Chip To Module Twin Axial Cable Channels For 400 Gb/s: Re-examining the Insertion Loss Equation

Richard Mellitz, Samtec, April 24, 2017
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Supporters

- Adee Ran - Intel
- Howard Heck - Intel
- Mike Dudek – Cavium
- Piers Dawe – Mellanox
- Rick Rabinovich- IXIA
- Upen Reddy Kareti – Cisco
- Yasuo Hidaka - Fujitsu

Agenda

- Topology
- Simulation Results
- Issue
- Recommendation

Board Layout for Chip to Module Designs are Challenging

- Routing density is one challenge for a high radix switch device or a large BGA device.
- The routing loss budget of 7.5 dB to the QSFP connector might require the best of the best PCB material or retimers
- There may be other ways to extend channel reach and work with the tight loss budget

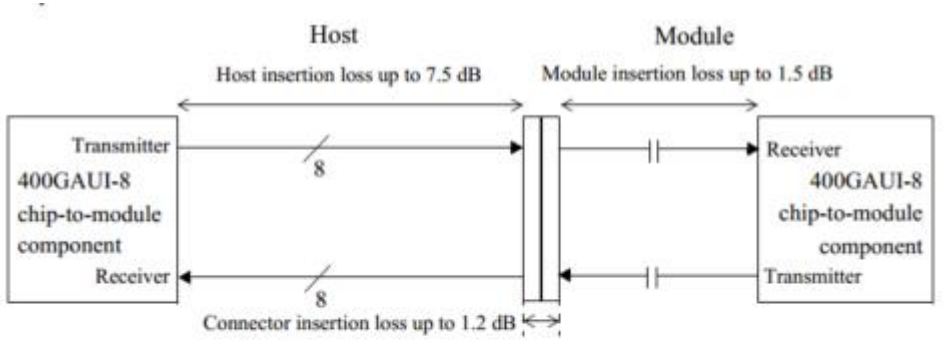


Figure 120E–3—400GAUI-8 chip-to-module insertion loss budget at 13.28 GHz

The nominal signaling rate for each lane is 26.5625 GBd. The chip-to-module interface is defined using a specification and test methodology that is similar to that used for CEI-56G-VSR-PAM defined in OIF-CEI-04.x [B55a].

$$Insertion\_loss(f) \le 0.0801 + 0.5736\sqrt{f} + 0.6046f \quad \text{(dB)} \qquad \text{(120E–1)}$$

