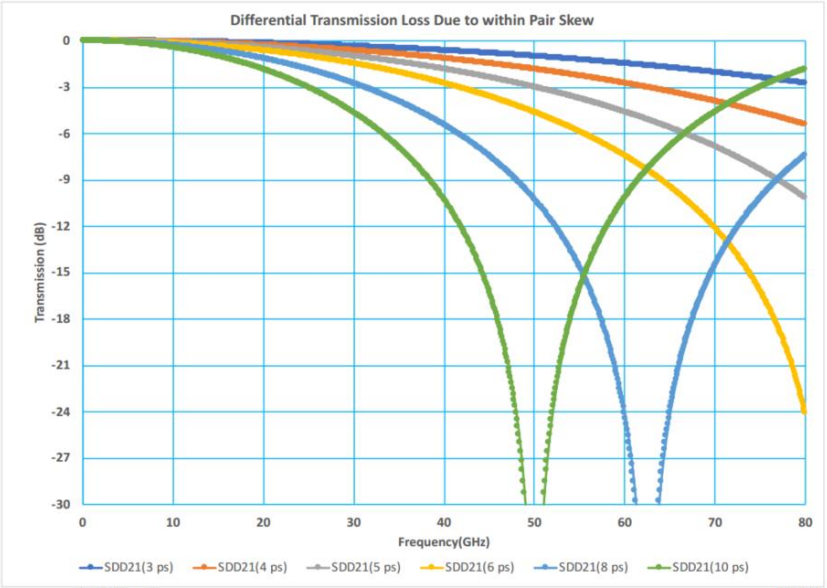
- Conversion of differential signal to CM signal
  - Frequency dependent
  - Causes distortion of the differential signal
  - Typically strong at high frequencies
  - Note that the channel (in CR/KR/C2C) can also cause D-C conversion
- Conversion of CM *noise* to differential *noise*
  - Note that the channel (in CR/KR/C2C) can also cause C-D conversion
- Common mode signal/noise impact on the receiver
  - Rx is also differential, but has finite CMRR
- EMI
  - Not performance related; other standards deal with this

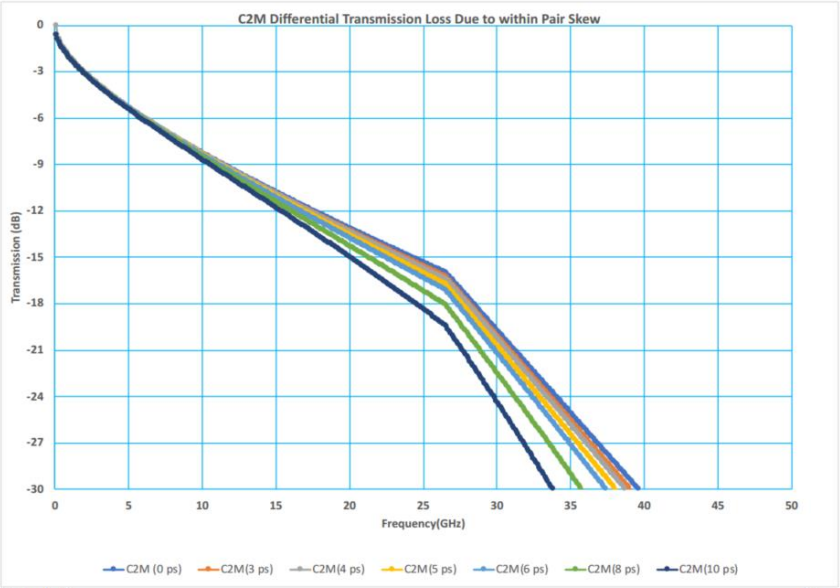
What should we really care about?

ghiasi_3ck_03a_0720 also suggest sources of CM Noise

Sources of Common Mode

- **Driver P/N asymmetry and interconnect P/N mismatch are the two sources of common mode generation**
  - Graph show the theoretical impact of 3-10 ps of skew on C2M IL where the penalty increases with the Baudrate increase , D. Nozadze, IEEE EPEPS, 2017
  - The CK channels already include effects of P/N mismatch but currently COM reference model and package don't excite the common modes and obviously the impact is overlooked at the receiver.



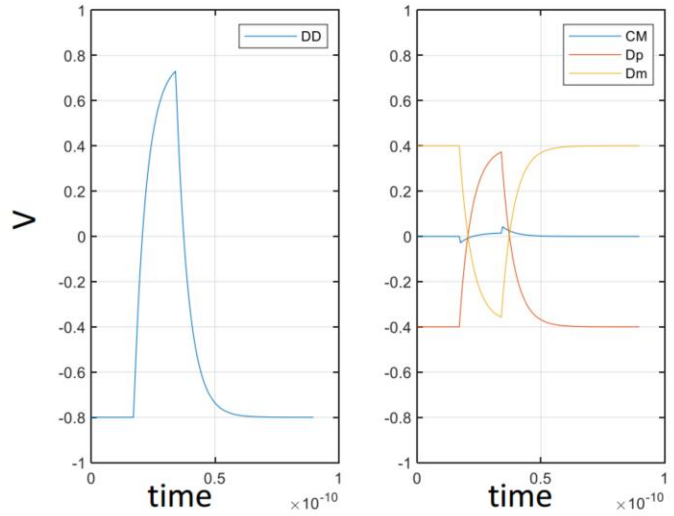


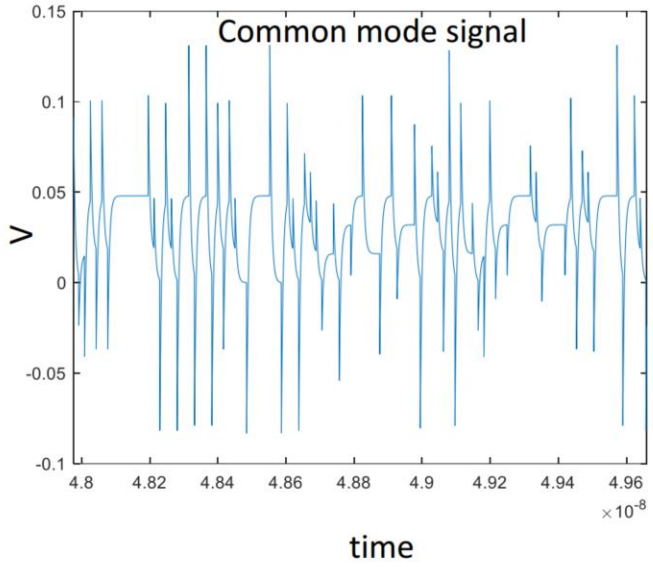
A. Ghiasi IEEE 802.3ck Task Force 4

mellitz_3ck_adhoc_01_061720 suggest similar CM sources

What might a common signal look like

- ❑ Intrapair Voltage Imbalance
- ❑ Intrapair Skew
- ❑ CM crosstalk





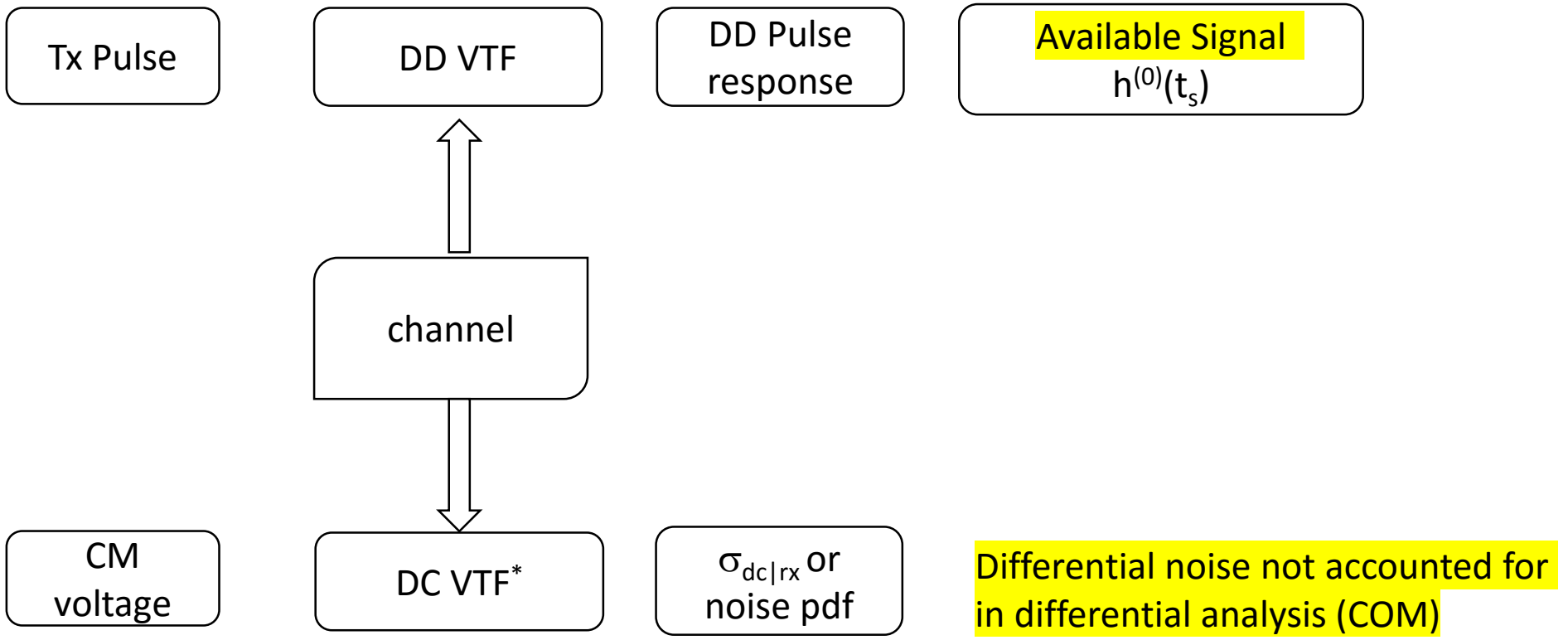
Should spec be an RMS and crest factor?

IEEE 802.3 100 Gb/s, 200 Gb/s, and 400 Gb/s Electrical Interfaces Task Force 9

Ways to look a CM noise impacting the differential signal at the receiver.

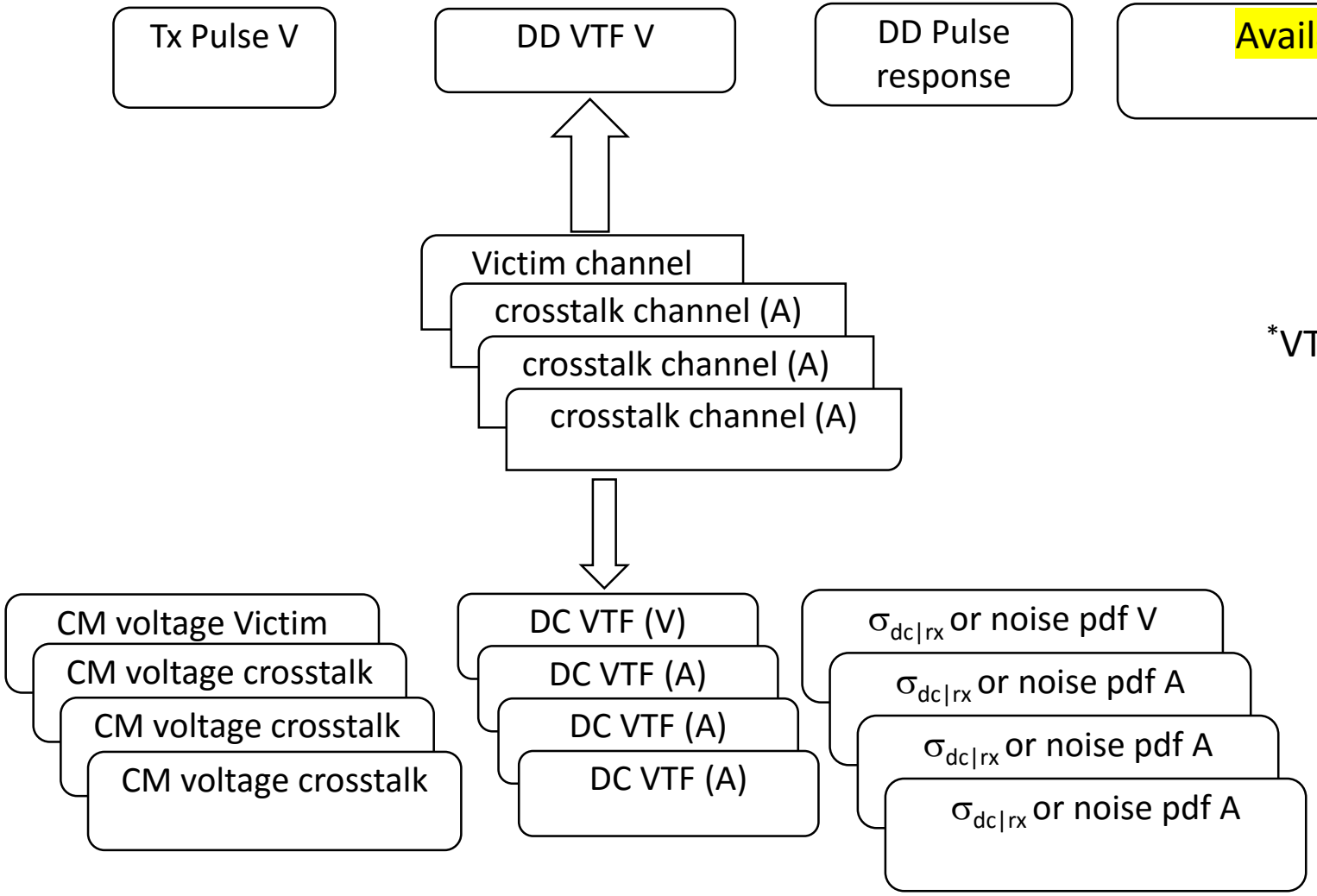
- Eventually CM noise looks like crosstalk
  - One big question is how much get to into the receiver
- wu_3ck_adhoc_01_090920.pdf – good way to get a feel for CM
  - SDC21 peaks
  - SDD21 (dB) – SDC21 (dB)
  - Integrated CM noise due to SDC21
- mellitz_3ck_adhoc_01_061720 – method to compute impact
  - Use the common mode to differential mode voltage transfer function
  - Trial impact version is COM
    - However the big question here is what to use as a CM source

Simple model



*VTF ~ voltage transfer function

A little more detail: Should Crosstalk CM be considered



*VTF ~ voltage transfer function

Differential noise not accounted for in differential analysis (COM)

… More in later slides

Getting a feel for understanding if crosstalk CM matters?

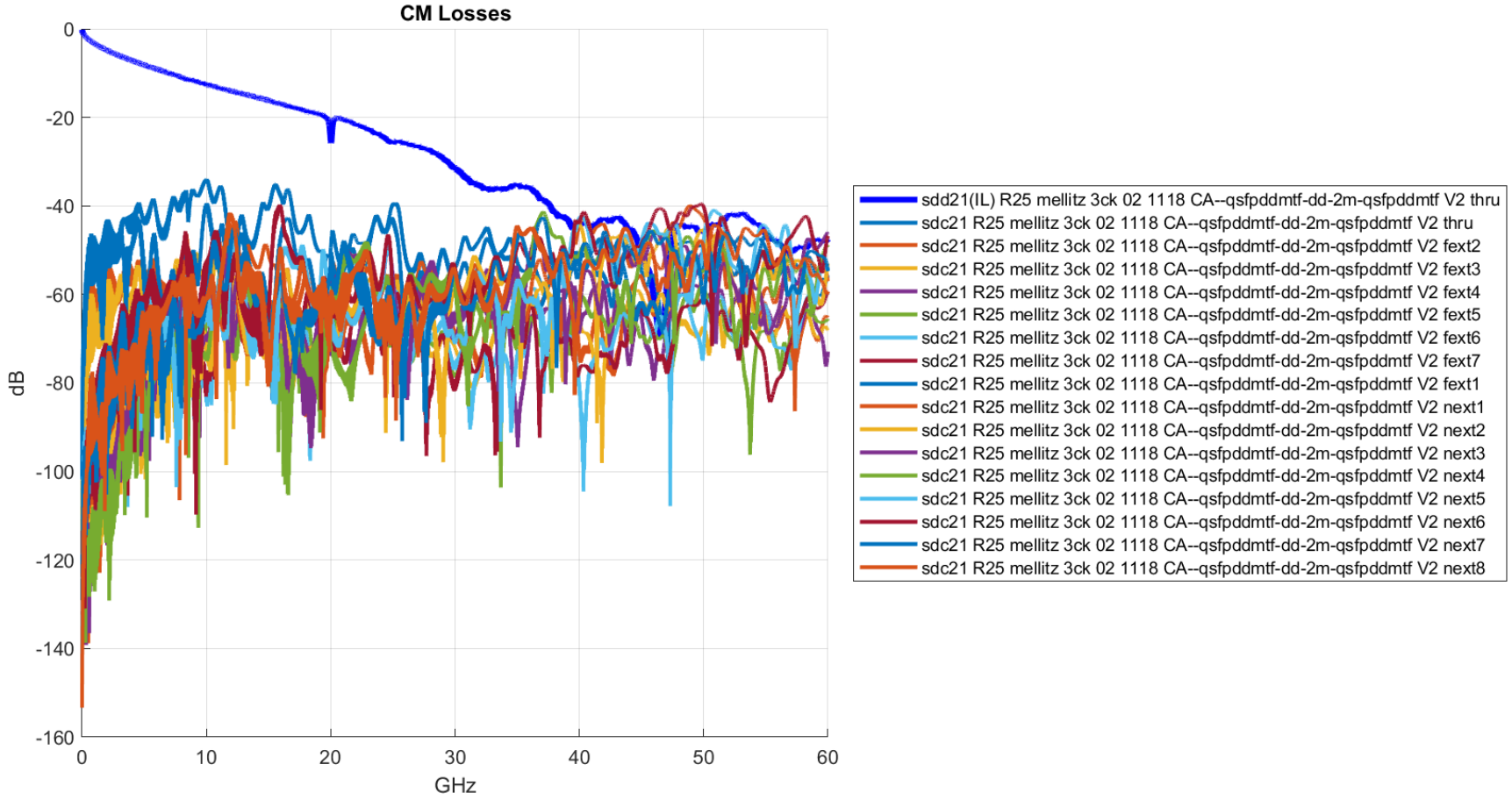
- crosstalk CM peaks are between 35 and 45 dB
  - For 1.5 m and 2 m cables,
- CM conversation is are not significant if the CM voltage is low
- Following 15 slides are snapshots sampling of the CM data
  - This should lend a feel for what channel CM data could be expected

