

# **212Gb/s Per Lane PAM4 KR Cabled Backplane Channels Room vs. High Temps**

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# Contributors

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- **Sam Kocsis - Amphenol**
- **Merrick Moeller - Amphenol**
- **Michael Rowlands - Amphenol**
- **Marc Charbonneau - Amphenol**
- **Vysakh Sivarajan - Amphenol**

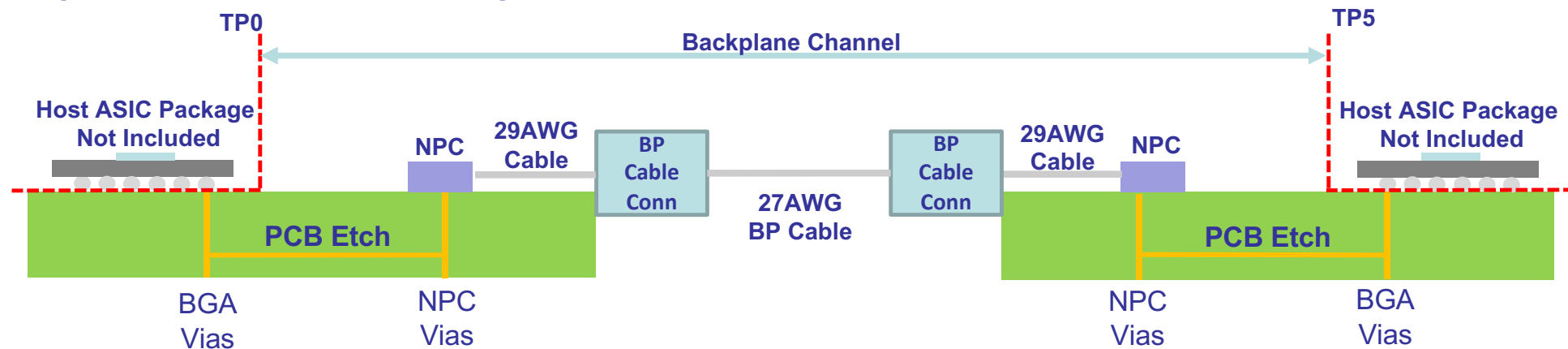
# Overview

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- This is a preliminary investigation into a typical host-to-host cabled backplane architecture
- These are high-loss KR channels, as are found in large switches and routers.
- The intent is to facilitate early discussion among participants using *realizable channels*
  - PCB trace s-parameter data measurement procedure similar to Delta-L but using AFR
  - Cable models vetted with measured data by Merrick Moeller, affiliated with Amphenol
    - Update to weaver 3dj\_01\_2305: updated twinax cable models at hi temp
  - Connector simulation models provided by Vysakh Sivarajan, affiliated with Amphenol
    - No update to weaver 3dj\_01\_2305: same connector models
  - All PCB footprints designed using HFSS and conform to the DFM rules of major fabricators
- These models are ball-to-ball to allow use with different package models
  - Bump-to-bump channel specification is still critical, owing to large package losses
- Development is continuing, so all models are subject to continuous refinement.
  - New channels will be contributed as refinements are made

# Description

- Simulation of a typical KR cabled backplane architecture over various cable lengths
- Contributions:
  - BGA / PCB trace / NPC via escapes simulated with HFSS
  - NPC + BP cable assemblies: provided by Michael Rowlands, affiliated with Amphenol
    - **No update to weaver 3dj\_01\_2305: same NPC and BP cable assembly models**
- Ball-to-Ball topology: does not include package effects
- This presentation does NOT propose the following:
  - Specific aggregate or cable losses
  - Specific host architecture implementations



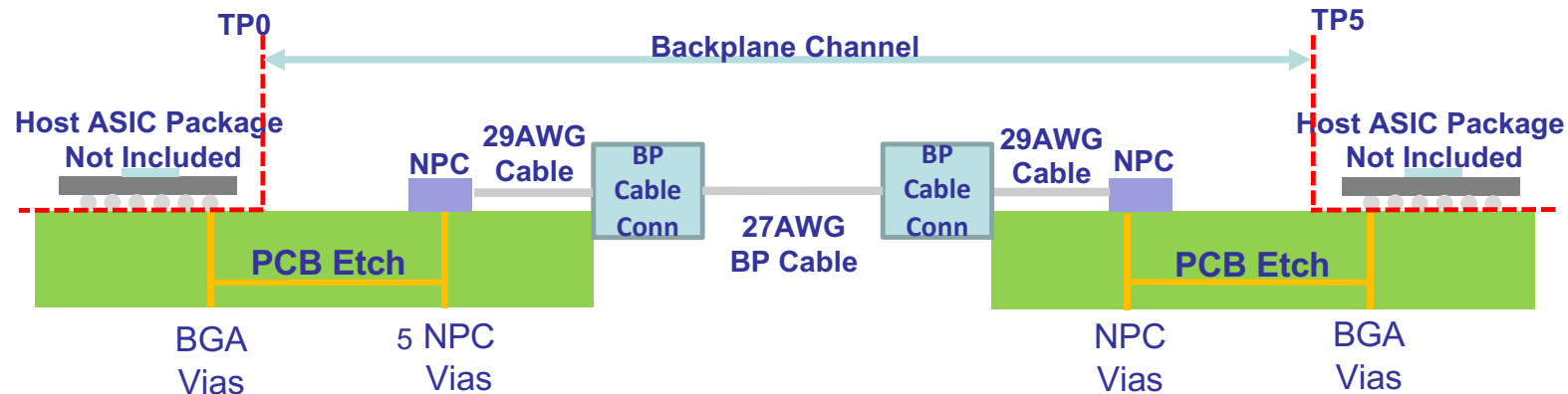
# KR Backplane Cable Assembly + Host

## PCB Composition

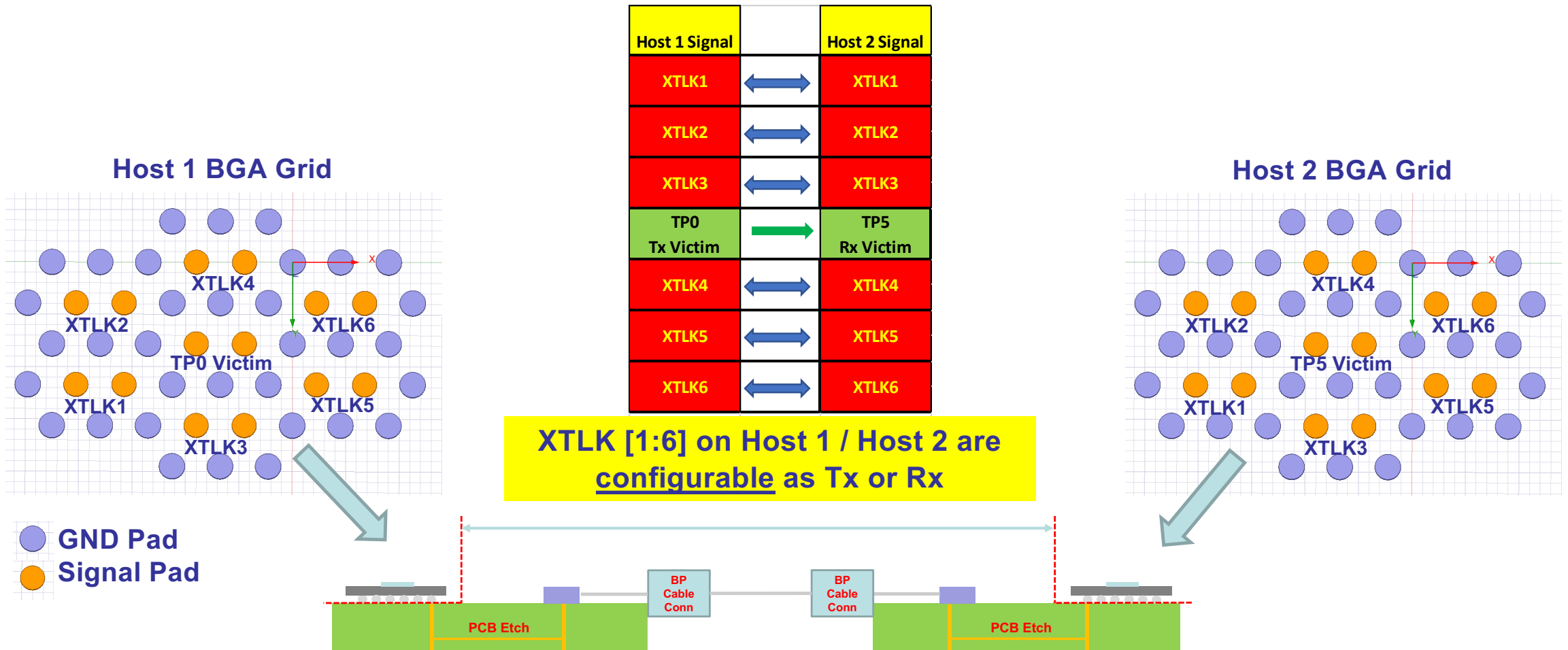
- BGA & NPC Breakout Footprints
  - ~ 3mm PTH breakout depth
  - 8 mil vias with 5 mil stubs
  - Conforms to current PCB fab design rules
  - Nothing exotic: no skip layers, no microvias
- Host Breakout Trace
  - Fanout length to NPC's: ~ 3 inches
  - Loss: ~ 1.25 dB/in @ 53.125 GHz
  - 90 ohm @ 6 mil line width
  - Room Temperature
    - **Update to weaver 3dj\_01\_2305: host breakout trace at 80°C included (loss ~ 1.40 dB/in @ 53.125 GHz)**

