

# **212Gb/s Per Lane PAM4 KR Cabled Backplane Channels with Asymmetric NPC Cable Lengths**

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# Contributors

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

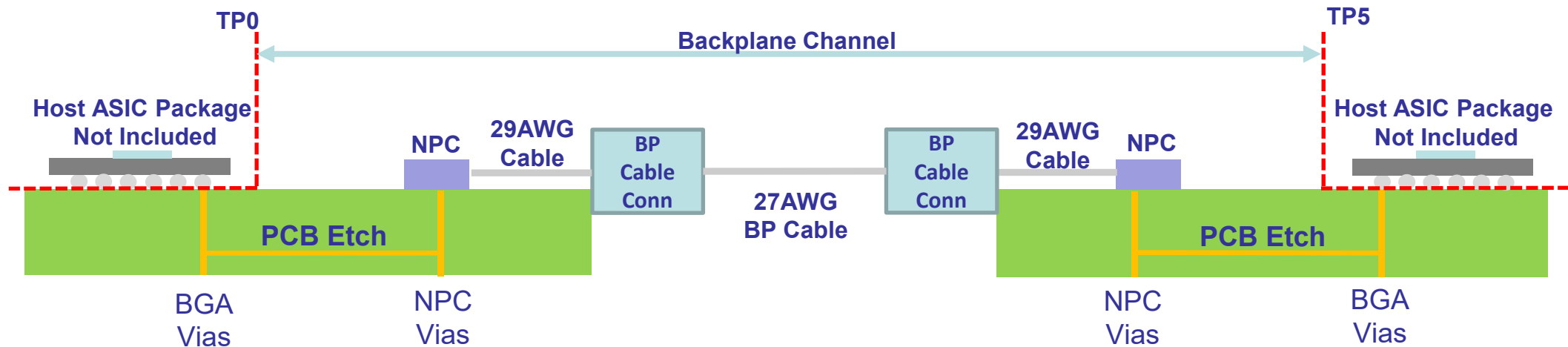
# Overview

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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\_2303: updated twinax cable models
  - Connector simulation models provided by Vysakh Sivarajan, affiliated with Amphenol
    - Update to weaver 3dj\_01\_2303: updated 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
    - Update to weaver 3dj\_01\_2303: includes updated 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



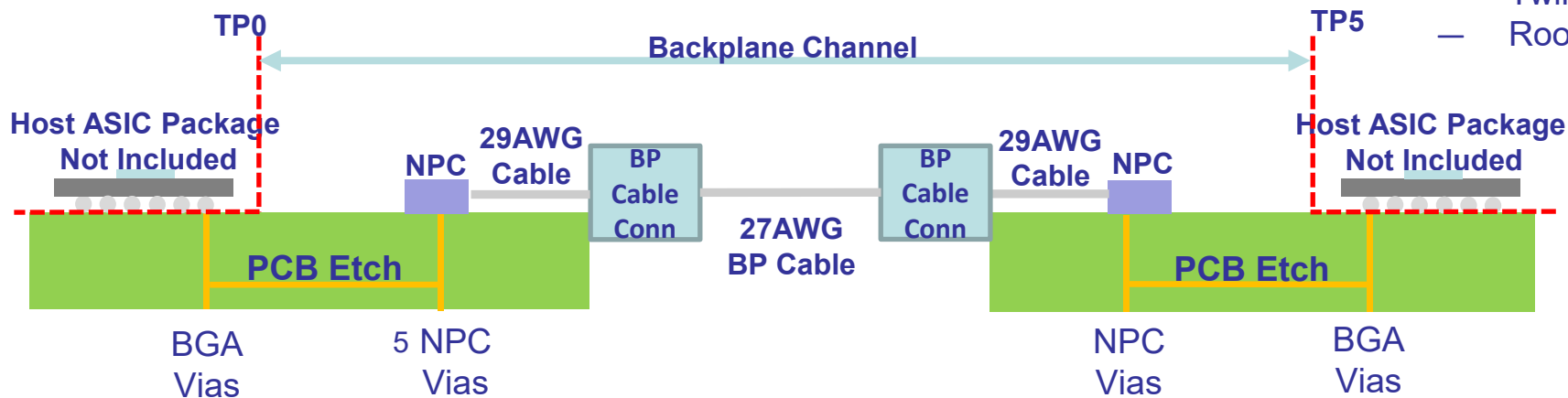
# KR Backplane Cable Assembly + Host

## PCB Composition

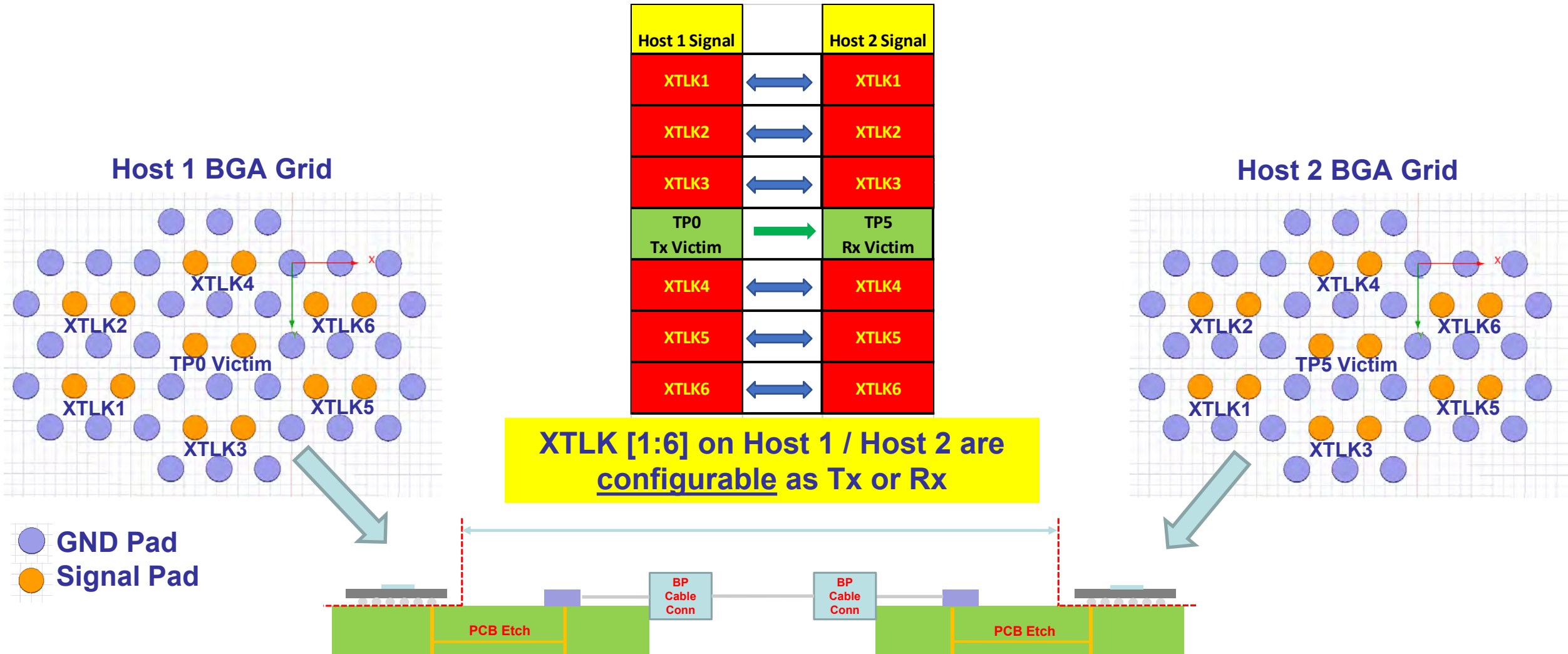
- BGA & NPC Breakout Footprints
  - ~ 3mm PTH breakout depth
  - 8 mil vias with 5 mil stubs
  - Conforms to current PCB fab design rules
  - Nothing exotic: no skip layers, no microvias
- Host Breakout Trace
  - Fanout length to NPC's: ~ 3 inches
  - Loss: ~ 1.25 dB/in @ 53.125 GHz
  - 90 ohm @ 6 mil line width
  - Room Temperature

