Connector Study and Concept

SI performance and Routing Length of VLC-PCB for 448G

April 14, 2025
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Abstract:

Basically I will explain of the connector and high speed routing of PCB by the VLC(Vertical Line Card) structure for 448G.

VLC is a structure that uses a vertical line card. See page 13.

The OSFP connector and cage are mounted vertically on the front side of the board, and the ASIC package is mounted on the back side or other Vertical PCB.

This brings the connector and package closer together, allowing for a shorter distance for high-speed signal wiring.

We mainly studied the possibility of 448G by High speed routing of PCB.

Contributions of Touchstone: Included Documentation

- OIF2025.137.00 Touchstone of VLC-OSFP connector for 448G - - **it will be uploaded end of April**
- OIF2025.138.00 Touchstone of 2D connector for 448G - - **it will be uploaded end of April**
- OIF2025.139.00 Touchstone of VLC-OSFP-XD connector for 448G - - **it will be delayed**

Supporters:

Chris Cole, Coherent Corp.

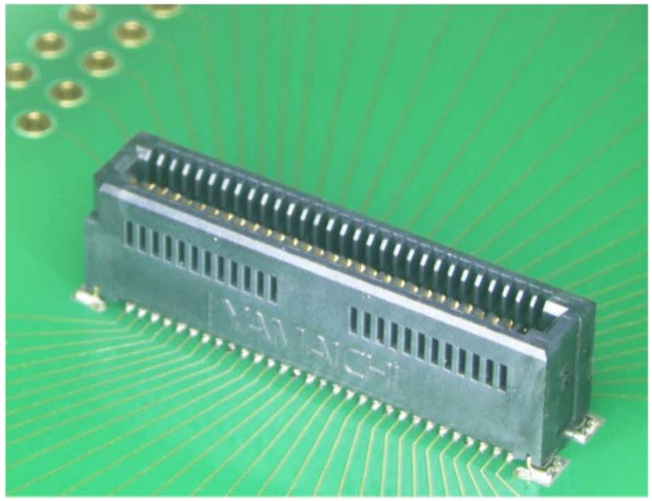
Peter Winzer, Nubis Communications

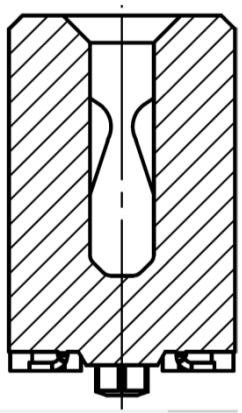
Toshiaki Sakai, Socionext

VLC-OSFP Connector for 448G

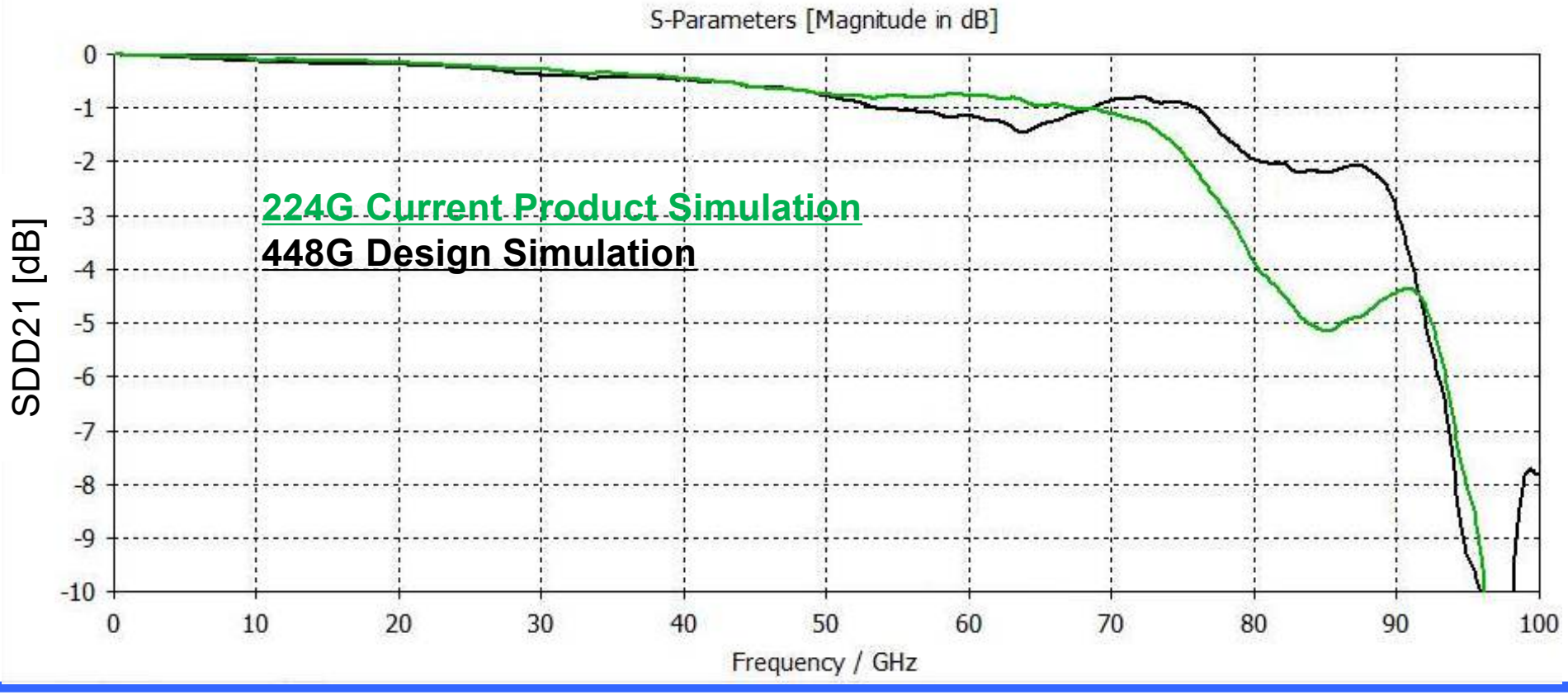
- Vertical Mounted OSFP Connector Simulation
- Connector have same pin mapping of OSFP.
- Connector Impedance is 92.5 ohm now.

Current OSFP-OSFP Connector





Differential Insertion Loss: Connector Only



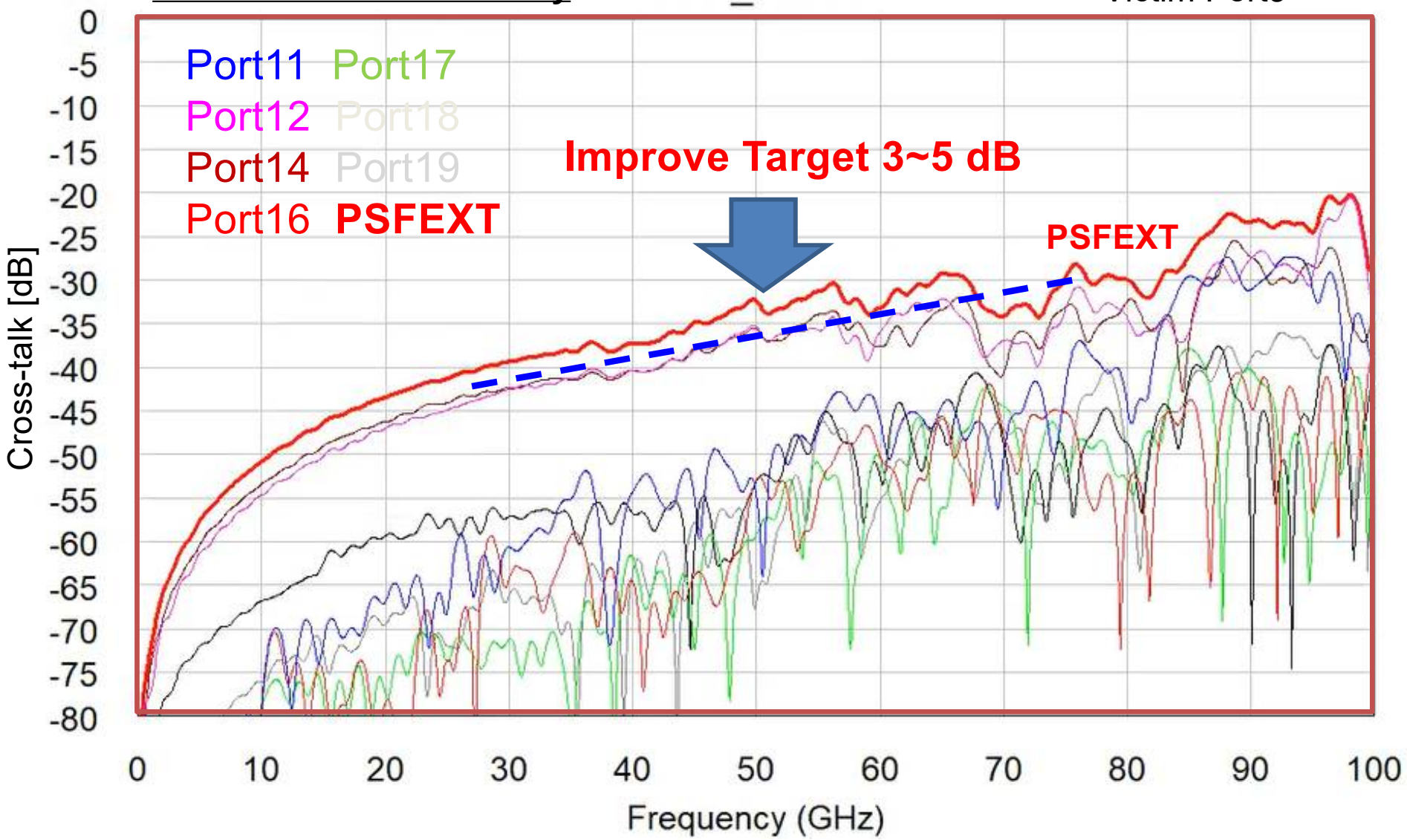
GND	1	GND	2	GND	3	GND	4	GND	CNT	GND	5	GND
GND	6	GND	7	GND	8	GND	9	GND	CNT	GND	10	GND
GND	11	GND	12	GND	13	GND	14	GND	CNT	GND	15	GND
GND	16	GND	17	GND	18	GND	19	GND	CNT	GND	20	GND

Victim

Aggressor

PS-FEXT: Connector Only

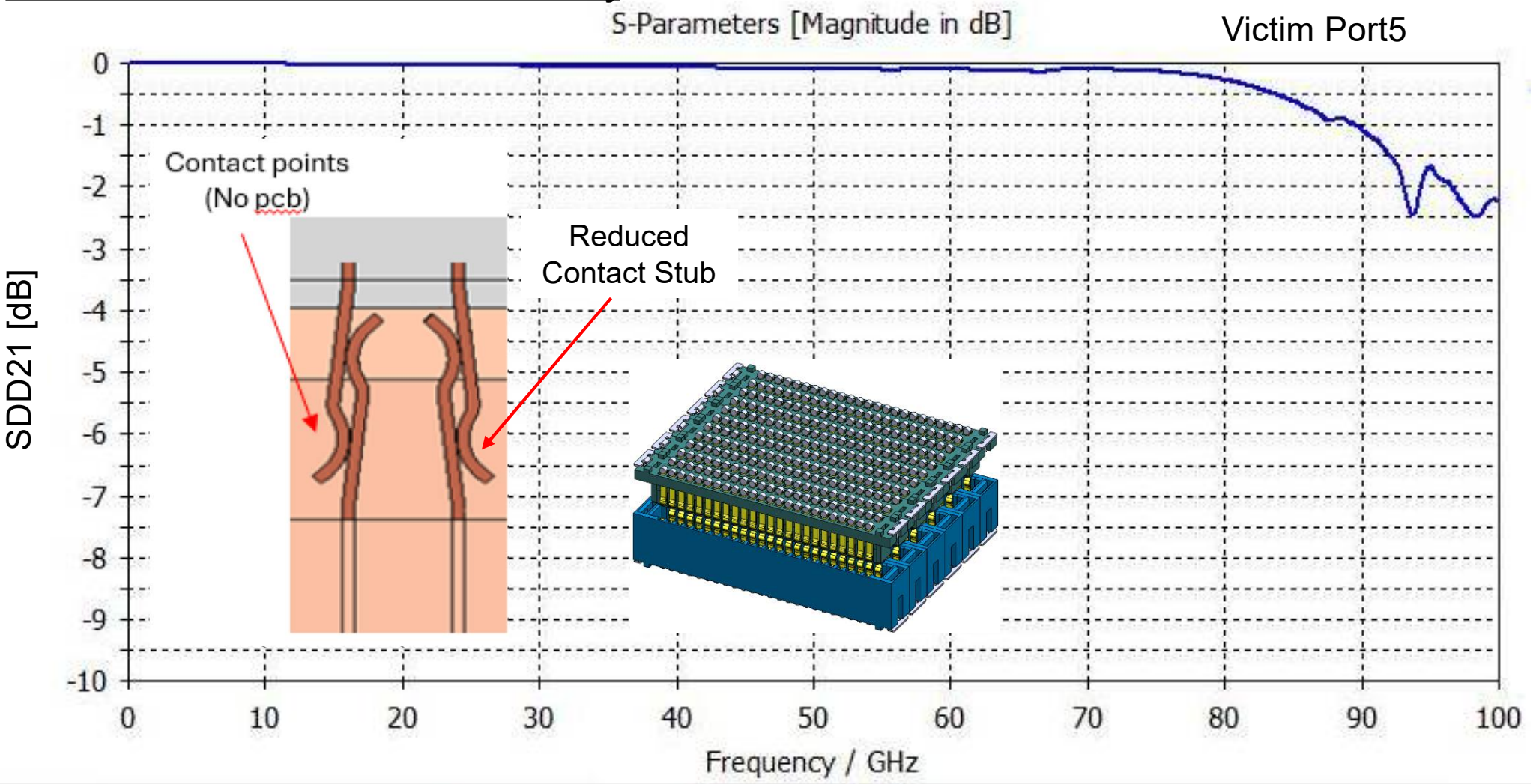
Victim Port3



2D Connector for 448G

- Tuning of Yamaichi Original 2D Connector Simulation
- Connector Impedance is 92.5 ohm now.

Differential Insertion Loss: Connector Only



Left Side Figure Reference：oif2025.084.02-Introductory Contribution On Some 448Gbps Tradeoffs

Top Side											
	GND	GND	1	GND	GND	2	GND	GND	3		
GND	4		GND	GND	5	GND	GND	6	GND	GND	
	GND	GND	7	GND	GND	8	GND	GND	9		
GND	10		GND	GND	11	GND	GND	12	GND	GND	

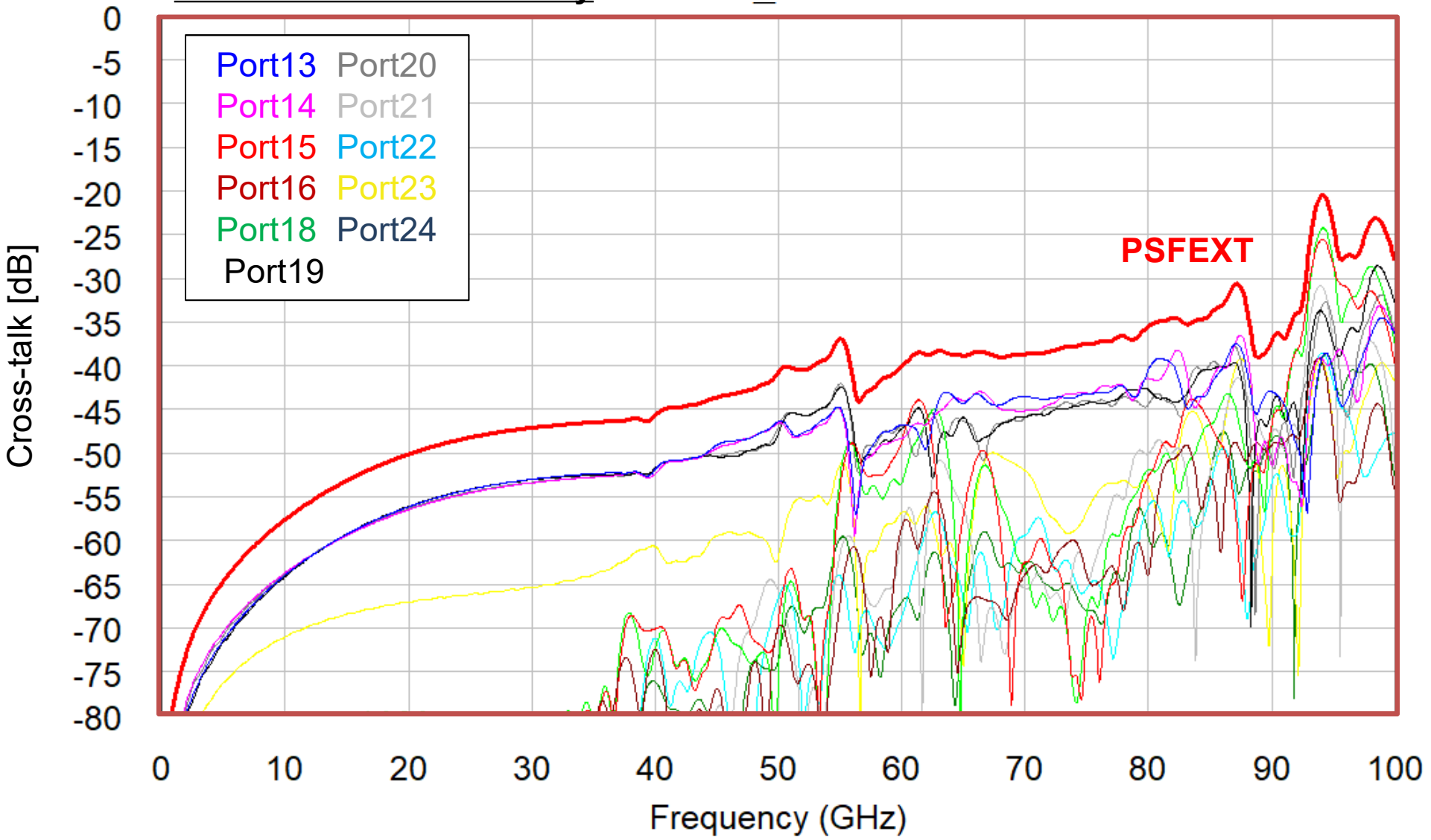
Bottom Side											
	GND	GND	13	GND	GND	14	GND	GND	15		
GND	16		GND	GND	17	GND	GND	18	GND	GND	
	GND	GND	19	GND	GND	20	GND	GND	21		
GND	22		GND	GND	23	GND	GND	24	GND	GND	

Victim

Aggressor

PS-FEXT: Connector Only

Victim Port5



Reference: 224G-VSR Calculation Result

- This calculation is reference to check for Cross talk and other parameters by 224G specification.
- The COM default host and module PCB models were added to the connector stand-alone characteristics and calculated as a channel model.
- Connector model is simulation based.
- Channel model doesn't included the via model..