## Cable Assembly Composition

- Near Packaged Copper (NPC)
  - 95 ohm 29 AWG Twinax lengths
    - **Update to weaver 3dj\_01\_2305: 150mm, 300mm lengths at 70°C included**
  - Room Temperature
    - Assumes symmetric and asymmetric lengths on both sides of channel
- BP Cable Connector + Twinax
  - 95 ohm 27 AWG
  - Twinax length: 800mm
  - Room Temperature
    - **Update to weaver 3dj\_01\_2305: 70°C cable included**



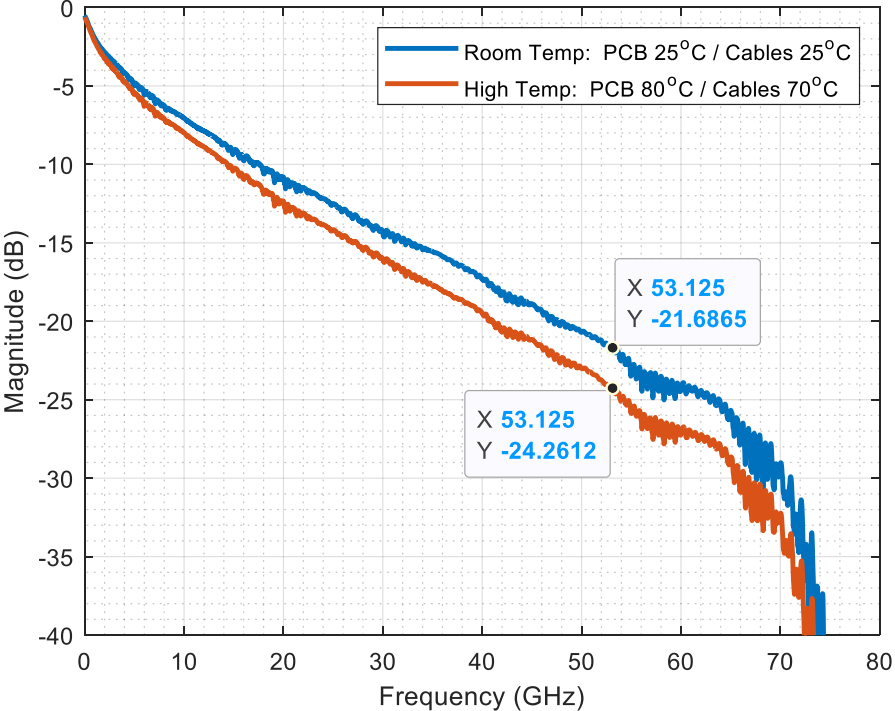
# Signaling Topology



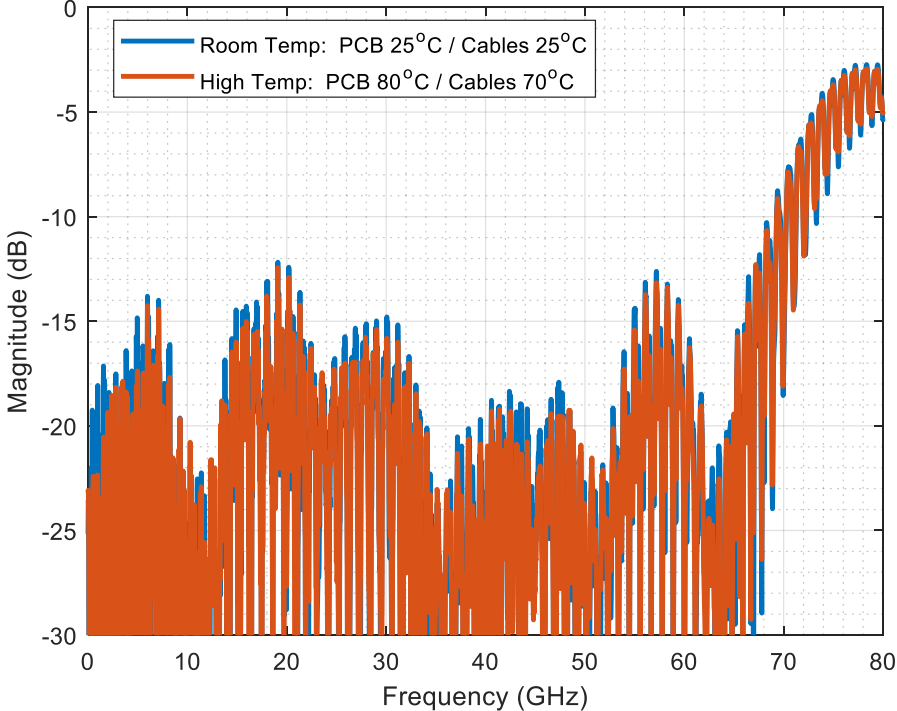
# KR BP Cable Channel Model: 150mm NPC / 800mm BP Cable / 150mm NPC

## Sdd21 / Sdd11

Sdd21 IL (TP0->TP5 Victim): 150mm NPC / 800mm BP Cable / 150mm NPC



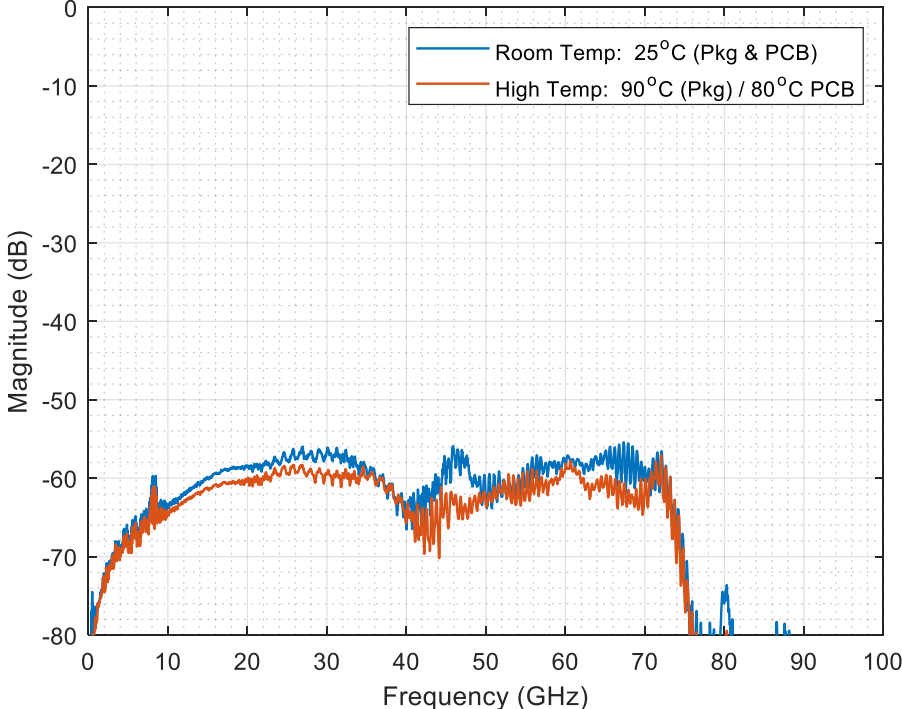
Sdd22 (TP5 Victim): 150mm NPC / 800mm BP Cable / 150mm NPC



