IBIS-AMI & COM Co-design for 25G Serdes

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AGENDA

- Traditional IBIS-AMI
- COM Overview
- IBIS-AMI Co-design with COM for 25G
- Two example channels
- Co-simulation Conclusion
- Next Steps

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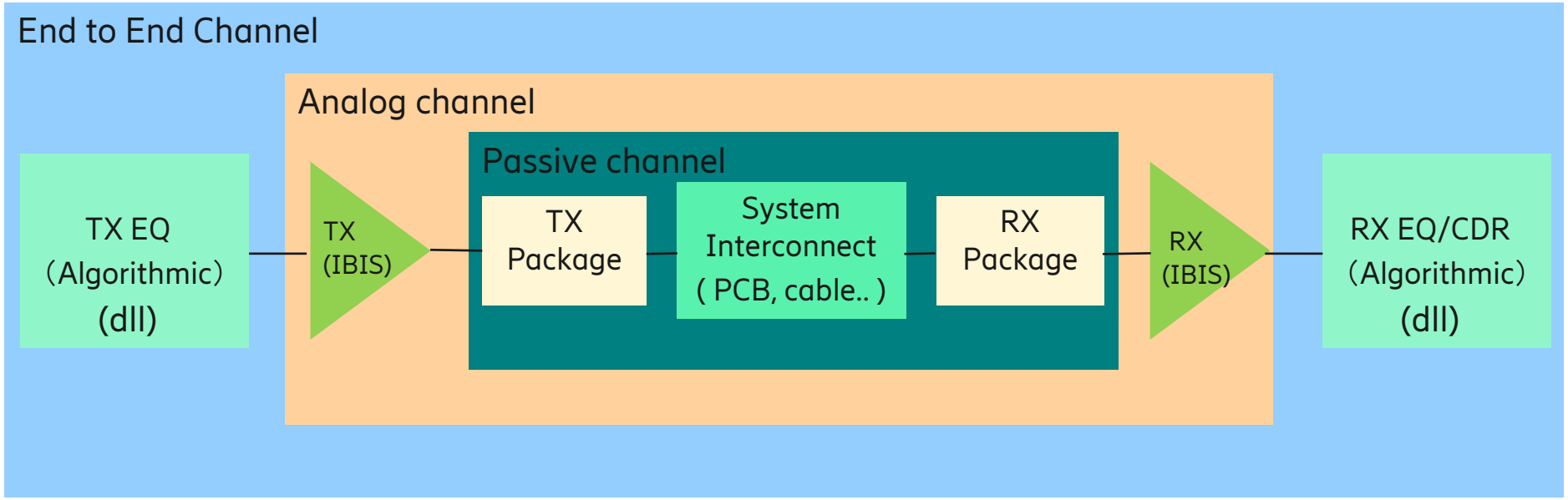
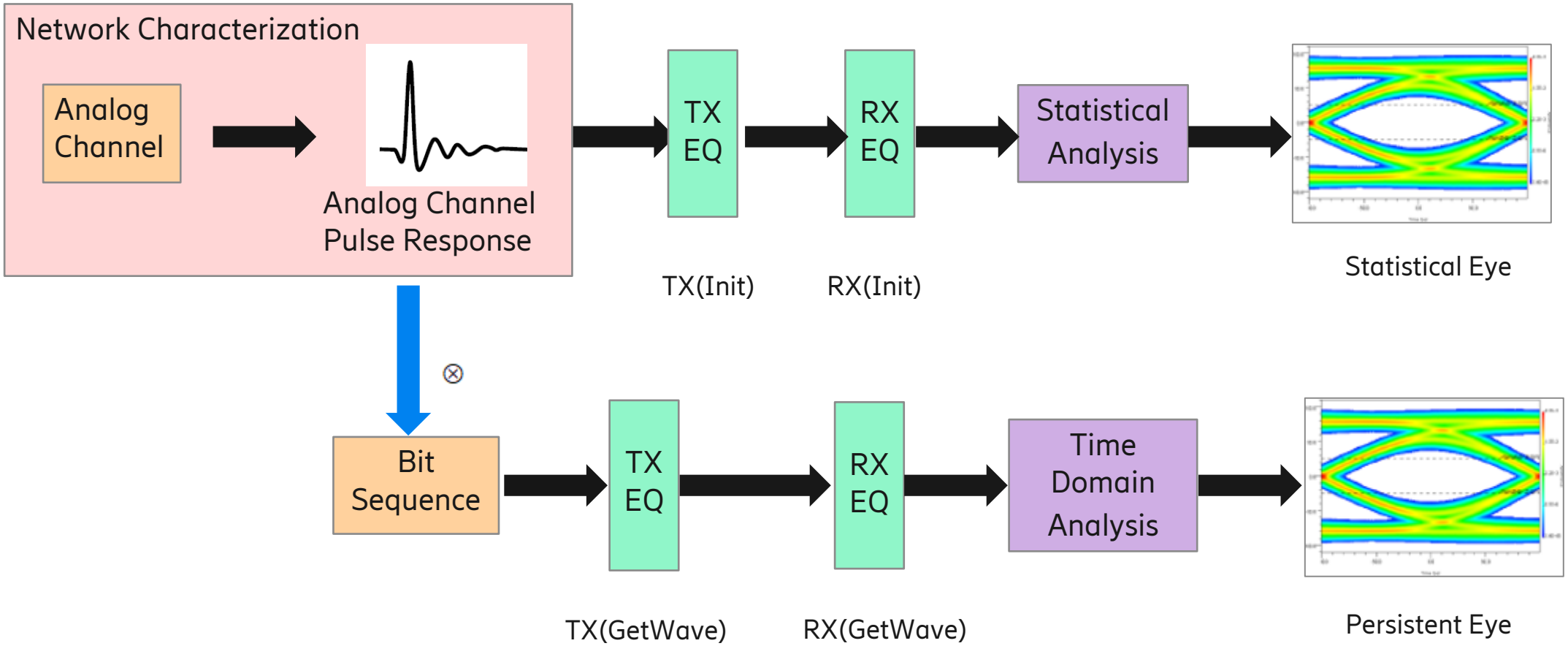
IBIS-AMI OVERVIEW

- IBIS is Input/output Buffer Information Specification
- AMI stands for Algorithmic Modeling Interface
- Analog model: drive strength/amplitude, rise/fall time, impedance
- Algorithmic model: Equalizer (CTLE, FFE, DFE) , clock data recovery