## Cable Assembly Composition

- Near Packaged Copper (NPC)
  - 95 ohm 29 AWG Twinax lengths
    - 200mm, 250mm, 300mm, 350mm, 400mm
    - **Update to weaver 3dj\_01\_2303: 150mm length now included**
  - Room Temperature
  - Assumes symmetric lengths on both sides of channel
    - **Update to weaver 3dj\_01\_2303: asymmetric lengths now included**
- BP Cable Connector + Twinax
  - 95 ohm 27 AWG
  - Twinax length: 800mm
  - Room Temperature

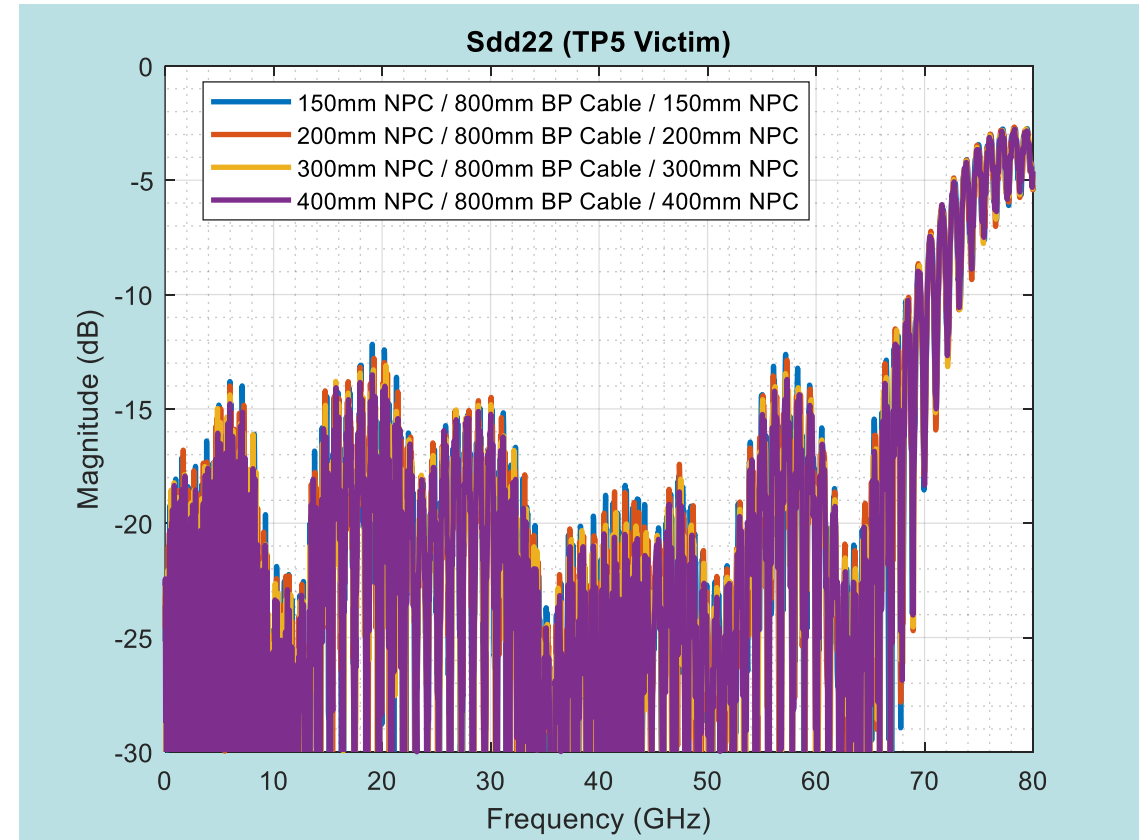
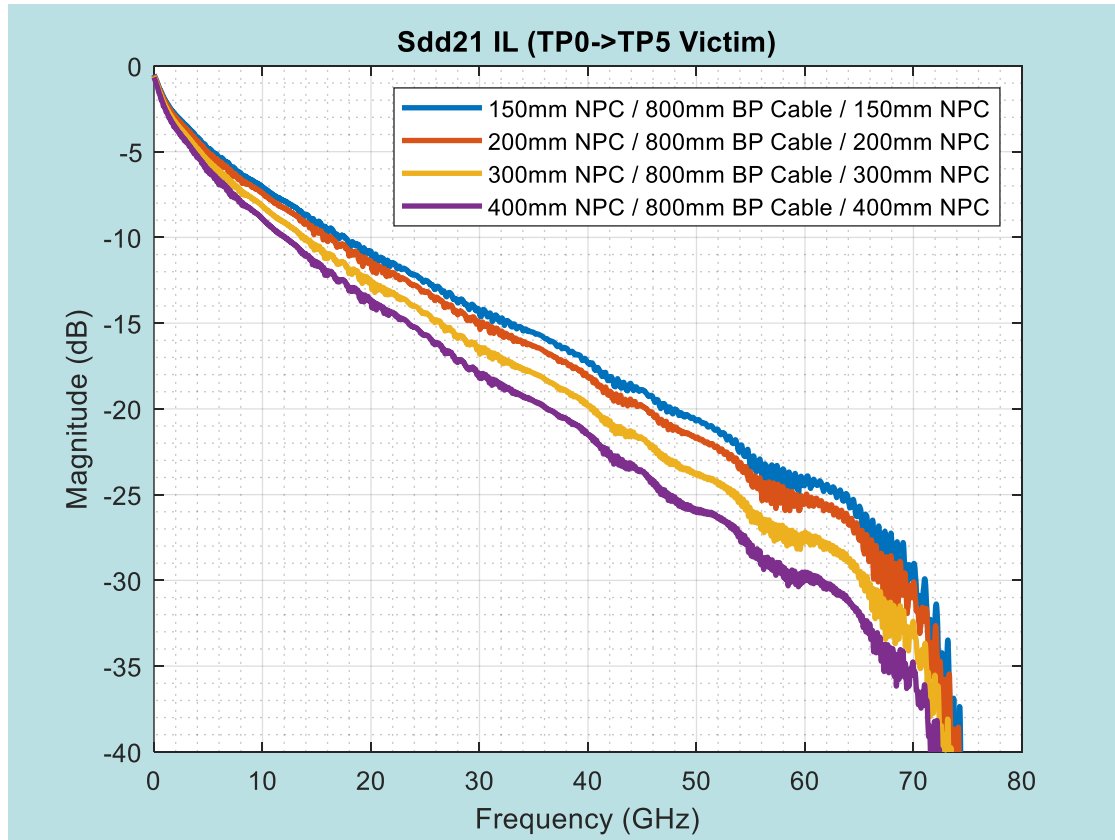


