

# 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

# AGENDA

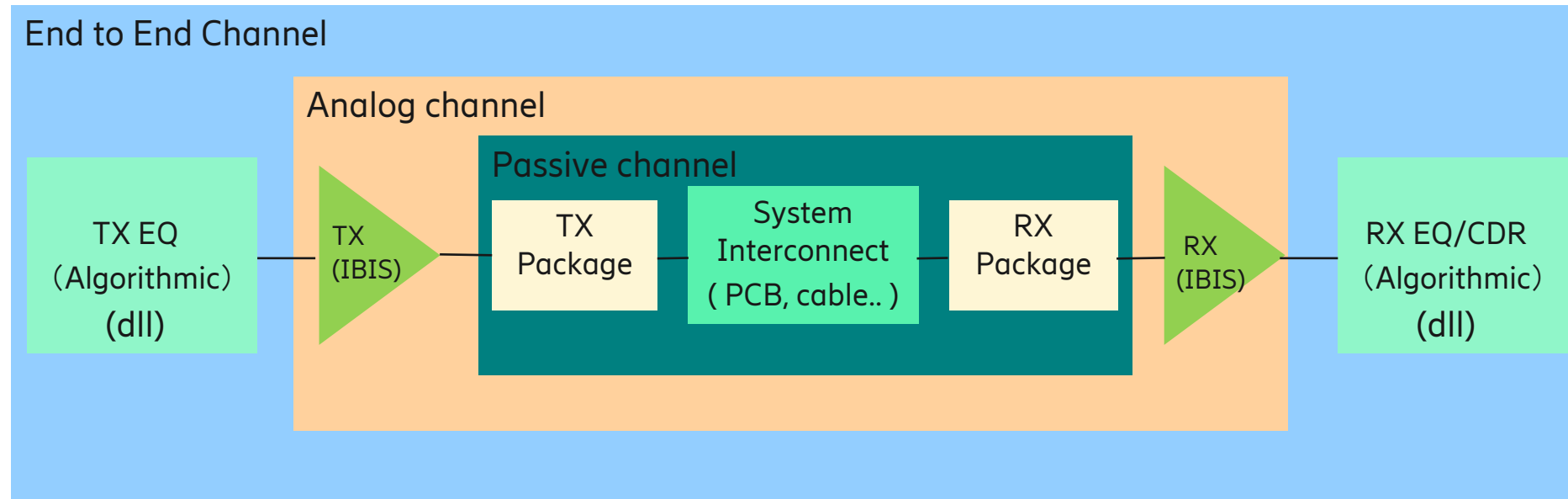


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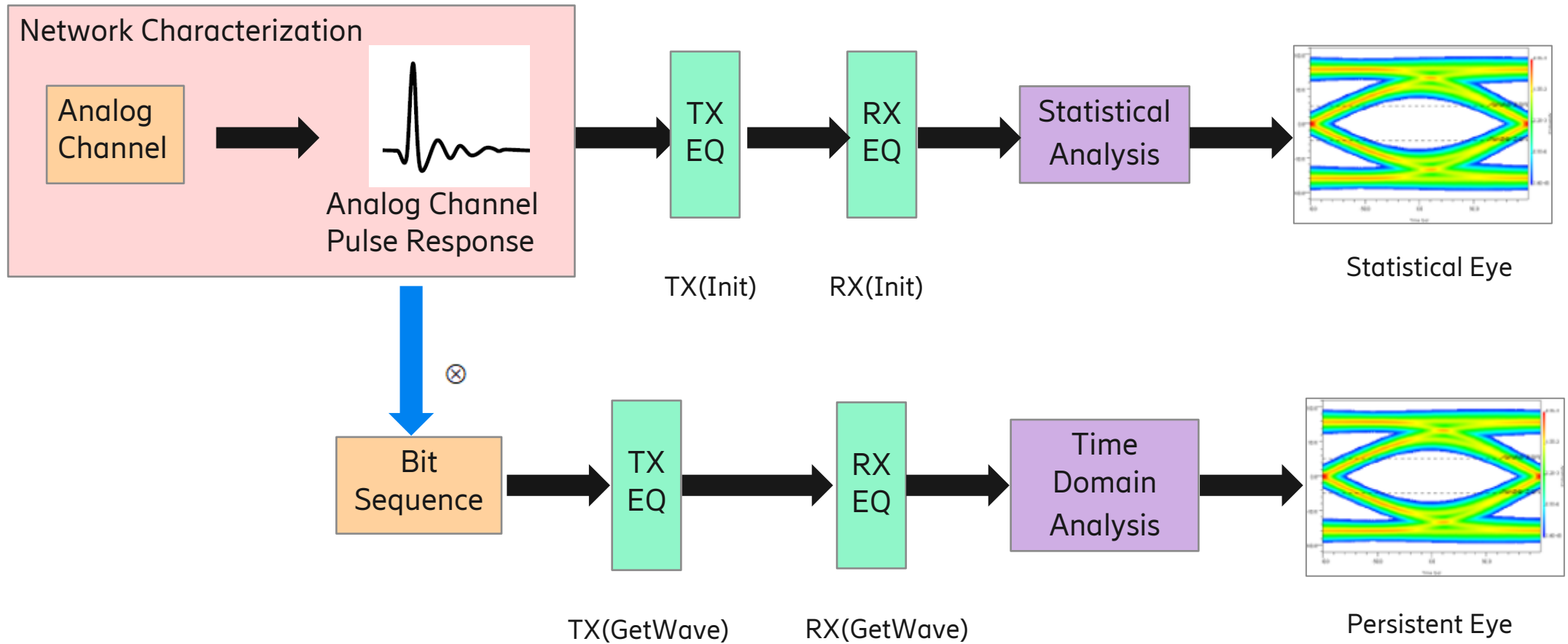
# IBIS-AMI OVERVIEW



