Preferable Improvements and Changes to FB-DiMM High-Speed Channel for 9.6Gbps Operation

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Content

- **FB-DiMM system and signal speed**
- **4-Key structure in high speed channel and improving method**
- **Electrical modeling**
- **Verification by Simulation and Measurement**
  - **S-parameter**
  - **Transient eye waveform**
- **System loss budget calculation**
- **Summary and Conclusion (Recommendation)**

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FB-DiMM system and Signal Speed

	→: Single-End signal	→: Differential signal (x6 speed)
FBD (DDR2)	400 – 800Mbps	2.4 – 4.8Gbps
FBD2 (DDR3)	800 – 1600Mbps	**4.8 – 9.6Gbps**

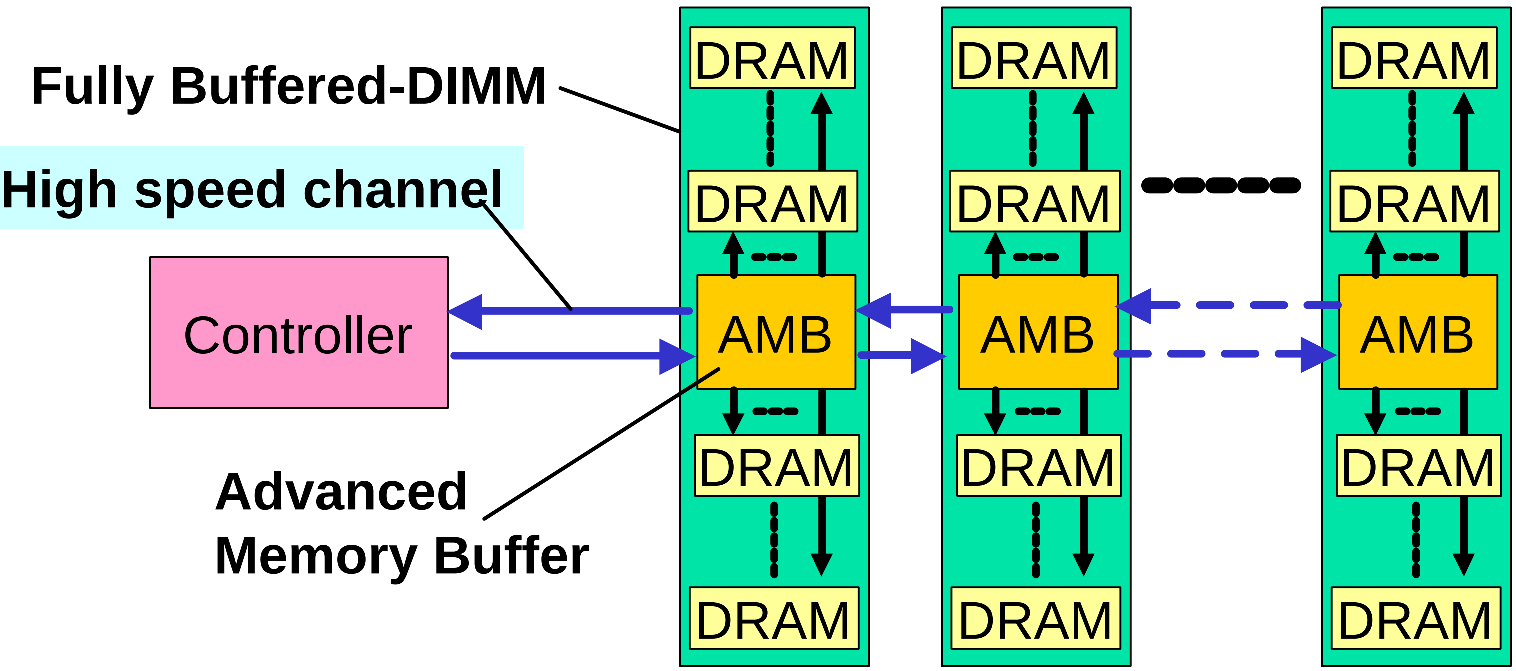
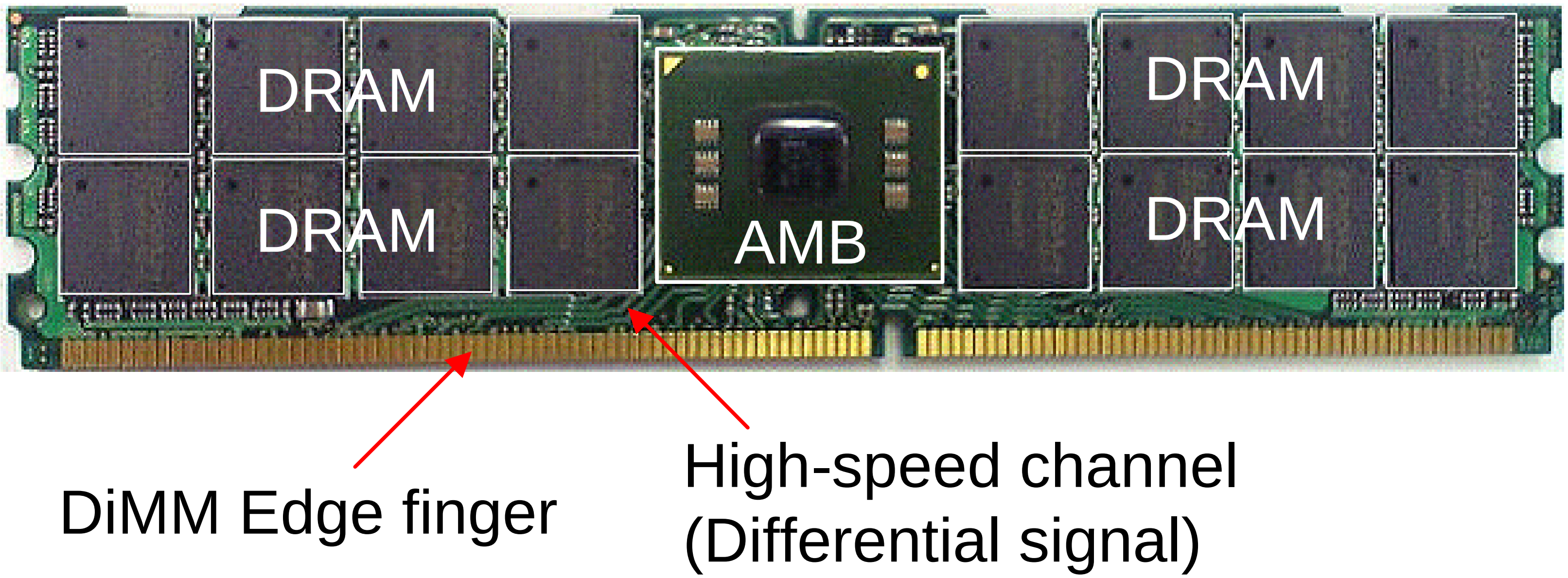