CM Data

- ❑ Slides of IL and CM loss for collection of cable posted channels
- ❑ Slides of comparison between CM an crosstalk pulse responses
  - Crosstalk uses Afe and Ane as pulse voltage
  - CM use 1 V as pulse voltage … will be adjusted later
- ❑ One slide for on channel comparing crosstalk and CM responses

mellitz_3ck_02_1118_CA--qsfpddmtf-dd-2m-qsfpddmtf_V2_thru

1



P2_TX8_P1_RX8_Normal

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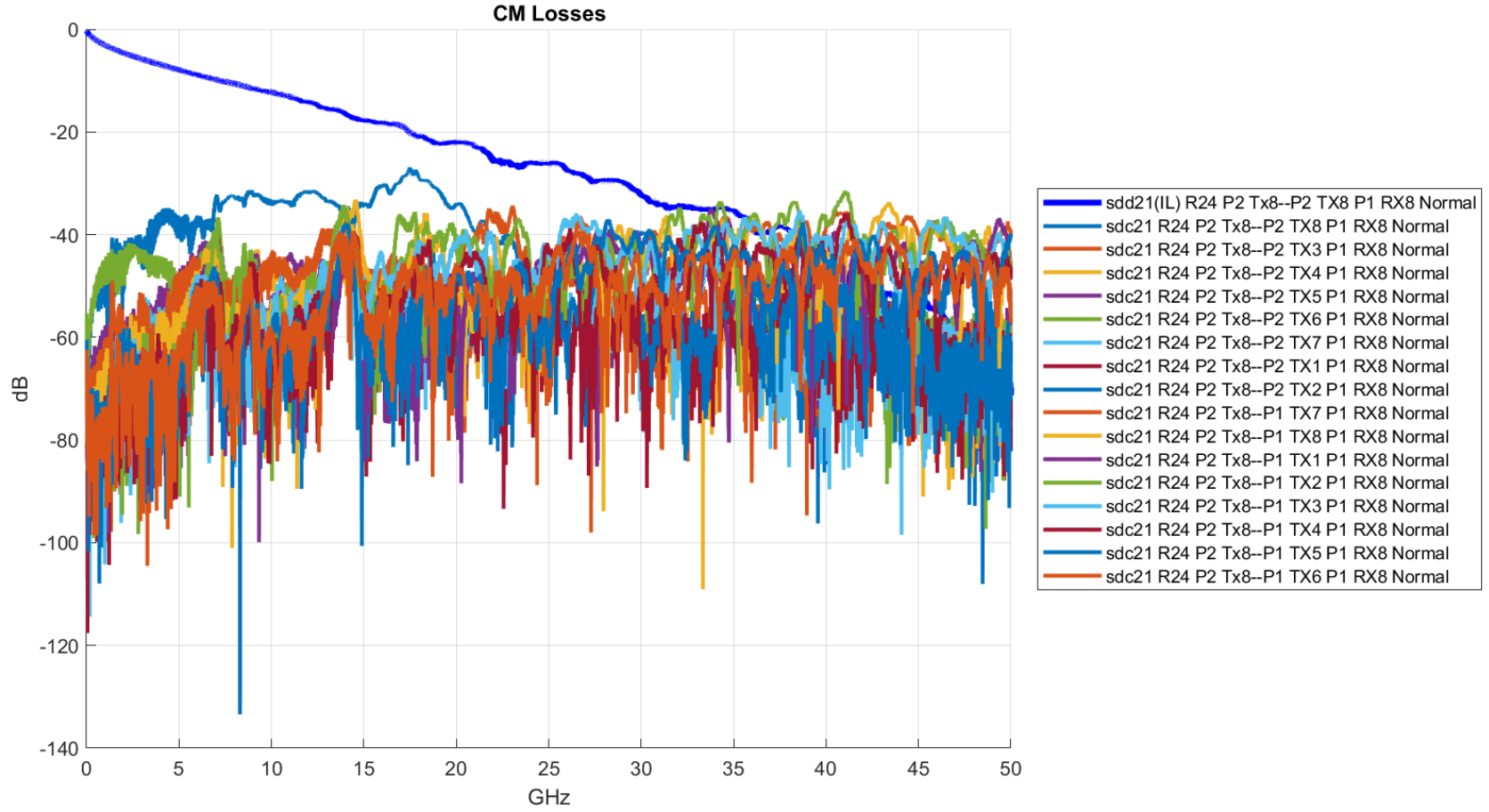

P1_TX4_P2_RX4_Normal

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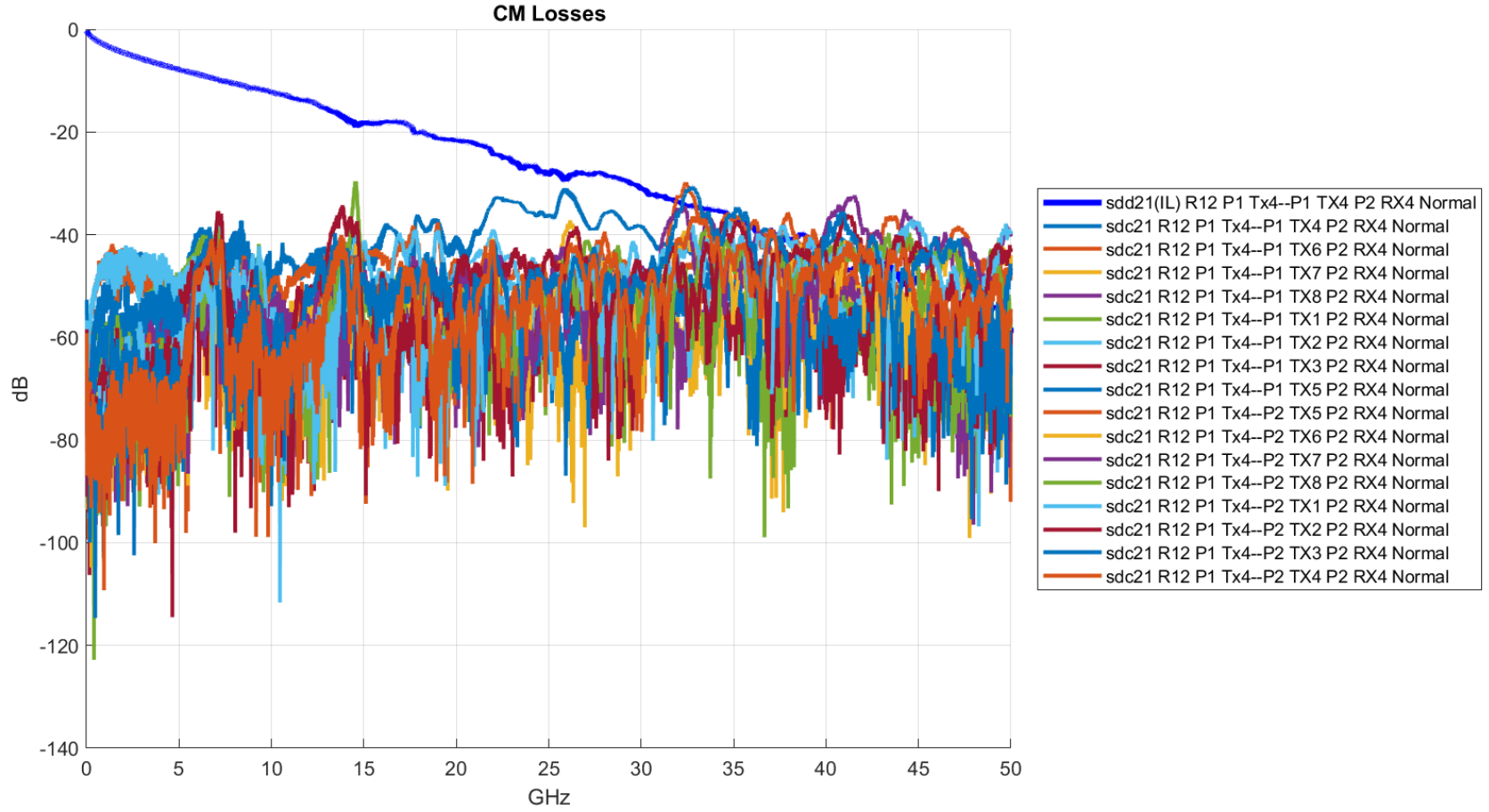

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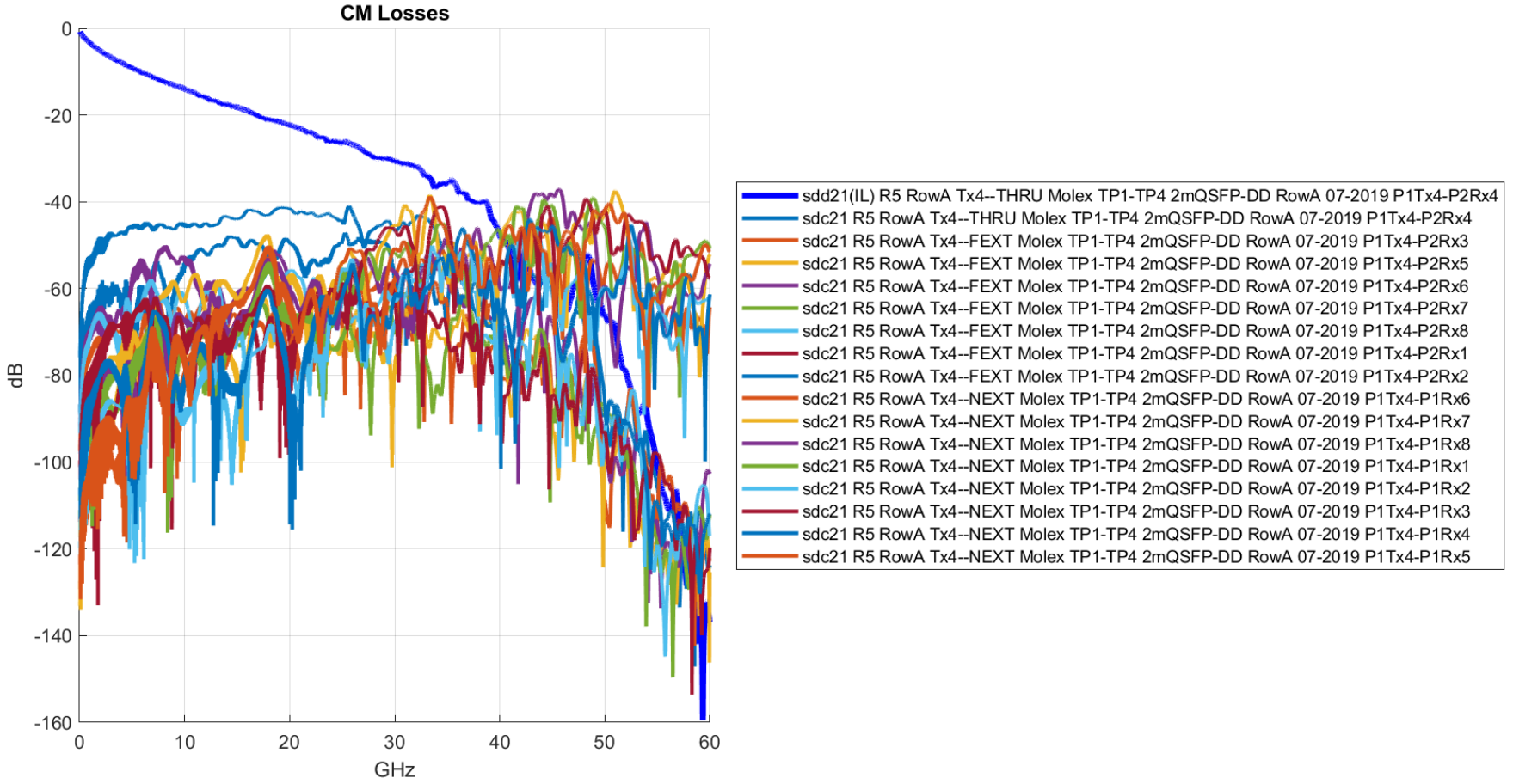
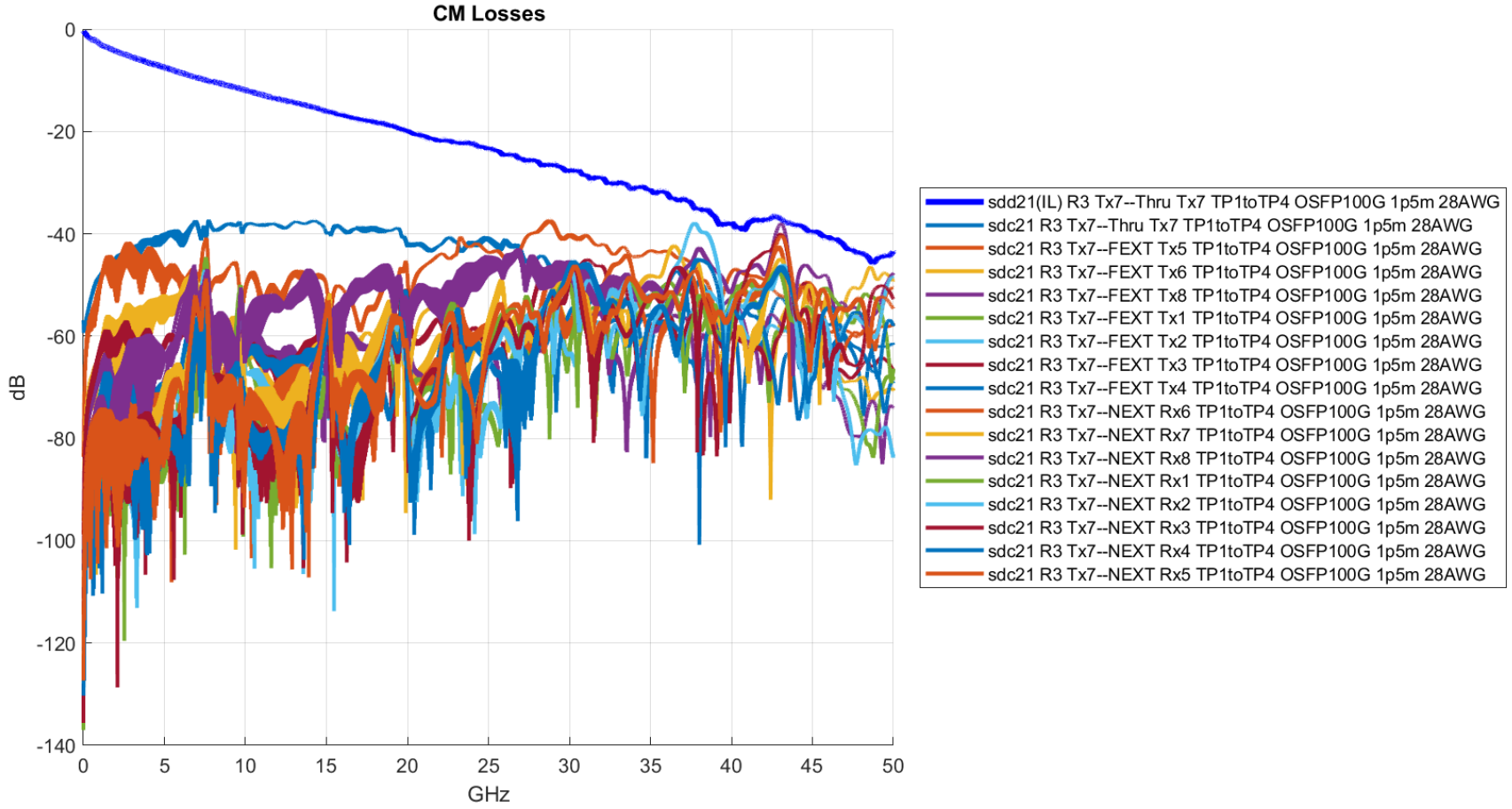


Thru_Tx7_TP1toTP4_OSFP100G_1p5m_28AWG

5



CA_19p875dB_thru

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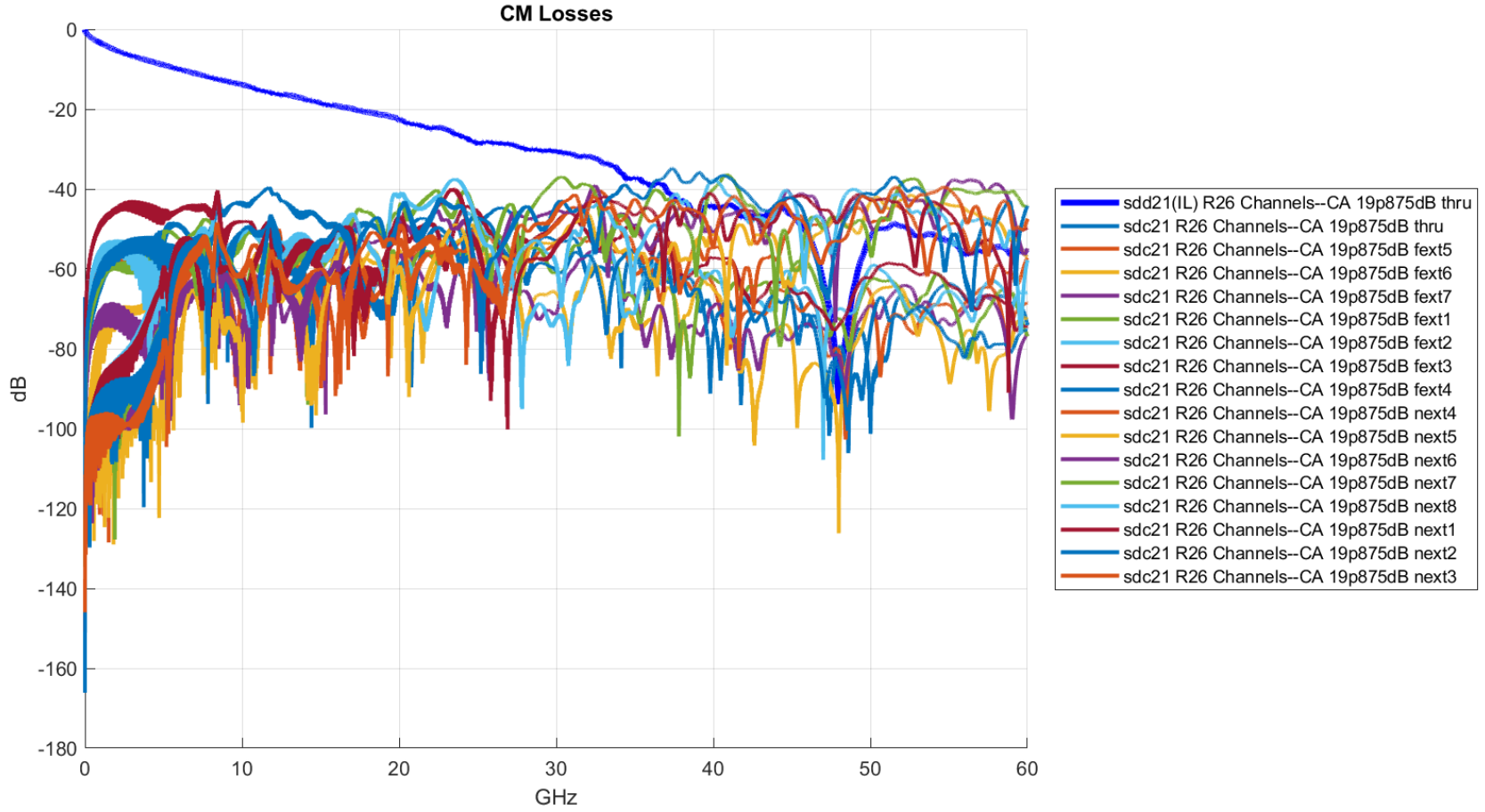

