EMI Analysis and Mitigation Techniques for 56G PAM4 Signaling

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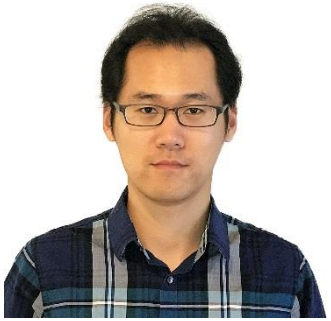
Speakers



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He received the M.S. degrees in electrical engineering from Missouri University of Science and Technology (Missouri S&T), Rolla, MO, USA, in 2014. At Missouri S&T, he focused on the analysis and measurement of EMC and signal integrity problems. He is currently a Hardware Engineer at Cisco Systems, Inc., San Jose, CA, USA.

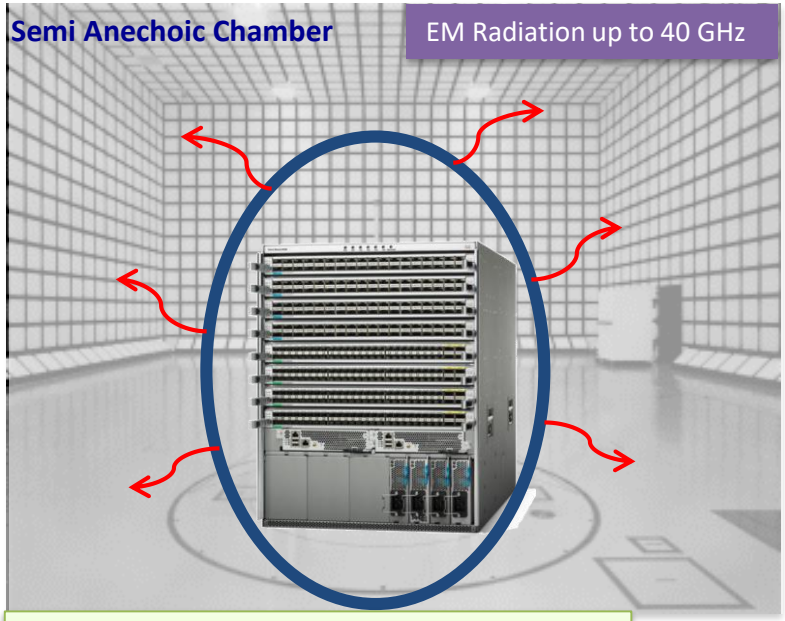
Outline

- Introduction
- SerDes evaluation board and NRZ/PAM4 signaling measurement
- Near field scanning of the board
- TRP and RE measurement of the board
- The effect from heatsink on radiation and possible mitigation methods
- Radiation comparison between the chips with and without ground lid
- Summary

Introduction

- PAM4 (4-level Pulse Amplitude Modulation) signaling is taking a precedence over traditional NRZ (Non-return-to-zero) signaling due to its two-fold bandwidth efficiency than the NRZ architecture
- Higher data rate, more channels and higher power consumption on the ASIC level
- Investigate potential EMI issues coming from ASIC chip in PAM4 mode
- Analyze the radiation from PAM4 56G ASIC chip with multiple measurement methods
  - Near field scanning
  - Reverberation chamber measurement
  - RE measurement
- Investigate the effect of both package lid and heatsink on the radiation

Introduction

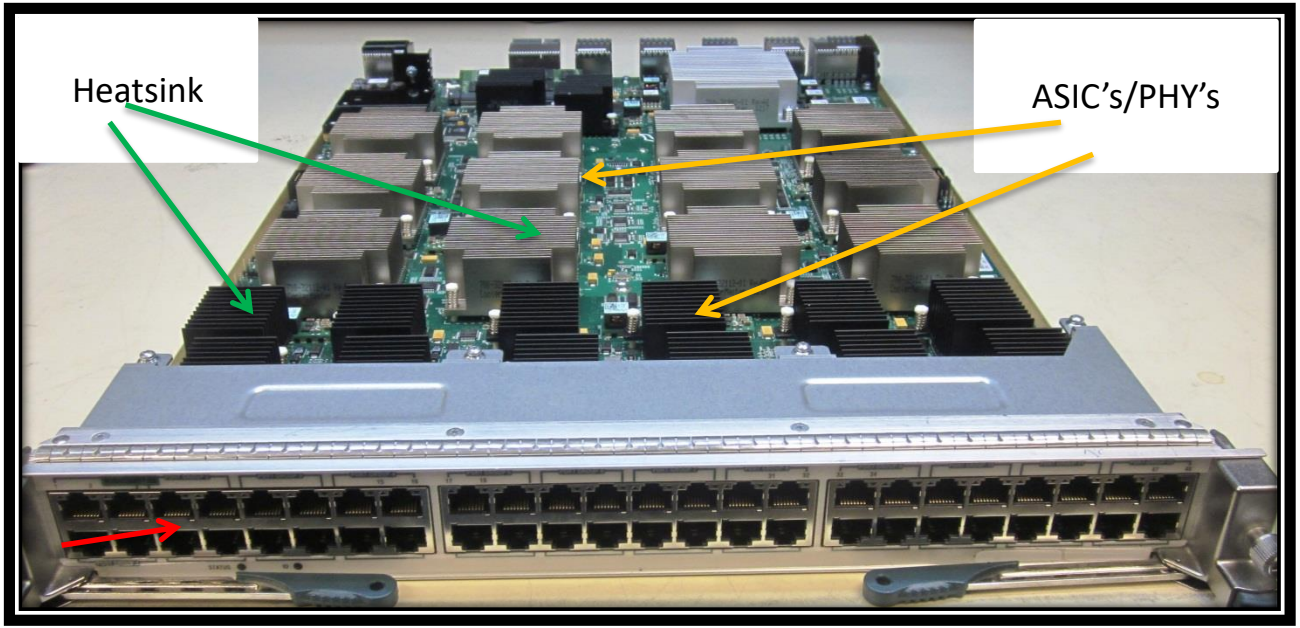


High-speed Modular networking product (10G/40G/100G)