VLC-OSFP

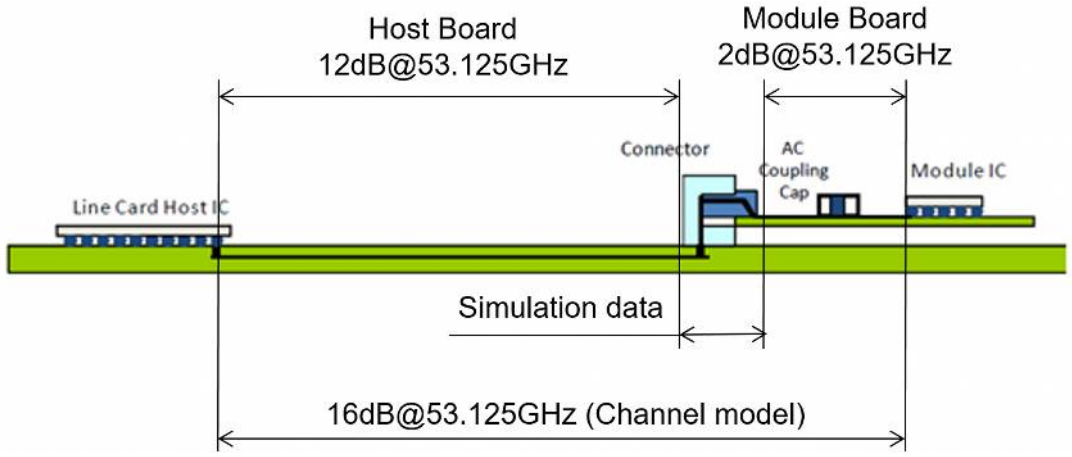
Include 7FEXT and 2NEXT

COM [dB]	ICN [mV]	MDFEXT [mV]	MDNEXT [mV]	ILD [dB]	ERL [dB]
6.01	1.20	1.20	0.06	0.024	14.28

2D Connector

Include 11FEXT

COM [dB]	ICN [mV]	MDFEXT [mV]	ILD [dB]	ERL [dB]
7.07	0.49	0.49	0.0064	23.91

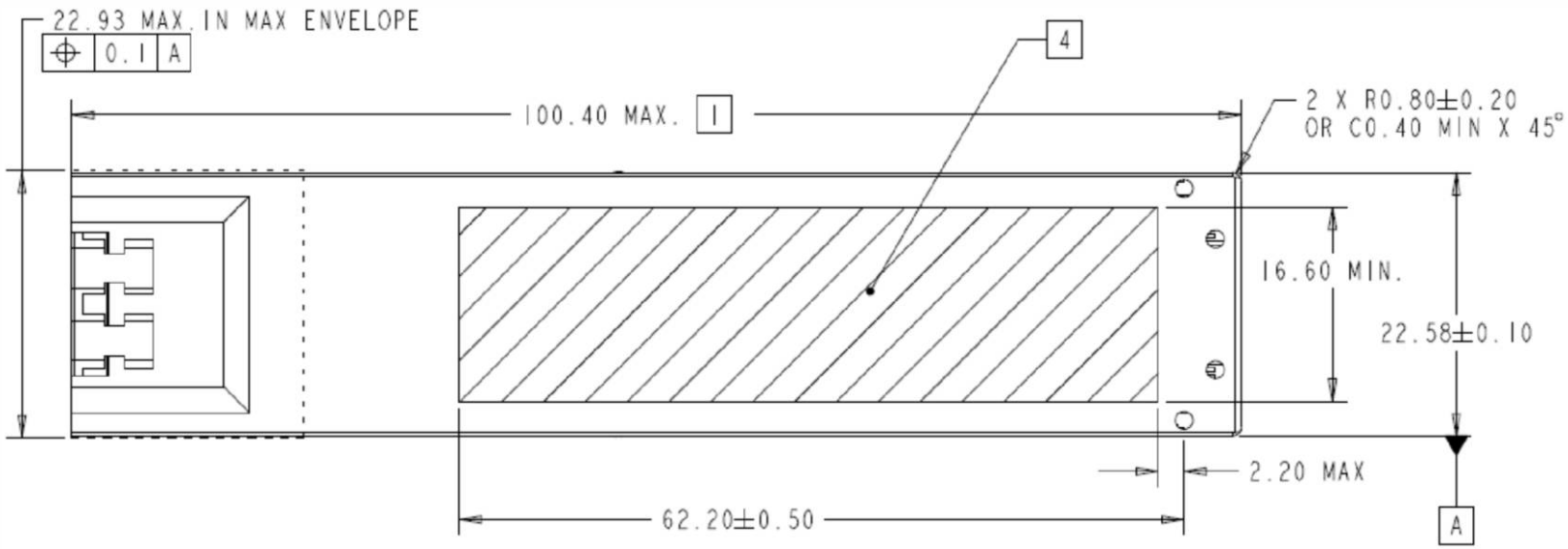


NOTE:

The config sheet used to calculate COM references values from 802.3dj.D1.2 and uses the COM4.80beta3 = COM4.80

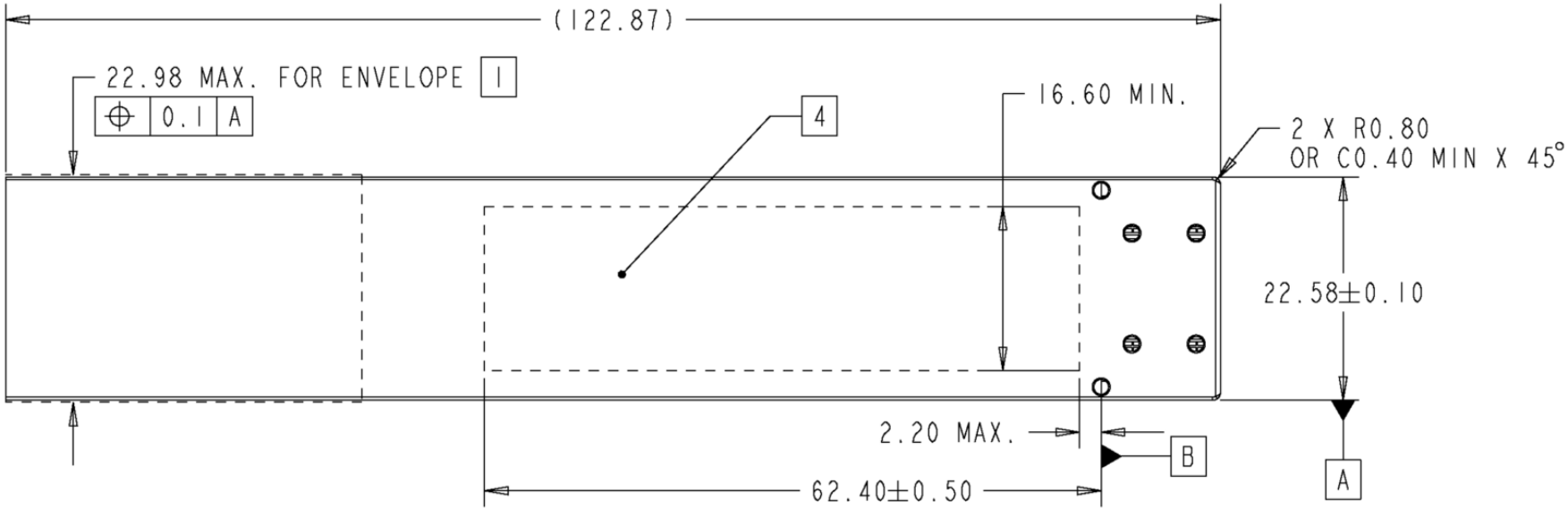
Standard Module: OSFP-RHS : 8 lanes (16 Differential Pairs/ DP)

Reference: OSFP Module_Specification_Rev5



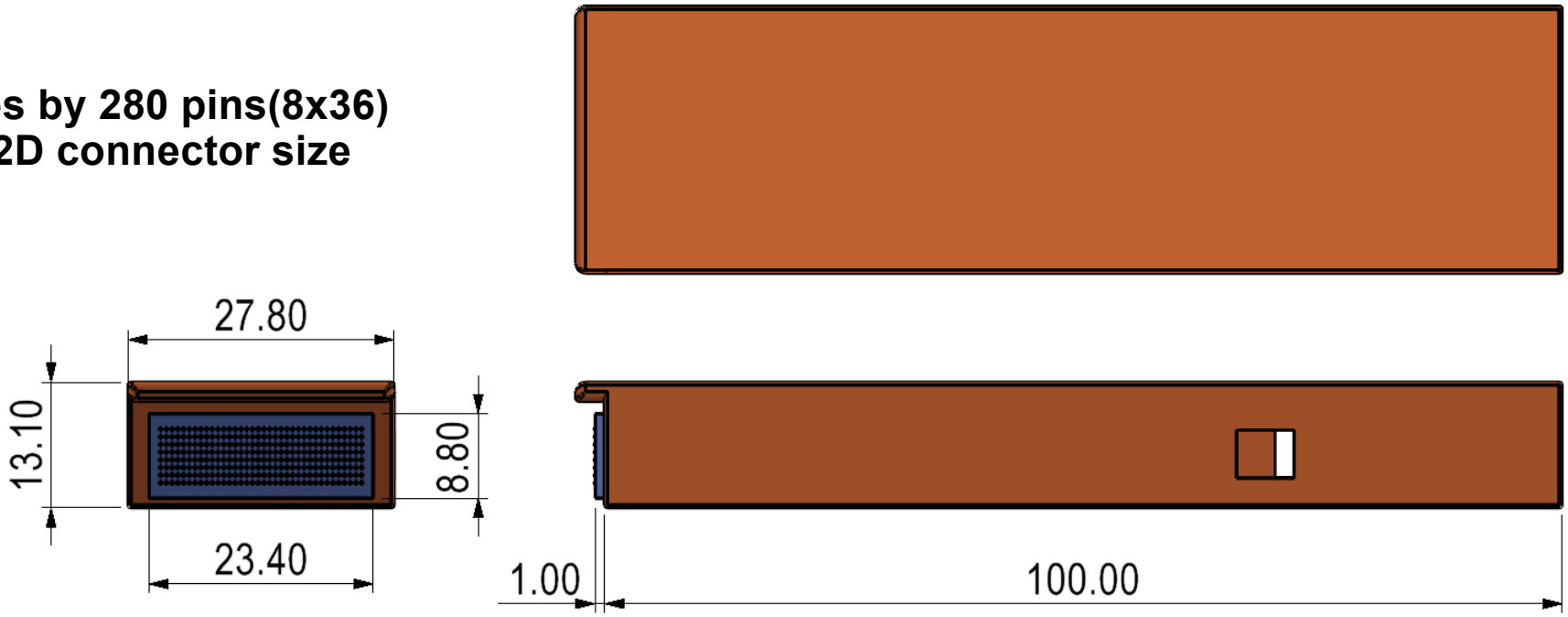
Standard Module: OSFP-XD-RHS : 16 lanes (32 DP)

Reference: Specification for OSFP-XD Rev 1.07



Idea of High Density Module: 32 lanes (64 DP)

32 lanes by 280 pins(8x36)
And 2D connector size

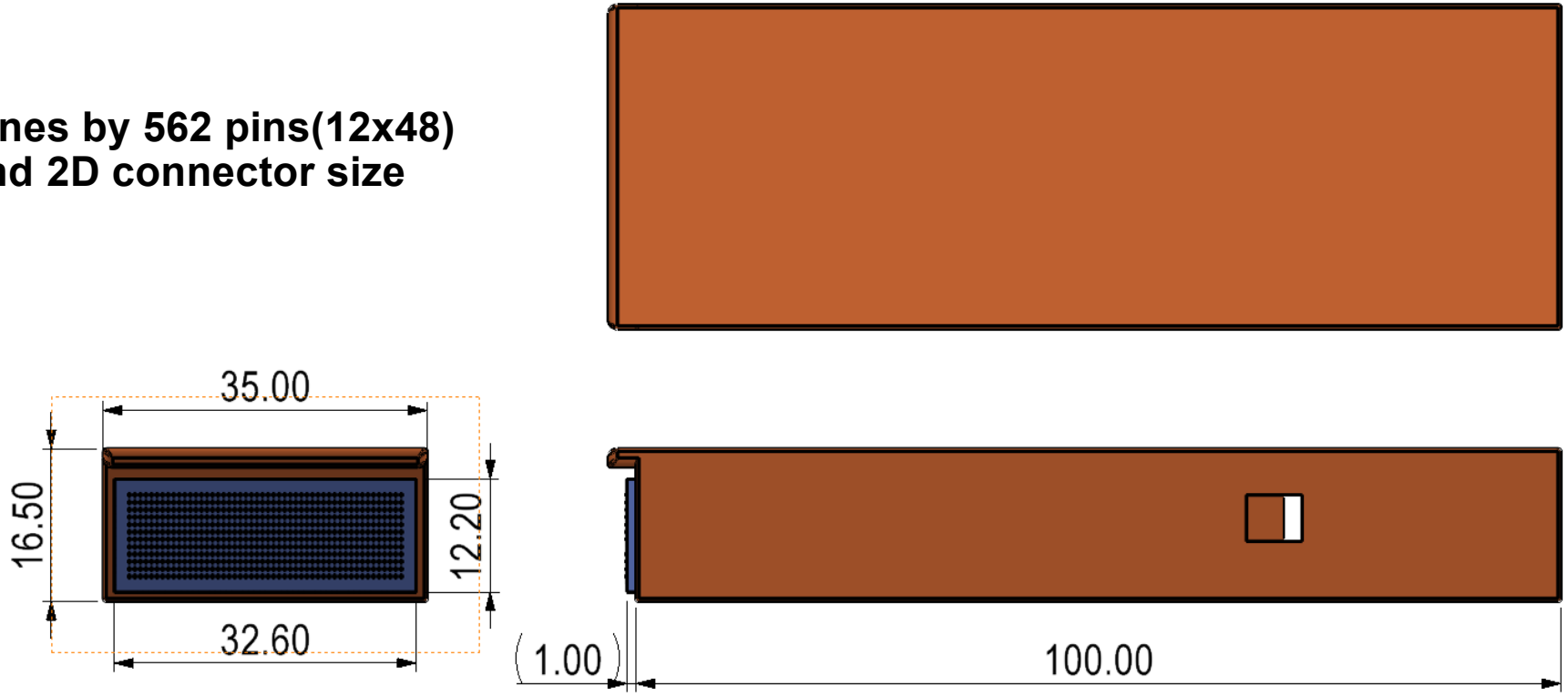


- PWR=12 pins, Control=4 pins

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	PWR	PWR	GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND
2	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	PWR	PWR	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND		
3		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	Cnt	PWR	GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND
4	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Cnt	Cnt	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND		
5		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	Cnt	PWR	GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND
6	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	PWR	PWR	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND		
7		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	PWR	PWR	GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND
8	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	PWR	PWR	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND		

Idea of High Density Module: 64 lanes (128 DP)