- 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



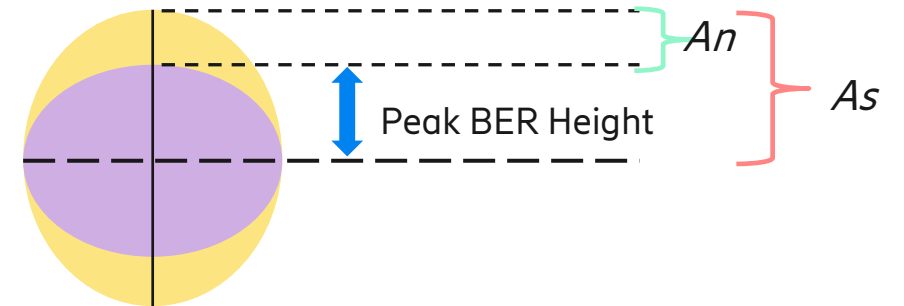
The Channel Operating Margin (COM) is a figure of merit for a channel derived from a measurement of its scattering parameters

COM is related to the ratio of a calculated signal amplitude to a calculated noise amplitude as defined by Equation

$$COM = 20 \times \log_{10}(A_s / A_n)$$

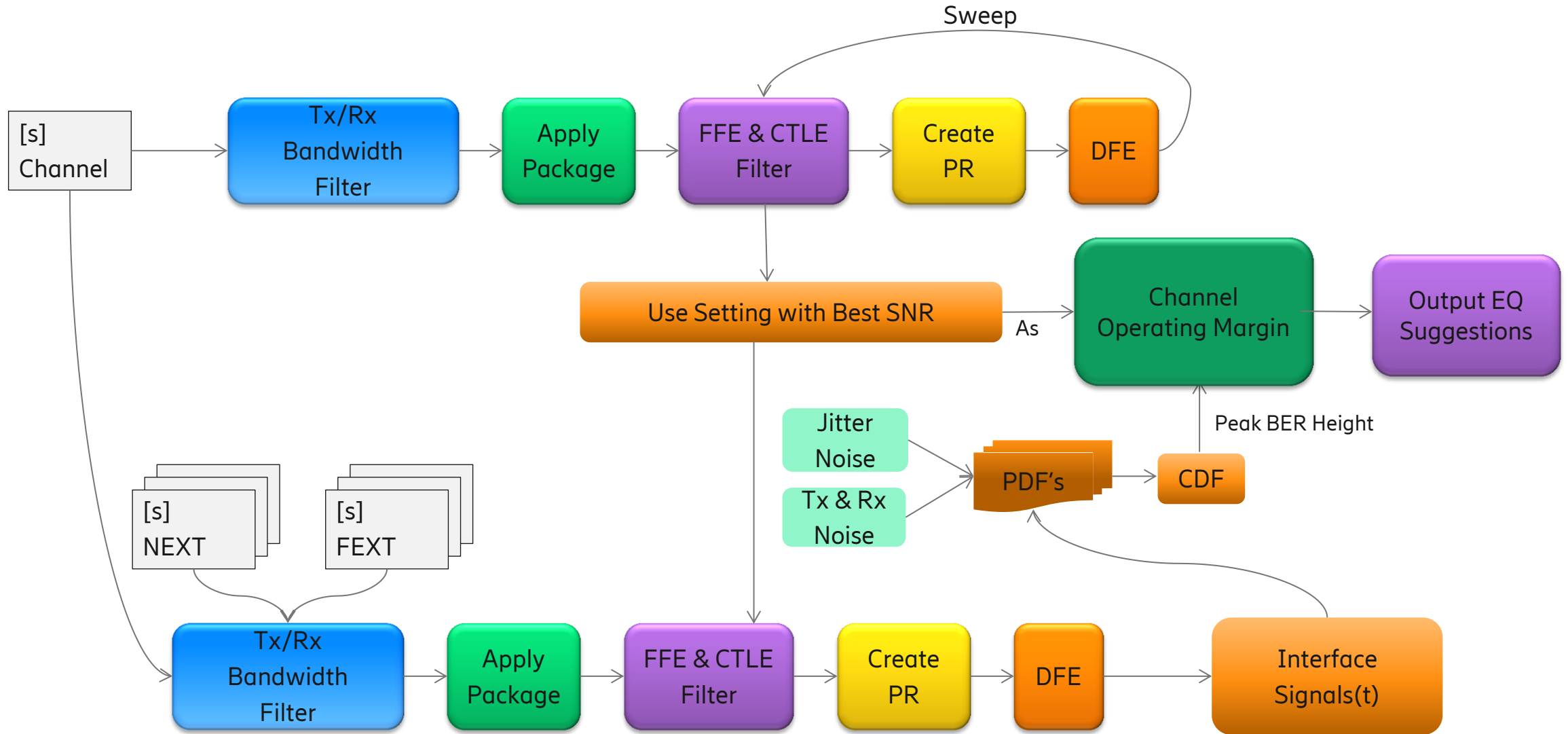
Where  $A_s$  is the signal amplitude,  $A_n$  is the noise amplitude  
COM has been adapted by various standards:

- IEEE 802.3
- OIF CEI
- JEDEC 204C



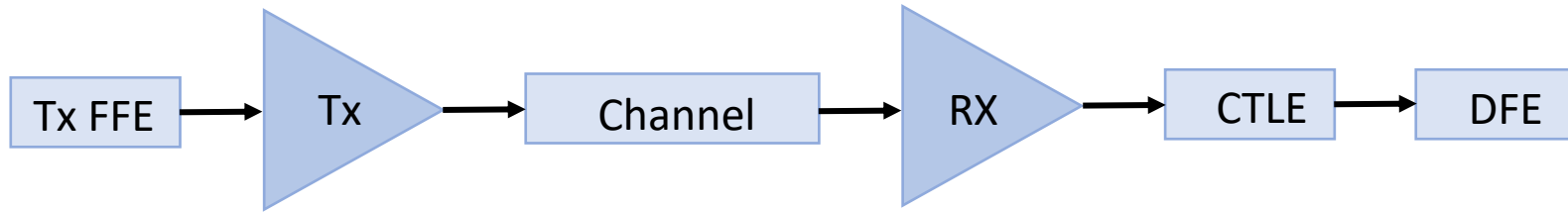
$$A_n (\text{Peak BER Noise}) = A_s - \text{Peak BER Height}$$

