COMMENT #111

Cable Assembly
Differential to Common Mode Conversion Loss Limit

Bruce Champion, TE

Supporters

- Alex Haser, Molex
- Sam Kocsis, Amphenol

Overview

- Comment Overview
- Review skew impact on insertion loss and mode conversion
- Proposed limit
- Questions

Comment Overview

- Comment addresses section 162.11.5 Diff to Common-mode Conversion Loss
  - Just like other parameters we're talking about (RL, ERL) we need to put some meaning behind it
  - For this particular parameter skew is the main driver for mode conversion in a Tp1-Tp4 measurement
  - Other things can attribute to mode conversion, but in a symmetrical Tp1-Tp4 set-up, skew is the leading cause
  - Various references point to using SCD21 (or SDC21) for evaluating skew
    - Mayevskiy, Eugene. Huffaker, James "White Paper: Intra Pair Skew Measurements in Gigabit Range Interconnects" 01 FEB 2016, TE Connectivity
    - M. Lai, J. Stephens, J. Ficke, P. Yelamarthy, K. Robers, D. Jenson, M. Marthick, "Skew Metric and BER Testing correlation for NRZ/PAM4 signaling" in DesignCon, Santa Clara, 2019.

162.11.5 Differential to common-mode conversion loss

The cable assembly differential to common-mode conversion loss shall meet the requirements of TBD.

Skew Impact on S_{dd21} & S_{cd21}

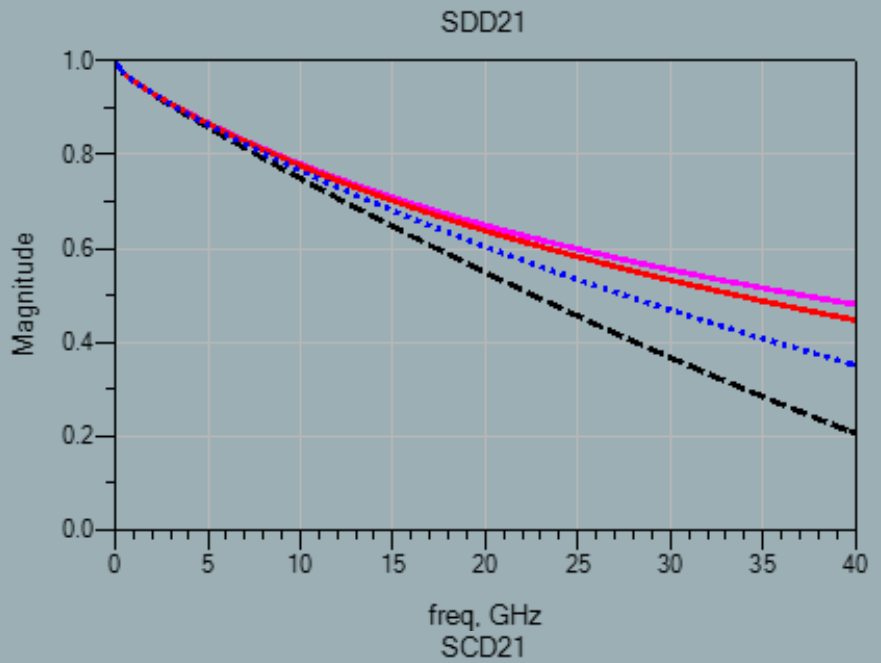
$$S_{dd21} = \frac{|S_{21}|e^{j\theta_{21}} + |S_{43}|e^{j\theta_{43}} - |S_{41}|e^{j\theta_{41}} - |S_{23}|e^{j\theta_{23}}}{2}$$