IBIS-AMI FLOW



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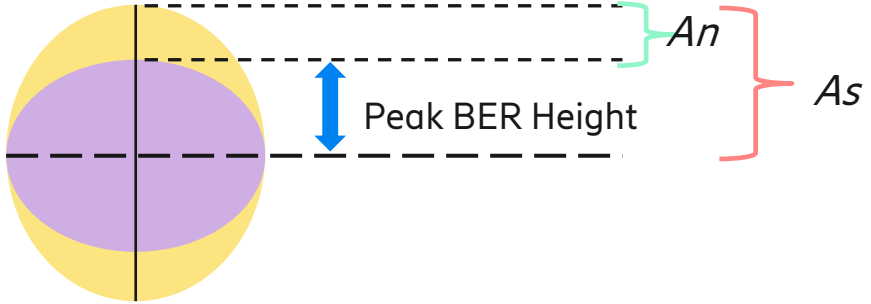
COM OVERVIEW

The Channel Operating Margin (COM) is a figure of merit for a channel derived from a measurement of its scattering parameters
COM is related to the ratio of a calculated signal amplitude to a calculated noise amplitude as defined by Equation

$$COM = 20 \times log10(As/An)$$

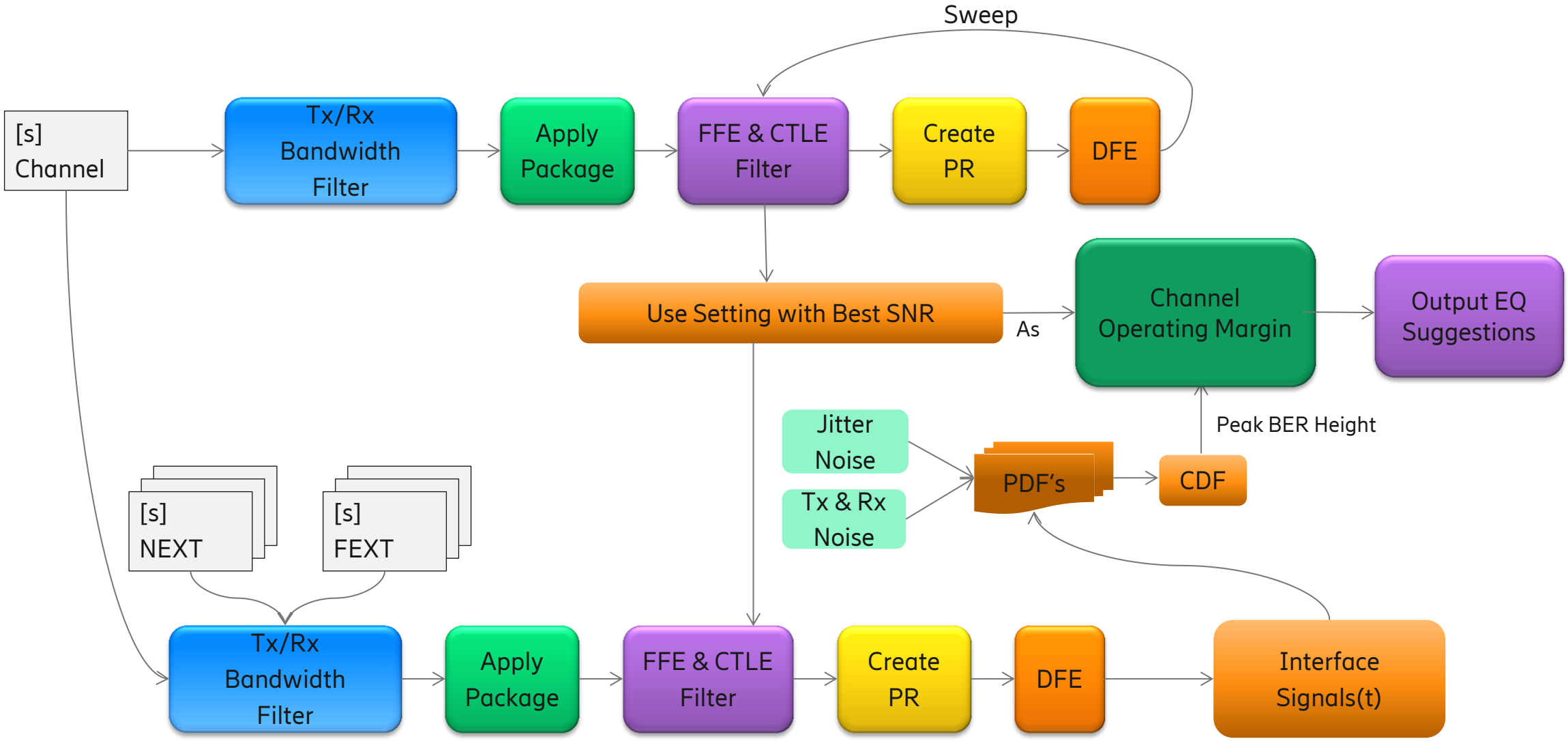


Where *As* is the signal amplitude, *An* is the noise amplitude
COM has been adapted by various standards:

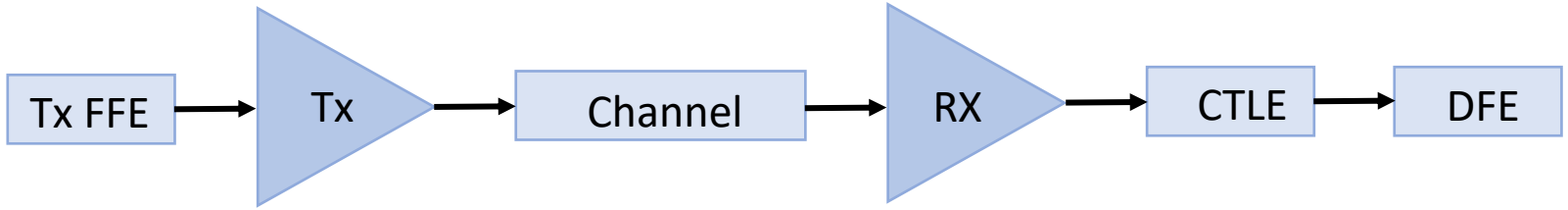
- IEEE 802.3
- OIF CEI
- JEDEC 204C

An (Peak BER Noise) = *As* - Peak BER Height

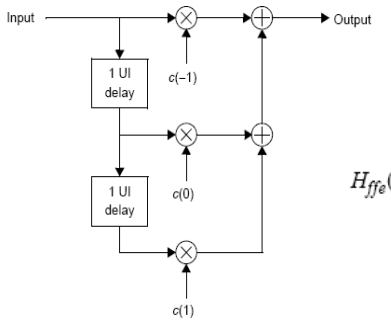
COM FLOW


Sweep
[s] Channel
Tx/Rx Bandwidth Filter
Apply Package
FFE & CTLE Filter
Create PR
DFE
Use Setting with Best SNR
As
Channel Operating Margin
Output EQ Suggestions
Peak BER Height
Jitter Noise
Tx & Rx Noise
PDF's
CDF
[s] NEXT
[s] FEXT
Tx/Rx Bandwidth Filter
Apply Package
FFE & CTLE Filter
Create PR
DFE
Interface Signals(t)

