

DDR Simulation with IBIS-AMI

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Introduction

- IBIS-AMI simulation flows adopted for single-ended (SE) signaling (DDR5, LPDDR5, etc.) in the last 1+ years
- EDA tools are implementing unique AMI solutions to SE signaling challenges
 - Common mode voltage
 - Tx non-linearities (rise/fall impedance and slew rate differences)
 - Forwarded Clock (DQ Strobe)
- What do these solutions look like?
- How do tools differ?
 - Subset of tools compared in simulation of LPDDR5 channel
- What's next to improve simulation flows and accuracy?

EDA Tool Comparison – Summary Table

Tool / Features	A	B	C	D	E	F
Multi-Edge Time-domain	No	Yes	Yes	Yes	No	No
DC Offset	0V	Yes	Yes	0V	Yes	0V
External Clock	No	Yes	No	No	No	No

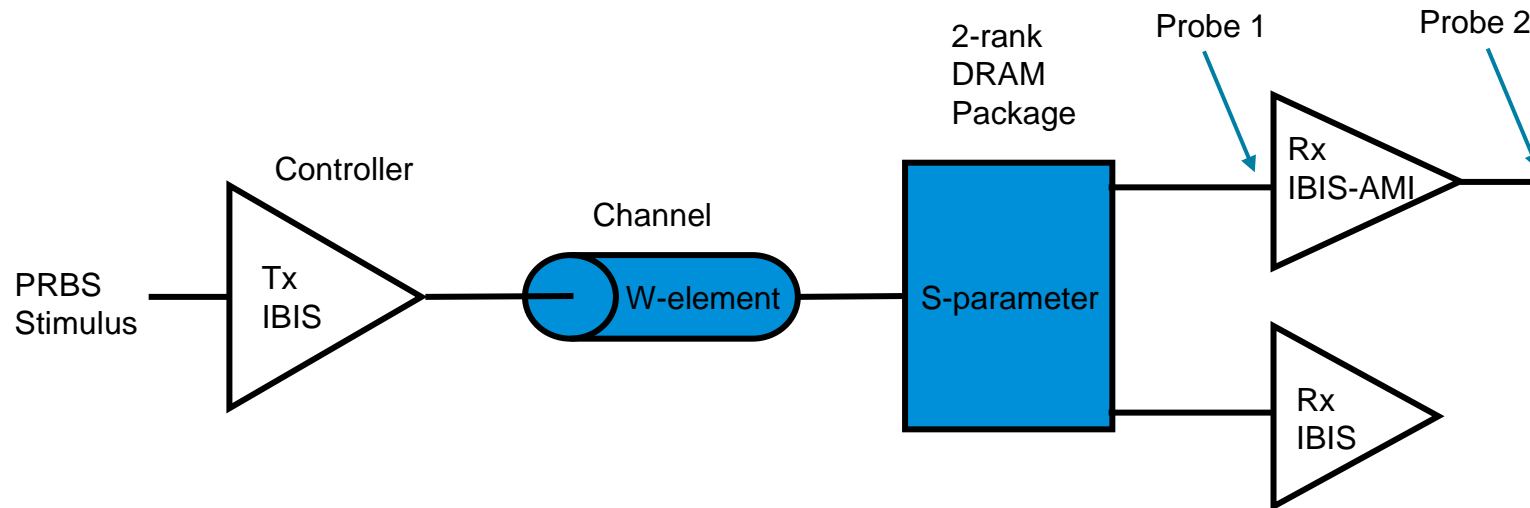
- Multi-Edge Time-domain can help improve accuracy by including more non-linear Tx effects
 - May include both rising/falling edge or multi-edge channel characterization
- DC Offset refers to the waveform input to AMI_GetWave being offset by the DC common mode voltage
 - If the DC Offset is included, the model user must set the Rx Vref AMI parameter to the DC common mode value.
- External Clock capability is currently untested. Several tools starting to add capability in new releases.

