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Common Mode Conundrums

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Preface

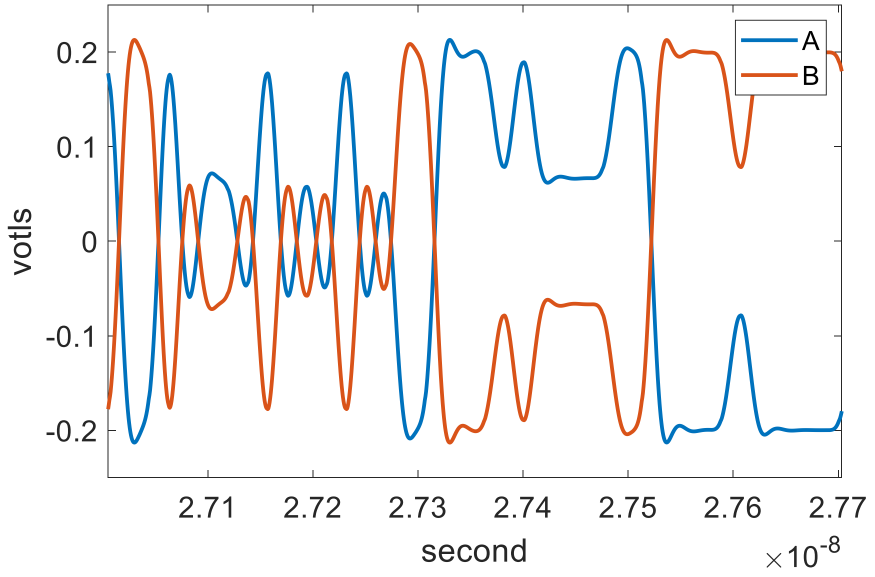
- Most of this presentation is to lend a feel for common mode issues and concerns
- The intent is to just touch on a few CM issues

Agenda

- Common Mode (CM) and Sources
- Coherency
- Modeling
- CM Package Results
- CM Channel with Package Results
- What Does the Receiver See?

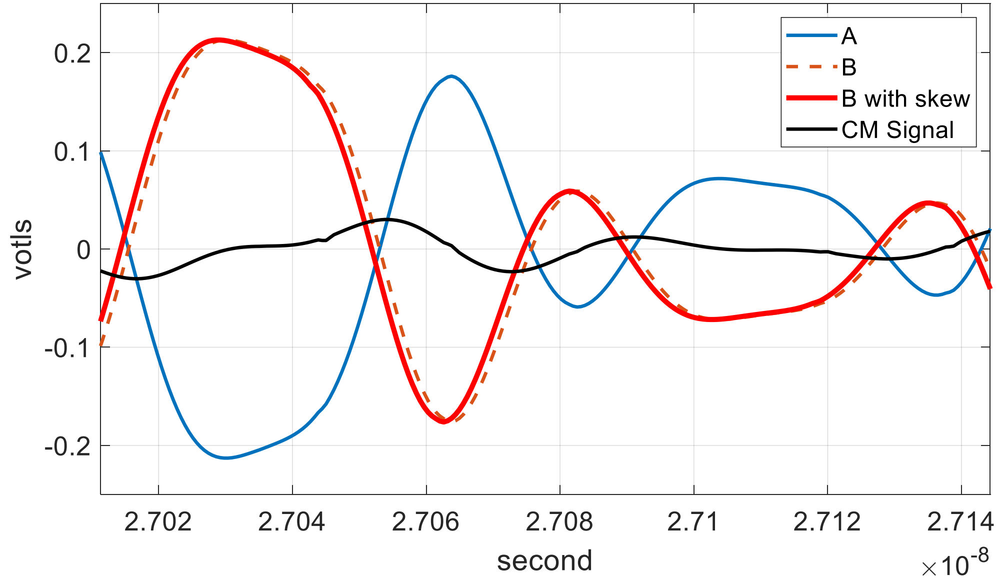
Basics

- Given 2 signal waveforms, A and B
- The differential signal = A – B
- The common mode signal = A + B
- For differential signaling
- A and B are complimentary
- If A == -B
  - Common mode signal is 0
- Basically imbalance causes common mode



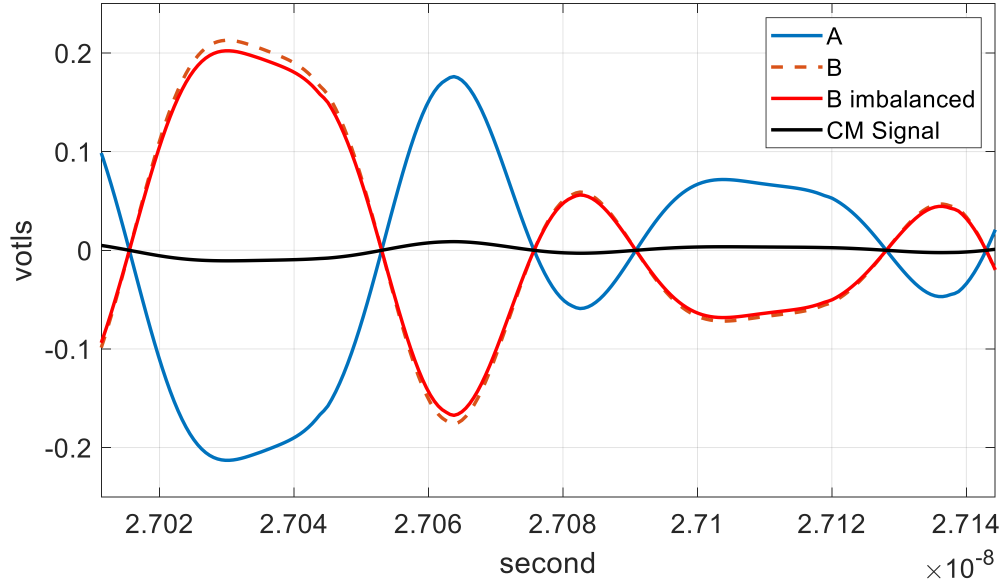
Coherent Sources of Common Mode (CM)

- Skew



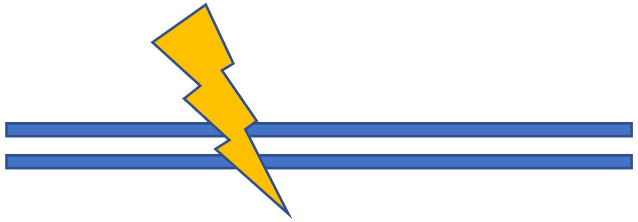
106.6 Gb/s PAM4 signaling

- Signal Imbalance

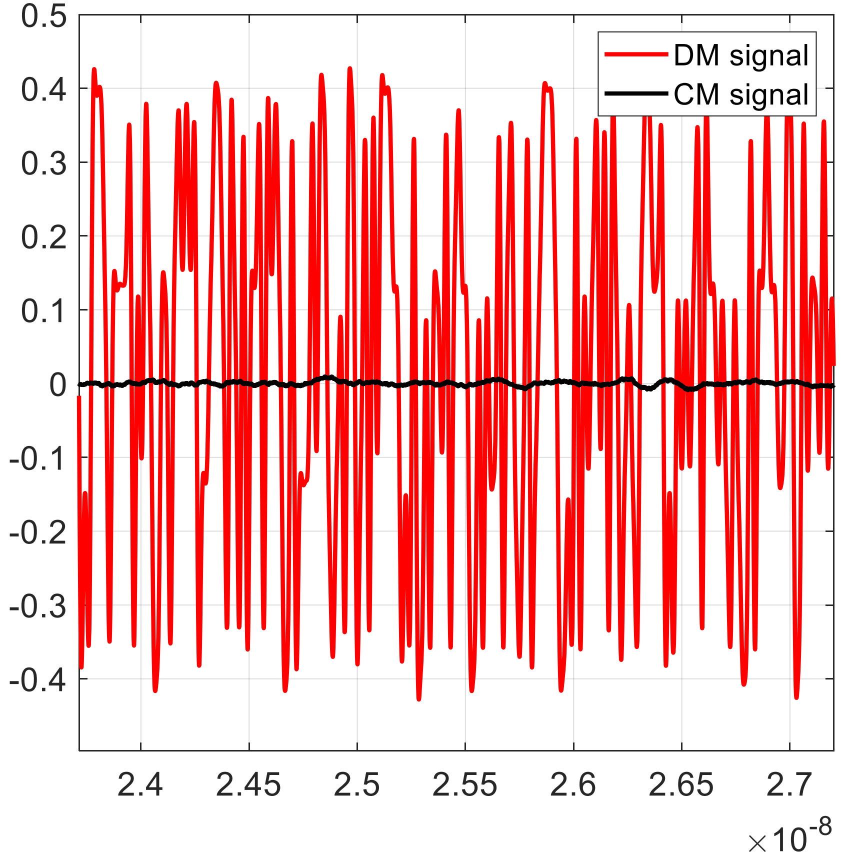


Asynchronous Sources of Common Mode (CM)

External Noise

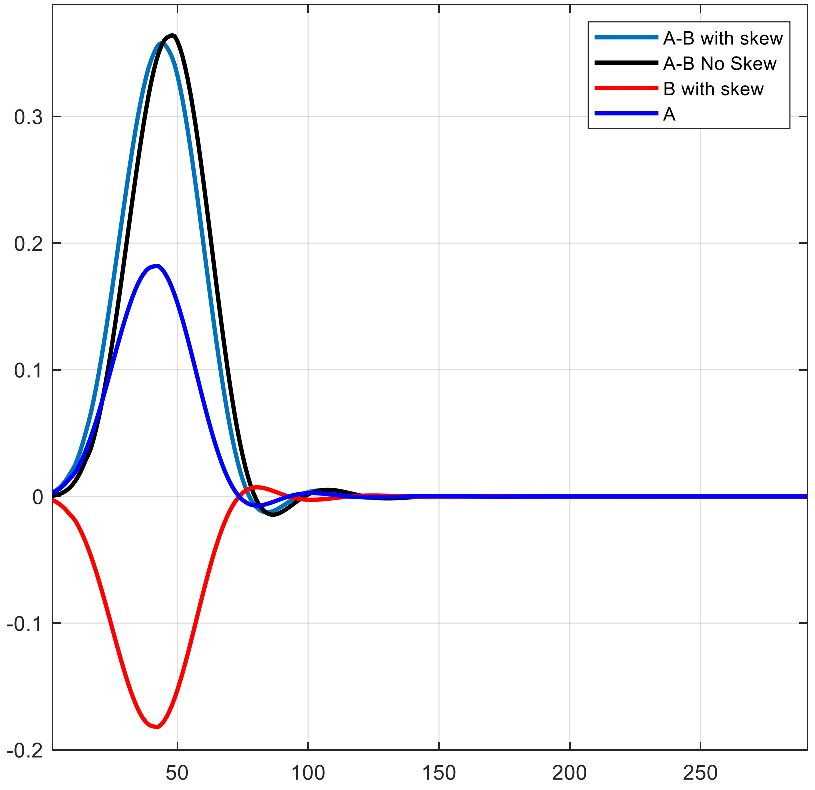


106.6 Gb/s PAM4 signaling



Coherent Common Mode Noise

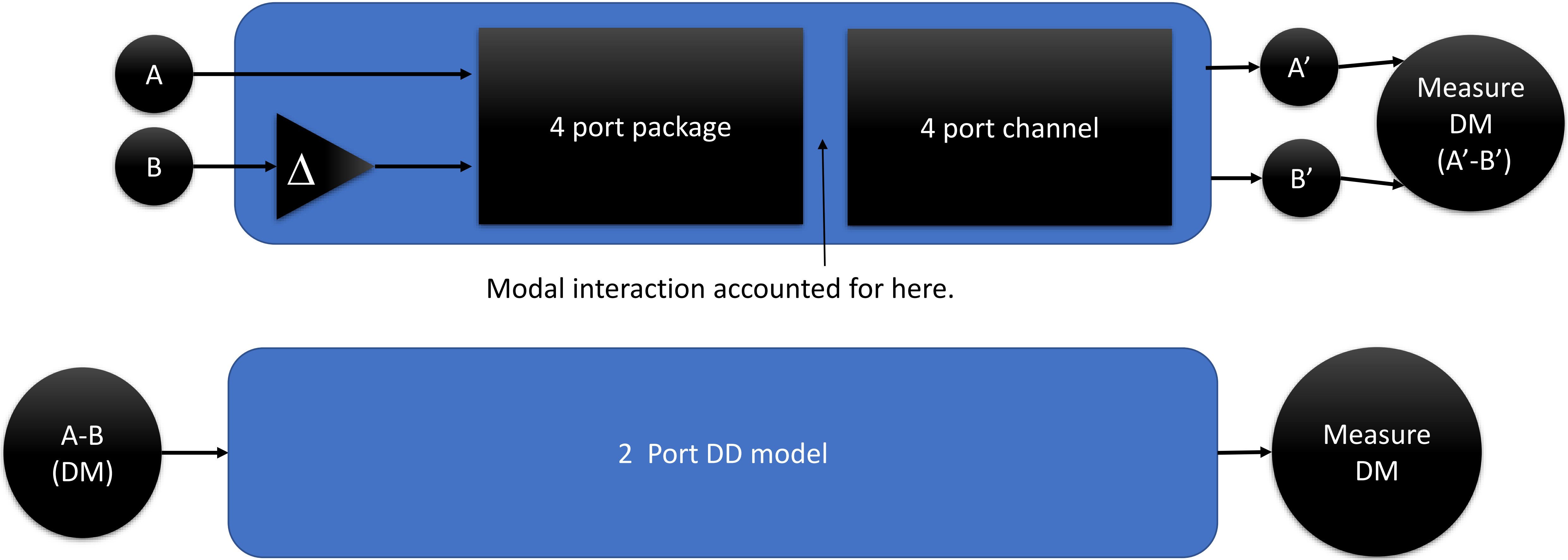
- The impairments are included in the differential signal
- The pulse response indicates that skew widens the pulse and reduce pulse height