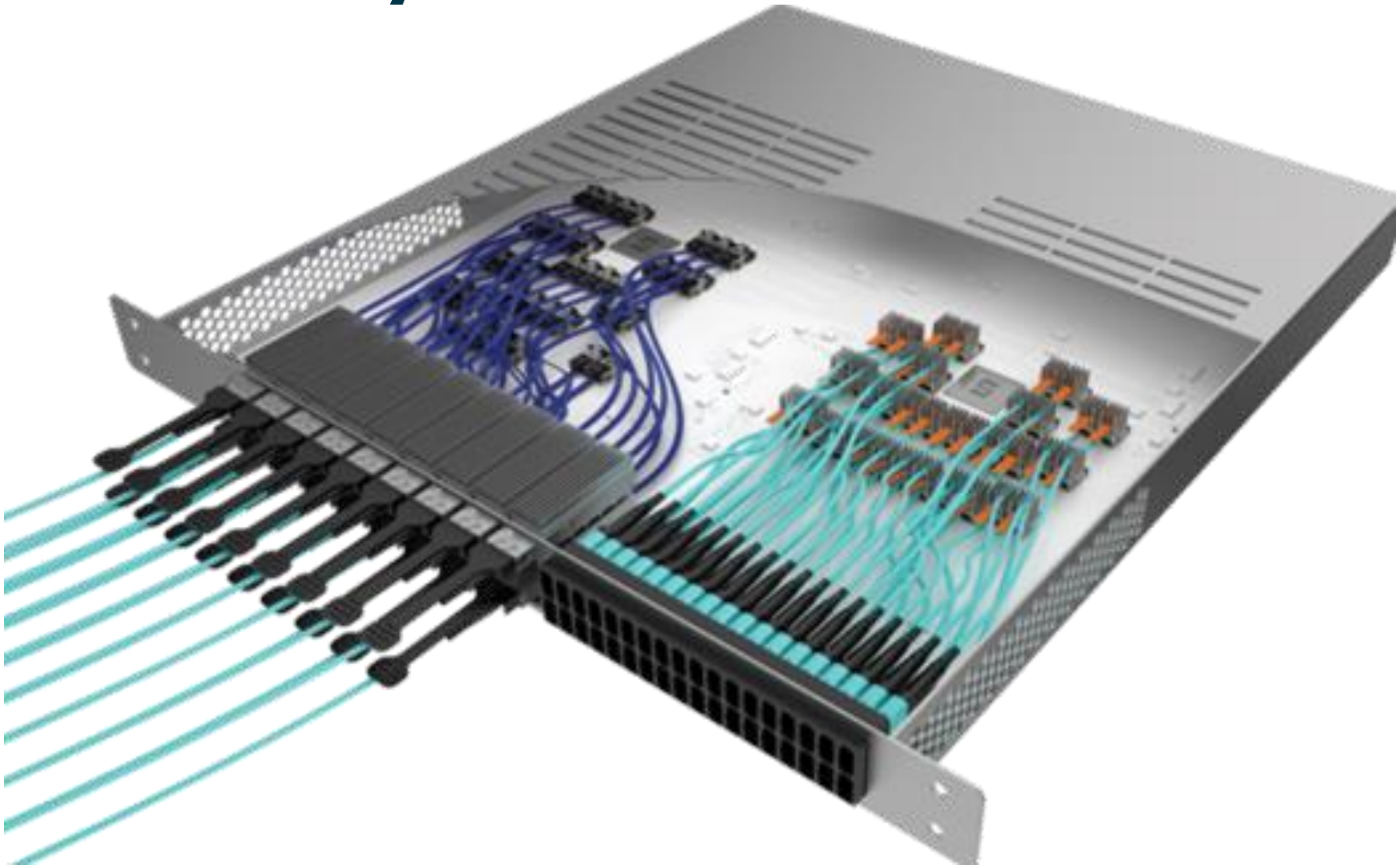
for $0.01 \le f \le 26.5625$

where

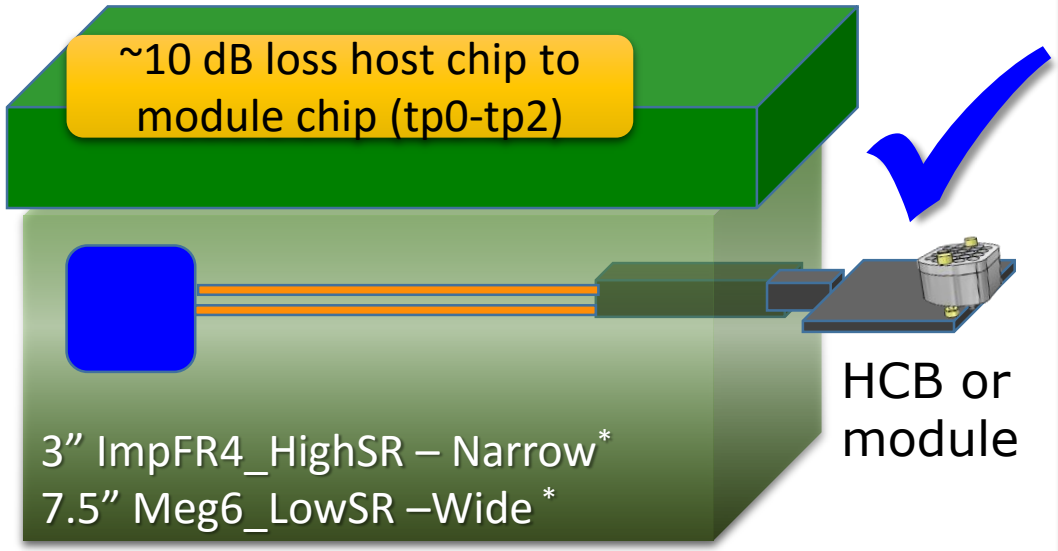
f is the frequency in GHz

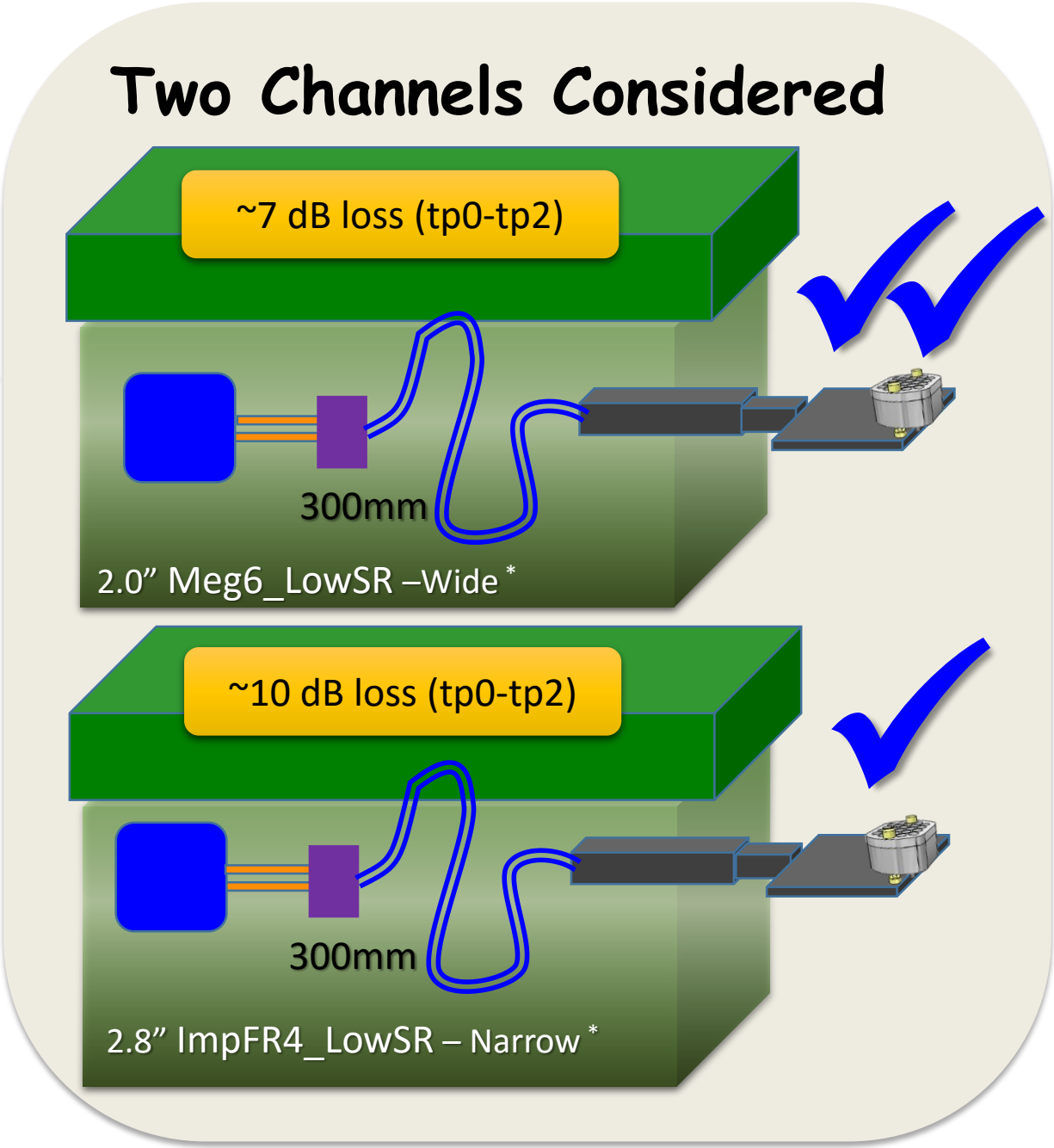
$Insertion\_loss(f)$ is the 200GAUI-4 