# KR BP Cable Channel Model: 150mm NPC / 800mm BP Cable / 150mm NPC

## Sdd21 / Sdd11 Power Sum FEXT

Power Sum FEXT (TP5 Victim): 150mm NPC / 800mm BP Cable / 150mm NPC



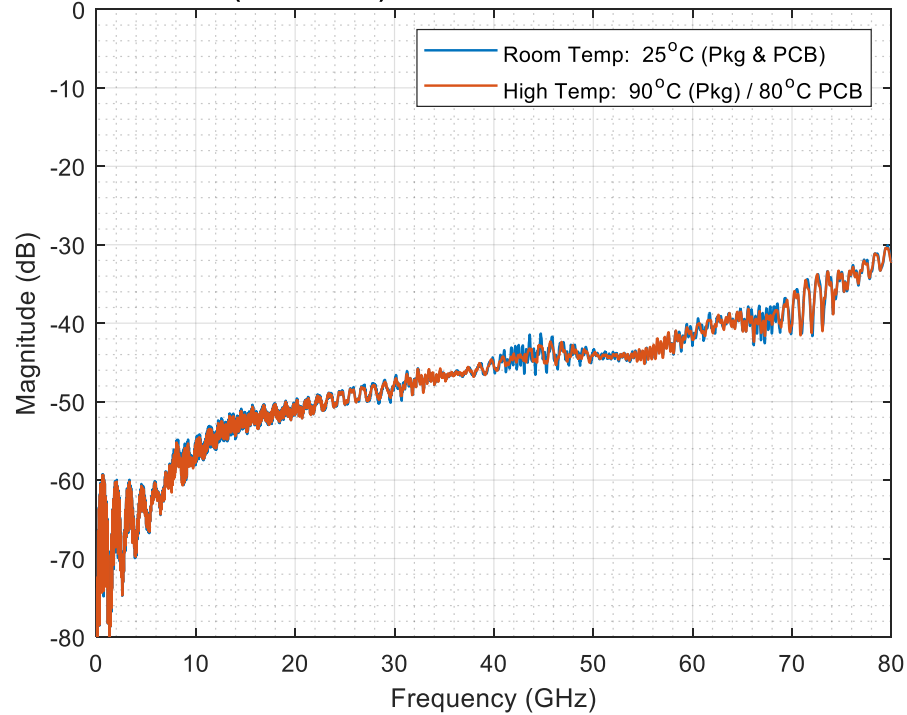
Host 1 Signal		Host 2 Signal	
Tx XTLK1	➔	Rx XTLK1	<b>FEXT1</b>
Tx XTLK2	➔	Rx XTLK2	<b>FEXT2</b>
Tx XTLK3	➔	Rx XTLK3	<b>FEXT3</b>
<b>TP0 Tx Victim</b>	➔	<b>TP5 Rx Victim</b>	
Tx XTLK4	➔	Rx XTLK4	<b>FEXT4</b>
Tx XTLK5	➔	Rx XTLK5	<b>FEXT5</b>
Tx XTLK6	➔	Rx XTLK6	<b>FEXT6</b>



# KR BP Cable Channel Model: 150mm NPC / 800mm BP Cable / 150mm NPC

## Power Sum NEXT

Power Sum NEXT (TP5 Victim): 150mm NPC / 800mm BP Cable / 150mm NPC

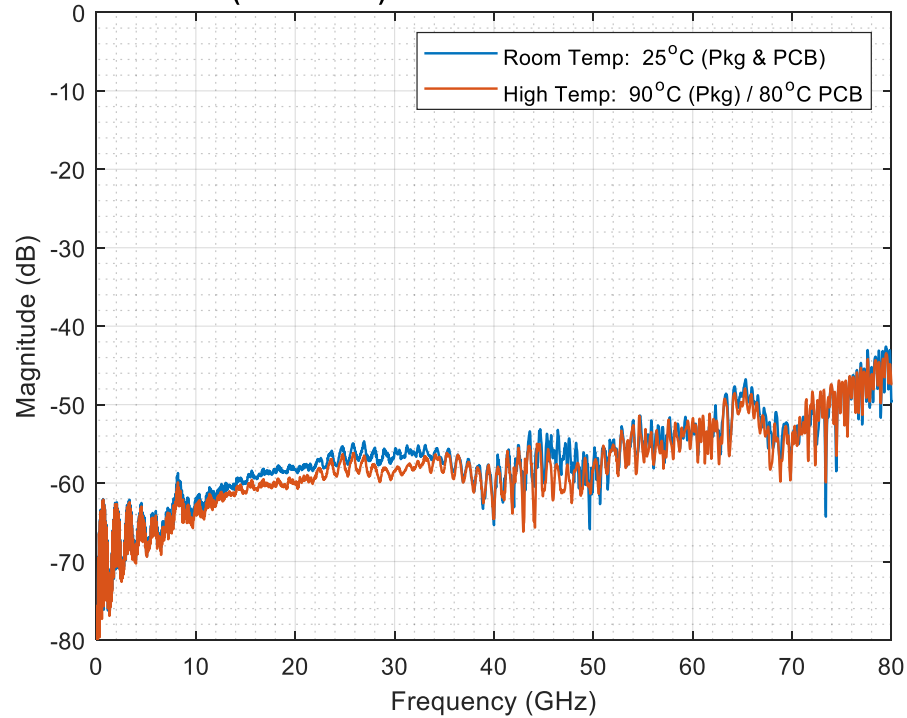


Host 1 Signal		Host 2 Signal	
Rx XTLK1	←	Rx XTLK1	<b>NEXT1</b>
Rx XTLK2	←	Tx XTLK2	<b>NEXT2</b>
Rx XTLK3	←	Tx XTLK3	<b>NEXT3</b>
<b>TP0 Tx Victim</b>	→	<b>TP5 Rx Victim</b>	
Rx XTLK4	←	Tx XTLK4	<b>NEXT4</b>
Rx XTLK5	←	Tx XTLK5	<b>NEXT5</b>
Rx XTLK6	←	Tx XTLK6	<b>NEXT6</b>