Common Mode Modeling

- In practice there are many source of common mode
- For this work we will emulate the CM effect with s
  - Skew
  - Drive impedance imbalance
  - Broad band additive white gaussian noise (AWGN) source

Full S-parameter and DM Simulation

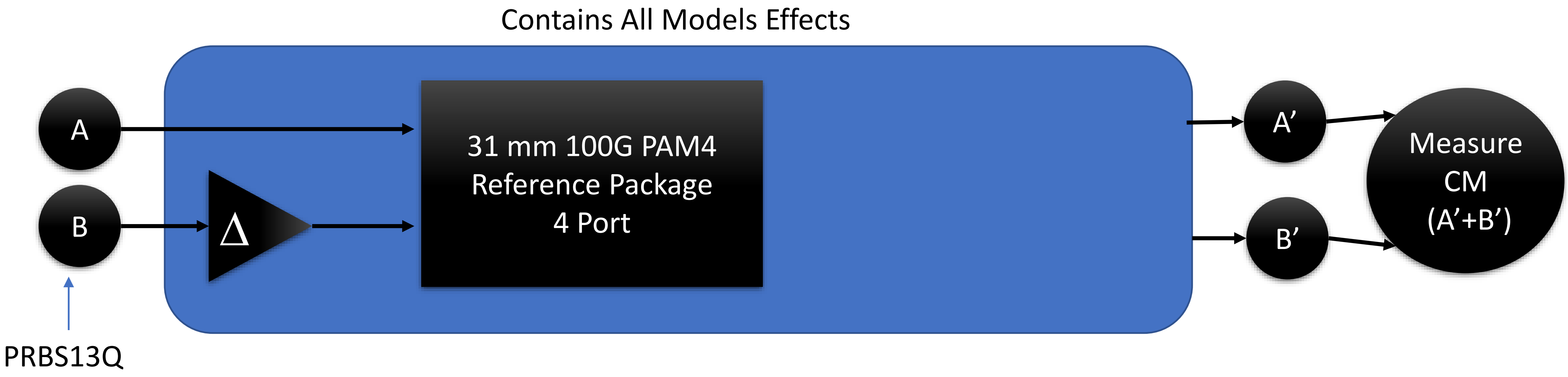


These two produce the same results.

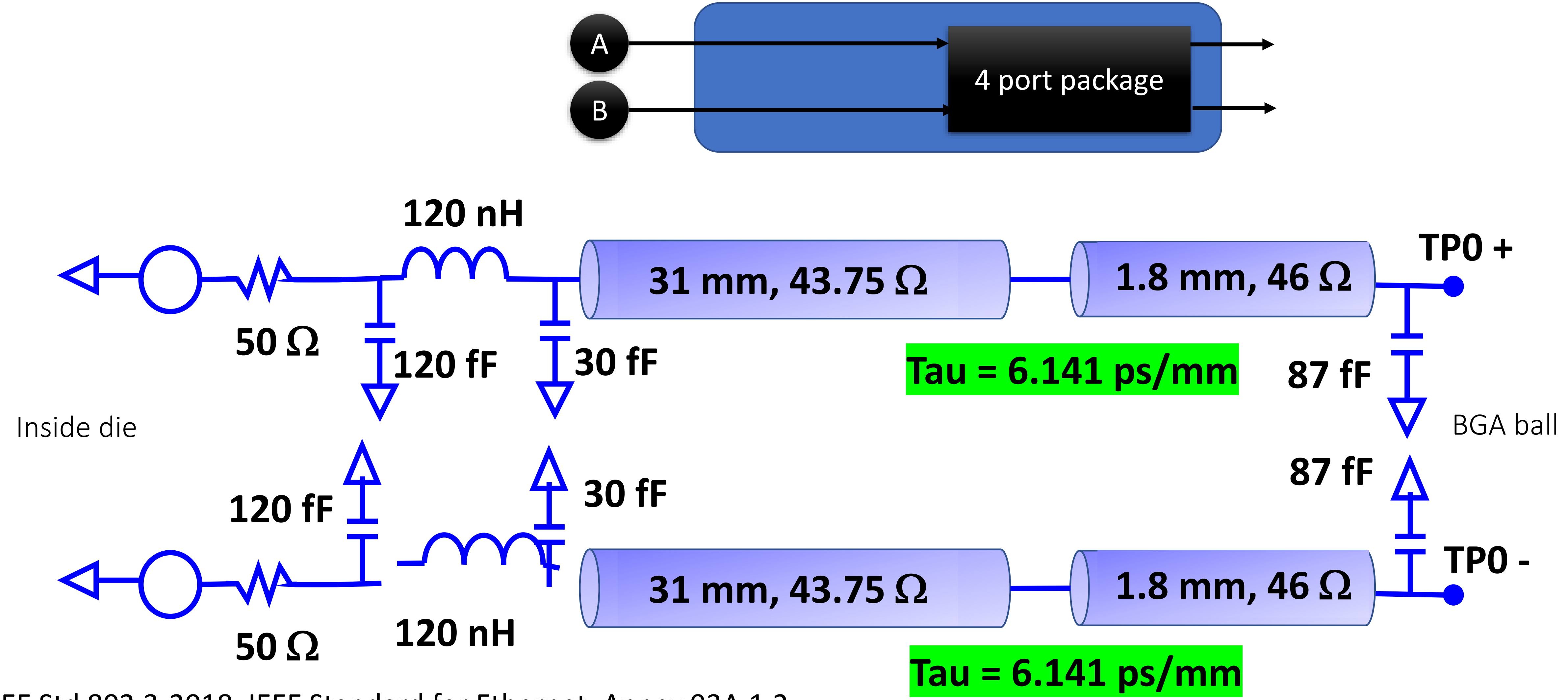
Consider Measurements at the BGA Ball of the Package

Inside Die

BGA Ball (TP0)



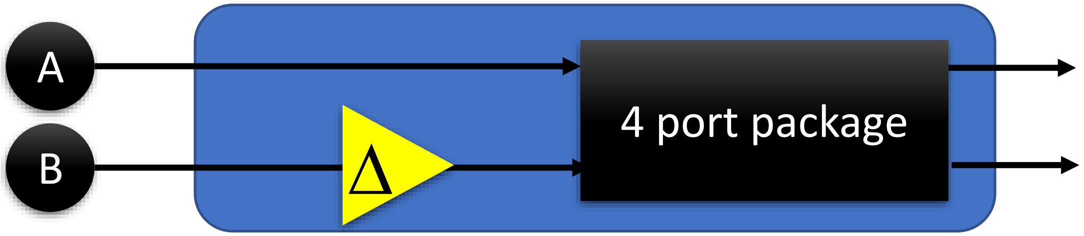
IEEE802.3ck 100G PAM 4 Reference Package

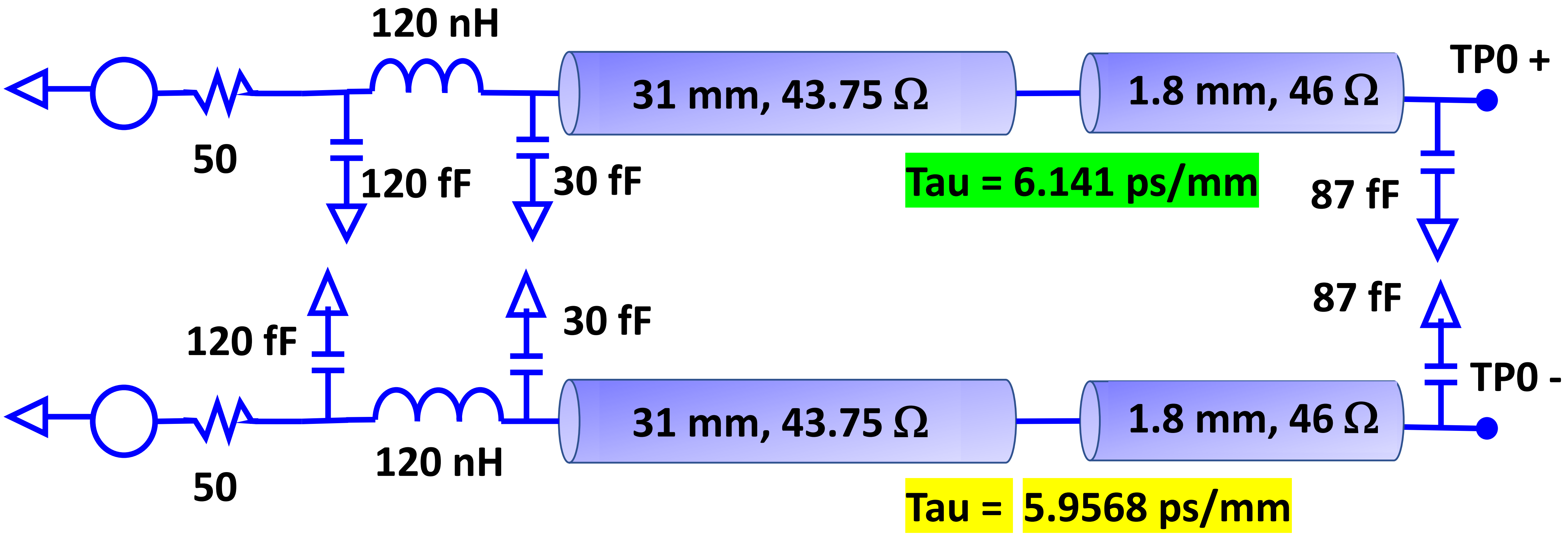


IEEE Std 802.3-2018, IEEE Standard for Ethernet, Annex 93A.1.2

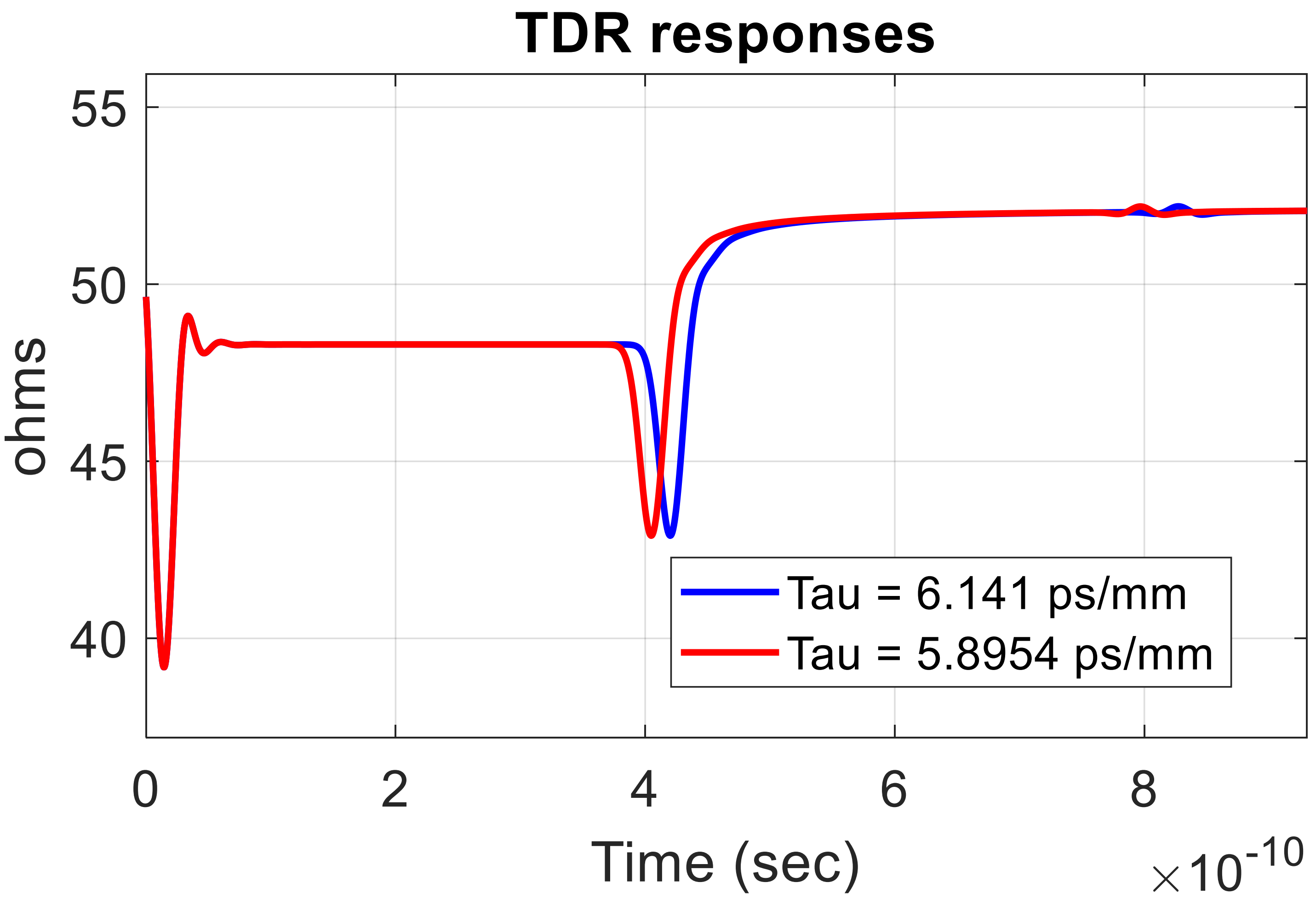
Reference Package Which Introduces Skew

Skew achieved by changing the transmission line propagation delay on one leg of the package.