# COM FLOW

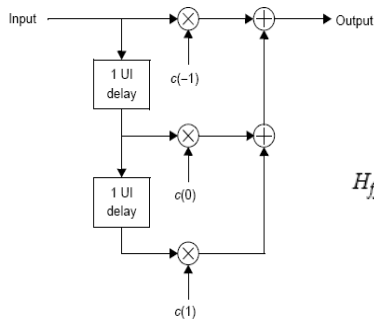




# COM CHANNEL TRANSFER FUNCTION



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



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

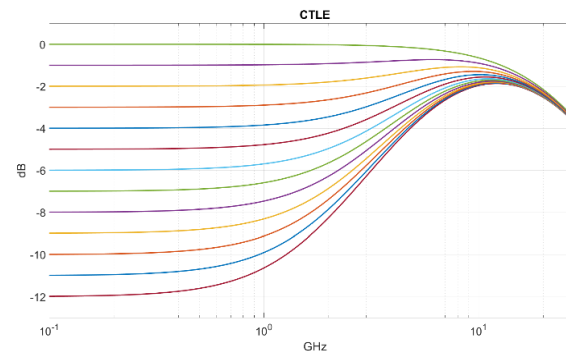
$$H_{ffe}(f) = \sum_{i=-1}^1 c(i) \exp(-j2\pi(i+1)(f/f_b))$$

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

Tx FFE

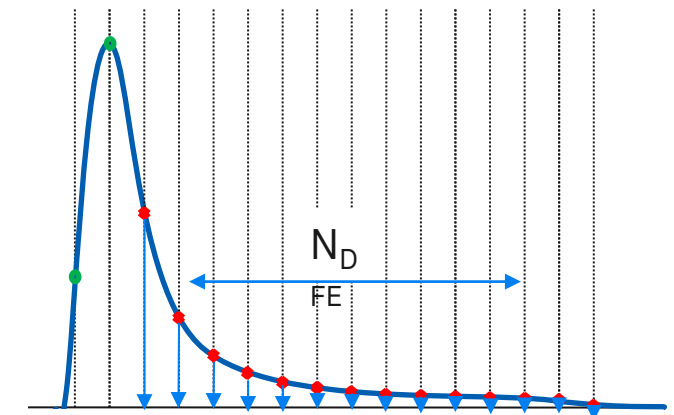
$$H_{ctf}(f) = \frac{10^{\epsilon_{DC}/20} + jf/f_z}{(1 + jf/f_{p1})(1 + jf/f_{p2})}$$

Continuous time filter, DC gain	$\epsilon_{DC}$	-12	dB
Minimum value		0	dB
Maximum value		1	dB
Step size			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

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

$A_S$  – peak signal amplitude

$\sigma_{TX}$  - transmitter noise

$\sigma_{ISI}$  - residual ISI

$\sigma_J$  – jitter contribution to amplitude noise

$\sigma_{XT}$  – peak crosstalk

$\sigma_N$  – spectral noise at the output 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

# AGENDA



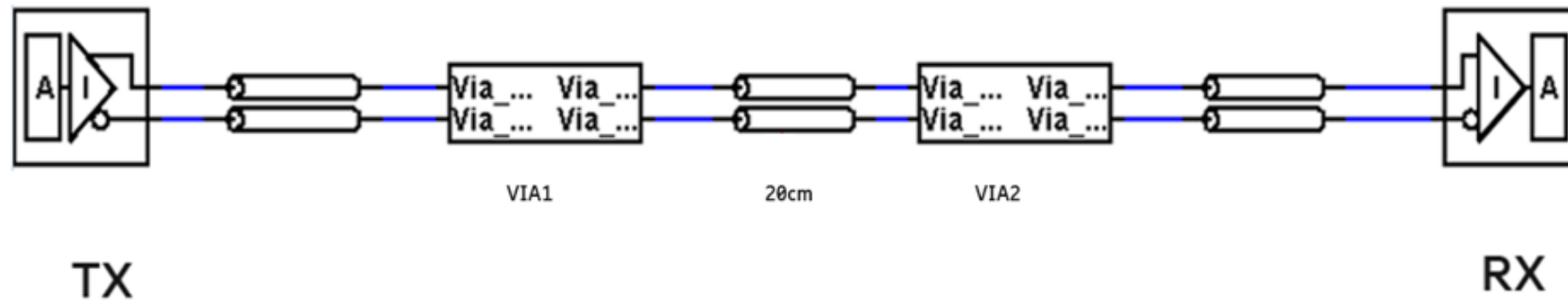
- Traditional IBIS-AMI
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# CASE1-SIMULATION TOPOLOGY