Photo of FB-DiMM (example)



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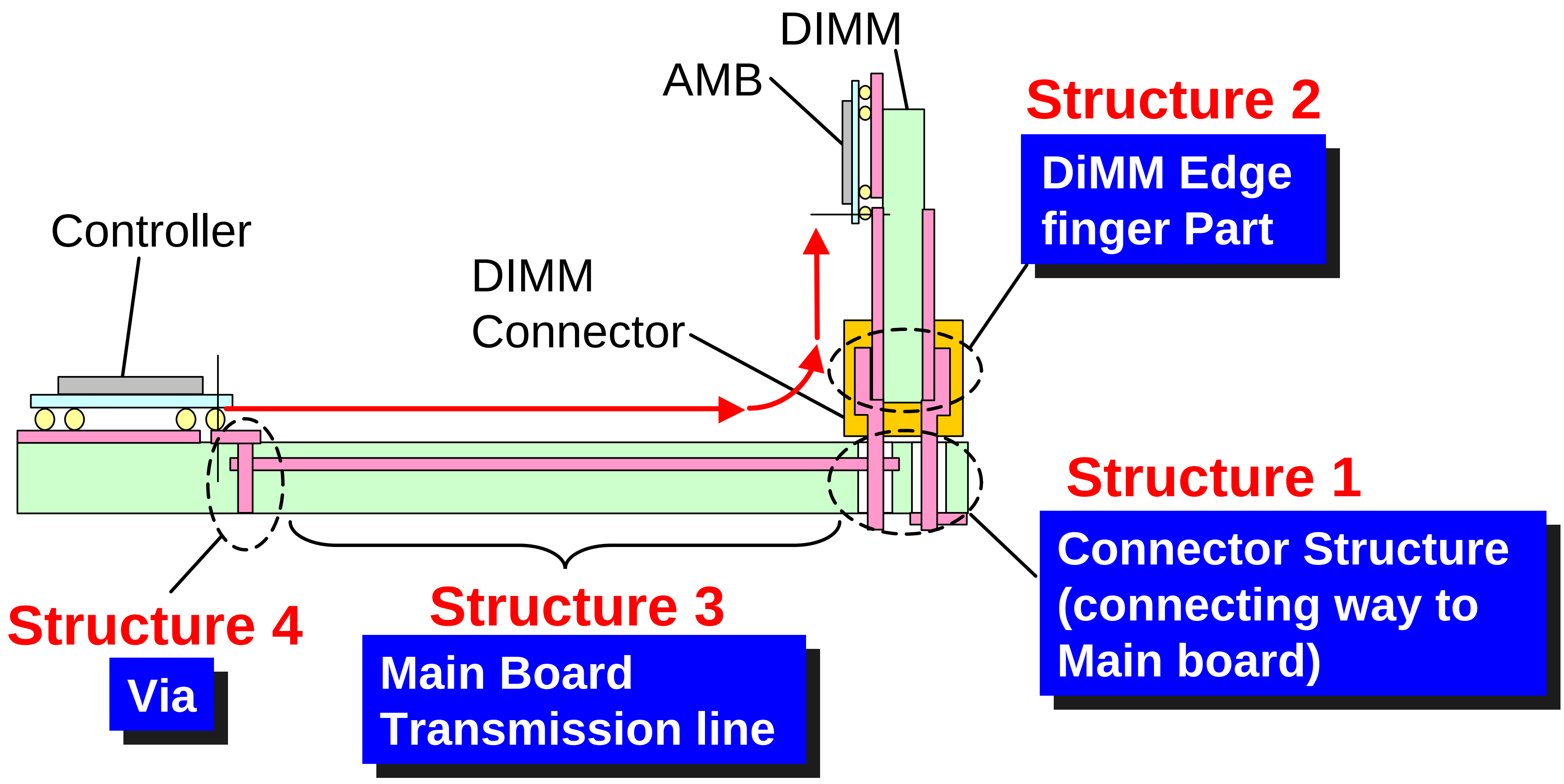
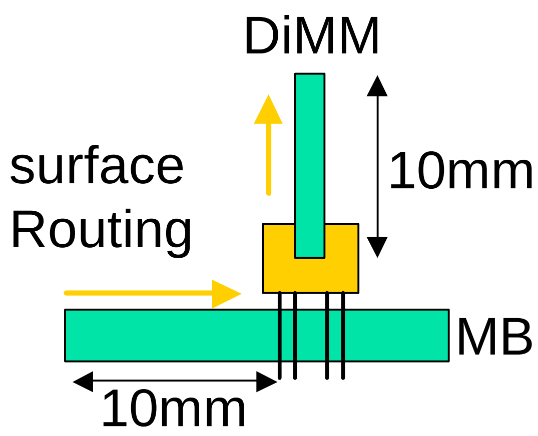
4-Key-structure in high speed channel

