

Asian Virtual IBIS Summit (JAPAN)

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# Maximum Frequency for S-parameter Model used in Channel Simulation

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FICT LIMITED

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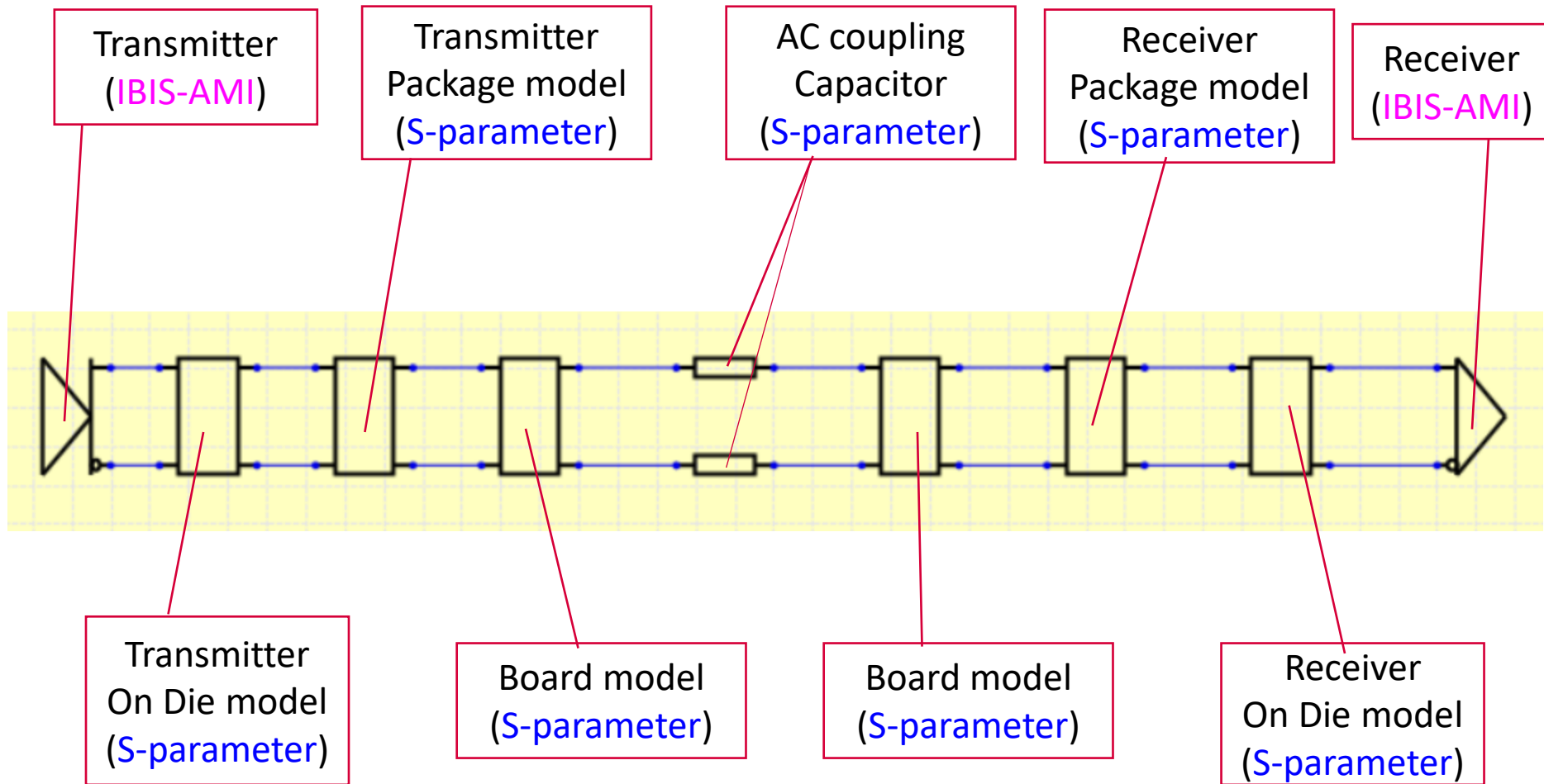
# Motivation

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In Channel Simulation using IBIS-AMI, we investigated whether each S-parameter model in the analog channel has data up to the frequency required for analysis.

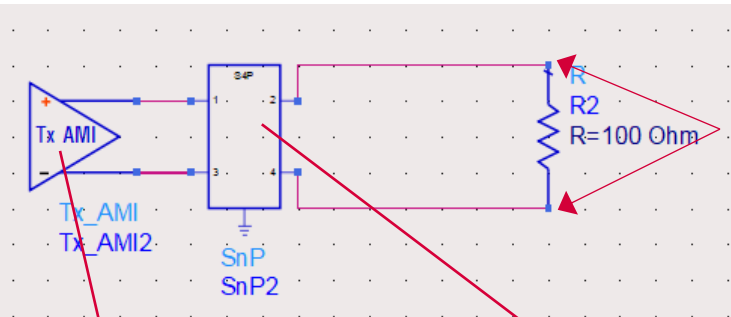
Investigate how to deal with missing frequencies in S-parameter models.