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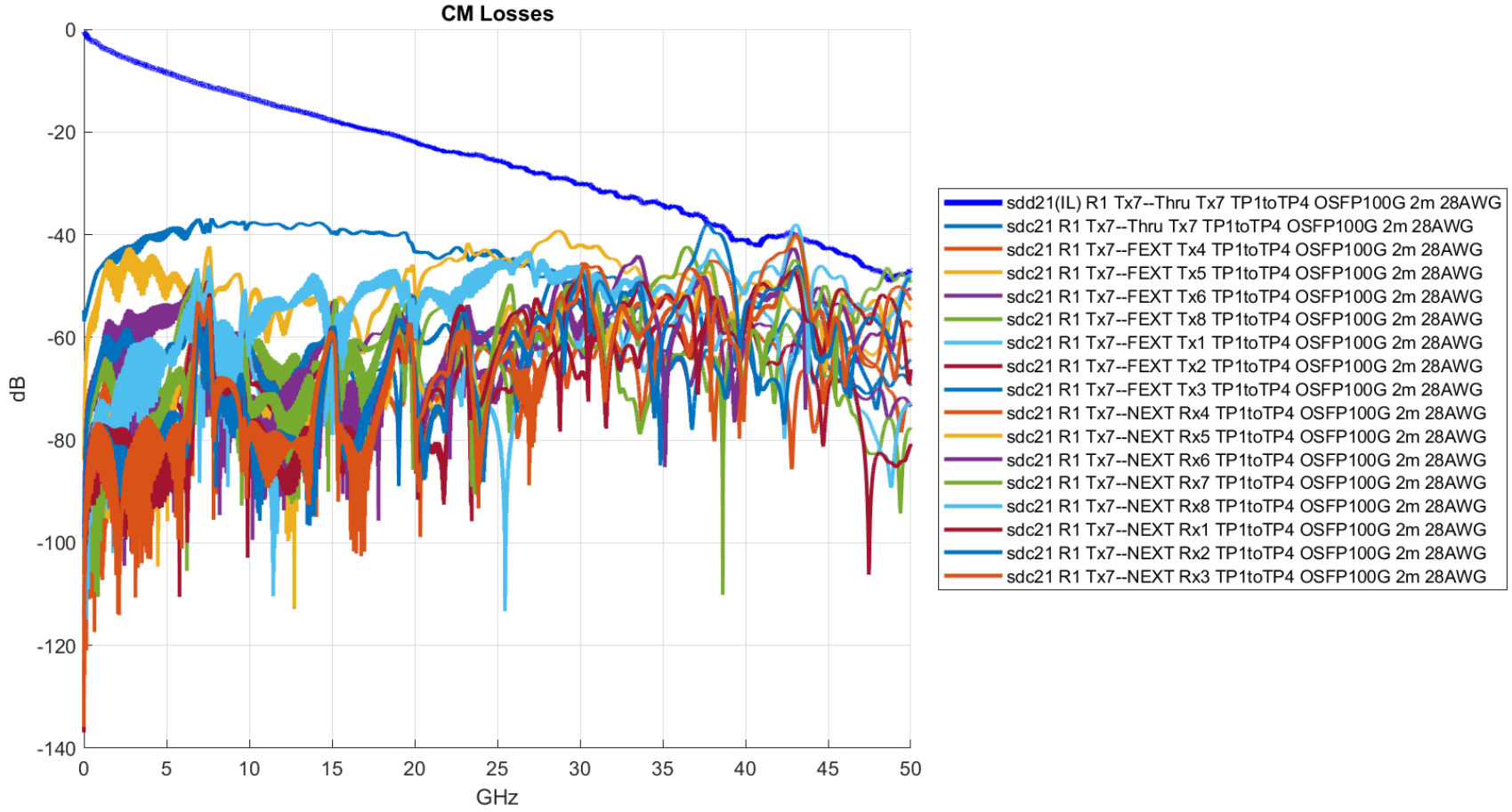
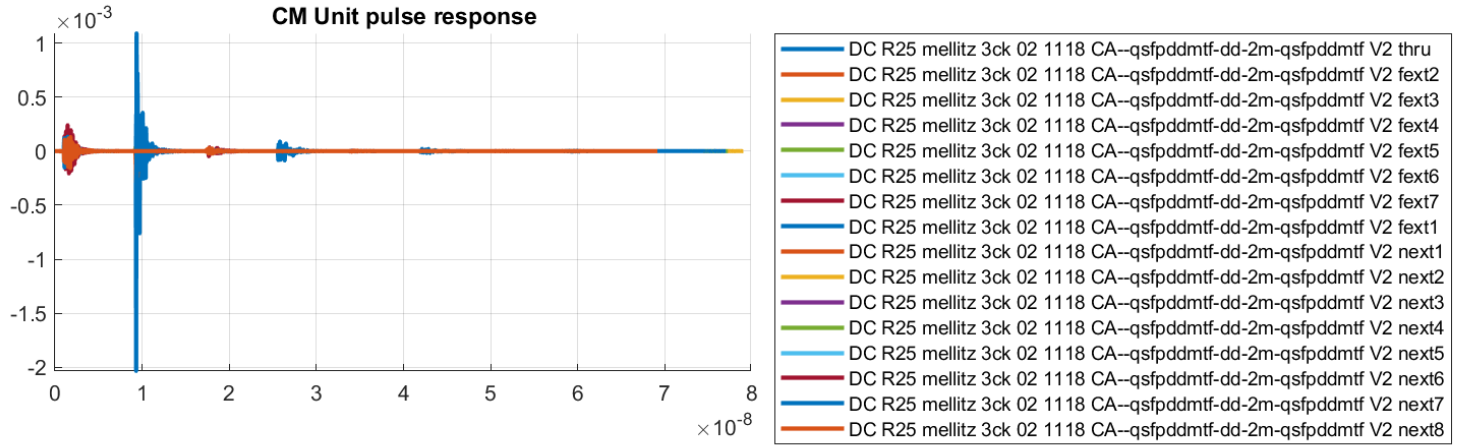
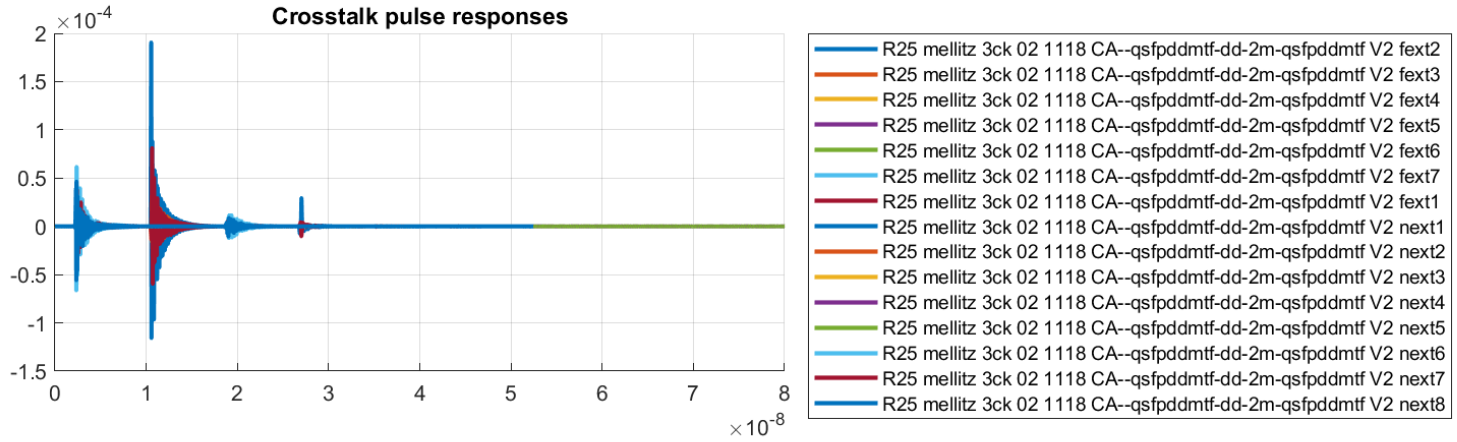
7



mellitz_3ck_02_1118_CA--qsfpddmtf-dd-2m-qsfpddmtf_V2_thru

8





P2_TX8_P1_RX8_Normal

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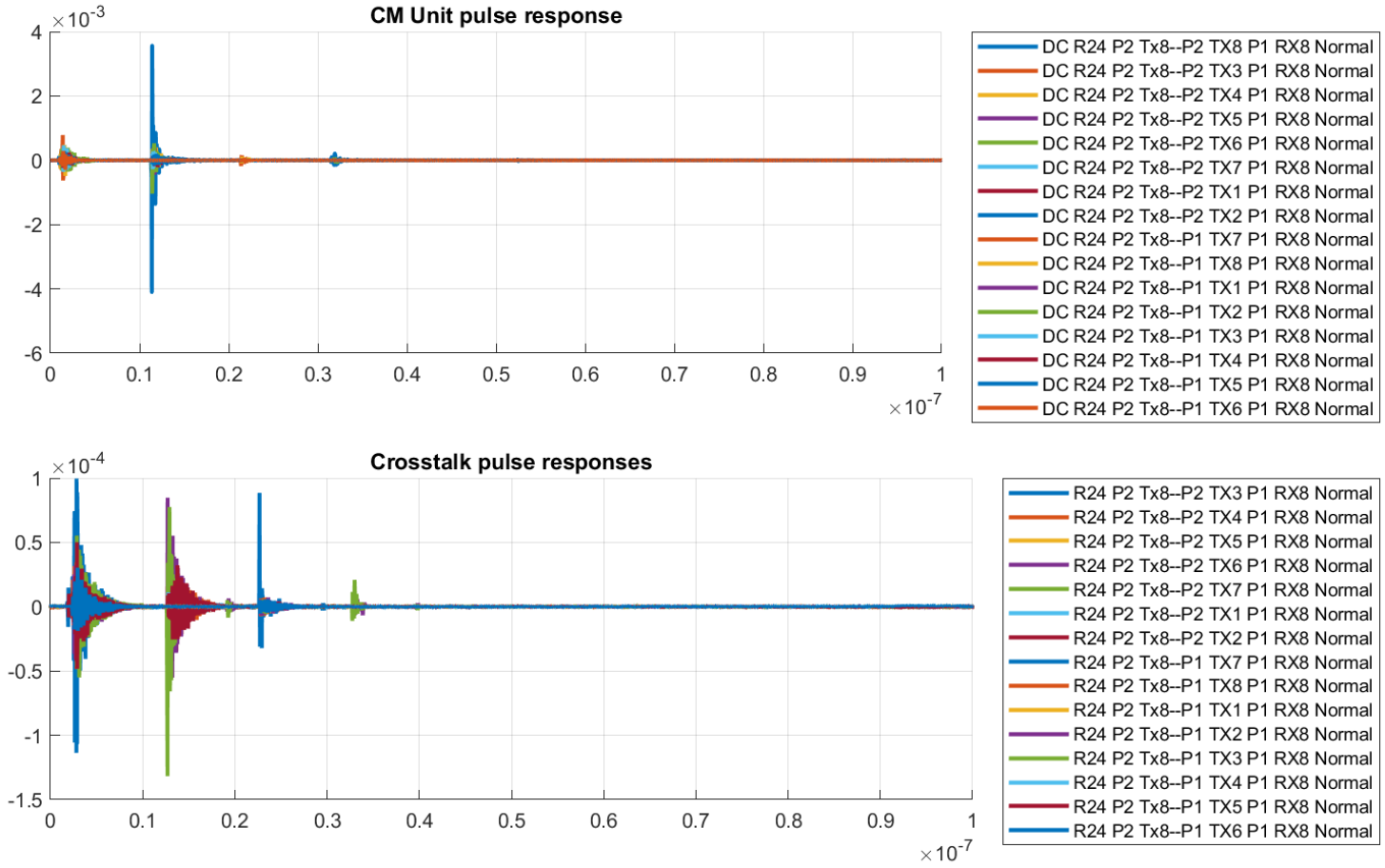

P1_TX4_P2_RX4_Normal

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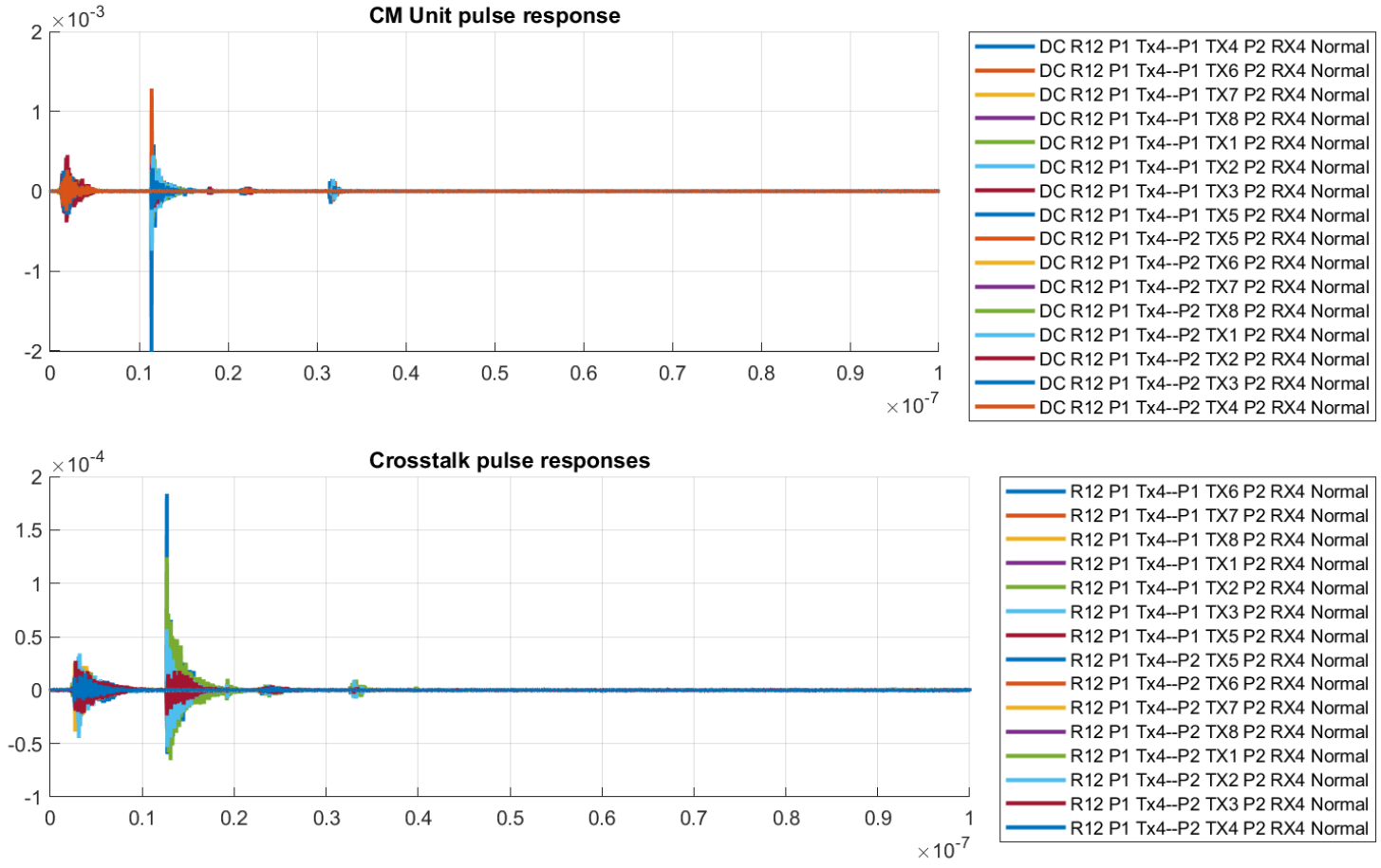