Data Rate/Channel	Critical EMI Frequency
10Gbps	10.3GHz
	20.6GHz
	30.9GHz
25Gbps	25.7GHz
56Gbps(PAM4)	28.1GHz

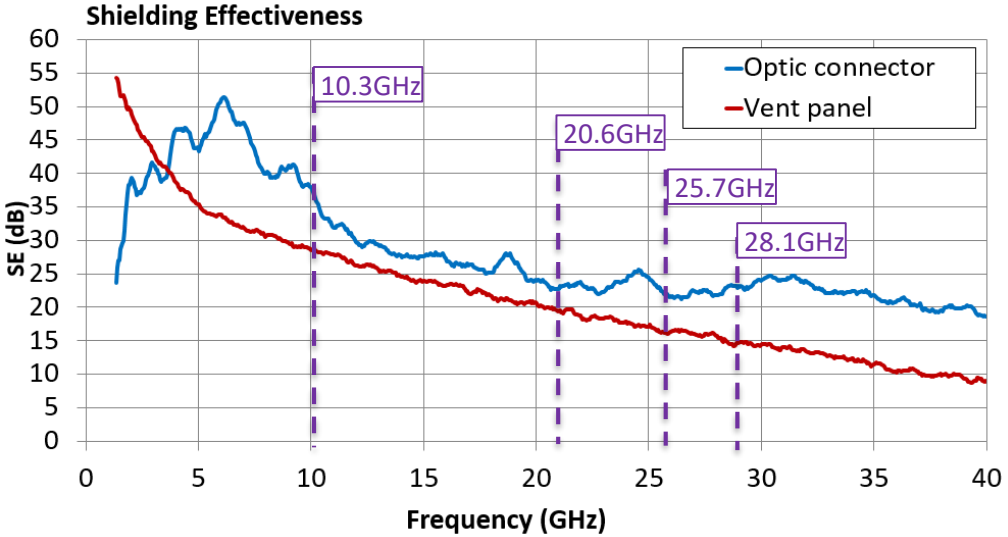
Even order harmonic of Nyquist frequency due to the mismatch of rise and fall time

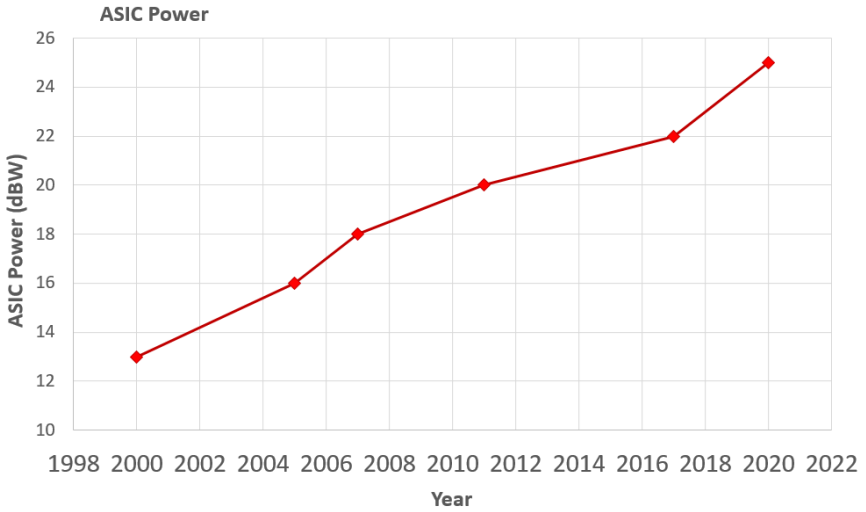
Introduction



- ASIC/PHY chip is one of dominant radiation sources inside the chassis
- Design via measurement to investigate EMI profile of sources

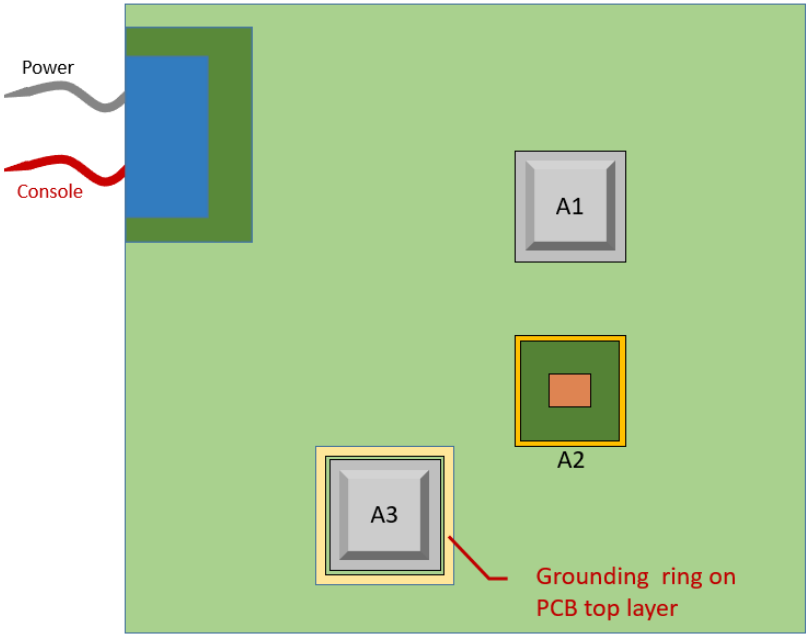
Introduction





- SE of components on chassis decreases while Freq. increases
- System Power requirements are increasing on new products