# Analog channel for 28Gbps NRZ transmission



# Frequency spectrum of transmitter output waveform

Transmitter output waveform simulation circuit

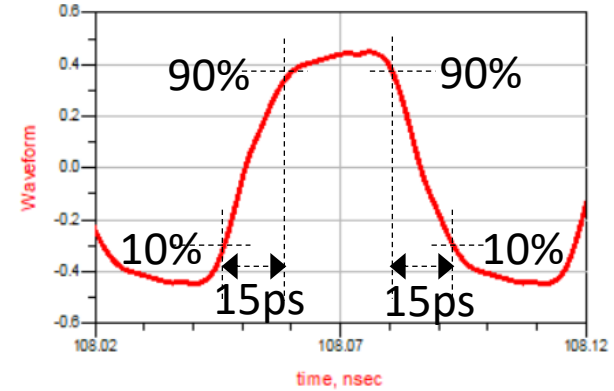


Waveform measurement point

28Gbps NRZ Transmitter IBIS-AMI

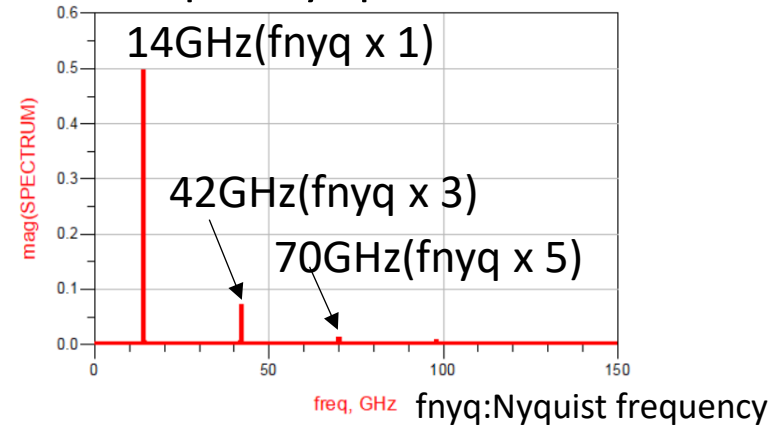
Transmitter On Die model (S-parameter 0Hz-100GHz)

14GHz(Nyquist frequency) repeat waveform



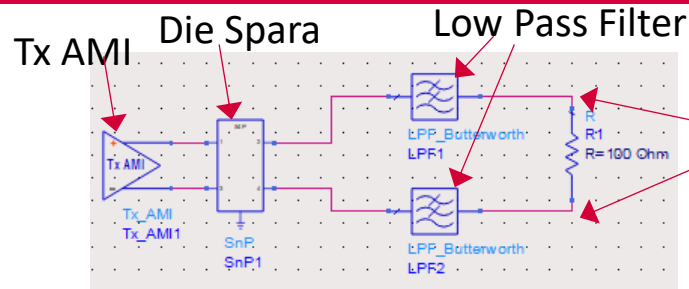
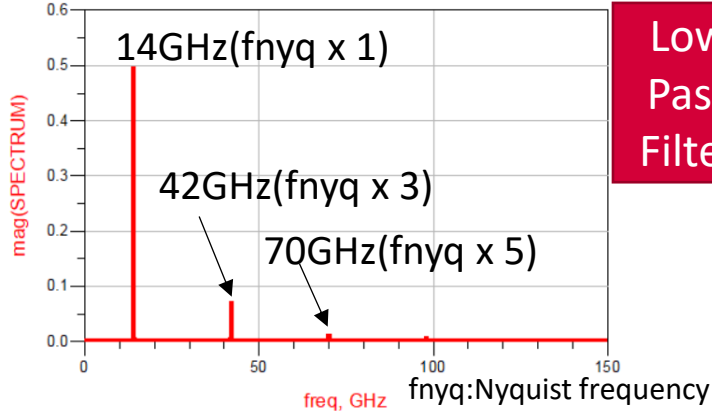
FFT

Frequency spectrum

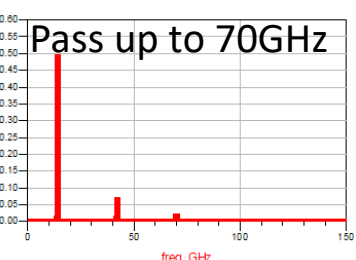
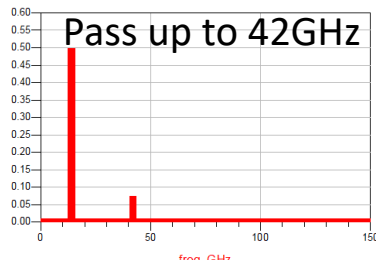
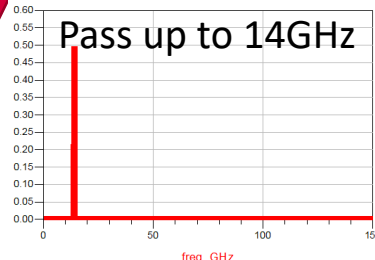


