Examples of C2C Channels With Impairments
10dB 16dB 18dB 20dB Test Cases

September 9th, 2019

Rick Rabinovich

KEYSIGHT
TECHNOLOGIES

C2C Channels With Impairments

Supporters

Richard Mellitz	SAMTEC
Brandon Gore	SAMTEC
Phil Sun	CREDO

C2C Channels With Impairments

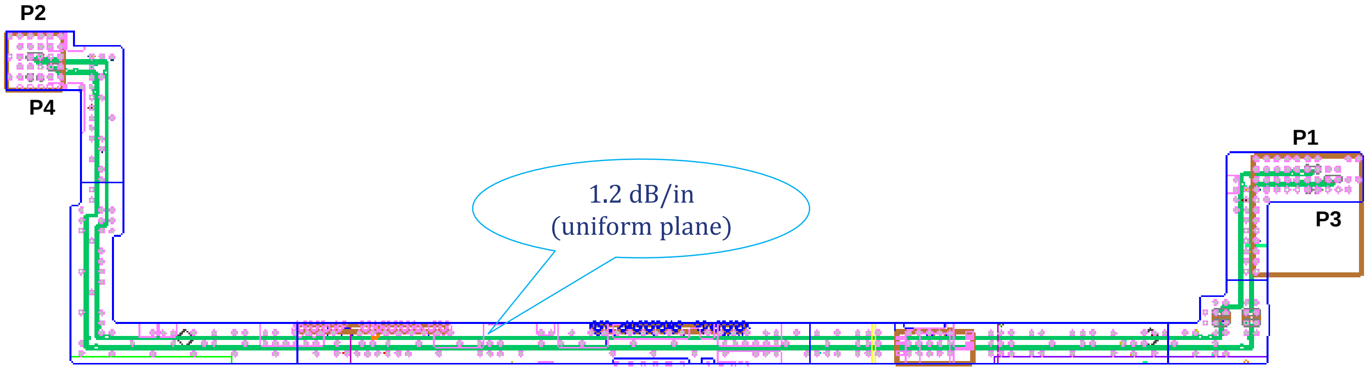
Examples of Channels with Impairments (Obstacles)

Perfect routing ideal scenario example vs. "actual" optimum routing

Set the specification based on a real "engineered (optimized)" channel rather than on an "ideal" channel

- Two-channel adaptation with AC coupling (~ connector)
- Dielectric similar to Megtron 7
- "Engineered Channel"

- Impairments:
  - Impedance tolerance
    - Z_{nom} ~ 94 ohms
  - Complex chip breakouts
  - Long and short via stripline mix
    - 105 mils (0.5 dB/via)
    - 22 mils (0.4 dB/via)
  - Six 90^{o} turns
    - Routing on grid
  - Asymmetric via distribution along the route



C2C Channels With Impairments

Introduction – Applicable to this Channel Set

Analyze four test IL cases:

10dB 16dB 18dB 20dB

Myth: "FEXT increases with trace length"

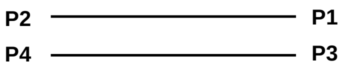
- Yes, **ONLY** if the traces coupled, otherwise
- Coupling occurs **MOSTLY** at the destination

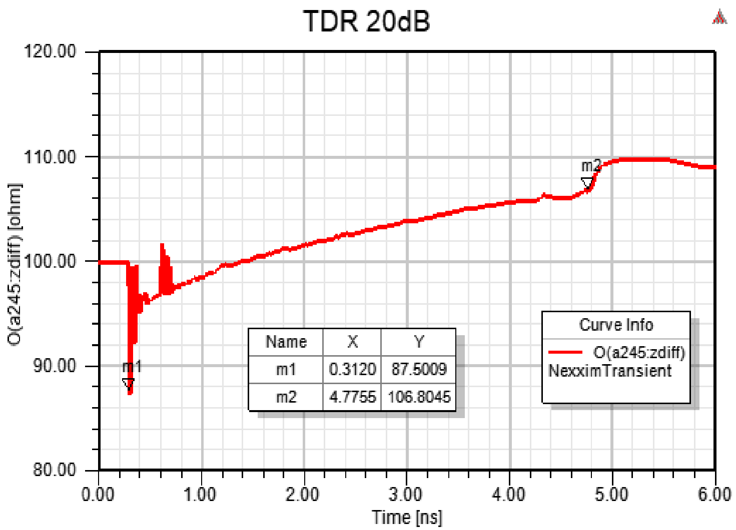
Verify: "NEXT is independent of trace length (and IL)"

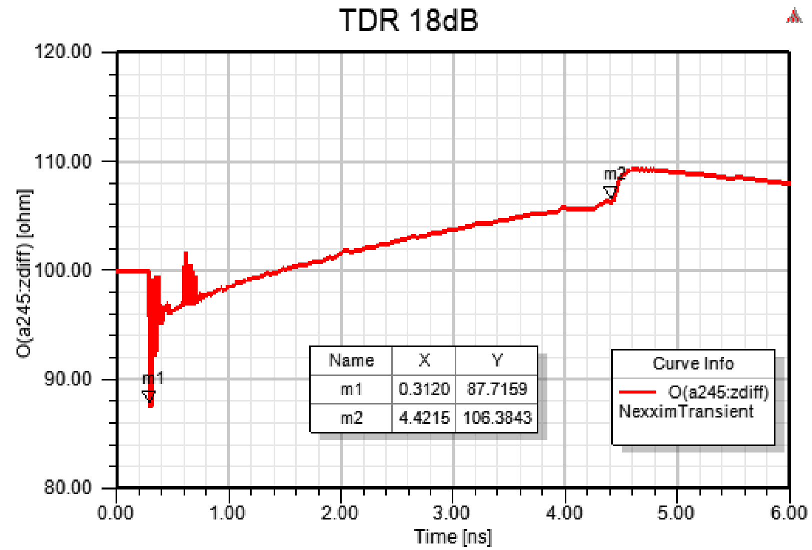
Observation: "RL is not too sensitive to channel length on long channels (> 7")