# Signaling Topology



# KR BP Cable Channel Model (Symmetric)

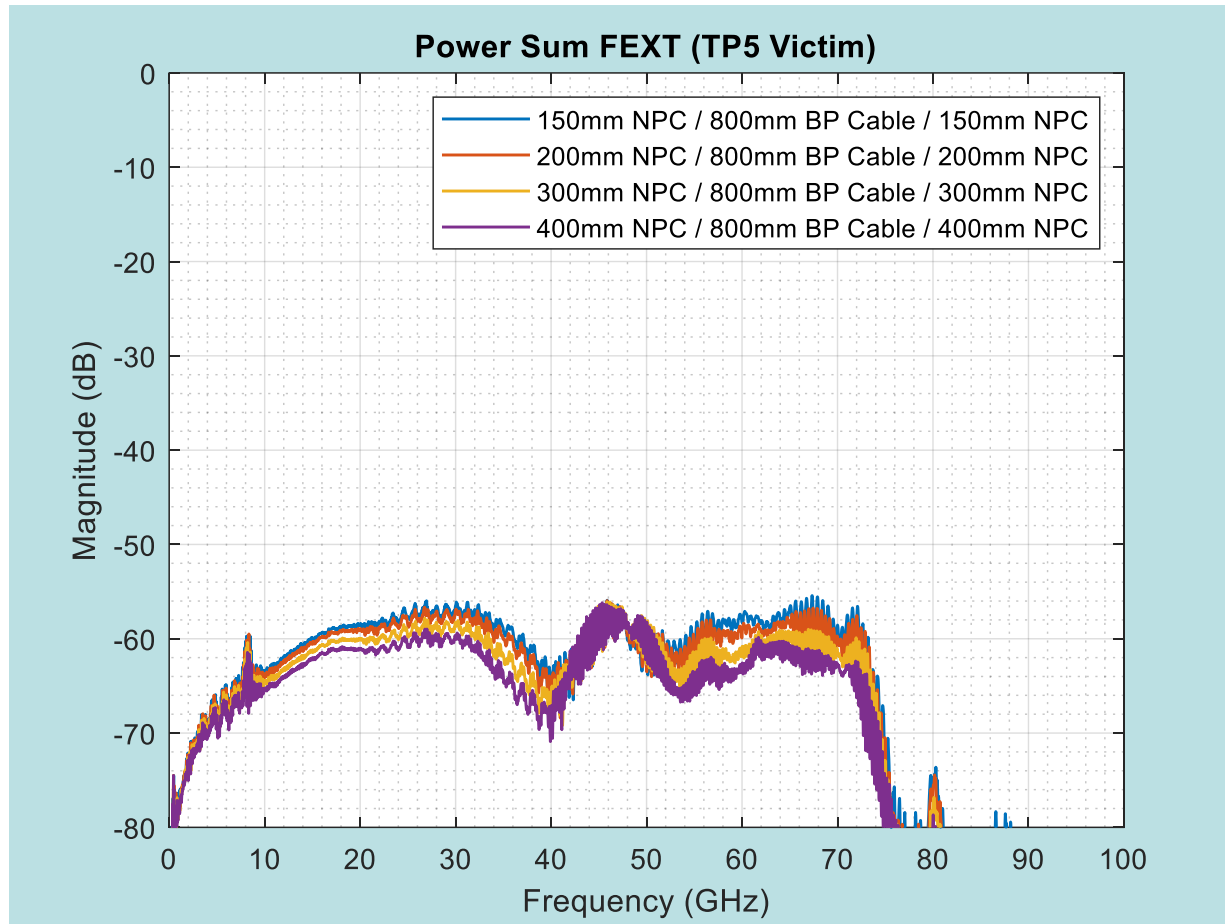
## Sdd21 / Sdd11



Host 1 NPC Cable (mm)	BP Cable (mm)	Host 2 NPC Cable (mm)	IL @ 53.125 GHz (dB)
150mm	800mm	150mm	21.69
200mm	800mm	200mm	22.74
300mm	800mm	300mm	24.68
400mm	800mm	400mm	26.94