COM CHANNEL TRANSFER FUNCTION



$$H(f) = H_{Tx}(f) \times H_{TxFFE}(f) \times H_{ch}(f) \times H_{Rx}(f) \times H_{RxCTLE}(f)$$



$$y(kT) = \sum_{n=1}^{N} c_n \cdot x(k+1-n)$$

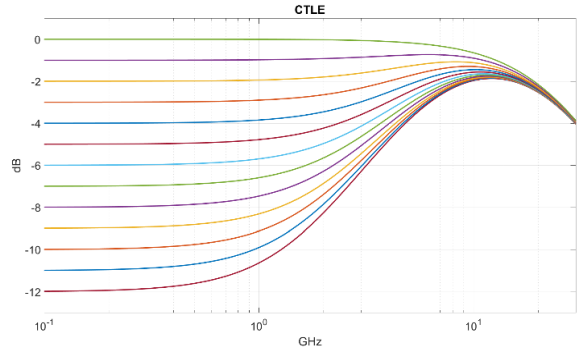
$$H_{ffe}(f) = \sum_{i=-1}^{1} c(i)\exp(-j2\pi(i+1)(f/f_b))$$

Transmitter equalizer, minimum cursor coefficient	$c(0)$	0.62	—
Transmitter equalizer, pre-cursor coefficient Minimum value Maximum value Step size	$c(-1)$	 −0.18 0 0.02	 — — —
Transmitter equalizer, post-cursor coefficient Minimum value Maximum value Step size	$c(1)$	 −0.38 0 0.02	 — — —

Tx FFE

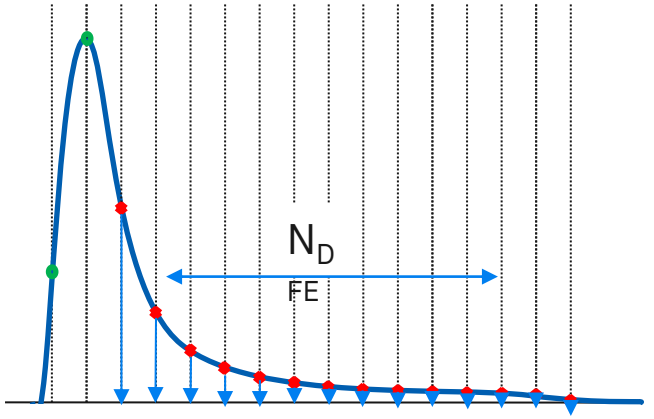
$$H_{ctf}(f) = \frac{10^{g_{DC}/20} + jf/f_z}{(1+jf/f_{p1})(1+jf/f_{p2})}$$

Continuous time filter, DC gain Minimum value Maximum value Step size	g_{DC}	 −12 0 1	 dB dB dB
Continuous time filter, zero frequency	f_z	f_b / 4	GHz
Continuous time filter, pole frequencies	f_{p1} f_{p2}	f_b / 4 f_b	GHz



Rx CTLE

Single Bit Response



Rx DFE

COM OPTIMAL EQ SETTINGS

- COM is a figure of merit (FOM), which calculates the ratio of peak signal level to the peak noise level at the receiver sampling latch, comprehending device Tx characteristics (i.e., driver filter, FFE filter, package S-parameters), channel characteristics (i.e., S-parameters) and receiver characteristics (i.e., Rx filter, CTLE filter, package S-parameters and DFE)
- Determine optimal equalization settings
  - An exhaustive search for the best SNR used as a FOM for finding the best FFE and CTLE setting
  - FFE and CTLE are optimized jointly
  - The DFE is only used to gate the SBR

$$FOM = 10log_{10}(\frac{A_S^2}{\sigma_{TX}^2 + \sigma_{ISI}^2 + \sigma_J^2 + \sigma_{XT}^2 + \sigma_N^2})$$

A_S – peak signal amplitude
σ_{TX} - transmitter noise
σ_{ISI} - residual ISI
σ_J – jitter contribution to amplitude noise
σ_{XT} – peak crosstalk
σ_N – spectral noise at the ouput of CTLE

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IBIS-AMI COMBINE WITH COM

- Can we use COM to evaluate the channel margin in early design phase of a project?
- Are the COM recommended equalization parameters suitable for the Channel?
- How can we combine the advantages of COM with IBIS-AMI?

25G CO-SIMULATION PROCESS

- Extraction of passive S parameter model of the simulation channel
- Use S parameter to do COM simulation
- IBIS simulation using COM recommended EQ parameter
- IBIS simulation to sweep EQ parameter
- Comparing the eye diagram in time domain

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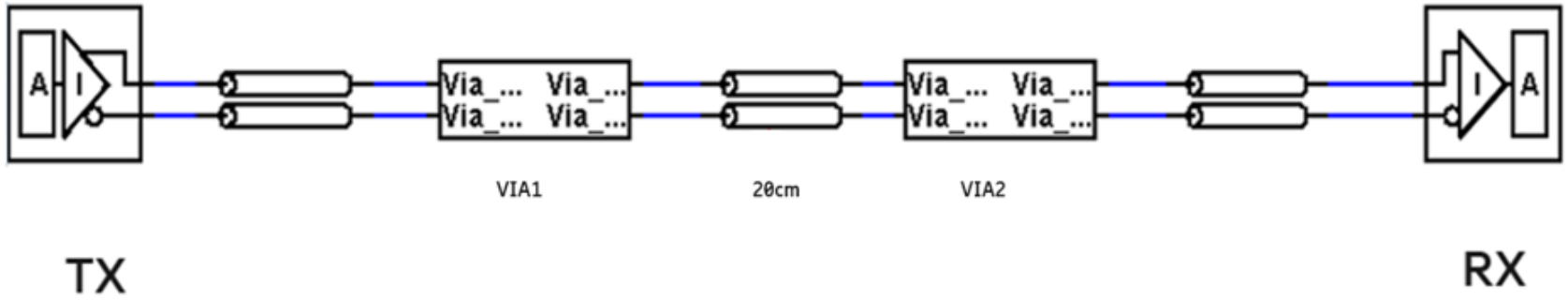
CASE1-SIMULATION TOPOLOGY