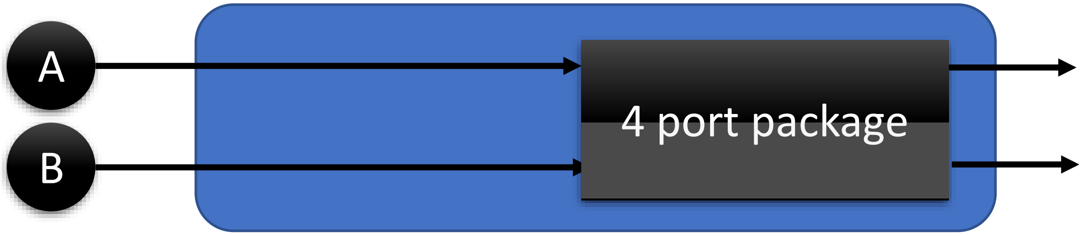


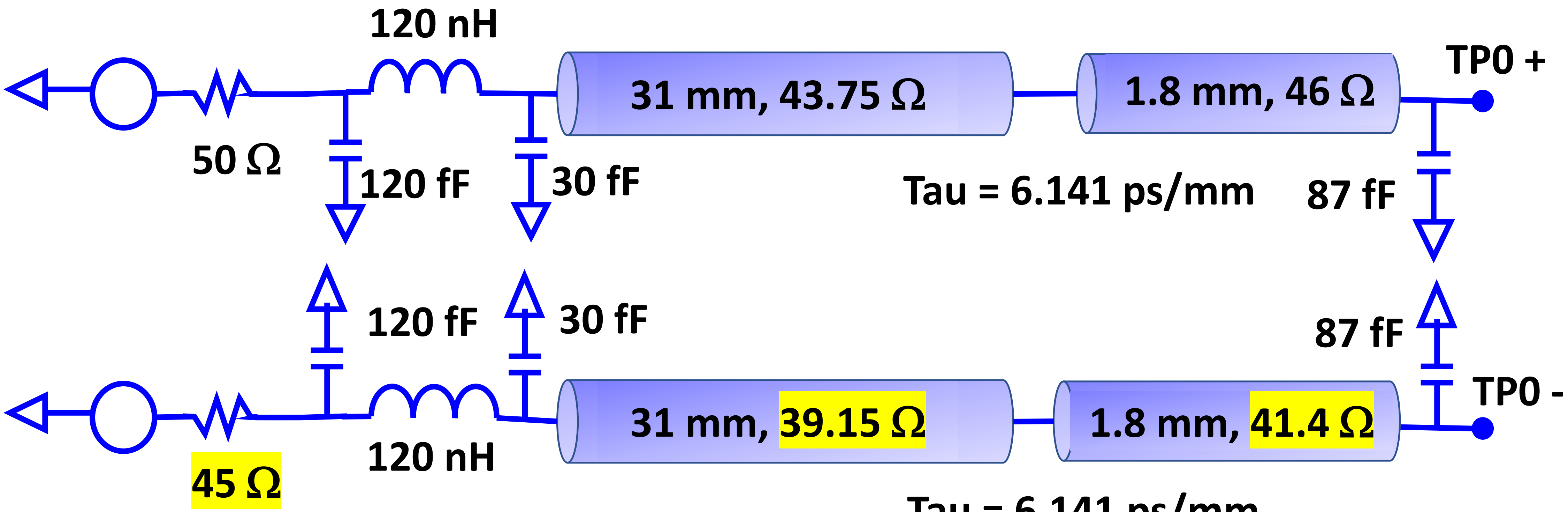
TDR (into TP0) Illustrating Skew (10ps Edge)



- Blue trace is for a leg of the standard model
- Red trace is for the leg where the propagation is faster

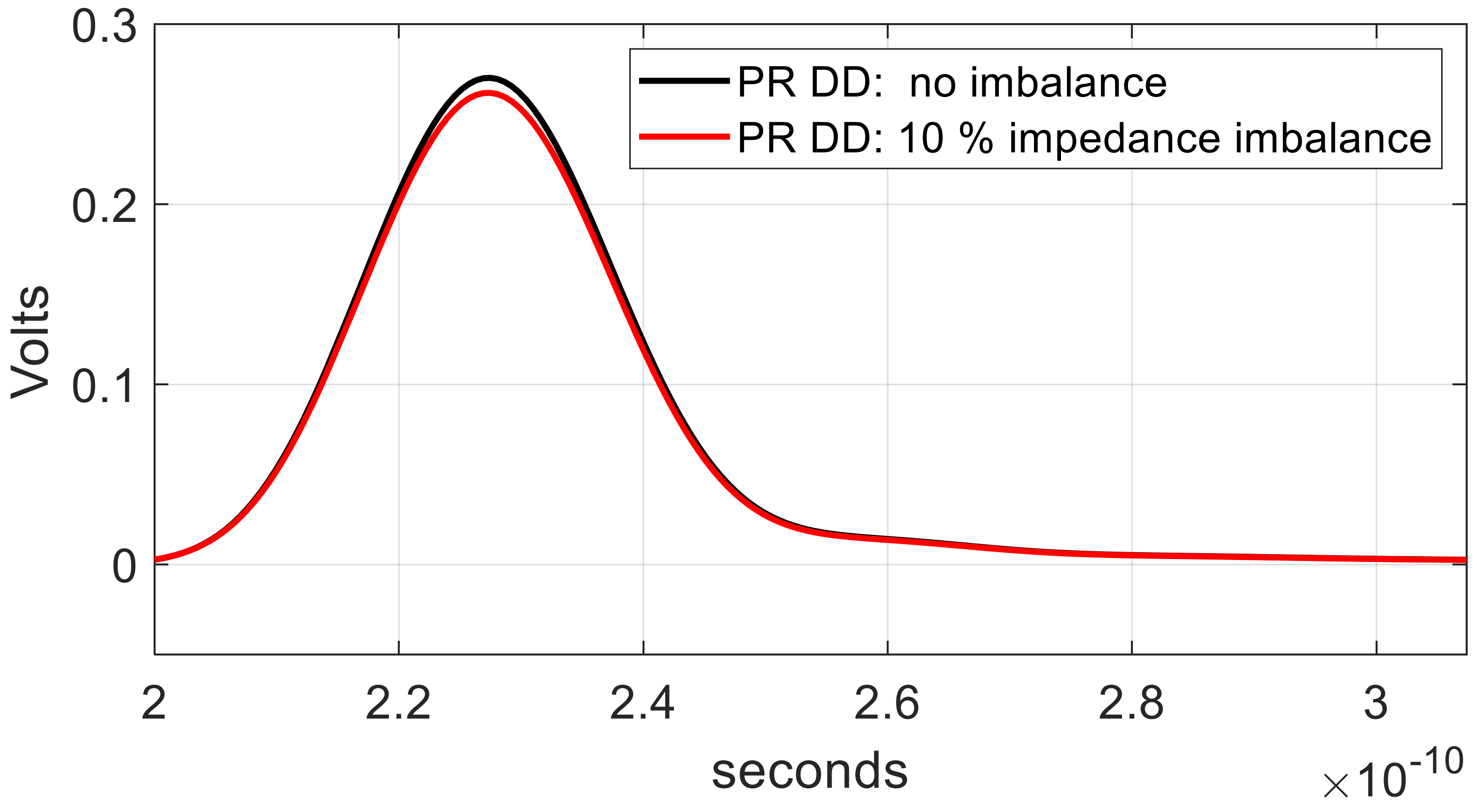
Reference Package Which Introduces Imbalance