# KR BP Cable Channel Model (Symmetric)

## Power Sum FEXT

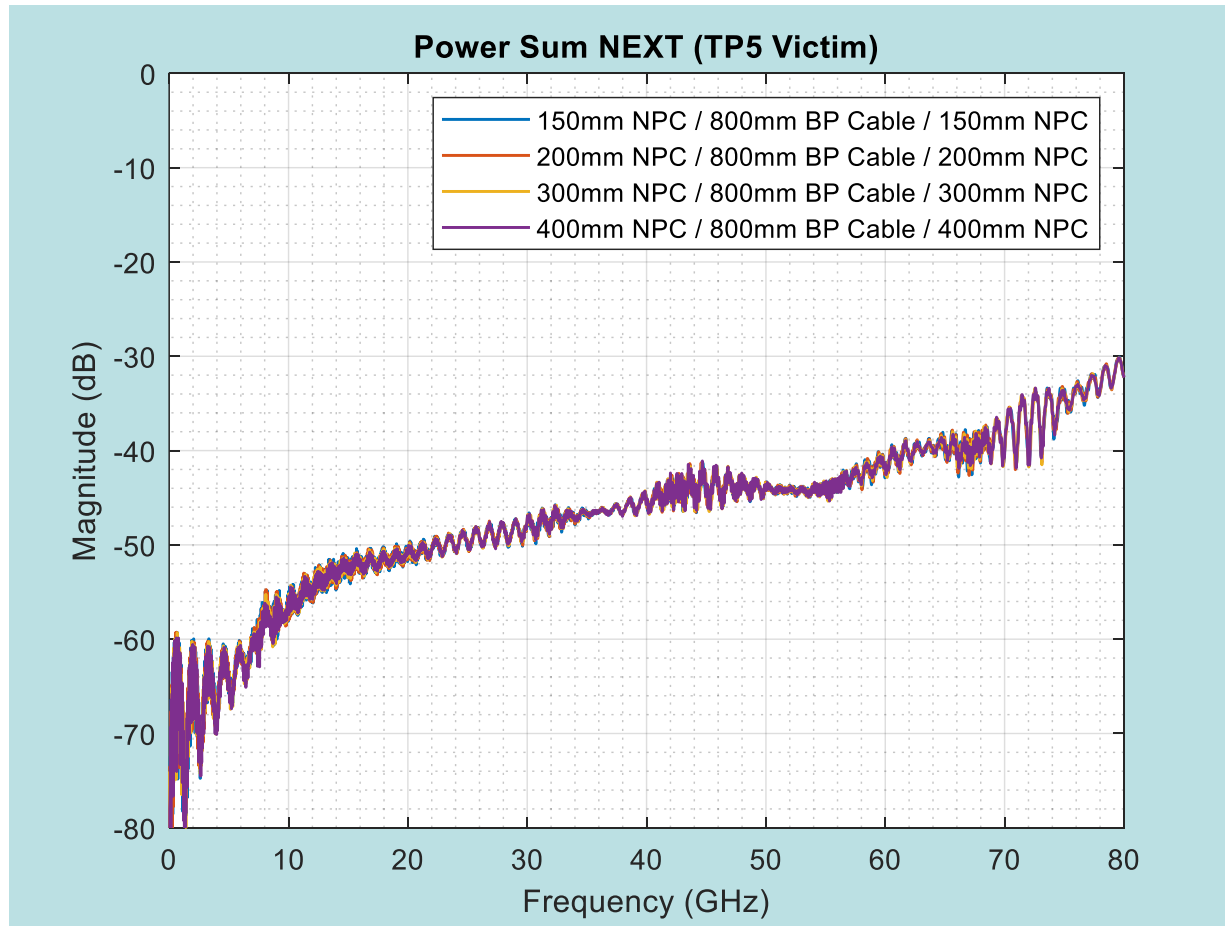


Host 1 Signal		Host 2 Signal	
Tx XTLK1	→	Rx XTLK1	<b>FEXT1</b>
Tx XTLK2	→	Rx XTLK2	<b>FEXT2</b>
Tx XTLK3	→	Rx XTLK3	<b>FEXT3</b>
<b>TP0 Tx Victim</b>	→	<b>TP5 Rx Victim</b>	
Tx XTLK4	→	Rx XTLK4	<b>FEXT4</b>
Tx XTLK5	→	Rx XTLK5	<b>FEXT5</b>
Tx XTLK6	→	Rx XTLK6	<b>FEXT6</b>



# KR BP Cable Channel Model (Symmetric)

## Power Sum NEXT



Host 1 Signal		Host 2 Signal
Rx XTLK1	←	Rx XTLK1
Rx XTLK2	←	Tx XTLK2
Rx XTLK3	←	Tx XTLK3
<b>TP0 Tx Victim</b>	→	<b>TP5 Rx Victim</b>
Rx XTLK4	←	Tx XTLK4
Rx XTLK5	←	Tx XTLK5
Rx XTLK6	←	Tx XTLK6