## Simulation Topology Configuration

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



# COM SIMULATION CONFIGURATION



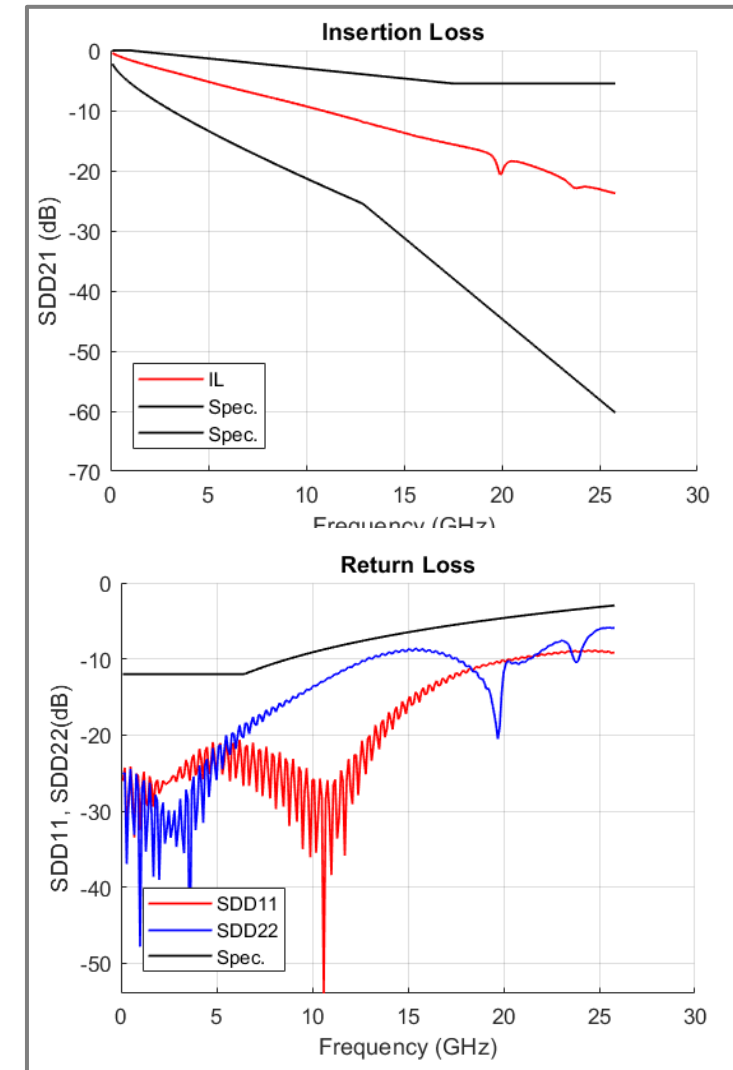
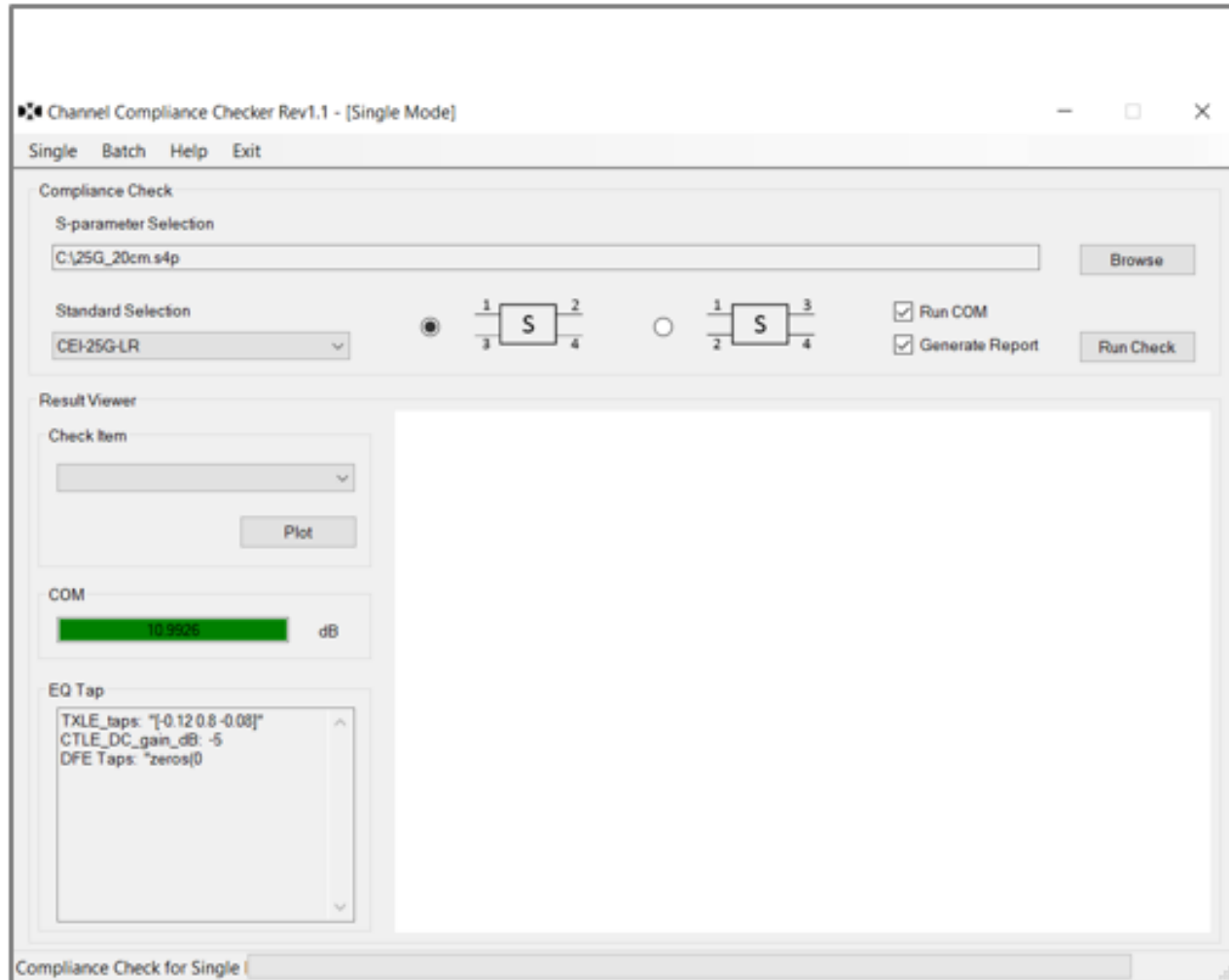
Table 93A-1 parameters			
Parameter	Setting	Units	Information
f_b	24.576	GBd	
f_min	0.05	GHz	
Delta_f	0.01	GHz	
C_d	[2.5e-4 2.5e-4]	nF	[TX RX]
z_p select	[1 2]		[test cases to run]
z_p (TX)	[12 30]	mm	[test cases]
z_p (NEXT)	[12 12]	mm	[test cases]
z_p (FEXT)	[12 30]	mm	[test cases]
z_p (RX)	[12 30]	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 93B 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	Units
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