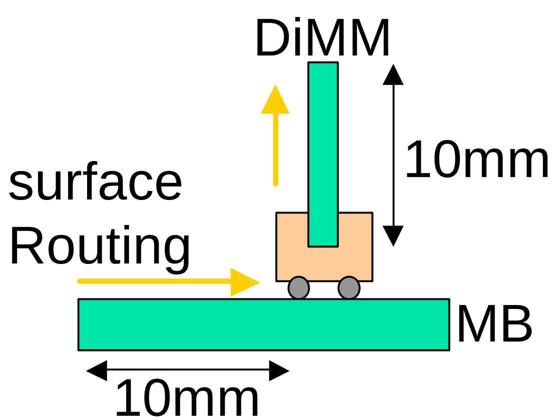


Connector type and measured S-parameter

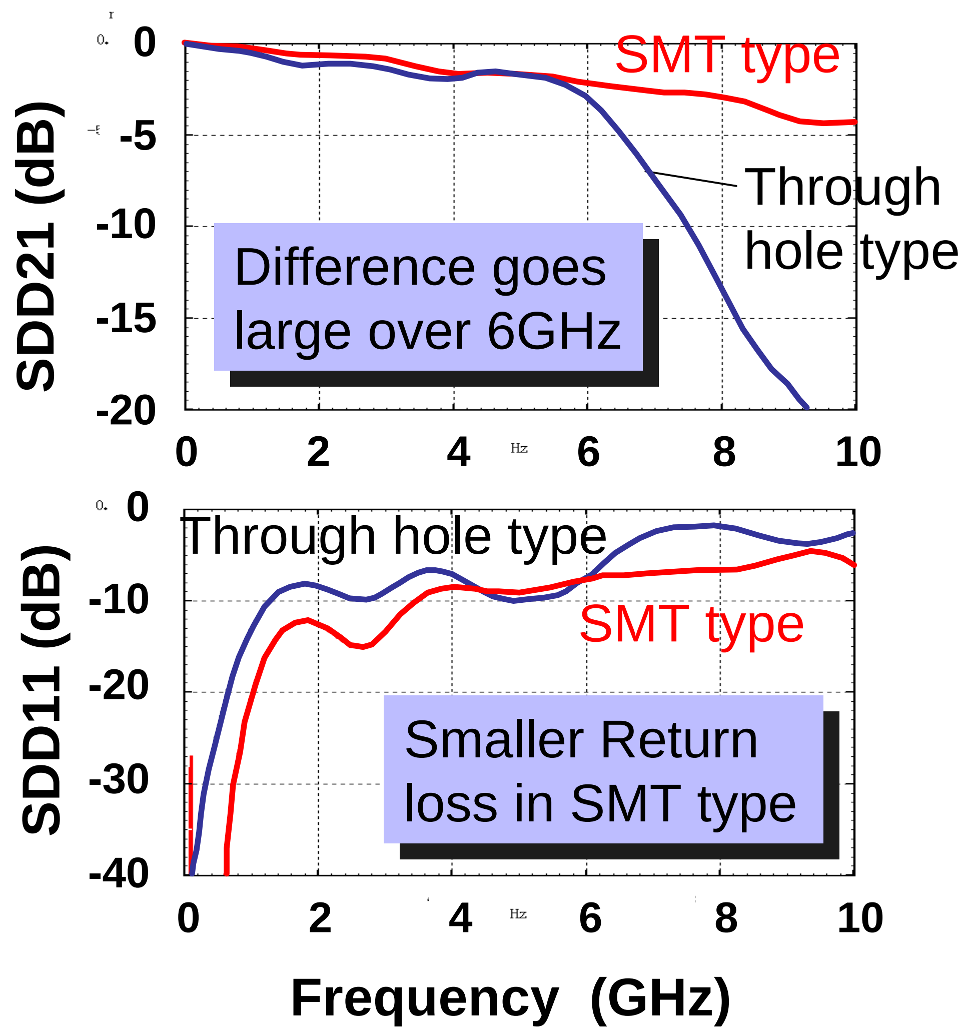
Structure 1



Through hole type



SMT (surface mount) type



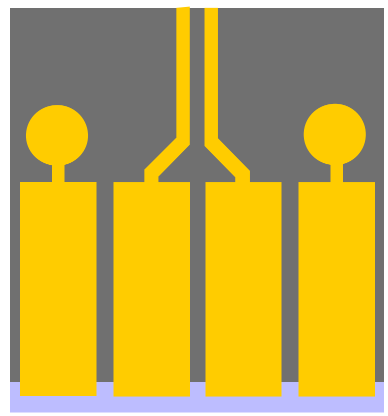