64 lanes by 562 pins(12x48)
And 2D connector size



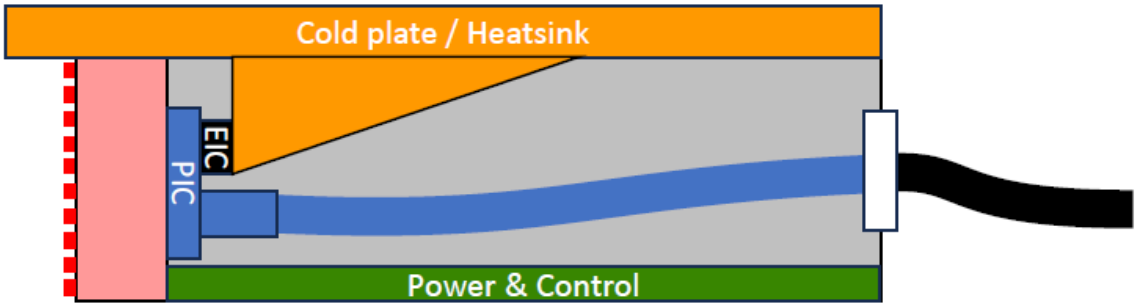
- PWR=17 pins, Control=7 pins

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
1		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	PWR	PWR	PWR	PWR	PWR	GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND
2	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	PWR	PWR	PWR	PWR	PWR	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND		
3		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	GND	GND	GND		Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND
4	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	Cnt	GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND		
5		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Cnt	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND
6	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	Cnt	GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND		
7		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Cnt	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND
8	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	Cnt	GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND		
9		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Cnt	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND
10	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	Cnt	GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND		
11		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	GND	GND	PWR	PWR	GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND
12	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	Tx		GND	GND	PWR	PWR	PWR	PWR	PWR	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND	Rx		GND	GND		

Inside Structure of High Density Module

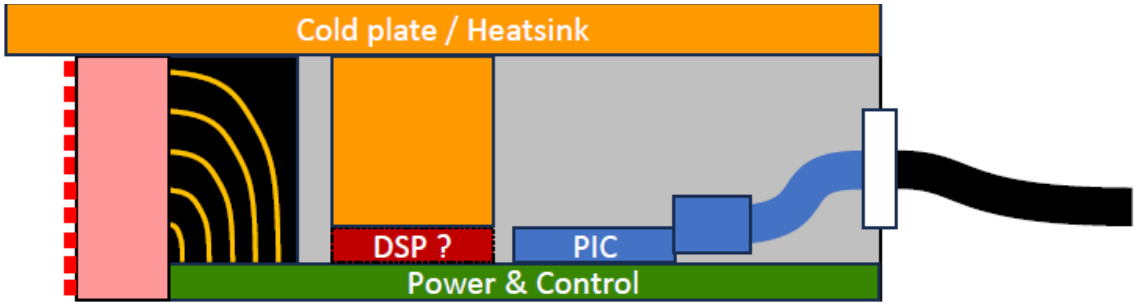
Vertically mounted chips with optical surface coupling:

- SI performance will be better.
- Is there enough space for mounting of PIC?
- Heat dissipation of PIC and EIC.



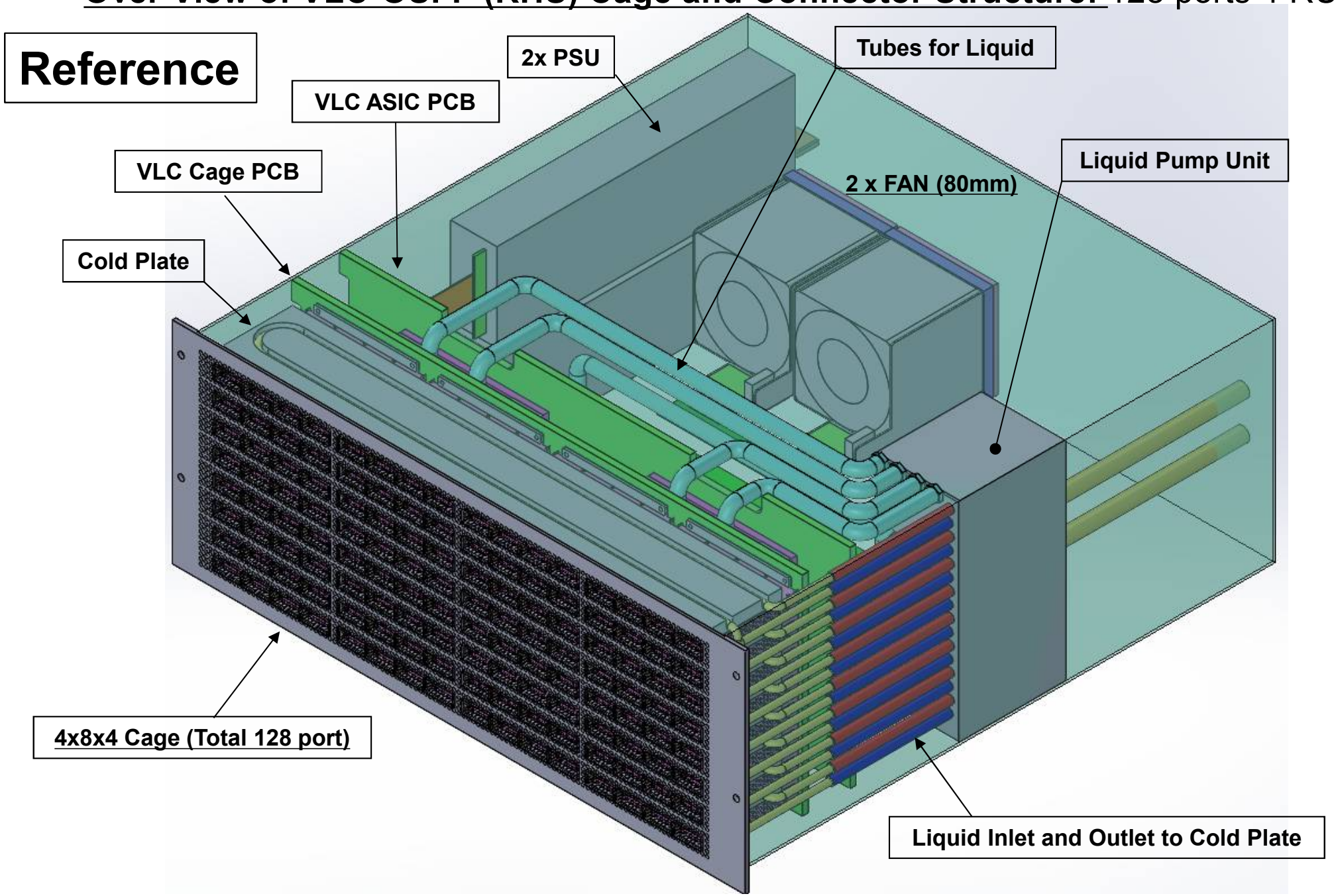
Horizontally mounted chips /Right angle terminal to module PCB:

- Right angle terminal will be worse for Insertion loss and Cross-talk
  Probably Insertion loss will be plus 2~3dB.
- Is there enough Insertion loss of module PCB?

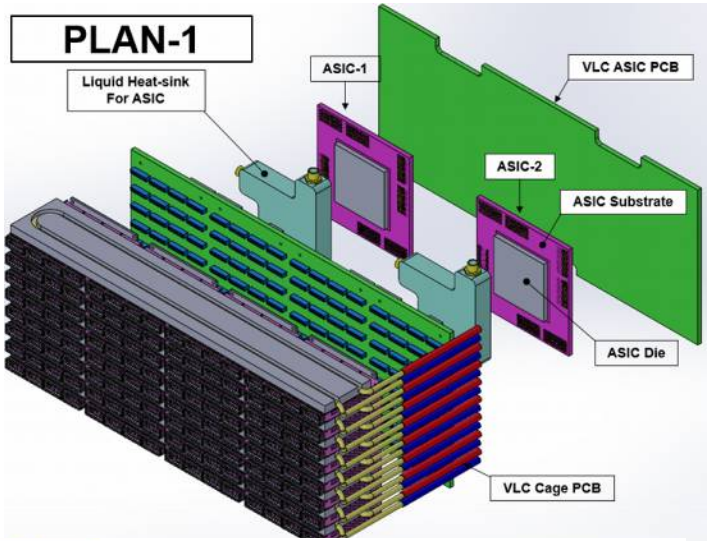


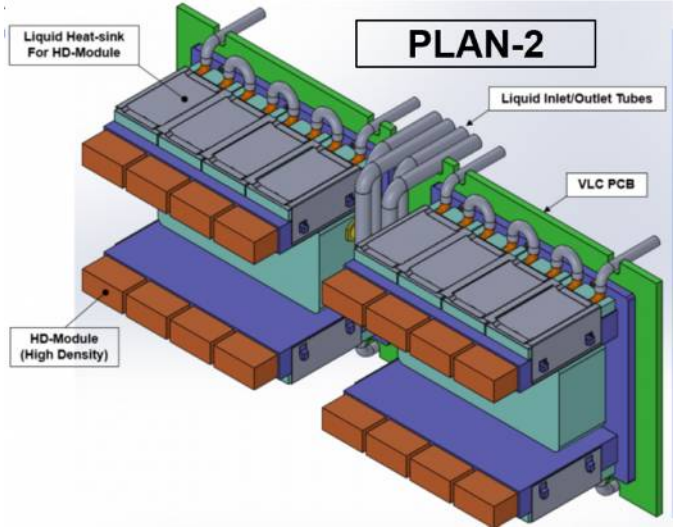
Reference: oif2025.010.02-High Density Connector - Sizing Considerations

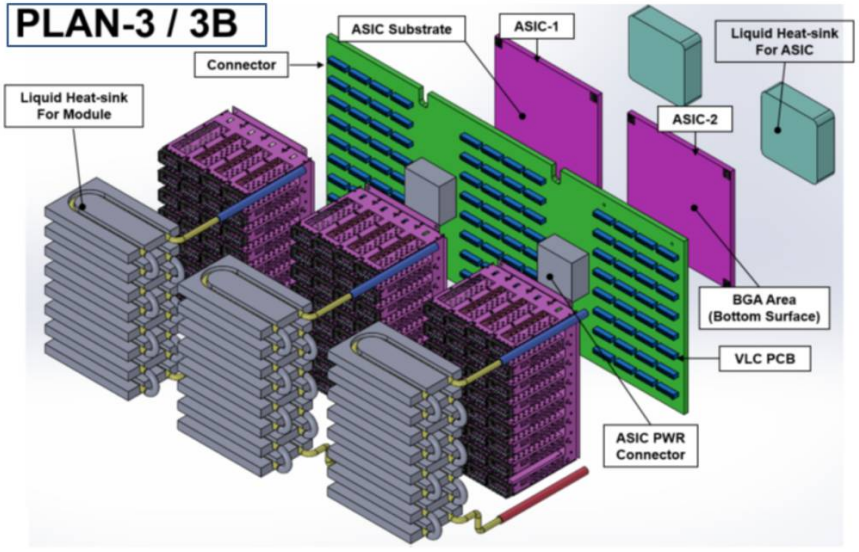
Over View of VLC-OSFP (RHS) Cage and Connector Structure: 128 ports 4 RU

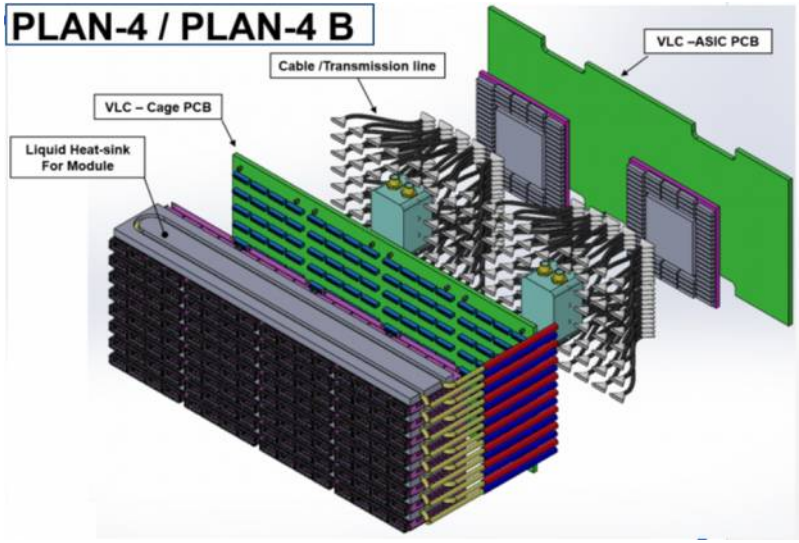


Concept of each PLANs				
PLAN	PCB	ASIC	Connection	Concept
PLAN-1	1	2	PCB Routing	CPC by B2B Connector
PLAN-2	1	1 or 2	Direct CPC	Direct Connection by High Density module
PLAN-3	1	1	PCB Routing	Connection by PCB
PLAN-3B		2		
PLAN-4	2	2	Twinax	OSFP and Cable receptacle separete soldring on PCB
PLAN-4B				Direct connect OSFP and Twinax
PLAN-5	1	2	PCB Routing	Connection by PCB + Cable using for Far End





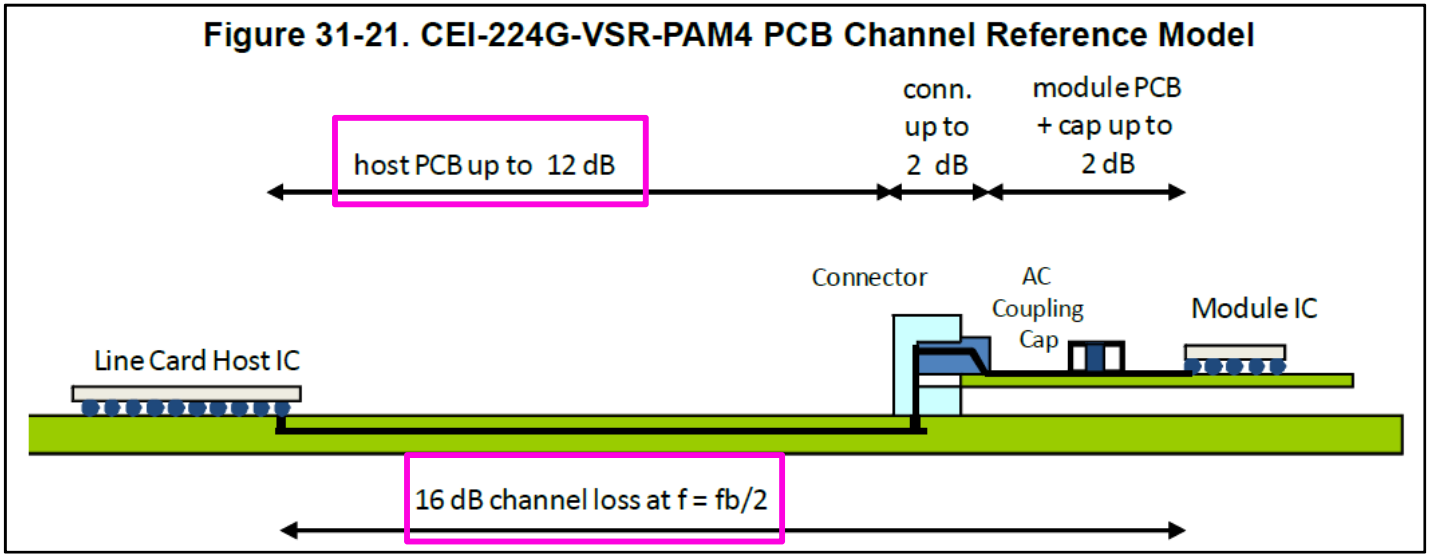




Target Insertion loss of Host PCB Loss and Channel Loss for Reference

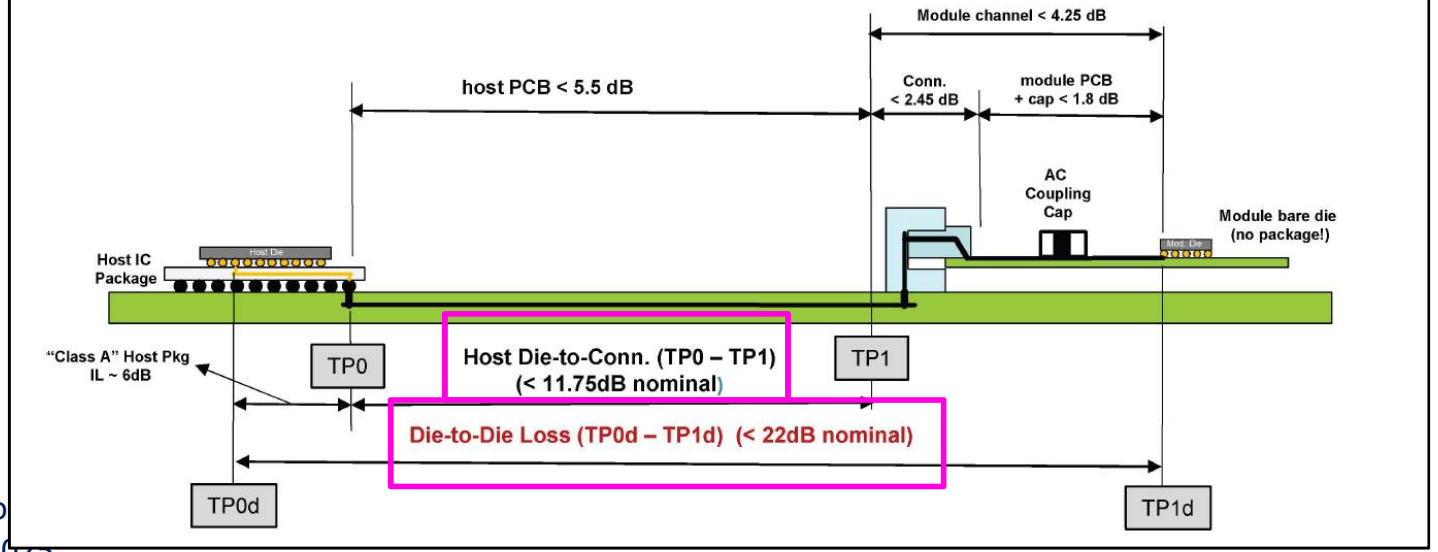
- Target of maximum insertion loss of host PCB and channel loss was referred to CEI-224G-VSR and Linear.
- I compared Insertion loss and Transmission length as each PLANs after next page.