**NEXT1**

**NEXT2**

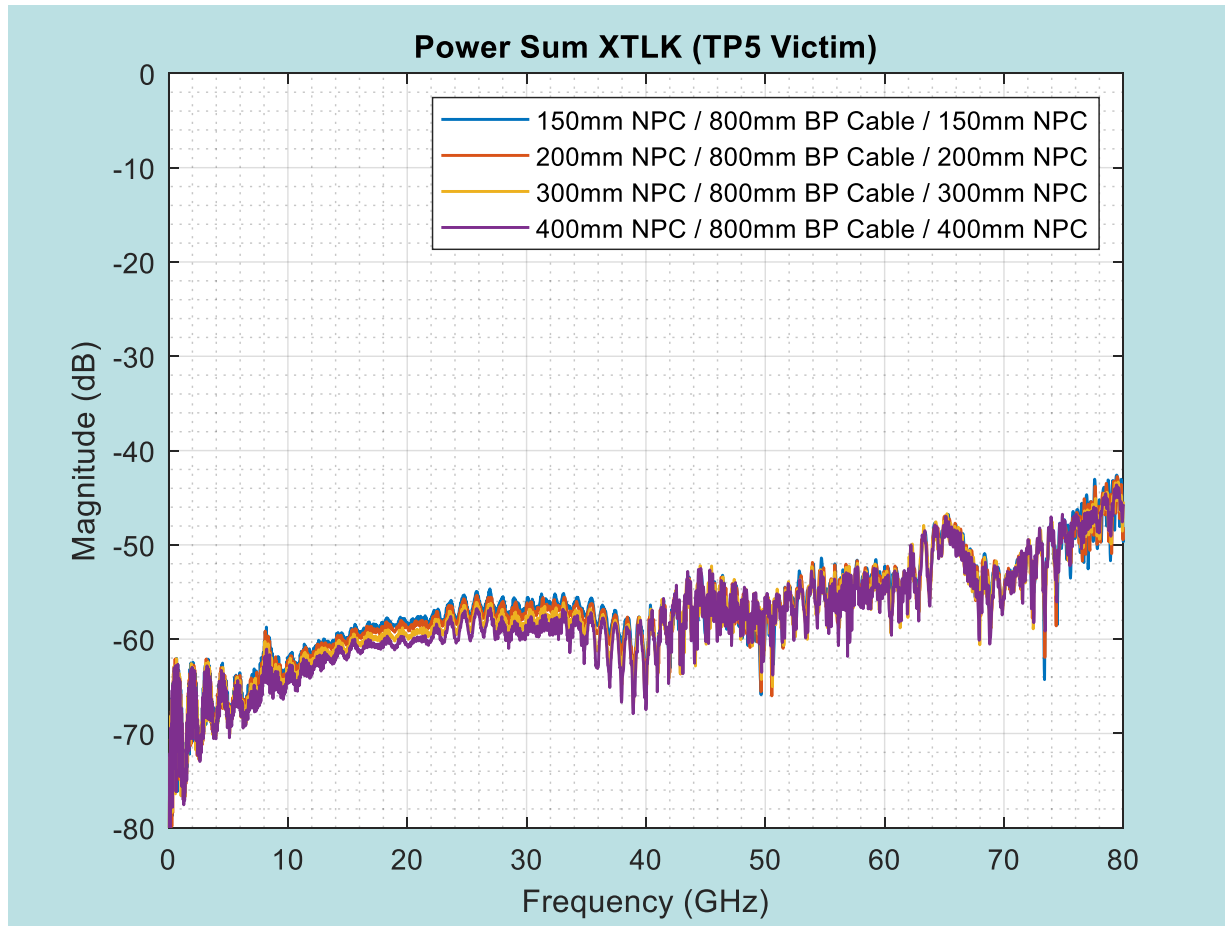
**NEXT3**

**NEXT4**

**NEXT5**

**NEXT6**

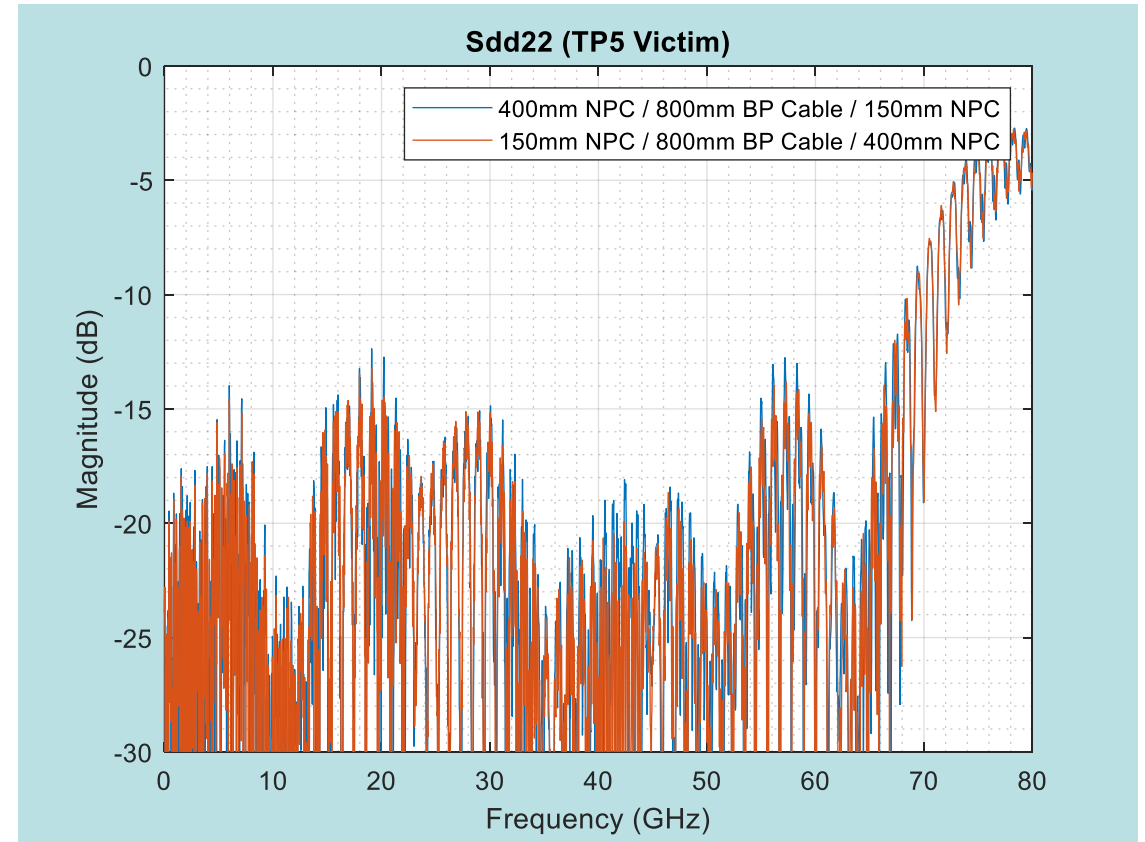
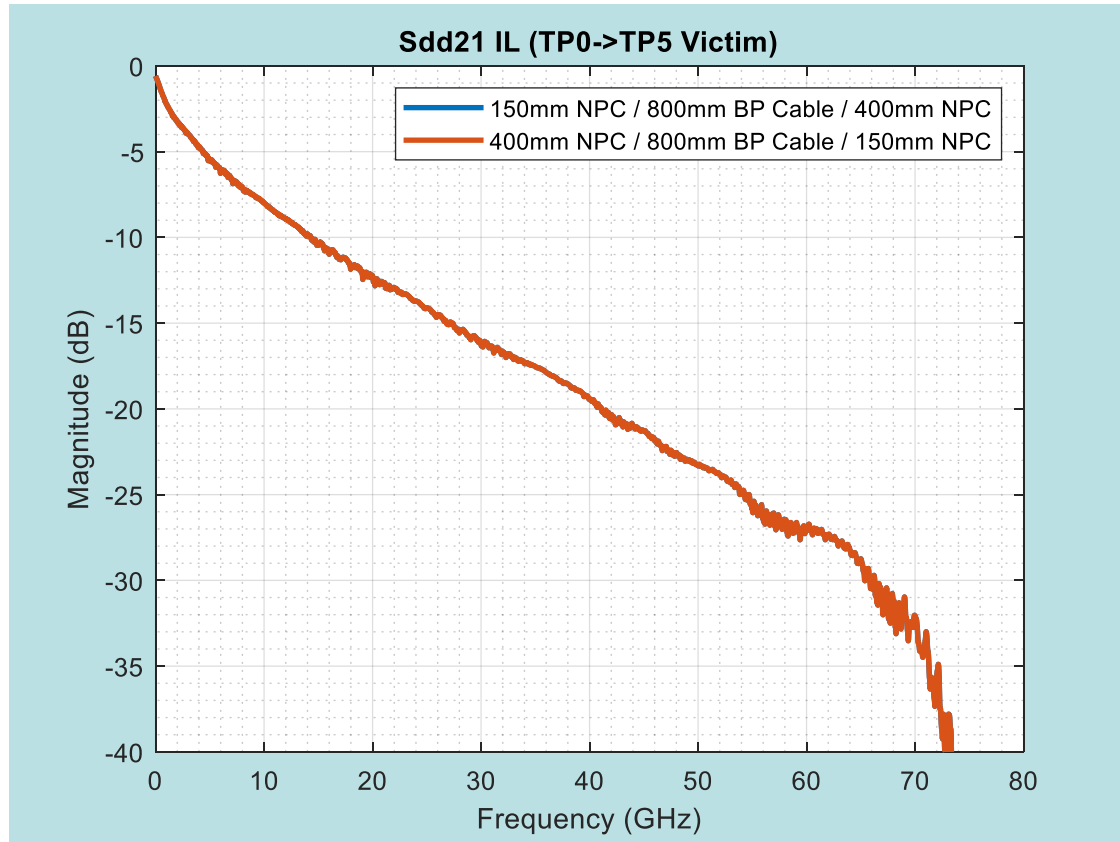
# KR BP Cable Channel Model (Symmetric) Power Sum XTLK (Mixed Tx/Rx Example)