# Frequency spectrum of transmitter output waveform

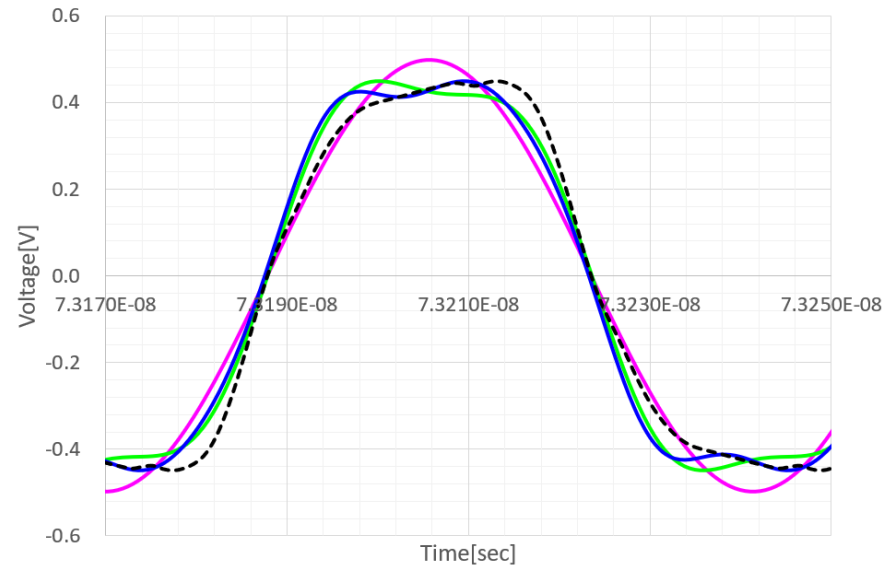
Original Waveform  
Frequency spectrum



Waveform  
measurement  
point



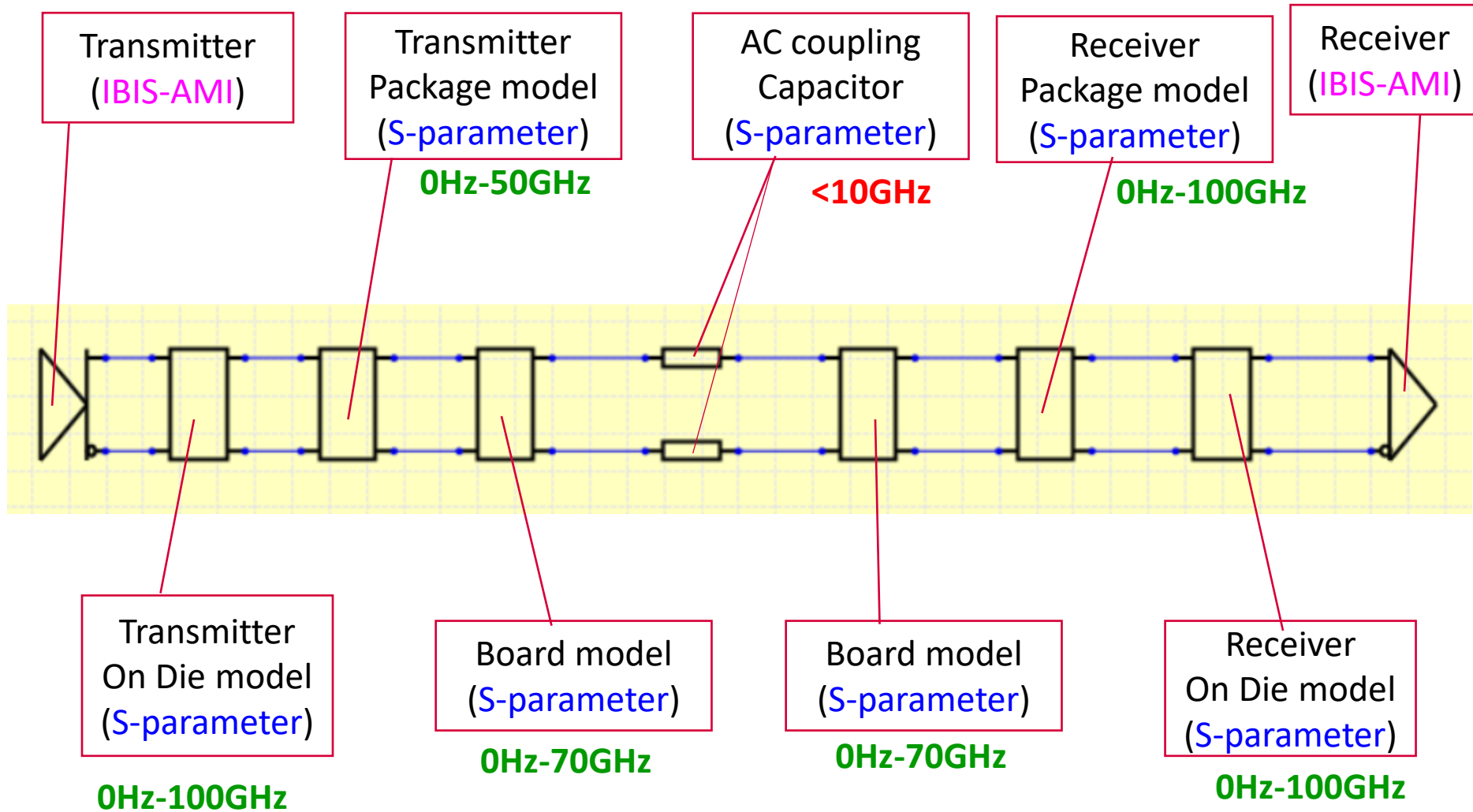
- black dotted line : Original Waveform
- pink solid line : Pass up to 14GHz
- Light Green solid line : Pass up to 42GHz
- Blue solid line : Pass up to 70GHz