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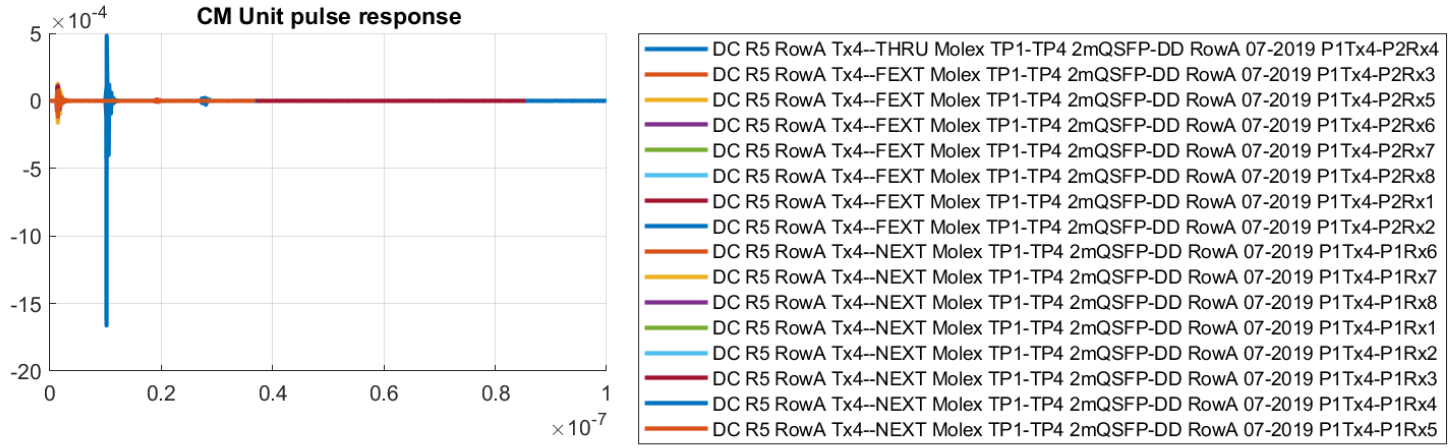
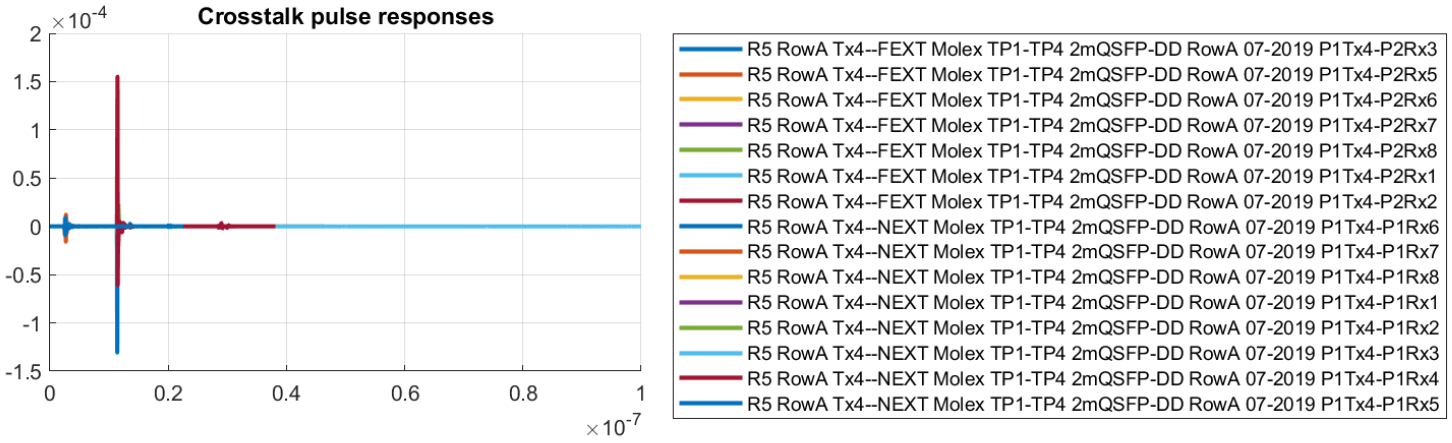
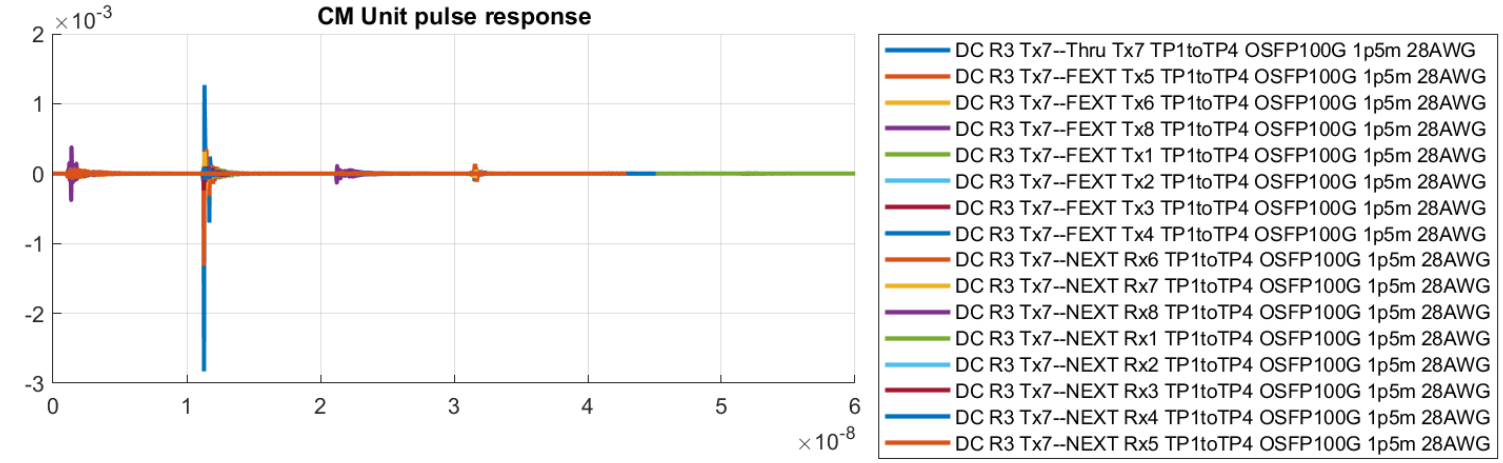
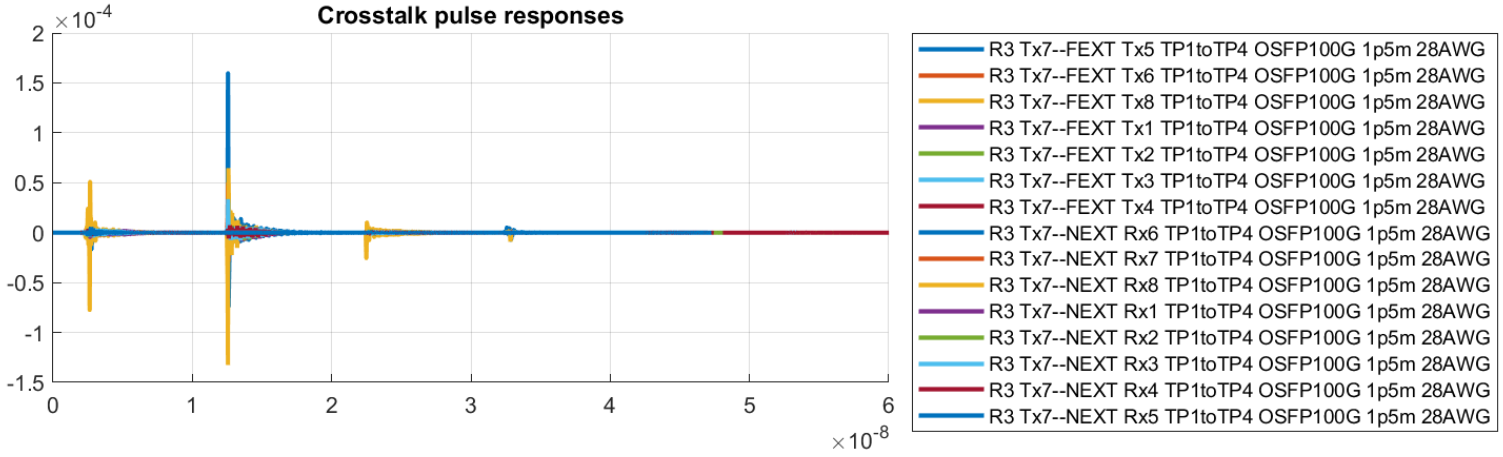