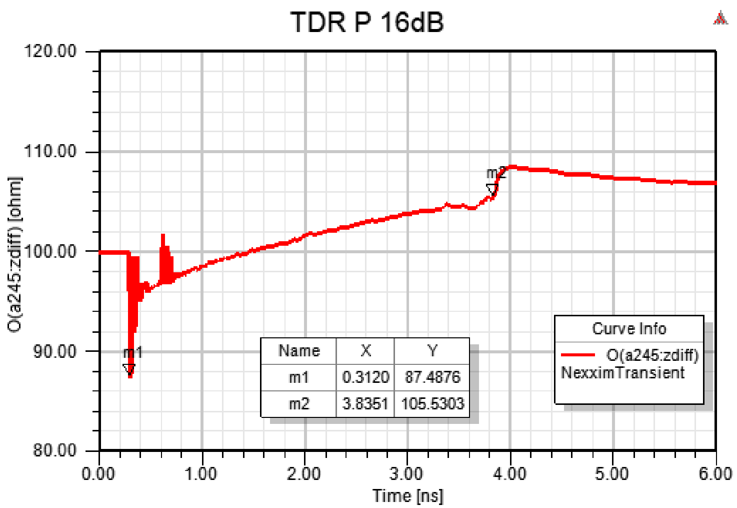
C2C Channels With Impairments

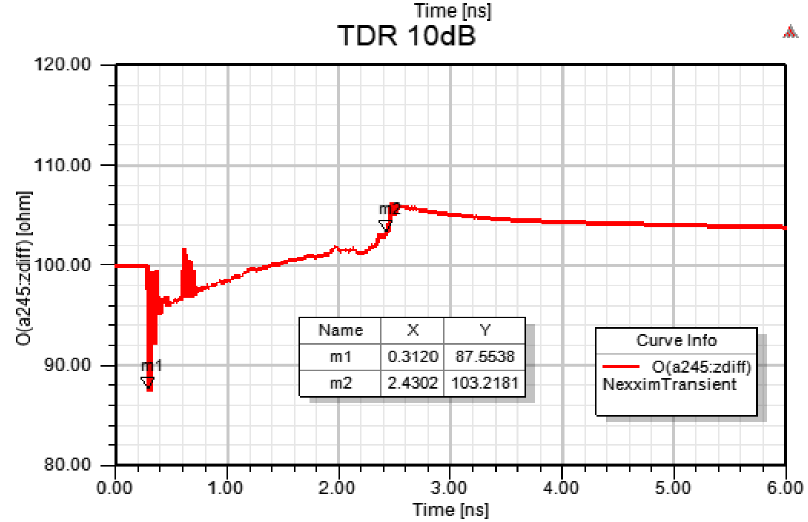
TDR – "Engineered Channel"





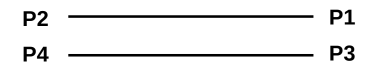


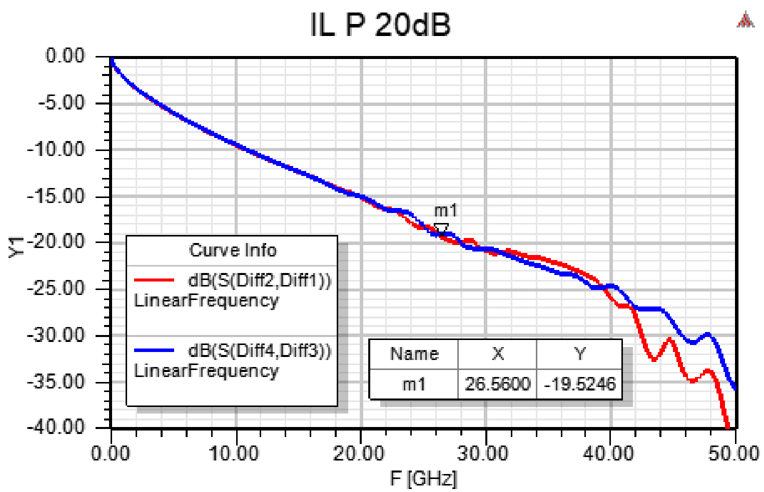


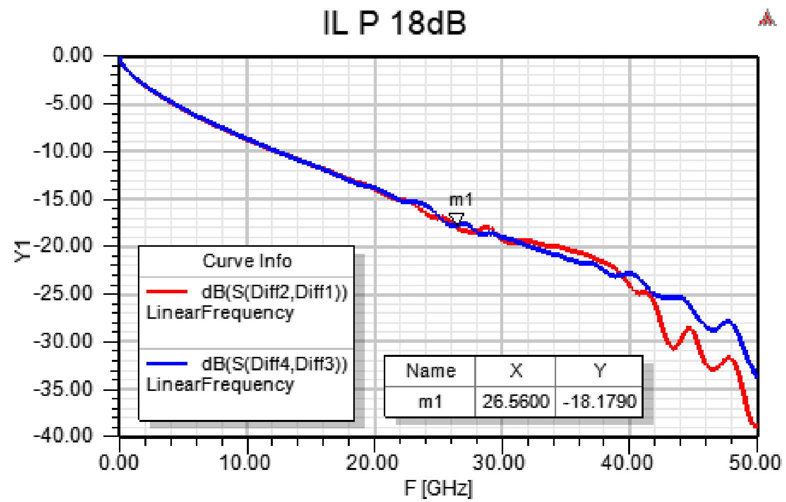


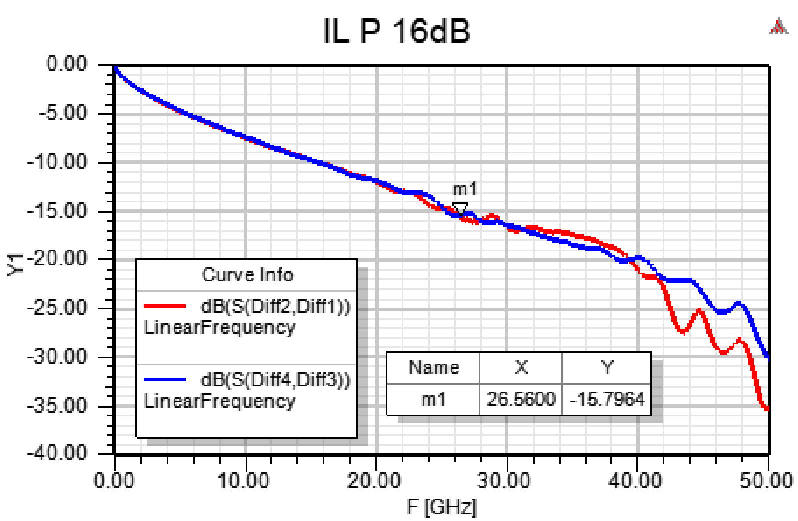
C2C Channels With Impairments

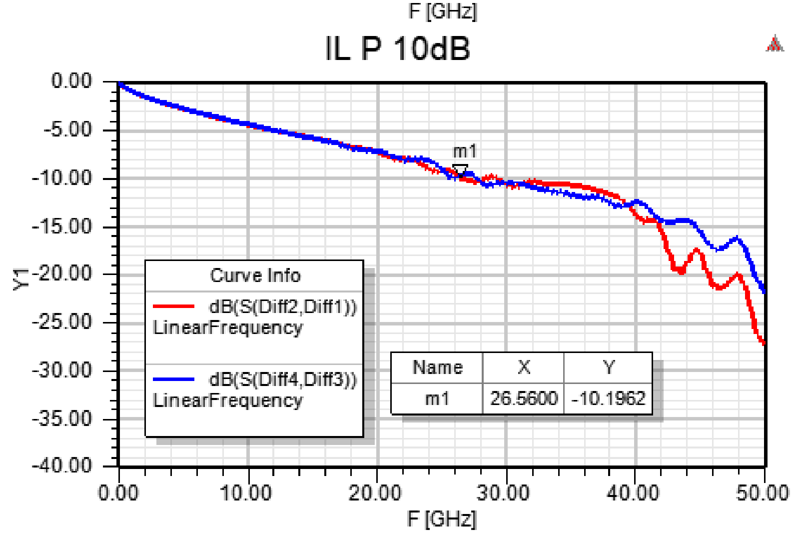
IL – "Engineered Channel"