or 400GAUI-8 chip-to-module insertion loss

Flyover twin axial cable is another solution to alleviate density



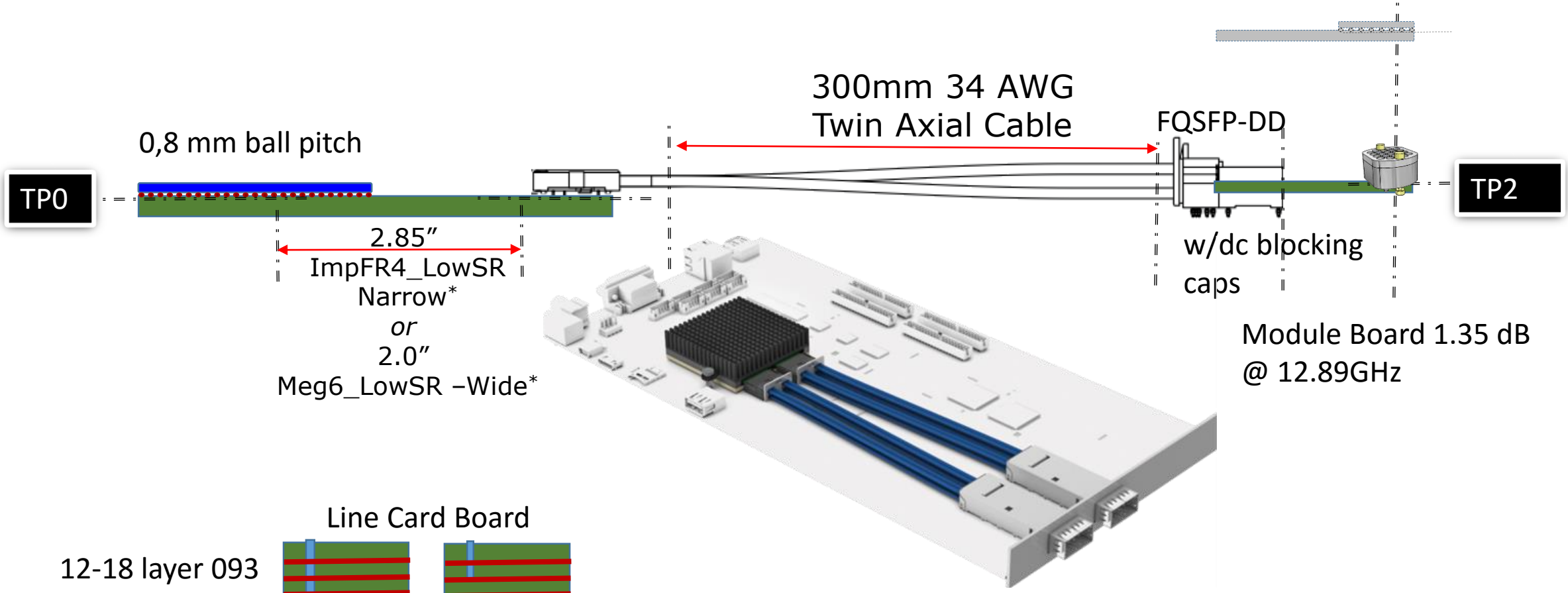
Flyover twin axial cables fit nicely in the line card "shoebox"