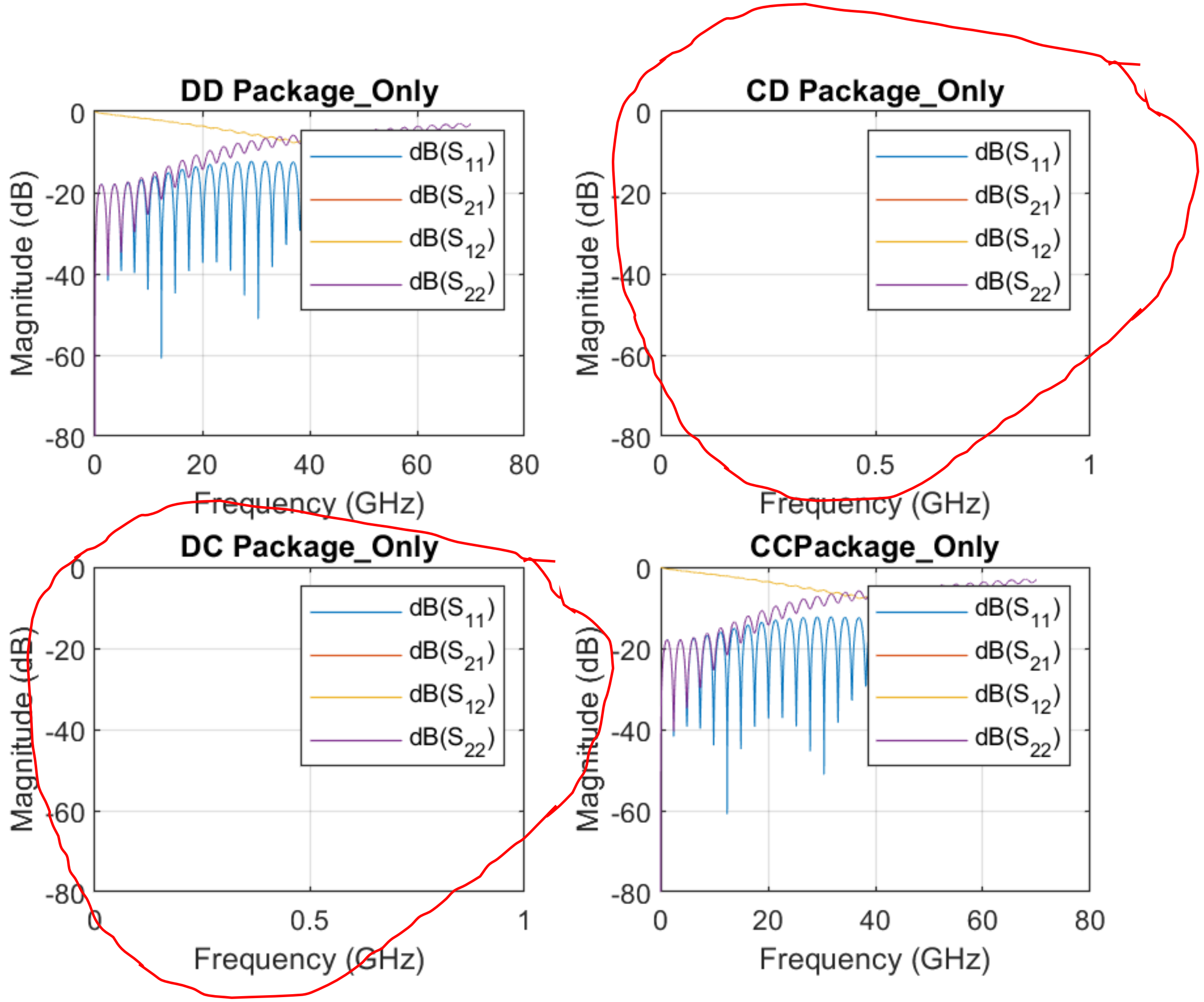


IEEE Std 802.3-2018, IEEE Standard for Ethernet, Annex 93A.1.2

Differential Pulse Response Illustrating the Effect of Introduced Imbalance



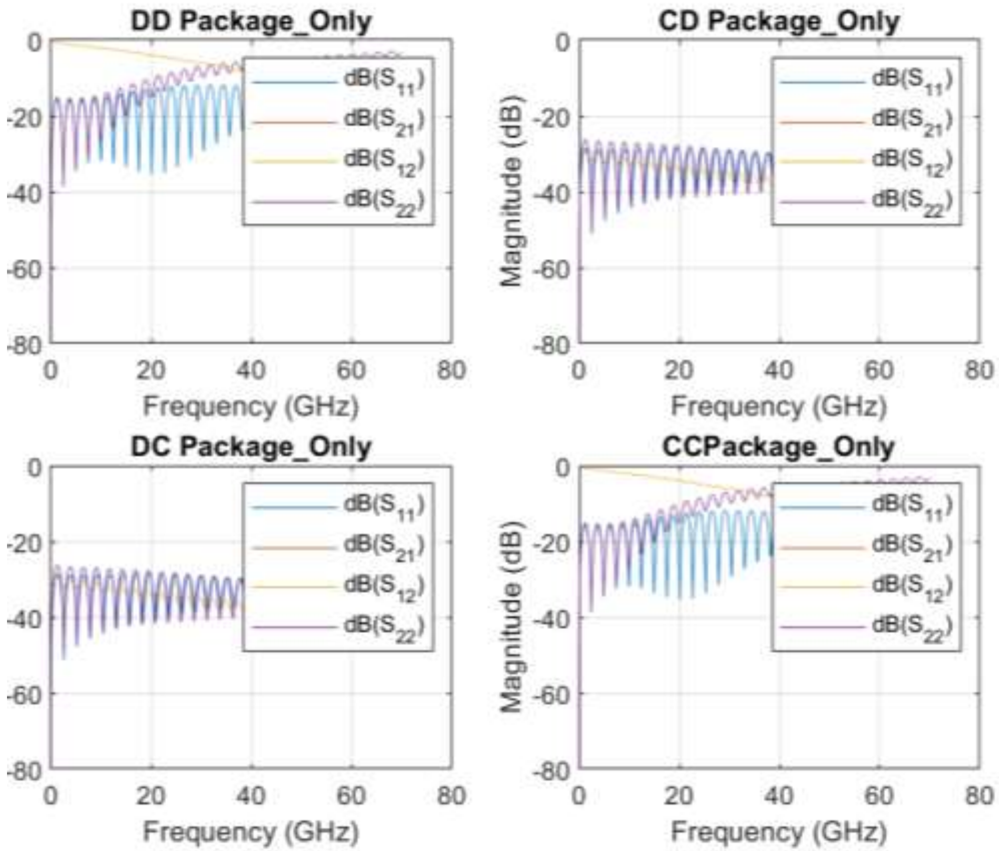
Mixed-Mode (MM) S-parameter Frequency Domain (FD) for Reference Package



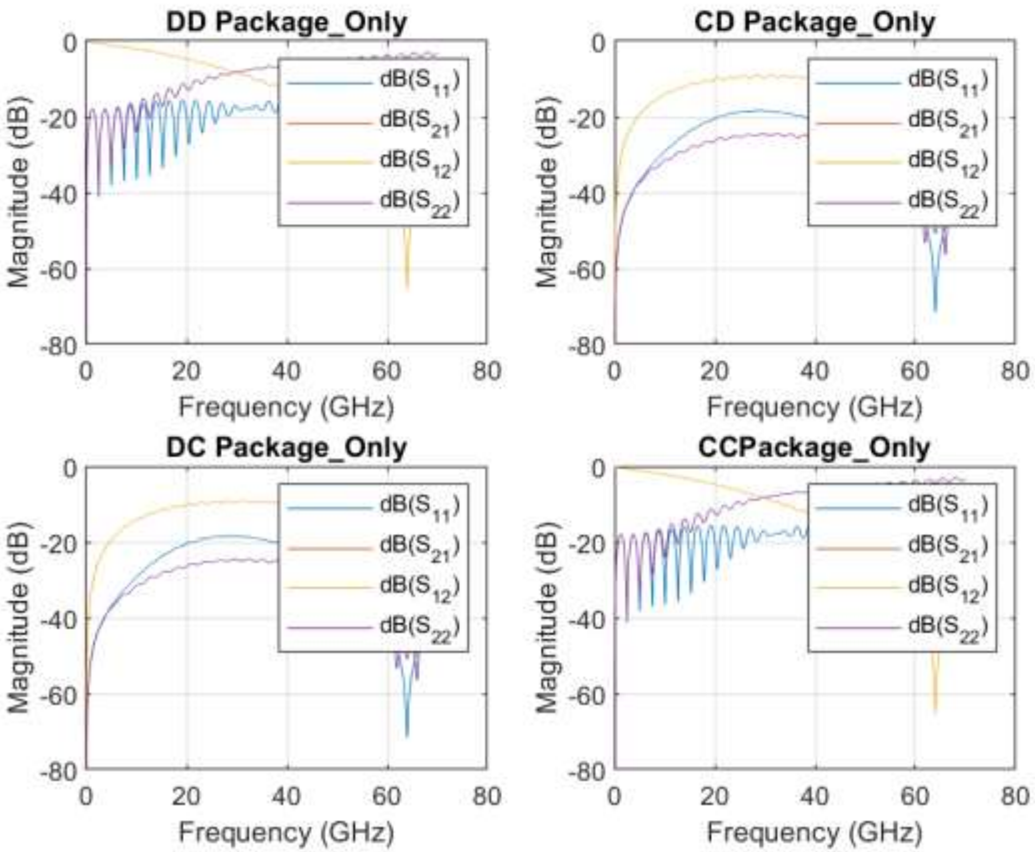
Mode conversions is expectedly missing.

Mixed-Mode (MM) S-parameters for Reference Package with Skew and Imbalance

10 % impedance imbalance

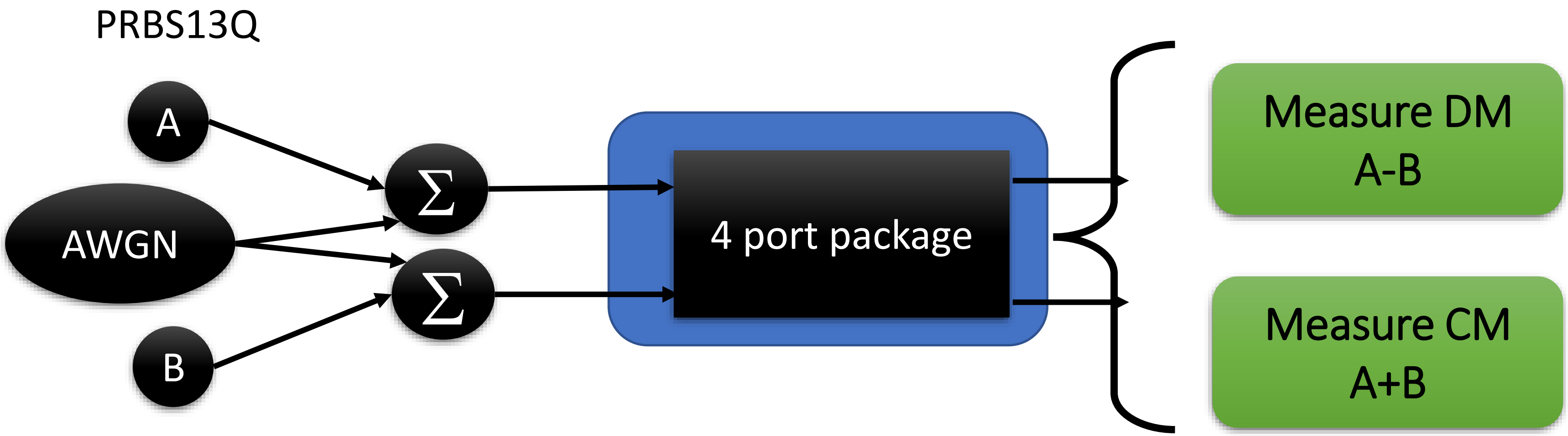


7.4 ps skew



Not intuitive which is skew and which is imbalance using MM FD plots.

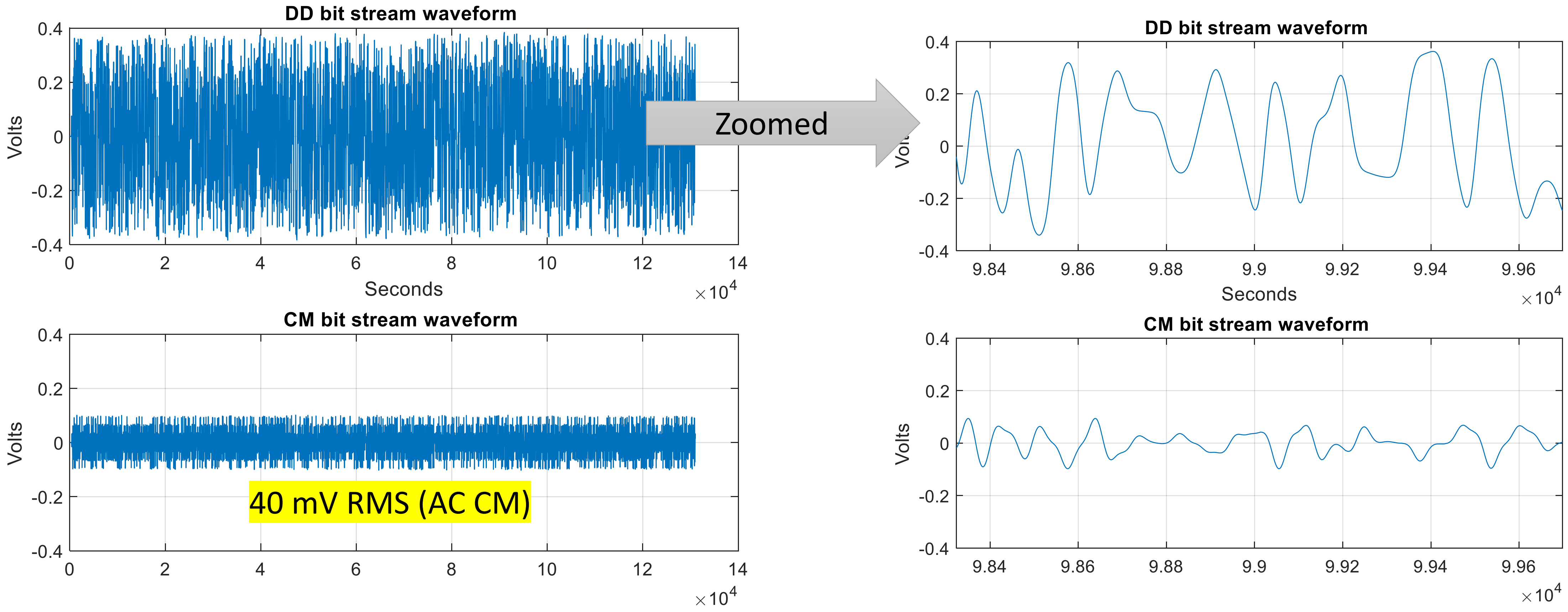
Deeper Dive into Common Mode



For Skew, Imbalance and Asynchronous CM Noise, examine:

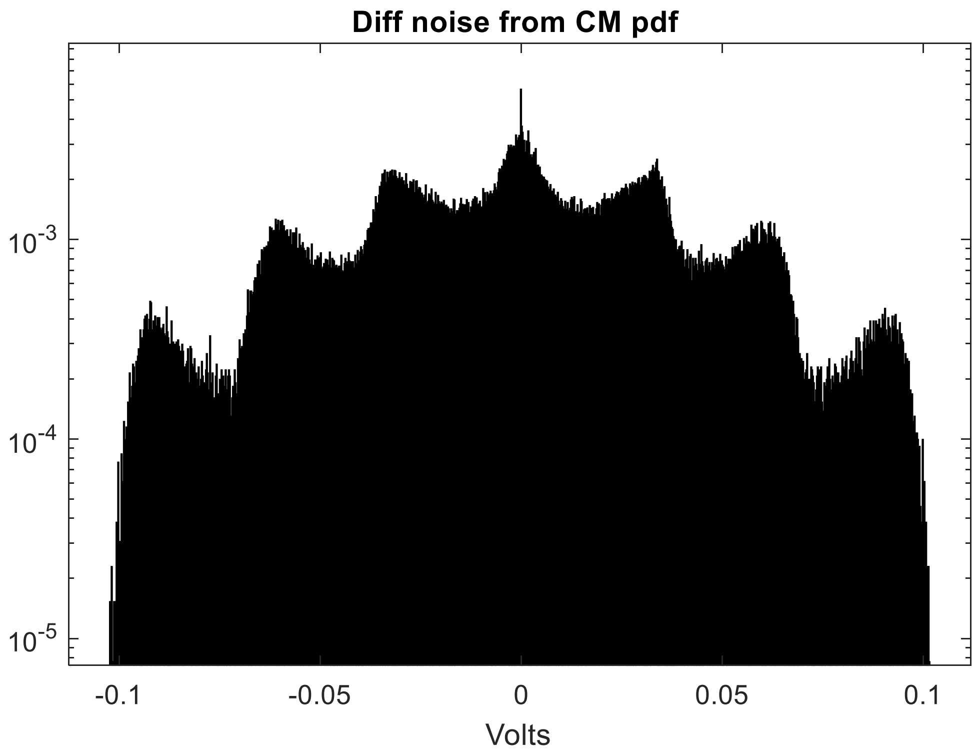
- Time Domain (TD) waveforms
  - 106.6 Gb/s PAM4 signaling using PRBS13Q
  - RMS CM reports
- Frequency Domain (FD) Plots