# KR BP Cable Channel Model: 150mm NPC / 800mm BP Cable / 150mm NPC

## Power Sum XTLK (Mixed Tx/Rx Example)

Power Sum XTLK (TP5 Victim): 150mm NPC / 800mm BP Cable / 150mm NPC

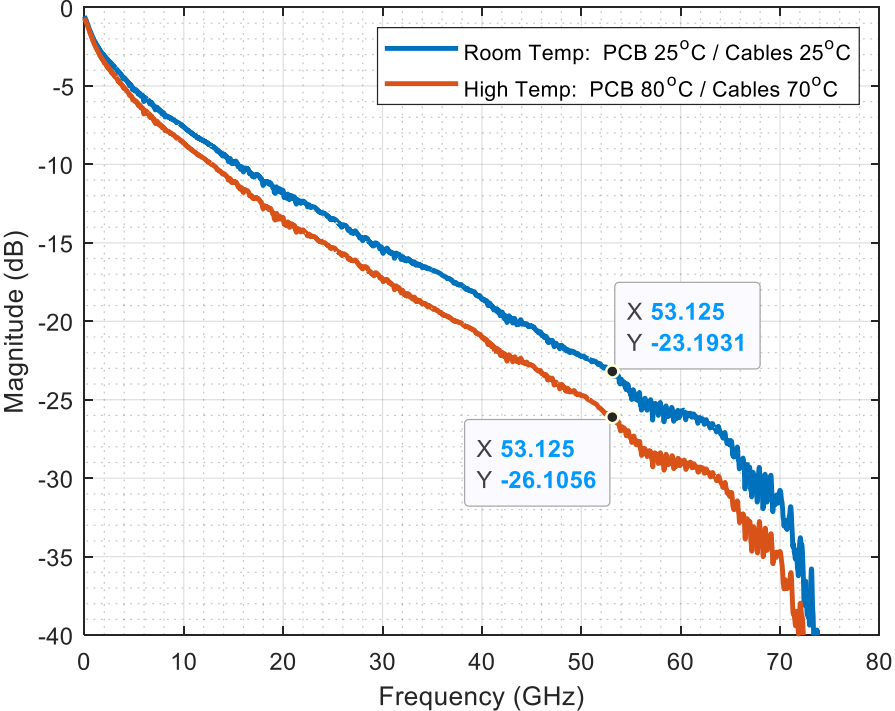


Host 1 Signal		Host 2 Signal	
Rx XTLK1	←	Tx XTLK1	<b>NEXT1</b>
Tx XTLK2	→	Rx XTLK2	<b>NEXT2</b>
Rx XTLK3	←	Tx XTLK3	<b>FEXT3</b>
<b>TP0 Tx Victim</b>	→	<b>TP5 Rx Victim</b>	
Tx XTLK4	→	Rx XTLK4	<b>FEXT4</b>
Tx XTLK5	→	Rx XTLK5	<b>FEXT5</b>
Rx XTLK6	←	Tx XTLK6	<b>NEXT6</b>

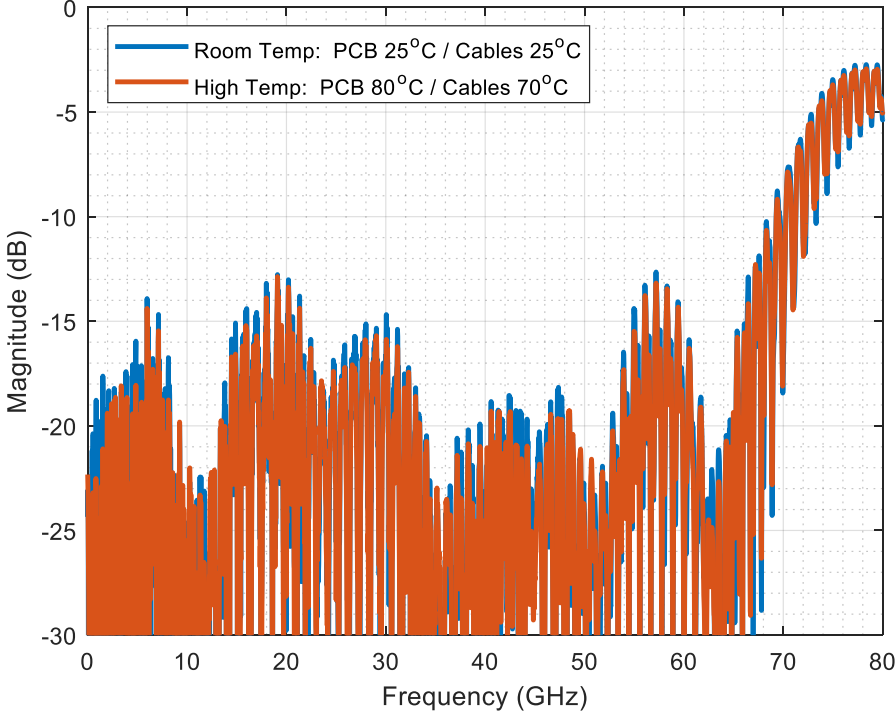
# KR BP Cable Channel Model: 150mm NPC / 800mm BP Cable / 300mm NPC

## Sdd21 / Sdd11

Sdd21 IL (TP0->TP5 Victim): 150mm NPC / 800mm BP Cable / 300mm NPC



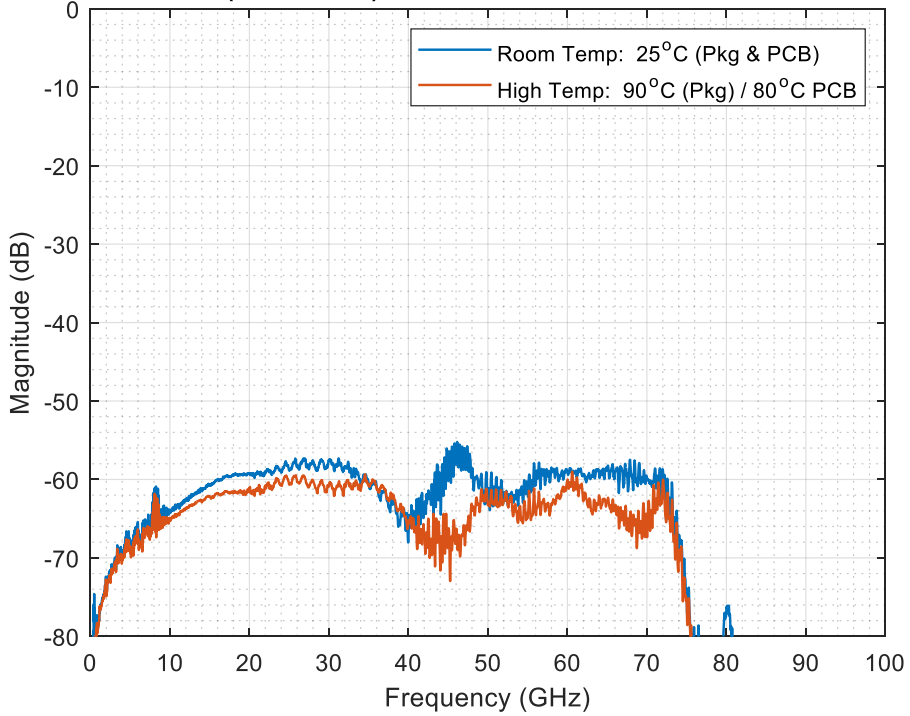
Sdd22 (TP5 Victim): 150mm NPC / 800mm BP Cable / 300mm NPC



# KR BP Cable Channel Model: 150mm NPC / 800mm BP Cable / 300mm NPC

## Sdd21 / Sdd11 Power Sum FEXT

Power Sum FEXT (TP5 Victim): 150mm NPC / 800mm BP Cable / 300mm NPC

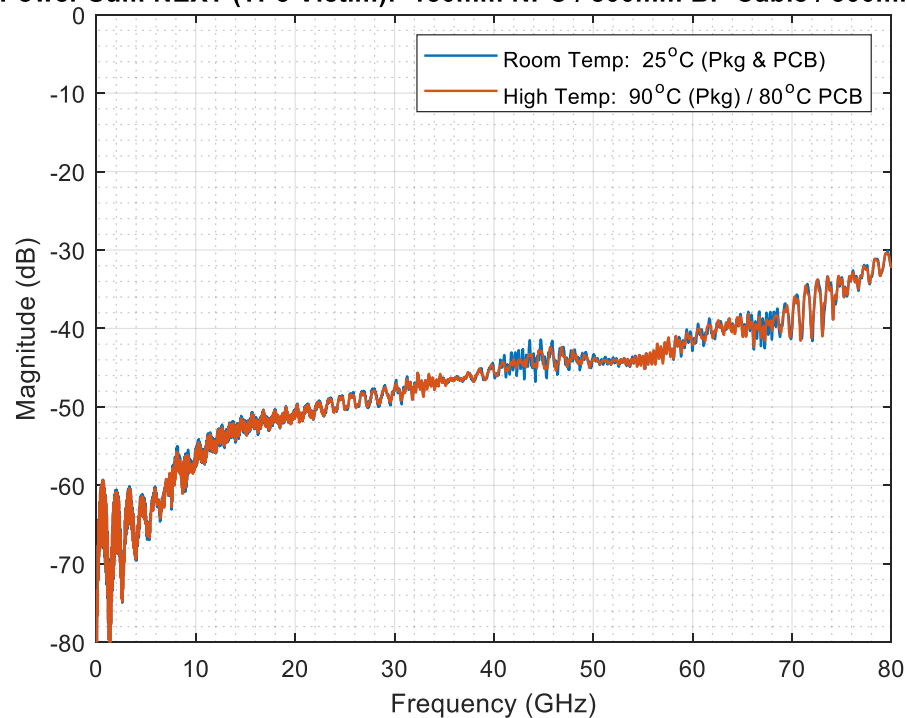


Host 1 Signal		Host 2 Signal	
Tx XTLK1	→	Rx XTLK1	<b>FEXT1</b>
Tx XTLK2	→	Rx XTLK2	<b>FEXT2</b>
Tx XTLK3	→	Rx XTLK3	<b>FEXT3</b>
<b>TP0 Tx Victim</b>	→	<b>TP5 Rx Victim</b>	
Tx XTLK4	→	Rx XTLK4	<b>FEXT4</b>
Tx XTLK5	→	Rx XTLK5	<b>FEXT5</b>
Tx XTLK6	→	Rx XTLK6	<b>FEXT6</b>