SerDes evaluation board and NRZ/PAM4 signaling measurement



- Active evaluation board with 3 ASIC chips
  - A1: with grounded lid
  - A2: without Lid
  - A3: with ungrounded lid
- All chips can run traffic in both NRZ and PAM4 mode through on-board loopback connections from Tx to Rx
- Added grounding ring around chip A3 for EMI study

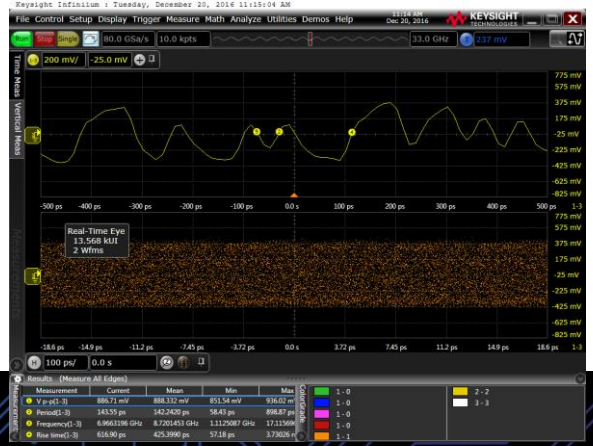
SerDes evaluation board and NRZ/PAM4 signaling measurement

- Chips on the board can be configured by specific software (NRZ/PAM4, data rate and signal amplitude)
- Set 28Gbps for NRZ and 56Gbps for PAM4
- Same amplitude value (Vp-p=1000mV) for both NRZ and PAM4 mode

	NRZ	PAM4
Vp-p (mV)	888.33	867.43

Note: Due to the scope bandwidth limitation, it couldn't show the eye diagram at 56G

NRZ signal



PAM4 signal

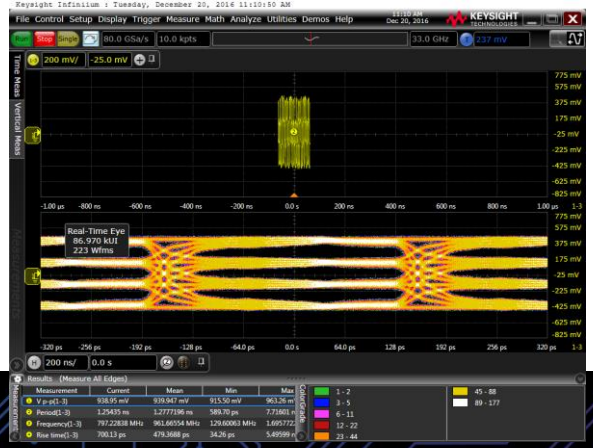
SerDes evaluation board and NRZ/PAM4 signaling measurement

- Set 3.125Gbps for NRZ and 6.25Gbps for PAM4
- Same amplitude value (Vp-p=1000mV) for both NRZ and PAM4 mode

	NRZ	PAM4
Vp-p (mV)	950.42	939.95

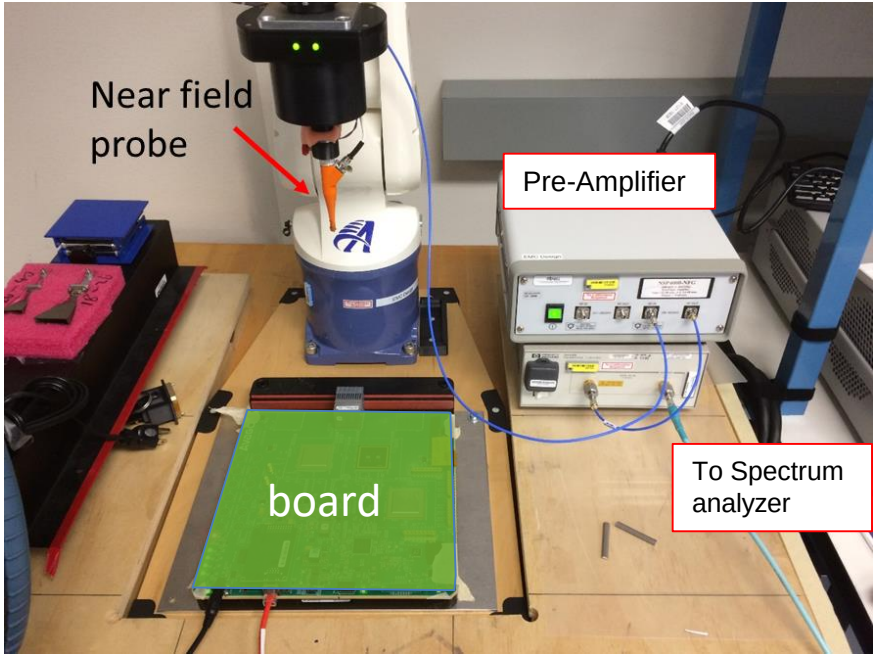
Note: with lower data rate, it can be seen clearly about the NRZ and PAM4 signal form the chips.