Simulation Setup

LPDDR5 DQ READ, **Note:** only tools A, B, and C compared in following slides

- 6.4Gbps
- Tx with 60 Ohm pulldown
- 80 Ohm ODT at each DRAM

- Rx DFE tap 1 set to -20mV



Tool A

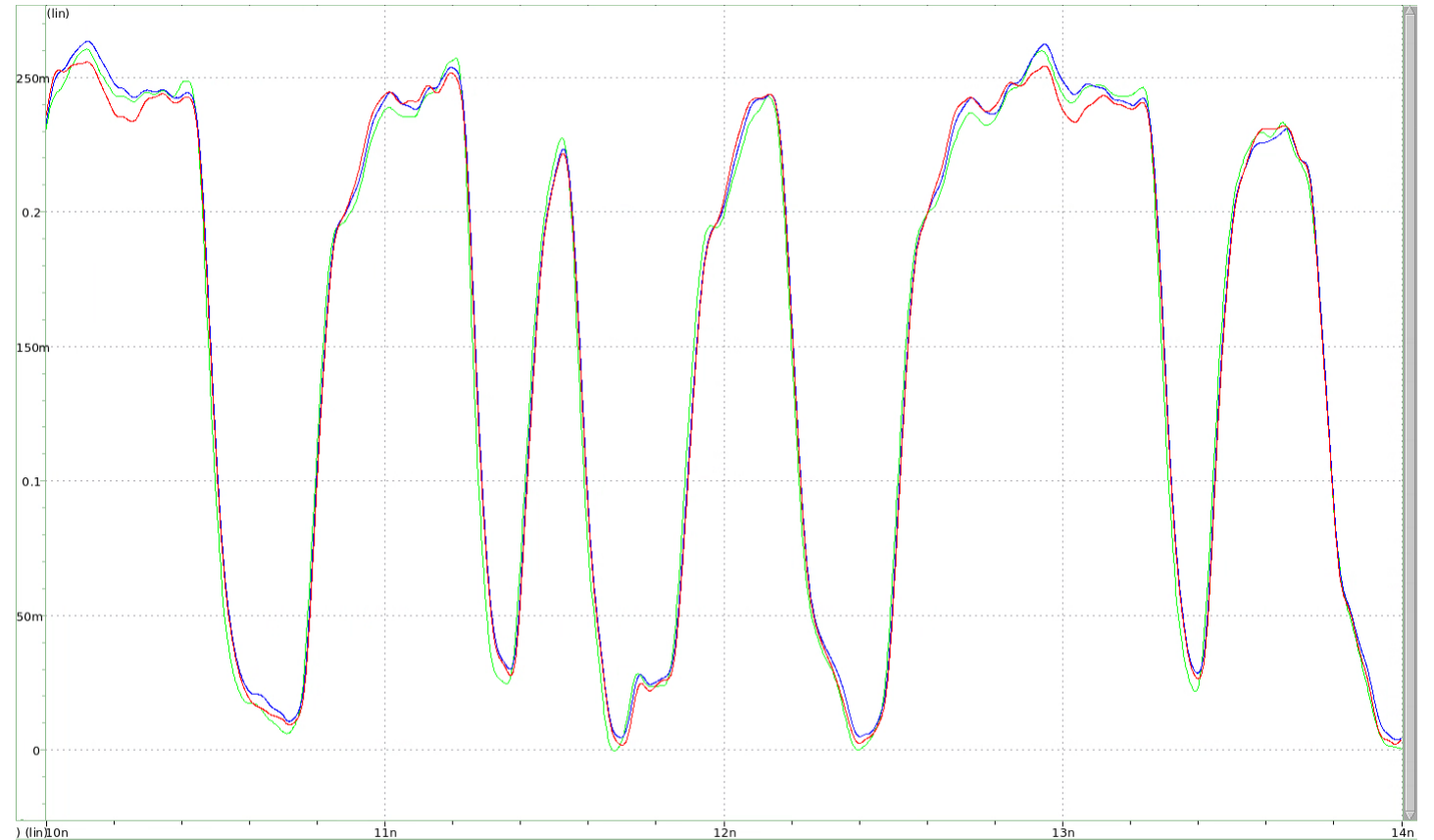
Transient vs. AMI with Rising Step Channel Characterization



Probe 1: Green=transient, Red=AMI rising char.