Figure 31-21. CEI-224G-VSR-PAM4 PCB Channel Reference Model



Reference: oif2024.532.00-CEI-224G-VSR-PAM4 Very Short Reach Interface

Figure 1-12. CEI-224G-linear-PAM4 PCB-Pluggable or NPO Module Channel Reference Model



Reference: oif2024.522.01-CEI-224G-Linear specification

Comparison of PLANs vs Insertion loss (Upper Side is better)

- Table shows the host PCB and channel insertion loss of **longest line** for each PLAN at 74 GHz and 89 GHz.
- This includes PCB routing, connectors, vias, and module PCB+AC-CAP line lengths and insertion losses.
- Material insertion loss has a large effect.

~10 dB	10~12dB	12dB~

~14 dB	14~16dB	16dB~

PLAN	Trans. Material	Longest Line		Line Loss [dB]		Via Loss [dB]		CPC-1 CONN		CPC-2 CONN		Host PCB Loss[dB]		OSFP CONN		Module PCB+CAP		Channel Loss[dB]	
		mm	inch	74GHz	89GHz	74GHz	89GHz	74GHz	89GHz	74GHz	89GHz	74GHz	89GHz	74GHz	89GHz	74GHz	89GHz	74GHz	89GHz
PLAN-2	Right Angle	0.0	0.00	0.00	0.00							0.0	0.0	4	4.5	2	2	6.0	6.5
	Mezzanine			0.00	0.00							0.0	0.0	2	2.5	2	2	4.0	4.5
PLAN-5	Low Loss	80.4	3.17	8.50	10.22	1.40	1.60					9.9	11.8	2	2.5	2	2	13.9	16.3
	Ultra Low			5.31	6.39							6.7	8.0	2	2.5	2	2	10.7	12.5
	Cable	80.0	3.15	2.11	2.54	1.40	1.60	1	1.5	2	2.5	6.5	8.1	2	2.5	2	2	10.5	12.6
PLAN-4		150.0	5.91	3.96	4.77	1.40	1.60	1	1.5	2	2.5	8.4	10.4	2	2.5	2	2	12.4	14.9
PLAN-4 B		150.0	5.91	3.96	4.61			1	1.5			5.0	6.1	3	3.5	2	2	10.0	11.6
PLAN-3 B	Low Loss	91.7	3.61	9.69	11.66	1.40	1.60					11.1	13.3	2	2.5	2	2	15.1	17.8
	Ultra Low			6.06	7.29							7.5	8.9	2	2.5	2	2	11.5	13.4
PLAN-1	Low Loss	56.5	2.22	5.97	7.18	1.40	1.60	3	3.5			10.4	12.3	2	2.5	2	2	14.4	16.8
	Ultra Low			3.73	4.49			3	3.5			8.1	9.6	2	2.5	2	2	12.1	14.1
PLAN-3	Low Loss	145.5	5.73	15.38	18.50	1.40	1.60					16.8	20.1	2	2.5	2	2	20.8	24.6
	Ultra Low			9.61	11.56							11.0	13.2	2	2.5	2	2	15.0	17.7

Material Insertion loss

(Refer: oif2024.532.00)

Material	dB/mm	Loss per Inch [dB]		
		56GHz	74GHz	89GHz
Low Loss PCB	0.080	2.03	2.69	3.23
Ultra Low Loss PCB	0.050	1.27	1.68	2.02
Twinax Cable	0.020	0.508	0.67	0.81

NOTE:

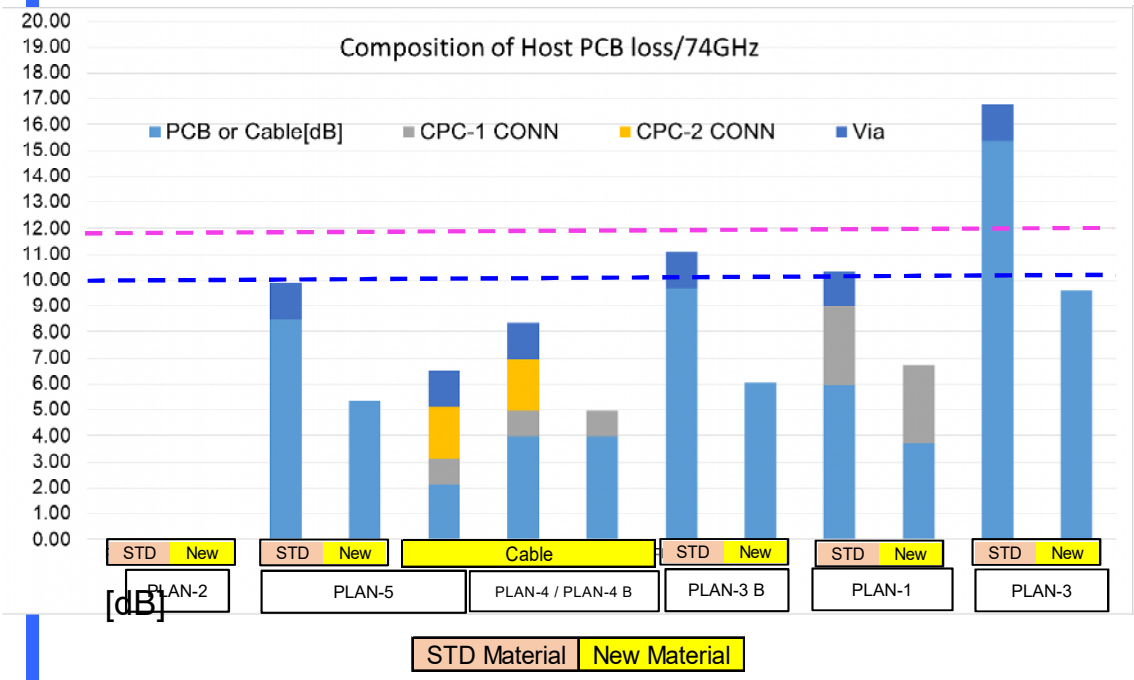
We will change the Host PCB Loss values by new materials of PCB and Cable at this Workshop and later.

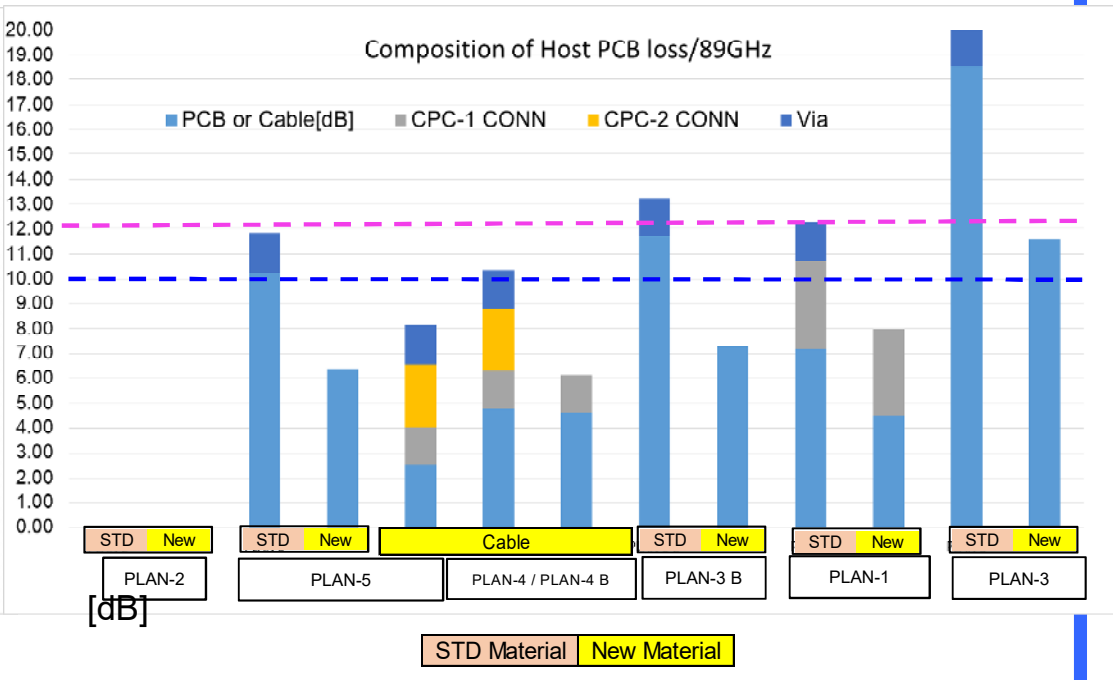
Concept of each PLANs

PLAN	PCB	ASIC	Connection	Concept
PLAN-1	1	2	PCB Routing	CPC by B2B Connector
PLAN-2	1	1 or 2	Direct CPC	Direct Connection by High Density module
PLAN-3	1	1	PCB Routing	Connection by PCB
PLAN-3B		2		
PLAN-4	2	2	Twinax	OSFP and Cable receptacle separete soldring on PCB
PLAN-4B				Direct connect OSFP and Twinax
PLAN-5	1	2	PCB Routing	Connection by PCB + Cable using for Far End

PLAN Comparison of Host PCB loss (the plan on the left shows a low insertion loss)

- This graph show Host PCB insertion loss at 74 GHz and 89 GHz.
- PLAN-2 (CPC with high-density modules) showed Zero lowest insertion loss.
- At 74 GHz, almost PLANs of the Host PCB are less than 12dB.
- The ultra-low loss PCBs except for PLAN-3 have a host PCB loss of 10 dB or less at 74GHz and 89 GHz.



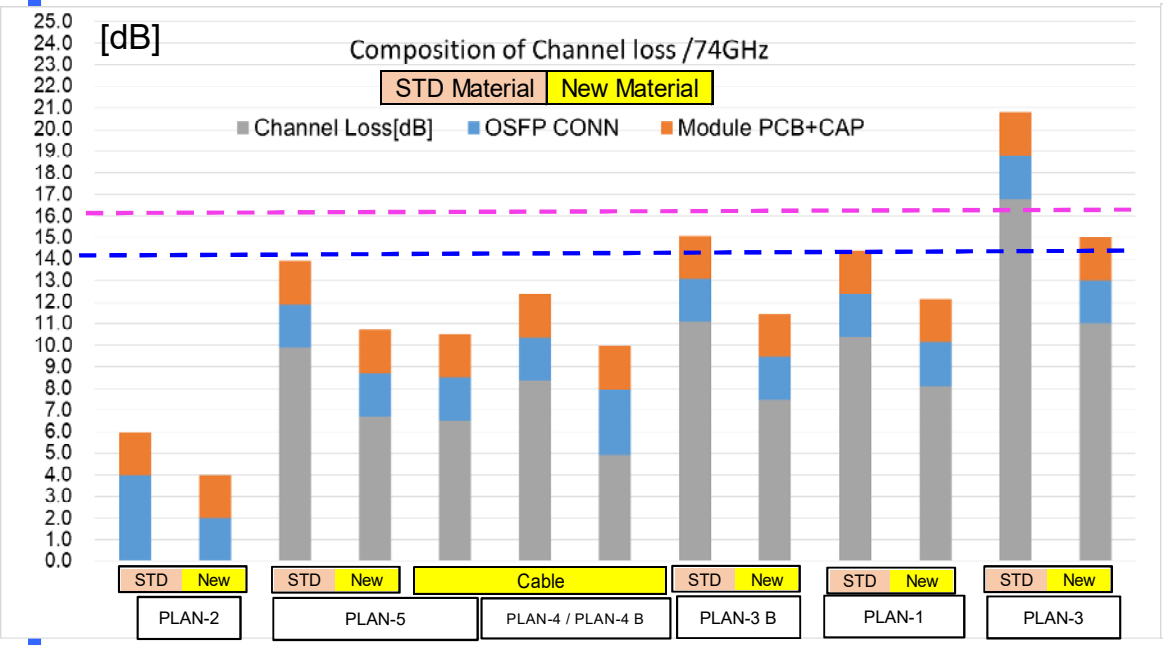


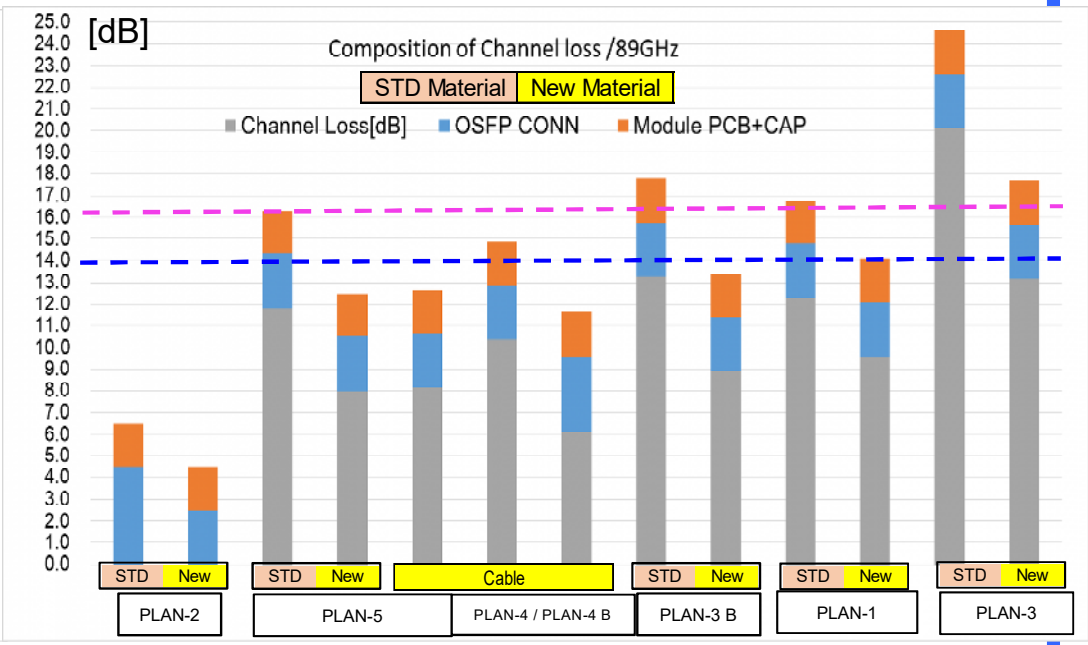
Concept of each PLANs

PLAN	PCB	ASIC	Connection	Concept
PLAN-1	1	2	PCB Routing	CPC by B2B Connector
PLAN-2	1	1 or 2	Direct CPC	Direct Connection by High Density module
PLAN-3	1	1	PCB Routing	Connection by PCB
PLAN-3B		2		
PLAN-4	2	2	Twinax	OSFP and Cable receptacle separete soldring on PCB
PLAN-4B				Direct connect OSFP and Twinax
PLAN-5	1	2	PCB Routing	Connection by PCB + Cable using for Far End

PLAN Comparison of Channel loss (the plan on the left shows a low insertion loss)

- This graphs show the Channel insertion loss at 74 GHz and 89 GHz.
- PLAN-2 (CPC with high-density modules) showed the lowest insertion loss.
- At 74 GHz, almost PLAN of the Channel insertion loss were less than 14dB.
- The ultra-low loss PCBs except for PLAN-3 have a Channel insertion loss of 12 dB or less at 89GHz.