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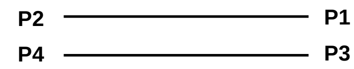
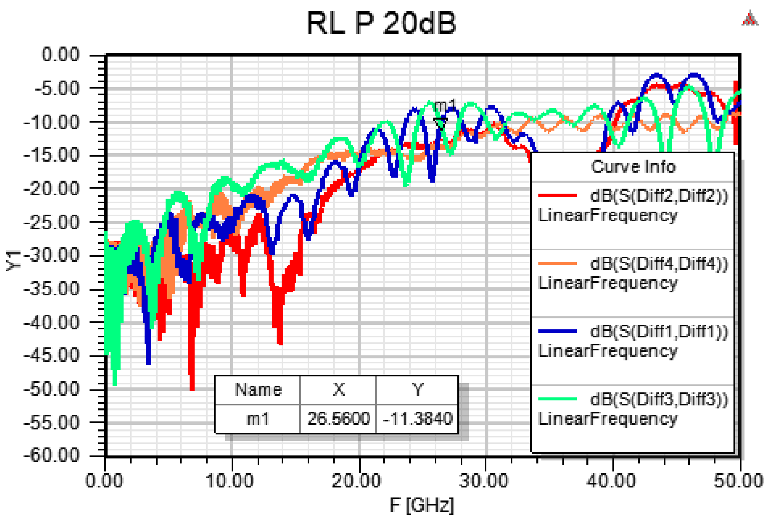
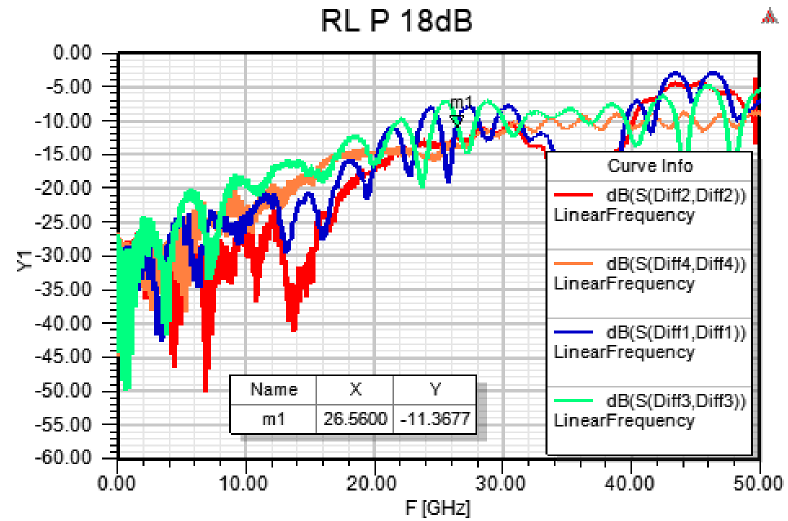
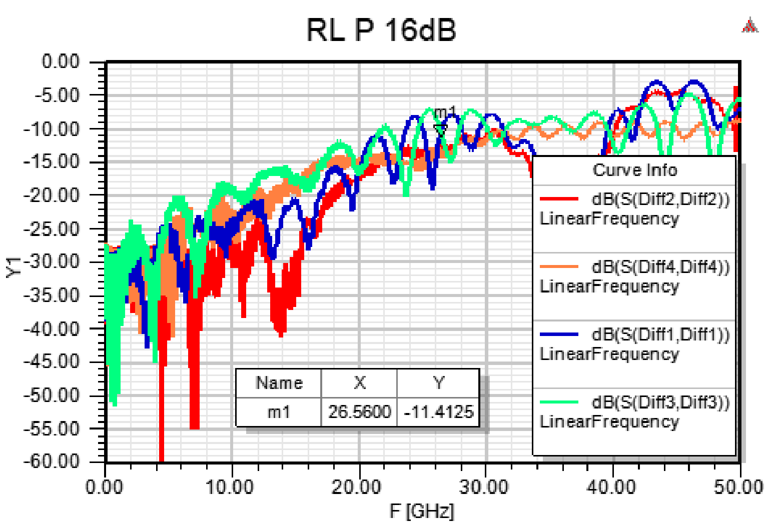
C2C Channel With Impairments