Thru_Tx7_TP1toTP4_OSFP100G_1p5m_28AWG

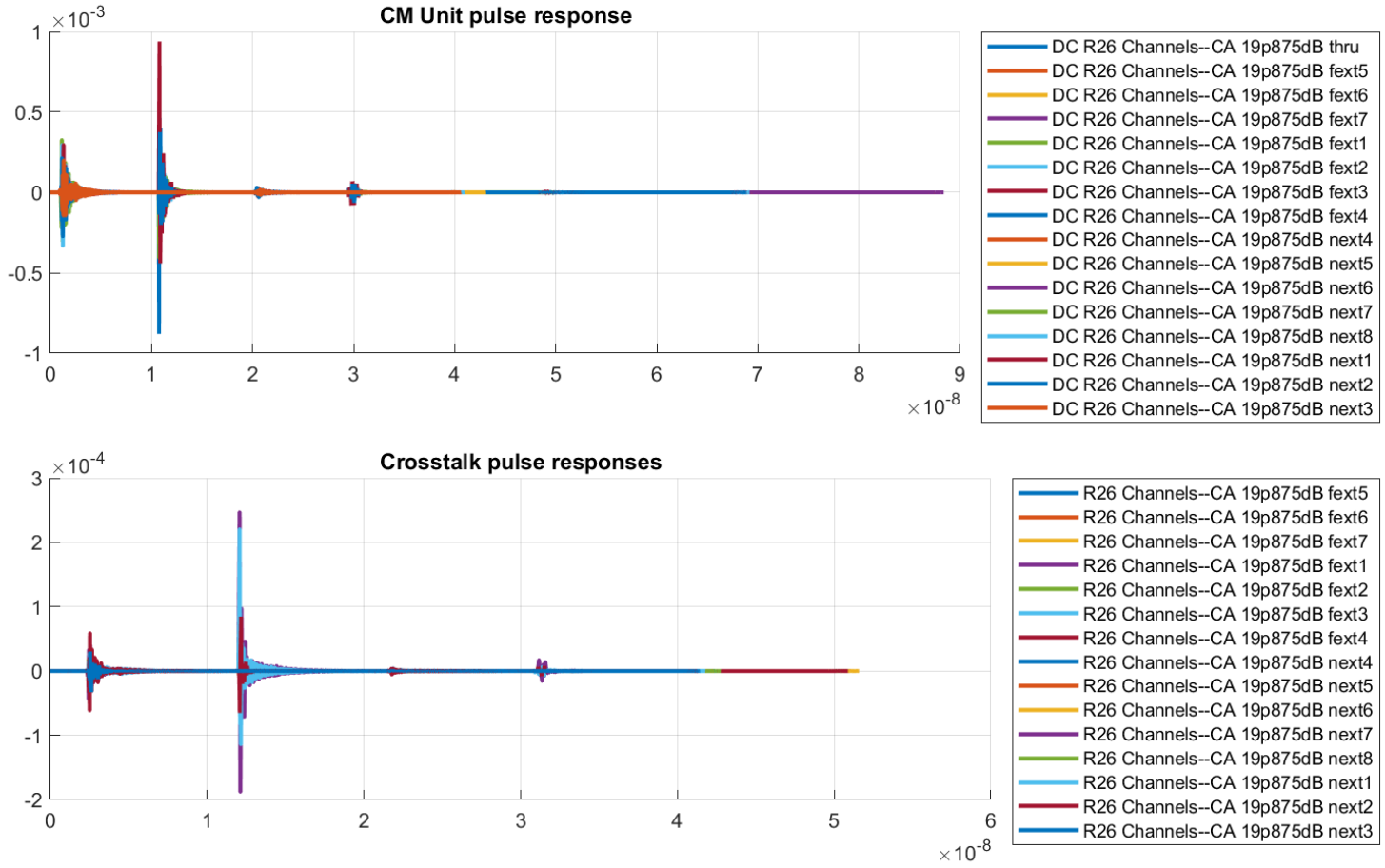
12



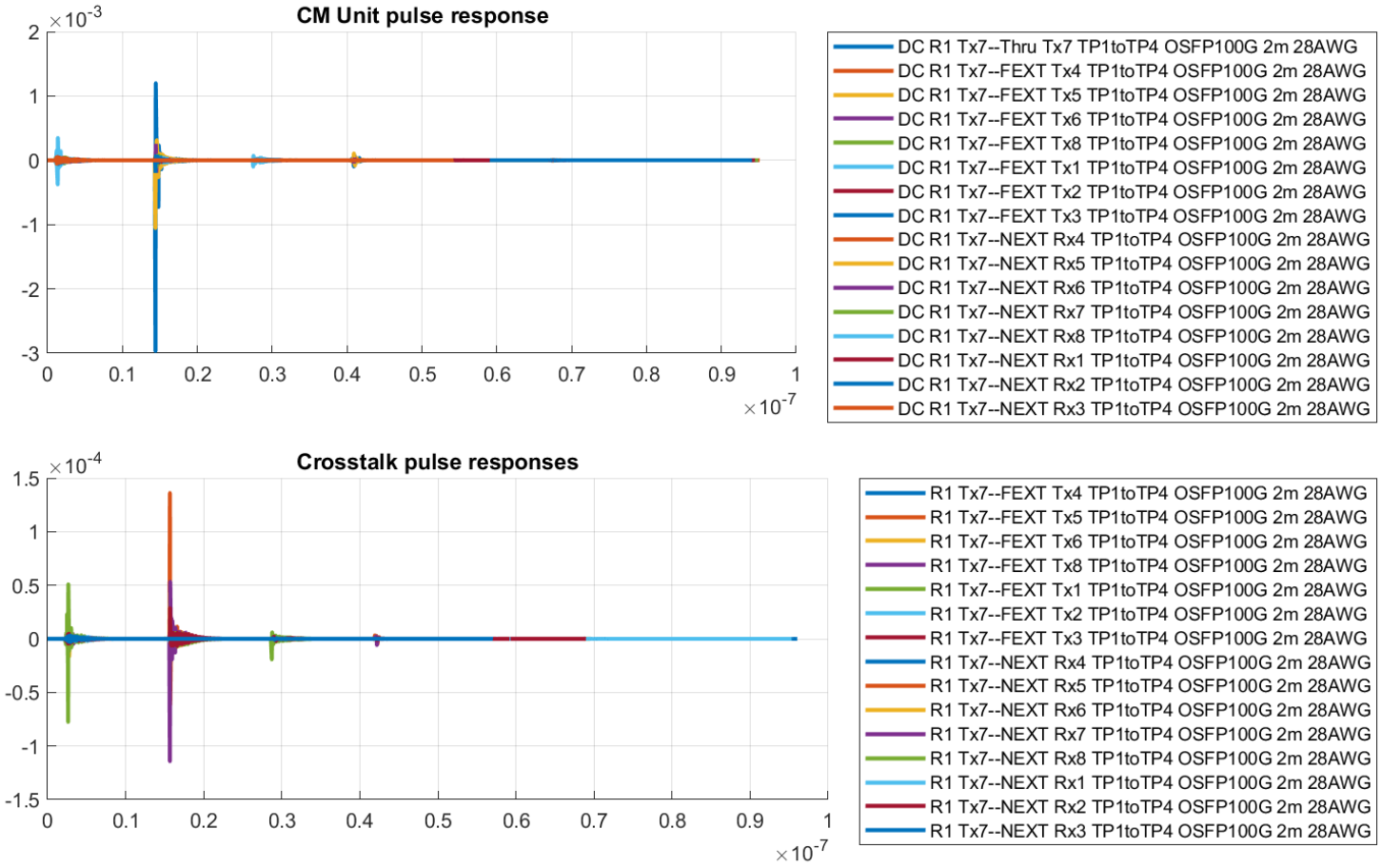


CA_19p875dB_thru

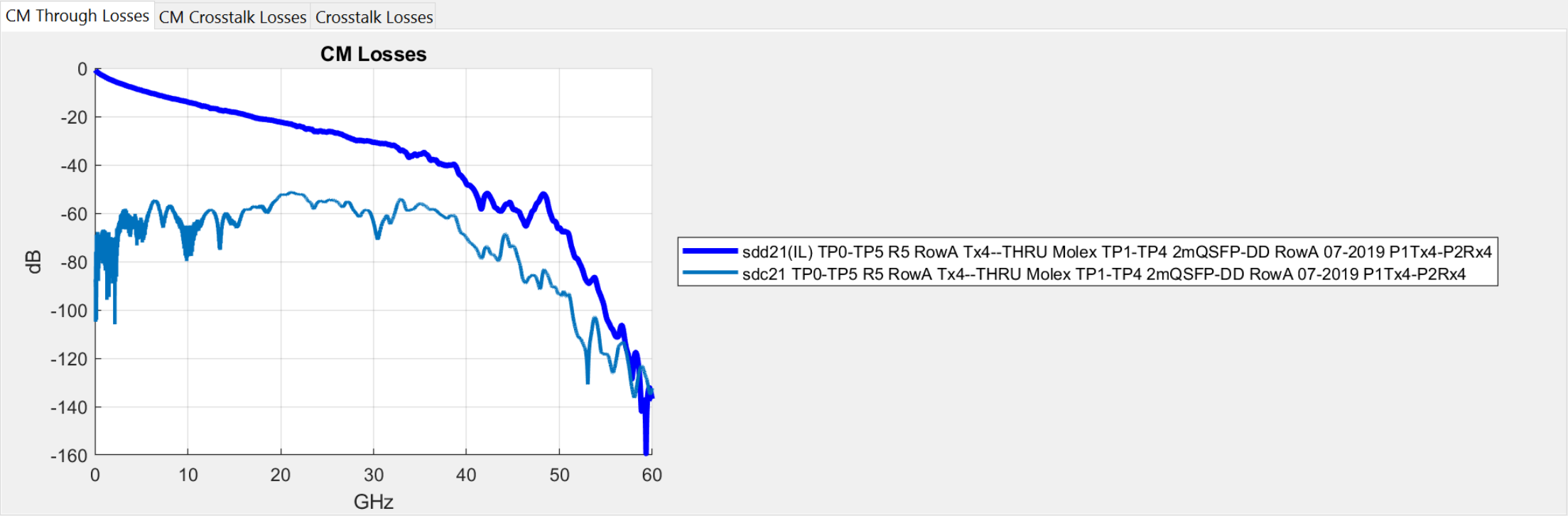
13



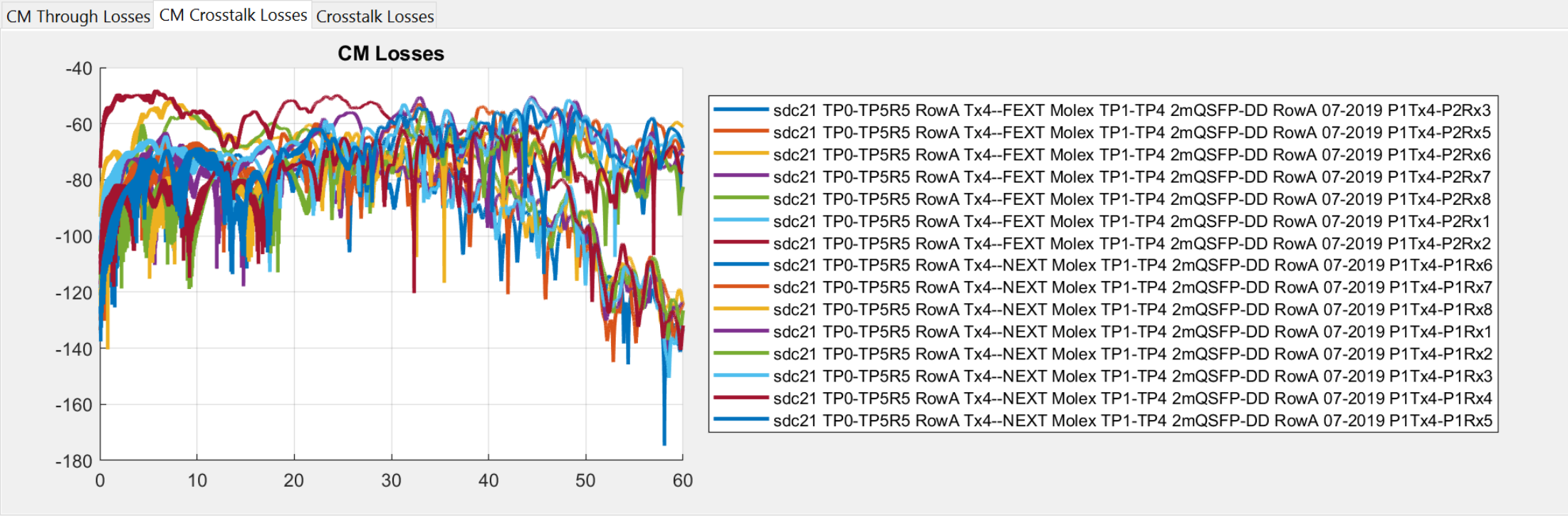
Thru_Tx7_TP1toTP4_OSFP100G_1p5m_28AWG



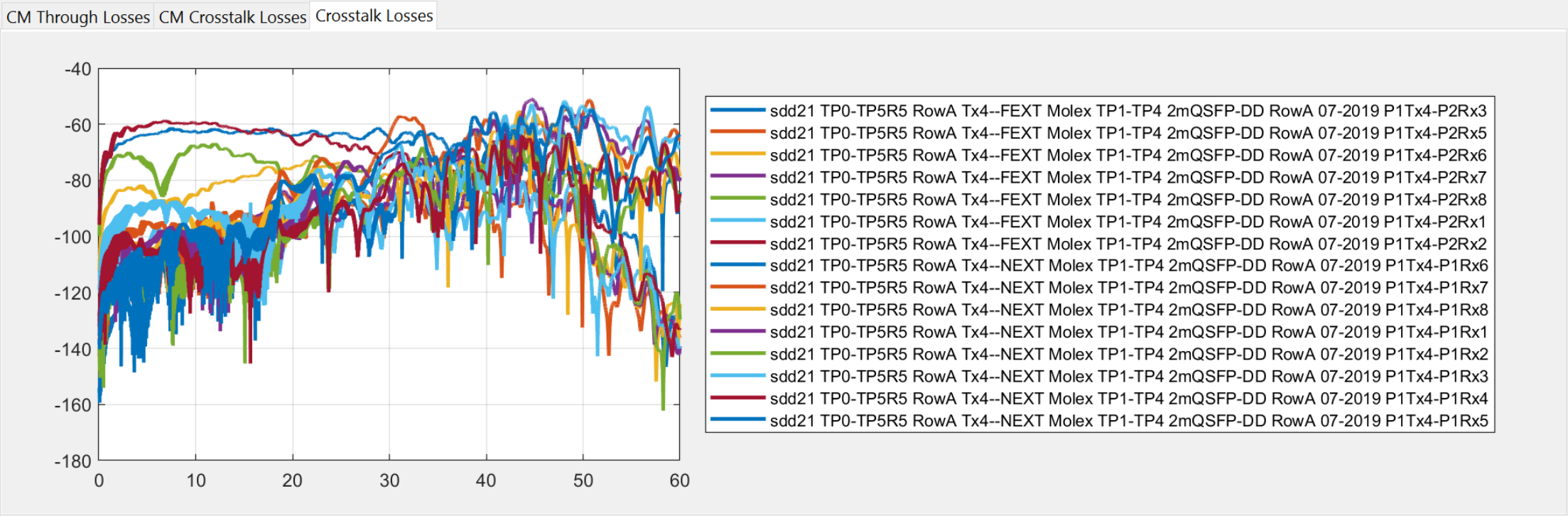
IL and Through CM response



CM responses



Crosstalk responses

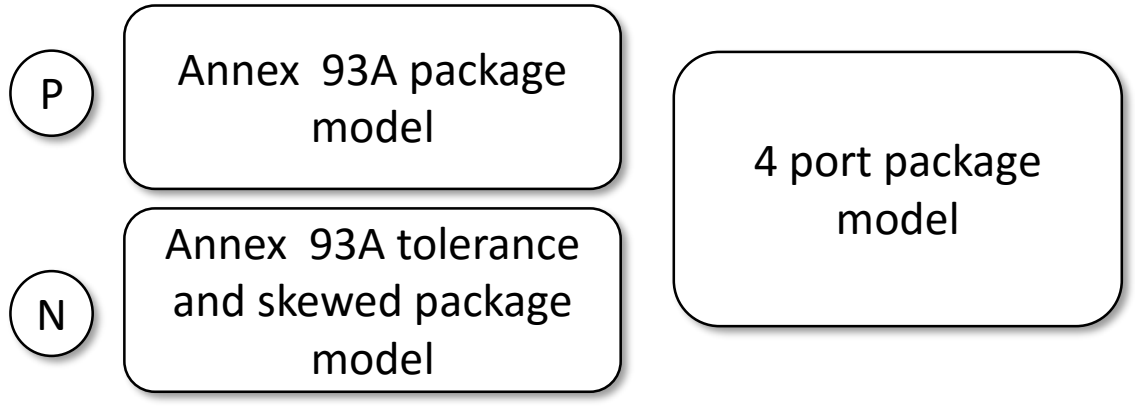


Evaluation of CM sources with waveform simulation

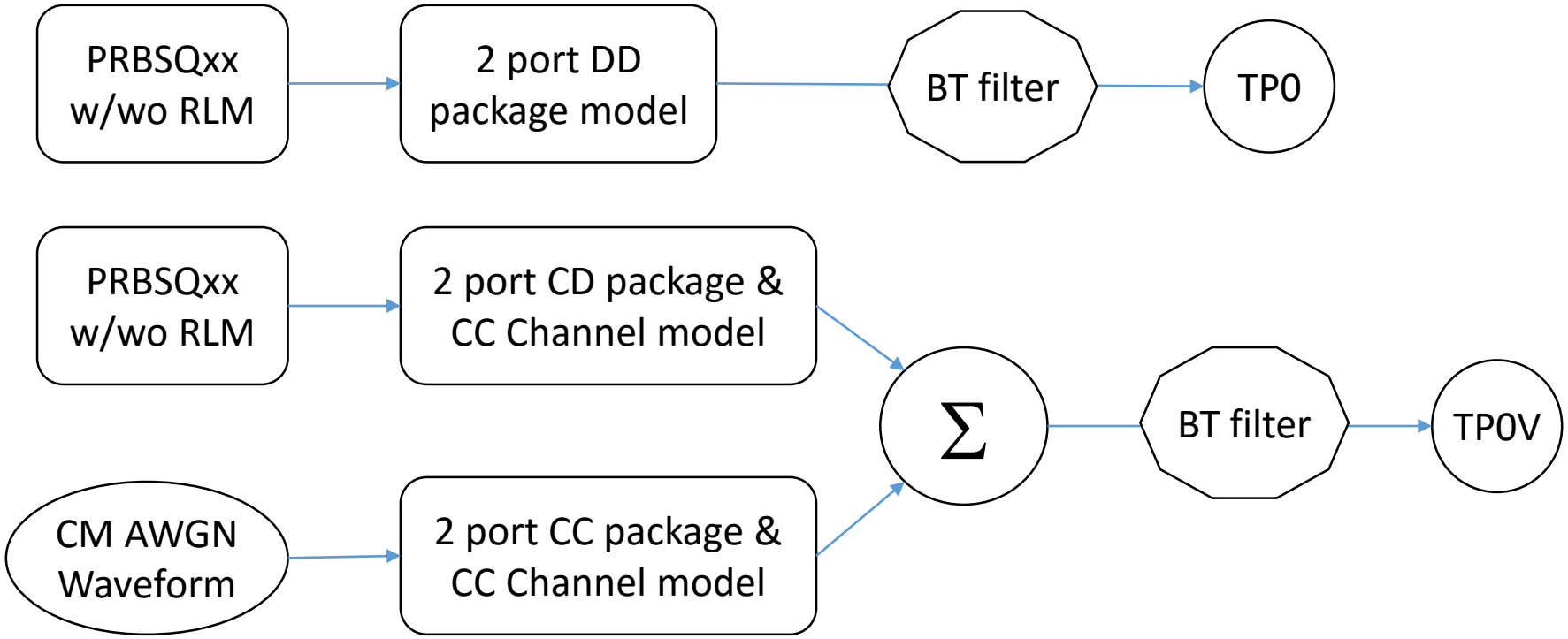
- Similar to ghiasi_3ck_03a_0720 and mellitz_3ck_adhoc_01_061720
- Emulate CM noise
  - Use toleranced package for each p/n leg for correlated CM
  - Use AWGN CM mode noise source at die pad drive for uncorrelated CM
  - Utilize waveform simulation with Matlab (not COM)
- What to observe
  - Waveforms
  - Noise probability density functions (PDF)
  - Noise Power Spectral densities (PSD)

Unbalanced and skewed package models

```
param.Zp=30;
param.Zp1=1.8;
param.Cd=120e-15*pvdt;
param.Cp=87e-15*pvdt;
param.Zc=87.5*pvdt;
param.Zc1=92.5*pvdt;
param.Lb=120e-12;
param.Cb=30e-15;
param.pkg_tau=0.00614*pvdtskew;
skew_ps= 0.00614*(1-pvdtskew)*1e-9/1e-12*param.Zp;
param.pkg_gamma0_a1_a2=[0  0.0009909  0.0002772];
param.Z0=50;
fprintf('%.2g ps skew  \n',skew_ps)
```



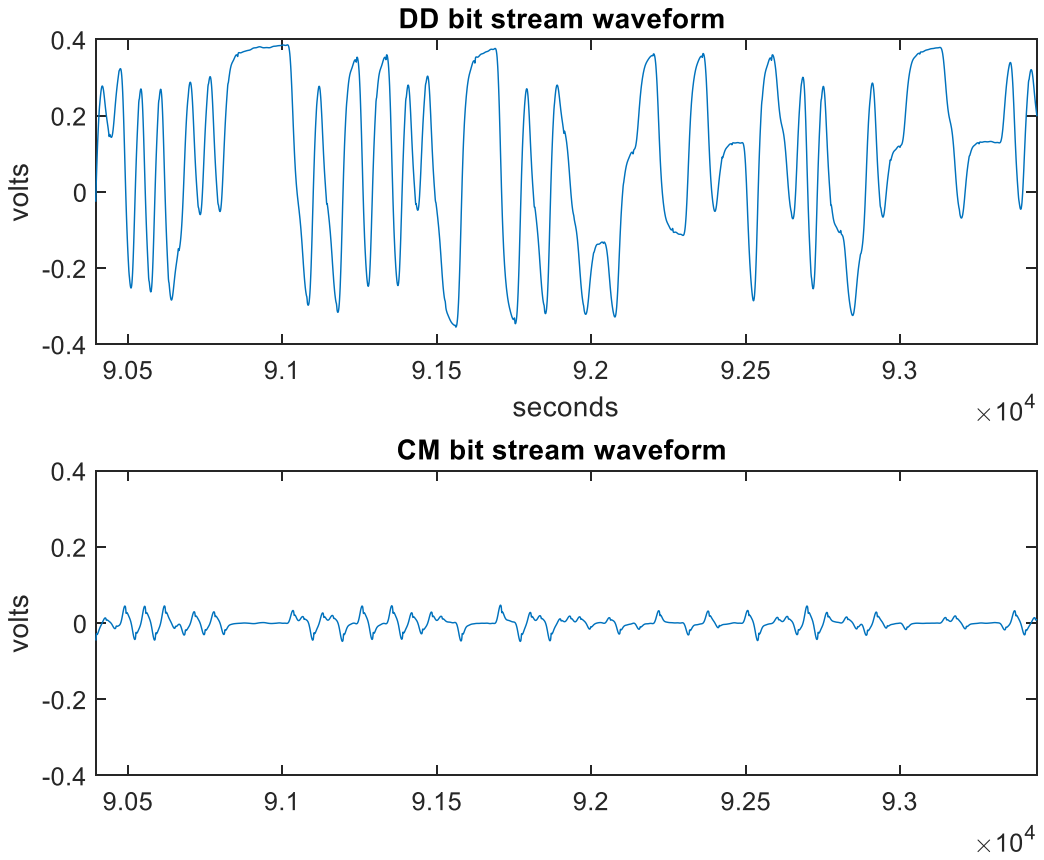
Simulation of common mode at package voltages at TP0 and TP0v