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

# KR BP Cable Channel Model (Asymmetric)

## Sdd21 / Sdd11

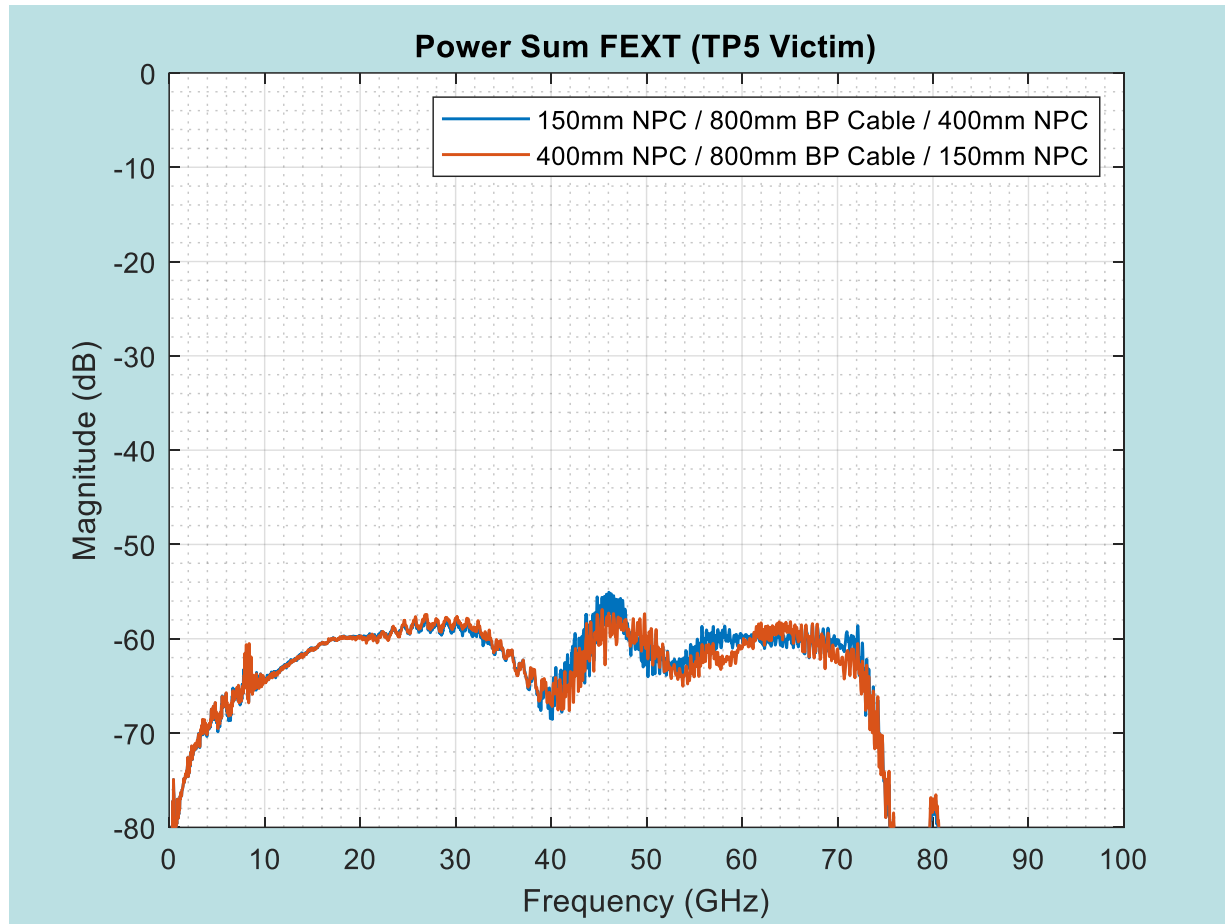


Host 1 NPC Cable (mm)	BP Cable (mm)	Host 2 NPC Cable (mm)	IL @ 53.125 GHz (dB)
150mm	800mm	400mm	24.36
400mm	800mm	150mm	24.36

**Shorter Host2 cable length (blue) shows higher return loss peaks at TP5 due to closer spacing between BGA and NPC vias**

# KR BP Cable Channel Model (Asymmetric)

## Power Sum FEXT



Host 1 Signal		Host 2 Signal
Tx XTLK1	→	Rx XTLK1
Tx XTLK2	→	Rx XTLK2
Tx XTLK3	→	Rx XTLK3
<b>TP0 Tx Victim</b>	→	<b>TP5 Rx Victim</b>
Tx XTLK4	→	Rx XTLK4
Tx XTLK5	→	Rx XTLK5
Tx XTLK6	→	Rx XTLK6