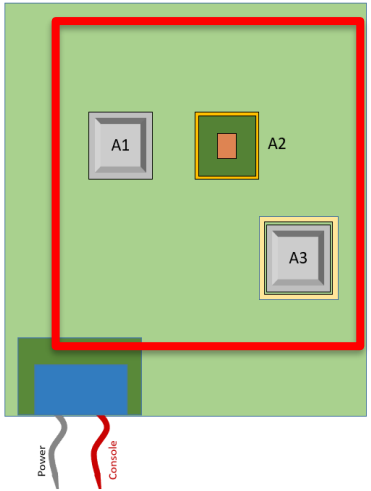
NRZ signal



PAM4 signal

Near field scanning of the board

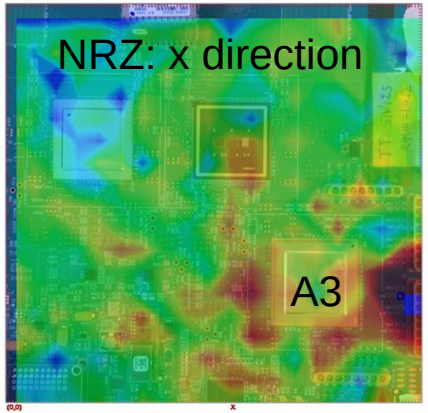




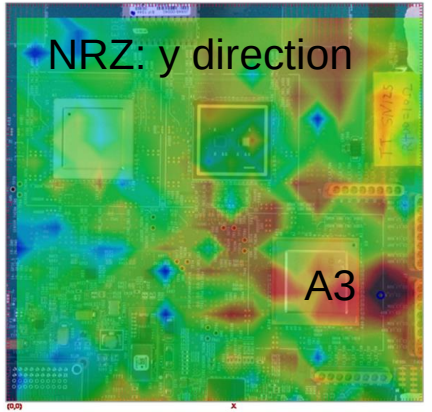
- Scanning area covers 3 chips (A3 activated).
- Measured frequency: 28.125 GHz
  (2nd Harmonic of 28G NRZ and 56G PAM4)
- Probe to board distance: 2mm
- Scanning resolution: 10 mm.

Near field scanning of the board (Results)

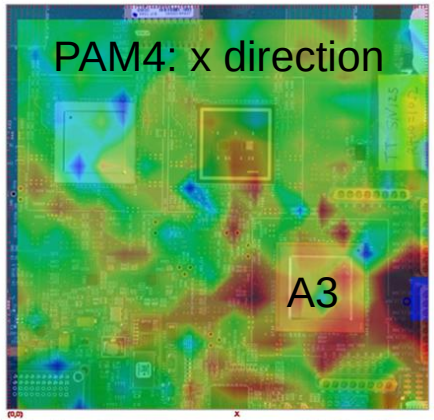
- A3 chip is running at either NRZ or PAM4 mode
- A3 Chip: with ungrounded lid
- Near field distribution of both PAM4 and NRZ mode are similar
- Max value difference is within 1 dB.