# KR BP Cable Channel Model: 150mm NPC / 800mm BP Cable / 300mm NPC

## Power Sum NEXT

Power Sum NEXT (TP5 Victim): 150mm NPC / 800mm BP Cable / 300mm NPC

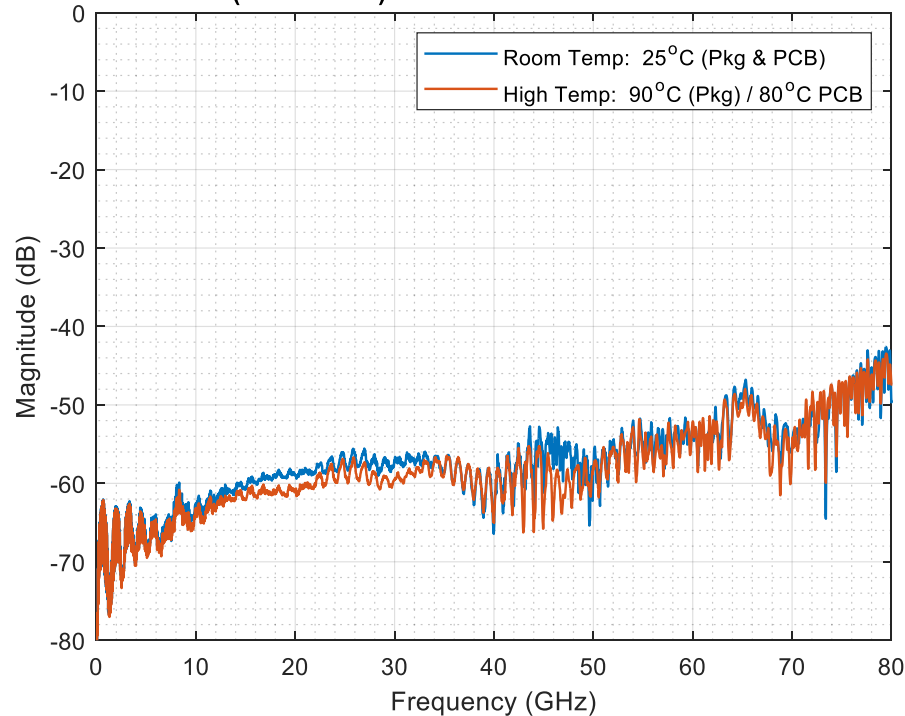


Host 1 Signal		Host 2 Signal	
Rx XTLK1	←	Rx XTLK1	NEXT1
Rx XTLK2	←	Tx XTLK2	NEXT2
Rx XTLK3	←	Tx XTLK3	NEXT3
TP0 Tx Victim	→	TP5 Rx Victim	
Rx XTLK4	←	Tx XTLK4	NEXT4
Rx XTLK5	←	Tx XTLK5	NEXT5
Rx XTLK6	←	Tx XTLK6	NEXT6

# KR BP Cable Channel Model: 150mm NPC / 800mm BP Cable / 300mm NPC

## Power Sum XTLK (Mixed Tx/Rx Example)

Power Sum XTLK (TP5 Victim): 150mm NPC / 800mm BP Cable / 300mm NPC

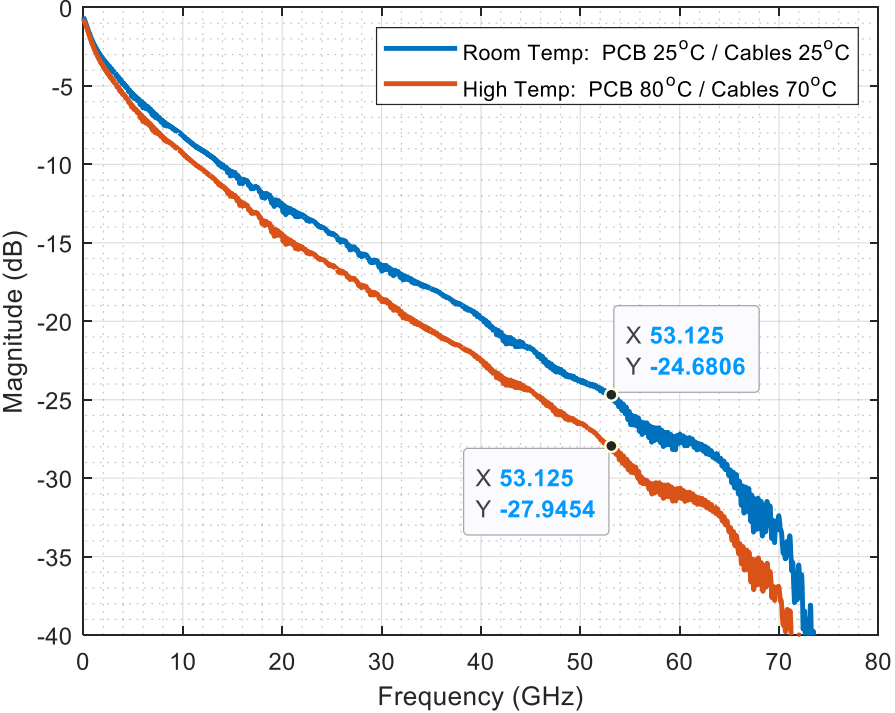


Host 1 Signal		Host 2 Signal	
Rx XTLK1	←	Tx XTLK1	<b>NEXT1</b>
Tx XTLK2	→	Rx XTLK2	<b>NEXT2</b>
Rx XTLK3	←	Tx XTLK3	<b>FEXT3</b>
<b>TP0 Tx Victim</b>	→	<b>TP5 Rx Victim</b>	
Tx XTLK4	→	Rx XTLK4	<b>FEXT4</b>
Tx XTLK5	→	Rx XTLK5	<b>FEXT5</b>
Rx XTLK6	←	Tx XTLK6	<b>NEXT6</b>

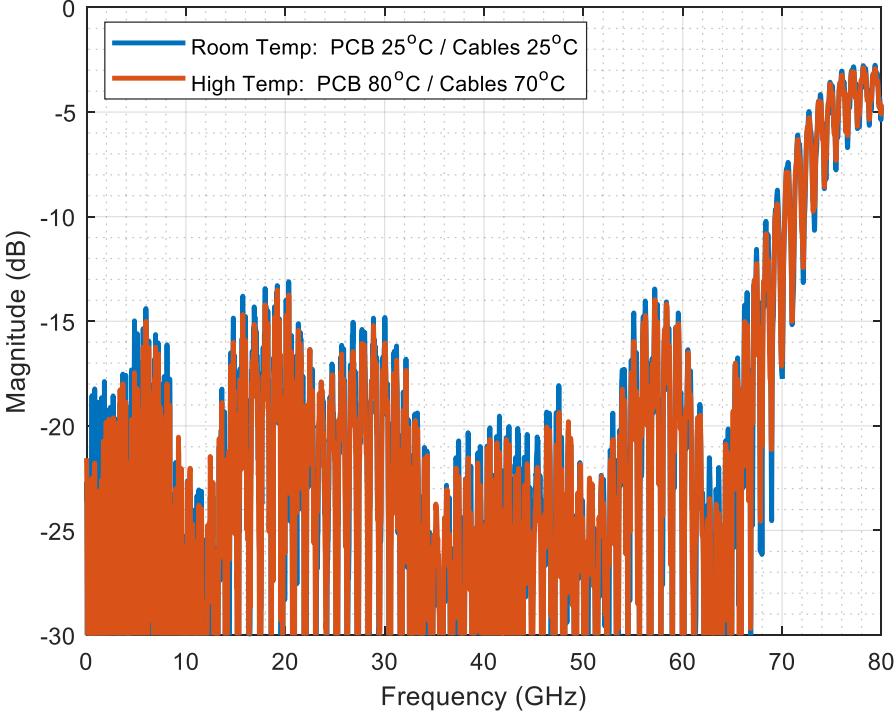
# KR BP Cable Channel Model: 300mm NPC / 800mm BP Cable / 300mm NPC