**FEXT1**

**FEXT2**

**FEXT3**

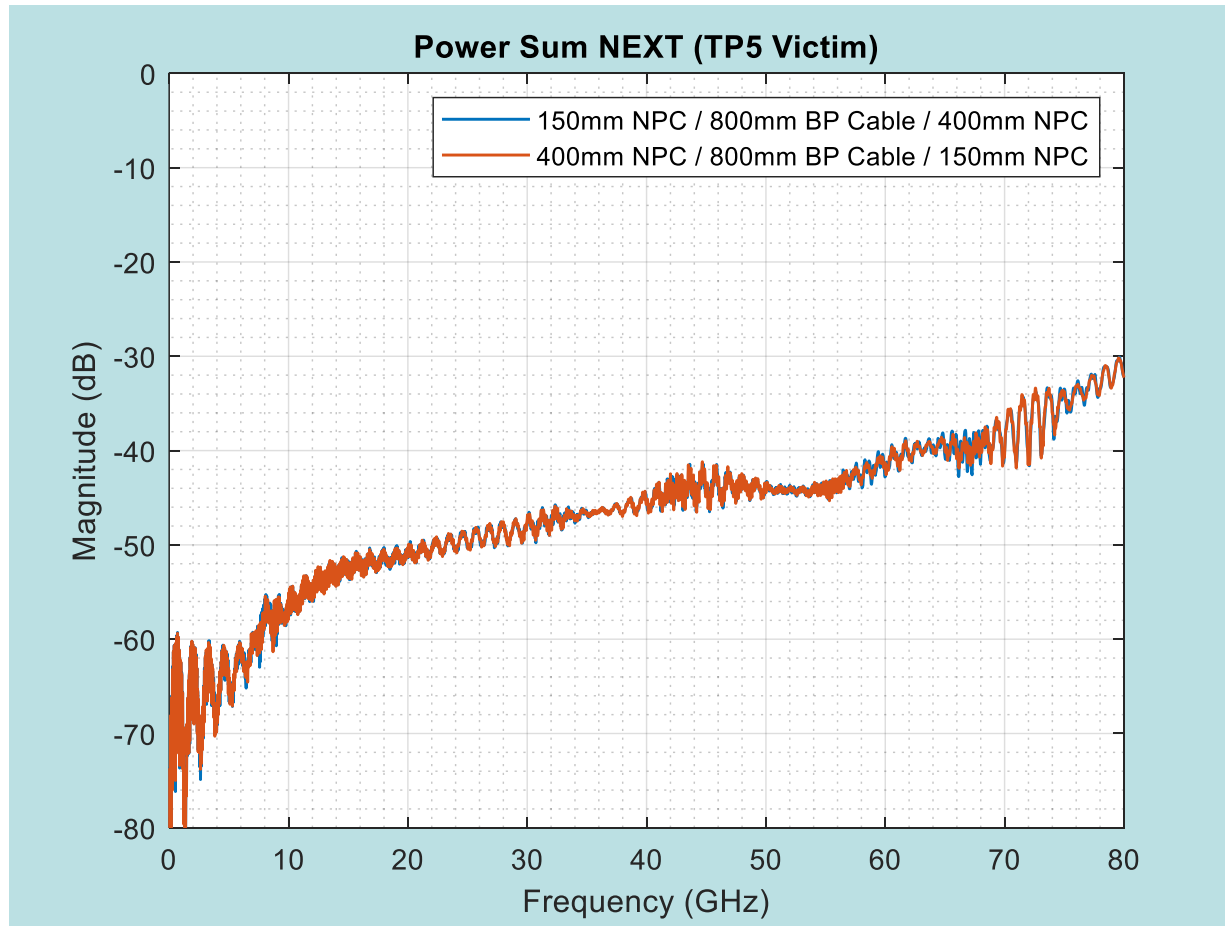
**FEXT4**

**FEXT5**

**FEXT6**

# KR BP Cable Channel Model (Asymmetric)

## Power Sum NEXT

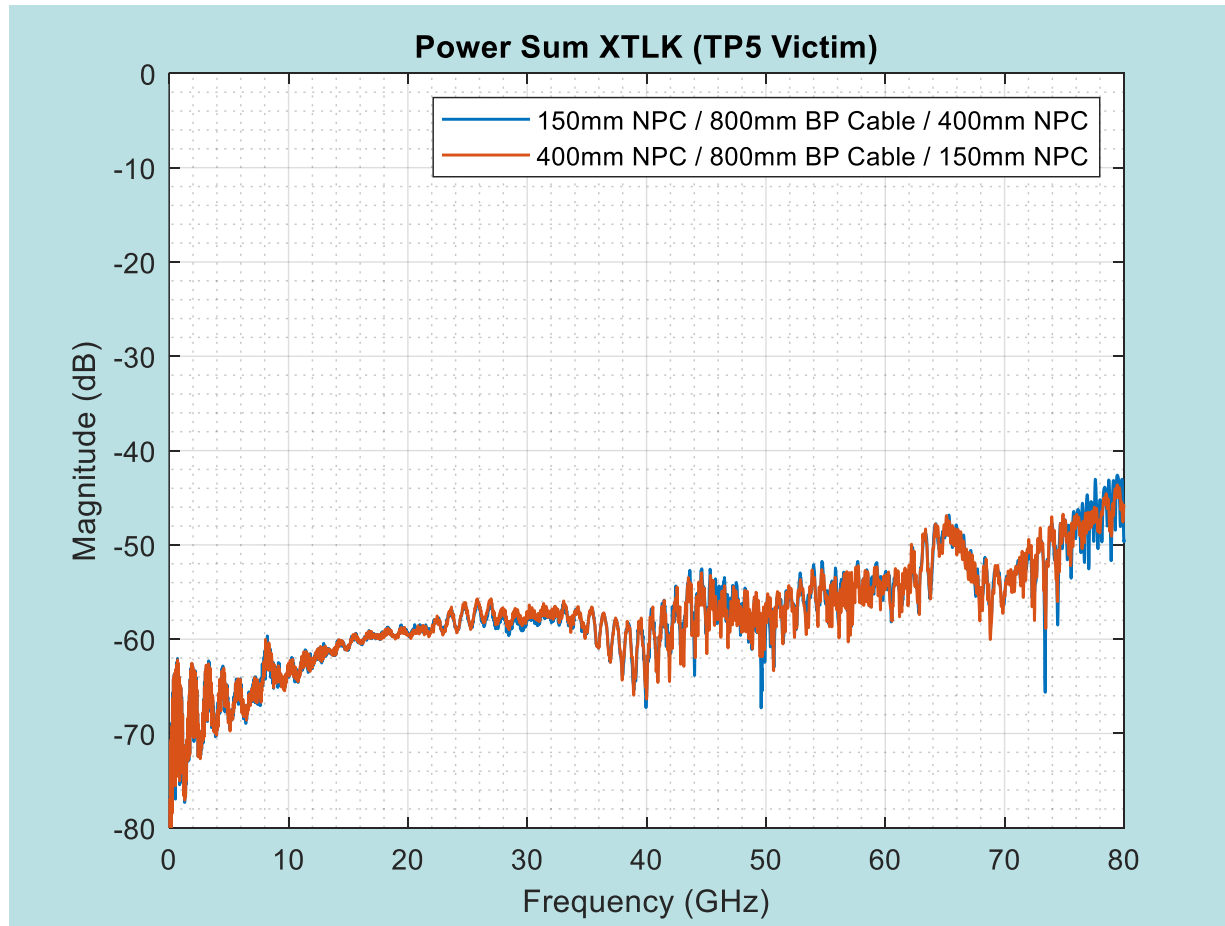


Host 1 Signal		Host 2 Signal	
Rx XTLK1	←	Rx XTLK1	NEXT1
Rx XTLK2	←	Tx XTLK2	NEXT2
Rx XTLK3	←	Tx XTLK3	NEXT3
TP0 Tx Victim	→	TP5 Rx Victim	
Rx XTLK4	←	Tx XTLK4	NEXT4
Rx XTLK5	←	Tx XTLK5	NEXT5
Rx XTLK6	←	Tx XTLK6	NEXT6

**Despite shorter Host 2 cable length (red), NEXT spectra are virtually the same. This implies that most of the NEXT coupling is happening at the BGA via field.**

# KR BP Cable Channel Model (Asymmetric)

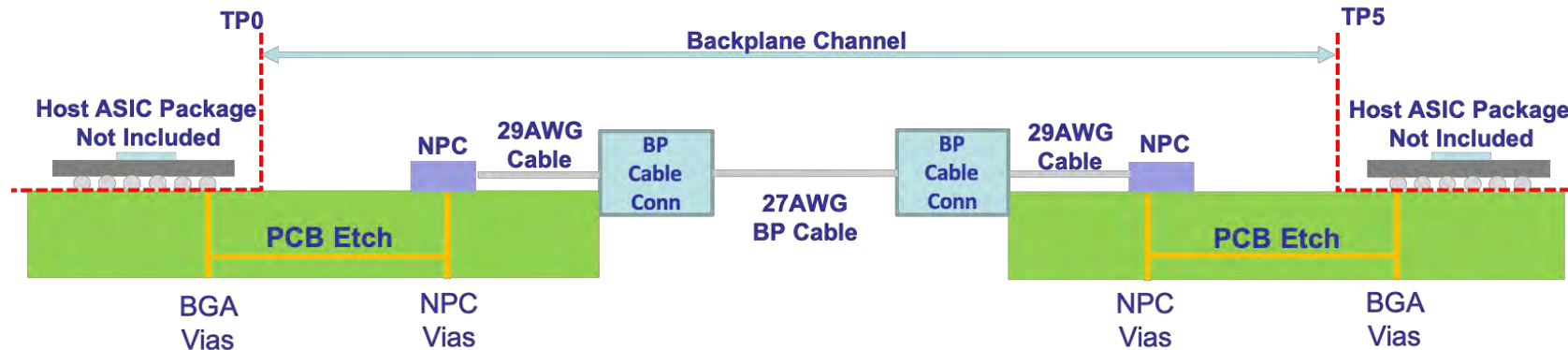
## Power Sum XTLK (Mixed Tx/Rx Example)



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

# Summary

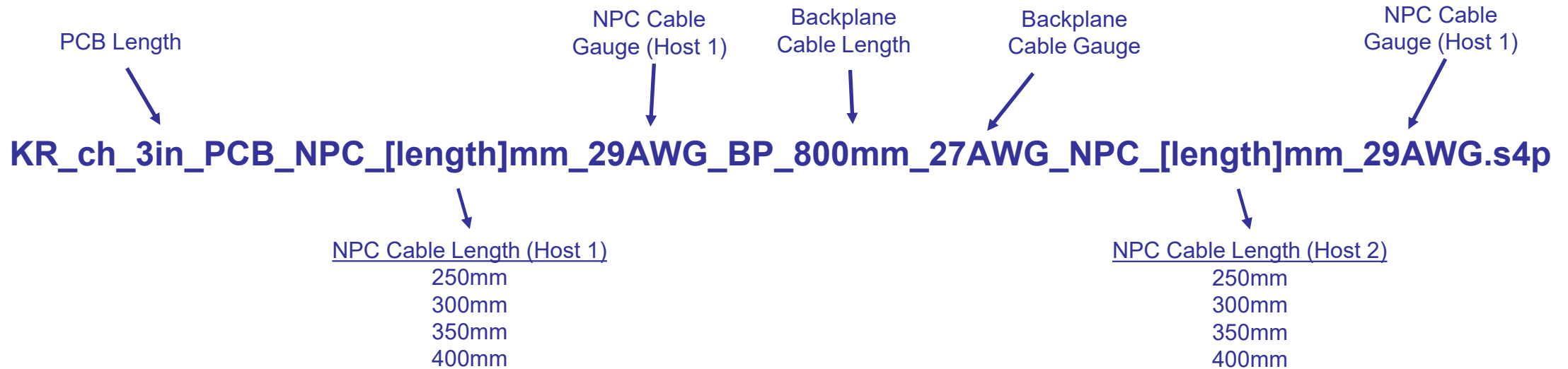
- Contributed channels model a KR link with a cable backplane – daughter cards use near package cabling



- Updates to weaver 3dj\_01\_2303**
  - ✓ Added 150mm NPC cable to extend range of losses
  - ✓ Added asymmetric NPC cable length combinations to extend # of variants from 5 to 36
  - ✓ Refreshed all channel models with updated cable, NPC, and BP Cable connector models
- 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