Layout of DiMM edge finger part and measured S-parameter

Structure 2

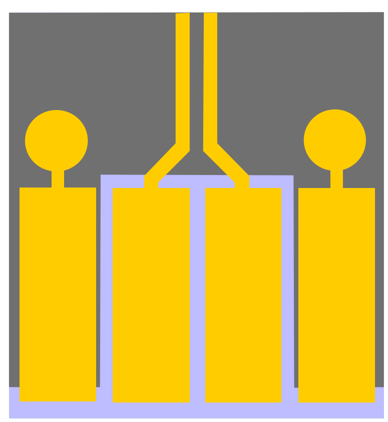
Connector: SMT type

: Metal Layer1 (signal)

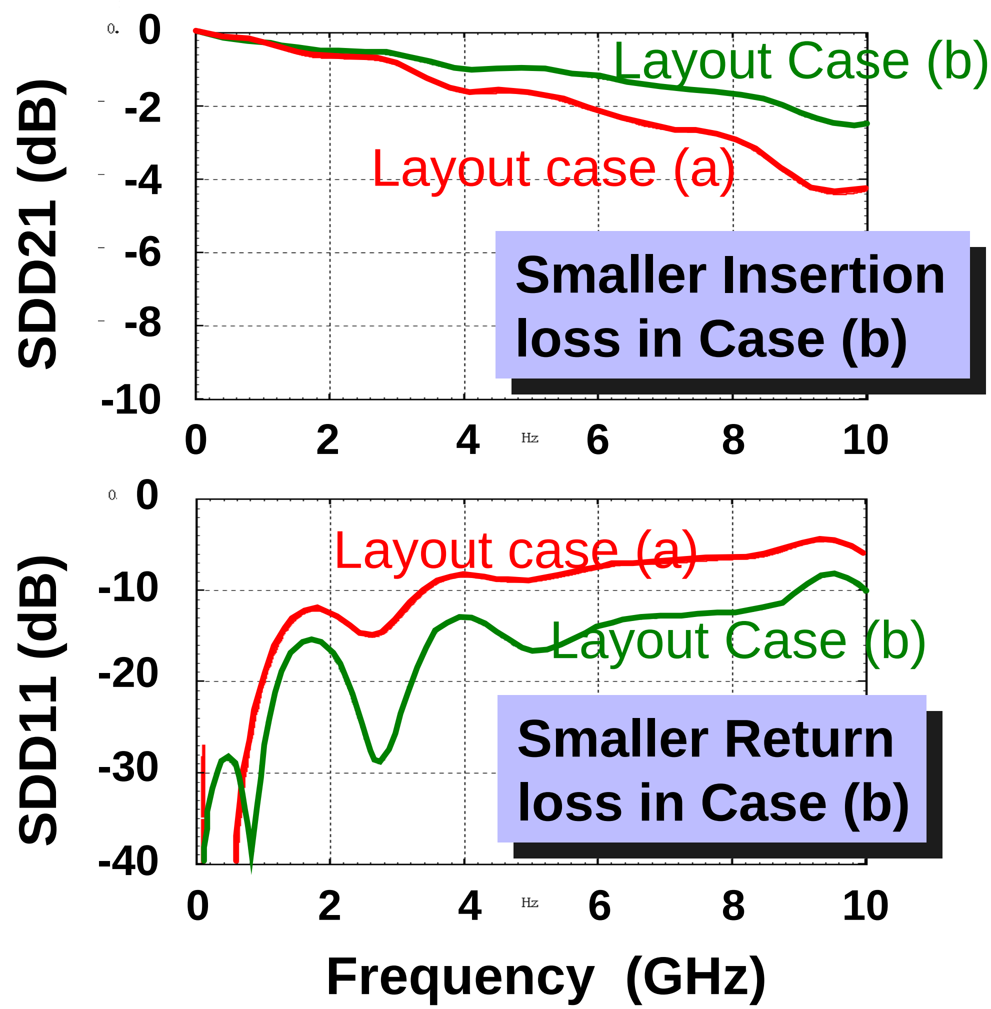
: Metal Layer2 (VSS)