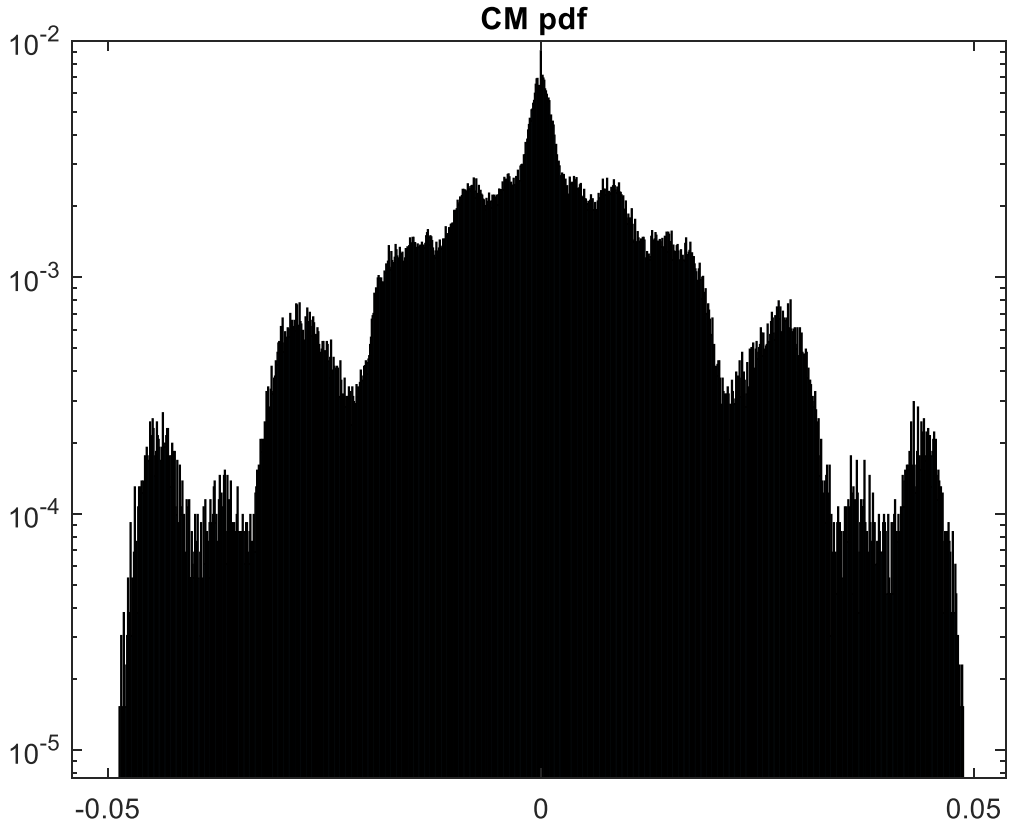


Simulation Conditions

- No Txffe
- Tr = 7.5 ps
- Av= 400 mV
- No noise or jitter
- BT filter

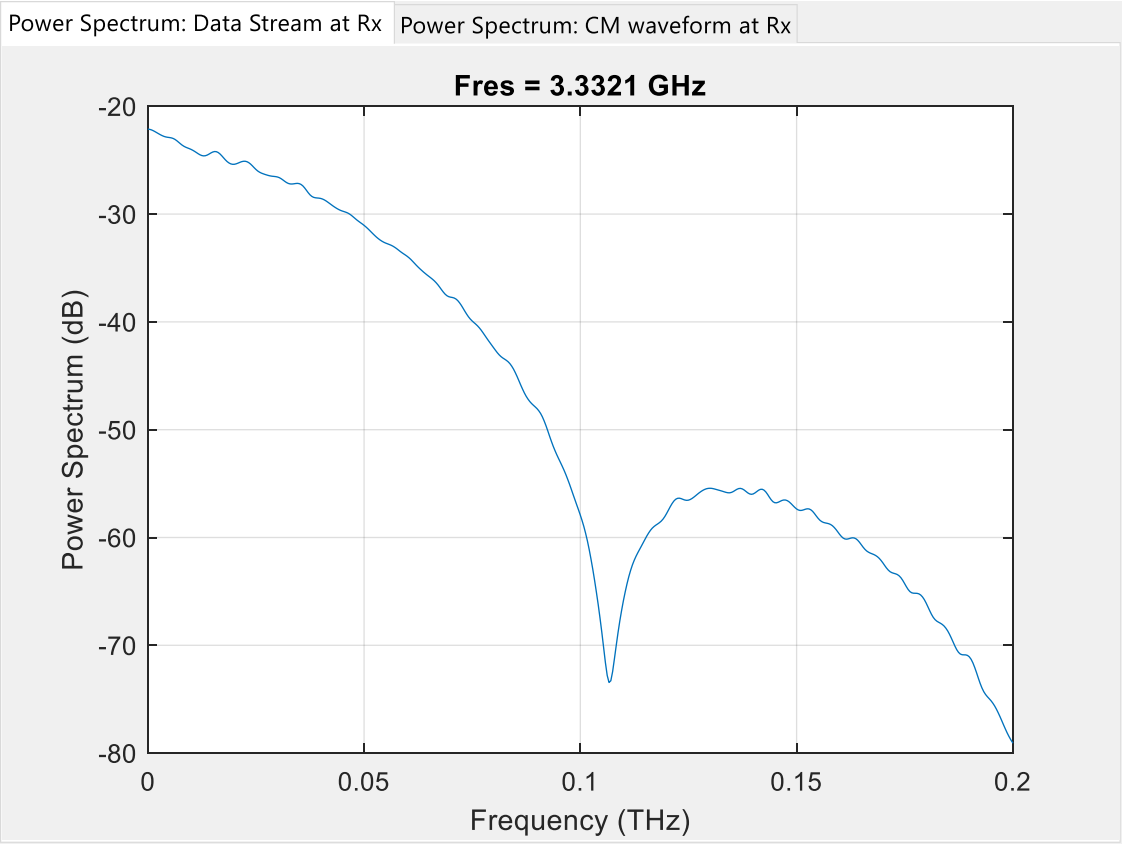
Introduce 3.7 ps p-n skew at TP0



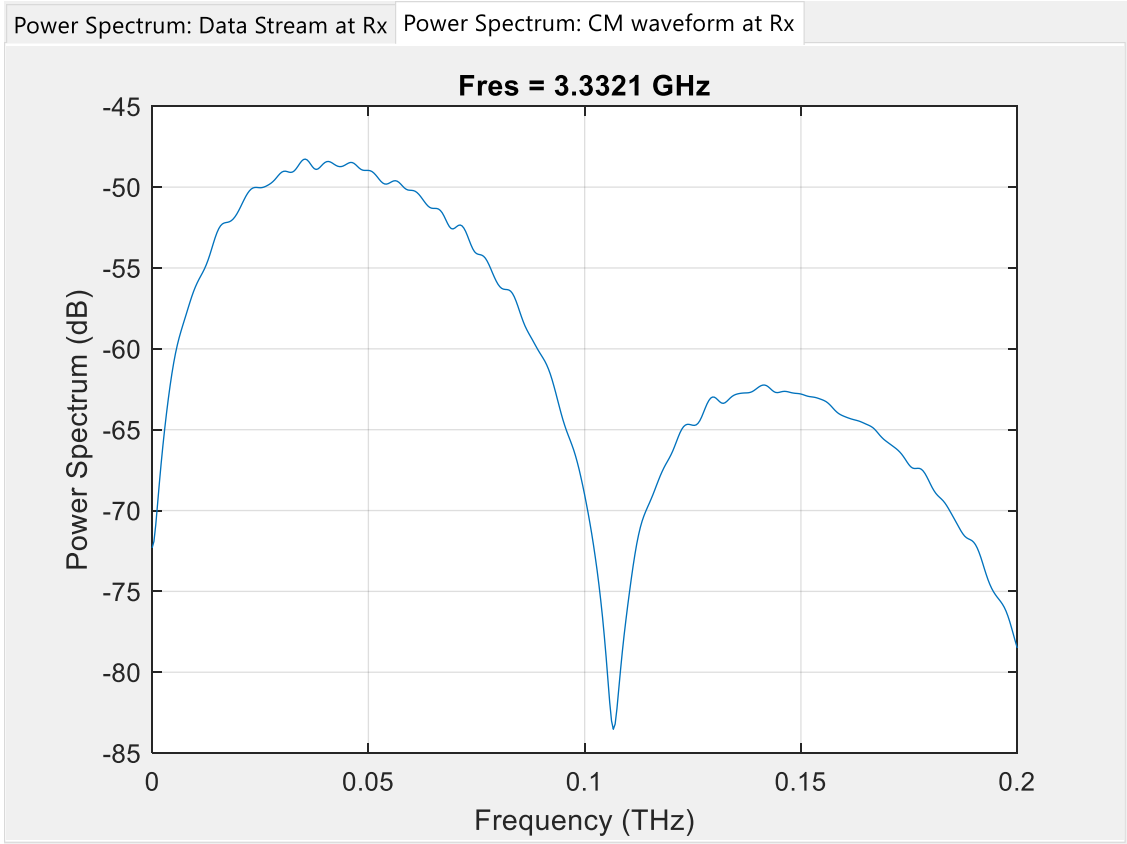


Noise PDF does not look Gaussian

PSD from 3.7 ps skew at TP0

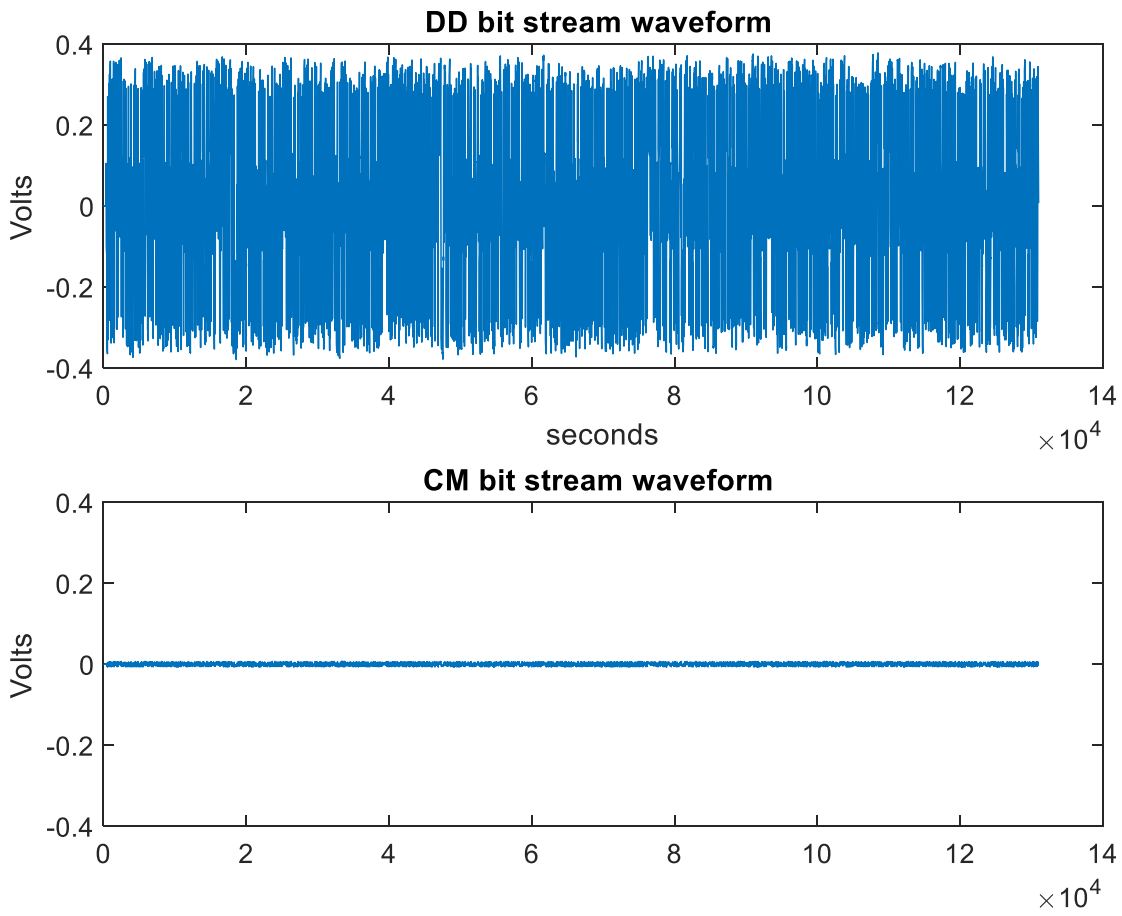


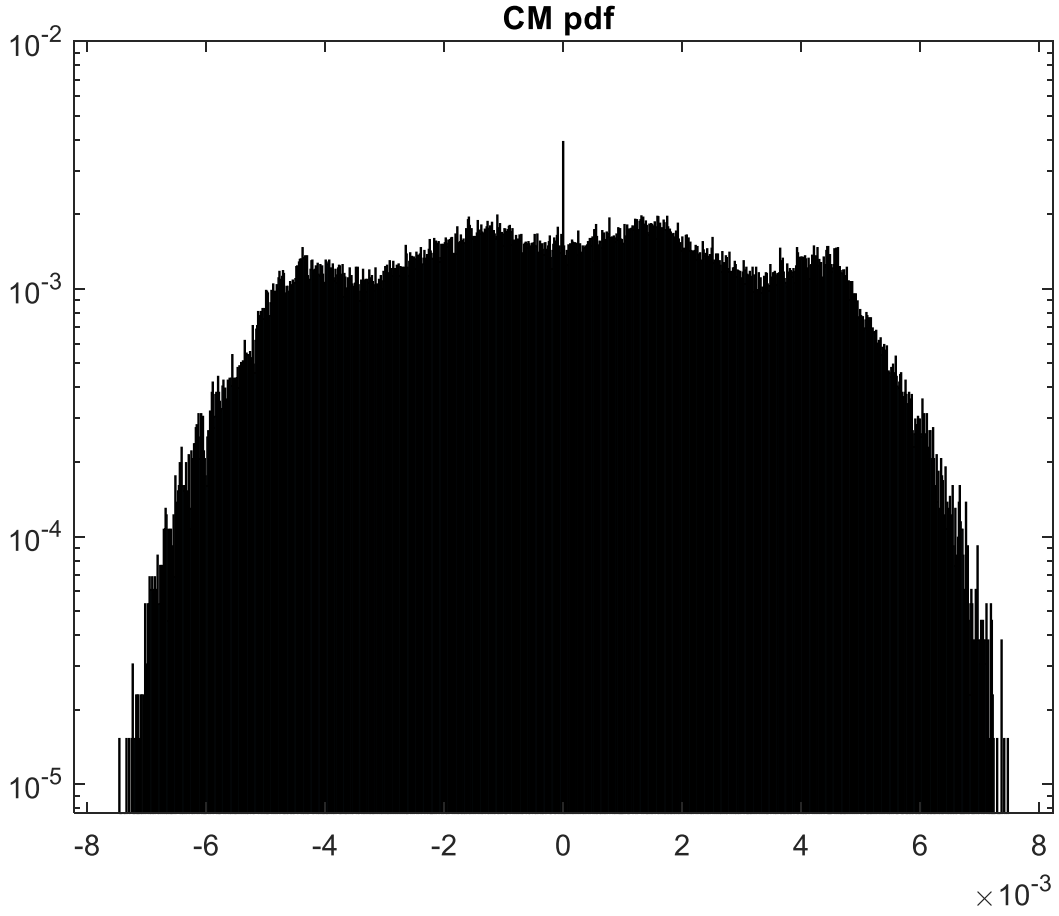
Data Stream PSD



CM waveform PSD

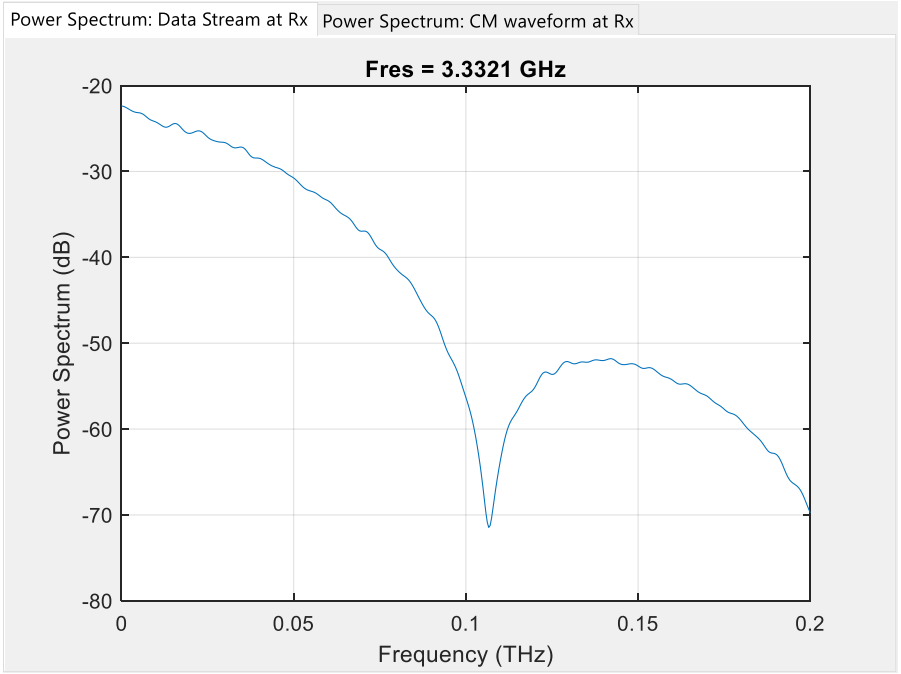
Introduce 10 % p-n package components variation at TP0