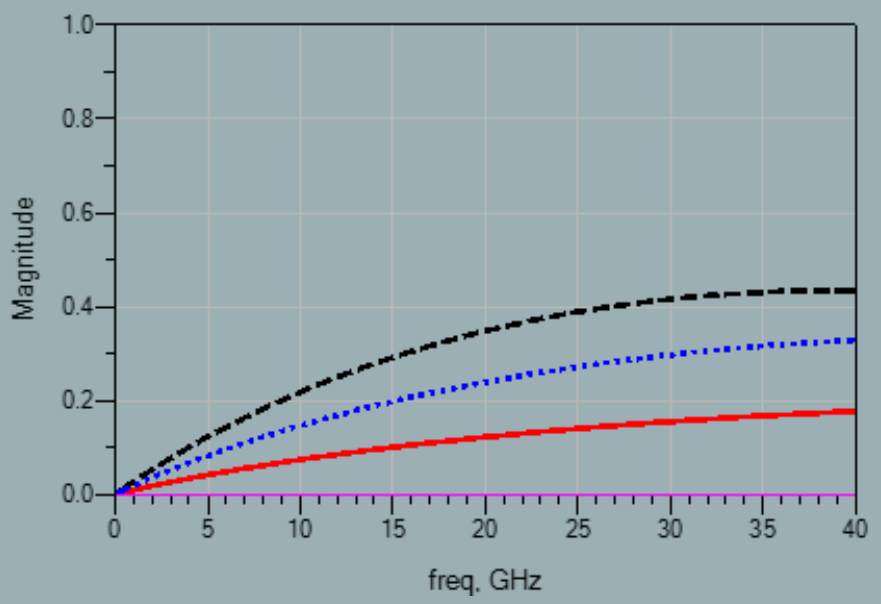
$$S_{dd21} = |IL|cos\left(\frac{\Delta\theta}{2}\right)e^{j\theta_{21}} - |X|cos\left(\frac{\Delta\theta_X}{2}\right)e^{j\theta_{41}}$$

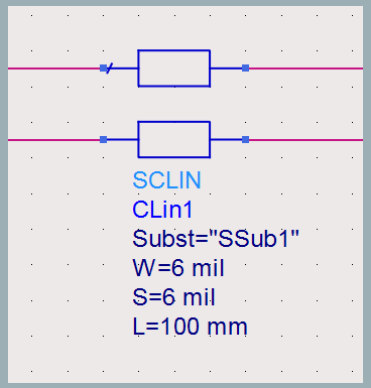
$$S_{cd21} = \frac{|S_{21}|e^{j\theta_{21}} - |S_{43}|e^{j\theta_{43}} + |S_{41}|e^{j\theta_{41}} - |S_{23}|e^{j\theta_{23}}}{2}$$

$$S_{cd21} = |IL|\left[-jsin\left(\frac{\Delta\theta}{2}\right)\right]e^{j\theta_{21}} + |X|\left[-jsin\left(\frac{\Delta\theta_X}{2}\right)\right]e^{j\theta_{41}}$$

- S_{dd21} is modified by cosine/S_{cd21} is modified by sine
- Higher frequencies impacted more than lower frequencies as skew increases
- If we subtract Sdd21 from Scd21 to account for conductive and dielectric losses, $\Delta\theta$ is driving the change
  - Skew is driving change in SCD21-SDD21
  - Limit line should be based on skew







Skew

0 ps (Pink)

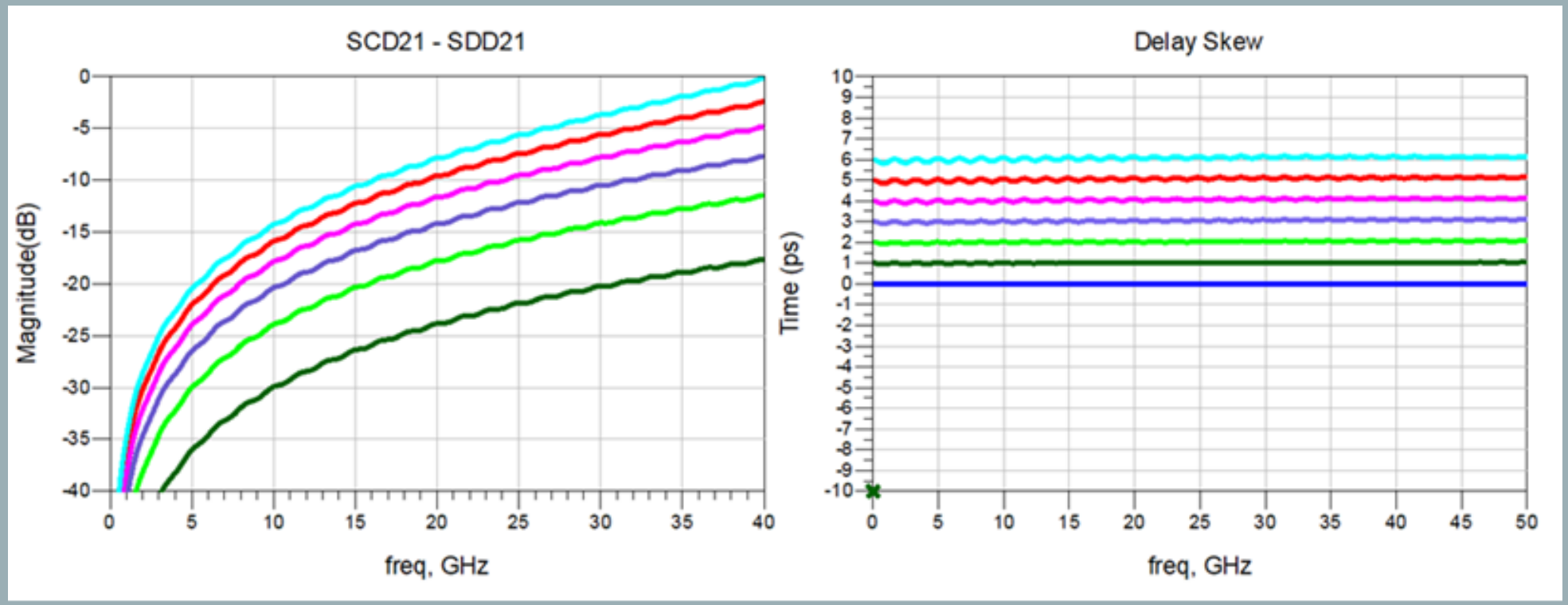
3 ps (Red)