Frequency of each S-parameter model in analog channel should be 70 GHz or higher.

# Frequency for each S-parameter model in analog channel

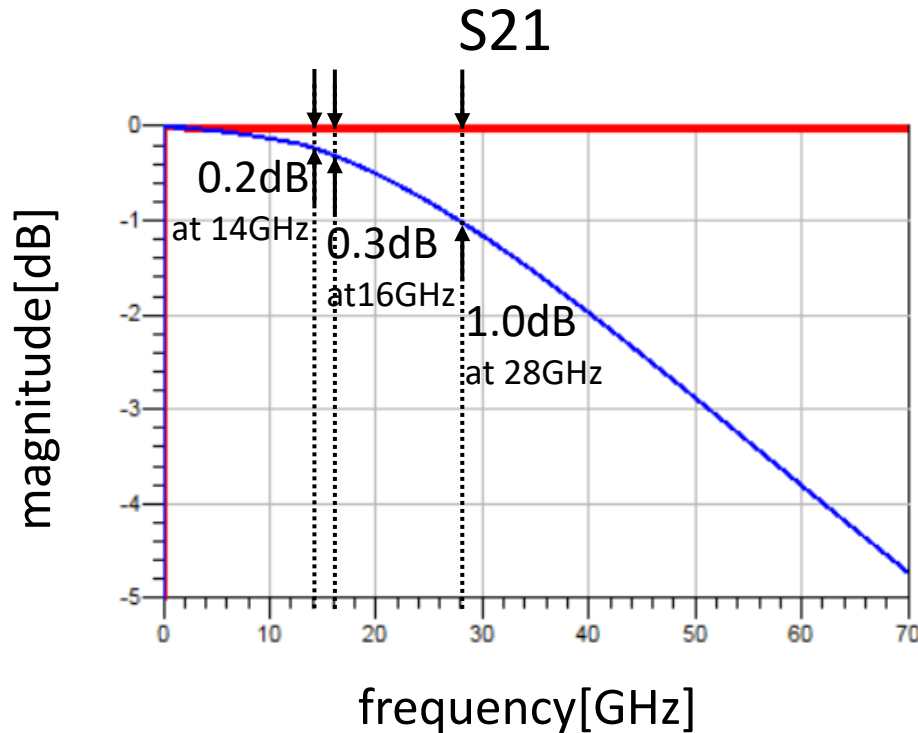
Analog channel for 28Gbps NRZ transmission



**AC coupling capacitor S-parameter model must be extrapolated above 70 GHz.**

# Extrapolated AC coupling capacitor S-parameters

Extrapolation of the original S-parameter of the AC coupling capacitor by the simulator



**Red solid line:**

Extrapolate at the highest frequency point to the target frequency  
(**Constant Extrapolation**)

**Blue solid line:**

Extrapolate linearly to the target frequency using a few points of the highest frequency  
(**Linear Extrapolation**)

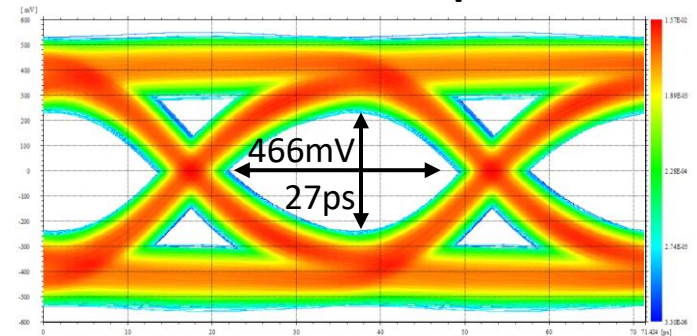
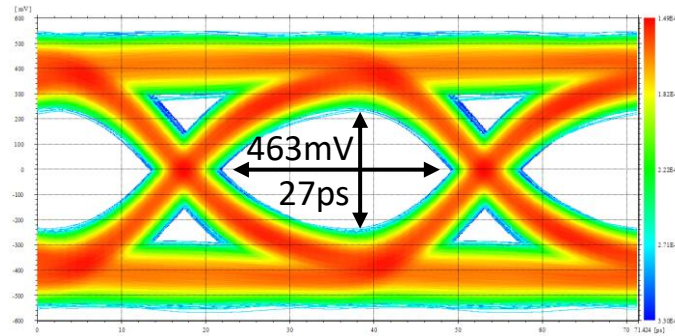
**Which curve is closer to the actual S-parameter?**