Layout case (a)

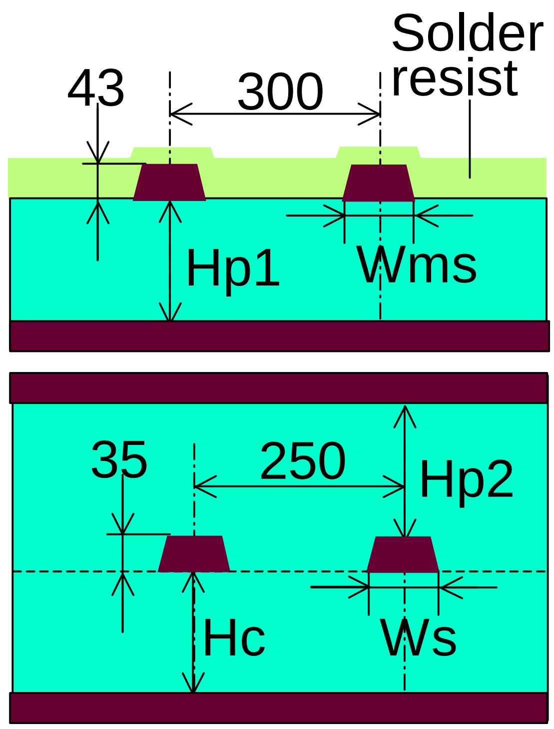


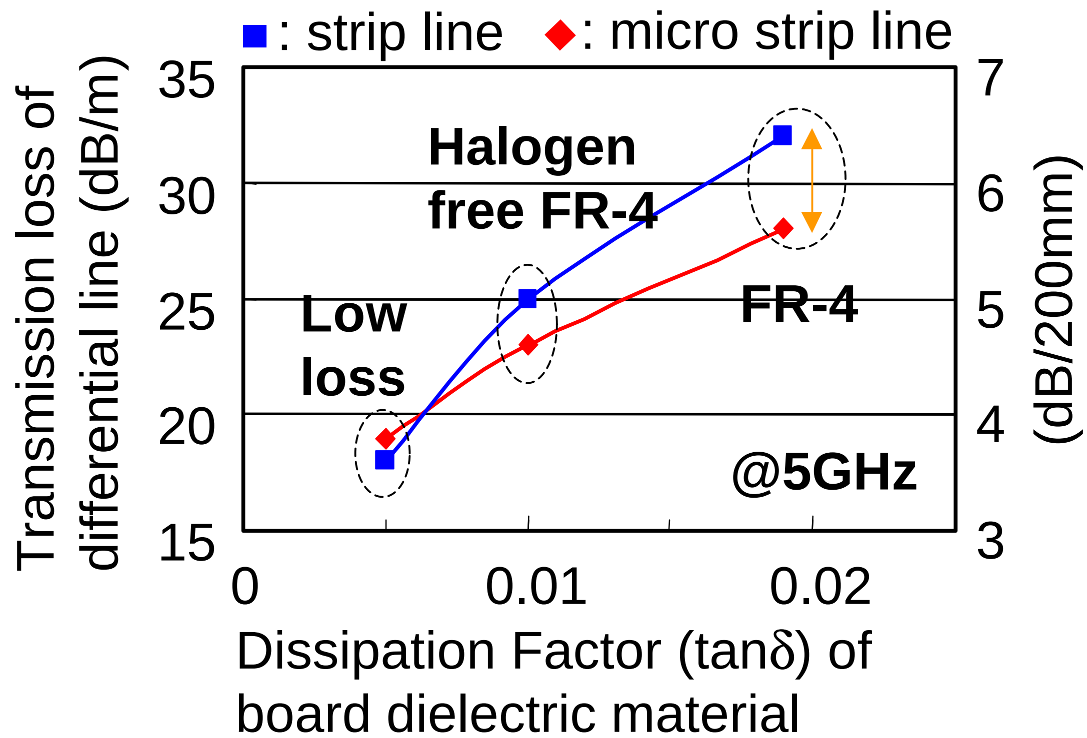
Layout case (b)