Tool B

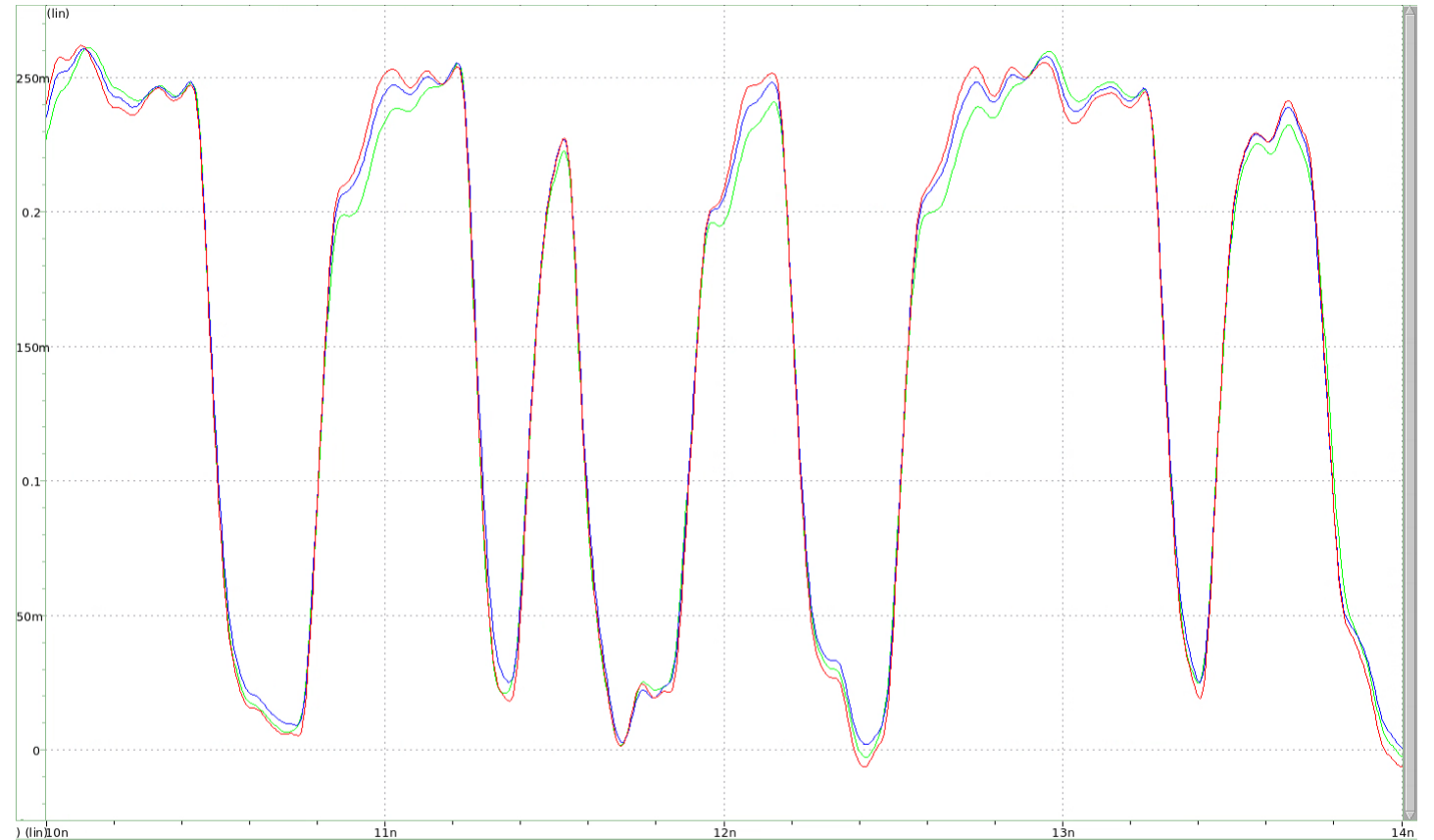
Transient vs. AMI with Rising and Rising/Falling Step Channel Characterization