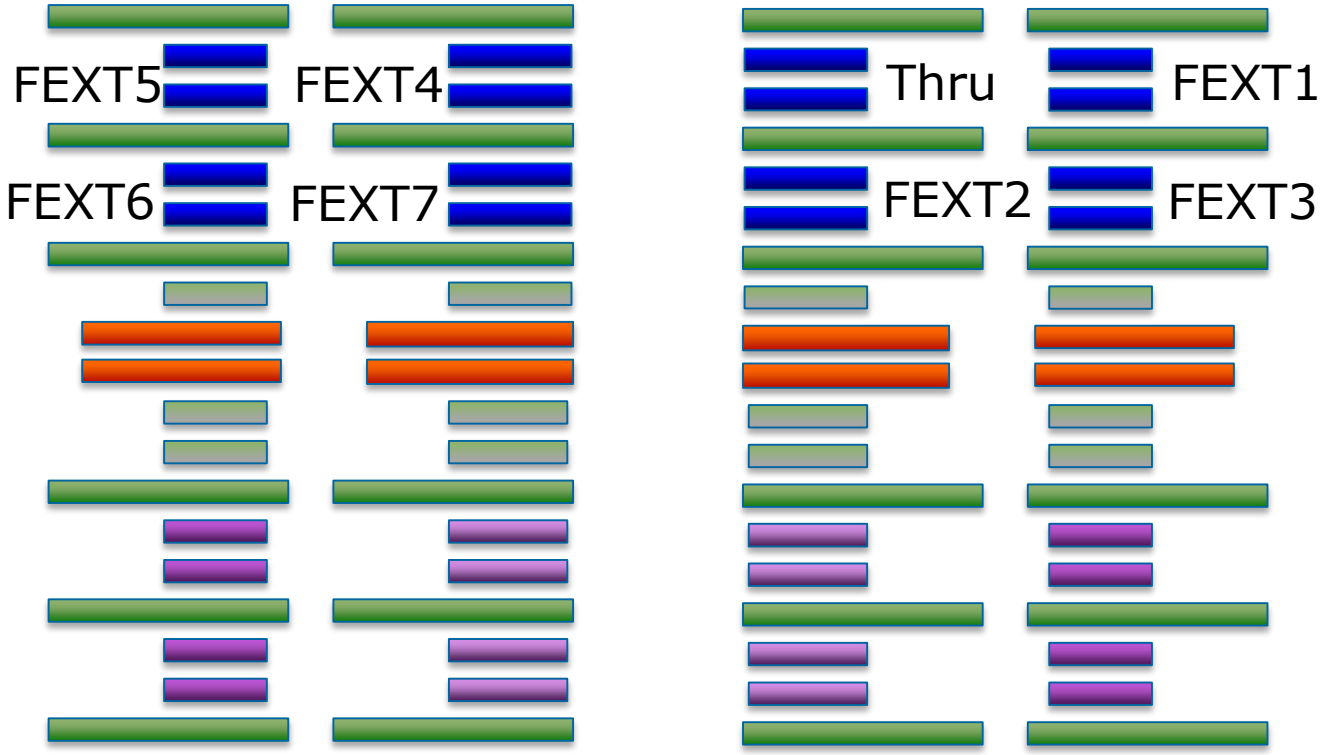
*Refer to table on slide 9 of
http://www.ieee802.org/3/bj/public/jan12/kochuparambil_01a_0112.pdf

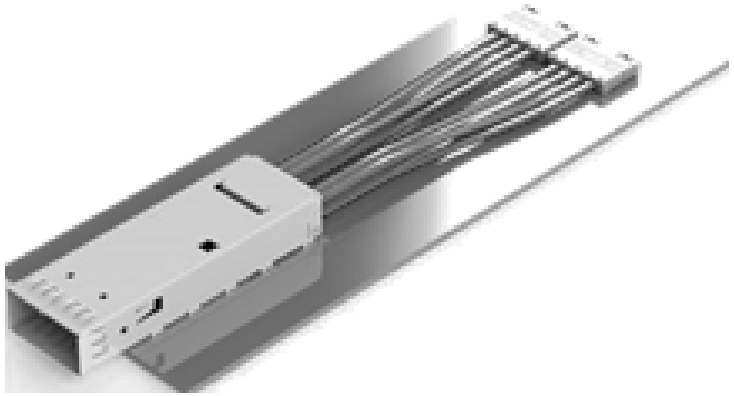
Topology – TP0 to TP2



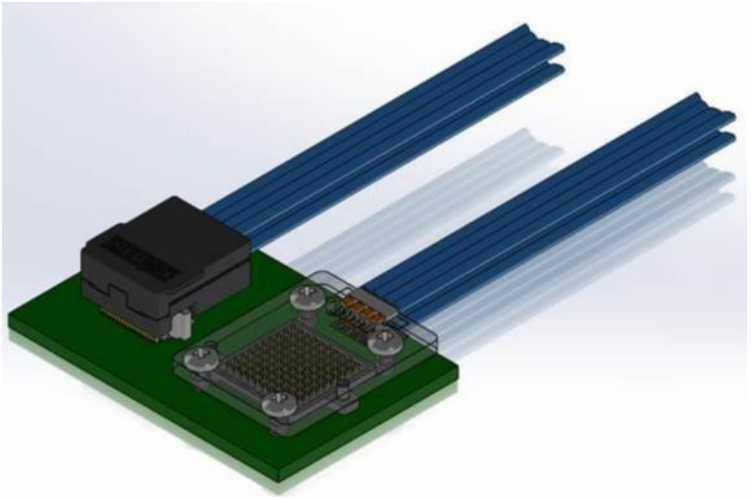
*Refer to table on slide 9 of
http://www.ieee802.org/3/bj/public/jan12/kochuparambil_01a_0112.pdf