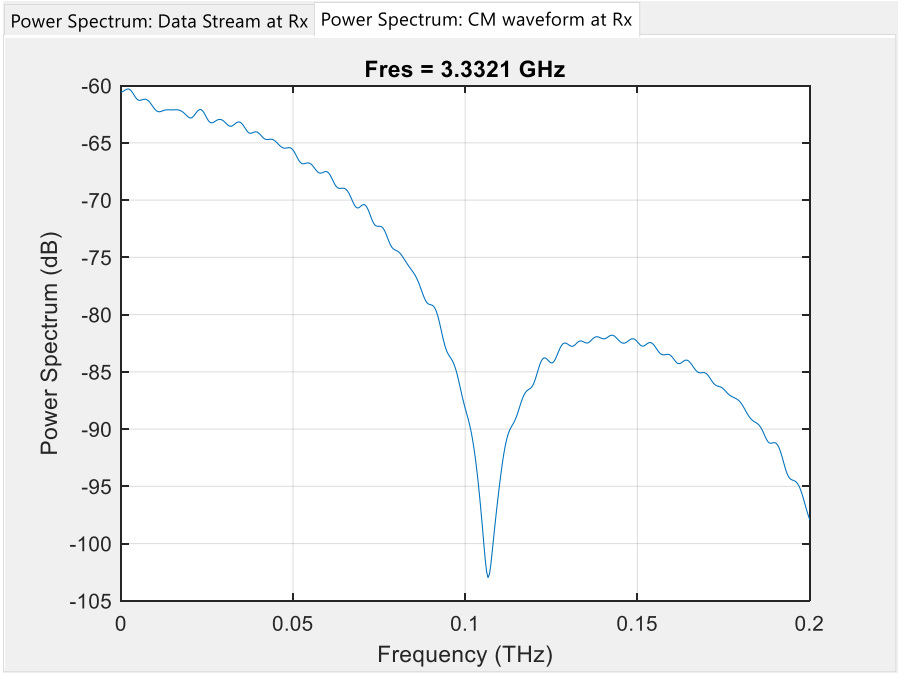


Not as much as might be expected

PSD from 10 % p-n package components variation at TP0

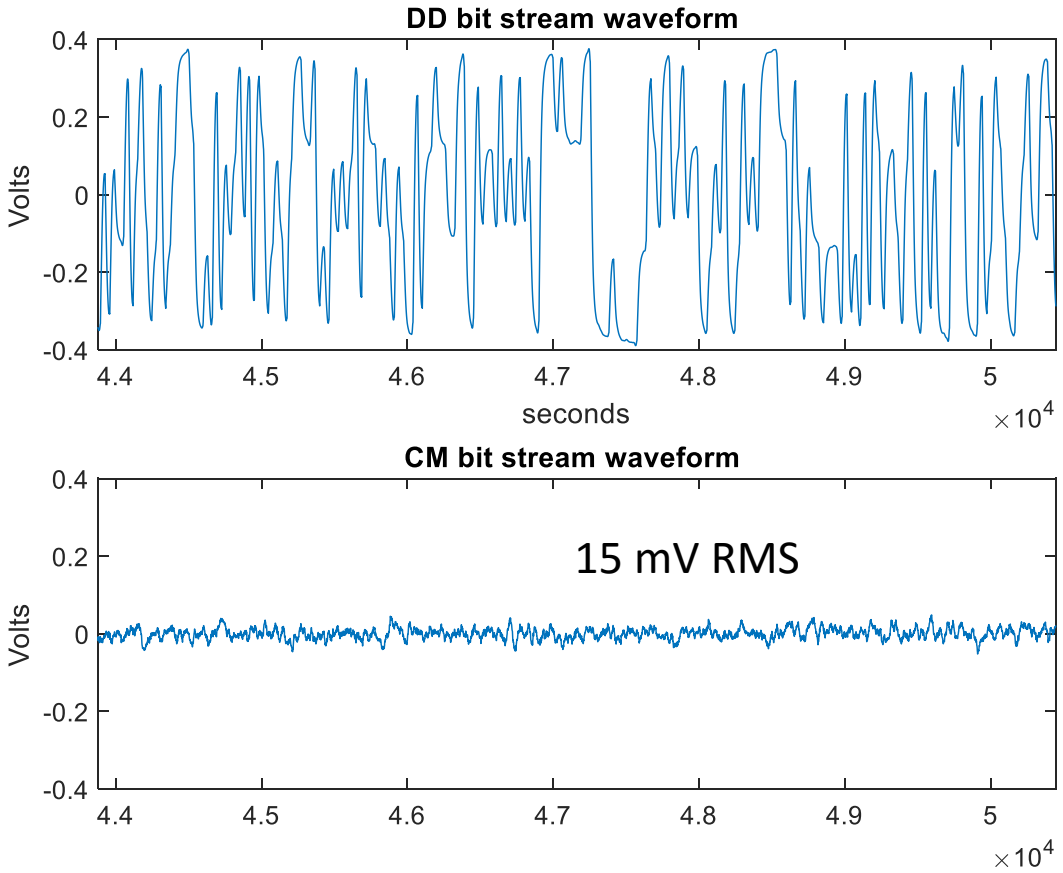


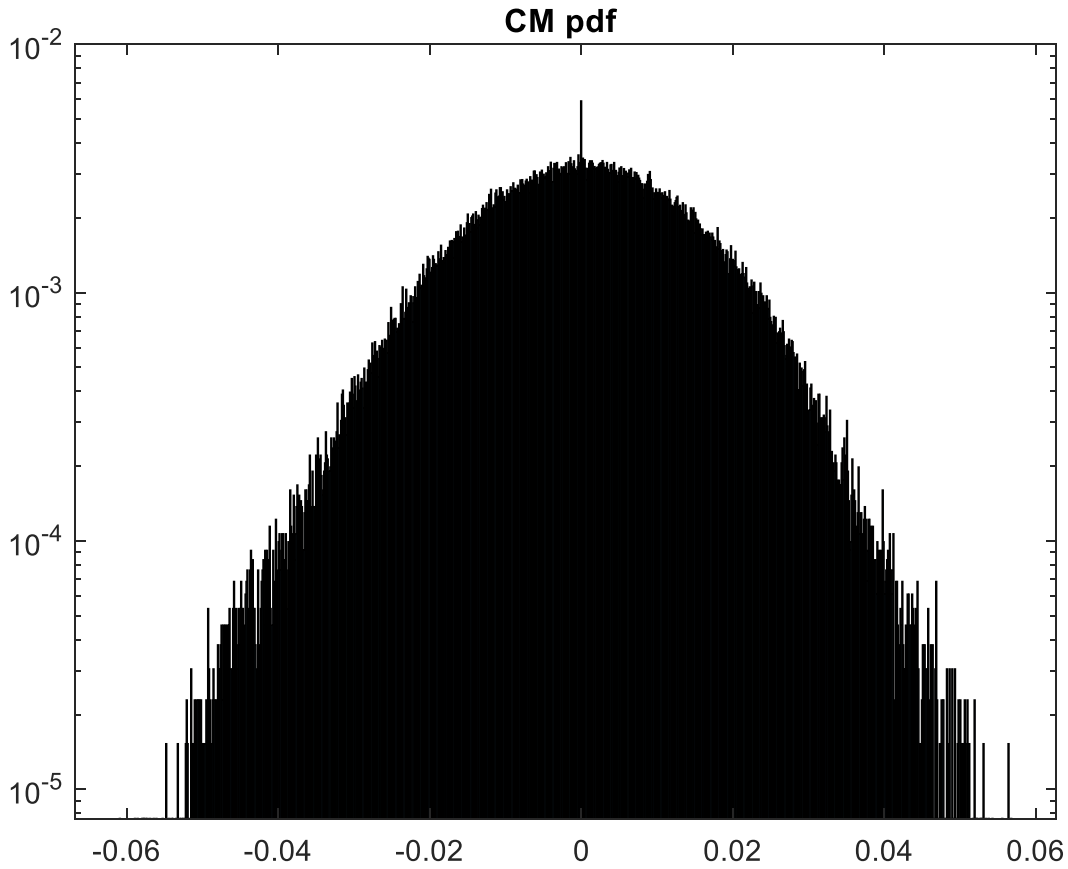
CM waveform PSD



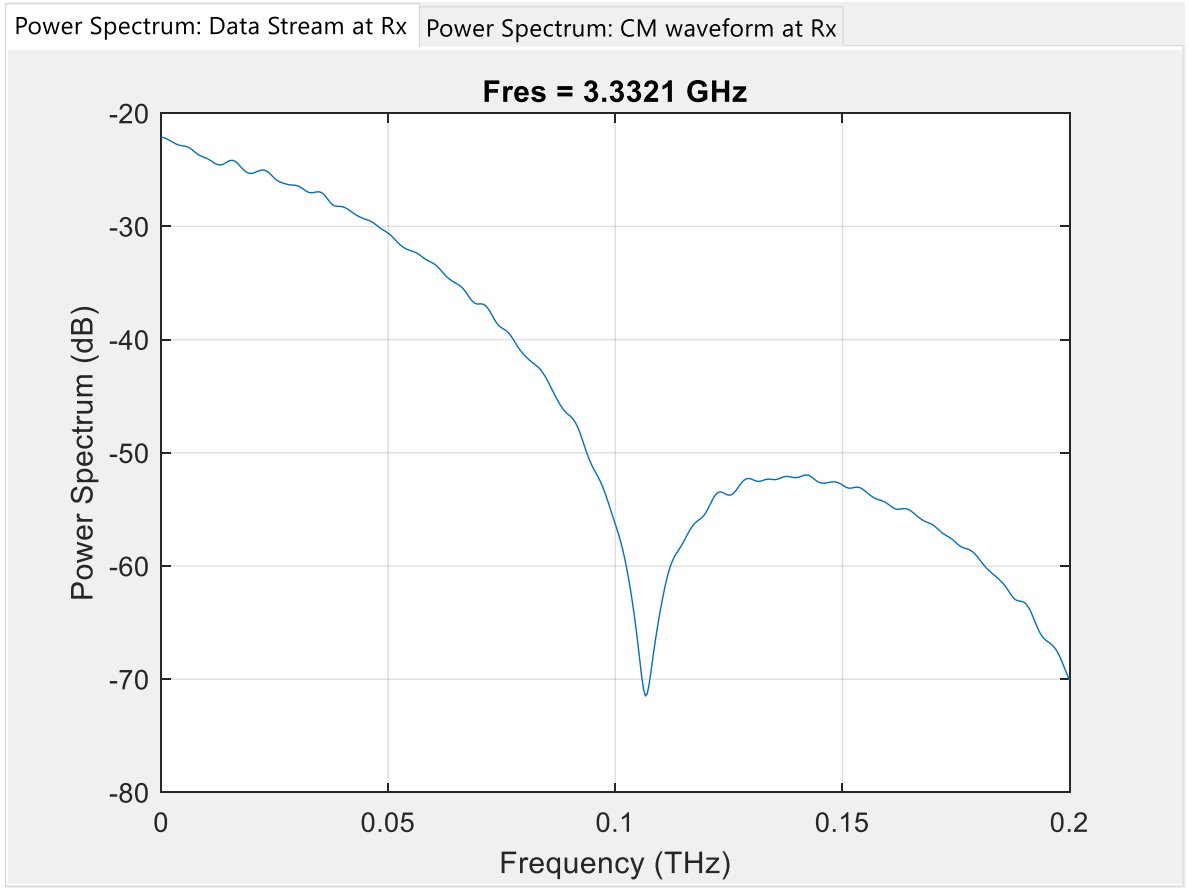
Data Stream PSD

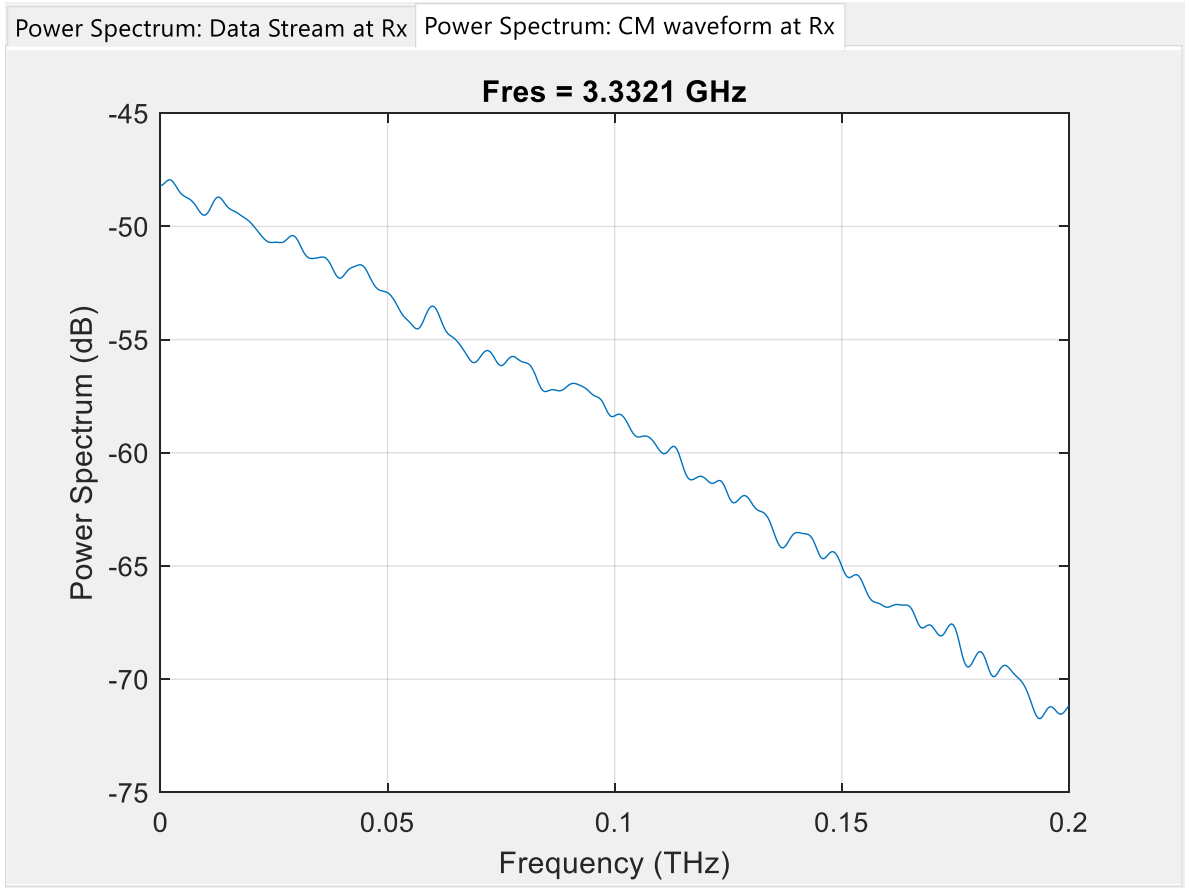
15 AC CM RMS at TP0 (Broad Band AWGN Source)





PSD from 15 AC CM RMS at TP0

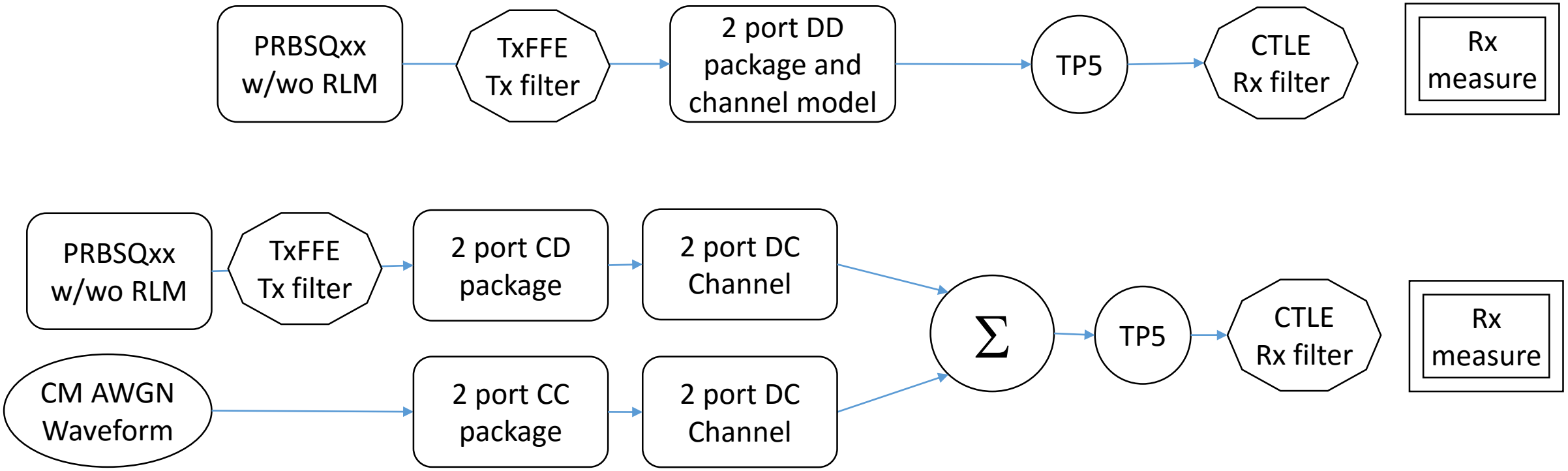




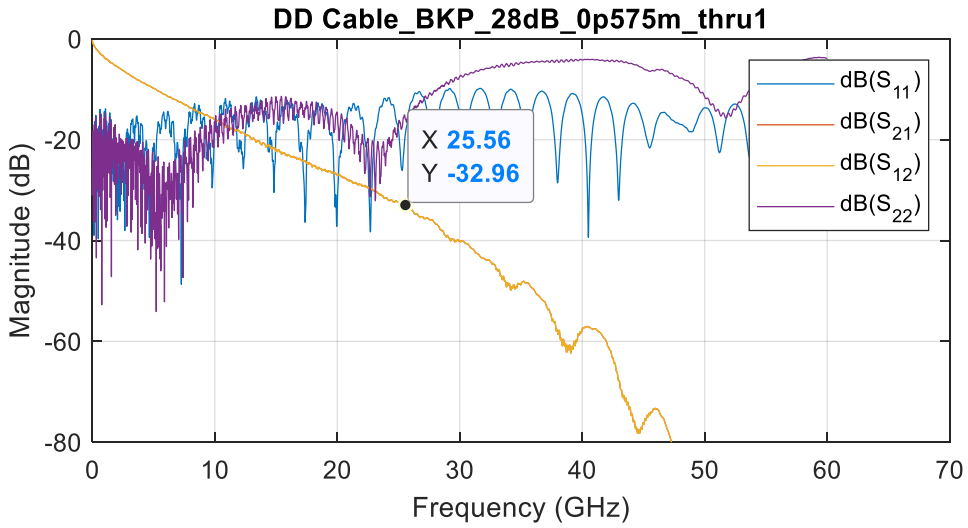
Now let's looks a channel simulation

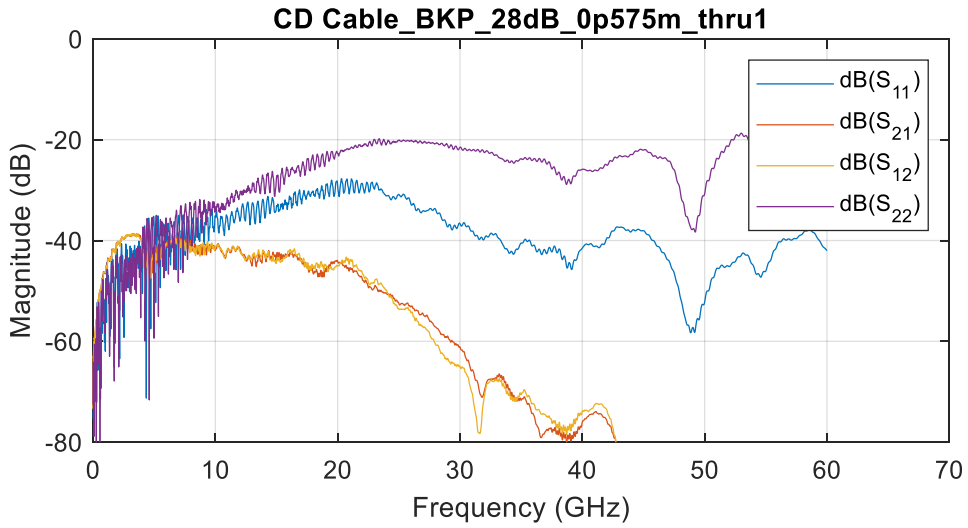
- ❑ Looking at Rx w/o Rx package
- ❑ No Jitter
- ❑ No Noise
- ❑ No DFE

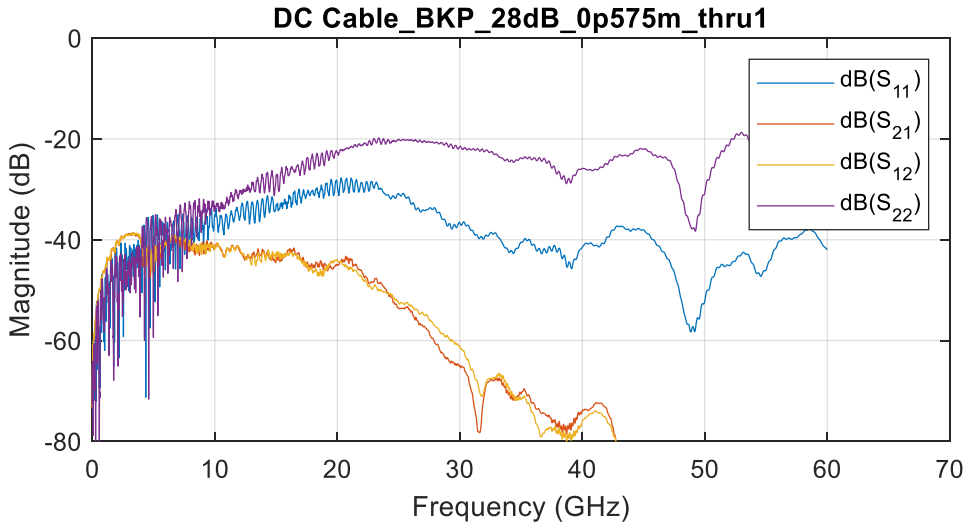
Simulation estimate of differential noise from common mode at receiver