Probe 1: Green=transient, Red=AMI rising char., Blue=AMI rising/falling char.

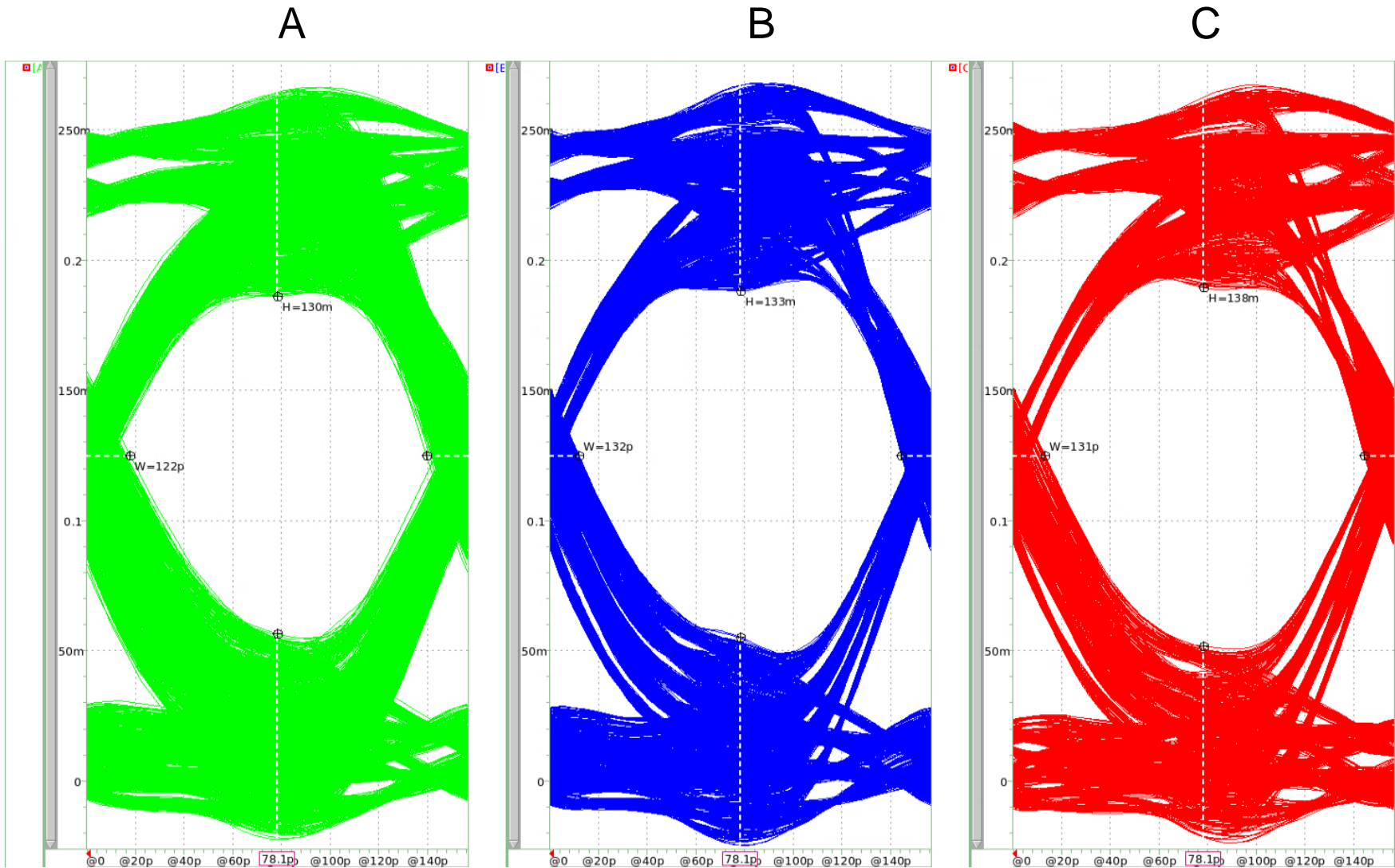
Tool C

Transient vs. AMI with Rising and