Concept of each PLANs				
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PLAN-3B		2		
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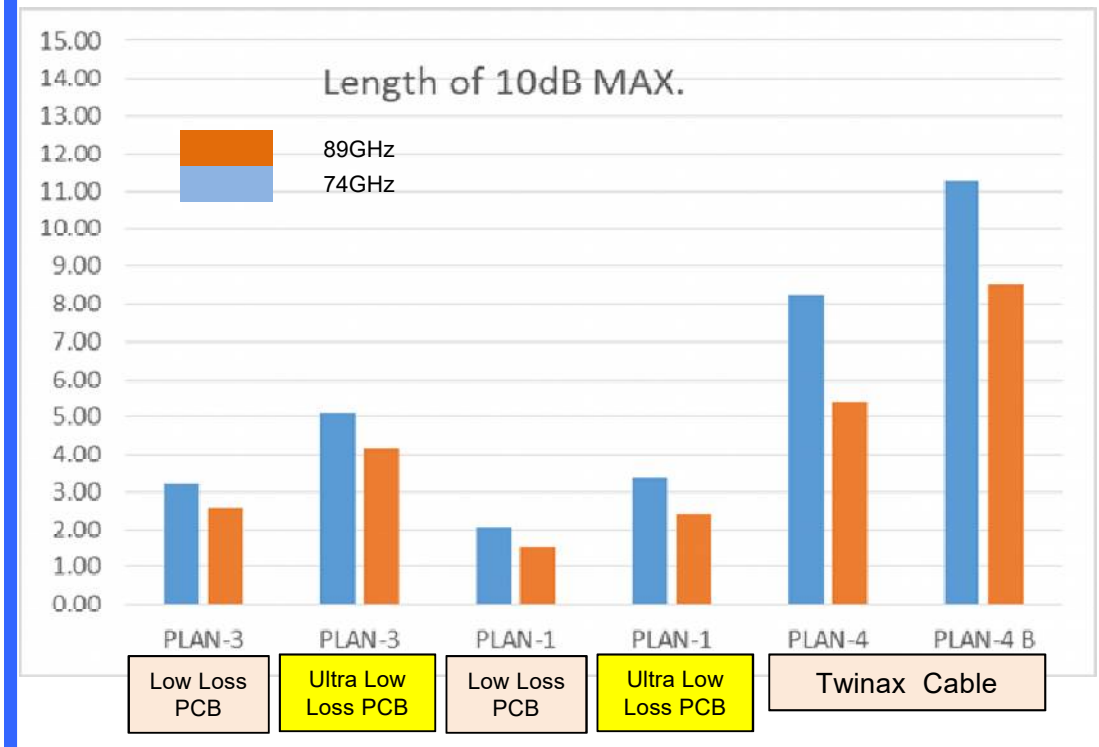
PLAN-4B				Direct connect OSFP and Twinax
PLAN-5	1	2	PCB Routing	Connection by PCB + Cable using for Far End

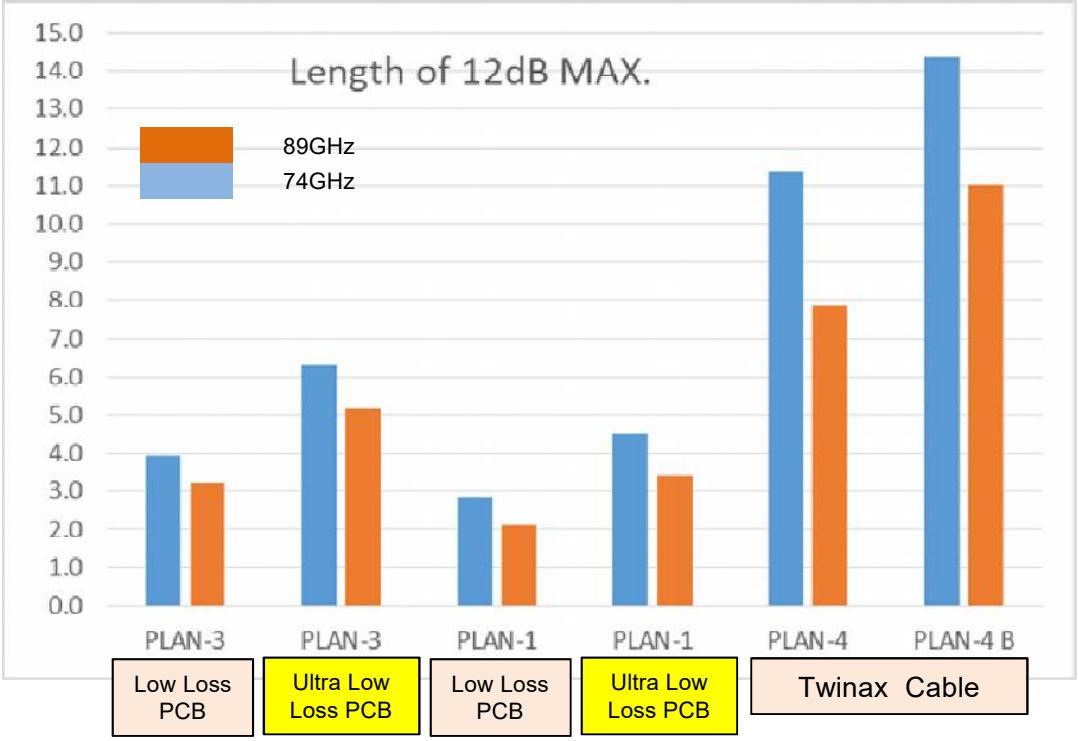
Host PCB/Cable Length of each plan at 10dB and 12dB of Host PCB Loss

- This graphs show PCB/Cable length at 10 dB and 12dB of Host PCB loss with each PLAN.

[inch]



[inch]



Concept of each PLANs				
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PLAN-3B		2		
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PLAN-4B				Direct connect OSFP and Twinax
PLAN-5	1	2	PCB Routing	Connection by PCB + Cable using for Far End

Summary

SI performance simulation of 448G connector

- In this presentation, we report the SI performance of tuned vertical mount OSFP and 2D connectors.
  The 2D connector showed good performance, but the VLC-OSFP connector can also achieve satisfactory insertion loss.
- For study of Cross-talk, ICN of COM parameter of 448G is not specified.
  Then ICN of 224G-PAM4 was used as a reference. And the results were excellent.
- We provide these touchstone files.
  As a result, we hope that committee members will utilize the 448G verification in advance.

Insertion Loss and Line Length for 448G

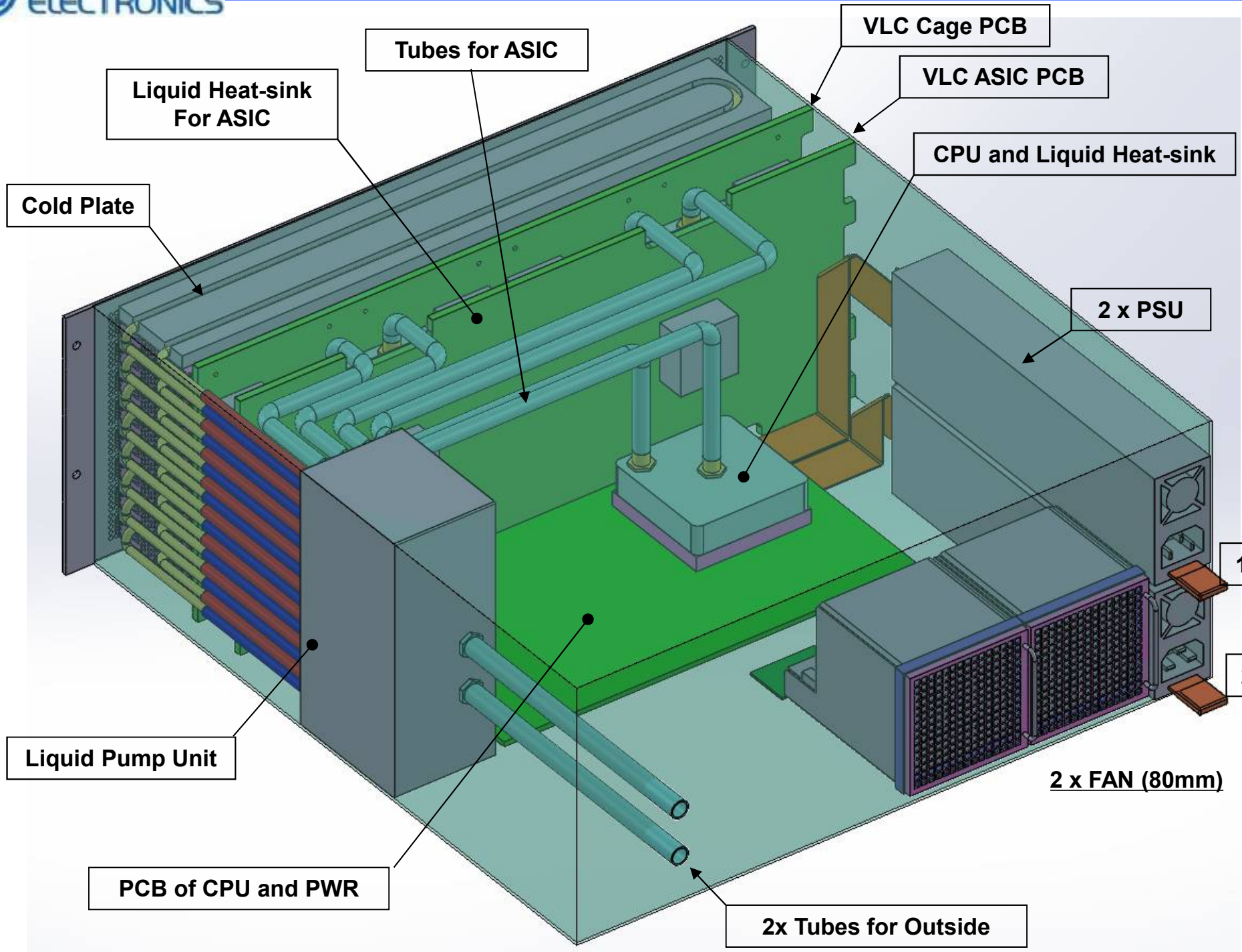
- We verified whether the VLC structure could achieve the insertion loss necessary for 448G transmission.
  The routing length are calculated of longest length in PCB and Cable.
- In this study, almost PLANs will be able to do 448G transmission.
  And it was found that by better setting the distance from the ASIC, an insertion loss of -10~12 dB of Host PCB loss can be achieved with 448G-PAM8 (74 GHz) or 448G-PAM6 (89 GHz).
- And PCB material is very important.

Next Step

- Further improvement of connector and others after discussion at this 448G workshop.
- SI performance improvement and S-parameters (Touchstone) of 448G compatible OSFP-XD connector.
- OSFP and new high density module heat dissipation structure and simulation over 50 ~ 100 watts.

The structure of VLC still has several points needed to improvement for actual use cases.
So we will improve these points for customers' actual use cases.

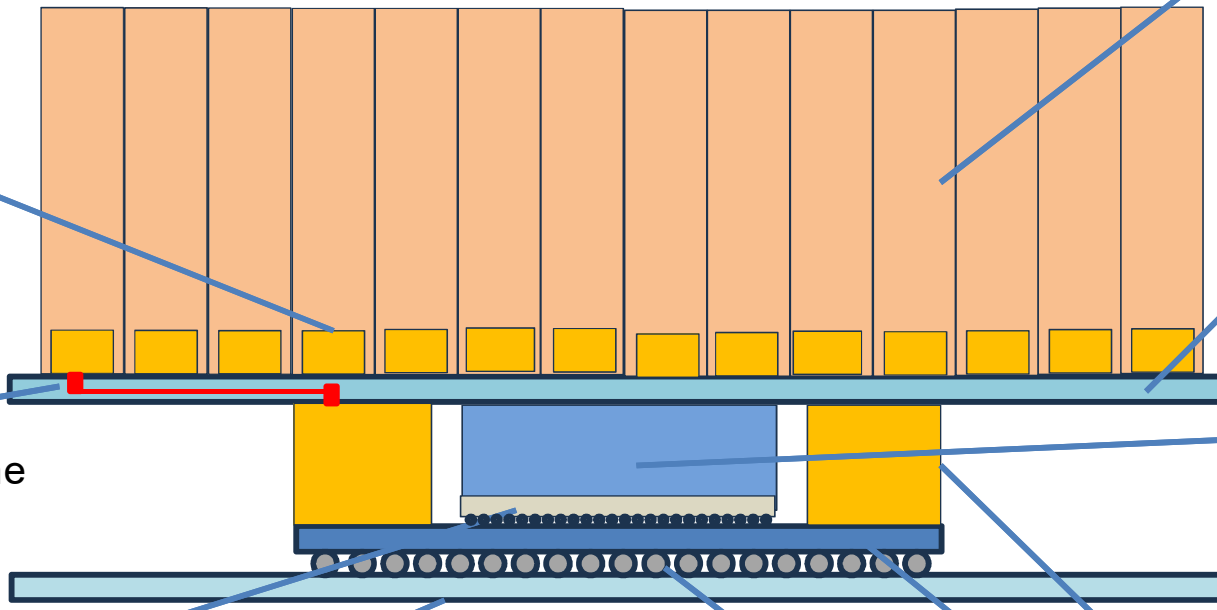
Backup Pages


VLC Cage PCB
Tubes for ASIC
VLC ASIC PCB
Liquid Heat-sink
For ASIC
CPU and Liquid Heat-sink
Cold Plate
2 x PSU
115V Inlet
225V Inlet
Liquid Pump Unit
2 x FAN (80mm)
PCB of CPU and PWR
2x Tubes for Outside

PLAN-1

VLC connector + ASIC :128 Ports/4RU Possible

not to scale



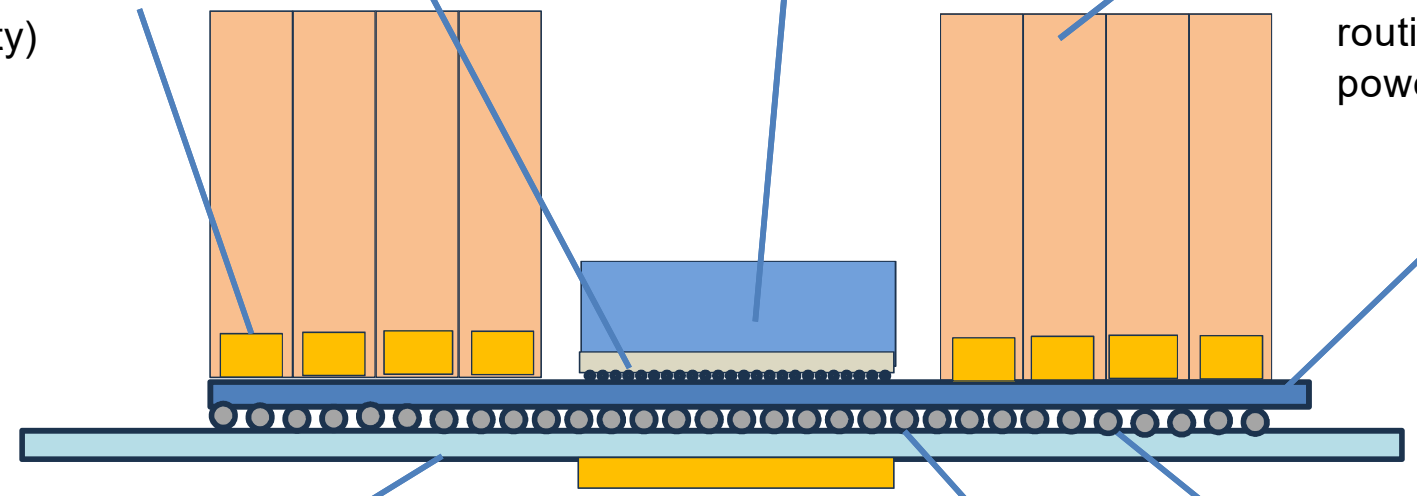
Need mechanical support structure.
Appropriate compression pressure needed for electrical contact.

PLAN-2

PLAN-2

VLC connector (High Density) + ASIC :96 Ports/4RU Possible

not to scale



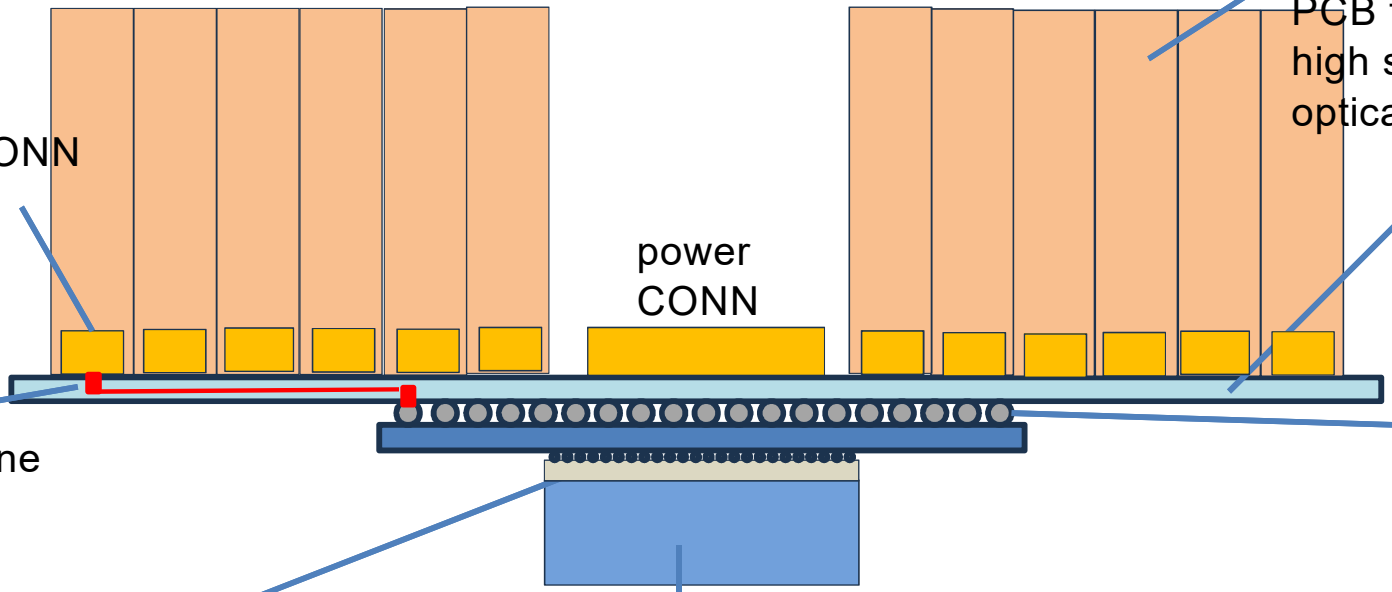
Need mechanical support structure.
Appropriate compression pressure needed for electrical contact.