Channel Allocation Example





Tx and Rx on separate cable bundles makes for very low NEXT



COM Table

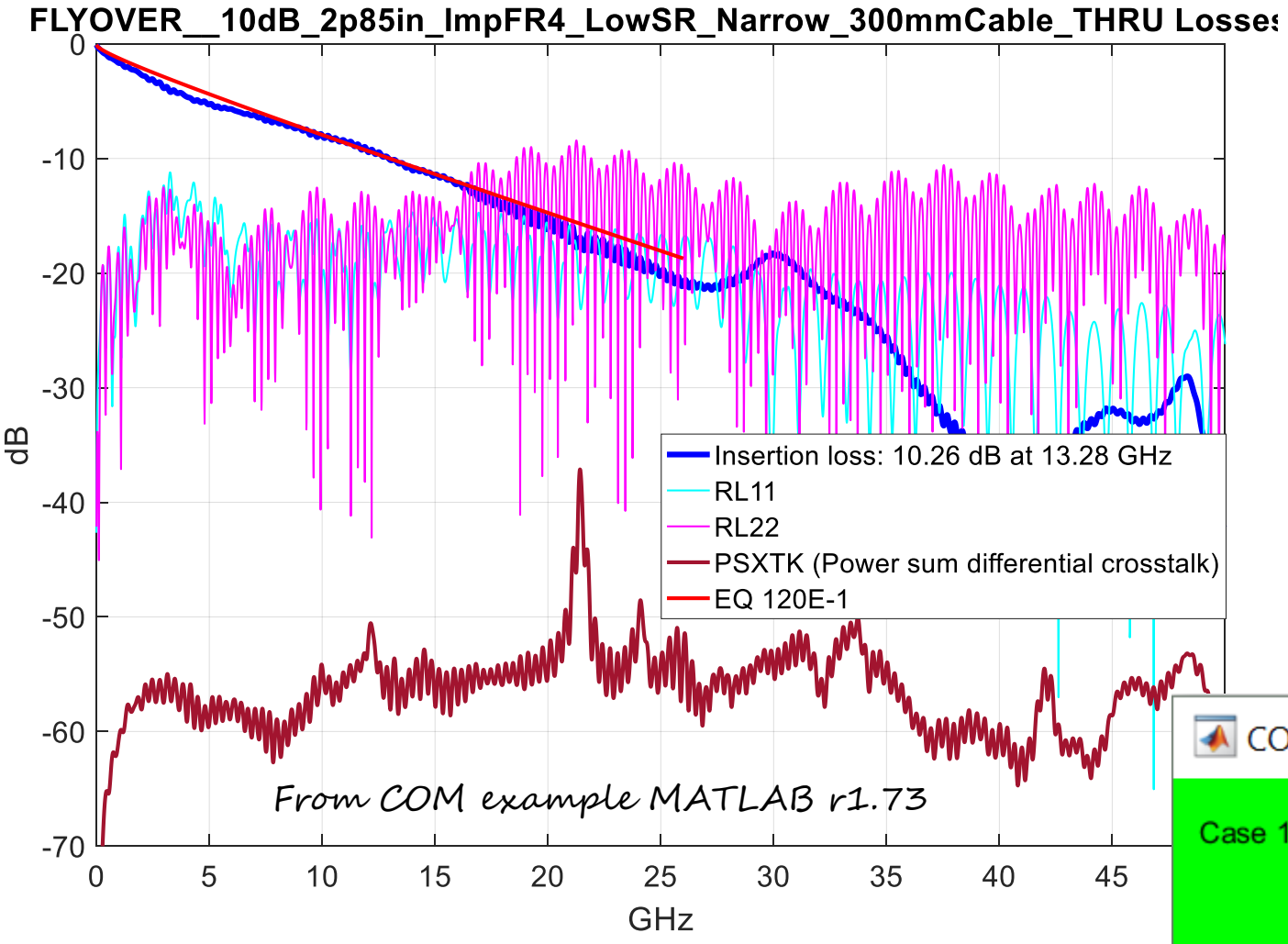
Motivated by http://www.ieee802.org/3/bs/public/16_09/healey_3bs_01_0916.pdf, http://www.ieee802.org/3/bs/public/17_03/dudek_3bs_01_0317.pdf and the D3.1 120d COM parameters

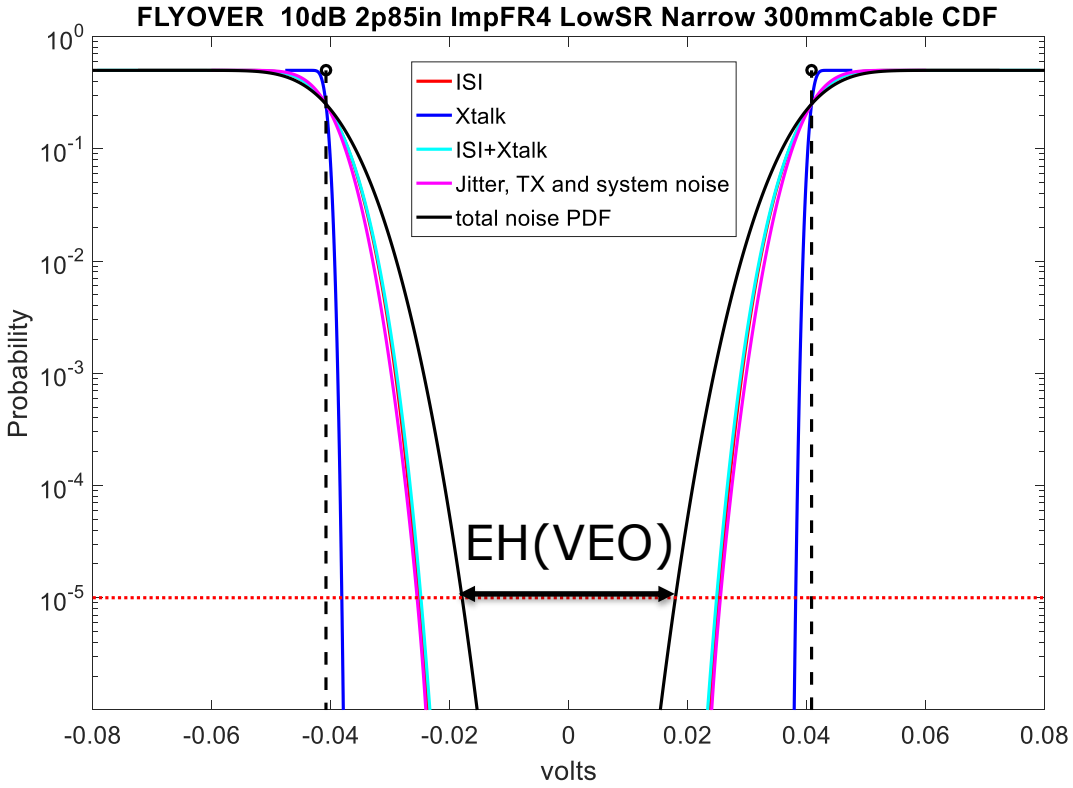
Table 93A-1 parameters			
Parameter	**Setting**	**Units**	**Information**
f_b	26.5625	GBd	
f_min	0.05	GHz	
Delta_f	0.01	GHz	
C_d	[1.8e-4 0]	nF	[TX RX]
z_p select	[1]		[test cases to run]
z_p (TX)	[12]	mm	[test cases]
z_p (NEXT)	[0]	mm	[test cases]
z_p (FEXT)	[0]	mm	[test cases]
z_p (RX)	[0]	mm	[test cases]
C_p	[0.9e-4 0]	nF	[TX RX]
R_0	50	Ohm	
R_d	[55 50]	Ohm	[TX RX]
f_r	0.75	*fb	
c(0)	0.6		min
c(-1)	[-0.15:0.05:0]		[min:step:max]
c(-2)	[0:0.025:0.1]		
c(1)	[-0.25:0.05:0]		[min:step:max]
g_DC	.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7	dB	[min:step:max]
f_z	6.155 5.733 5.353 5.007 4.	GHz	
f_p1	5 15.6 15.6 15.6 15.6 15.6 1	GHz	
f_p2	1 14.1 14.1 14.1 14.1 14.1 1	GHz	
A_v	0.45	V	
A_fe	0.45	V	
A_ne	0.63	V	
L	4		
M	32		
N_b	0	UI	
b_max(1)	0.5		
b_max(2..N_b)	0.2		
sigma_RJ	0.01	UI	
A_DD	0.02	UI	
eta_0	0.00E+00	V^2/GHz	
SNR_TX	32	dB	
R_LM	0.95		
DER_0	1.00E-05		