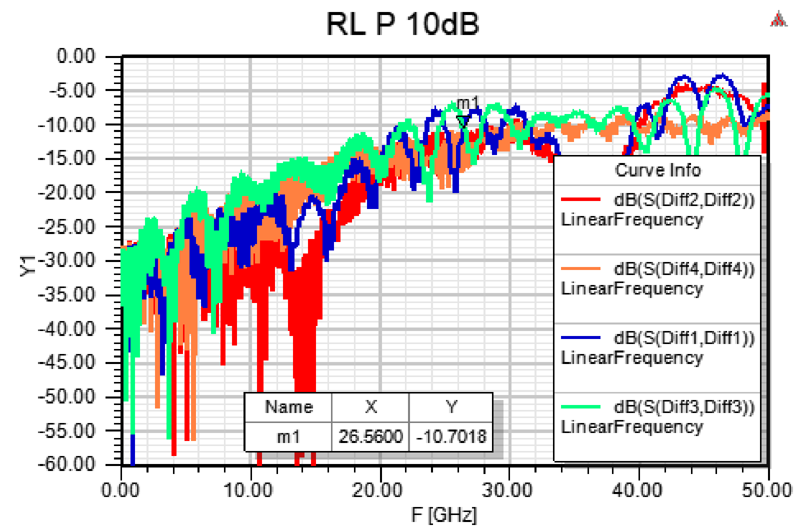
RL





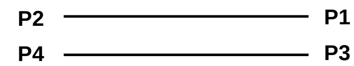




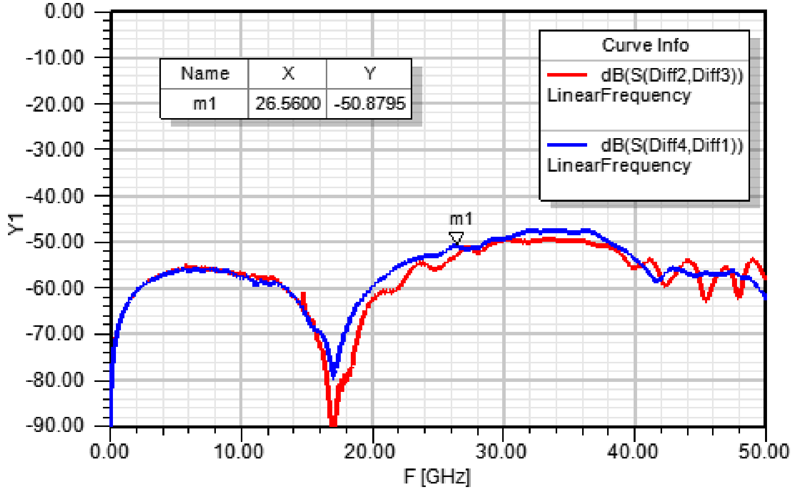


C2C Channels With Impairments

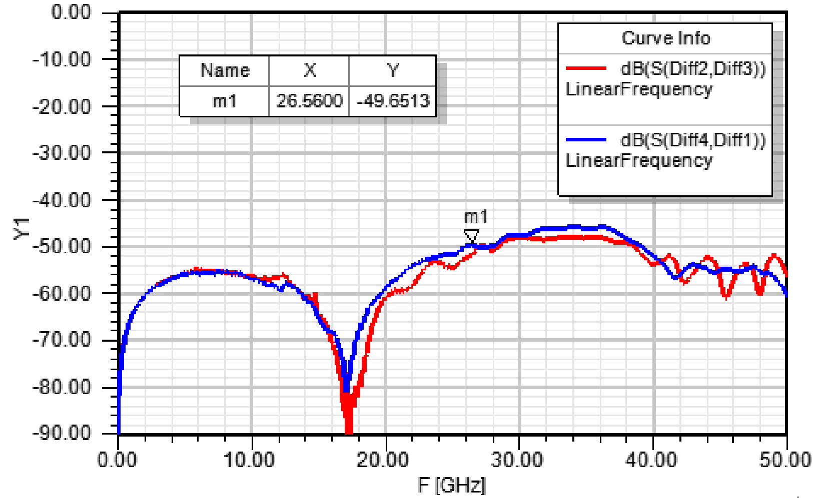
FEXT



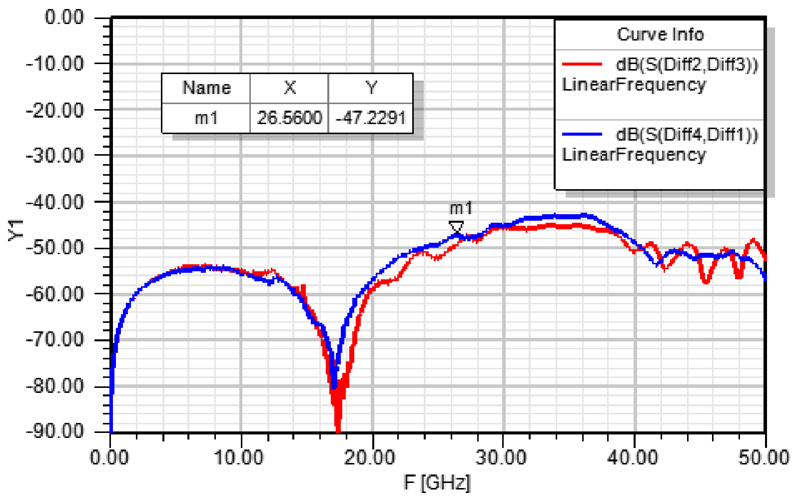
FEXT P 20dB



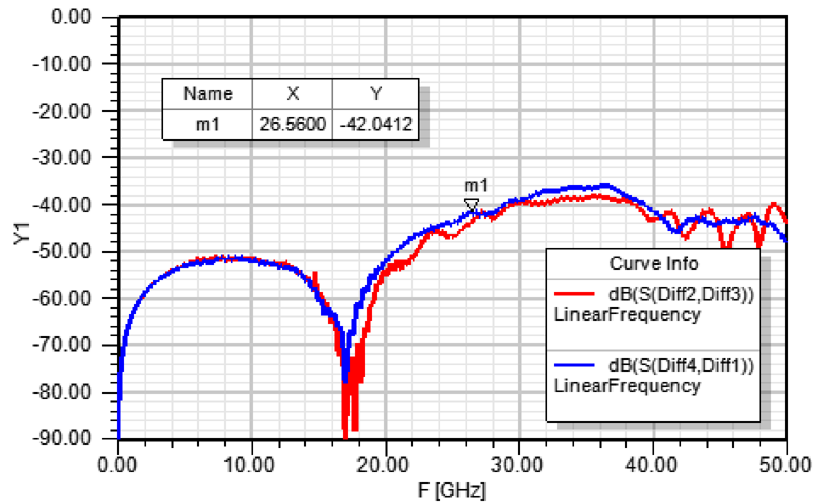
FEXT P 18dB



FEXT P 16dB



FEXT P 10dB



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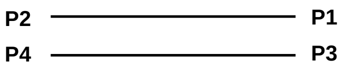
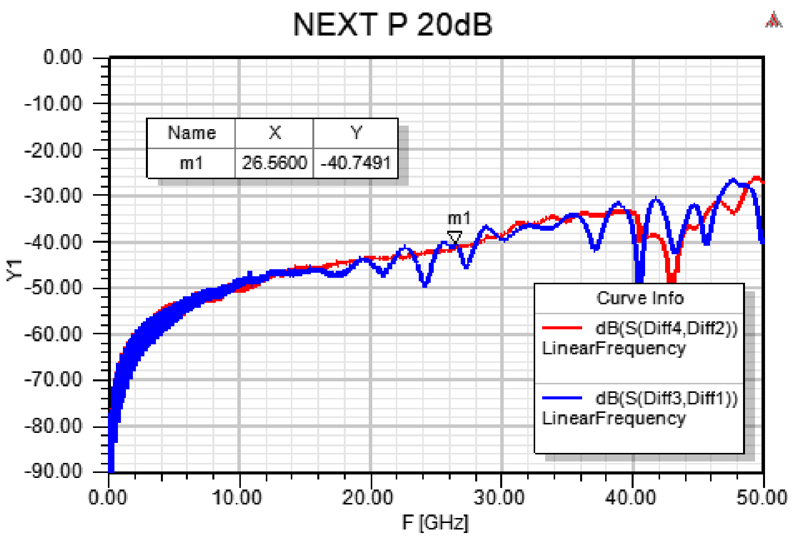
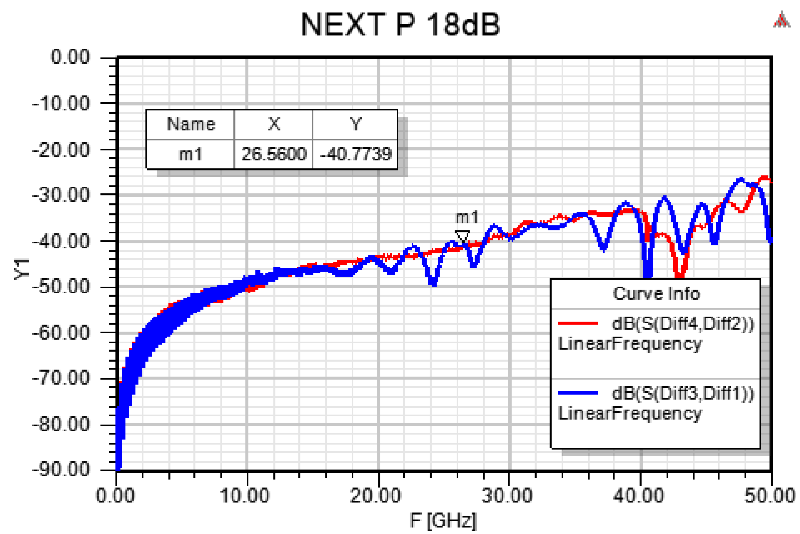
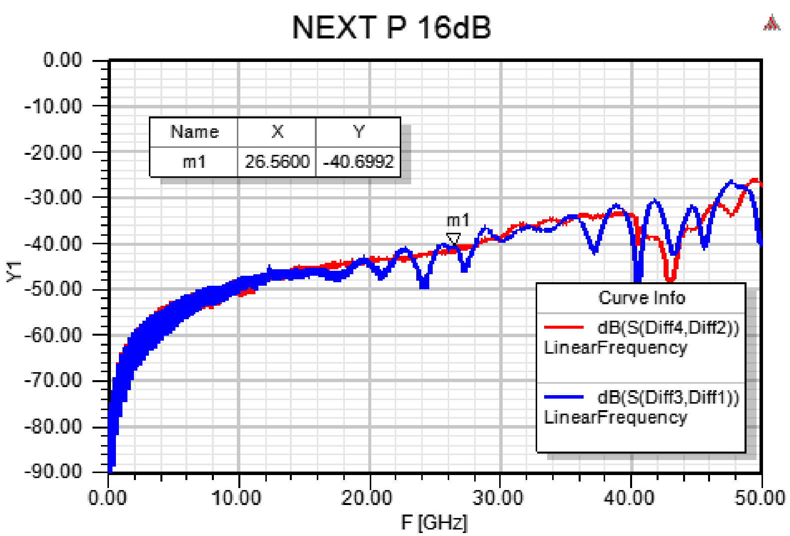
C2C Channels With Impairments