## Sdd21 / Sdd11

Sdd21 IL (TP0->TP5 Victim): 300mm NPC / 800mm BP Cable / 300mm NPC



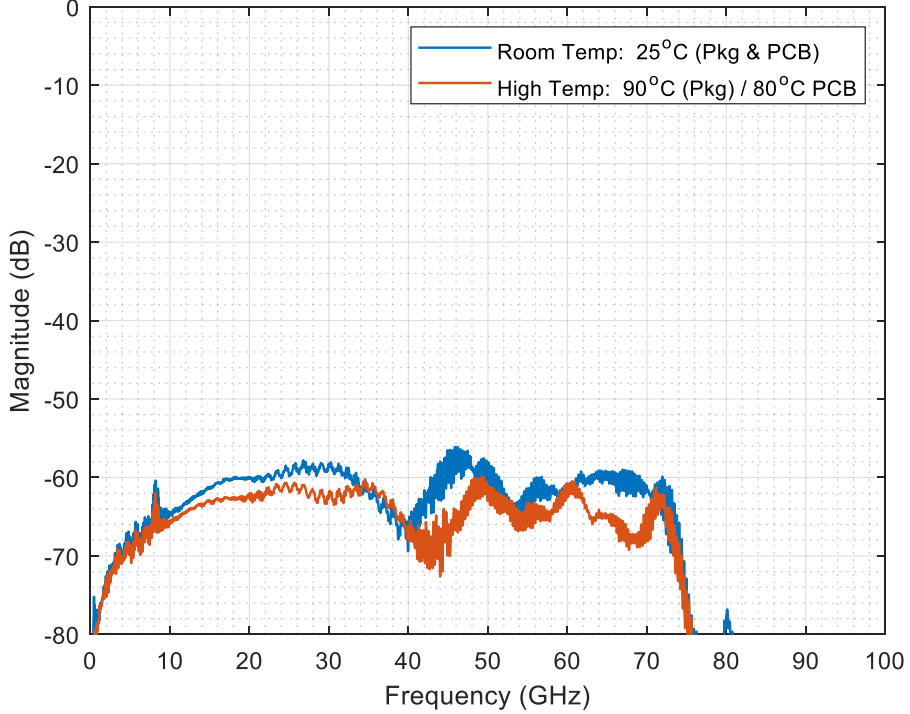
Sdd22 (TP5 Victim): 300mm NPC / 800mm BP Cable / 300mm NPC



# KR BP Cable Channel Model: 300mm NPC / 800mm BP Cable / 300mm NPC

## Sdd21 / Sdd11 Power Sum FEXT

Power Sum FEXT (TP5 Victim): 300mm NPC / 800mm BP Cable / 300mm NPC



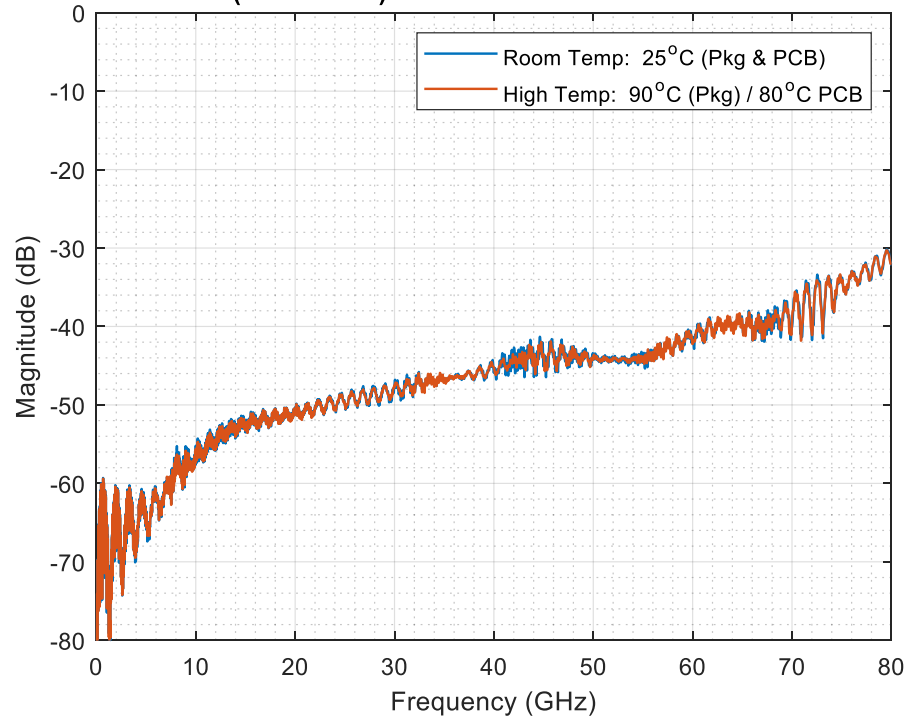
Host 1 Signal		Host 2 Signal	
Tx XTLK1	➔	Rx XTLK1	FEXT1
Tx XTLK2	➔	Rx XTLK2	FEXT2
Tx XTLK3	➔	Rx XTLK3	FEXT3
TP0 Tx Victim	➔	TP5 Rx Victim	
Tx XTLK4	➔	Rx XTLK4	FEXT4
Tx XTLK5	➔	Rx XTLK5	FEXT5
Tx XTLK6	➔	Rx XTLK6	FEXT6



# KR BP Cable Channel Model: 300mm NPC / 800mm BP Cable / 300mm NPC

## Power Sum NEXT

Power Sum NEXT (TP5 Victim): 300mm NPC / 800mm BP Cable / 300mm NPC

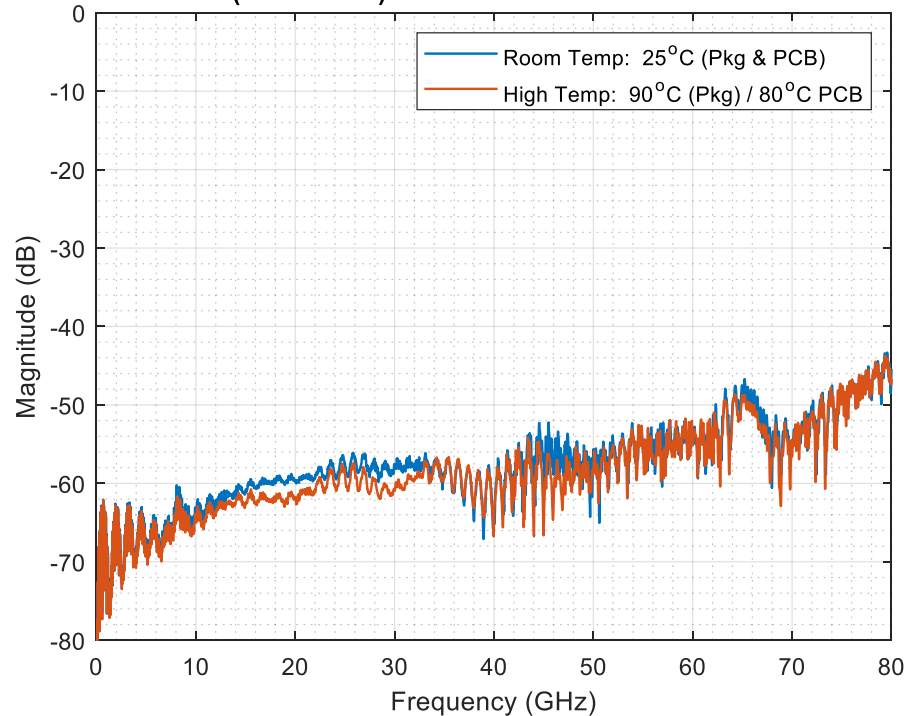


Host 1 Signal		Host 2 Signal	
Rx XTLK1	←	Rx XTLK1	<b>NEXT1</b>
Rx XTLK2	←	Tx XTLK2	<b>NEXT2</b>
Rx XTLK3	←	Tx XTLK3	<b>NEXT3</b>
<b>TP0 Tx Victim</b>	→	<b>TP5 Rx Victim</b>	
Rx XTLK4	←	Tx XTLK4	<b>NEXT4</b>
Rx XTLK5	←	Tx XTLK5	<b>NEXT5</b>
Rx XTLK6	←	Tx XTLK6	<b>NEXT6</b>