# Compare two S-parameter models by eye diagram

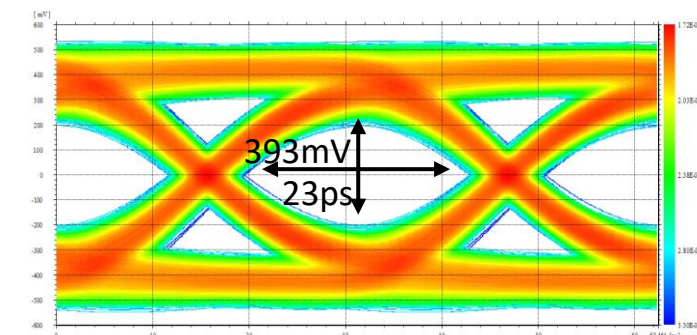
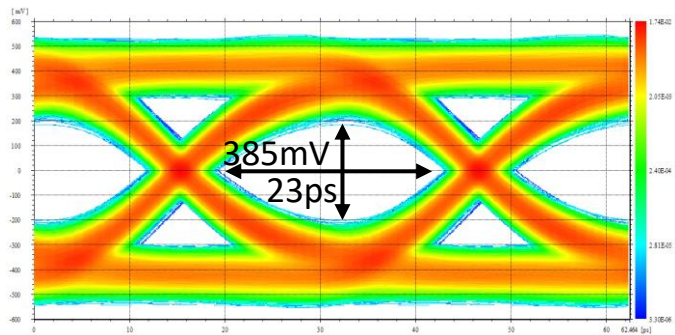
**Use S-parameter  
with Constant Extrapolation**

**Use S-parameter  
with Linear Extrapolation**

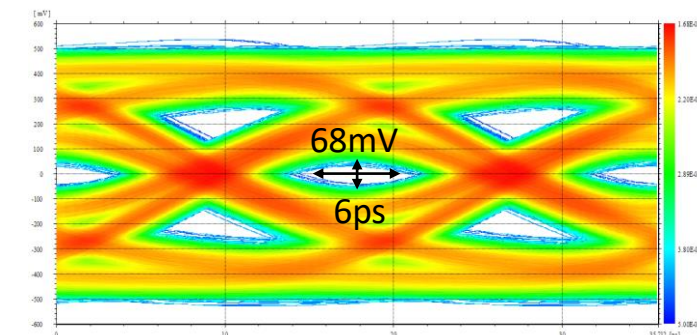
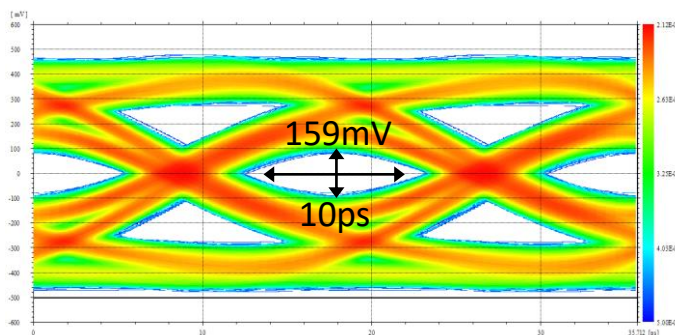
28Gbps NRZ  
(fnyq=14GHz)



32Gbps NRZ  
(fnyq=16GHz)



56Gbps NRZ  
(fnyq=28GHz)



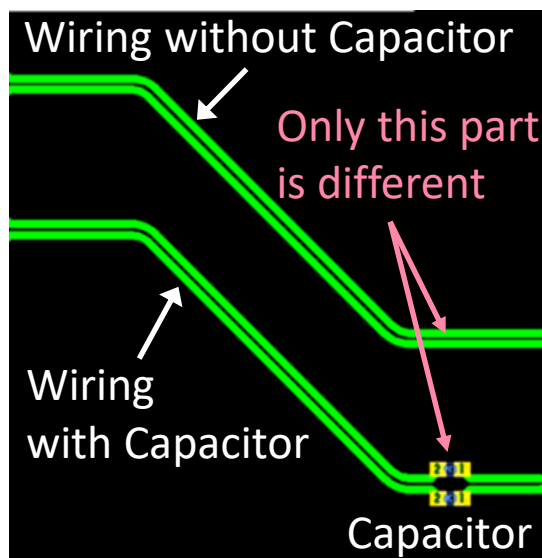
**At 56Gbps NRZ(,112Gbps PAM4) with Nyquist frequency = 28GHz, model differences affect eye opening.**