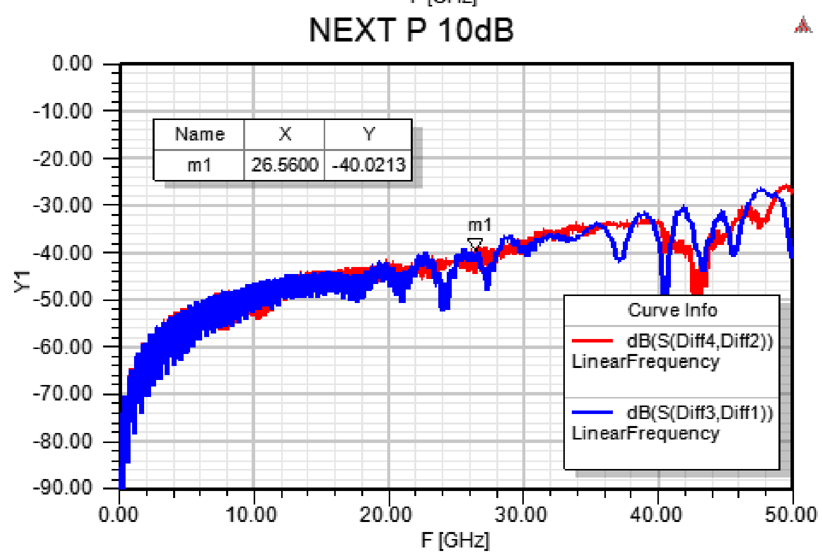
NEXT











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C2C Channels With Impairments

Observations – Applicable to this Channel Set

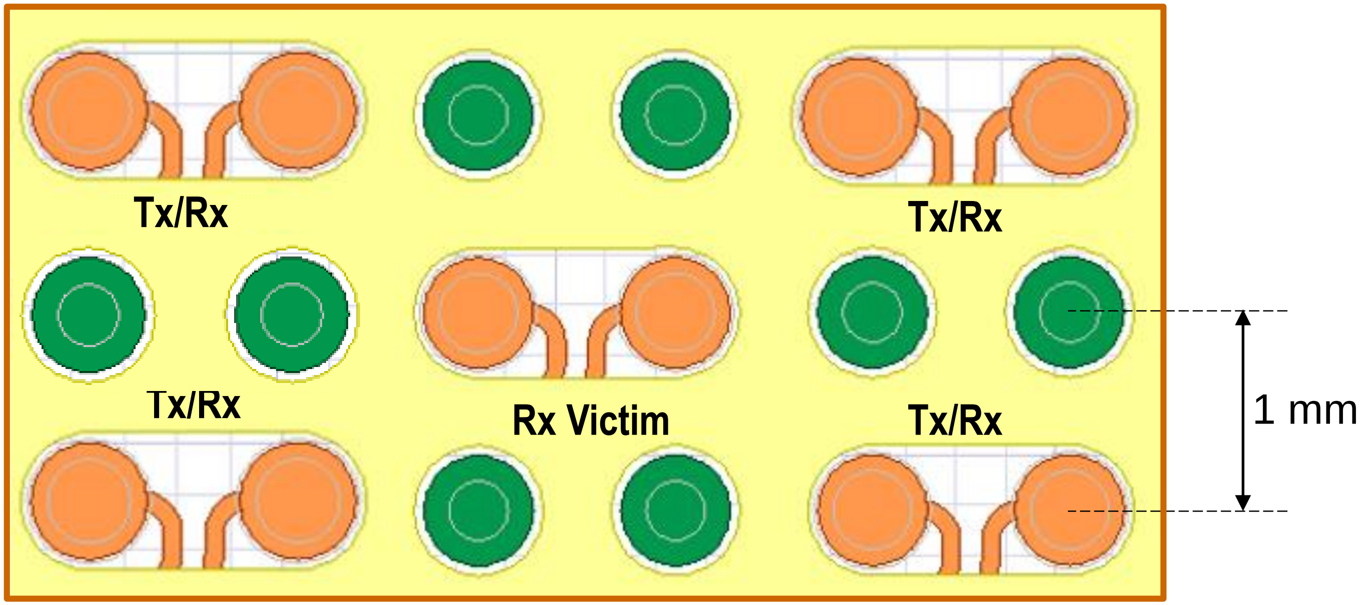
1. FEXT decay tracks IL (uncoupled differential pairs)
    1. COM (S/N) insensitive to FEXT for variable trace length
        1. Signal and FEXT decreased at about the same rate

2. NEXT is independent of IL
    1. Signal decay with invariable NEXT => COM very sensitive to NEXT for variable trace length

3. Return Loss is independent of IL (statement valid up to minimum length of 6.75")

C2C Channels With Impairments

Chip Footprint



FEXT: Rx → Rx Victim
NEXT: Tx → Rx Victim

C2C Channels With Impairments

COM Results & Analysis

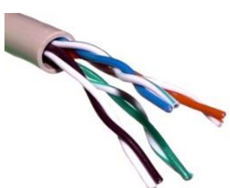
P2 ——— P1

COM								
	N_b = 12		b_max(1) = 0.85		b_max(2..N_b) = 0.3			
Nominal	10 dB		16 dB		18 dB		20 dB	
(1) Length	6.76 in (172 mm)		11.5 in (292 mm)		13.48 in (342 mm)		14.68 in (373 mm)	
IL (measured)	10.20 dB		15.80 dB		18.18 dB		19.52 dB	
FEXT/NEXT	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
0/0	6.13	6.15	6.62	6.14	6.41	5.65	6.21	5.58
3/0	5.70	5.85	6.27	5.87	6.10	5.42	5.92	5.37
3/1	5.12	5.26	4.95	4.63	4.24	3.85	3.75	3.52
2/2	4.74	4.82	3.96	3.73	2.96	2.76	2.35	2.26
3/2	4.66	4.82	3.91	3.68	2.92	2.71	2.31	2.21
3/3	4.24	4.44	3.12	2.91	1.93	1.84	1.17	1.19
3/4	3.85	4.09	2.46	2.26	1.10	1.07	0.36	0.34

(1) Glass weave and manufacturing variability are not included in simulation and could cause degradation of the reach

FEXT/NEXT (3/4) Ratio Precedence:

- 2006 - IEEE802.3an (aka 10 GBASE-T)
- Ratio applied to 100m 4-pair twisted cable



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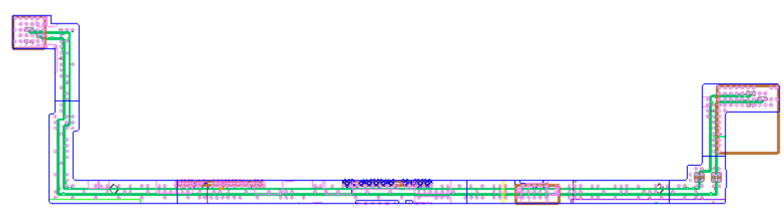

Is the (3/4) ratio applicable for C2C (and other .ck objectives)? Too conservative?