PLAN-3

PLAN-3

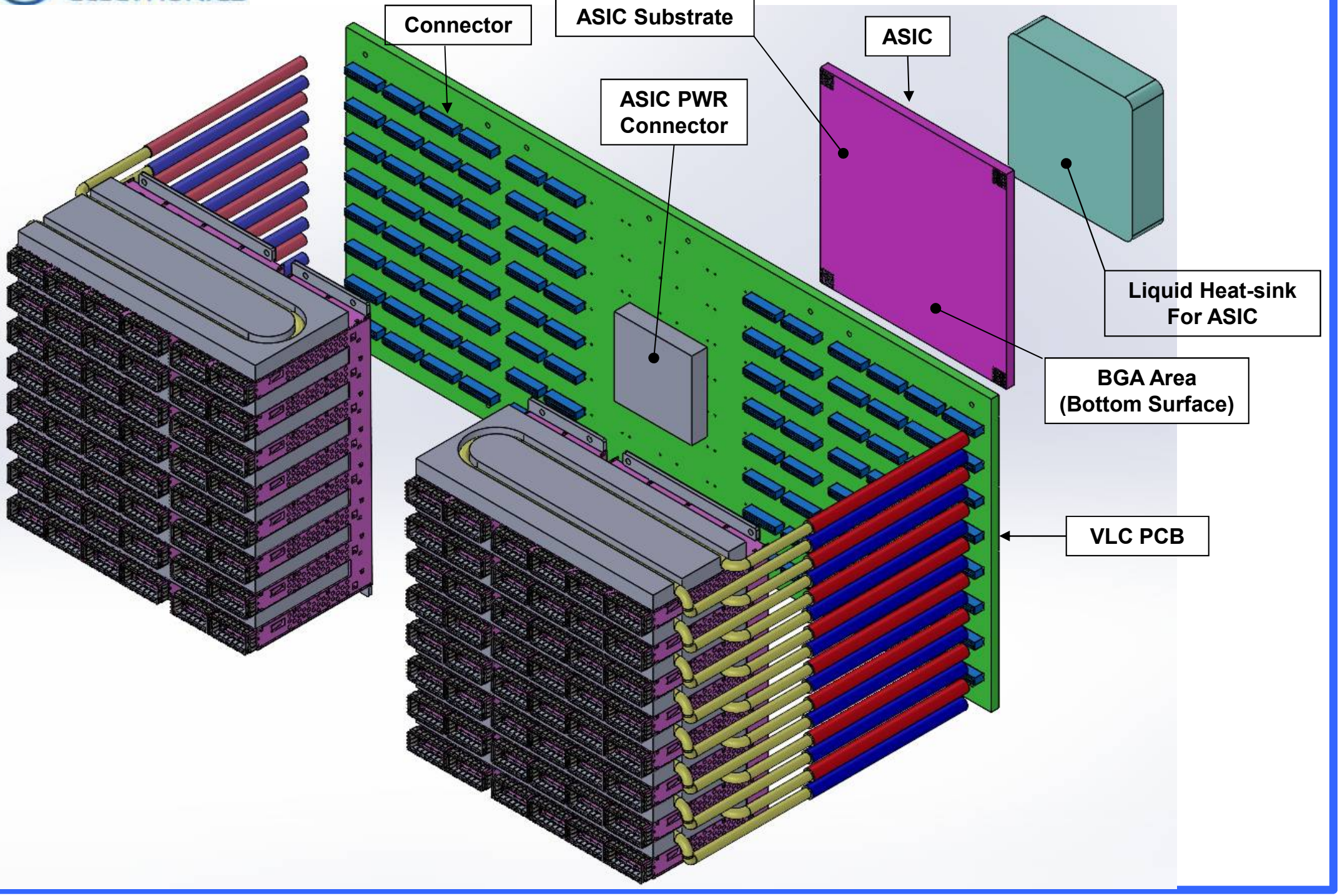
VLC connector + ASIC :96 Ports/4RU Possible

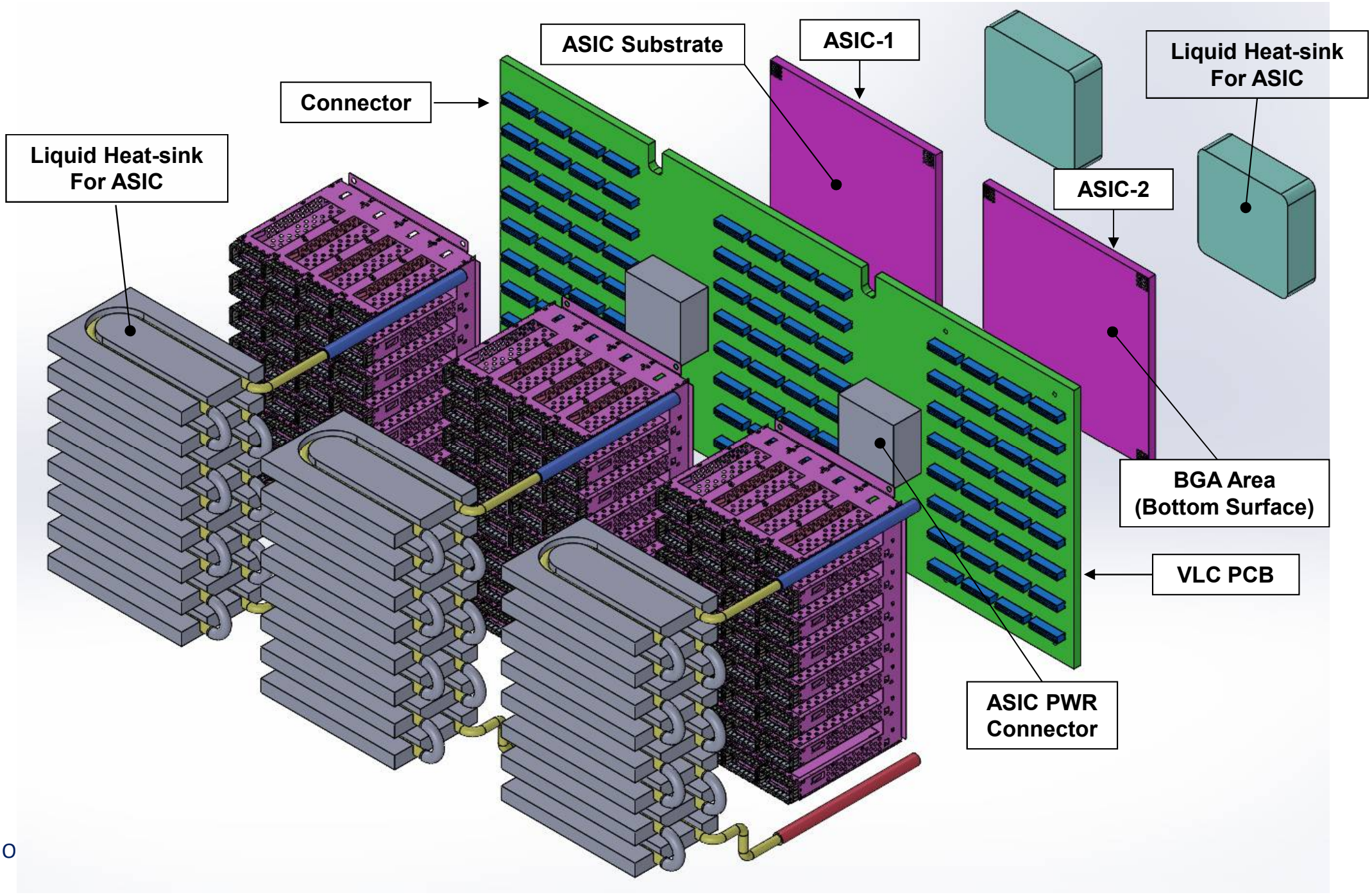
not to scale



“original structure”
For 224Gbps, this structure may be good enough.

Need mechanical support structure.
Appropriate compression pressure needed for electrical contact.


Connector
ASIC Substrate
ASIC
ASIC PWR Connector
Liquid Heat-sink For ASIC
BGA Area (Bottom Surface)
VLC PCB


ASIC Substrate
ASIC-1
Liquid Heat-sink
For ASIC
Connector
Liquid Heat-sink
For ASIC
ASIC-2
BGA Area
(Bottom Surface)
VLC PCB
ASIC PWR
Connector