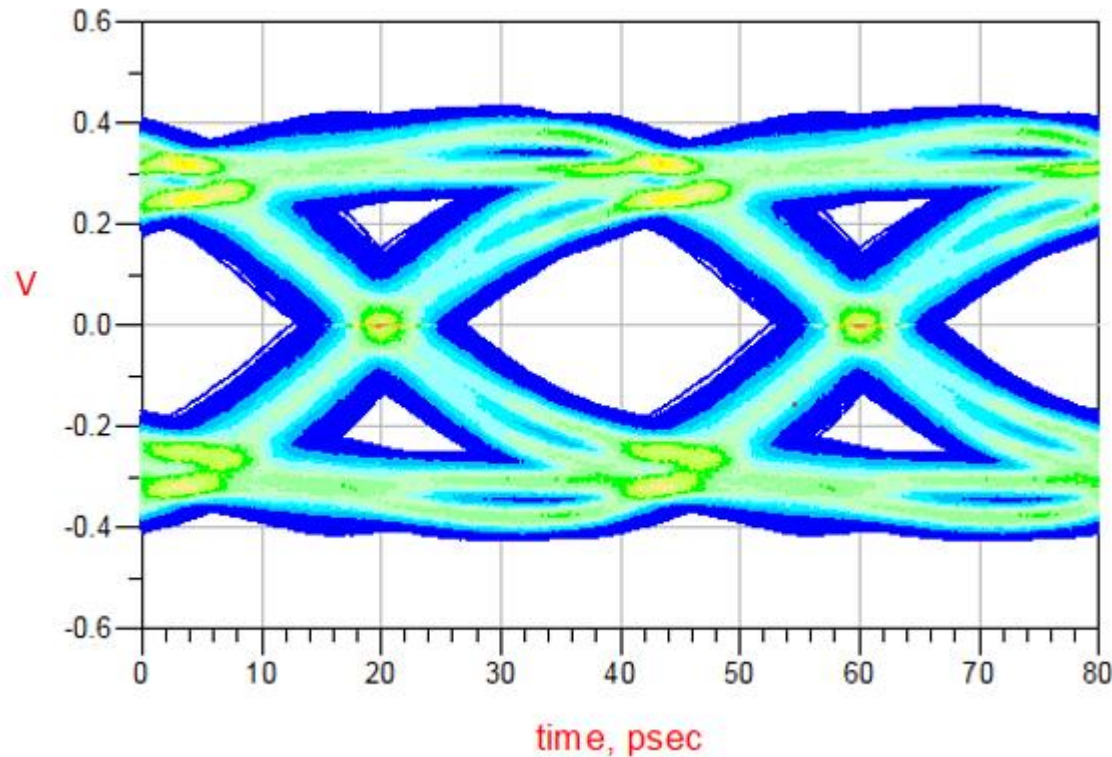
All parameter come from IEEE 802.3bj



# 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

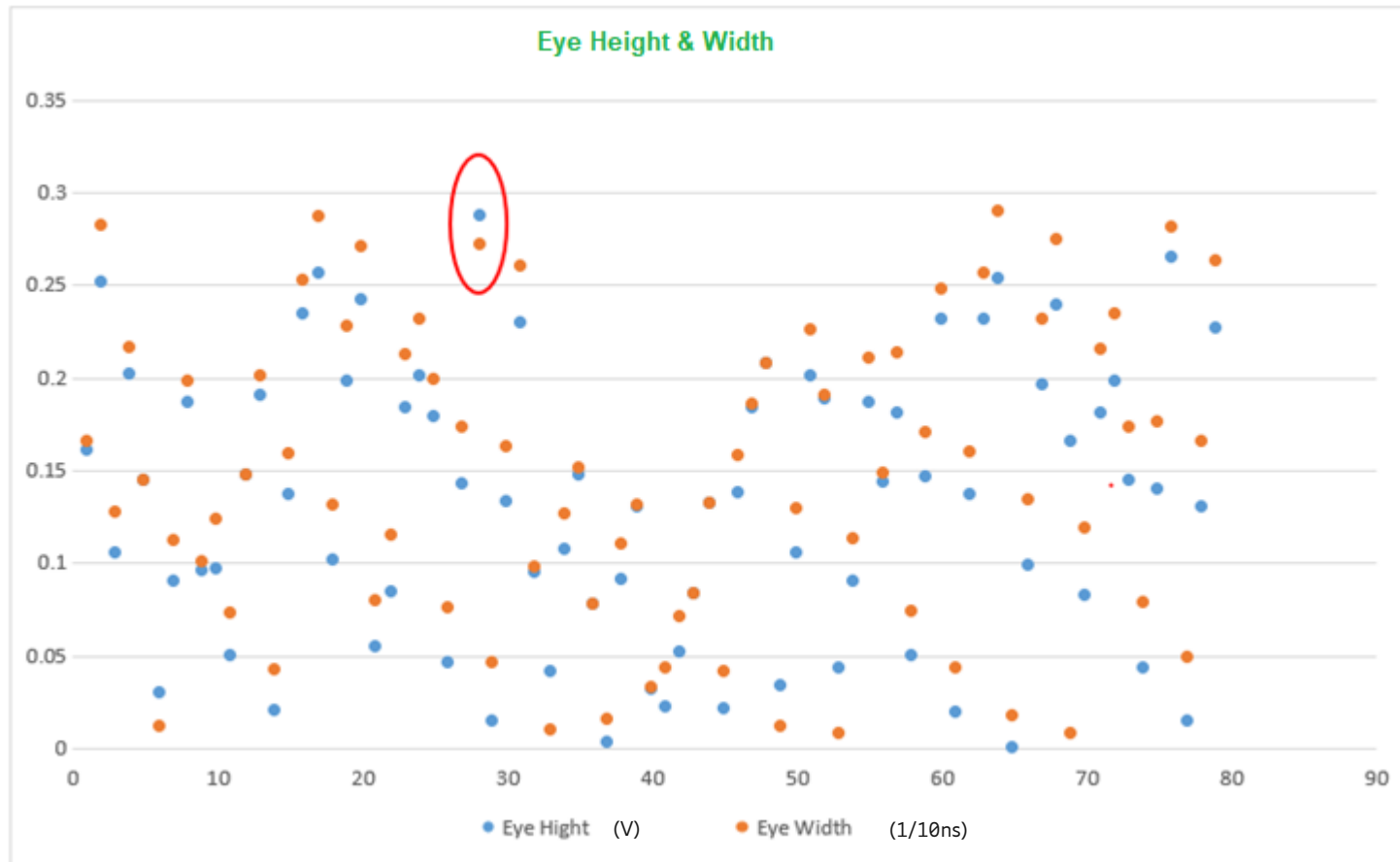
C(0)=0.8

C(1)=-0.08