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C2C Channels With Impairments

COM & ICN Results

P2 —— P1

COM								
	N_b = 5		b_max(1) = 0.85		b_max(2..N_b) = 0.2			
Nominal	10 dB		16 dB		18 dB		20 dB	
Length	6.76 in (172 mm)		11.5 in (292 mm)		13.48 in (342 mm)		14.68 in (373 mm)	
IL (measured)	10.20 dB		15.80 dB		18.18 dB		19.52 dB	
FEXT/NEXT	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
0/0	3.91	5.42	3.51	5.32	3.41	5.16	3.41	4.97
3/0	3.66	5.00	3.25	4.99	3.17	4.87	3.17	4.72
4/0	3.58	4.87	3.16	4.88	3.10	4.78	3.10	4.66
3/1	3.25	4.39	2.16	3.62	1.63	3.11	1.37	2.84
	N_b = 5		b_max(1) = 0.85		b_max(2..N_b) = 0.3			
3/1	3.25	4.39	2.16	3.62	1.63	3.11	1.37	2.84
	N_b = 5		b_max(1) = 0.75		b_max(2..N_b) = 0.2			
4/0	3.58	4.87	3.16	4.88	3.10	4.78	3.10	4.67

ICN								
	N_b = 5		b_max(1) = 0.85		b_max(2..N_b) = 0.2			
Nominal	10 dB		16 dB		18 dB		20 dB	
Length	6.76 in (172 mm)		11.5 in (292 mm)		13.48 in (342 mm)		14.68 in (373 mm)	
IL (measured)	10.20 dB		15.80 dB		18.18 dB		19.52 dB	
FEXT/NEXT	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
0/0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3/0	3.02	3.02	1.59	1.59	1.24	1.24	1.08	1.08
4/0	3.48	3.48	1.83	1.83	1.43	1.43	1.25	1.25
3/1	4.52	4.52	3.68	3.68	3.54	3.54	3.48	3.48
	N_b = 5		b_max(1) = 0.85		b_max(2..N_b) = 0.3			
3/1	4.52	4.52	3.68	3.68	3.54	3.54	3.48	3.48
	N_b = 5		b_max(1) = 0.75		b_max(2..N_b) = 0.2			
4/0	3.48	3.48	1.83	1.83	1.43	1.43	1.25	1.25

COM								
	N_b = 7		b_max(1) = 0.85		b_max(2..N_b) = 0.2			
Nominal	10 dB		16 dB		18 dB		20 dB	
Length	6.76 in (172 mm)		11.5 in (292 mm)		13.48 in (342 mm)		14.68 in (373 mm)	
IL (measured)	10.20 dB		15.80 dB		18.18 dB		19.52 dB	
FEXT/NEXT	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
0/0	4.10	5.78	4.01	5.42	3.78	5.19	3.72	5.05
3/0	3.84	5.46	3.77	5.10	3.55	4.90	3.49	4.79
4/0	3.76	5.36	3.69	4.99	3.47	4.81	3.41	4.72
3/1	3.41	4.86	2.72	3.80	2.10	3.24	1.76	2.89
	N_b = 7		b_max(1) = 0.85		b_max(2..N_b) = 0.3			
3/1	3.41	4.96	2.68	3.80	2.29	3.24	1.88	2.89

ICN								
	N_b = 7		b_max(1) = 0.85		b_max(2..N_b) = 0.2			
Nominal	10 dB		16 dB		18 dB		20 dB	
Length	6.76 in (172 mm)		11.5 in (292 mm)		13.48 in (342 mm)		14.68 in (373 mm)	
IL (measured)	10.20 dB		15.80 dB		18.18 dB		19.52 dB	
FEXT/NEXT	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
0/0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3/0	3.02	3.02	1.59	1.59	1.24	1.24	1.08	1.08
4/0	3.48	3.48	1.83	1.83	1.43	1.43	1.25	1.25
3/1	4.52	4.52	3.68	3.68	3.54	3.54	3.48	3.48
	N_b = 7		b_max(1) = 0.85		b_max(2..N_b) = 0.3			
3/1	4.52	4.52	3.68	3.68	3.54	3.54	3.48	3.48

COM								
	N_b = 4		b_max(1) = 0.75		b_max(2..N_b) = 0.2			
Nominal	10 dB		16 dB		18 dB		20 dB	
Length	6.76 in (172 mm)		11.5 in (292 mm)		13.48 in (342 mm)		14.68 in (373 mm)	
IL (measured)	10.20 dB		15.80 dB		18.18 dB		19.52 dB	
FEXT/NEXT	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
0/0	3.46	5.16	3.38	5.24	3.30	5.16	3.36	4.97
3/0	3.18	4.71	3.07	4.93	3.05	4.87	3.11	4.72
4/0	3.10	4.57	2.98	4.82	2.96	4.76	3.02	4.66
3/1	2.76	4.05	1.93	3.53	1.48	3.07	1.24	2.83
	N_b = 4		b_max(1) = 0.85		b_max(2..N_b) = 0.2			
4/0	3.10	4.57	2.98	4.82	2.96	4.76	3.02	4.66

ICN								
	N_b = 4		b_max(1) = 0.75		b_max(2..N_b) = 0.2			
Nominal	10 dB		16 dB		18 dB		20 dB	
Length	6.76 in (172 mm)		11.5 in (292 mm)		13.48 in (342 mm)		14.68 in (373 mm)	
IL (measured)	10.20 dB		15.80 dB		18.18 dB		19.52 dB	
FEXT/NEXT	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
0/0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3/0	3.02	3.02	1.59	1.59	1.24	1.24	1.08	1.08
4/0	3.48	3.48	1.83	1.83	1.43	1.43	1.25	1.25
3/1	4.52	4.52	3.68	3.68	3.54	3.54	3.48	3.48
	N_b = 4		b_max(1) = 0.85		b_max(2..N_b) = 0.2			
	3.48	3.48	1.83	1.83	1.43	1.43	1.25	1.25

C2C Channels With Impairments

Rx Configuration Summary and Polls

Keep Tx isolated from Rx ←

- ✓ Passing COM for up to IL=20dB with 4 FEXTs
  - N_b = 5
  - b_max(1) = 0.75
  - bmax(2..N_b) = 0.2

From the unapproved minutes P802.3ck Task Force July 16-18 2019, Vienna

Straw Poll #5:
I would support the proposed C2C "no FEC termination" parameters in lusted_3ck_02_0719, slide 10 as an initial target for investigation
Y: 43 , N: 0 , A: 5

Straw Poll #6:
I would support continuing to explore another C2C case (appx 26-28 dB IL and segmented FEC) in addition to the C2C "no FEC termination" from Straw Poll #5
Y: 6 , N: 22 , A: 12

C2C Channels With Impairments

Summary

To reach a broad market potential we need:

1. Good Engineering Practices:
    - Engineer the channel, i.e., trace geometries, material selection, stackup definition, antipads, via diameter, stubs, breakouts, etc.
    - Engineer the connector including footprint
    - Engineer the chip footprint ←
        - Provide sufficient number of ground returns
        - Keep adequate separation between TXs and RXs
2. TF Straw Poll Guidance:
    - Support for C2C with “no FEC termination”
    - No support for IL ~ 26-28 dB and segmented FEC
3. Define the C2C channel to cover the highest percentage of applications.
4. It has been shown that a **20 dB channel** with impairments satisfies a 3 dB COM

Recommendation:

Support a single C2C reach with no FEC termination

- Normative: COM
- Informative: channel reach to be IL=20 dB @ 26.56 GHz

Q & A

C2C Channels With Impairments

COM Configuration Table

Table 93A-1 parameters			
Parameter	**Setting**	**Units**	**Information**
f_b	53.125	GBd	
f_min	0.05	GHz	
Delta_f	0.01	GHz	
C_d	[1.2e-4 1.2e-4]	nF	[TX RX]
L_s	[0.12, 0.12]	nH	[TX RX]
C_b	[0.3e-4 0.3e-4]	nF	[TX RX]
z_p select	[1 2]		[test cases to run]
z_p (TX)	[12 31; 1.8 1.8]	mm	[test cases]
z_p (NEXT)	[12 29; 1.8 1.8]	mm	[test cases]
z_p (FEXT)	[12 31; 1.8 1.8]	mm	[test cases]
z_p (RX)	[12 29; 1.8 1.8]	mm	[test cases]
C_p	[0.87e-4 0.87e-4]	nF	[TX RX]
R_0	50	Ohm	
R_d	[45 45]	Ohm	[TX RX]
A_v	0.39	V	vp/vf=.694
A_fe	0.39	V	vp/vf=.694
A_ne	0.578	V	
L	4		
M	32		
filter and Eq			
f_r	0.75	*fb	
c(0)	0.5		min
c(-1)	[-0.3:0.02:0]		[min:step:max]
c(-2)	[0:0.02:0.12]		[min:step:max]
c(-3)	[-0.06:0.02: 0]		[min:step:max]
c(1)	[-0.2:0.05:0]		[min:step:max]
N_b	5	UI	
b_max(1)	0.75		
b_max(2..N_b)	0.2		
g_DC	[-20:1:0]	dB	[min:step:max]
f_z	21.25	GHz	
f_p1	21.25	GHz	
f_p2	53.125	GHz	
g_DC_HP	[-6:1:0]		[min:step:max]
f_HP_PZ	0.6640625	GHz	

I/O control		
DIAGNOSTICS	1	logical
DISPLAY_WINDOW	1	logical
CSV_REPORT	1	logical
RESULT_DIR	.\results\100GEL_KR_{date}\	
SAVE_FIGURES	1	logical
Port Order	[2 1 4 3]	
RUNTAG	KR_eval_	
COM_CONTRIBUTION	0	logical
Operational		
COM Pass threshold	3	dB
ERL Pass threshold	10	dB
DER_0	1.00E-05	
T_r	6.16E-03	ns
FORCE_TR	1	logical
Include PCB	0	logical
TDR and ERL options		
TDR	1	logical
ERL	1	logical
ERL_ONLY	0	logical
TR_TDR	0.01	ns
N	3000	
beta_x	2.53E+09	
rho_x	**0.25**	
fixture delay time	0	s
TDR_W_TXPKG	0	
N_bx	24	UI
Receiver testing		
RX_CALIBRATION	0	logical
Sigma BBN step	5.00E-03	V
Noise, jitter		
sigma_RJ	0.01	UI
A_DD	0.02	UI
eta_0	8.20E-09	V^2/GHz
SNR_TX	33	dB
R_LM	0.95	

Table 93A–3 parameters		
Parameter	**Setting**	**Units**
package_tl_gamma0_a1_a2	[0 0.0009909 0.0002772]	
package_tl_tau	6.141E-03	ns/mm
package_Z_c	[87.5 87.5 ; 92.5 92.5]	Ohm

Table 92–12 parameters 5.2dB at 26.56GHz		
Parameter	**Setting**	
board_tl_gamma0_a1_a2	*[0 0.000599 0.0001022]*	1.286 dB/in or 0.0506 dB/mm at 100 ohms
board_tl_tau	*6.200E-03*	ns/mm
board_Z_c	90	Ohm
z_bp (TX)	*102.7*	mm
z_bp (NEXT)	*102.7*	mm
z_bp (FEXT)	*102.7*	mm
z_bp (RX)	*102.7*	mm

Floating Tap Control		
N_bg	**0**	**0 1 2 or 3 groups**
N_bf	*4*	taps per group
N_f	40	UI span for floating taps
bmaxg	0.1	max DFE value for floating taps

yellow indicates WIP

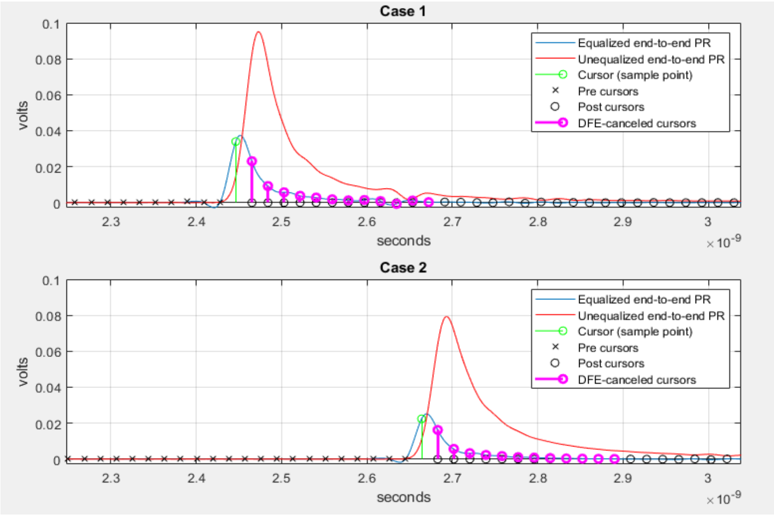
KEYSIGHT TECHNOLOGIES

C2C Channels With Impairments

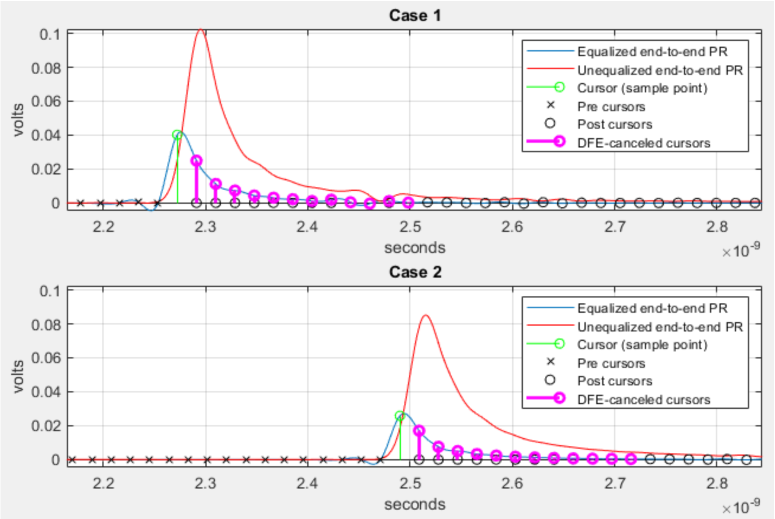
Pulse Responses (1)