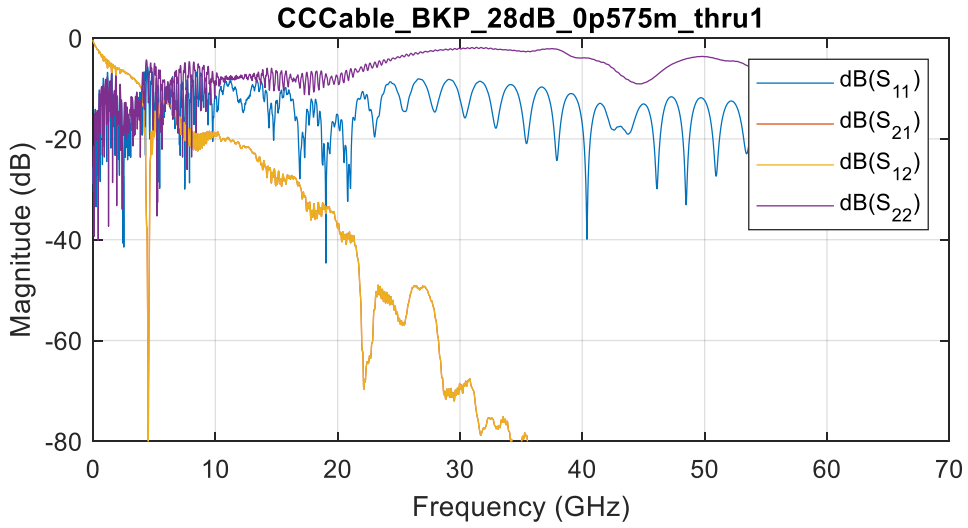


Use a 28 dB channel Plus a Tx package

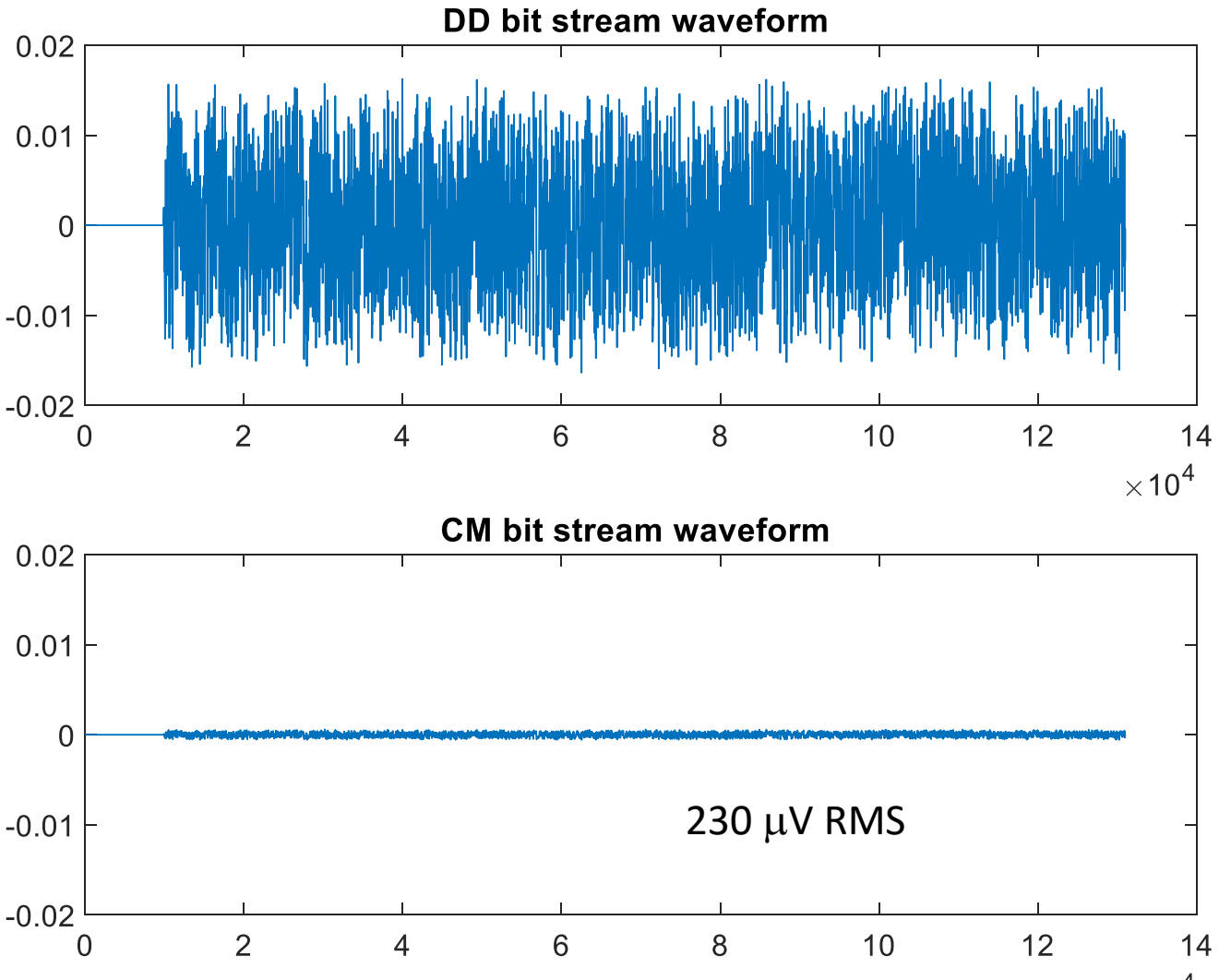


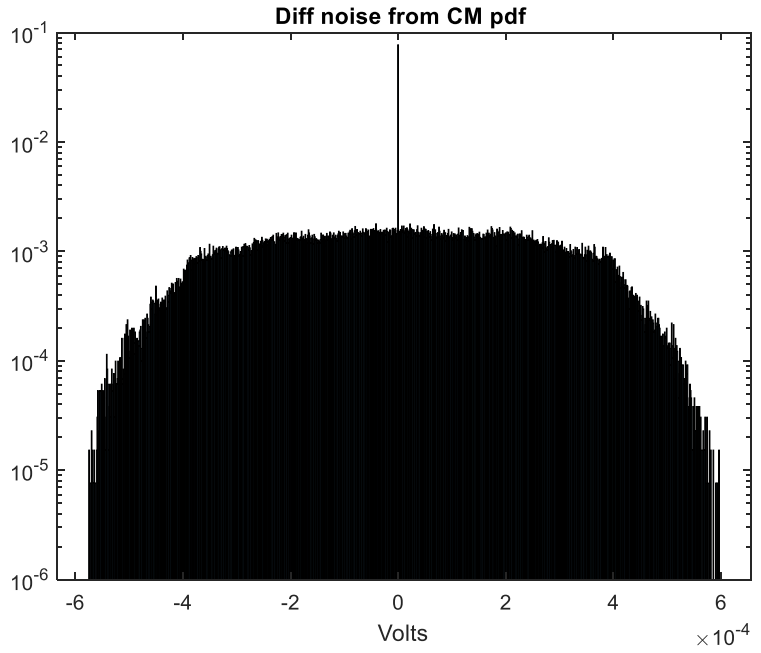




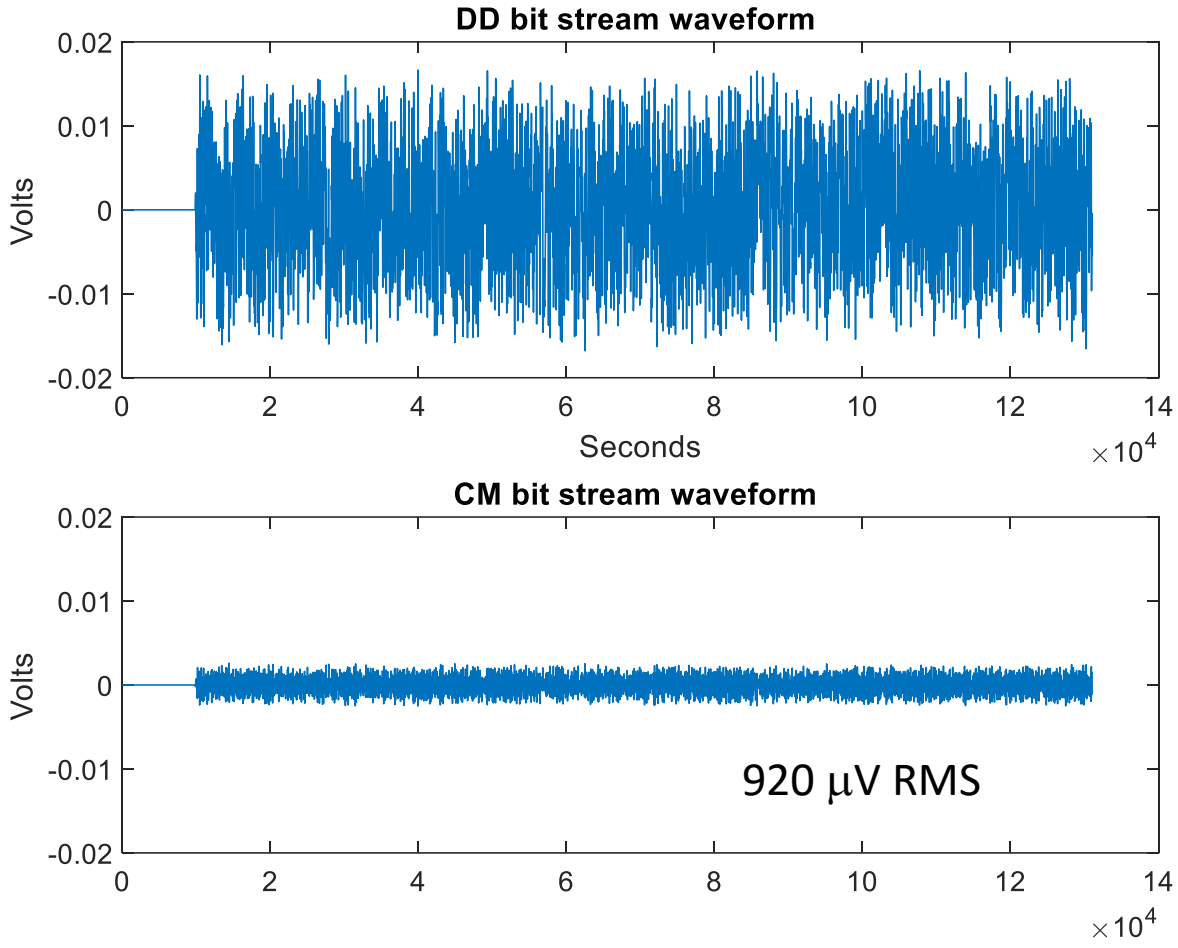


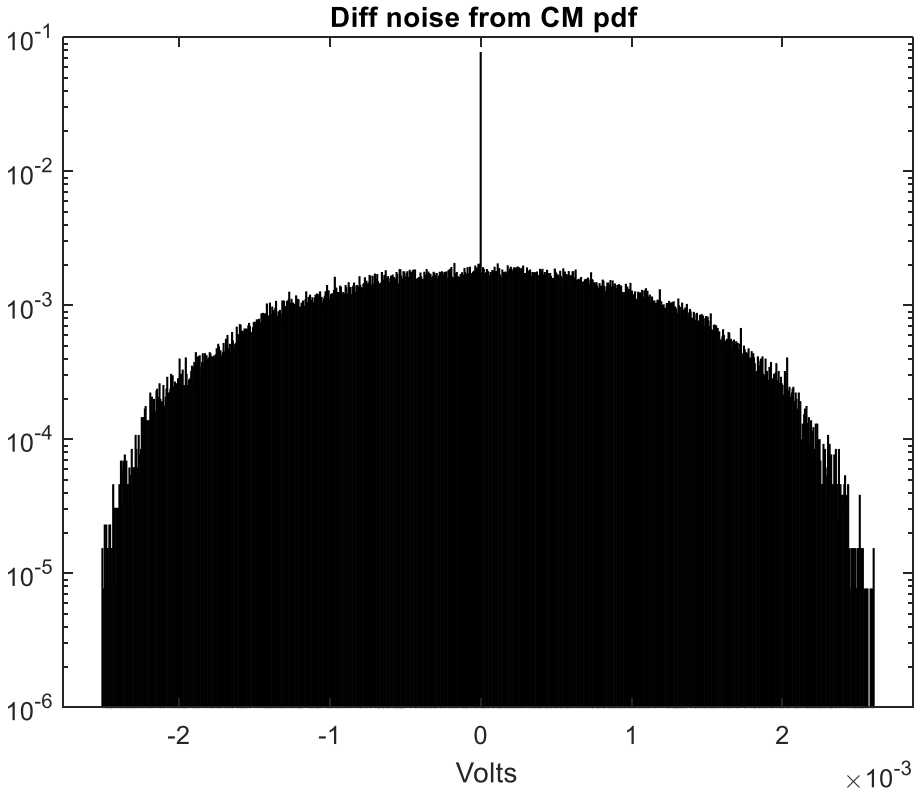
10 % p-n package components variation at Rx



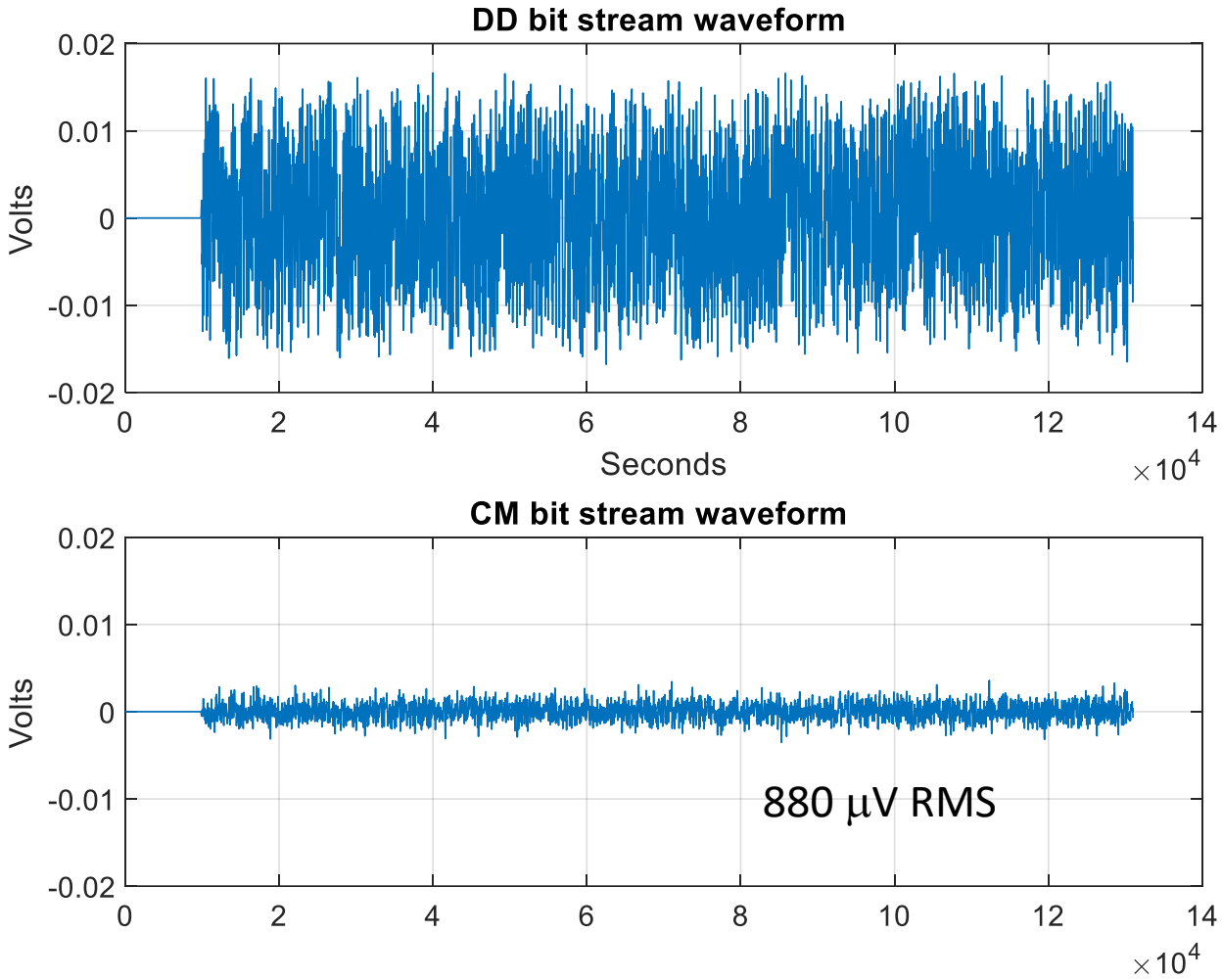


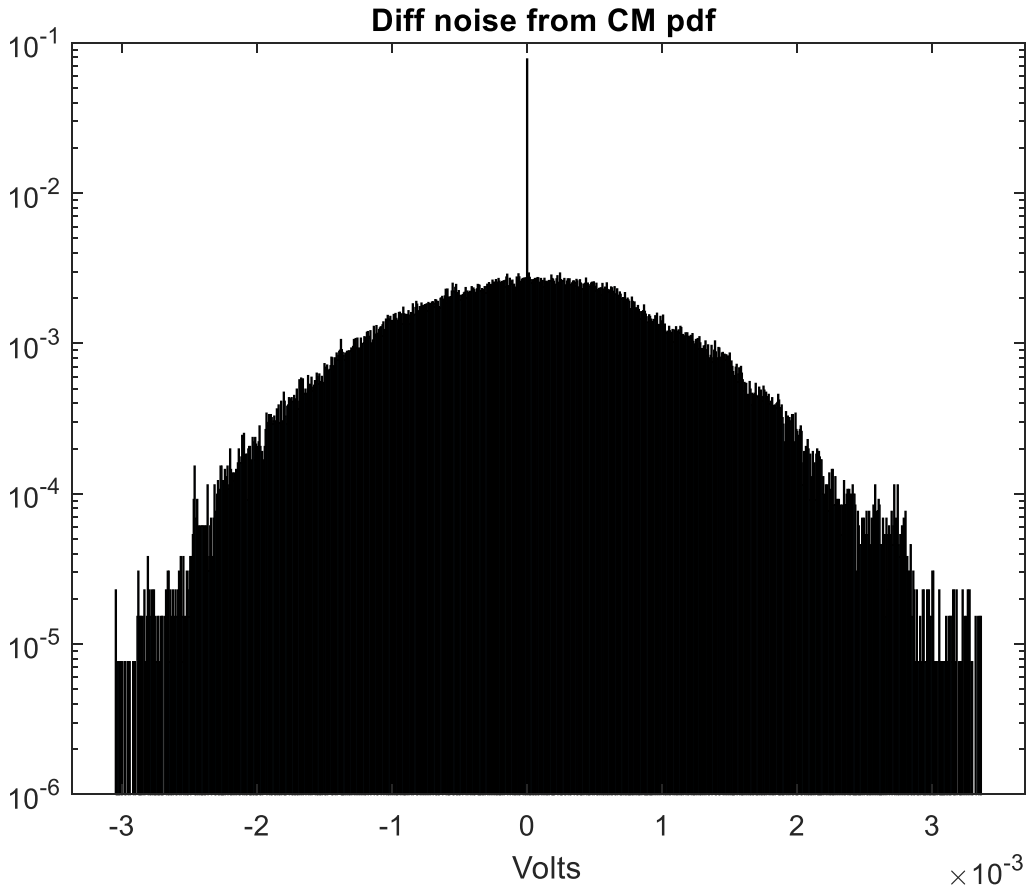
3.7 ps p-n skew


DD bit stream waveform
Volts
Seconds
$\times 10^4$
CM bit stream waveform
Volts
920 µV RMS
$\times 10^4$

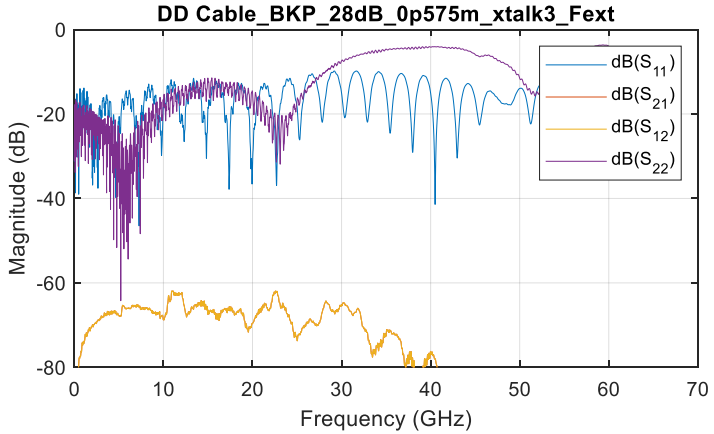

Diff noise from CM pdf
Volts
$\times 10^{-3}$

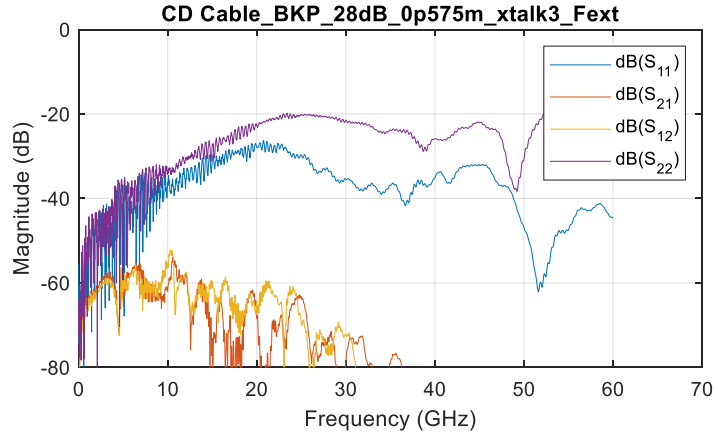
Noise at Rx with 15 AC CM RMS at TP0 (Broad Band AWGN Source)

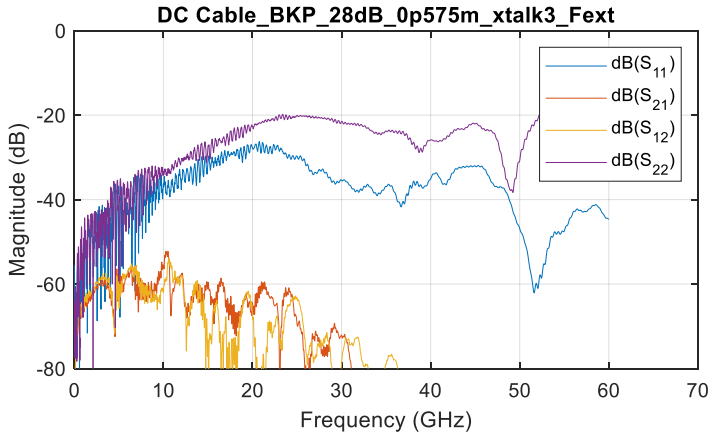


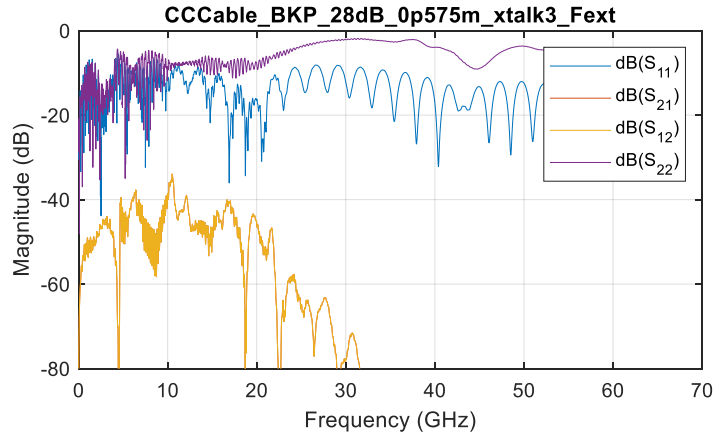


Now let’s look at 1 crosstalk file for the 28 dB channel

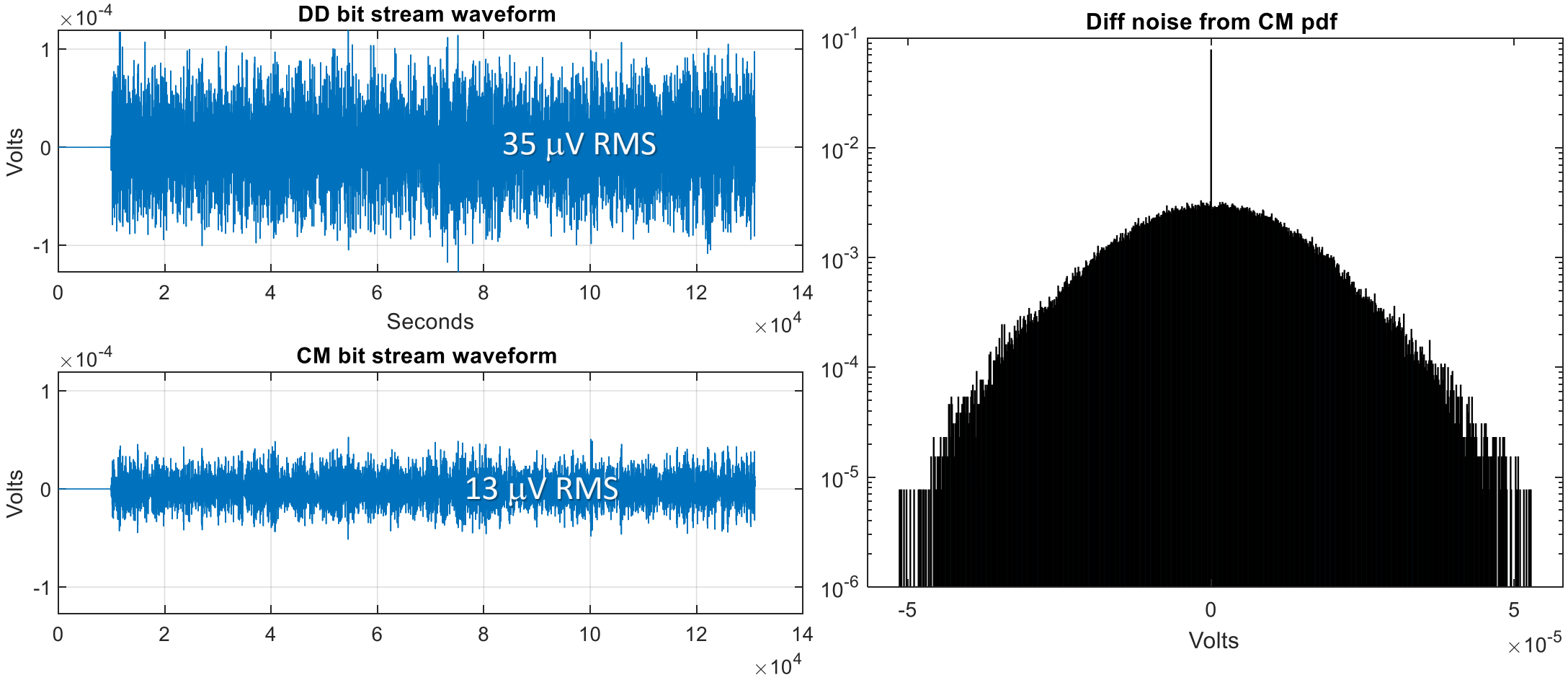








Crosstalk noise compared CM cause by 3.7 ps package skew, 10 % p-n package components , and 15 mV BBN (TP0)



Actions Required

Measurement proposals

Discussion: This all boils down to what is observable

- ran_3ck_04_1020 suggests
  - Refine AC common mode measurements to separate correlated and uncorrelated components
- What could be considered
  - How small a CM voltage is reasonable?
  - Time sampled CM signal acquisition
    - What are the Attributes which are different from simulation
  - PDF of signal
    - DD or Modes
    - RMS
    - Instrument noise removal
  - Bandwidth filters
  - Pattern lock trigger or untriggered
  - New → Specify 95% confidence factor for the noise measurements.
    - This may mitigate instrument differences