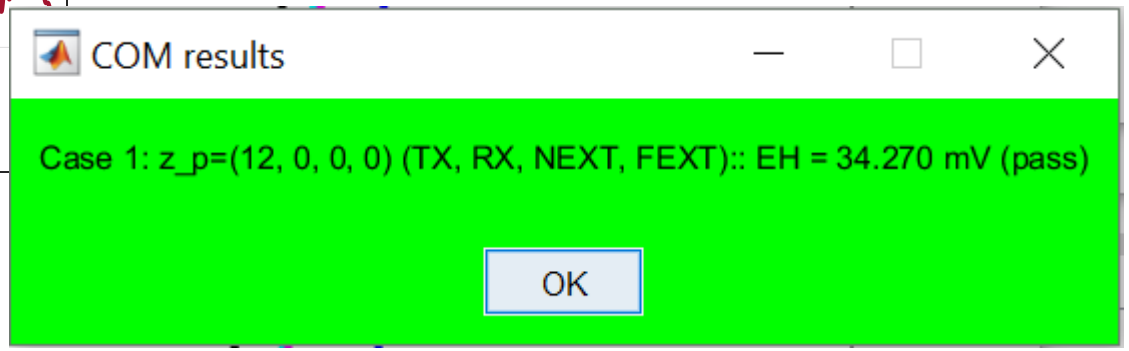
I/O control			
DIAGNOSTICS	1	logical	
DISPLAY_WINDOW	1	logical	
Display frequency domain	1	logical	
CSV_REPORT	1	logical	
RESULT_DIR	.\results\C2M_{date}\		
SAVE_FIGURES	0	logical	
Port Order	[1 3 2 4]		
RUNTAG	C2M_		
Receiver testing			
RX_CALIBRATION	0	logical	
Sigma BBN step	5.00E-03	V	
IDEAL_TX_TERM	0	logical	
T_r	1.30E-02	ns	
FORCE_TR	1	logical	
Non standard control options			
COM_CONTRIBUTION	0	logical	
TDR	0	logical	
Operational control			
COM Pass threshold	5	dB	
Include PCB	0	Value	0, 1
PHY_type	C2M		
EH_min	32	Value	EH limit
EH_max	1000	Value	EH limit
f_HP_P	2 1.2 1.2 1.2 1.2 1.2 1.2 1	GHz	
f_HP_Z	.1 1.075 1.05 1.025 1 1 1 1 1	GHz	

Table 93A–3 parameters		
Parameter	**Setting**	**Units**
package_tl_gamma0_a1_a2	[0 1.734e-3 1.455e-4]	
package_tl_tau	6.141E-03	ns/mm
package_Z_c	90	Ohm

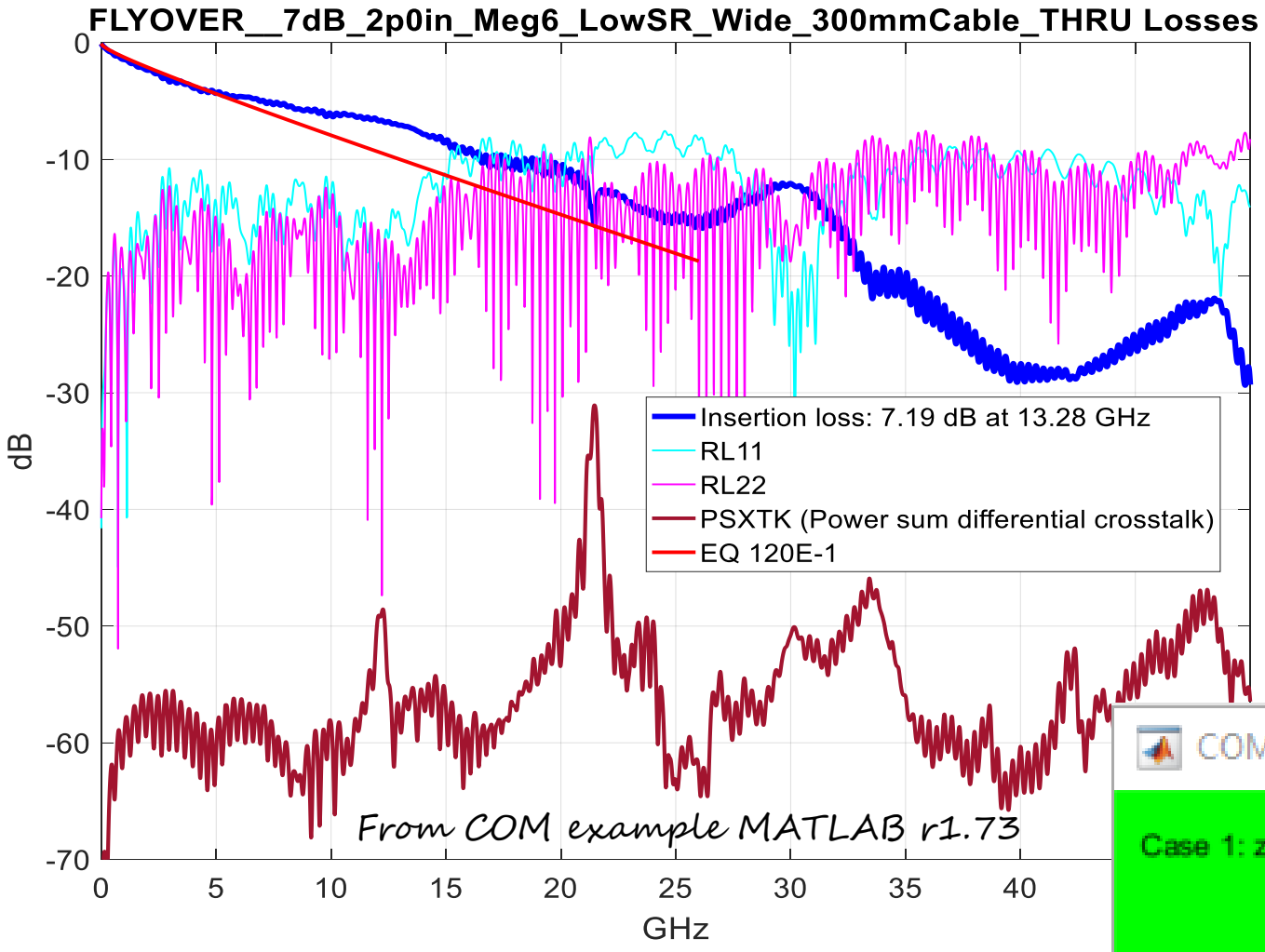
10 dB Loss Channel Seems to Have Acceptable Performance