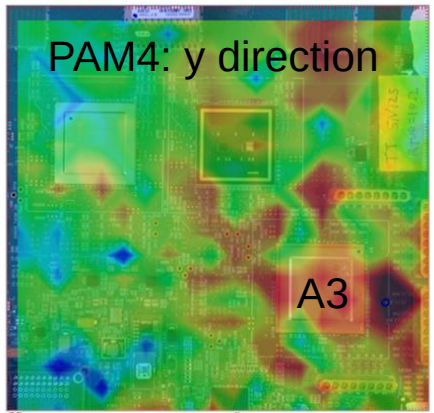
X-direction Max value: -25.8 dBm



Y-direction Max value: -23.8 dBm



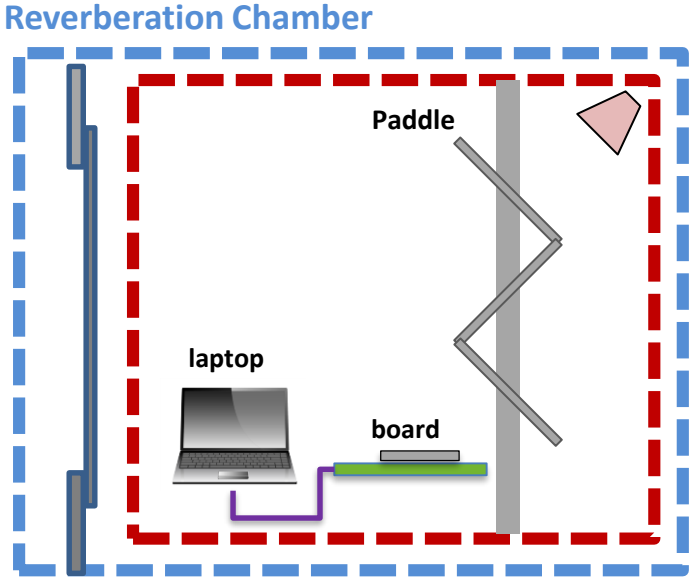
X-direction Max value: -25.3 dBm

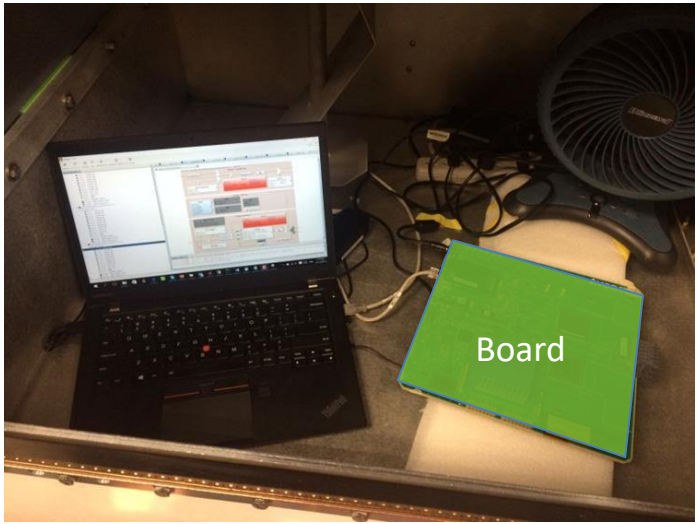


Y-direction Max value: -23.6 dBm

Maximum value for near field results (dBm)	
NRZ	PAM4
-23.6	-23.8

TRP measurement of the board





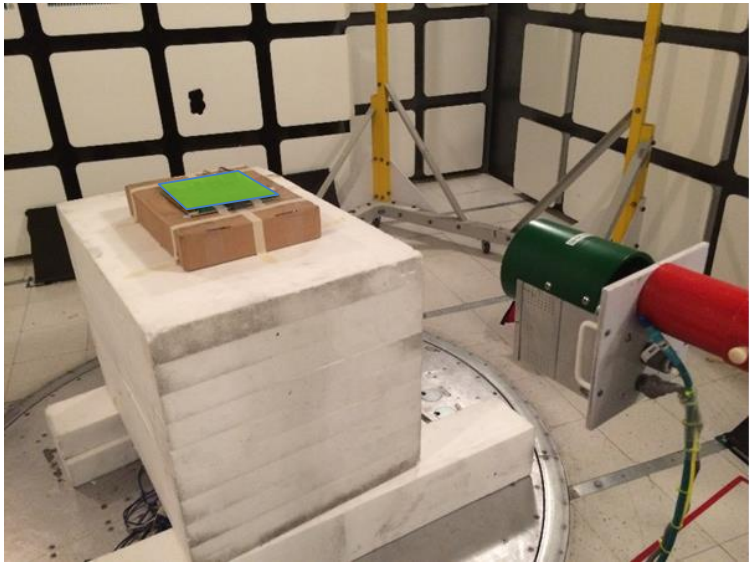
- Total radiated power (TRP) is measured in a reverberation chamber
- Only A3 chip is activated during the measurement
- Same chip configuration as in near field scanning

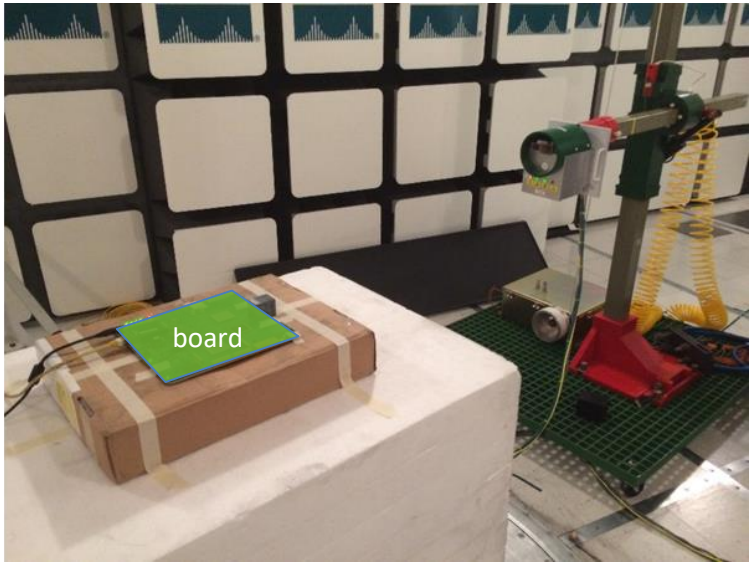
TRP measurement of the board (Results)

	NRZ	PAM4
TRP (dBm)	-81.7	-82.6

- Center frequency: 28.15207 GHz
- Span: 50 kHz, RBW: 1 kHz
- Average time: 500
- TRP results shows that the difference between these two signals is within 1 dB

RE measurement of the board





- RE test are performed in the 3 meter semi-anechoic chamber.
- Evaluation board is placed on the turntable with 1m above the floor.
- Distance form chip to antenna is 1m

RE measurement of the board (Results)

At 28.15207 GHz

	NRZ	PAM4
RE (AV:dBuV/m)	35.21	34.78

- Same chip configuration as in near field scanning and TRP measurement
- Measured frequency range: 28 GHz – 28.2 GHz, RBW: 30 kHz
- Turntable: 0-360 degree, Antenna height: 1 m – 2 m.
- RE results still shows that the difference between these two signals is within 1 dB

Summary of the Measurement Results (Near field/TRP/RE)

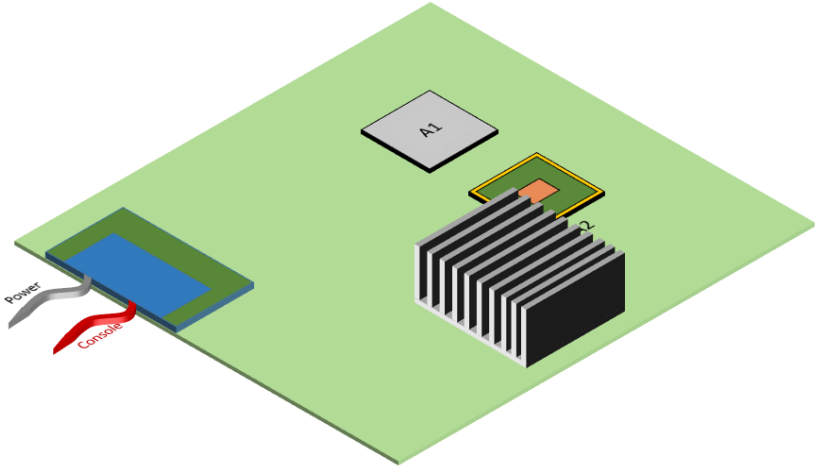
At 28.15207 GHz

A3 Chip (Package lid floating)		
Measurements	NRZ	PAM4
Near field scanning (dBm)	-23.6	-23.8
TRP Test (dBm)	-81.7	-82.6
RE Test (dBuV/m)	35.21	34.78