Dielectric material and Measured transmission loss

Structure 3





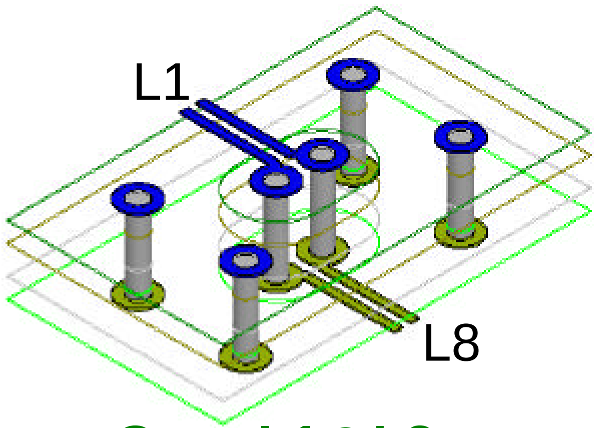
Unit:um

	Wms	Hp1	Ws	Hc	Hp2
FR-4	135	125	115	145	165
Halogen free FR-4	145	110	110	150	160
Low loss	170	125	105	125	110

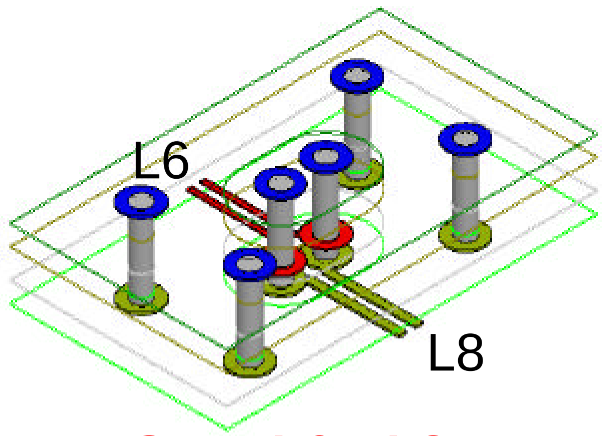
Lower Transmission loss is Preferable. But we cannot free from the material cost.