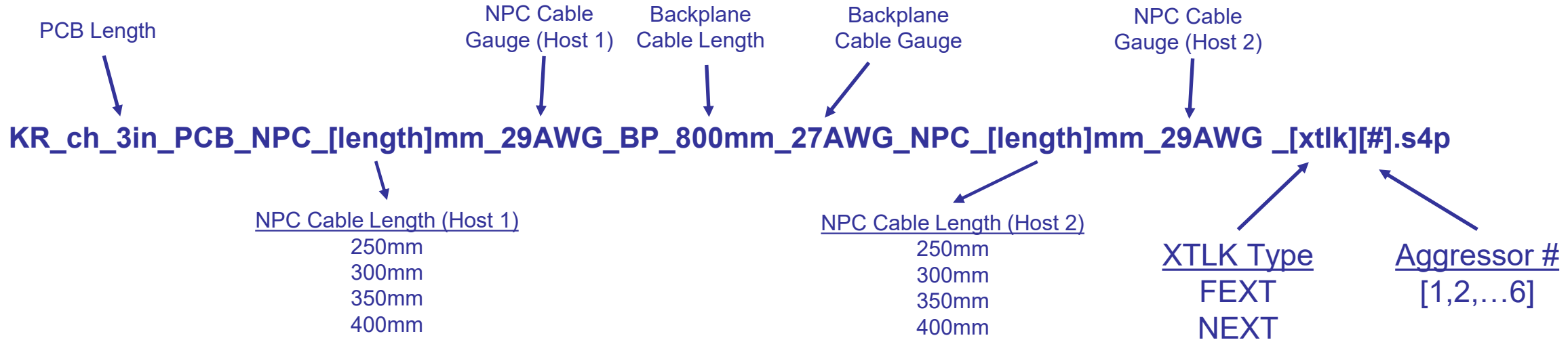






# KR Backplane Cable Channels

## 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, 200, 250, 300, 350, 400] mm**

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

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

# KR Backplane Cable Channels

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## XTLK Channel Files:

**Host 1 NPC Cable: 200mm**

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

KR\_ch\_3in\_PCB\_NPC\_200mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT1.s4p  
KR\_ch\_3in\_PCB\_NPC\_200mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT2.s4p  
KR\_ch\_3in\_PCB\_NPC\_200mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT3.s4p  
KR\_ch\_3in\_PCB\_NPC\_200mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT4.s4p  
KR\_ch\_3in\_PCB\_NPC\_200mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT5.s4p  
KR\_ch\_3in\_PCB\_NPC\_200mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT6.s4p

KR\_ch\_3in\_PCB\_NPC\_200mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_NEXT1.s4p  
KR\_ch\_3in\_PCB\_NPC\_200mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_NEXT2.s4p  
KR\_ch\_3in\_PCB\_NPC\_200mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_NEXT3.s4p  
KR\_ch\_3in\_PCB\_NPC\_200mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_NEXT4.s4p  
KR\_ch\_3in\_PCB\_NPC\_200mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_NEXT5.s4p  
KR\_ch\_3in\_PCB\_NPC\_200mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_NEXT6.s4p

# KR Backplane Cable Channels

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## XTLK Channel Files:

**Host 1 NPC Cable: 250mm**

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

KR\_ch\_3in\_PCB\_NPC\_250mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT1.s4p  
KR\_ch\_3in\_PCB\_NPC\_250mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT2.s4p  
KR\_ch\_3in\_PCB\_NPC\_250mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT3.s4p  
KR\_ch\_3in\_PCB\_NPC\_250mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT4.s4p  
KR\_ch\_3in\_PCB\_NPC\_250mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT5.s4p  
KR\_ch\_3in\_PCB\_NPC\_250mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT6.s4p

KR\_ch\_3in\_PCB\_NPC\_250mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_NEXT1.s4p  
KR\_ch\_3in\_PCB\_NPC\_250mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_NEXT2.s4p  
KR\_ch\_3in\_PCB\_NPC\_250mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_NEXT3.s4p  
KR\_ch\_3in\_PCB\_NPC\_250mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_NEXT4.s4p  
KR\_ch\_3in\_PCB\_NPC\_250mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_NEXT5.s4p  
KR\_ch\_3in\_PCB\_NPC\_250mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_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\_NPC\_300mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT1.s4p  
KR\_ch\_3in\_PCB\_NPC\_300mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT2.s4p  
KR\_ch\_3in\_PCB\_NPC\_300mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT3.s4p  
KR\_ch\_3in\_PCB\_NPC\_300mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT4.s4p  
KR\_ch\_3in\_PCB\_NPC\_300mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT5.s4p  
KR\_ch\_3in\_PCB\_NPC\_300mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT6.s4p

KR\_ch\_3in\_PCB\_NPC\_300mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_NEXT1.s4p  
KR\_ch\_3in\_PCB\_NPC\_300mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_NEXT2.s4p  
KR\_ch\_3in\_PCB\_NPC\_300mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_NEXT3.s4p  
KR\_ch\_3in\_PCB\_NPC\_300mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_NEXT4.s4p  
KR\_ch\_3in\_PCB\_NPC\_300mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_NEXT5.s4p  
KR\_ch\_3in\_PCB\_NPC\_300mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_NEXT6.s4p

# KR Backplane Cable Channels

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## XTLK Channel Files:

**Host 1 NPC Cable: 350mm**

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

KR\_ch\_3in\_PCB\_NPC\_350mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT1.s4p

KR\_ch\_3in\_PCB\_NPC\_350mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT2.s4p

KR\_ch\_3in\_PCB\_NPC\_350mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT3.s4p

KR\_ch\_3in\_PCB\_NPC\_350mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT4.s4p

KR\_ch\_3in\_PCB\_NPC\_350mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT5.s4p

KR\_ch\_3in\_PCB\_NPC\_350mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT6.s4p

KR\_ch\_3in\_PCB\_NPC\_350mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_NEXT1.s4p

KR\_ch\_3in\_PCB\_NPC\_350mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_NEXT2.s4p

KR\_ch\_3in\_PCB\_NPC\_350mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_NEXT3.s4p

KR\_ch\_3in\_PCB\_NPC\_350mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_NEXT4.s4p

KR\_ch\_3in\_PCB\_NPC\_350mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_NEXT5.s4p

KR\_ch\_3in\_PCB\_NPC\_350mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_NEXT6.s4p

# KR Backplane Cable Channels

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## XTLK Channel Files:

**Host 1 NPC Cable: 400mm**

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

KR\_ch\_3in\_PCB\_NPC\_400mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT1.s4p

KR\_ch\_3in\_PCB\_NPC\_400mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT2.s4p

KR\_ch\_3in\_PCB\_NPC\_400mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT3.s4p

KR\_ch\_3in\_PCB\_NPC\_400mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT4.s4p

KR\_ch\_3in\_PCB\_NPC\_400mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT5.s4p

KR\_ch\_3in\_PCB\_NPC\_400mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_FEXT6.s4p

KR\_ch\_3in\_PCB\_NPC\_400mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_NEXT1.s4p

KR\_ch\_3in\_PCB\_NPC\_400mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_NEXT2.s4p

KR\_ch\_3in\_PCB\_NPC\_400mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_NEXT3.s4p

KR\_ch\_3in\_PCB\_NPC\_400mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_NEXT4.s4p

KR\_ch\_3in\_PCB\_NPC\_400mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_NEXT5.s4p

KR\_ch\_3in\_PCB\_NPC\_400mm\_29AWG\_BP\_800mm\_27AWG\_NPC\_###mm\_29AWG\_NEXT6.s4p