Simulation Topology Configuration

- Signal Rate: 25Gbps
- PCB Material: Mid-loss FR4
- PCB Channel Length: 20 cm



COM SIMULATION CONFIGURATION

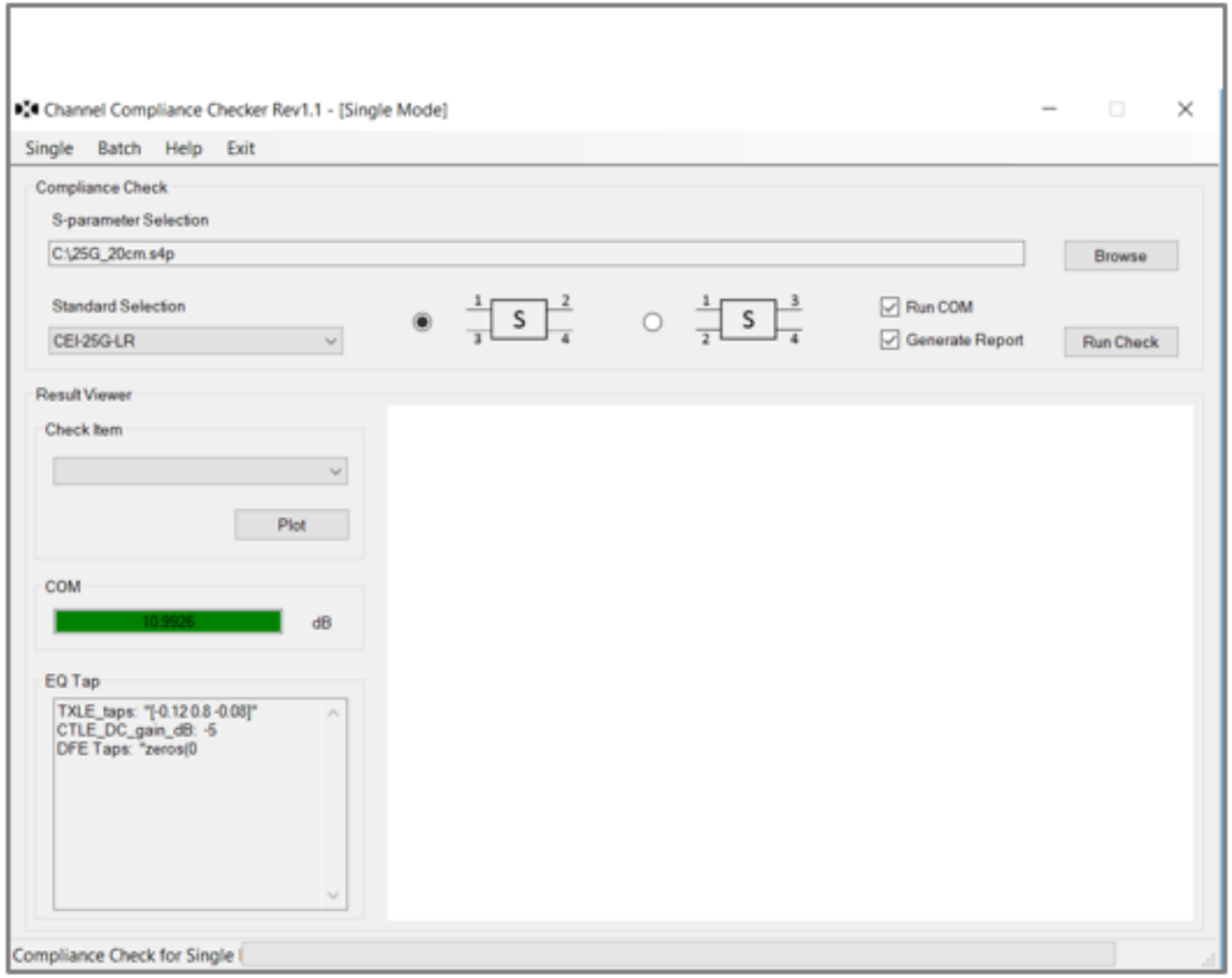
Table 93A-1 parameters			
Parameter	**Setting**	**Units**	**Information**
f_b	24.576	GBd	
f_min	0.05	GHz	
Delta_f	0.01	GHz	
C_d	[2.5e-4 2.5e-4]	nF	[TX RX]
z_p select	[1 2]		[test cases to run]
z_p (TX)	[12 30]	mm	[test cases]
z_p (NEXT)	[12 12]	mm	[test cases]
z_p (FEXT)	[12 30]	mm	[test cases]
z_p (RX)	[12 30]	mm	[test cases]
C_p	[1.8e-4 1.8e-4]	nF	[TX RX]
R_0	50	Ohm	
R_d	[55 55]	Ohm	[TX RX]
f_r	0.75	*fb	
c(0)	0.62		min
c(-1)	[-0.18:0.02:0]		[min:step:max]
c(1)	[-0.38:0.02:0]		[min:step:max]
g_DC	[-12:1:0]	dB	[min:step:max]
f_z	6.144	GHz	
f_p1	6.144	GHz	
f_p2	24.576	GHz	
A_v	0.4	V	
A_fe	0.4	V	
A_ne	0.6	V	
L	2		
M	32		
N_b	0	UI	
b_max(1)	1		
b_max(2..N_b)	1		
sigma_RJ	0.01	UI	
A_DD	0.05	UI	
eta_0	5.20E-08	V^2/GHz	
SNR_TX	27	dB	
R_LM	1		
DER_0	1.00E-12		
Operational control			
COM Pass threshold	3	dB	
Include PCB	0	logical	

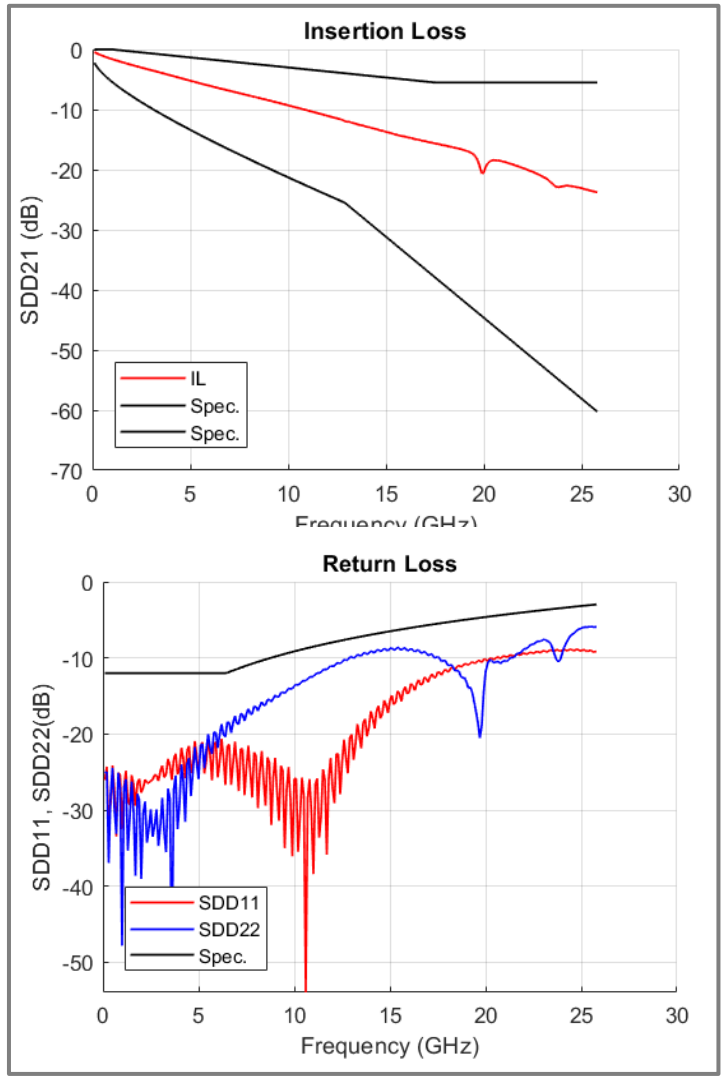
Table 9[illegible]A¨C2 parameter		
Parameter	**Setting**	**Units**
package_tl_tau	6.141E-03	ns
package_tl_gamma0_a1_a2	[0 1.734e-3 1.455e-4]	
package_Z_c	78.2	Ohm