P2 —— P1

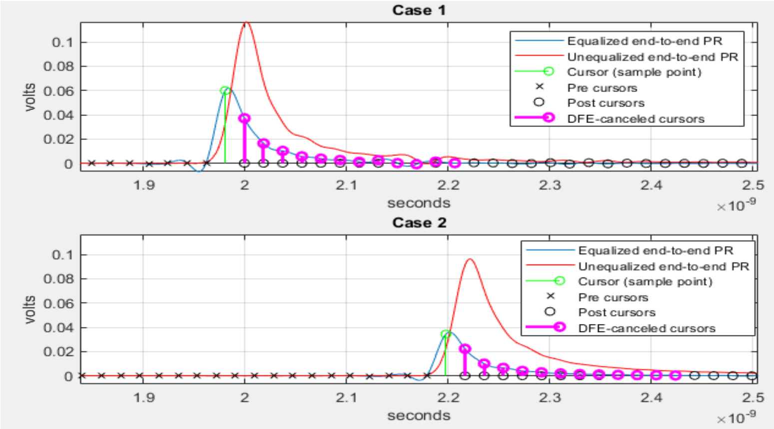
20 dB - 3/1 - N_b = 12 – bmax(2..N_b) = 0.3



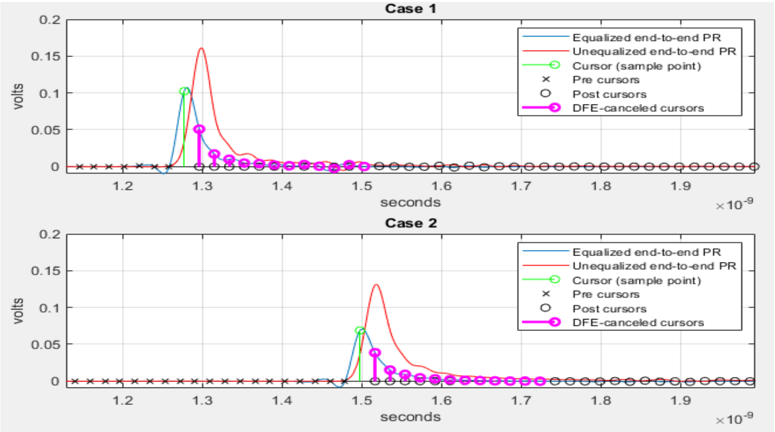
18 dB - 3/1 - N_b = 12 – bmax(2..N_b) = 0.3



16 dB - 3/1 - N_b = 12 – bmax(2..N_b) = 0.3



10 dB - 3/1 - N_b = 12 – bmax(2..N_b) = 0.3



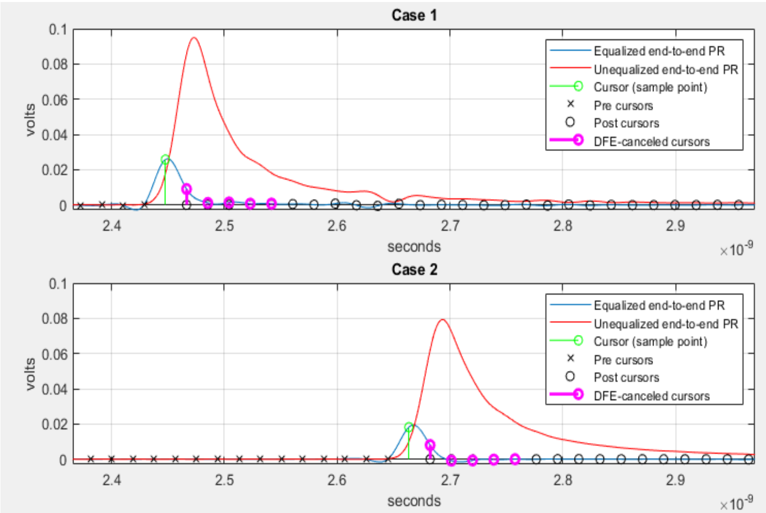
KEYSIGHT TECHNOLOGIES

C2C Channels With Impairments

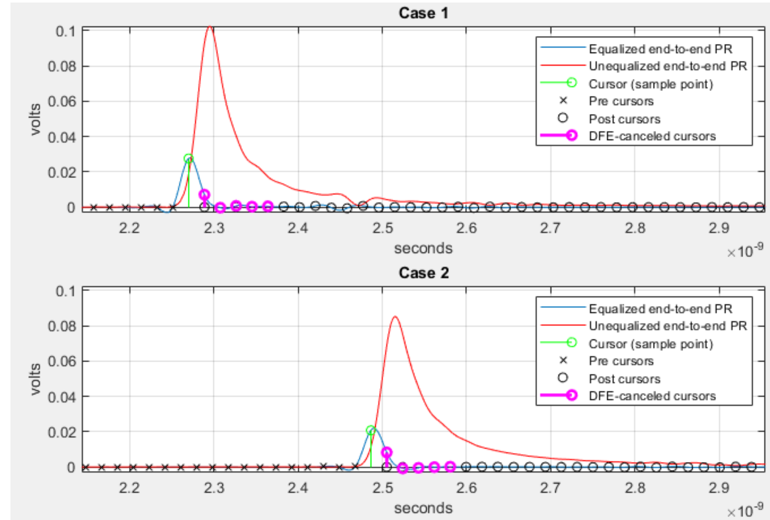
Pulse Responses (2)

P2 —————————— P1

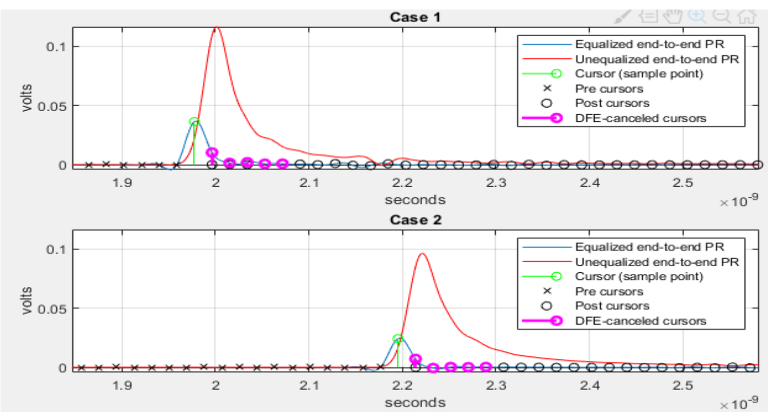
20 dB - 3/1 - N_b = 5 – bmax(2..N_b) = 0.2



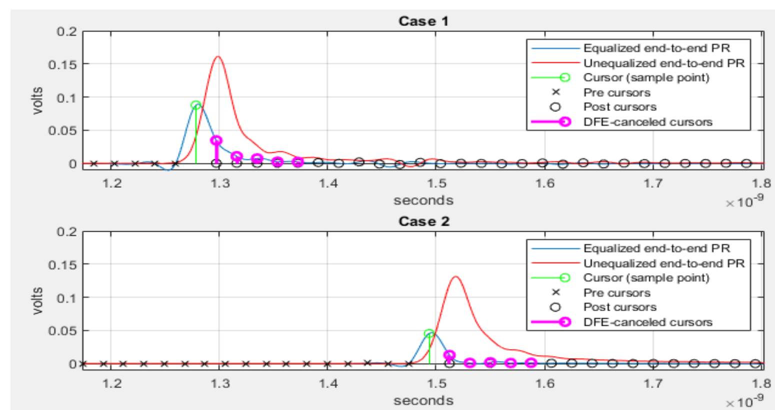
18 dB - 3/1 - N_b = 5 – bmax(2..N_b) = 0.2



16 dB - 3/1 - N_b = 5 – bmax(2..N_b) = 0.2



10 dB - 3/1 - N_b = 5 – bmax(2..N_b) = 0.2



KEYSIGHT TECHNOLOGIES