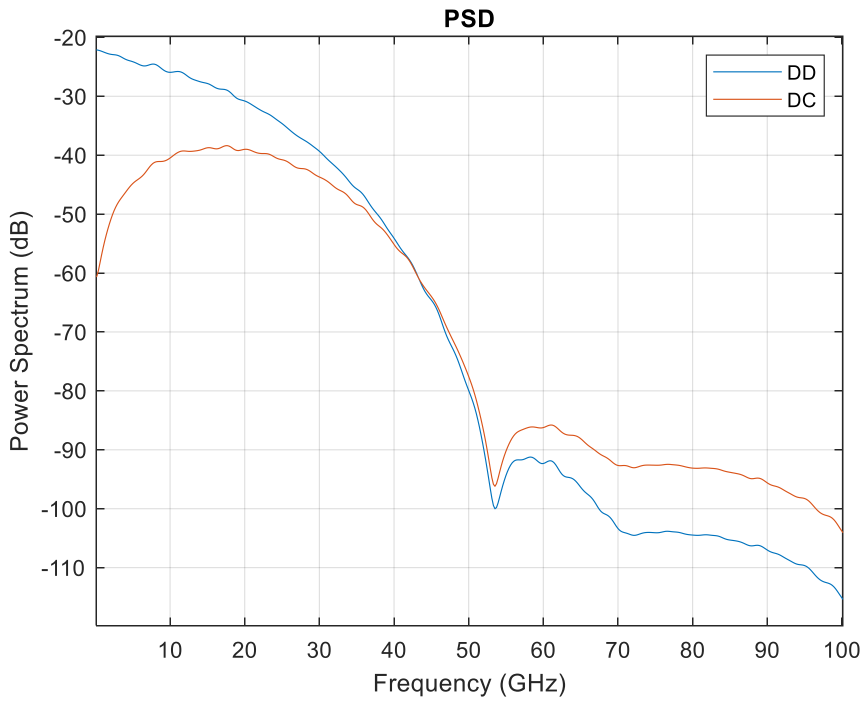
DM and CM Waveforms for 5.5ps of Skew



RMS is not really the whole story.

Histogram for CM and Power Spectral Density (PSD) for 5.5 ps Skew



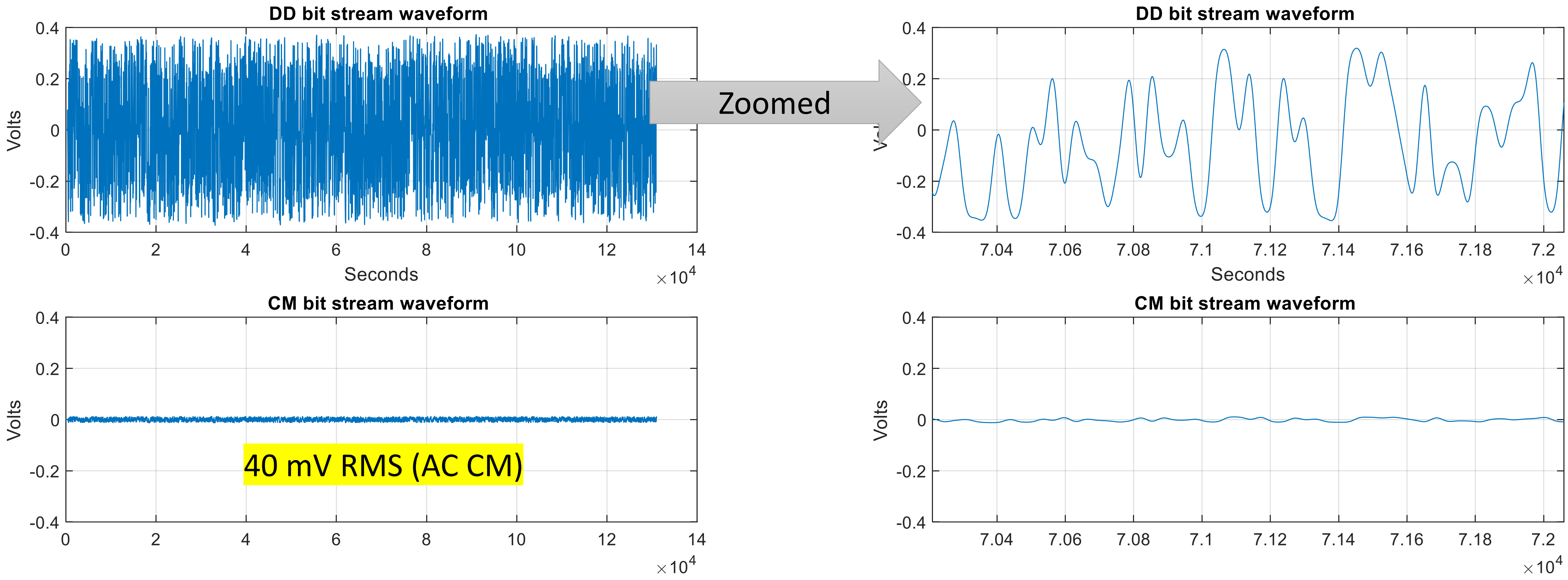


CM noise due to skew is not really Gaussian
This questions how RMS noise would be used.

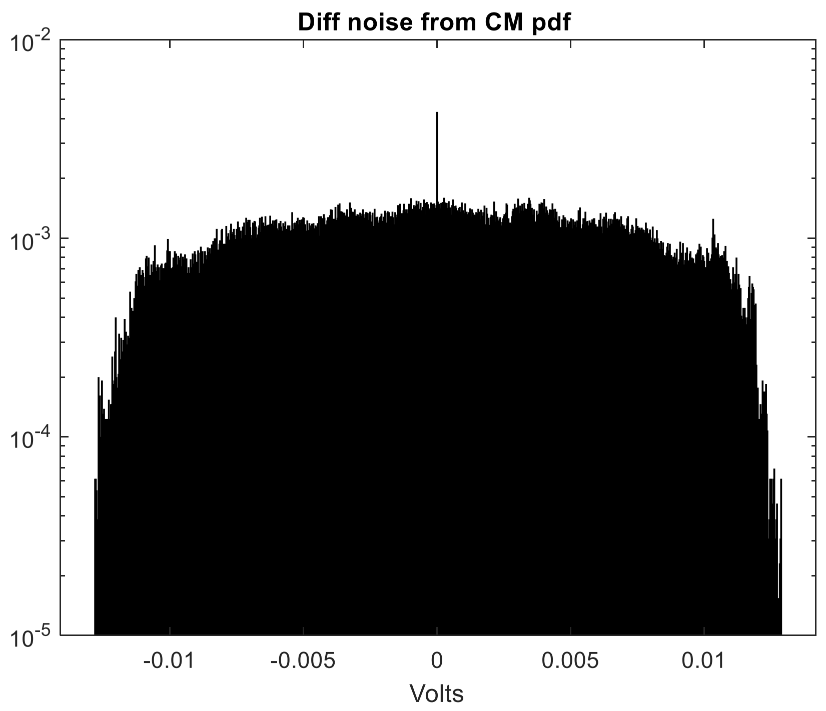
The blue curve is the PSD for the differential signal.

The red curve represents the PSD content for the measured COM.

DM and CM Waveforms for 10% Impedance Imbalance



Histogram for CM and PSD for 10% Impedance Imbalance



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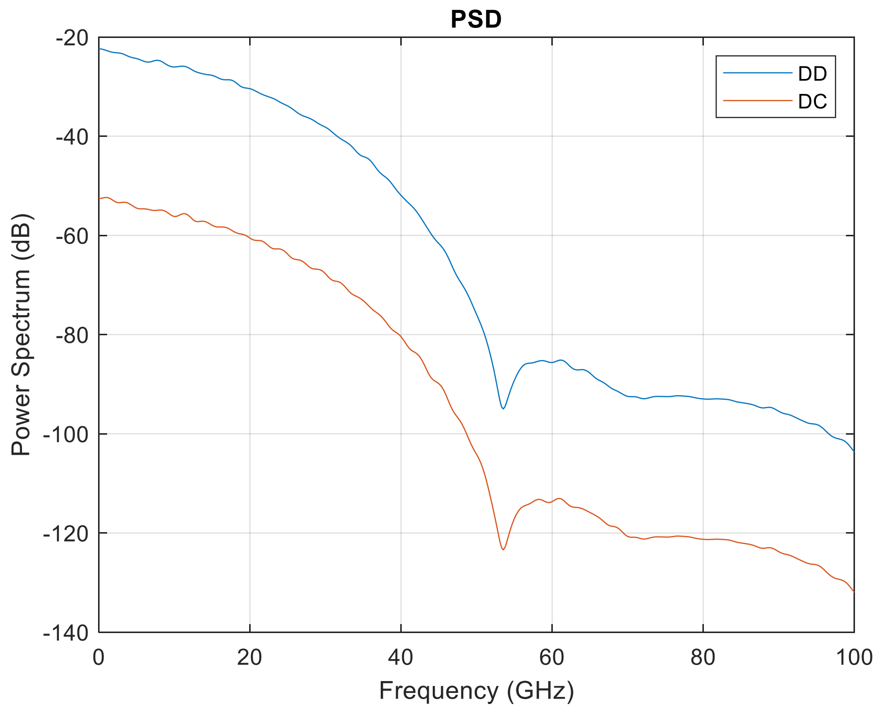

The blue curve is the PSD for the differential signal.

The red curve represents the PSD content for the measured COM.