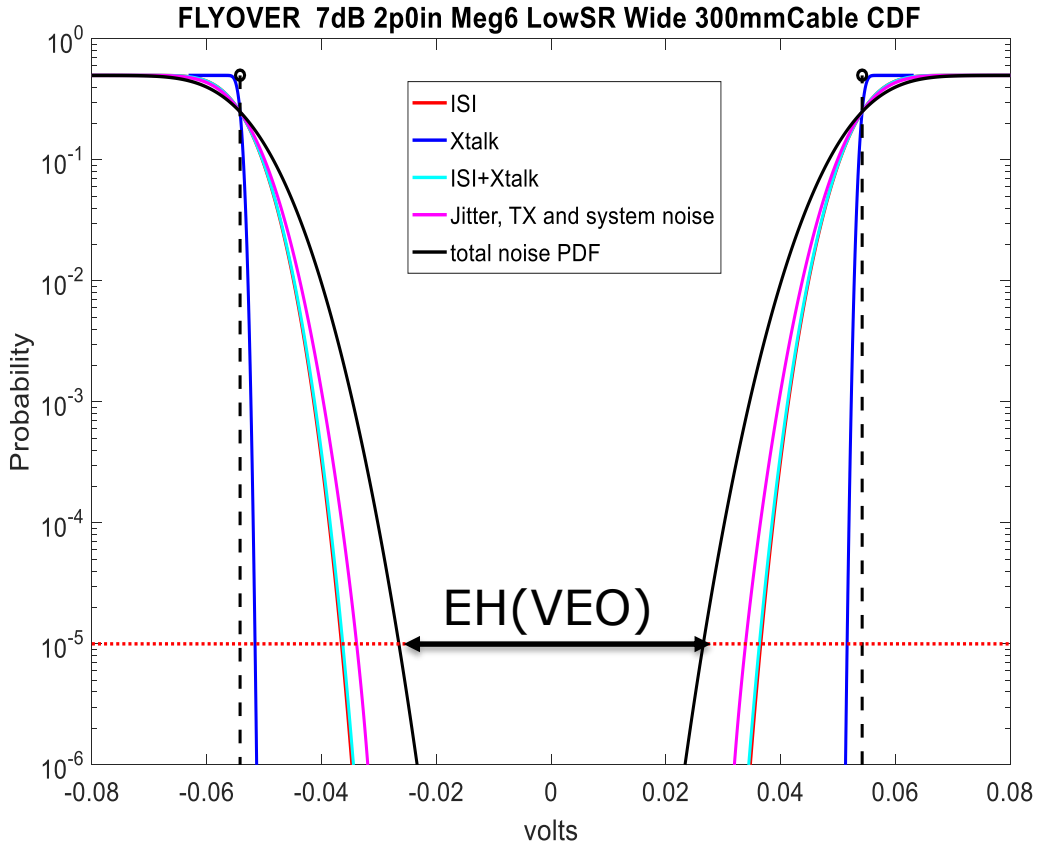


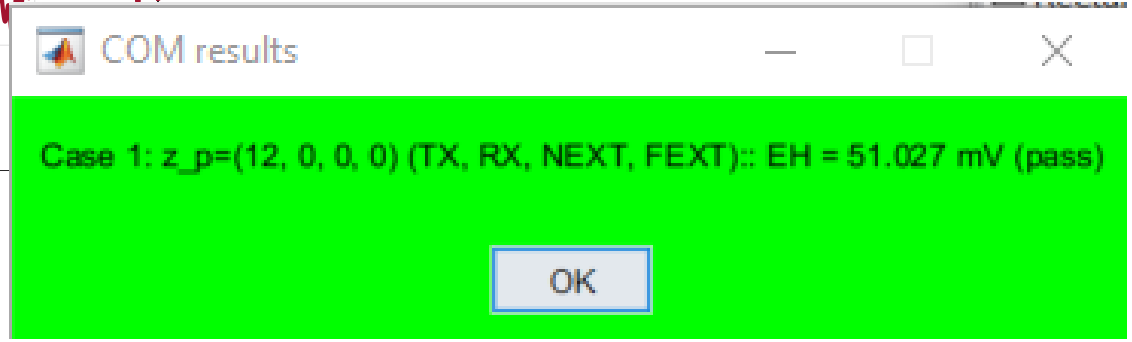




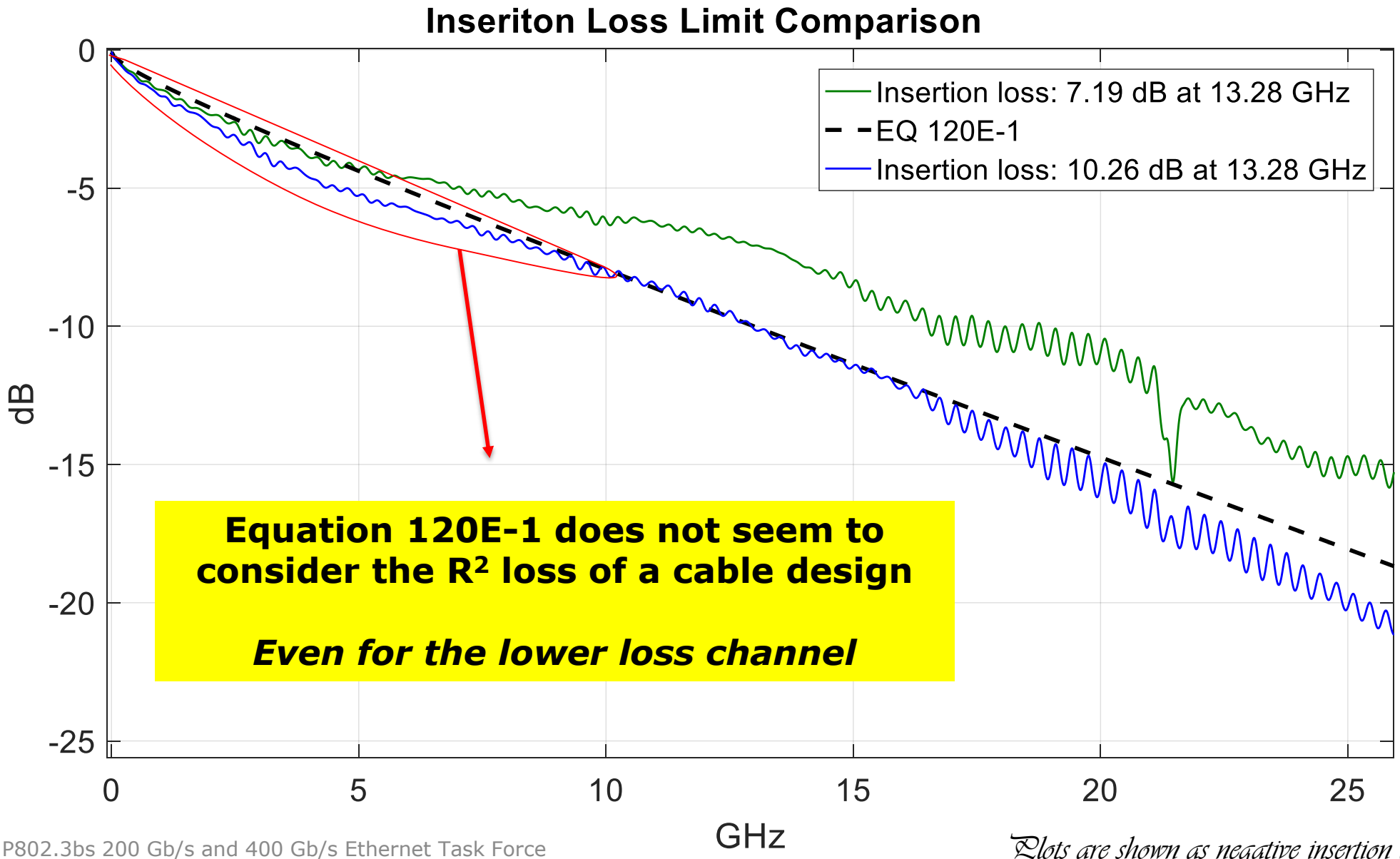
7 dB Loss Channel Seems to Have Even Better Performance







The Issue: Cable R^2 Loss Not Considered



Plots are shown as negative insertion loss

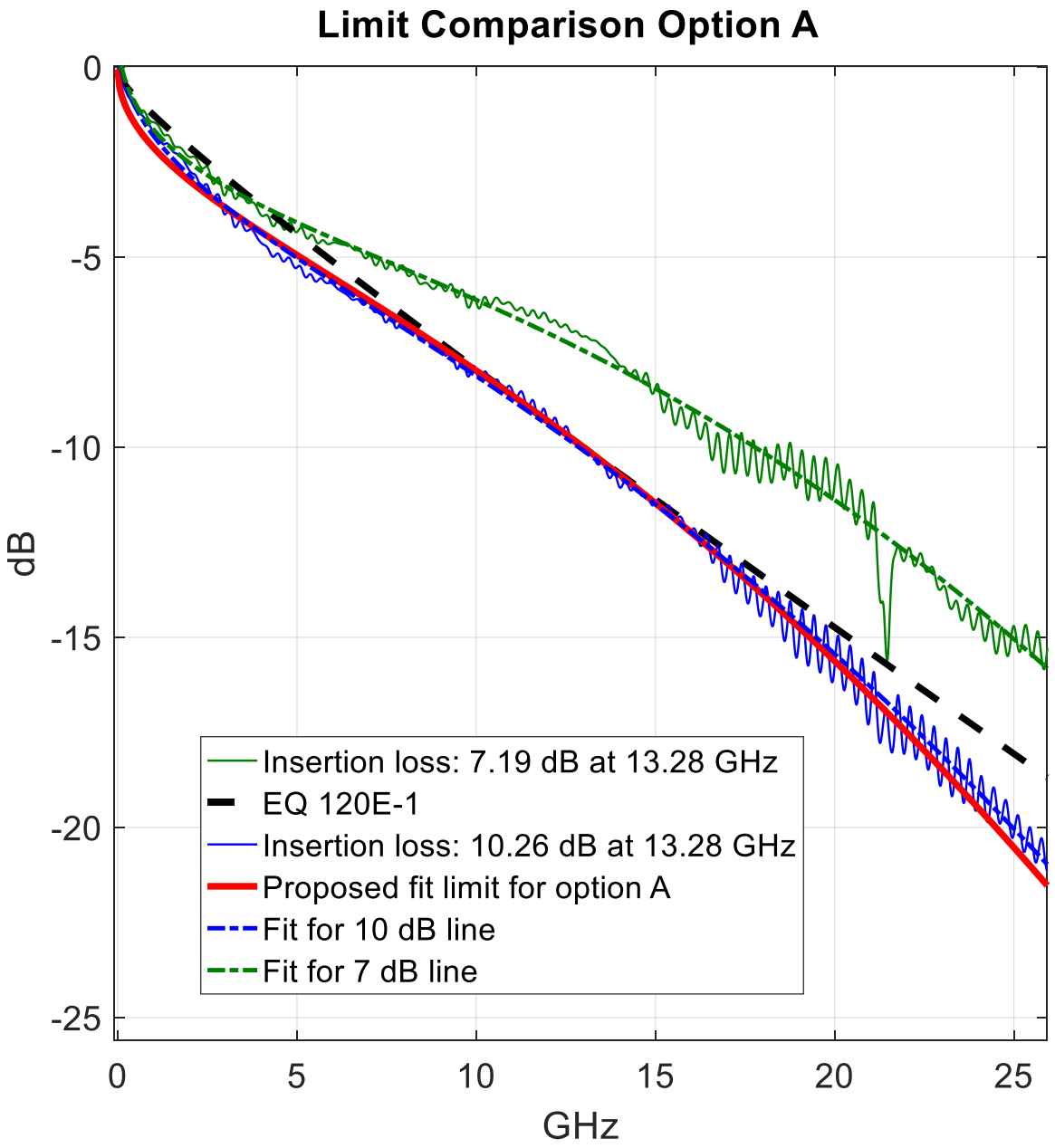
Option A

- Change equation 120E-1 to form of 93A-51 and change text to

"The supported insertion loss fit budget is characterized by Equation (120E–1) and illustrated in Figure 120E–4. " The insertion loss fit is describe in 93A.3