Table 92¨C12 parameter		
Parameter	**Setting**	
board_tl_tau	6.191E-03	ns
board_tl_gamma0_a1_a2	[0 4.114e-4 2.547e-4]	
board_Z_c	109.8	Ohm
z_bp (TX)	151	mm
z_bp (NEXT)	72	mm
z_bp (FEXT)	72	mm
z_bp (RX)	151	mm

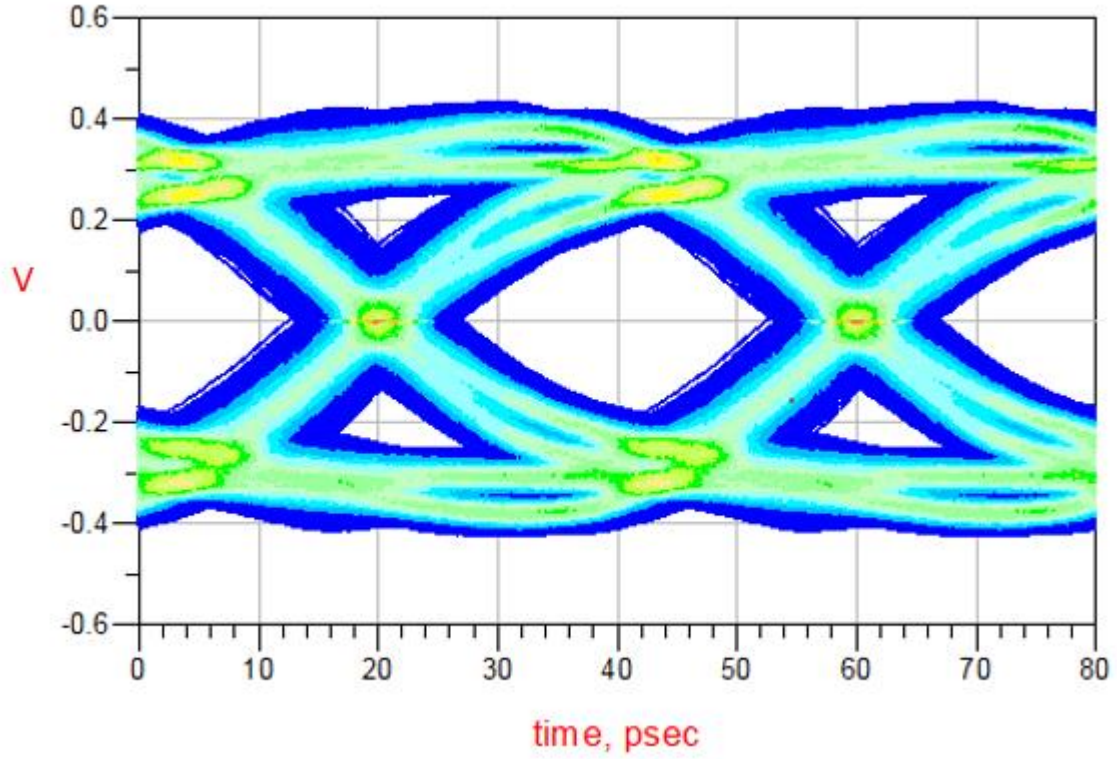
All parameter come from IEEE 802.3bj

COM SIMULATION RESULT





IBIS-AMI SIMULATION WITH COM RECOMMENDED PARAMETER



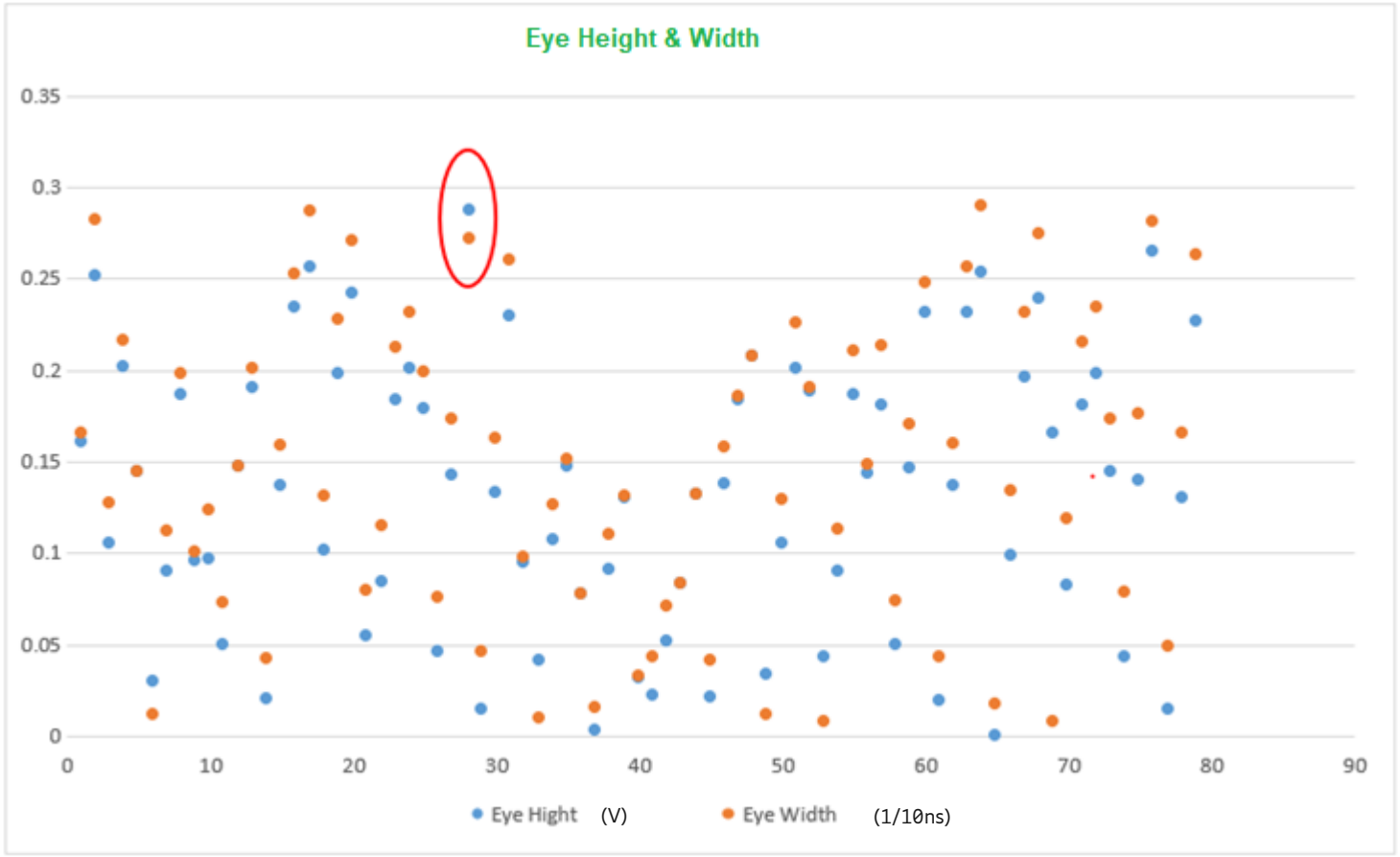
Eye Diagram after RX EQ

index	Width	Height
0.000	2.780E-11	0.289

EQ Parameters: COM Recommend

TX: C(-1)=-0.12
C(0)=0.8
C(1)=-0.08
RX: CTLE=-5
DFE off

IBIS-AMI SWEEP PARAMETERS RESULT



In the red circle is COM recommend EQ parameters

✓ COM recommended EQ parameters produce an acceptable eye opening, but possibly less optimal than the eye opening obtained by time domain simulation

Sweep parameter:

TX: C(-1),C(0),C(1)