Via connection and modeled S-parameter

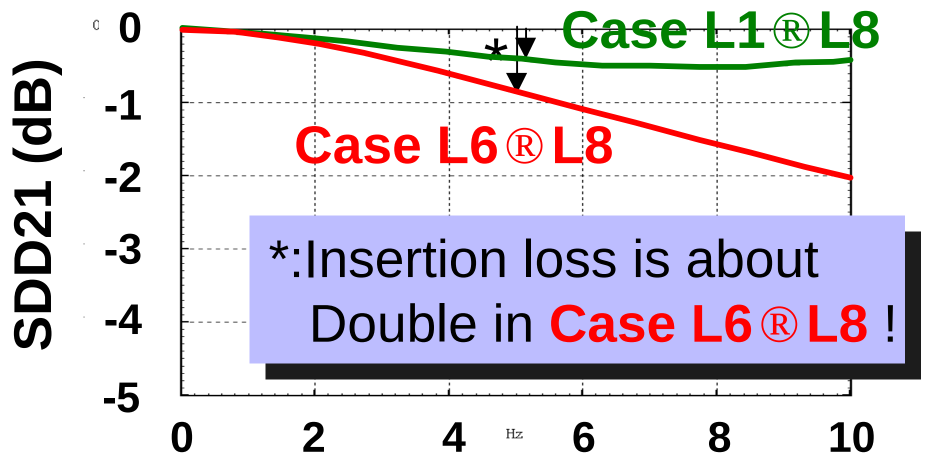
Structure 4

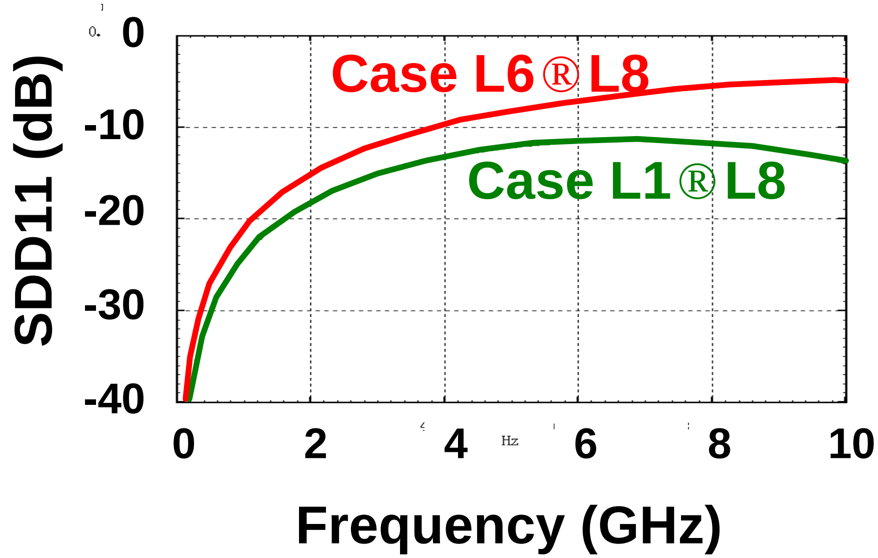


Case L1®L8



Case L6®L8





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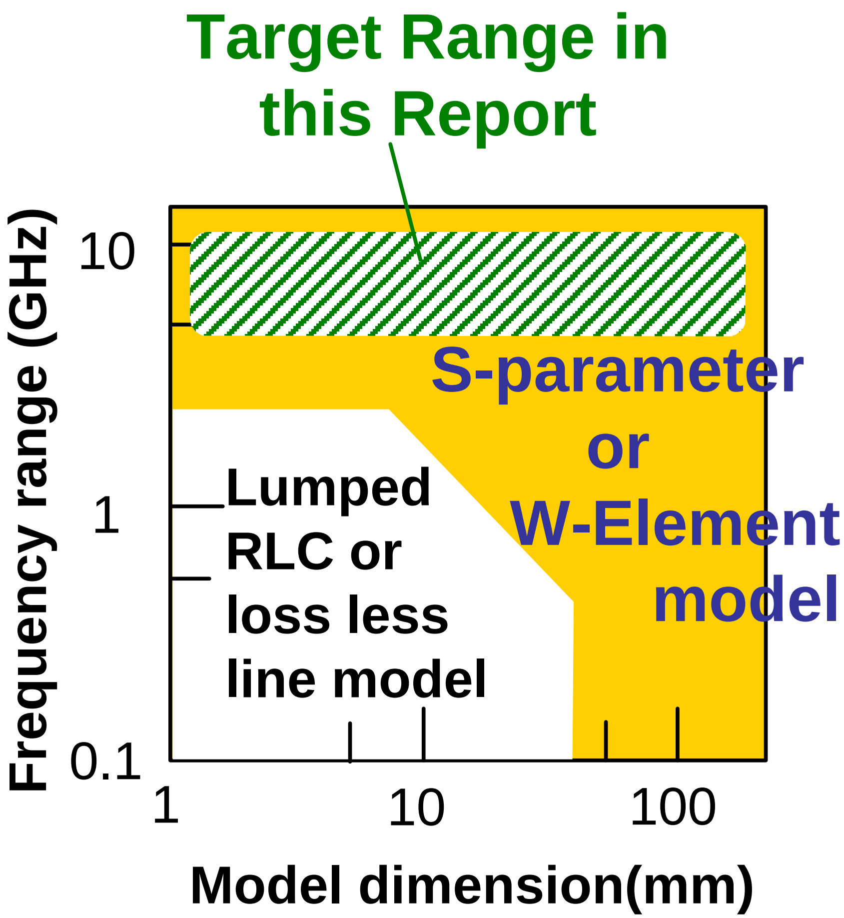
Electrical model type and Range coverage

- **Lumped RLC model**
  <u>It is not appropriate to use over 2-3GHz range.</u>

- **W-Element model**
  Preferable to use for transmission line. <u>Because of scalability of the model.</u> And transient calculation is fast.

- **S-parameter model**
  We can use for all parts, <u>but it rather difficult to handle.</u>



Comment to each modeling

- **W-Element model (for Lossy line)**
  - **Modeling by 2D-EM Field solver**

    Some transient simulator has implemented 2D Field solver. And is easy to operate. But, be careful for the accuracy.
  - **Modeling by 3D-EM Field solver**

    It is rather difficult to handle. Because model is in fact the S-parameter in some cases.