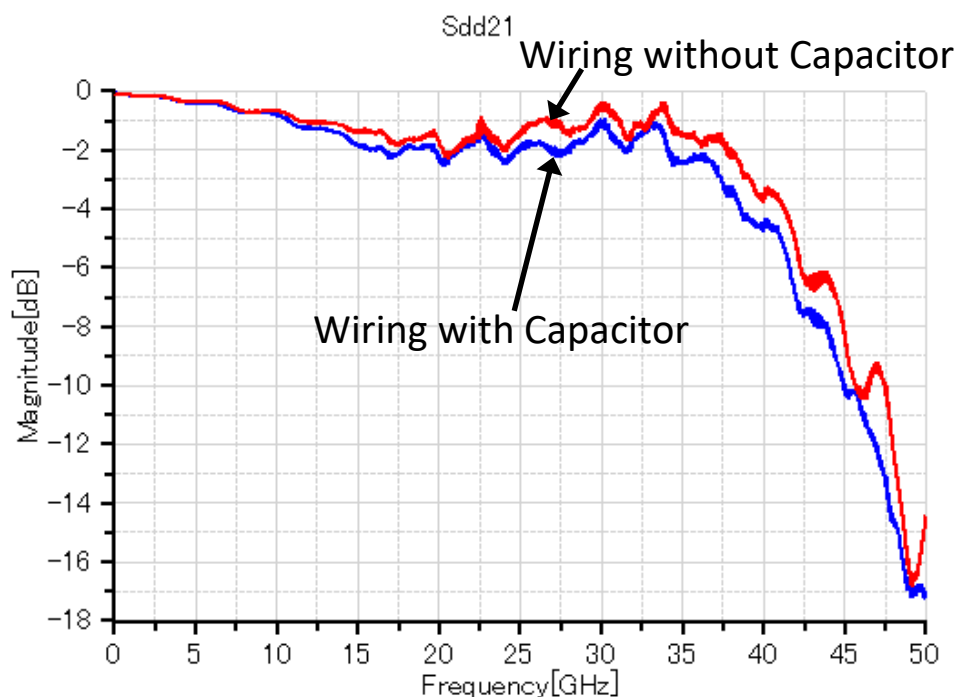
# Measured S-parameter of AC coupling capacitor

Capacitor loss was obtained by measuring the S-parameters of wiring without capacitors and wiring with capacitors, and from the difference.

## Measurement pattern in the evaluation board



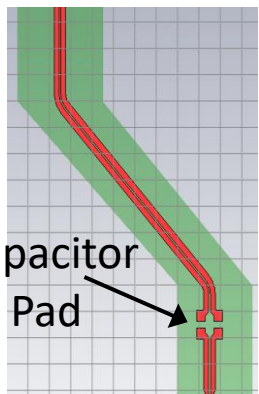
## Measurement result



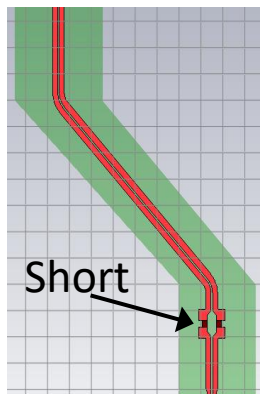
# Verification of the impact of capacitor mounting pads on loss difference

- Short the capacitor pads in Fig. 1 with a conductor as shown in Fig. 2.
- SDD21 of the wiring in Fig. 2 is obtained by simulation.
- Compare with SDD21 wiring without capacitor pad in Fig.3.

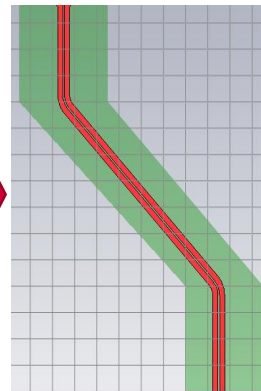
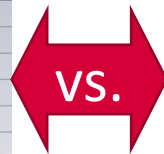
## Simulation models