RX: CTLE=-5

DFE off

# IBIS-AMI SWEEP PARAMETERS RESULT ≡



✓ 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

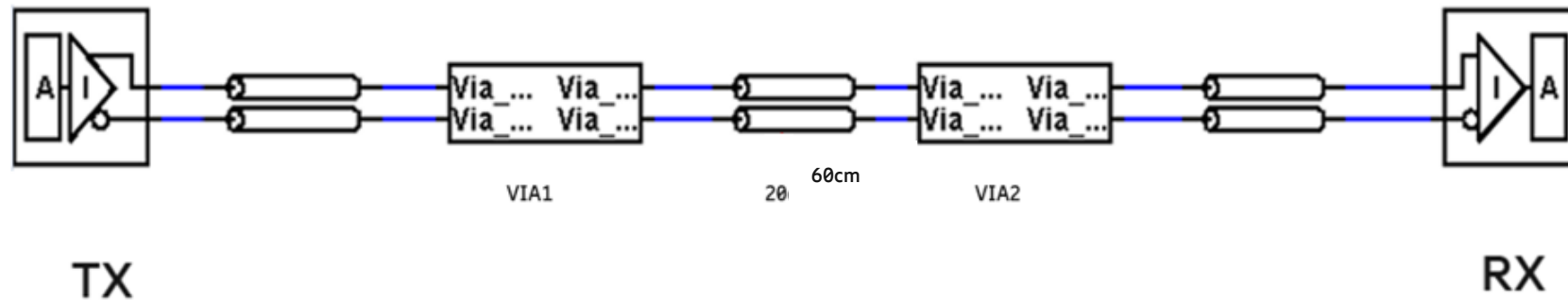
In the red circle is COM recommend EQ parameters