RX: CTLE

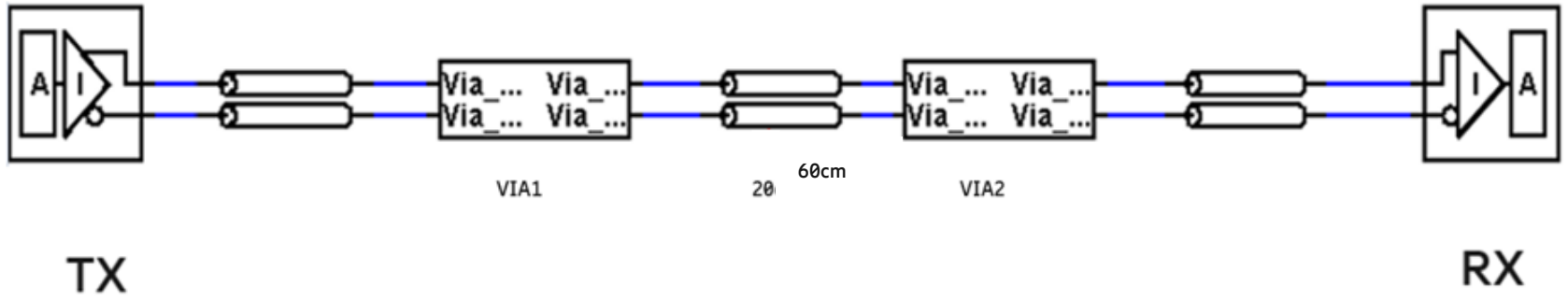
Total case: 80

Time Domain Simulation

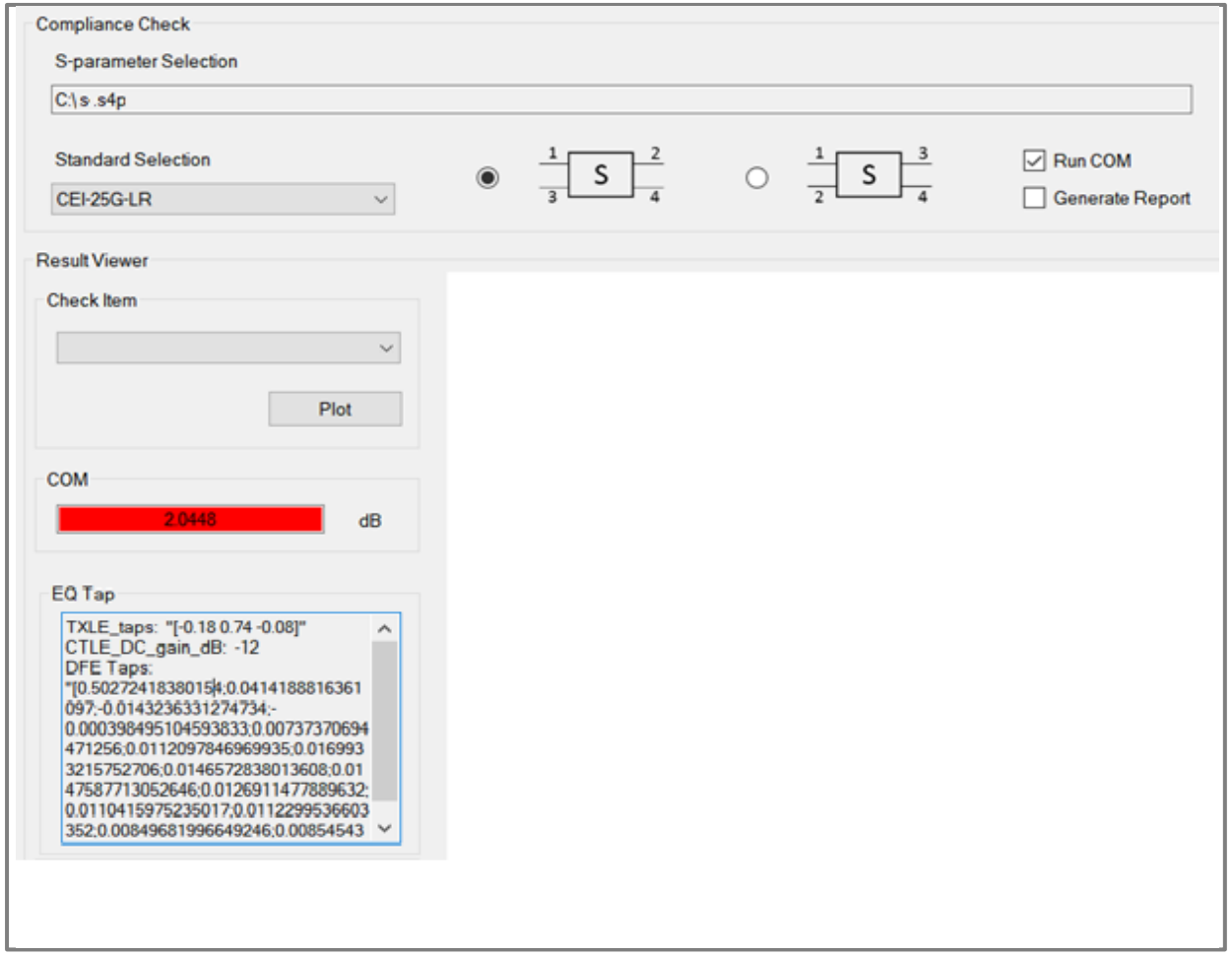
CASE2-SIMULATION TOPOLOGY

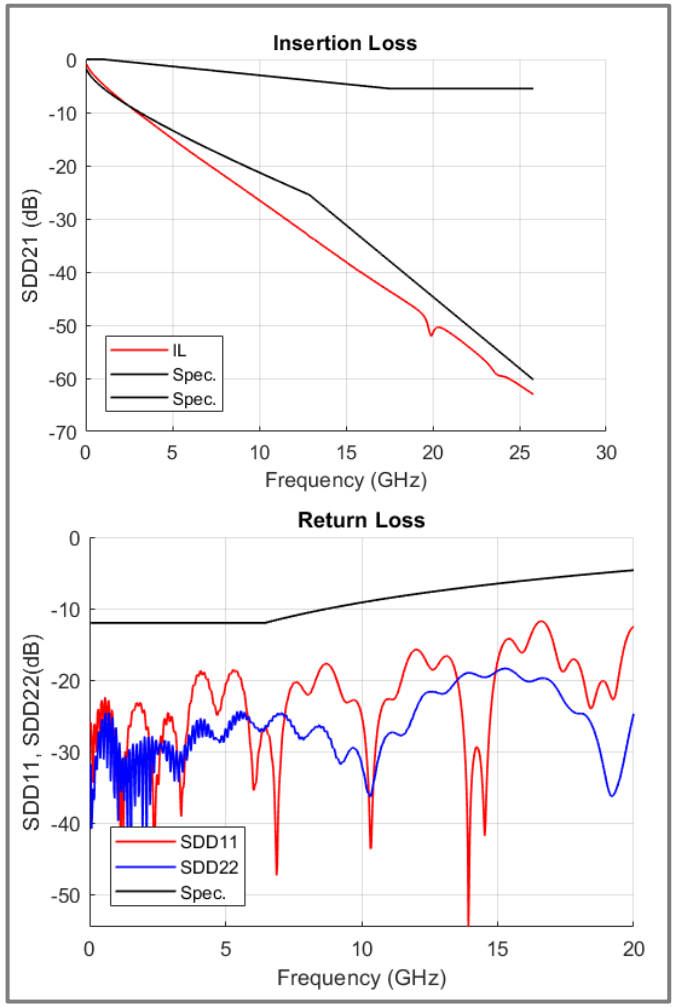
Simulation Topology Configuration

- Signal Rate: 25Gbps
- PCB Material: Mid-loss FR4
- PCB Channel Length: 60 cm

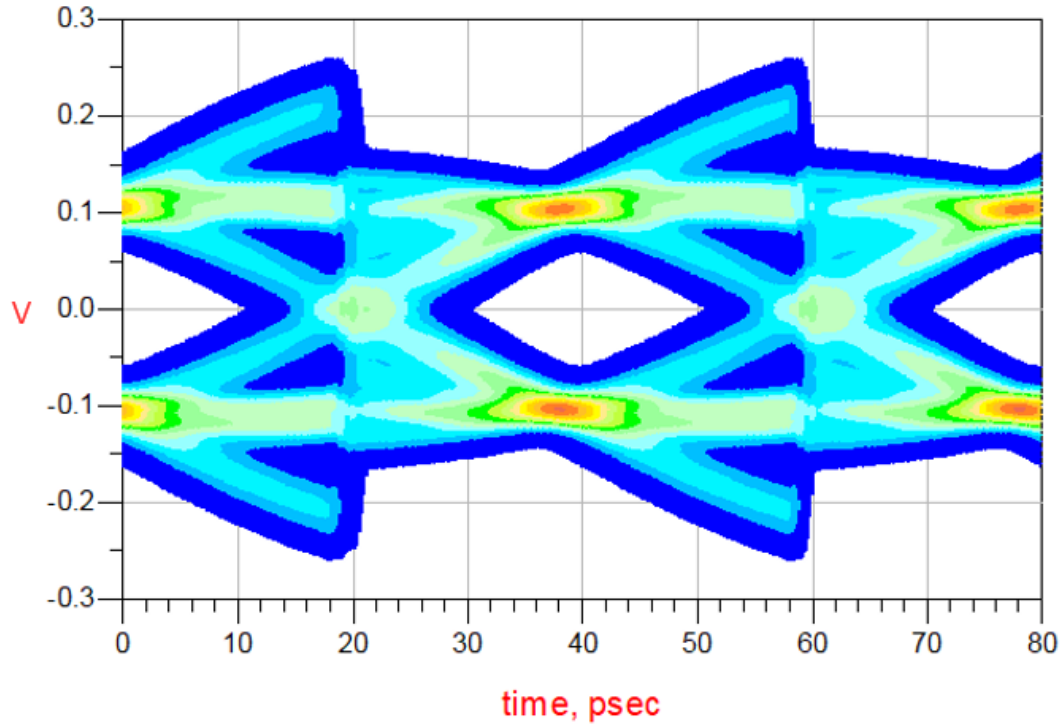


COM SIMULATION RESULT





IBIS-AMI SIMULATION WITH COM RECOMMENDED PARAMETER

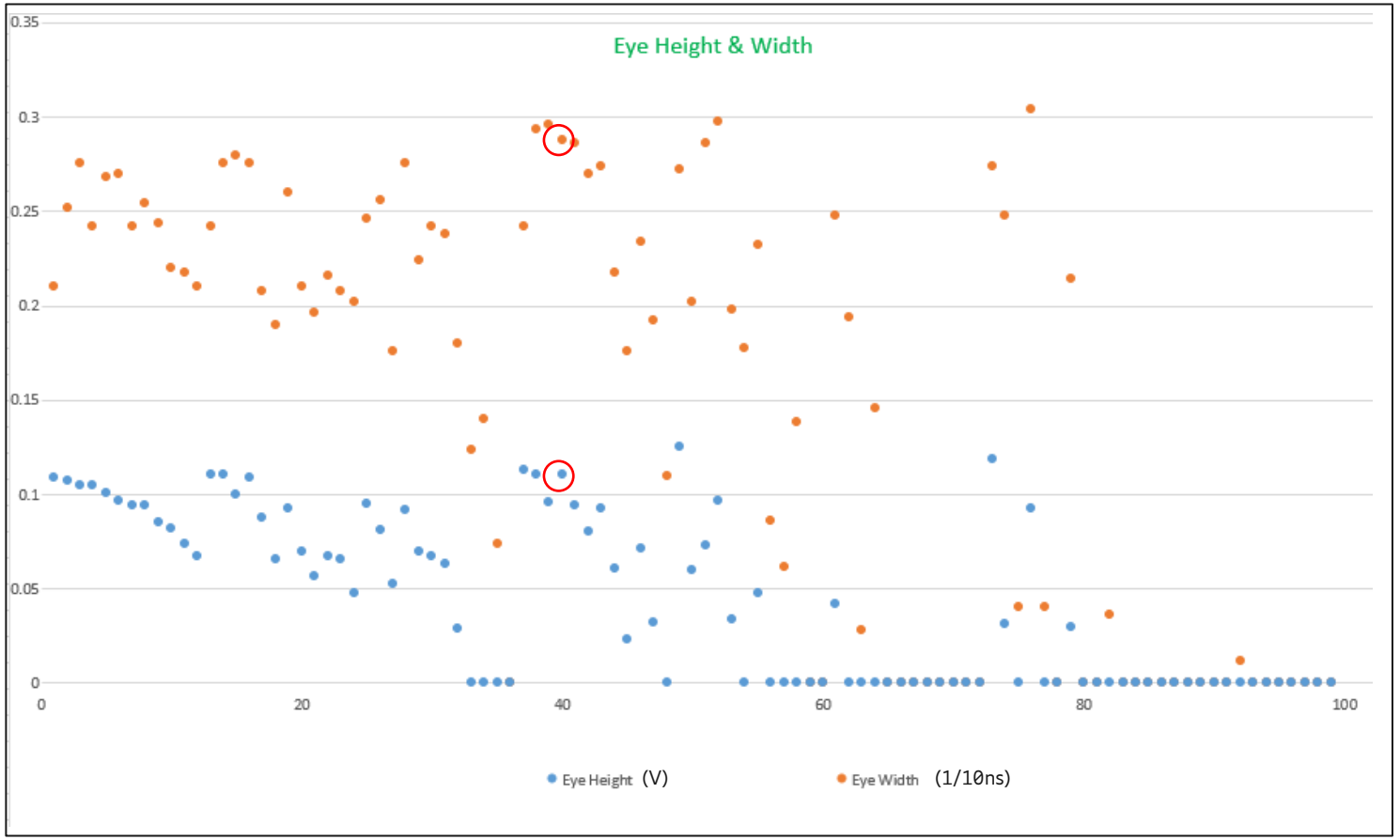


Eye Diagram after RX EQ