6 ps (Blue)

9 ps (Black)

Proposed Limit

- We can calculate time skew (Delay Skew) as a function of frequency as shown below
- Plots represent a stripline trace with varying levels of time delay added to one leg
  - As time skew is increased, mode conversion is also increased
  - The Delay Skew plot is very flat in these images because this type of skew manifests itself as a "Frequency-independent" type of skew.

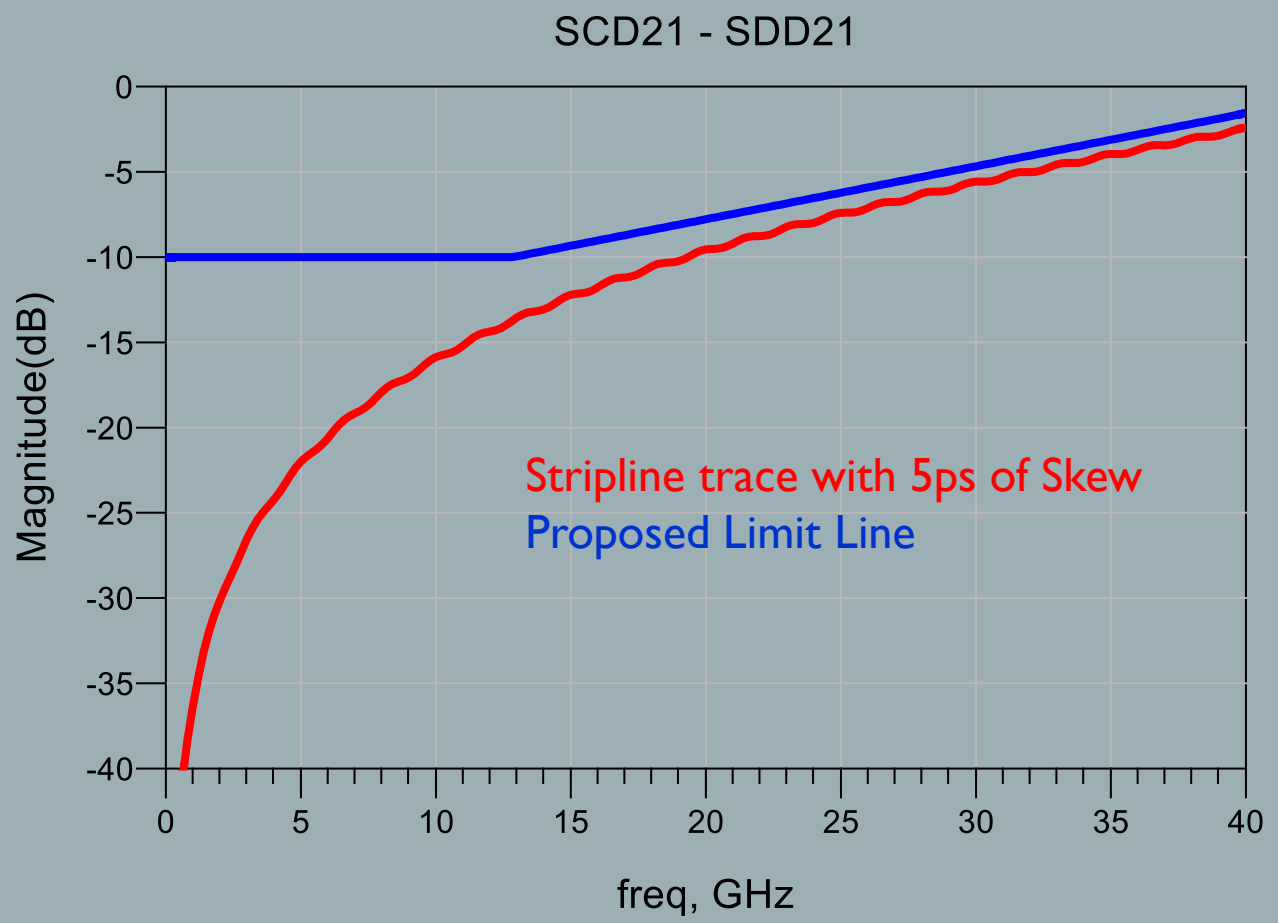


Proposed Limit

- A limit line based on skew is proposed