# CASE2-SIMULATION TOPOLOGY



## Simulation Topology Configuration

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




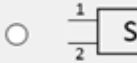
# COM SIMULATION RESULT



Compliance Check

S-parameter Selection  
C:\s.s4p

Standard Selection  
CEI-25G-LR

Run COM  
 Generate Report

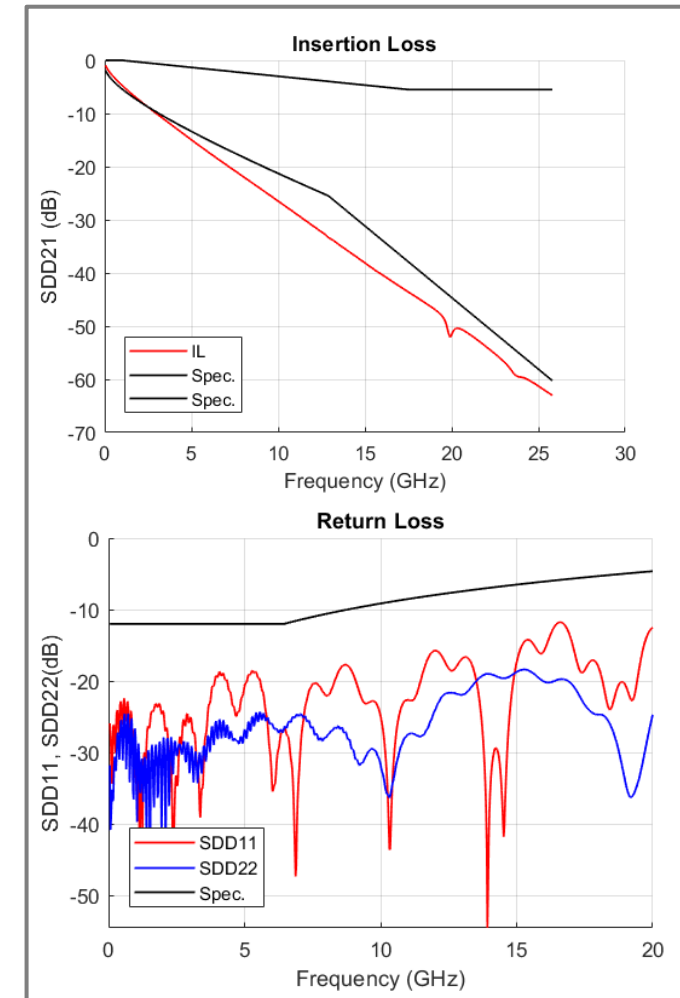
Result Viewer

Check Item  
Plot

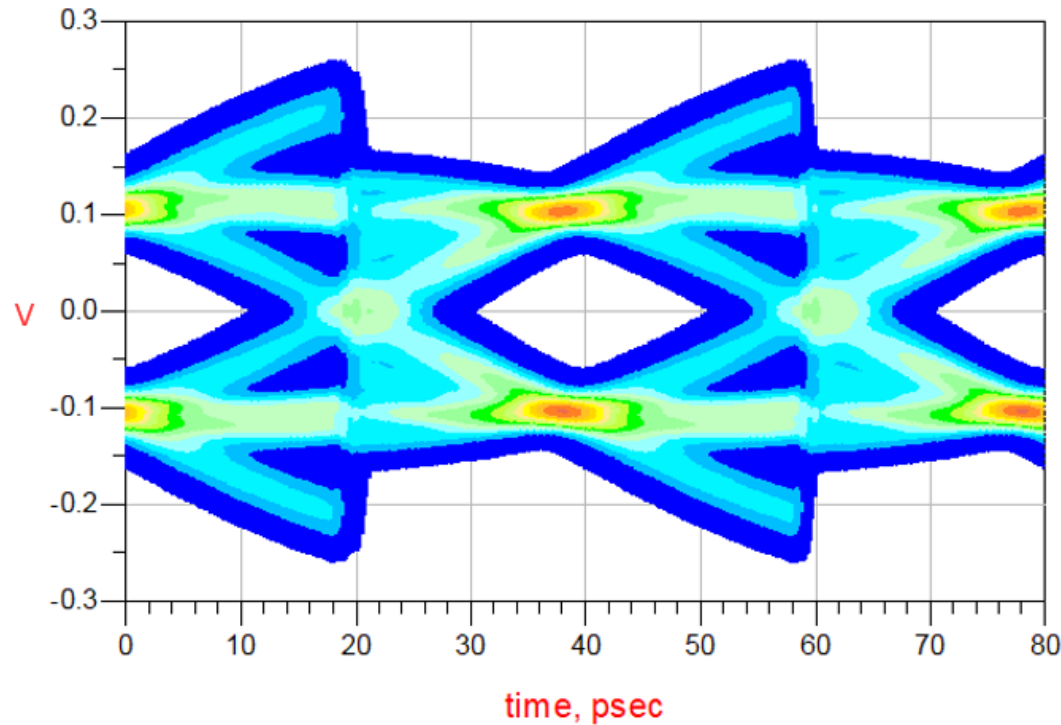
COM  
20448 dB

EQ Tap

```
TXLE_taps: "[-0.18 0.74 -0.08]"  
CTLE_DC_gain_dB: -12  
DFE Taps:  
[0.50272418380154;0.0414188816361  
0.097;-0.0143236331274734;-  
0.000398495104593833;0.00737370694  
471256.0;0.0112097846969935;0.016993  
3215752706.0;0.0146572838013608;0.01  
47587713052646;0.0126911477889632;  
0.0110415975235017;0.0112299536603  
352.0;0.00849681996649246;0.00854543]
```