DM and CM Waveforms Using an Uncorrelated 158 mV AWGN CM Noise Source

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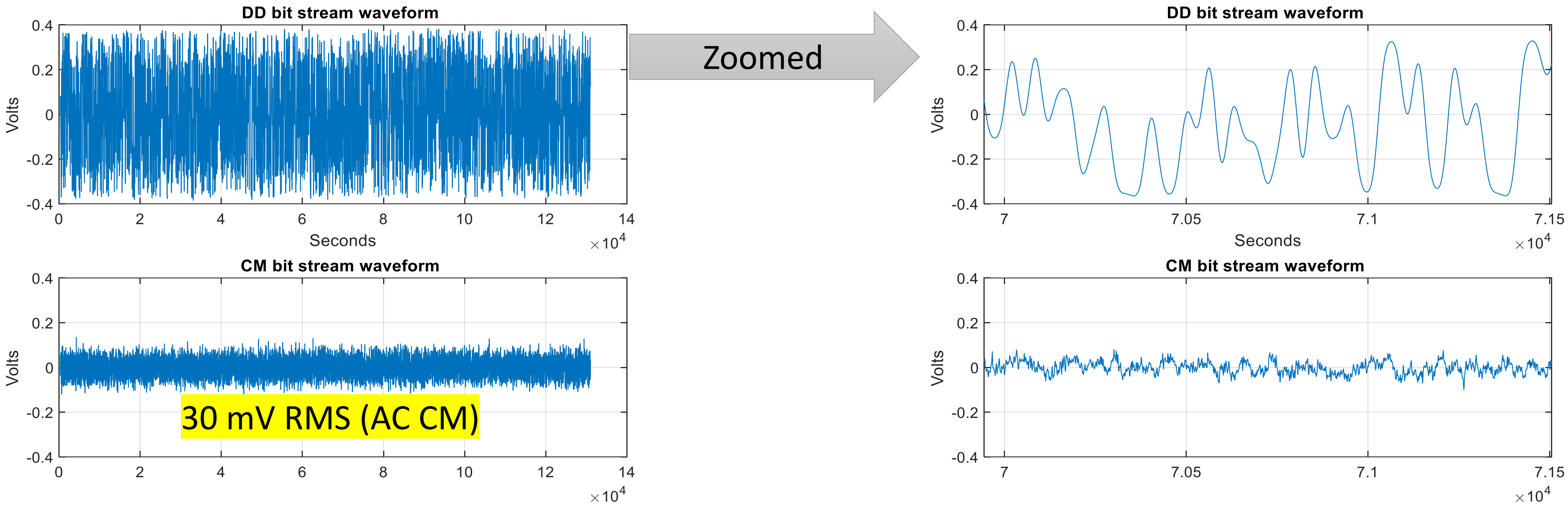
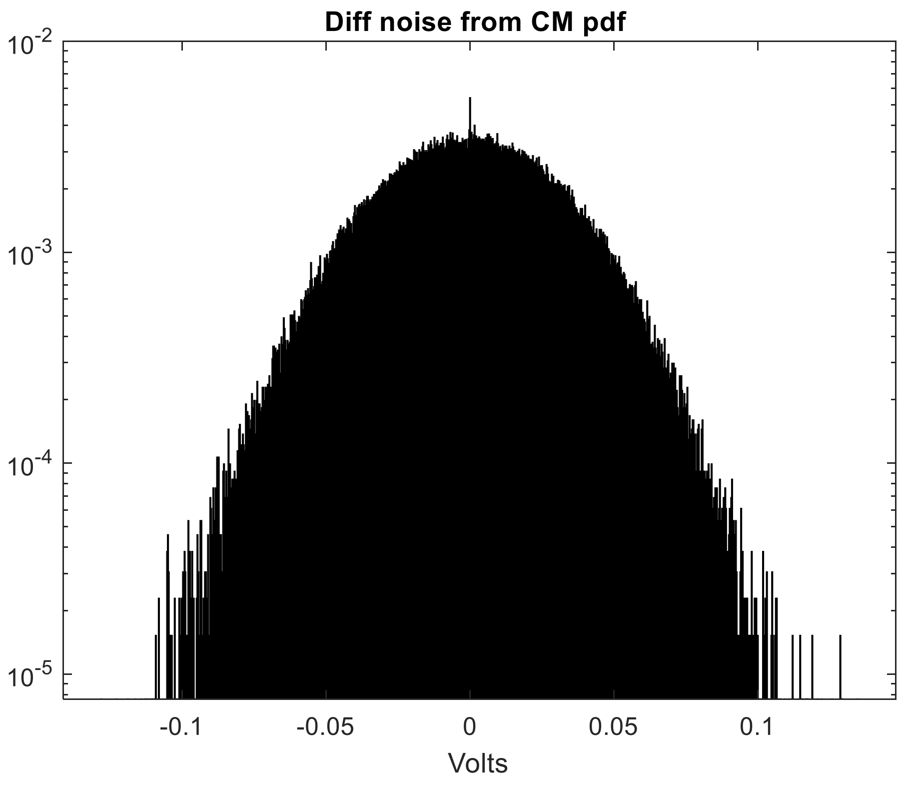
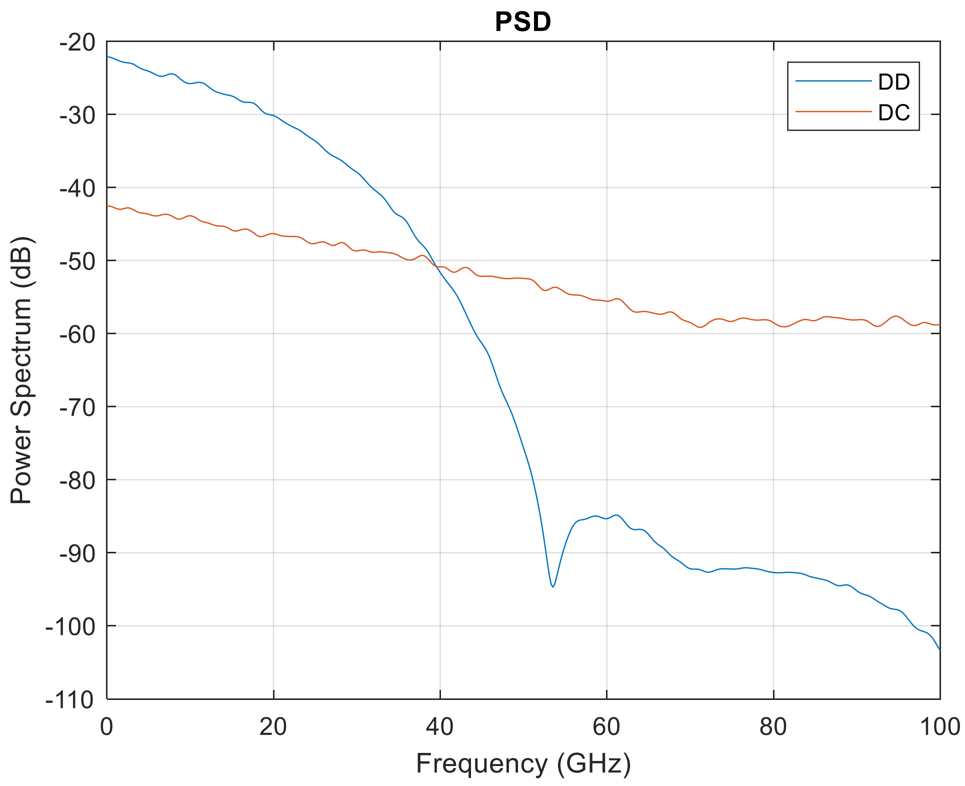


Measured at the output of the package.

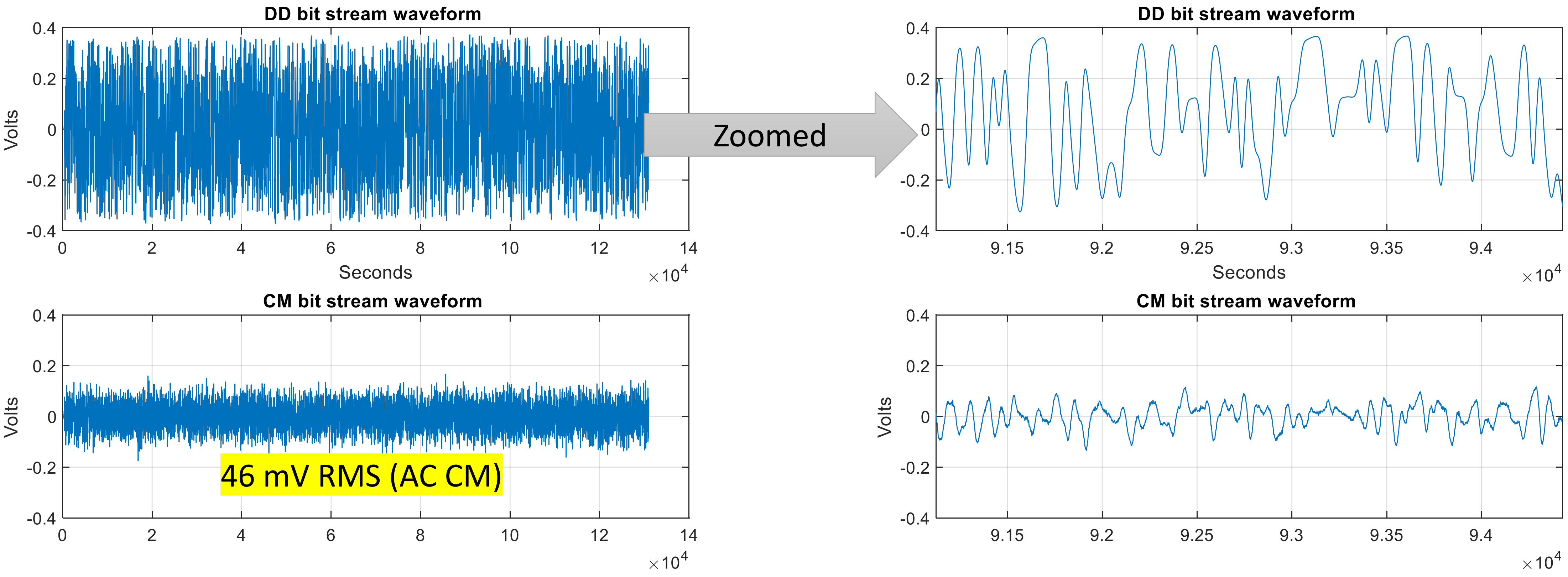
Histogram for CM and PSD Using an Uncorrelated 158 mV AWGN CM Noise Source





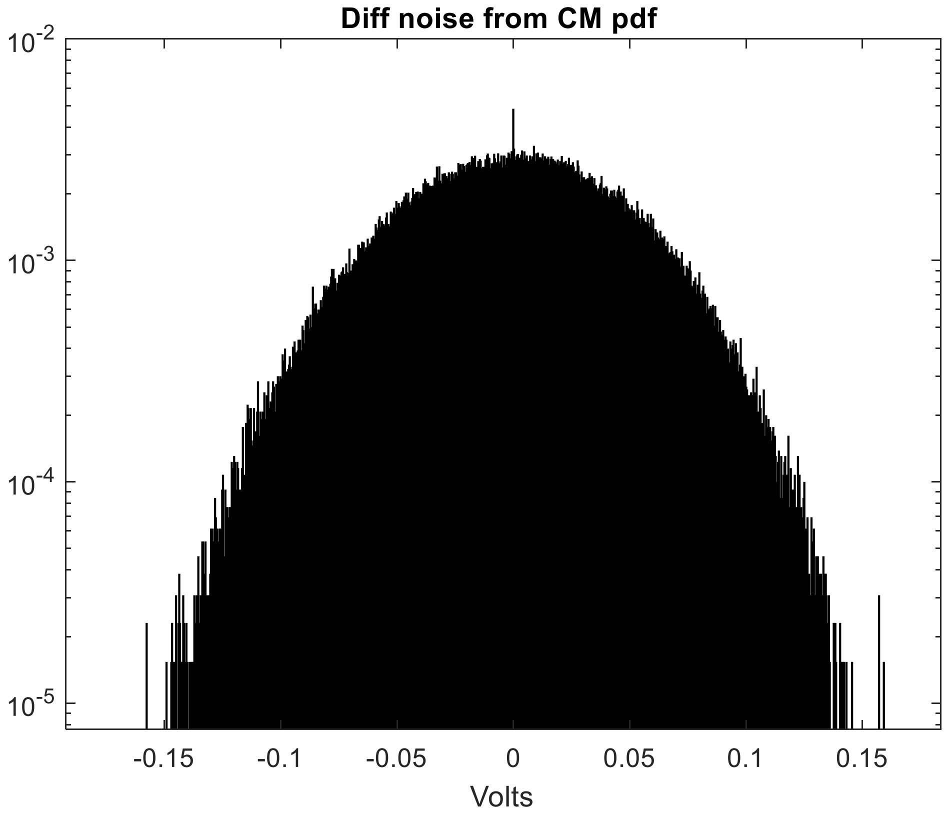
As expected, it looks Gaussian.

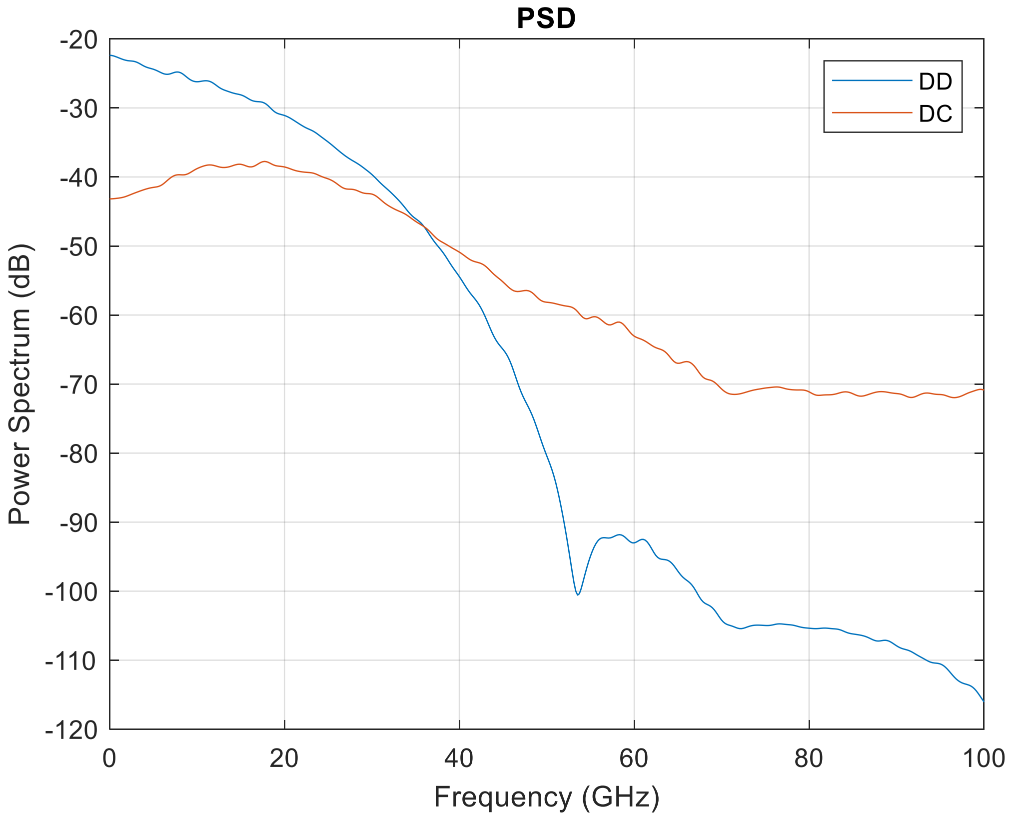
DM and CM Waveforms Using Skew, Imbalance and CM AWGN



Dilemma: Part of the AC CM noise is already incorporated in the DM waveform.

Histograms Look Gaussian When All Prior CM Sources Are Used





Dilemma: breaking down what CM noise is could be challenging just using the noise histogram and PSD.