Rising/Falling Step Channel Characterization



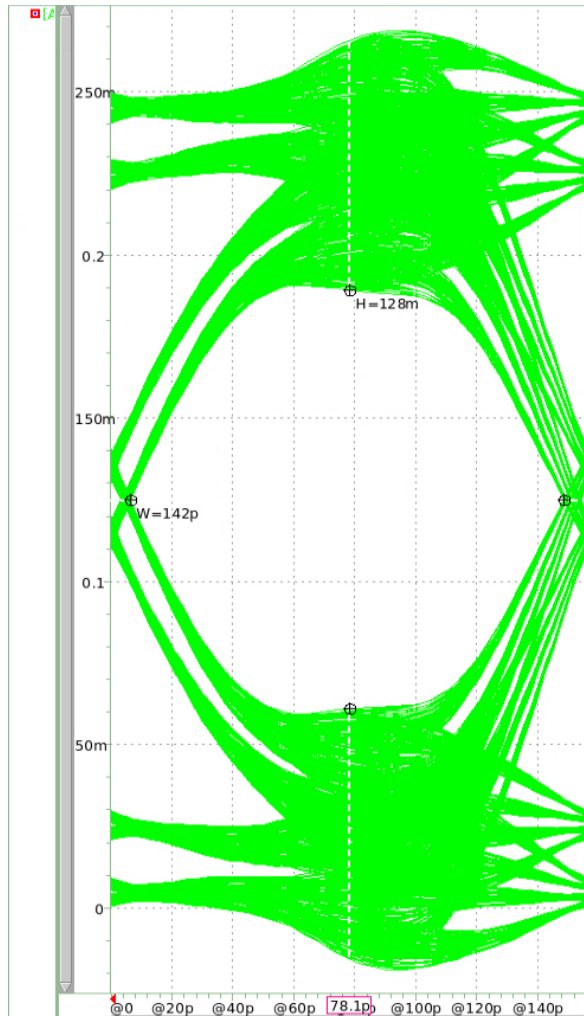
Probe 1: Green=transient, Red=AMI rising char., Blue=AMI rising/falling char.