# IBIS-AMI SIMULATION WITH COM RECOMMENDED PARAMETER

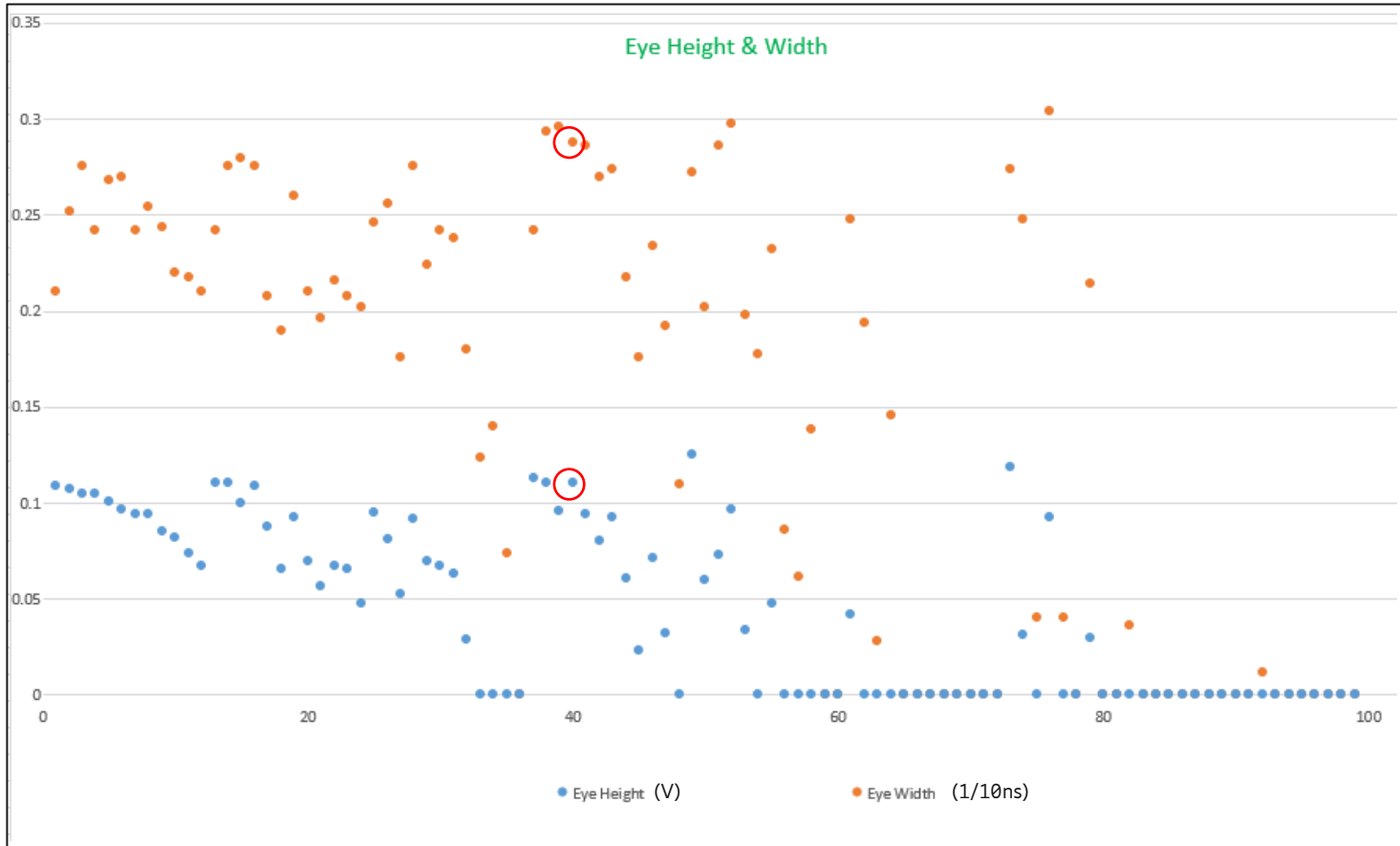


Eye Diagram after RX EQ

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

EQ Parameters: Use COM Recommended

# IBIS-AMI SWEEP PARAMETERS RESULT ≡



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

Sweep parameter:

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

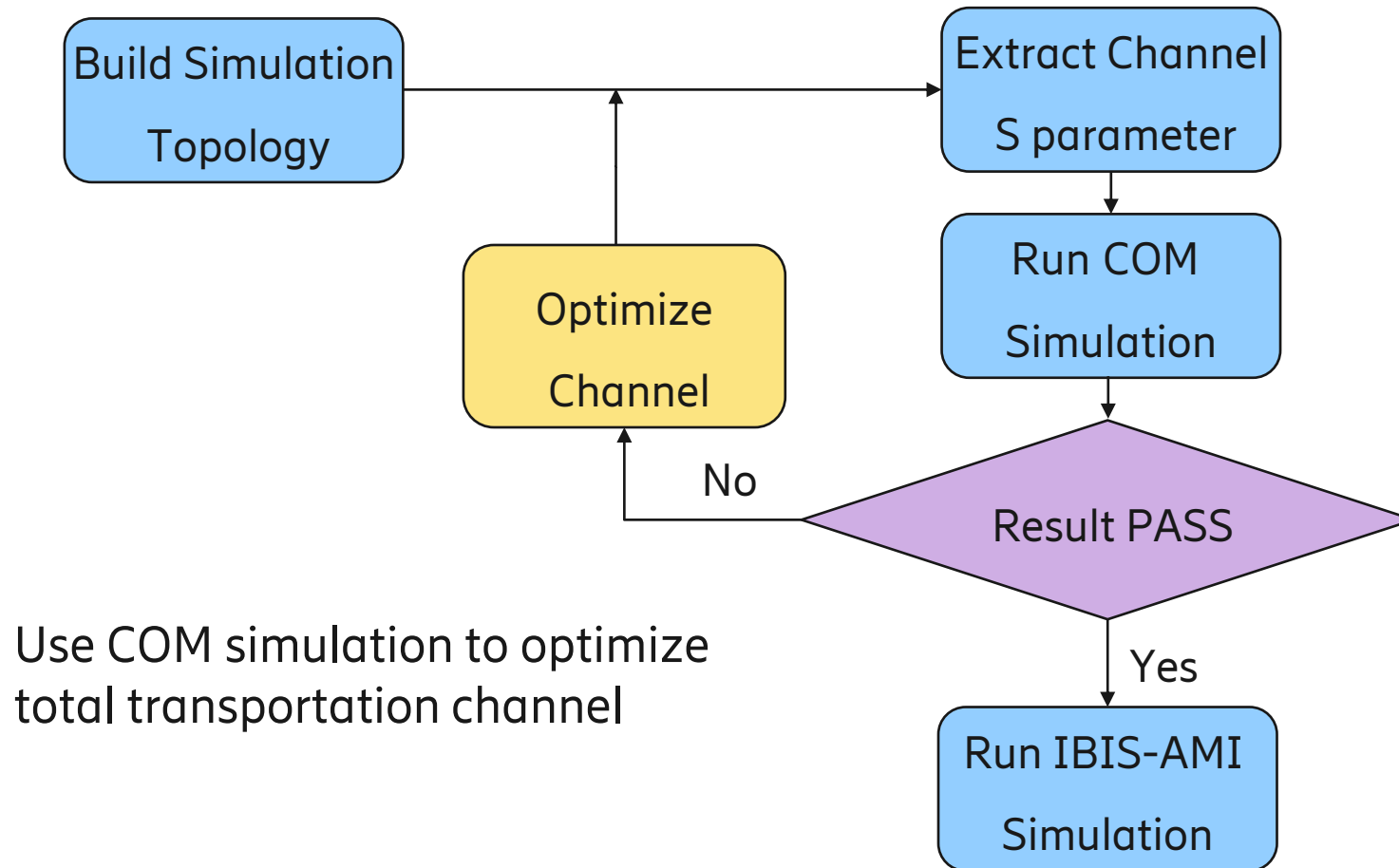
RX: CTLE&DFE

Total case: 100

Time Domain Simulation

In the red circle is COM recommended EQ parameters

# CO-DESIGN SIMULATION FLOW





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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