index	...robe1.Height)	...Probe1.Width)
0.000	0.109	2.100E-11

EQ Parameters: Use COM Recommended

IBIS-AMI SWEEP PARAMETERS RESULT



In the red circle is COM recommended EQ parameters

- ✓ COM recommended EQ parameters produce a good time domain eye diagram

Sweep parameter:

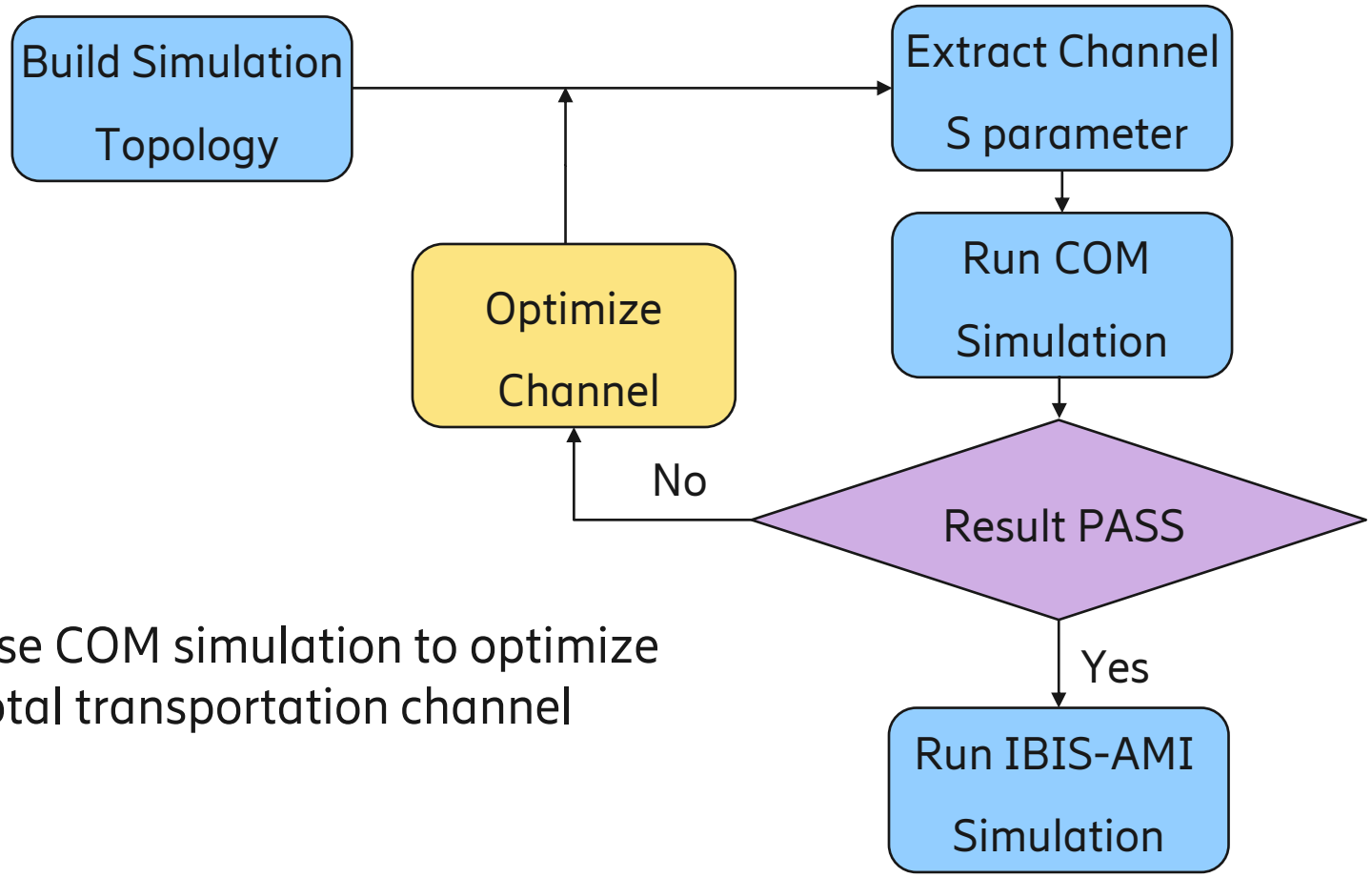
TX: C(-1),C(0),C(1)

RX: CTLE&DFE

Total case: 100

Time Domain Simulation

CO-DESIGN SIMULATION FLOW



Use COM simulation to optimize total transportation channel

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CO-SIMULATION CONCLUSION

- COM enables passive channel evaluation of high-speed signals at early design phase
- COM recommended EQ parameters are suitable for same channel in time domain simulation
- COM simulation is faster, making them more suitable for the post-layout phase of large designs to sweep EQ parameters

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NEXT STEPS

- Model crosstalk in actual link
- Co-simulation for 56G PAM-4
- Accuracy of IBIS-AMI model
- Correlation of Co-simulation with measurement