- Limit line is based on 5 ps of skew
- 5 ps allows for skew in cable assembly along with skew in MCBs
- Limit line:

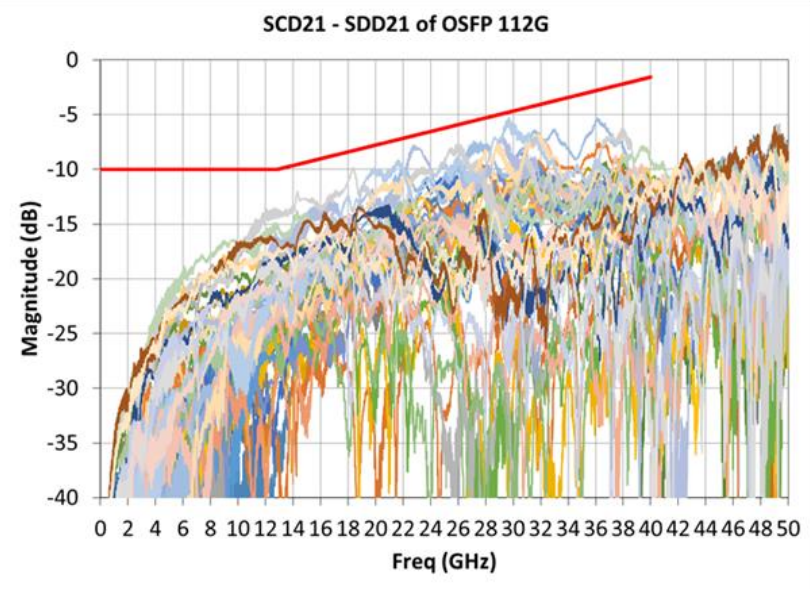
$$S_{CD21}(f) - S_{DD21}(f) \geq \begin{cases} 10 & for\ 0.05 \leq f < 12.89 \\ 14 - 0.3108 * f & for\ 12.89 \leq f \leq 40 \end{cases}$$

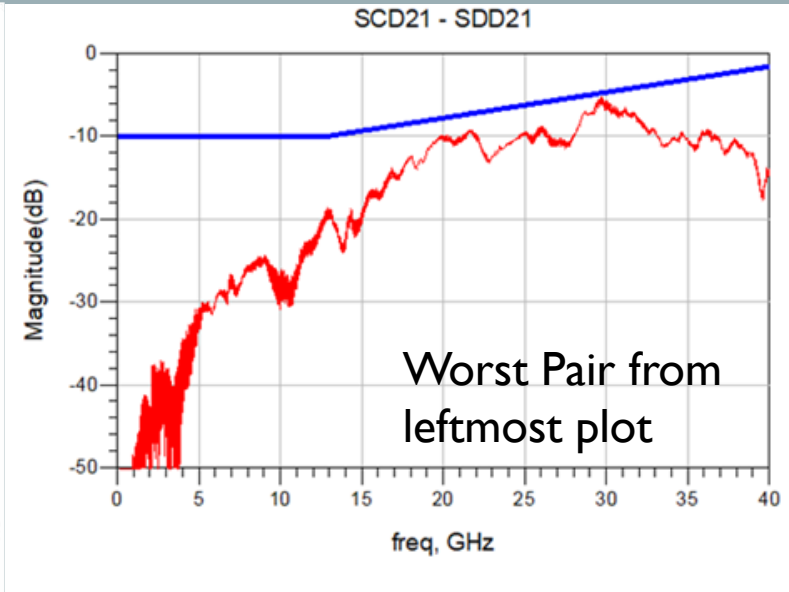
  - f is frequency in GHz
  - $S_{CD21}(f)$ is the cable assembly differential to common-mode conversion loss
  - $S_{DD21}(f)$ is the cable assembly differential insertion loss