**Fig.1**  
Original wiring  
model with  
capacitor

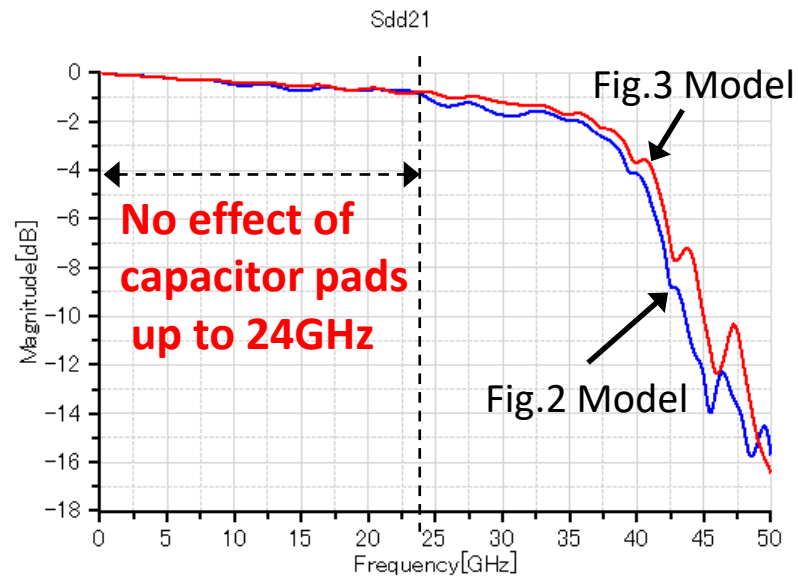


**Fig.2**  
Wiring model  
with shorted  
capacitor pad



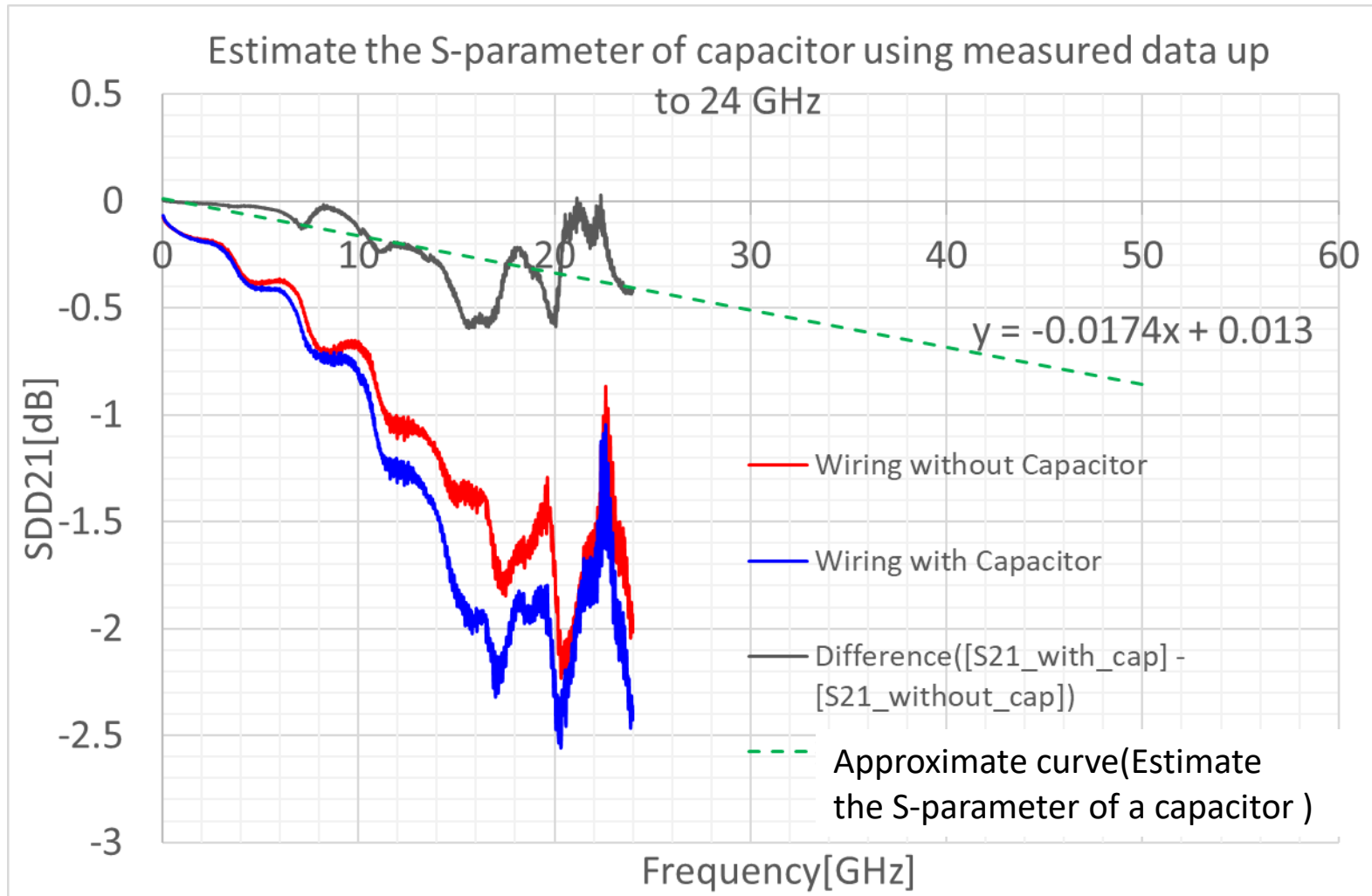
**Fig.3**  
Original wiring  
model without  
capacitor