Thoughts on How to Measure Non-Coherent CM Noise: Similar to Measuring σ_n for SNDR

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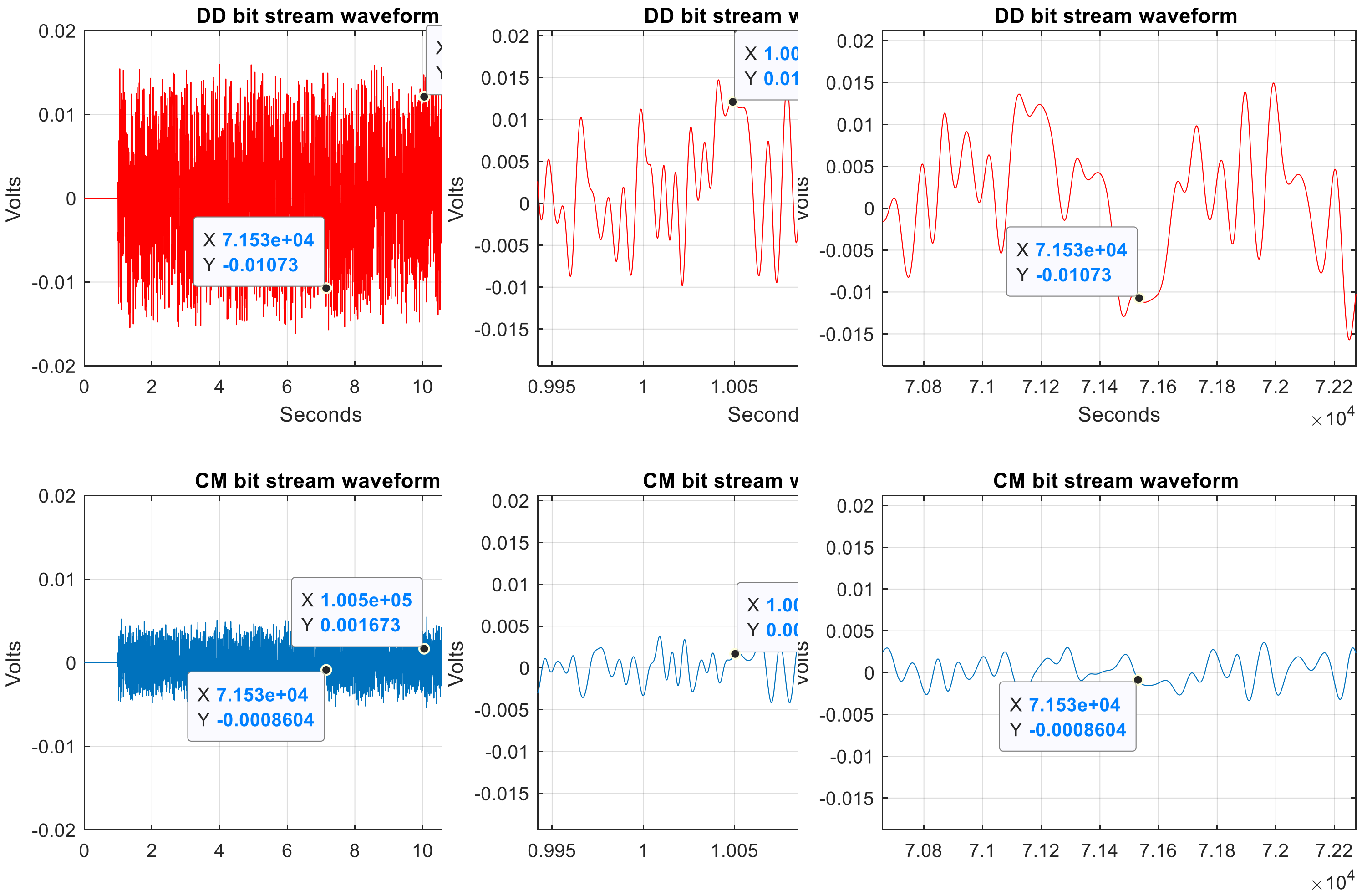
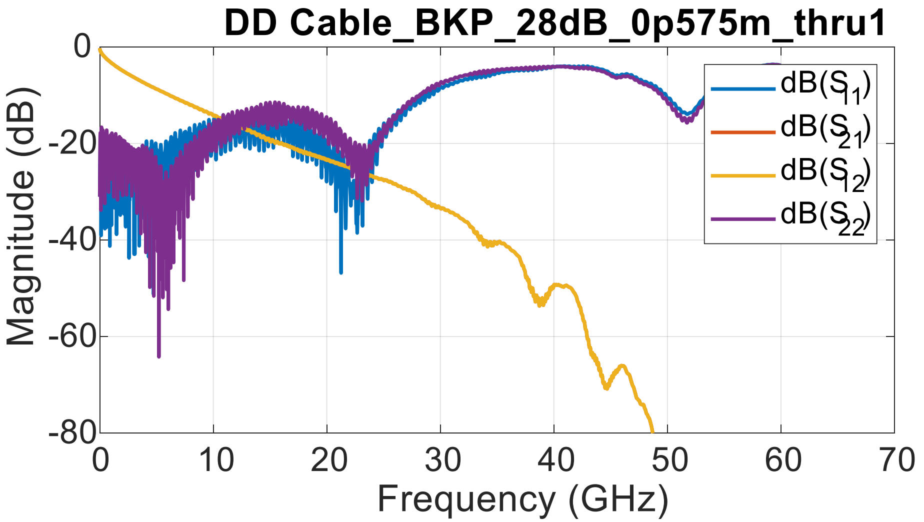
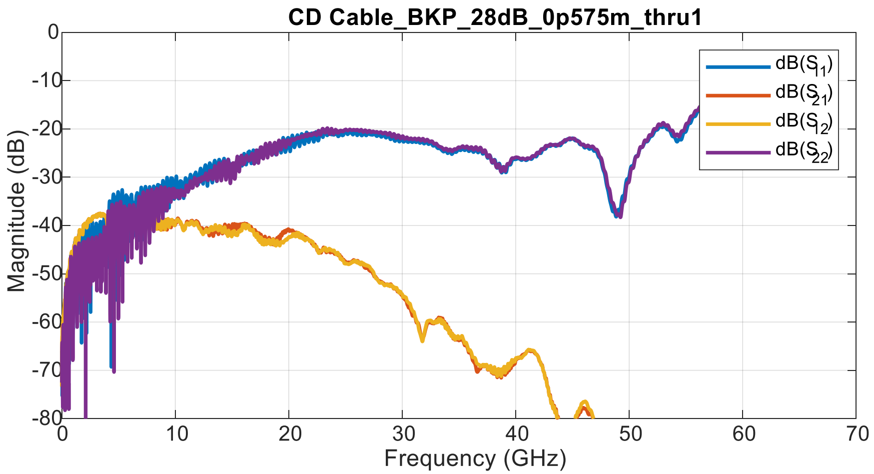
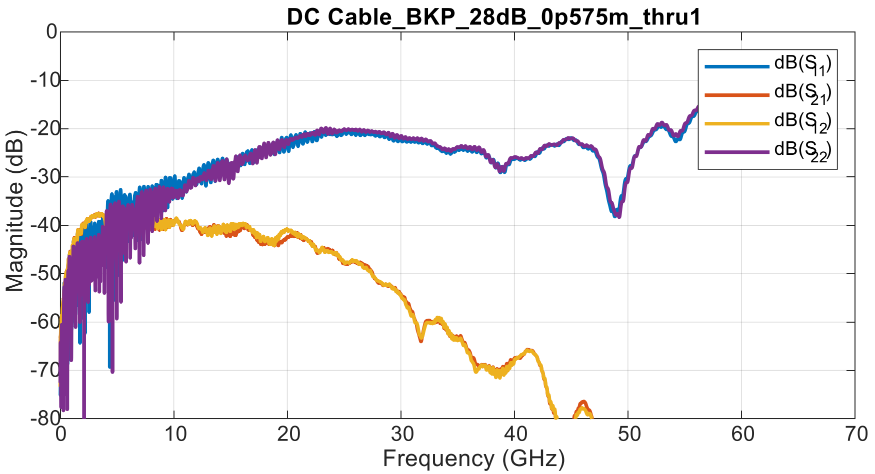


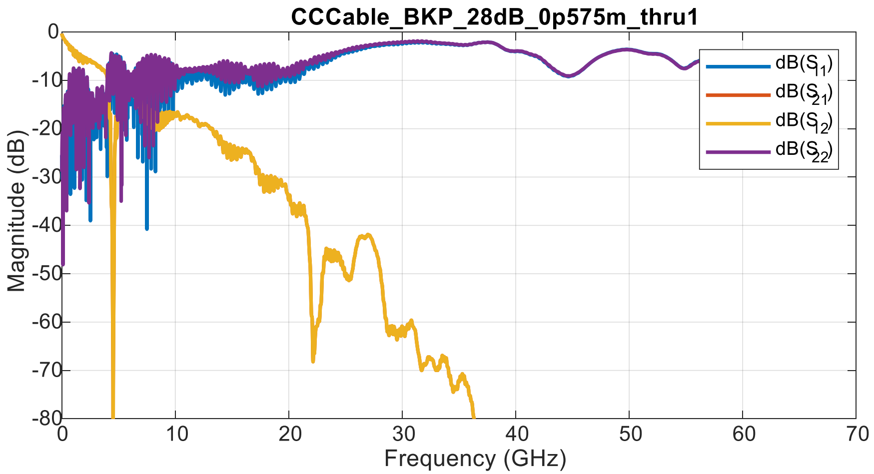
- Trigger on PRBS13Q data pattern for the long run of the each of the 4 symbols
- A sufficiently large number of repeats of the data pattern is required
- Acquire the variance for the CM voltage at each level
- Average the variance for all the levels
- This will be way lower than the CM voltage from skew and imbalance

Channel Used for this Example
28 dB Loss at 26.56 GHz





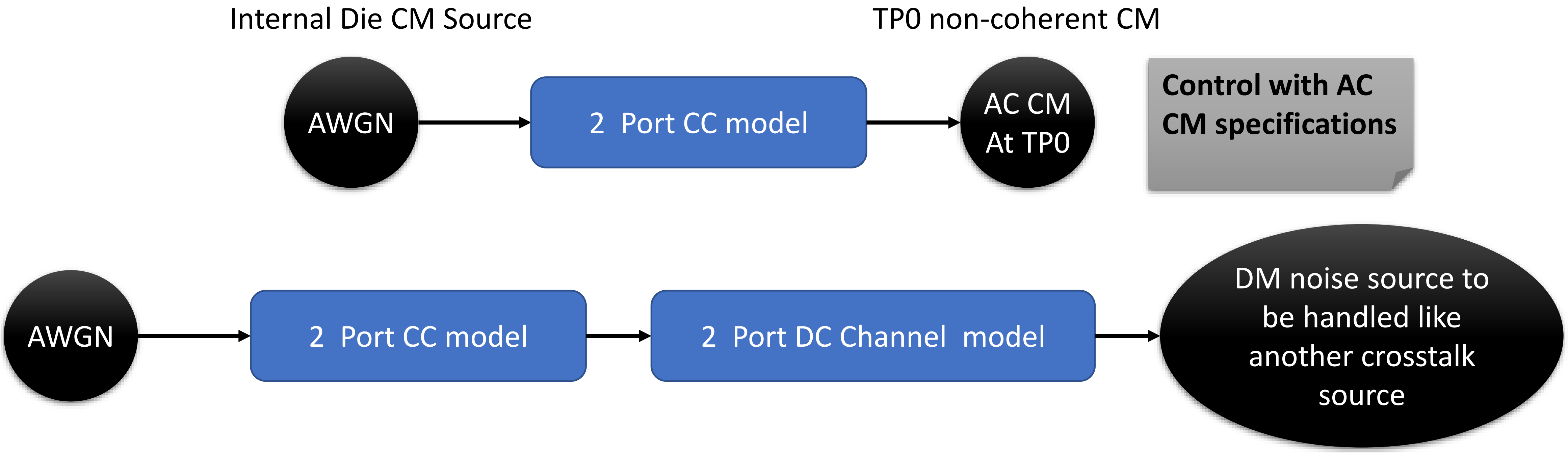




https://www.ieee802.org/3/ck/public/18_11/heck_3ck_01_1118.pdf

CM Impact on DM Simulation

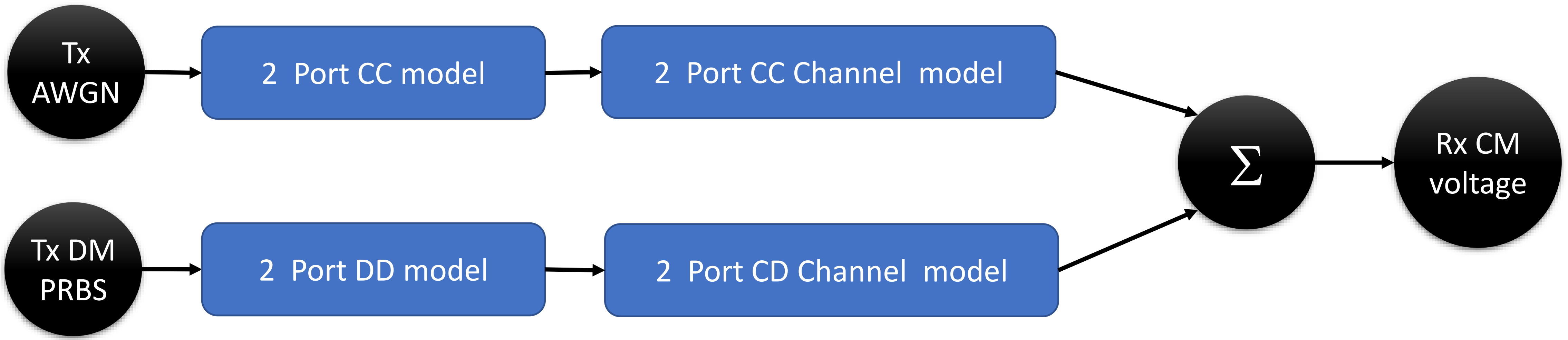
This is only one of the CM conundrums.