# KR BP Cable Channel Model: 300mm NPC / 800mm BP Cable / 300mm NPC

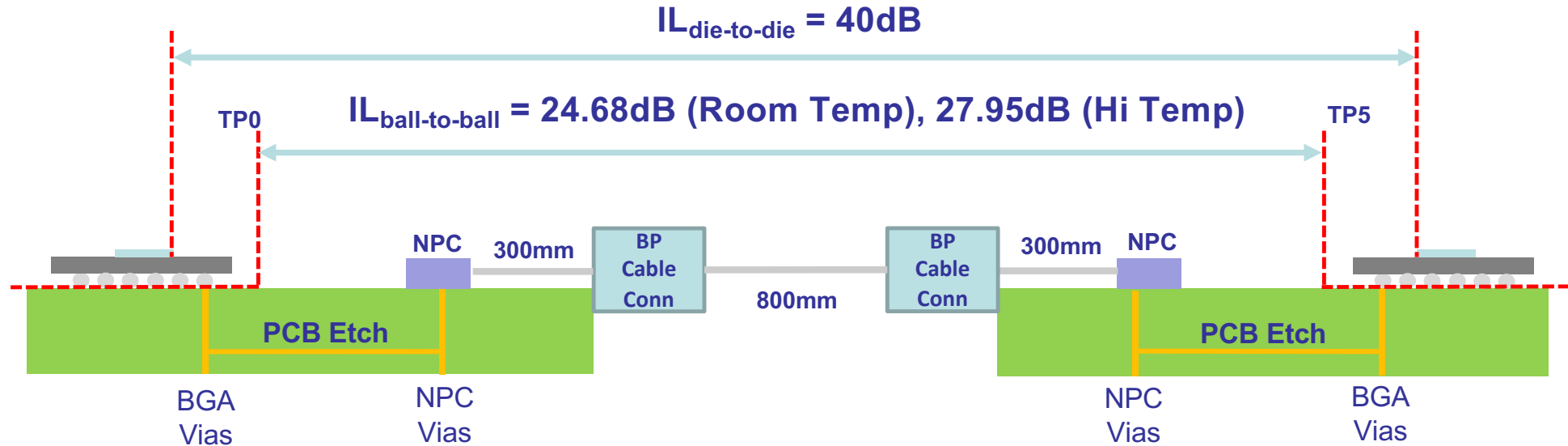
## Power Sum XTLK (Mixed Tx/Rx Example)

Power Sum XTLK (TP5 Victim): 300mm NPC / 800mm BP Cable / 300mm NPC



Host 1 Signal		Host 2 Signal	
Rx XTLK1	←	Tx XTLK1	<b>NEXT1</b>
Tx XTLK2	→	Rx XTLK2	<b>NEXT2</b>
Rx XTLK3	←	Tx XTLK3	<b>FEXT3</b>
<b>TP0 Tx Victim</b>	→	<b>TP5 Rx Victim</b>	
Tx XTLK4	→	Rx XTLK4	<b>FEXT4</b>
Tx XTLK5	→	Rx XTLK5	<b>FEXT5</b>
Rx XTLK6	←	Tx XTLK6	<b>NEXT6</b>

# Closing Thoughts...

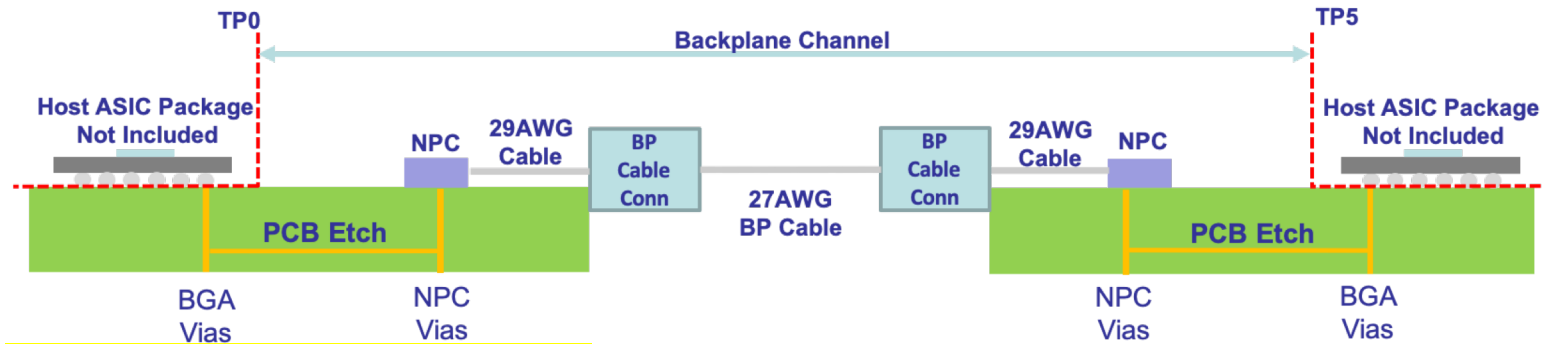


## Implementation of a large fabric topology

- Assume large radix ASICs with ~40 mm pkg traces (representative of a large fabric chips)
  - Package loss at 0.16dB/mm (room temp) ([ghiasi 3df 01 220927](#)) fits in the loss budget with 3dB margin
  - Package loss at 0.19dB/mm (at 90C) ([ghiasi 3df 01 220927](#)) exceeds the loss budget by 3dB
- Loss increase with temperature must be accounted for in both packages & boards

# Summary

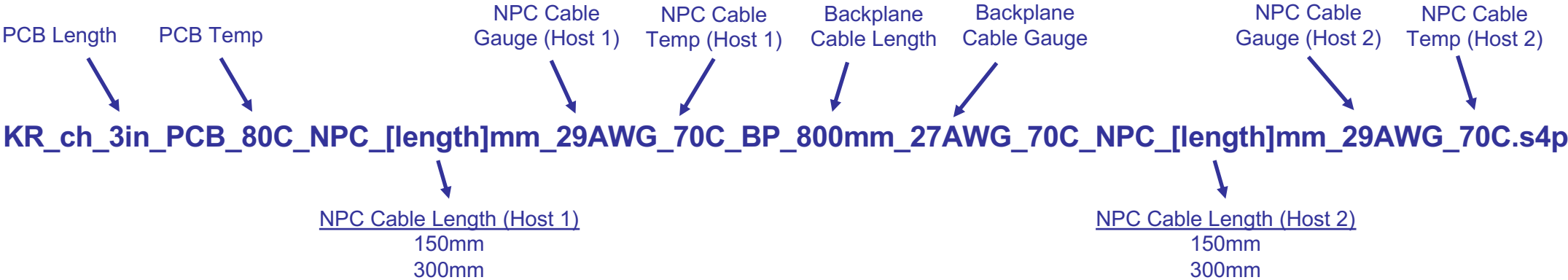
- Contributed channels model a KR link with a cable backplane – daughter cards use near package cabling