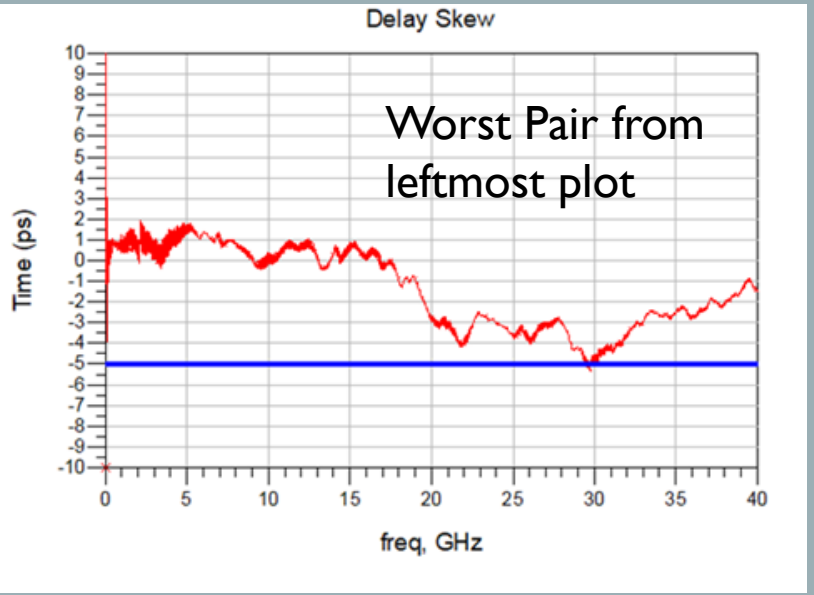


Proposed Limit

- Various cable assemblies have been measured against this limit and it a reasonable limit to pass in production
- These assemblies have also been distributed to various silicon vendors generating good BER
- BER vs skew as %UI does not seem to be intuitive (Have not seen a direct correlation)
- Word of caution
  - Not all skew is created equal
  - Skew on previous slides is frequency-independent (No change in Delay Skew across frequency)
  - Cables assemblies typically have frequency-dependent skew response (Cable & Design dependent)
  - Some have better skew at lower frequencies
  - Some have better skew at higher frequencies