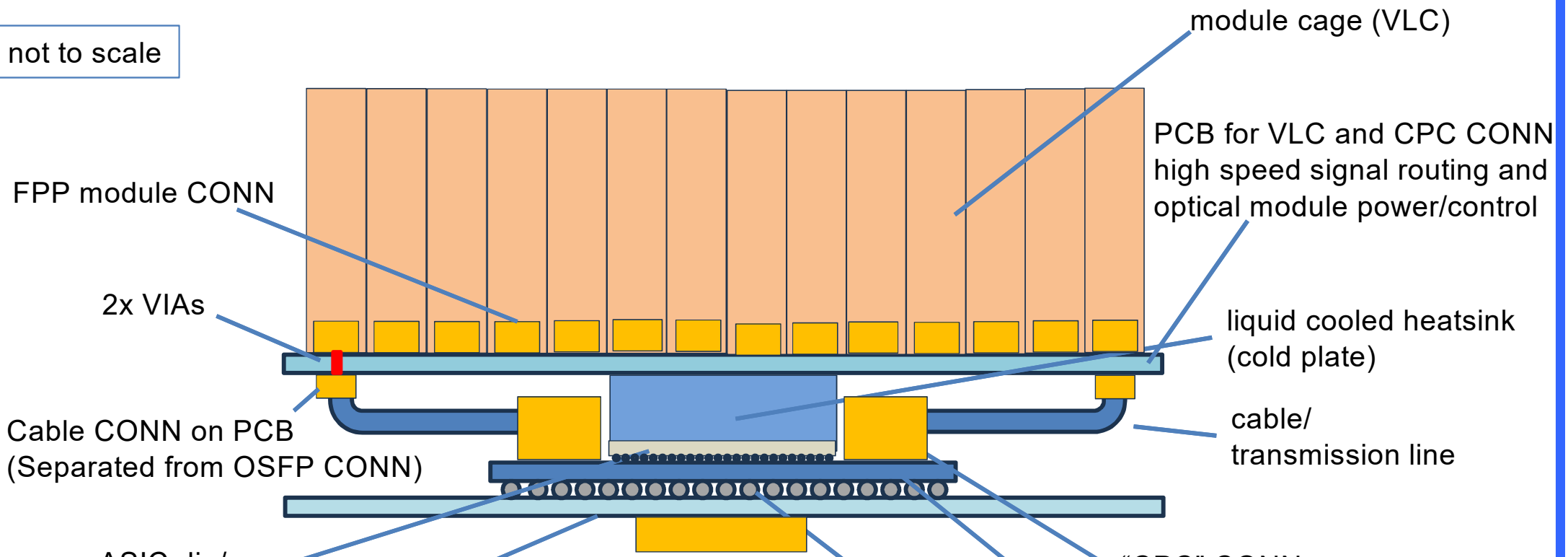
PLAN-4

Cable Assemble of 3 Points Connection

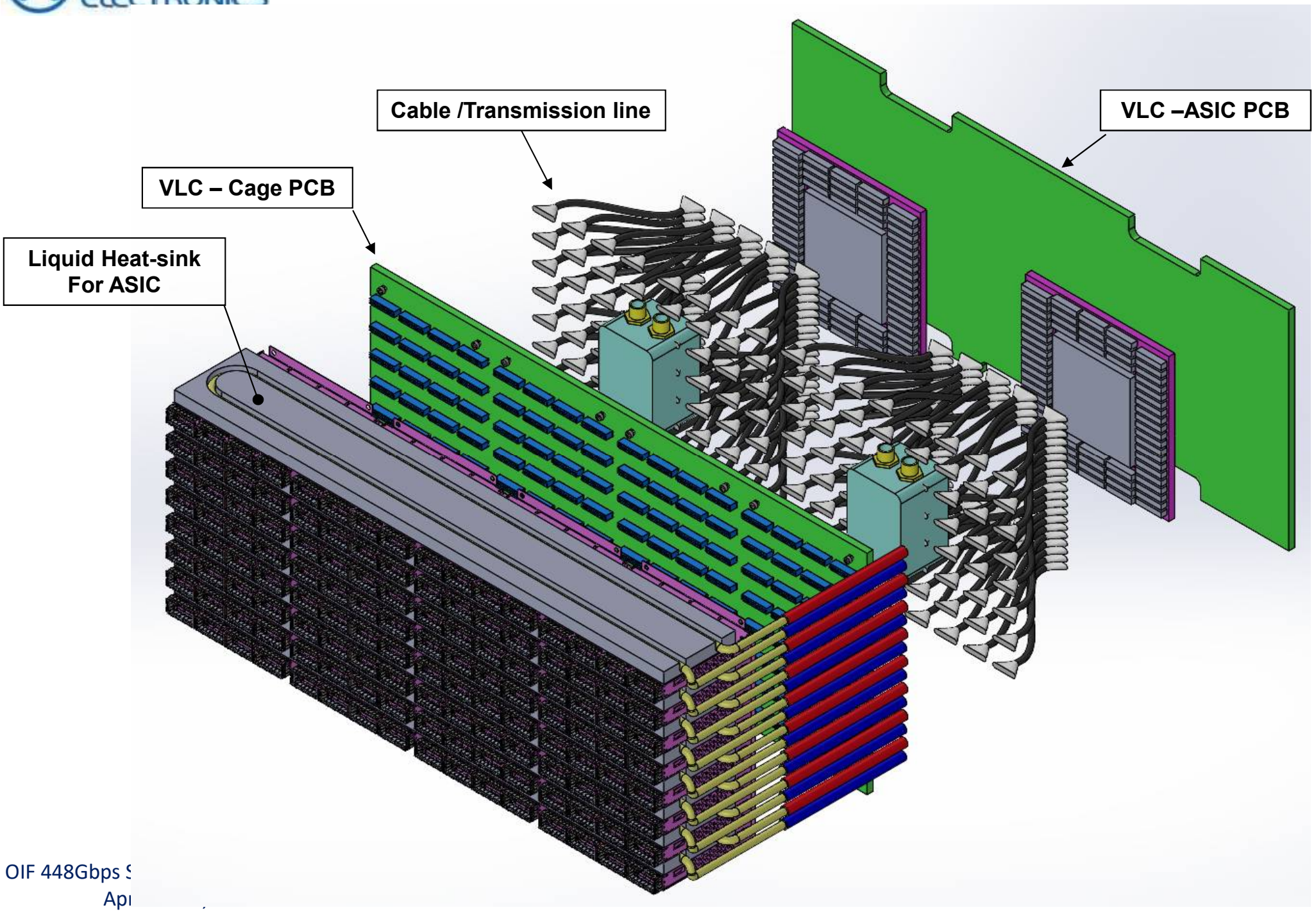
PLAN-4

VLC connector + ASIC :128 Ports/4RU Possible

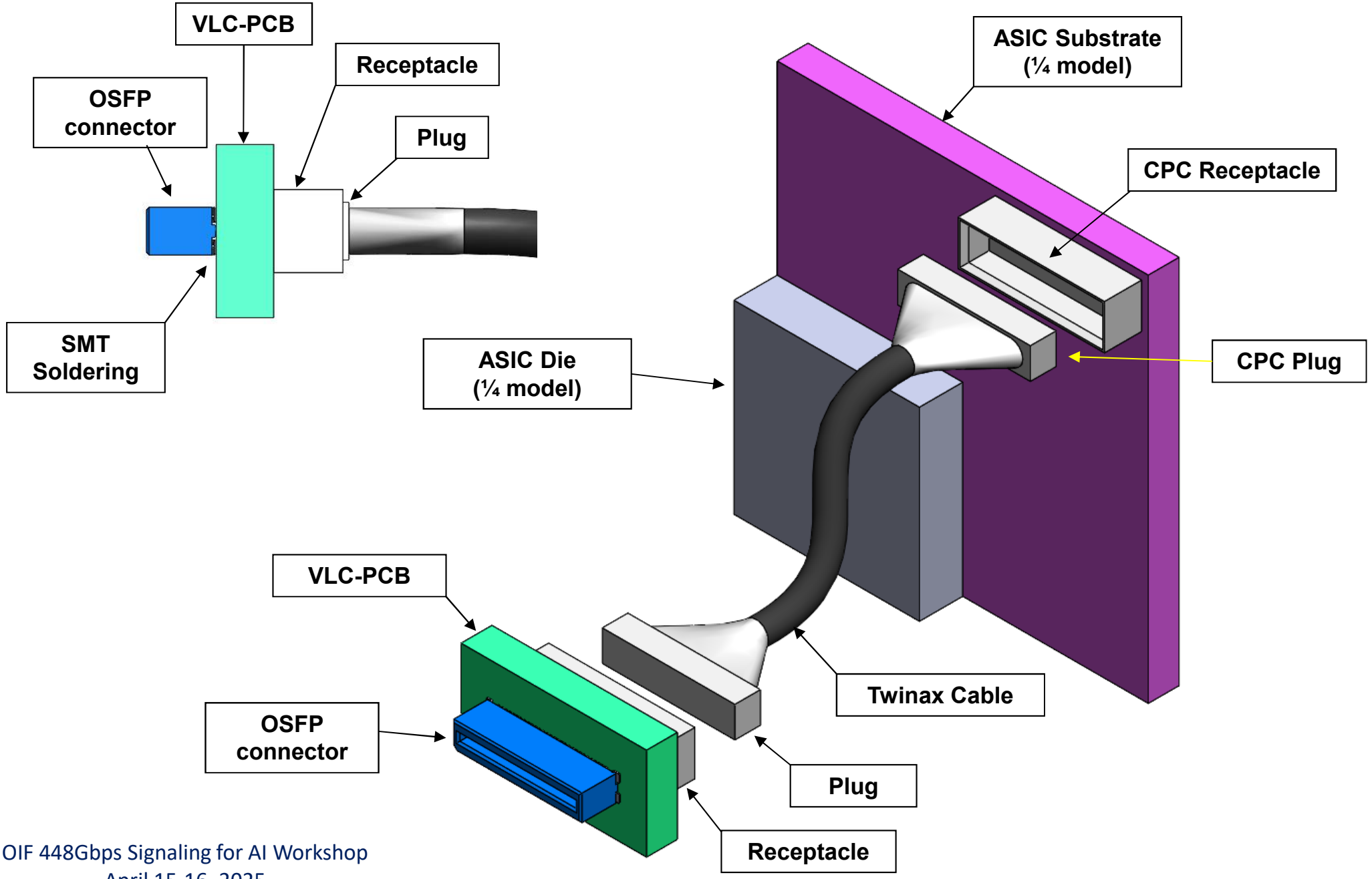
not to scale



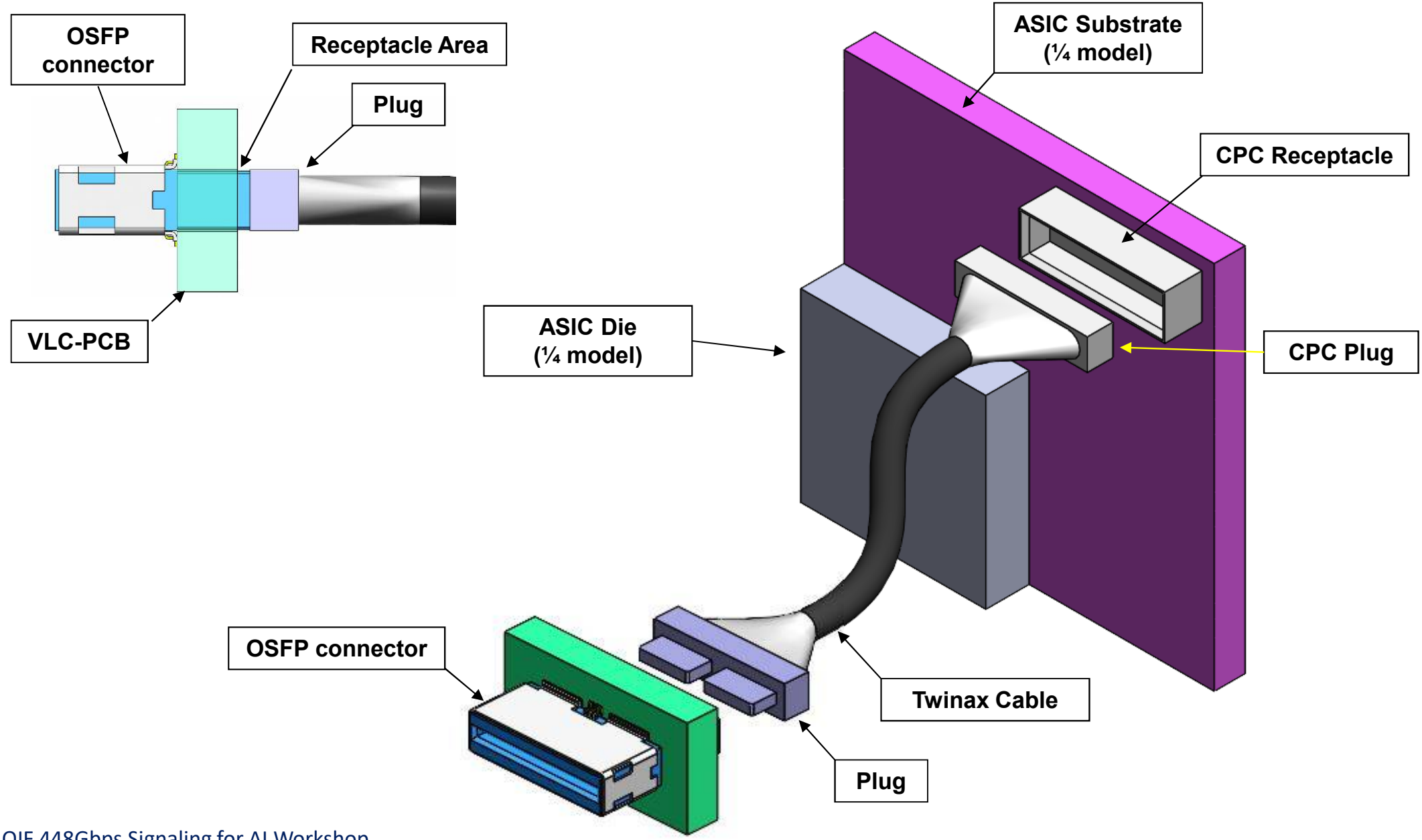
Need mechanical support structure.
Appropriate compression pressure needed for electrical contact.


Cable /Transmission line
VLC –ASIC PCB
VLC – Cage PCB
Liquid Heat-sink
For ASIC

Cable Assemble Structure



Cable Assemble Structure

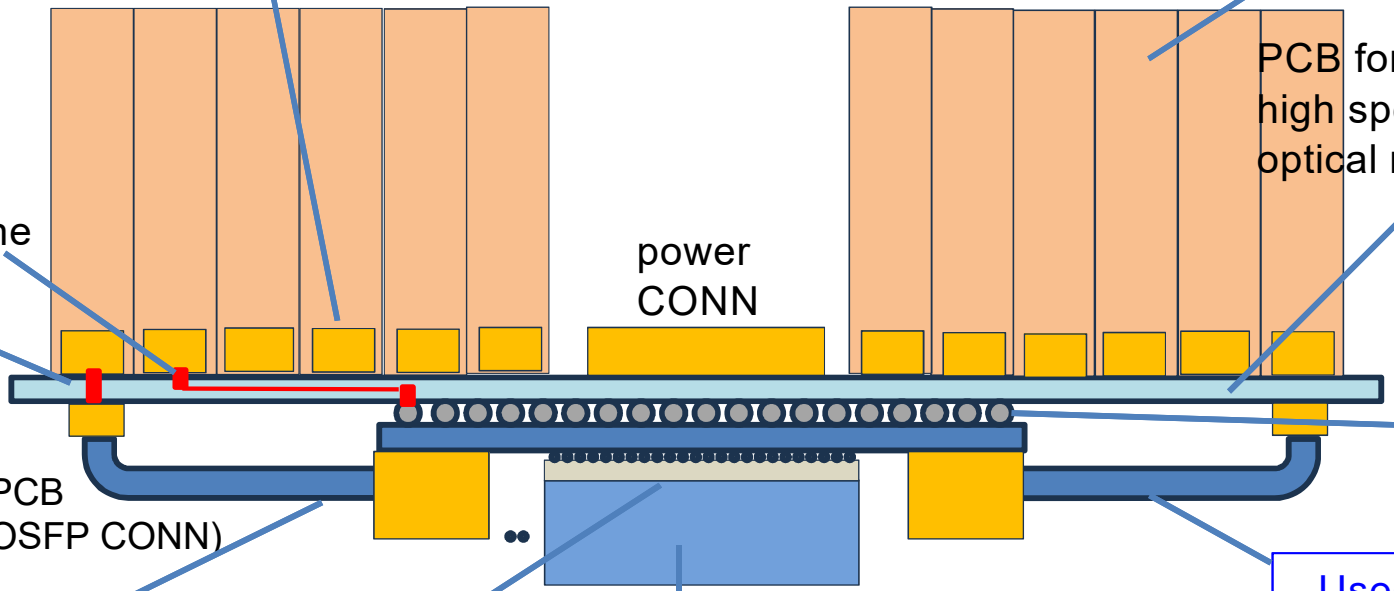


PLAN-5

PLAN-5: using cable for far end connector

VLC connector + ASIC :96 Ports/4RU Possible

not to scale



“original structure”
For 224Gbps, this structure may be good enough.

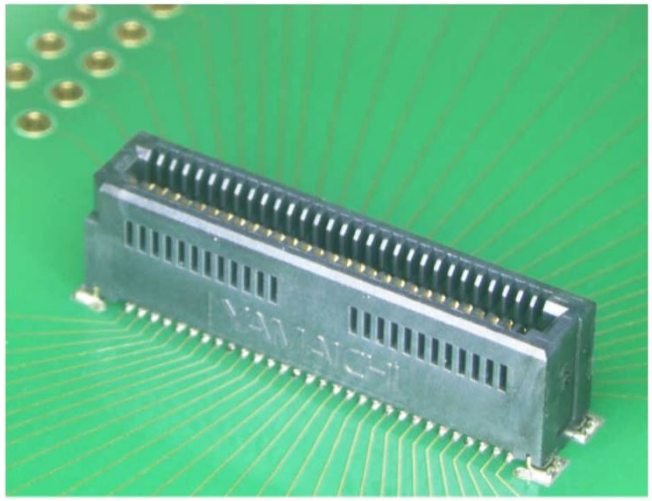
Need mechanical support structure.
Appropriate compression pressure needed for electrical contact.

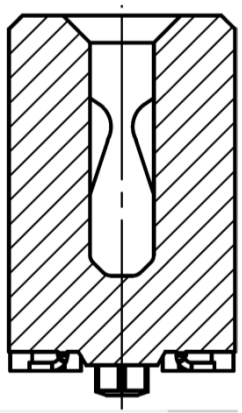
SI Performance of 448G Connectors By Simulation

VLC-OSFP Connector for 448G

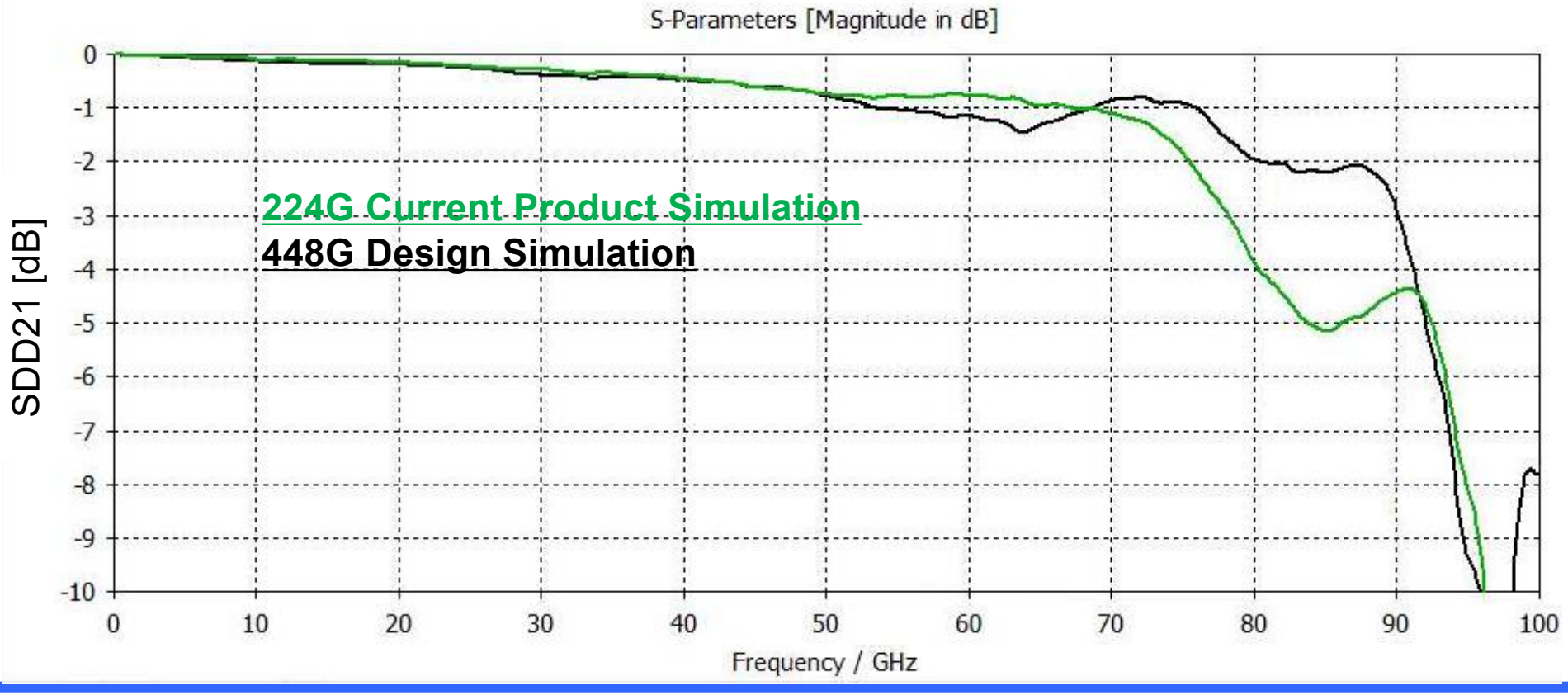
- Vertical Mounted OSFP Connector Simulation
- Connector have same pin mapping of OSFP.
- Connector Impedance is 92.5 ohm now.

Current OSFP-OSFP Connector





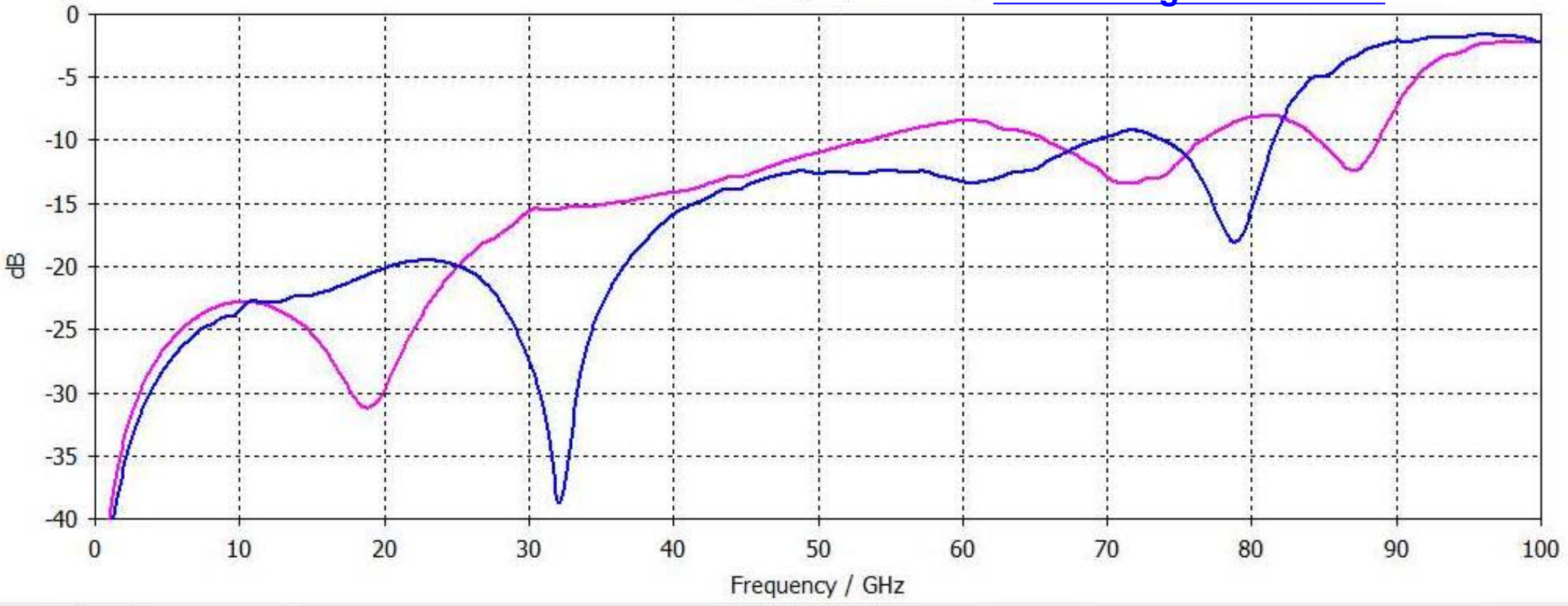
Differential Insertion Loss: Connector Only