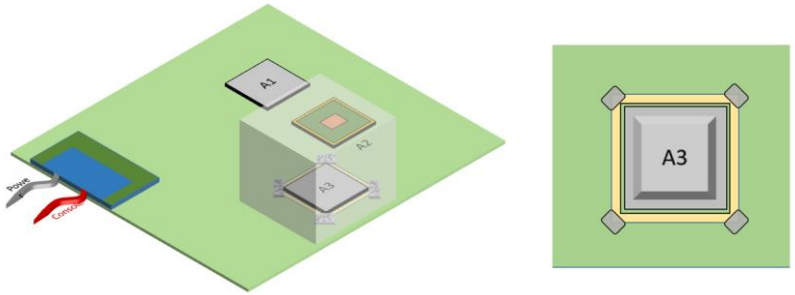
All measurements show that with the same traffic/chip setting, the radiation from chip is almost the same in both NRZ and PAM4 mode

The effect from heatsink on radiation and possible mitigation methods

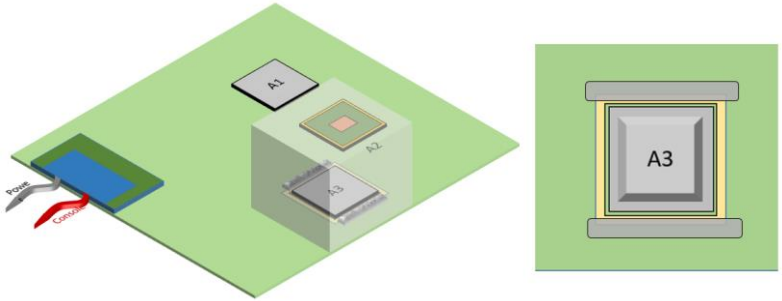
- Heatsink on chip may cause additional EMI issue due to the resonance.
- The change of radiation in different grounding methods of heatsink



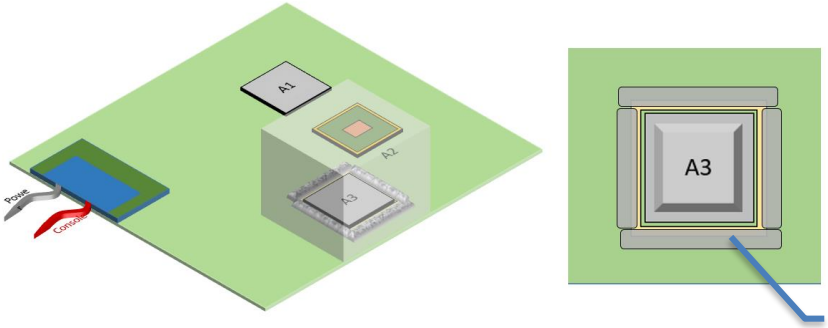
The effect from heatsink on radiation and possible mitigation methods



4 corner point grounding

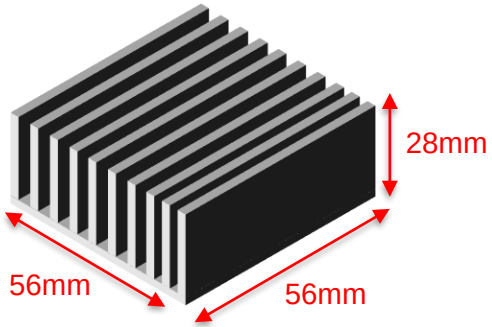


2 strips grounding



4 strips grounding

FOF gasket



Measurement Results for Heatsink Influence

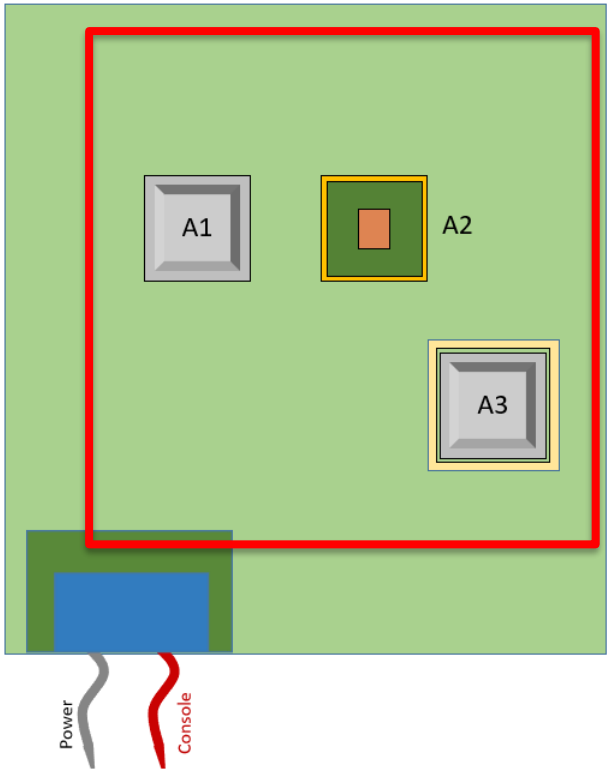
- Adding the heatsink on the chip will increase the radiation level around 1dB.
- With 4 grounding points on the chip corner, it will reduce about 1 dB for the radiation level.
- 2 strips grounding case will reduce the radiation level about 4 dB.
- 4 strips grounding case will reduce the radiation level about 5 dB.