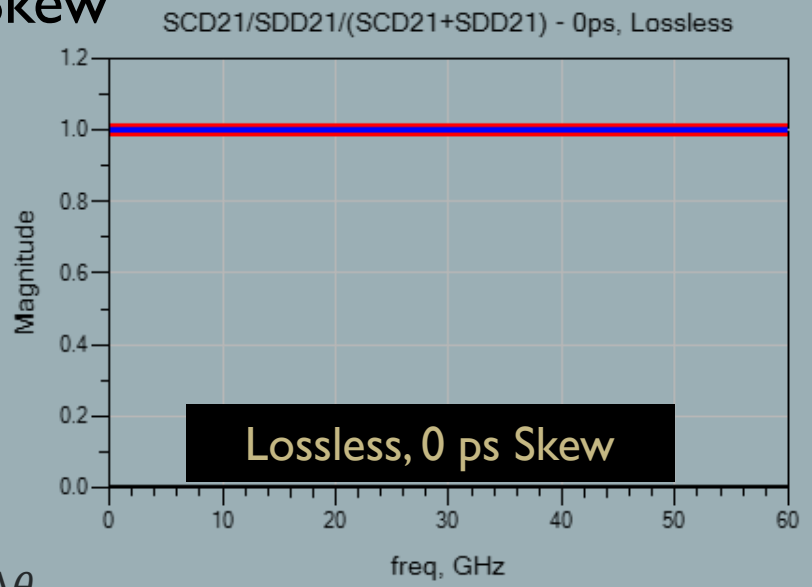


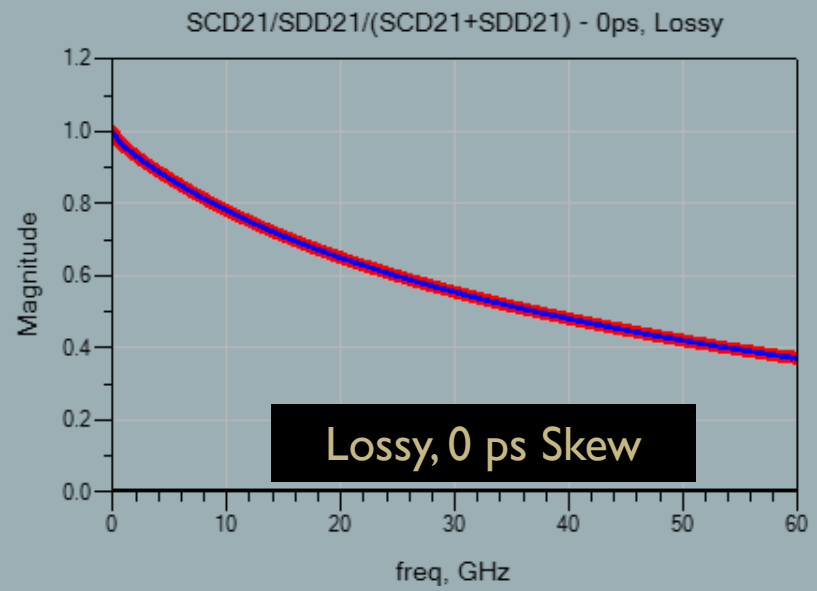
Summary

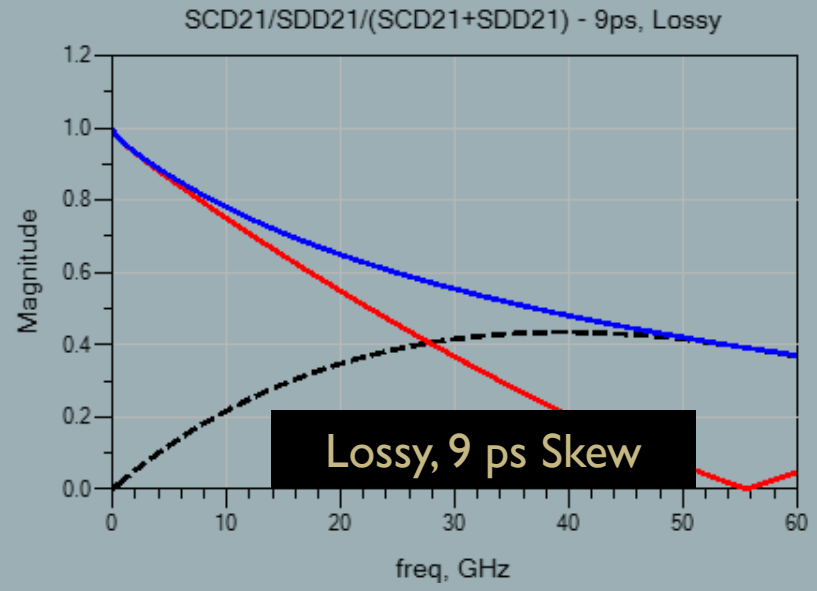
- Reviewed skew impact on insertion loss and mode conversion
- Why we can base limit on skew
- Proposed limit
- Questions

Appendix: Limit can be based on Skew

- From previous slide
  - S_{dd21} is modified by cosine function
  - S_{cd21} is modified by sine function
- Lossless cases
  - $S_{dd21} + S_{cd21} = 1$
  - *For 0 ps of skew*
    - $\Delta\theta = 0,\ S_{dd21} = 1,\ S_{cd21} = 0$
  - *For 9 ps of skew*
    - $\Delta\theta \neq 0$
    - S_{dd21} & S_{cd21} *are modified based on* $\Delta\theta$
- Lossy cases
  - $S_{dd21} + S_{cd21} \neq 1$
    - Due to conductive & dielectric losses
  - *For 0 ps of skew*
    - $\Delta\theta = 0,\ S_{dd21} = cos\left(\frac{\Delta\theta}{2}\right),\ S_{cd21} = 0$
  - *For 9 ps of skew*
    - $\Delta\theta \neq 0$
    - $S_{dd21} = cos\left(\frac{\Delta\theta}{2}\right),\ S_{cd21} = -jsin\left(\frac{\Delta\theta}{2}\right)$
- If we subtract Sdd21 from Scd21 to account for conductive and dielectric losses, we can estimate limit line based on skew







S_{dd21}(Red), S_{cd21}(Black), S_{dd21}+S_{cd21}(Blue)