- Updates to weaver 3dj\_01\_2303**
  - ✓ Added 150mm and 300mm NPC cable at 70C (NPC & BP Cable connector models still at room temp)
  - ✓ Added 800mm BP cable at 70C
  - ✓ Added Host PCB at 80C
  - ✓ TP0 to TP5 insertion losses range from 24.26dB to 27.95dB at high temp conditions
- TP0 to TP5 insertion losses range from 21.69dB to 26.94dB in 36 different model variants
- Each variant contains 7 signal lanes: 1 victim and 6 aggressors
- Return losses less than -10dB to 70GHz
- Power summed FEXT less than -50dB to ~80GHz
- Power summed NEXT less than -40dB to ~65GHz

# KR Backplane Cable Channels

## File Naming Convention: TP0→TP5 Thru Channels



# KR Backplane Cable Channels

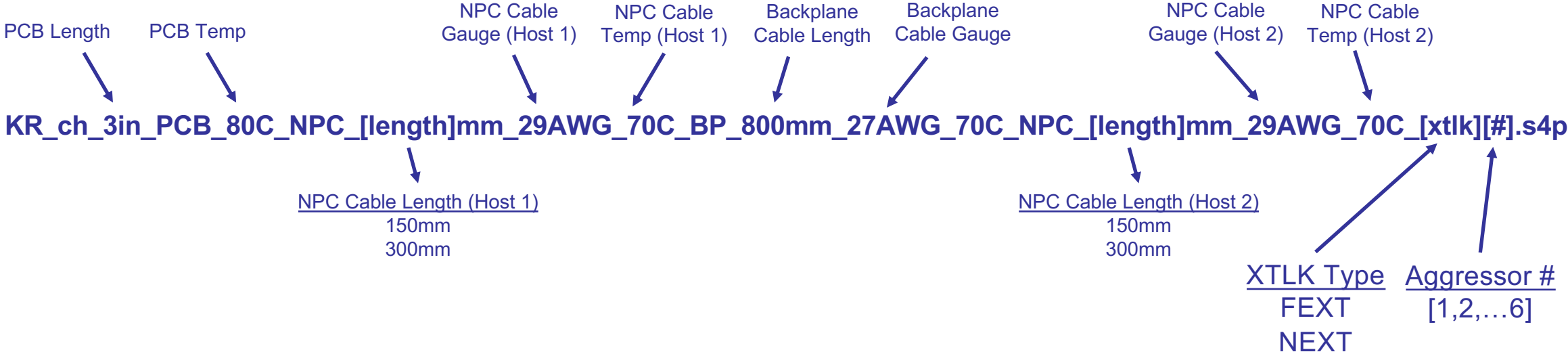
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## Thru Channel Files:

KR\_ch\_3in\_PCB\_80C\_NPC\_150mm\_29AWG\_70C\_BP\_800mm\_27AWG\_70C\_NPC\_150mm\_29AWG\_70C.s4p  
KR\_ch\_3in\_PCB\_80C\_NPC\_150mm\_29AWG\_70C\_BP\_800mm\_27AWG\_70C\_NPC\_300mm\_29AWG.\_70Cs4p  
KR\_ch\_3in\_PCB\_80C\_NPC\_300mm\_29AWG\_70C\_BP\_800mm\_27AWG\_70C\_NPC\_150mm\_29AWG.\_70Cs4p  
KR\_ch\_3in\_PCB\_80C\_NPC\_300mm\_29AWG\_70C\_BP\_800mm\_27AWG\_70C\_NPC\_300mm\_29AWG.\_70Cs4p

# KR Backplane Cable Channels

## File Naming Convention: XTLK Channels



# KR Backplane Cable Channels

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## XTLK Channel Files:

**Host 1 NPC Cable: 150mm**

**Host 2 NPC Cable: ### = [150, 300] mm**

KR\_ch\_3in\_PCB\_80C\_NPC\_150mm\_29AWG\_70C\_BP\_800mm\_27AWG\_70C\_NPC\_###mm\_29AWG\_70C\_FEXT1.s4p  
KR\_ch\_3in\_PCB\_80C\_NPC\_150mm\_29AWG\_70C\_BP\_800mm\_27AWG\_70C\_NPC\_###mm\_29AWG\_70C\_FEXT2.s4p  
KR\_ch\_3in\_PCB\_80C\_NPC\_150mm\_29AWG\_70C\_BP\_800mm\_27AWG\_70C\_NPC\_###mm\_29AWG\_70C\_FEXT3.s4p  
KR\_ch\_3in\_PCB\_80C\_NPC\_150mm\_29AWG\_70C\_BP\_800mm\_27AWG\_70C\_NPC\_###mm\_29AWG\_70C\_FEXT4.s4p  
KR\_ch\_3in\_PCB\_80C\_NPC\_150mm\_29AWG\_70C\_BP\_800mm\_27AWG\_70C\_NPC\_###mm\_29AWG\_70C\_FEXT5.s4p  
KR\_ch\_3in\_PCB\_80C\_NPC\_150mm\_29AWG\_70C\_BP\_800mm\_27AWG\_70C\_NPC\_###mm\_29AWG\_70C\_FEXT6.s4p

KR\_ch\_3in\_PCB\_80C\_NPC\_150mm\_29AWG\_70C\_BP\_800mm\_27AWG\_70C\_NPC\_###mm\_29AWG\_70C\_NEXT1.s4p  
KR\_ch\_3in\_PCB\_80C\_NPC\_150mm\_29AWG\_70C\_BP\_800mm\_27AWG\_70C\_NPC\_###mm\_29AWG\_70C\_NEXT2.s4p  
KR\_ch\_3in\_PCB\_80C\_NPC\_150mm\_29AWG\_70C\_BP\_800mm\_27AWG\_70C\_NPC\_###mm\_29AWG\_70C\_NEXT3.s4p  
KR\_ch\_3in\_PCB\_80C\_NPC\_150mm\_29AWG\_70C\_BP\_800mm\_27AWG\_70C\_NPC\_###mm\_29AWG\_70C\_NEXT4.s4p  
KR\_ch\_3in\_PCB\_80C\_NPC\_150mm\_29AWG\_70C\_BP\_800mm\_27AWG\_70C\_NPC\_###mm\_29AWG\_70C\_NEXT5.s4p  
KR\_ch\_3in\_PCB\_80C\_NPC\_150mm\_29AWG\_70C\_BP\_800mm\_27AWG\_70C\_NPC\_###mm\_29AWG\_70C\_NEXT6.s4p



# KR Backplane Cable Channels

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## XTLK Channel Files:

**Host 1 NPC Cable: 300mm**

**Host 2 NPC Cable: ### = [150, 200, 250, 300, 350, 400] mm**

KR\_ch\_3in\_PCB\_80C\_NPC\_300mm\_29AWG\_70C\_BP\_800mm\_27AWG\_70C\_NPC\_###mm\_29AWG\_70C\_FEXT1.s4p  
KR\_ch\_3in\_PCB\_80C\_NPC\_300mm\_29AWG\_70C\_BP\_800mm\_27AWG\_70C\_NPC\_###mm\_29AWG\_70C\_FEXT2.s4p  
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KR\_ch\_3in\_PCB\_80C\_NPC\_300mm\_29AWG\_70C\_BP\_800mm\_27AWG\_70C\_NPC\_###mm\_29AWG\_70C\_FEXT5.s4p  
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KR\_ch\_3in\_PCB\_80C\_NPC\_300mm\_29AWG\_70C\_BP\_800mm\_27AWG\_70C\_NPC\_###mm\_29AWG\_70C\_NEXT1.s4p  
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KR\_ch\_3in\_PCB\_80C\_NPC\_300mm\_29AWG\_70C\_BP\_800mm\_27AWG\_70C\_NPC\_###mm\_29AWG\_70C\_NEXT4.s4p  
KR\_ch\_3in\_PCB\_80C\_NPC\_300mm\_29AWG\_70C\_BP\_800mm\_27AWG\_70C\_NPC\_###mm\_29AWG\_70C\_NEXT5.s4p  
KR\_ch\_3in\_PCB\_80C\_NPC\_300mm\_29AWG\_70C\_BP\_800mm\_27AWG\_70C\_NPC\_###mm\_29AWG\_70C\_NEXT6.s4p