At 28.15207 GHz

Configuration	TRP test (dBm)		RE test (dBuV/m)	
	NRZ	PAM4	NRZ	PAM4
A3 without heatsink	-81.7	-82.6	34.78	35.21
A3 with heatsink	-82.1	-83.8	38.24	37.35
A3 with heatsink 4 points ground	-83.9	-83.8	36.90	36.11
A3 with heatsink 2 strips ground	-87.2	-85.2	32.24	34.05
A3 with heatsink 4 strips ground	-86.6	-87.4	30.87	32.81

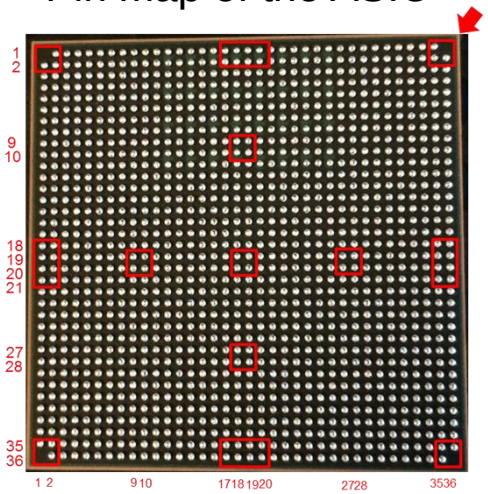
The Influence of Package Lid Configuration to the Radiation Level

- The grounding of heatsink or sealing of chip lid edge may greatly affect the radiation level of the chip.
- A3 Chip: chip with package lid floating (normal chip)
- A1 Chip: chip with package lid grounded



DC Resistance of Ground Pins of ASIC with Ground Lid

Pin map of the ASIC



DC Resistance Value of A1 (Unit: Ohm)

	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
1		0.88															0.41	S	0.46	S															0.41	
2	0.89	0.86															0.41	S	0.41	S															0.4	0.9
3																																				
4																																				
5																																				
6																						33	34	35	36											
7																																				
8																										0.41										
9																		0.9	0.9																	
10																		S	0.91							0.4	0.9									
11																																				
12																																				
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14																																				
15																																				
16																																				
17																																				
18	0.87	0.85																																	0.41	0.41
19	0.41	0.41							S	S								0.88	0.9						0.89	0.93									0.86	0.9
20	0.41	0.4							S(10,6)	0.42								S	0.43						S	0.42									0.4	0.4
21	0.41	0.4																																	0.42	0.42
22																																				
23																																				
24																																				
25																																				
26																																				
27																		0.45	0.56																	
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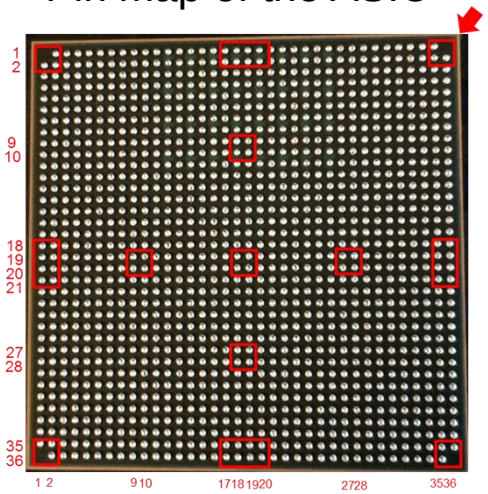
33																																				
34																																				
35	0.39	0.39															0.41	0.42	0.41	0.41															0.39	0.41
36		0.41															S	S	0.42	S															0.43	

Several ground pins on the 4 corners and edge has been measured on the DC level.

DC Resistance of Ground Pins of ASIC with Unground Lid

Pin map of the ASIC



DC Resistance Value of A3 (Unit: MegOhm)

	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
1		0.95															2.6	1.8	0.2	1.2															1.1	
2	0.19	0.22															1.5	0.9	1.0	0.62															0.7	1.2
3																																				
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16																																				
17																																				
18	0.7	0.8																																	1.4	2.1
19	1.1	0.4							0.14	0.18								0.3	0.3							1.3	1.4								1.8	2.1
20	1.3	1.1							0.19	0.2								0.5	0.28							1.4	2.2								1.3	2.5
21	1.7	0.9																																	1.8	2.7
22																																				
23																																				
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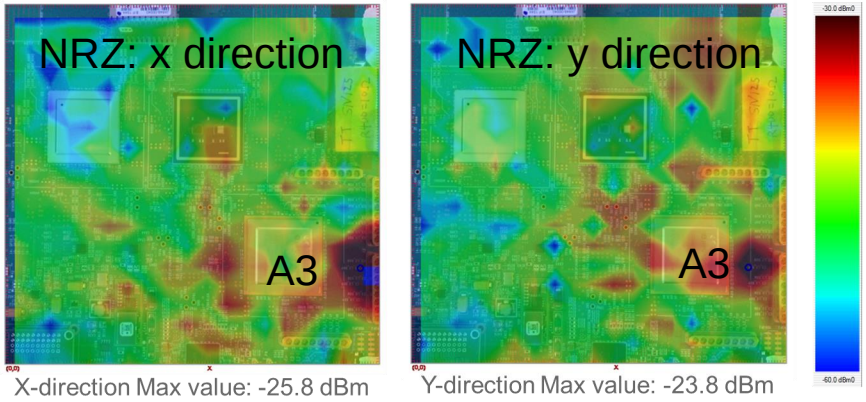
25																																				
26																																				
27																		2.0	1.6																	
28																		1.6	2.8																	
29																																				
30																																				
31																																				
32																																				
33																																				
34																																				
35	1.6	1.7															1.1	1.2	1.3	1.1															0.65	0.45
36		1.4															1.9	2.0	1.1	1.9															0.5	