$$IL_{fitted}(f) = a_0 + a_1\sqrt{f} + a_2 f + a_4 f^2 \qquad \text{(93A-51)}$$

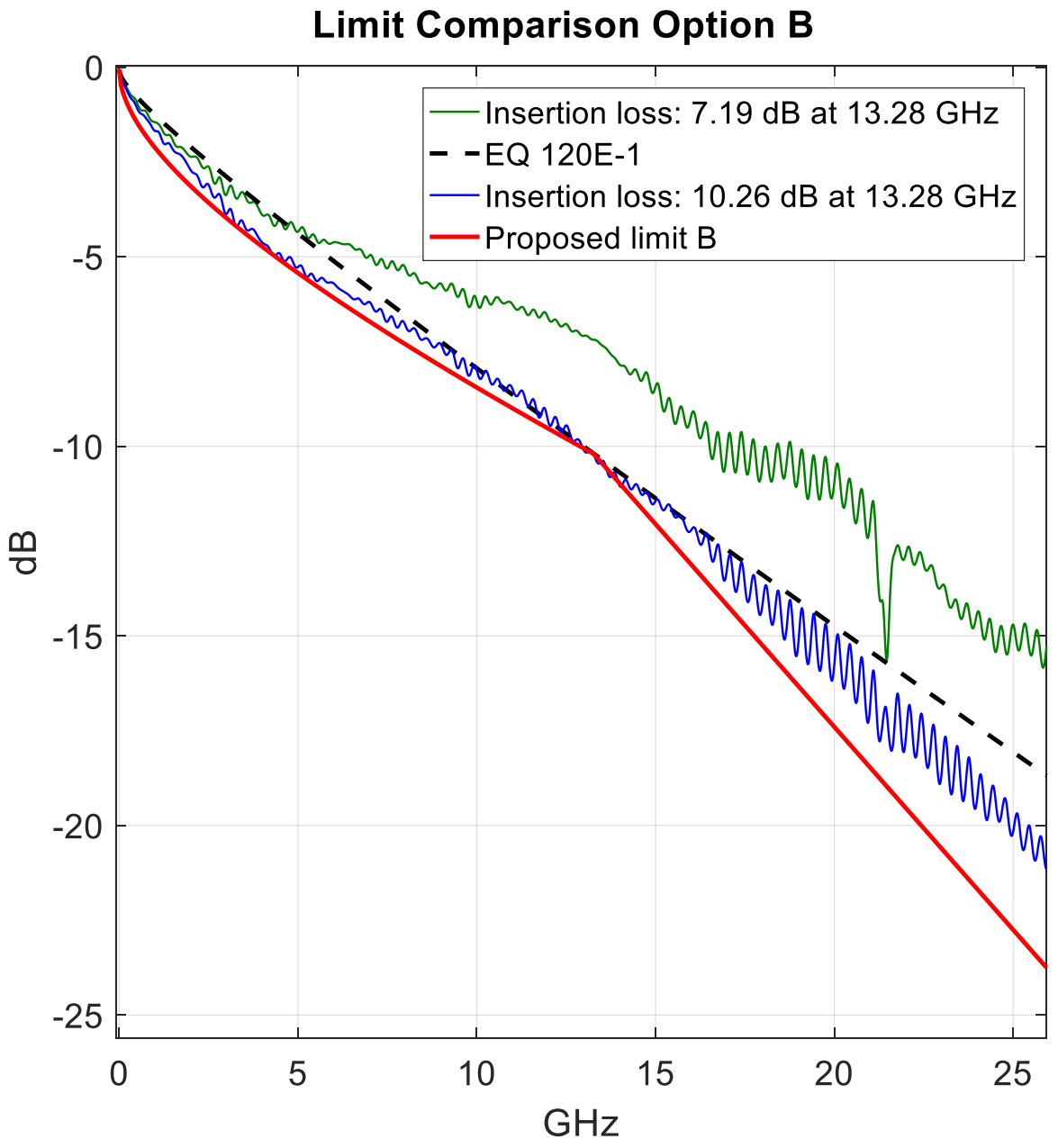
- [a0 a1 a2 a4] =
  [0.05 1.65 0.155 0.0117]



Option B

- Use a limit line which encompasses r² cable loss.

$$Insertion\_loss(f) = \begin{cases} 0.05 + 1.8\sqrt{f} + 0.2705f \ \ (dB) & f \leq 13.28 \\ -4.0096 + 1.07f \ \ (dB) & f > 13.28 \end{cases}$$



Option C

- Add words to the effect that cable designs may not have to meet the low frequency masks
- Maybe something like:
  - Change
    - "The supported insertion loss budget is characterized by Equation (120E–1) and illustrated in Figure 120E–4. "
  - To
    - "The supported insertion loss budget is characterized by Equation (120E–1) and illustrated in Figure 120E–4. However some designs using low loss material such as twin axial cable may dip below the line characterized by Equation 120E-1. Any design that meets the Transmitter and Receiver specifications given in sections 120E-2 to 120E-4 is acceptable."

Summary

- Flyover twin axial cable chip to module channel models provided for further analysis
- Broaden chip to module potential market applications to include twin axial cable
  - Choose from Option A, B, or C
- Recommendation: Option B
  - Use a limit line which encompasses r^2 cable loss and a wider range of applications

Files and Naming

mellitz_3bs_01_041817.zip Tag name: 10 dB C2M Flyover tp0-tp2 channel

```
FLYOVER__7dB_2p0in_Meg6_LowSR_Wide_300mmCable_FEXT_1.s4p
FLYOVER__7dB_2p0in_Meg6_LowSR_Wide_300mmCable_FEXT_2.s4p
FLYOVER__7dB_2p0in_Meg6_LowSR_Wide_300mmCable_FEXT_3.s4p
FLYOVER__7dB_2p0in_Meg6_LowSR_Wide_300mmCable_FEXT_4.s4p
FLYOVER__7dB_2p0in_Meg6_LowSR_Wide_300mmCable_FEXT_5.s4p
FLYOVER__7dB_2p0in_Meg6_LowSR_Wide_300mmCable_FEXT_6.s4p
FLYOVER__7dB_2p0in_Meg6_LowSR_Wide_300mmCable_THRU.s4p
```

mellitz_3bs_02_041817.zip Tag name: 7 dB C2M Flyover tp0-tp2 channel

```
FLYOVER__10dB_2p85in_ImpFR4_LowSR_Narrow_300mmCable_FEXT_1.s4p
FLYOVER__10dB_2p85in_ImpFR4_LowSR_Narrow_300mmCable_FEXT_2.s4p
FLYOVER__10dB_2p85in_ImpFR4_LowSR_Narrow_300mmCable_FEXT_3.s4p
FLYOVER__10dB_2p85in_ImpFR4_LowSR_Narrow_300mmCable_FEXT_4.s4p
FLYOVER__10dB_2p85in_ImpFR4_LowSR_Narrow_300mmCable_FEXT_5.s4p
FLYOVER__10dB_2p85in_ImpFR4_LowSR_Narrow_300mmCable_FEXT_6.s4p
FLYOVER__10dB_2p85in_ImpFR4_LowSR_Narrow_300mmCable_FEXT_7.s4p
FLYOVER__10dB_2p85in_ImpFR4_LowSR_Narrow_300mmCable_THRU.s4p
```