## Simulation result

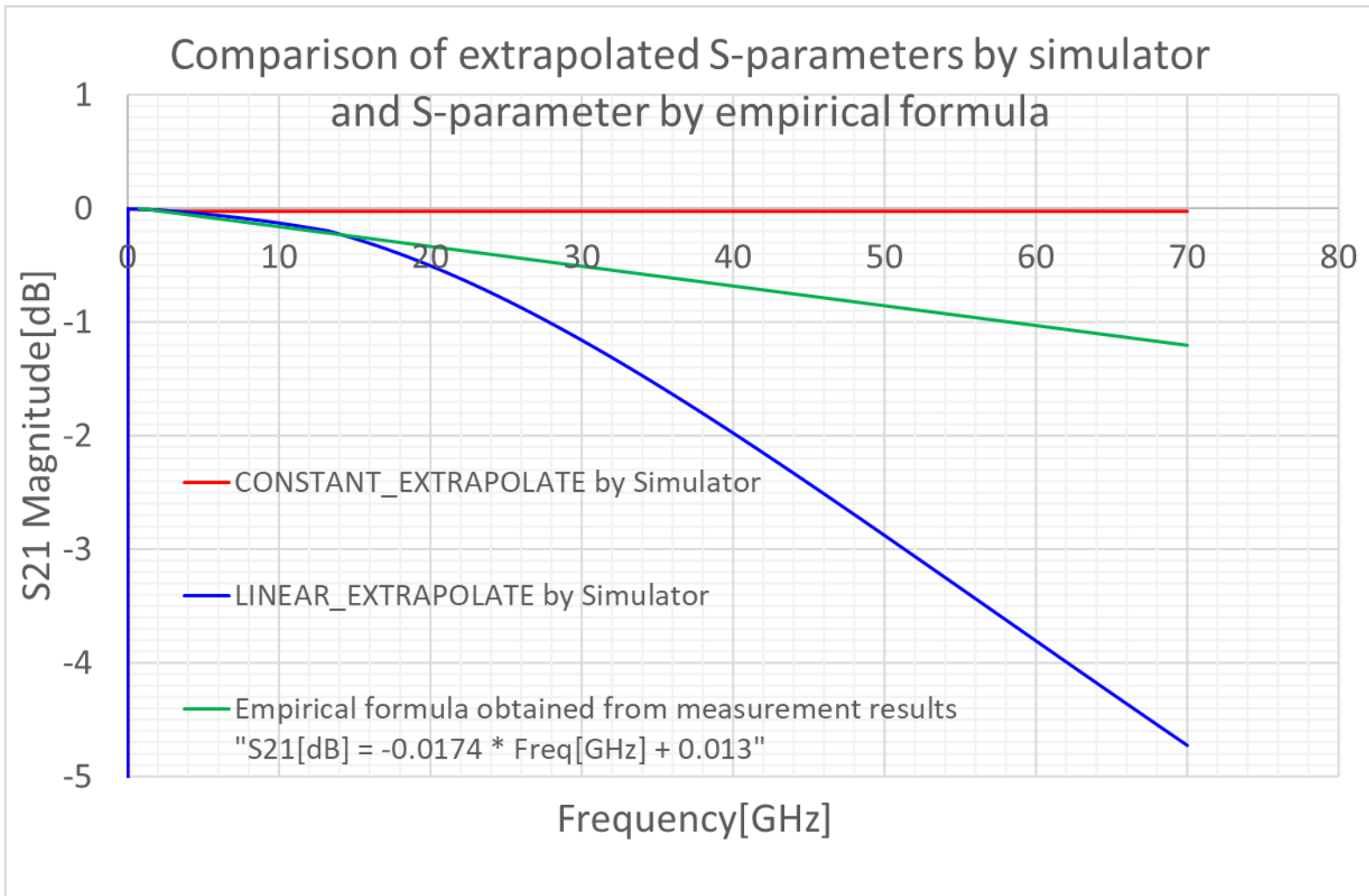


Estimate the S-parameter of a capacitor using measured data up to 24 GHz.

# Estimate the S-parameter of capacitor using measured data



# Compare simulator extrapolation and empirical extrapolation



How can I find a touchstone that matches the S21 obtained by the empirical formula?  
→Future tasks

# Summary

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- We investigated the frequency of each S-parameter model of analog channel in IBIS-AMI channel simulation.
- The S-parameters of the AC coupling capacitor were insufficient for the maximum frequency required for analysis, so extrapolation was performed using a simulator.
- Generate two types of S-parameter models by extrapolation.
- Up to 32Gbps, there was almost no difference in eye waveforms for both models.
- At 56Gbps NRZ (Nyquist frequency 28GHz), there was a large difference in eye opening between both models.
- Therefore, we investigated which of the two S-parameter models was closer to the measured data.  
Neither matched.
- Current extrapolation methods yield only two S-parameter models.  
In the future, it will be necessary to find a way to extrapolate the original S-parameters to match the measured data.

# References

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- JEITA/IBIS Seminar Textbook  
“第7回 JEITA/IBIS セミナー IBIS 解析入門  
Sparameter とは”  
JEITA EDA Model Specialty Committee  
November 12, 2018  
for S-parameter model

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