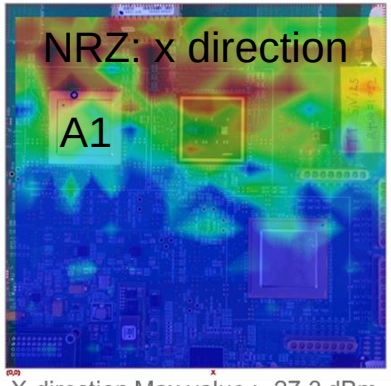
Several ground pins on the 4 corners and edge has been measured on the DC level.

Radiation comparison between the chips with and without ground lid

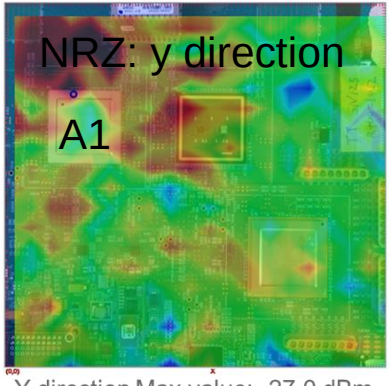


X-direction Max value: -25.8 dBm

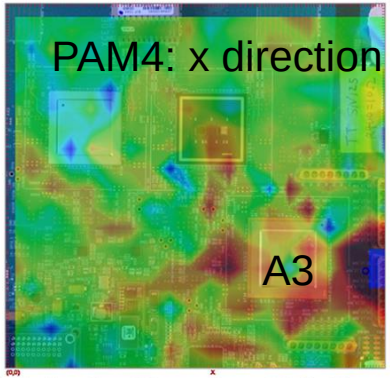
Y-direction Max value: -23.8 dBm



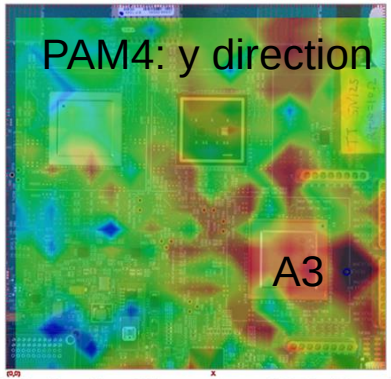
X-direction Max value : -27.3 dBm



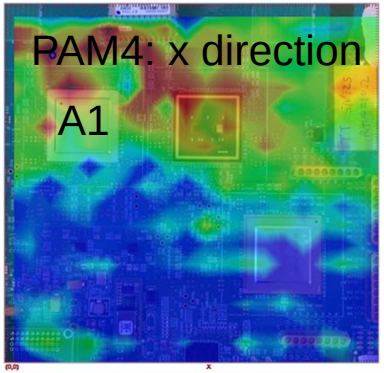
Y-direction Max value: -27.0 dBm



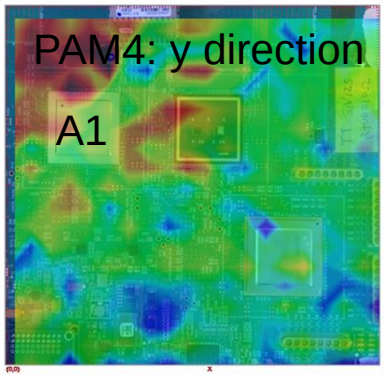
X-direction Max value: -25.3 dBm



Y-direction Max value: -23.6 dBm



X-direction Max value: -29.2 dBm



Y-direction Max value: -28.0 dBm

Radiation comparison between the chips with and without ground lid

	Max value (dBm)	NRZ	PAM4
A1 Chip	X Direction	-29.2	-27.3
	Y Direction	-28.0	-27.0
A3 Chip	X Direction	-25.3	-25.8
	Y Direction	-23.6	-23.8

- With the package lid grounded, the maximum near field value of A1 Chip is around 3-4 dB lower than the A3 Chip.
- Note: these two chip are in different location of the PCB, all of these configuration may affect the near field results accuracy.
- RE and TRP measurement need to be preformed to investigate the radiation level of these two chips.

Radiation comparison between the chips with and without ground lid

Configuration	TRP test (dBm)		RE test (dBuV/m)	
	NRZ	PAM4	NRZ	PAM4
A3 without heatsink	-81.7	-82.6	34.78	35.21
A1 without heatsink	-81.9	-81.9	36.71	38.24
A3 with heatsink	-82.1	-83.8	38.24	37.35
A1 with heatsink	-82.4	-82.0	37.06	37.05

- Total radiation (TRP) from A3 and A1 is very similar
- For RE test, A1 is 2-3 dB lower than A3. that may due to the change of radiation pattern, both grounding lid and chip location can affect pattern
- With heatsink, A1 and A3 having similar RE results

Summary

- No observable difference in radiation at 28GHz on this ASIC board between the PAM4 and NRZ mode
- Ungrounded heatsink on chip doesn’t change TRP much, but changes the radiation pattern
- For 28GHz, only 2 or 4 sides grounding/sealing around heatsink can provide considerable EMI reduction
- In this case, grounding lid on the chip doesn’t affect much for total radiation power and radiated emission (RE)

Thank you!

QUESTIONS?