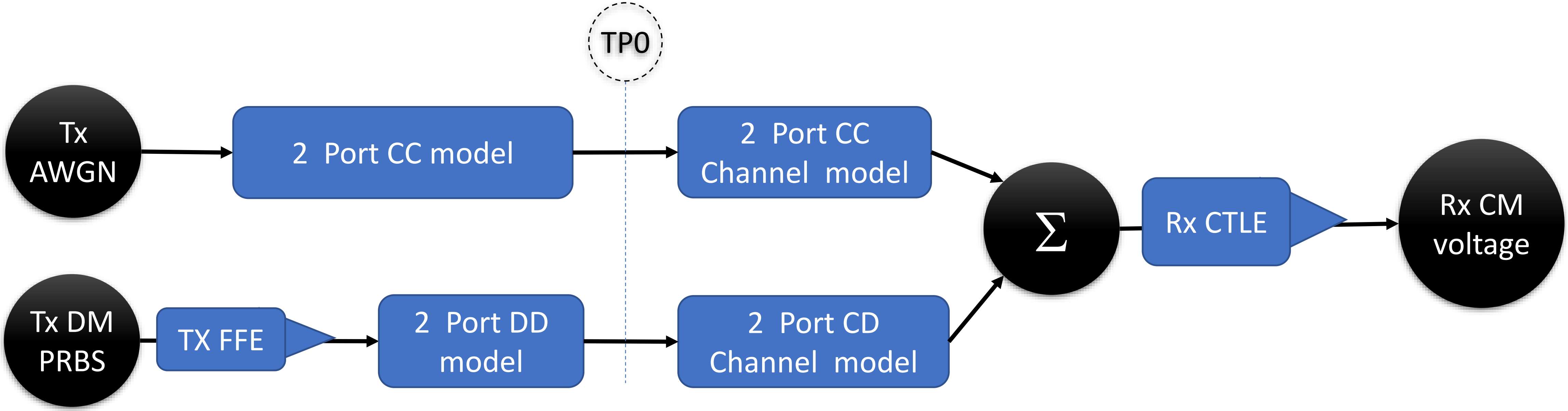
CM Receiver (Rx) Tolerance

This is the second CM conundrum.

- How much CM will a receiver see
- This is not really a part of the DM analysis per se

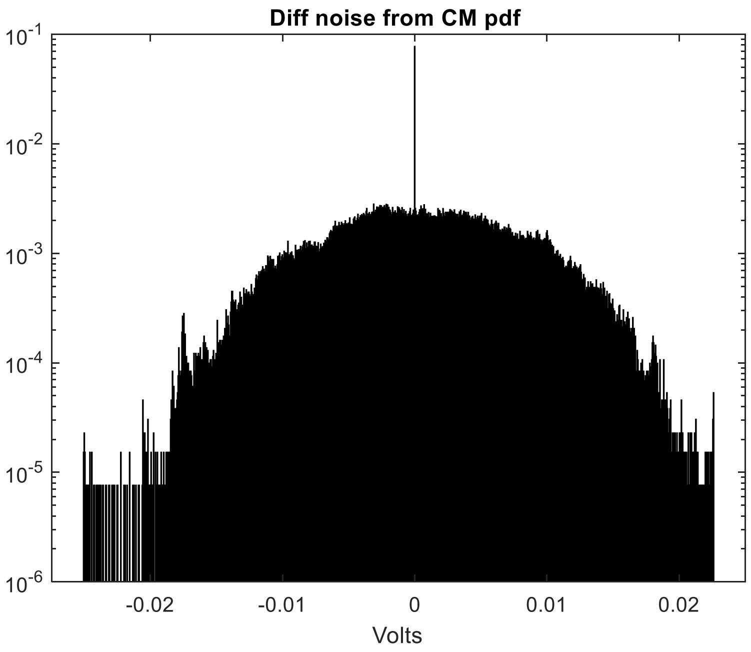


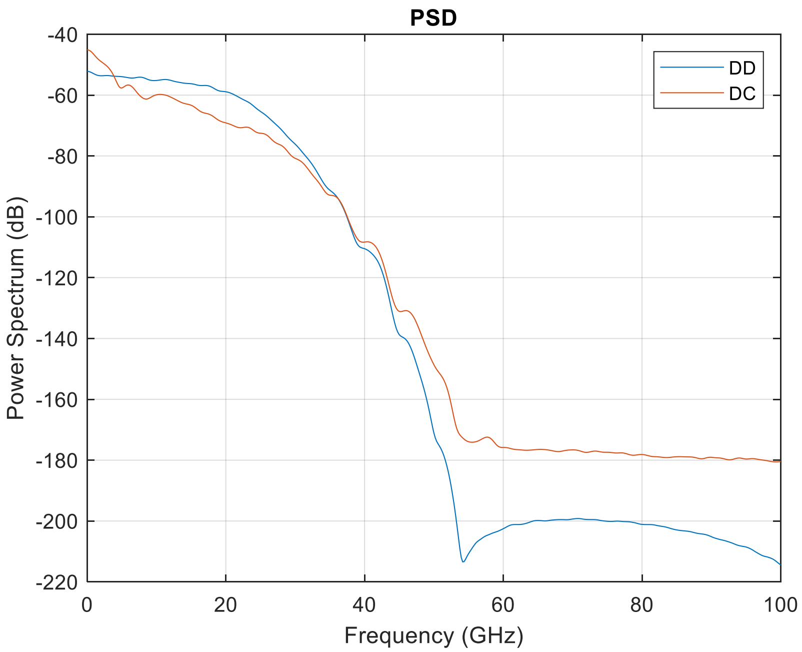
6.7 mV CM RMS Seen at Rx



5.5 ps Tx skew
10 % impedance imbalance
30 mv AWGN at TP0

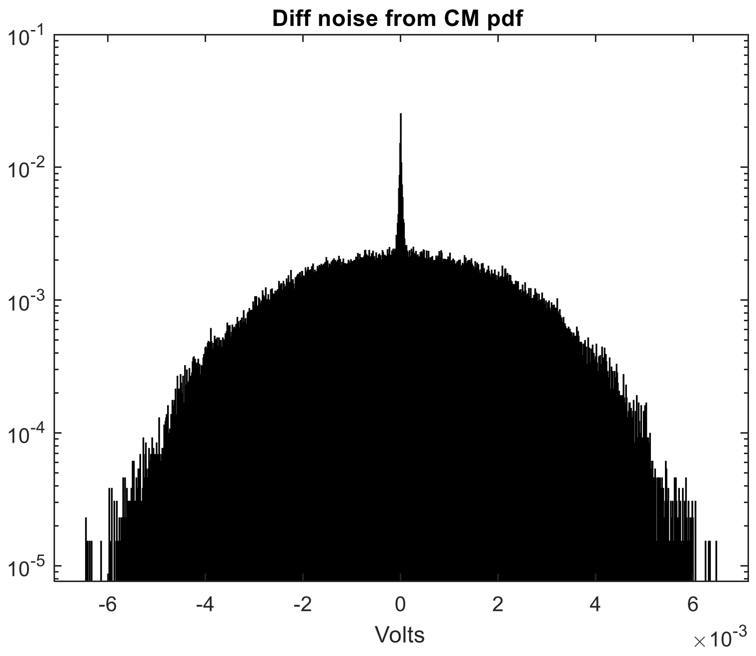
CM Histogram and PSD

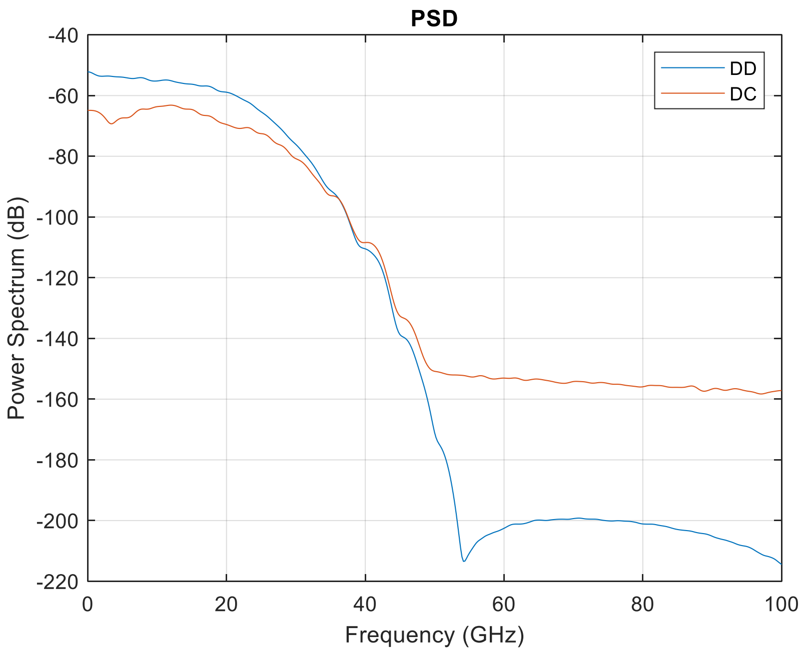




Food for thought: limit the AC CM bandwidth.

Limit BW to 2.6 GHz and CM Drops AC CM RMS to 1.9 mV at the Rx



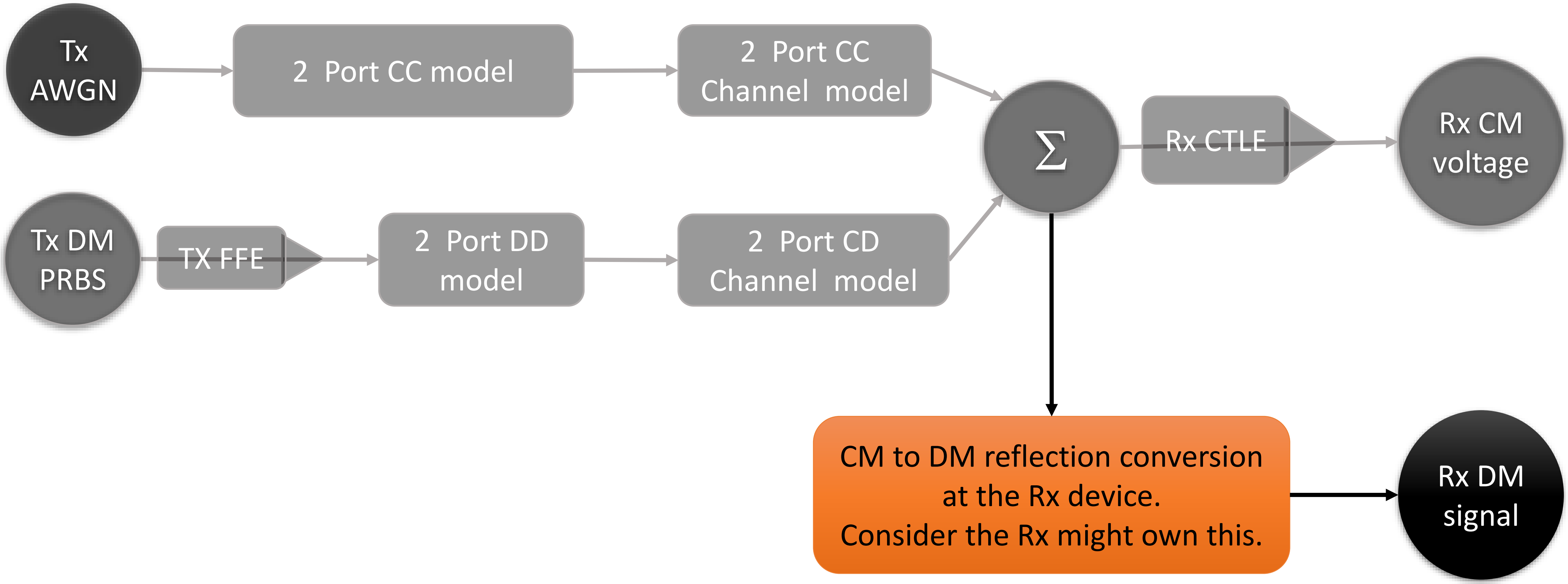


More work to be done for this.

Consider most power supply noise is below 1 GHz.

This is the Third CM Conundrum

Re-generation through CM to DM model reflections … more work here later…



Summary

- Common mode generation can be modeled as skew, imbalance and noise
- Spectral and statistical content are required for CM management
- Coherent and synchronous CM noise should be separated for analysis

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