Return Loss

224G Current Product Simulation

448G Design Simulation



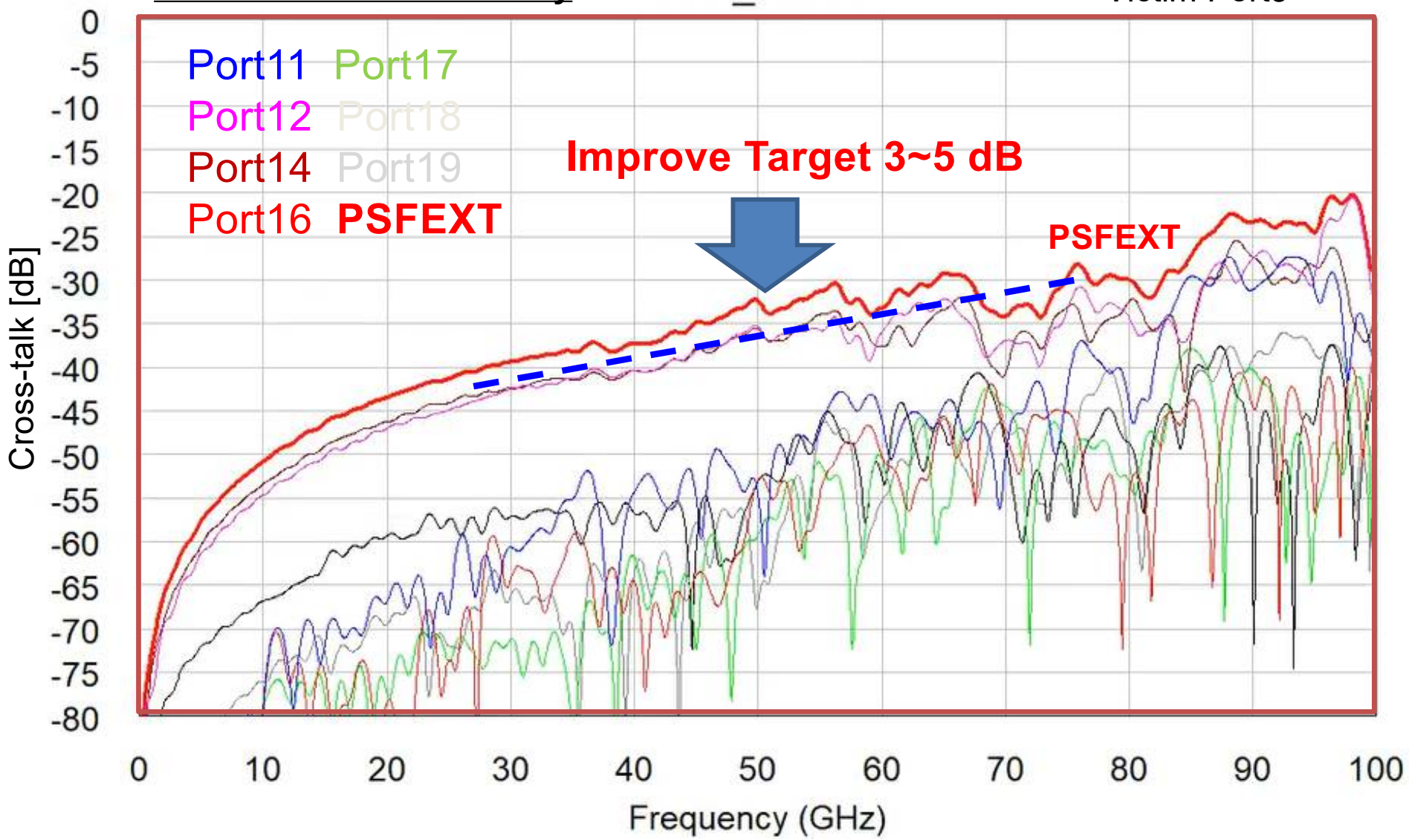
GND	1	GND	2	GND	3	GND	4	GND	CNT	GND	5	GND
GND	6	GND	7	GND	8	GND	9	GND	CNT	GND	10	GND
GND	11	GND	12	GND	13	GND	14	GND	CNT	GND	15	GND
GND	16	GND	17	GND	18	GND	19	GND	CNT	GND	20	GND

Victim

Aggressor

PS-FEXT: Connector Only

Victim Port3



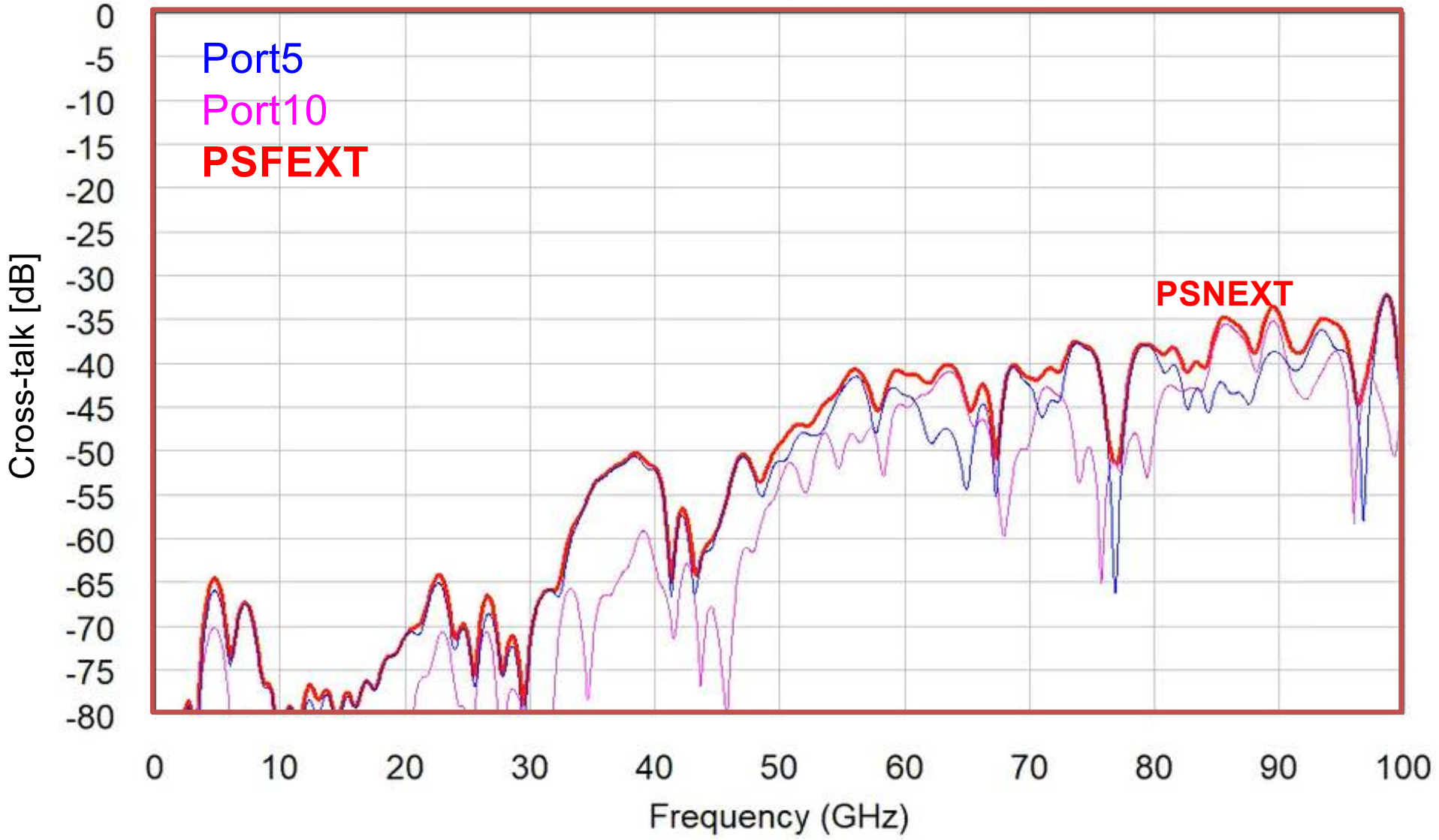
GND	1	GND	2	GND	3	GND	4	GND	CNT	GND	5	GND
GND	6	GND	7	GND	8	GND	9	GND	CNT	GND	10	GND
GND	11	GND	12	GND	13	GND	14	GND	CNT	GND	15	GND
GND	16	GND	17	GND	18	GND	19	GND	CNT	GND	20	GND

Victim

Agressor

PS-NEXT

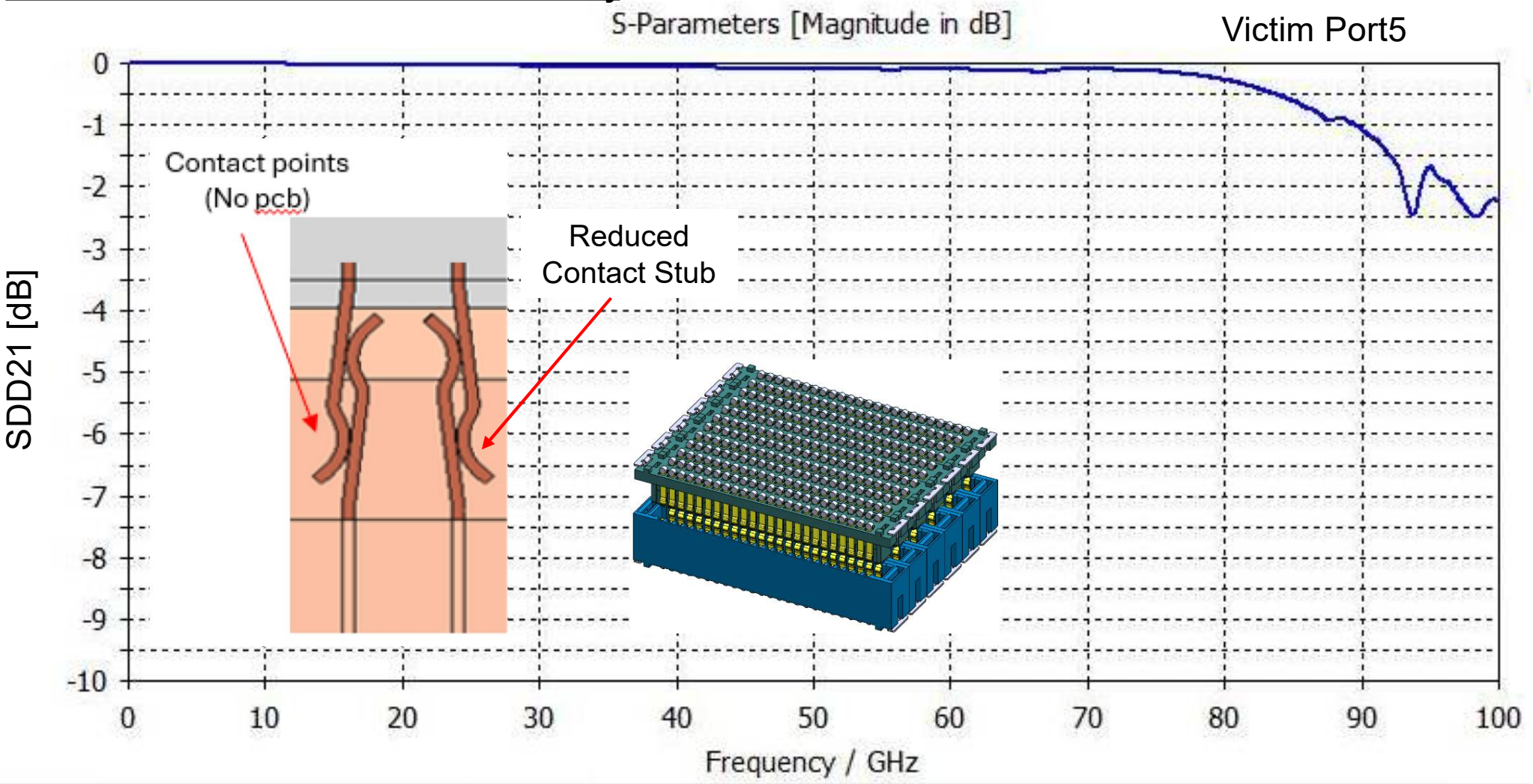
Victim Port4



2D Connector for 448G

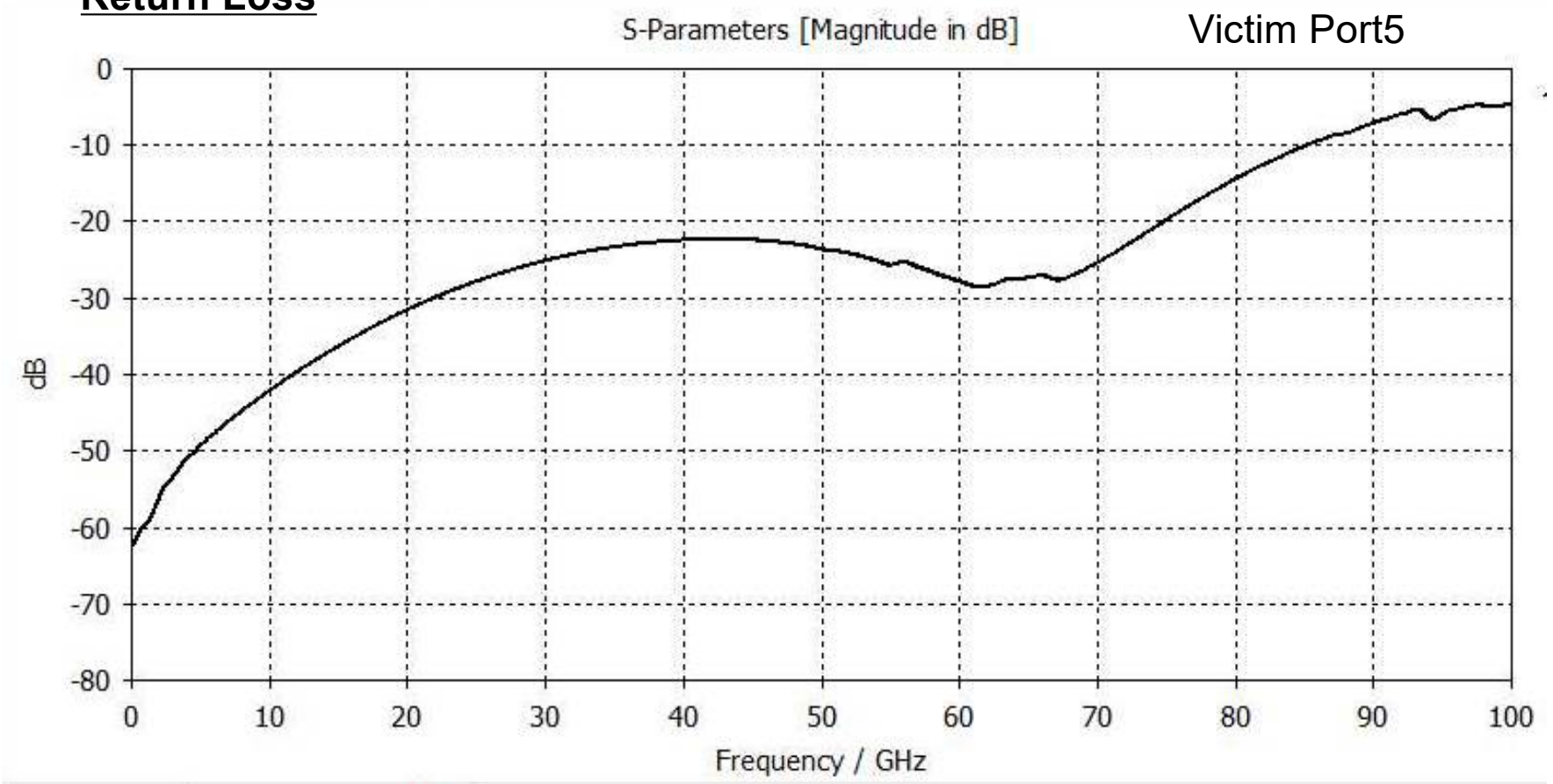
- Tuning of Yamaichi Original 2D Connector Simulation
- Connector Impedance is 92.5 ohm now.

Differential Insertion Loss: Connector Only



Left Side Figure Reference：oif2025.084.02-Introductory Contribution On Some 448Gbps Tradeoffs

Return Loss


S-Parameters [Magnitude in dB]
Victim Port5
0
-10
-20
-30
-40
-50
-60
-70
-80
dB
0
10
20
30
40
50
60
70
80
90
100
Frequency / GHz

Top Side												
	GND	GND	1	GND	GND	2	GND	GND	3			
GND	4		GND	GND	5		GND	GND	6		GND	GND
	GND	GND	7	GND	GND	8	GND	GND	9			
GND	10		GND	GND	11		GND	GND	12		GND	GND

Bottom Side												
	GND	GND	13	GND	GND	14	GND	GND	15			
GND	16		GND	GND	17		GND	GND	18		GND	GND
	GND	GND	19	GND	GND	20	GND	GND	21			
GND	22		GND	GND	23		GND	GND	24		GND	GND

Victim

Aggressor

PS-FEXT: Connector Only

Victim Port5