Transient Sim. at Probe 1: Tool A/B/C Comparison

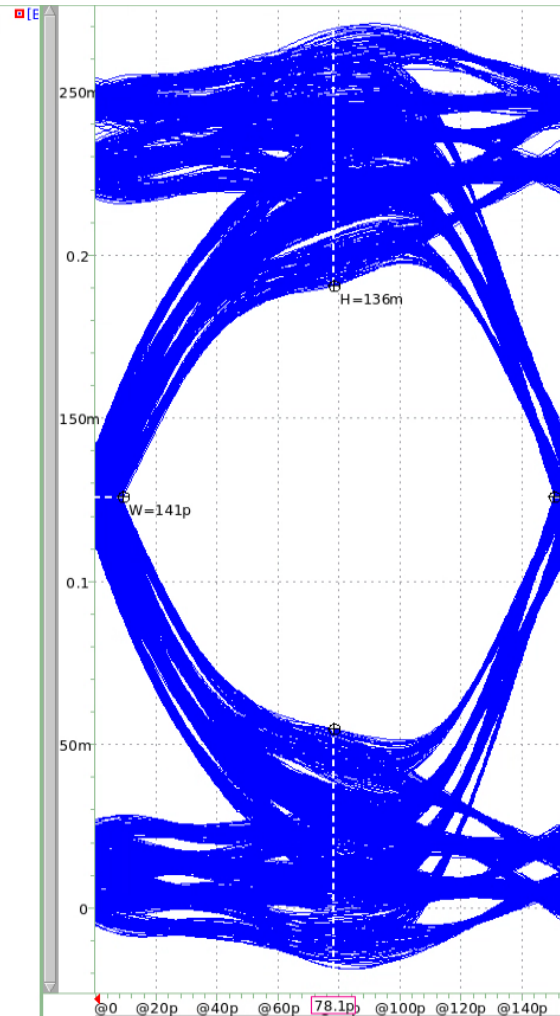


AMI Sim. at Probe 1: Tool A/B/C Comparison

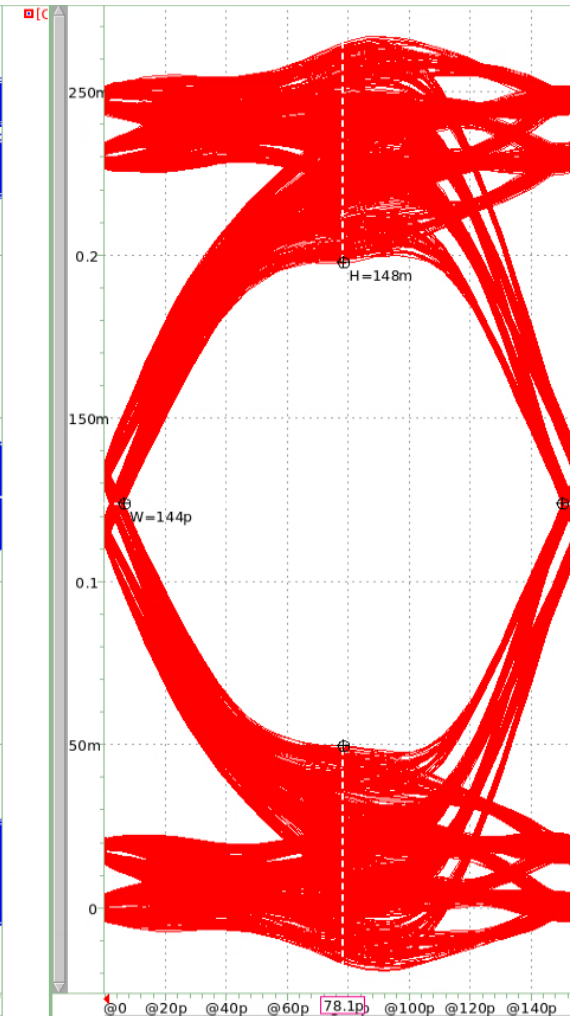
A



B

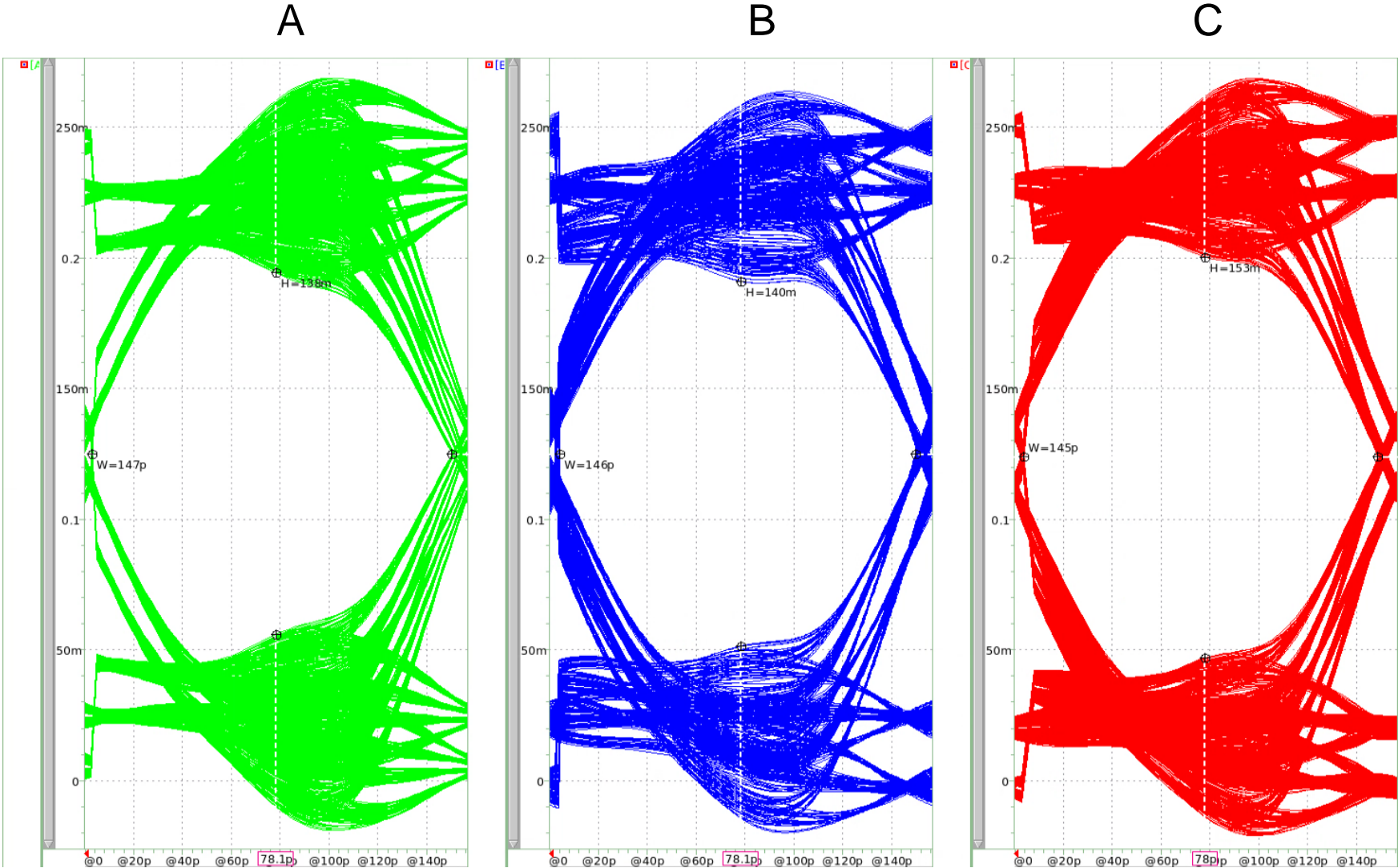


C



Note: Tool B and C results use rise/fall edge channel characterization

AMI Sim. at Probe 2 (-20mV DFE): Tool A/B/C



Results Summary

Eye Diagram Measurements

Tool	Metric	Transient	AMI	AMI -20mV DFE
A	Eye Height (mV)	130	128	138
	Eye Width (ps)	122	142	147
B	Eye Height (mV)	133	136	140
	Eye Width (ps)	132	141	146
C	Eye Height (mV)	138	148	153
	Eye Width (ps)	131	144	145

Summary

- Multi-edge channel characterization is improving AMI simulation accuracy for non-linear Tx
 - Still room for improvement
 - Tx models with Equalization have not been tested for accuracy
- EDA tools are inconsistent with handling of DC common mode voltage in the input waveform to the Rx AMI_GetWave
 - Requires a Rx Vref parameter be set by the user specific to the EDA tool
 - BIRD197.7 should clarify this, but some tools will need to change their existing flows
- External Clock for Rx AMI models needs further attention
 - BIRD will be needed to define this

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