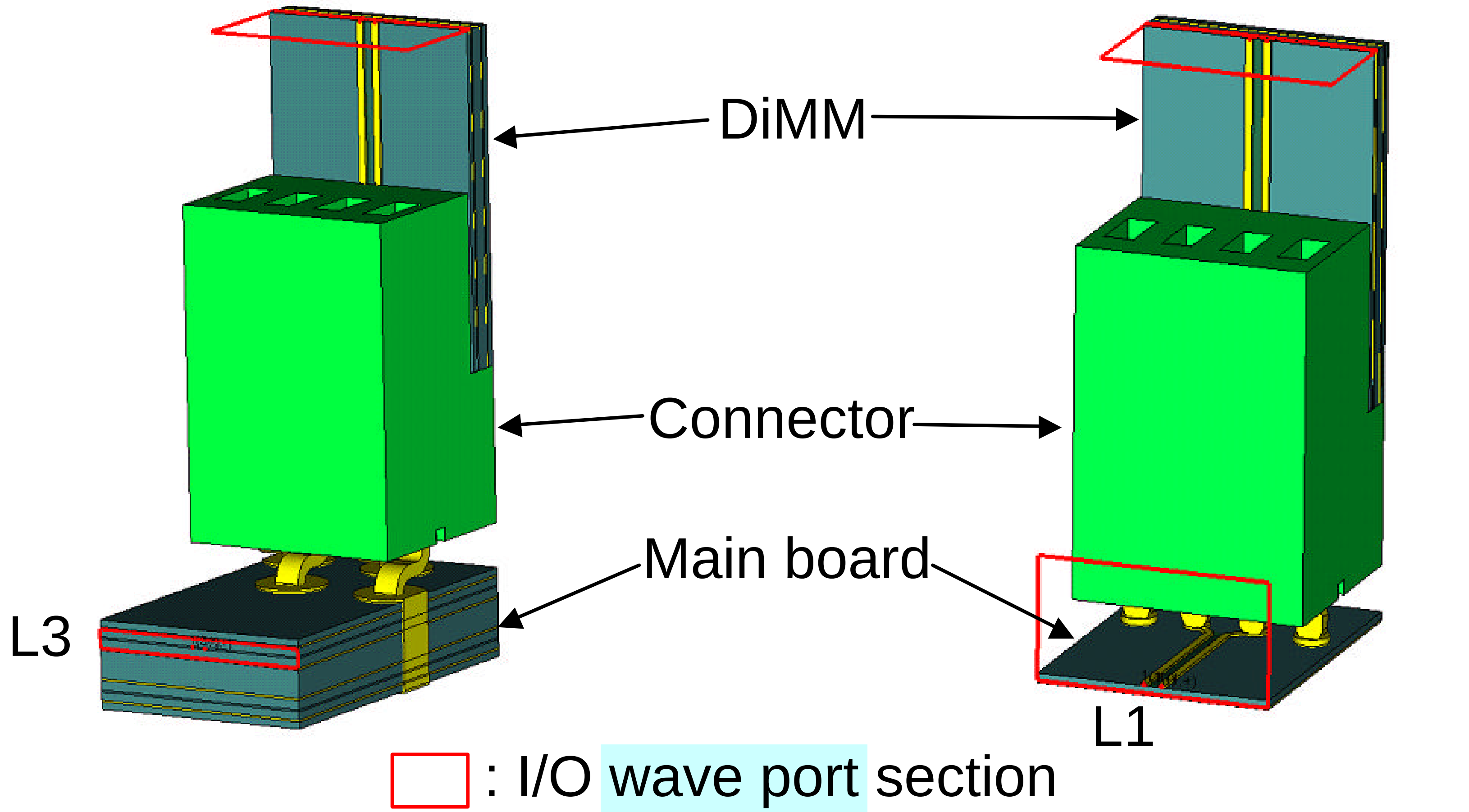
- **S-parameter model (Frequency table type)**
  - **Modeled by 3D-EM Field solver**

    Restriction exist in port number and dimension of the model because of available memory size and CPU time in executing.
  - **Measured data (by network analyzer)**

    It is very rare case, to get measured S-parameter. Because it need special structure test sample include calibration purpose test fixture.

Modeling example of connector (3D-EM)

Thru hole type **SMT(BGA) type**



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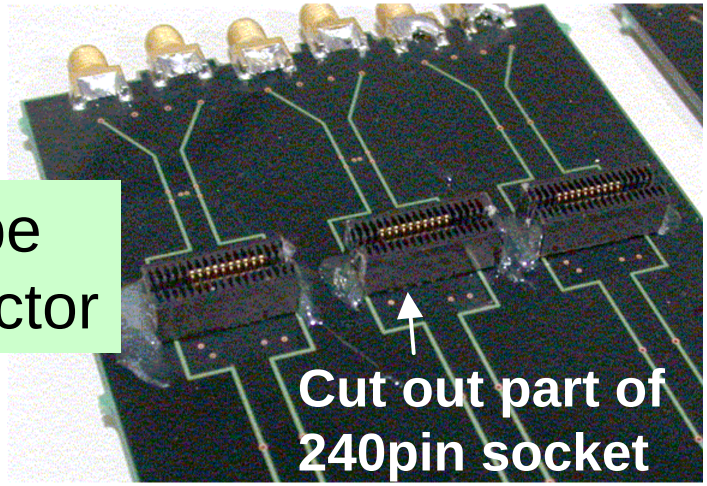
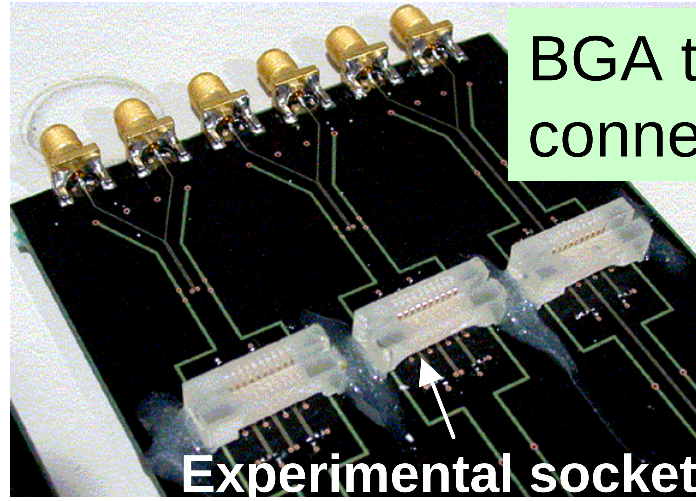
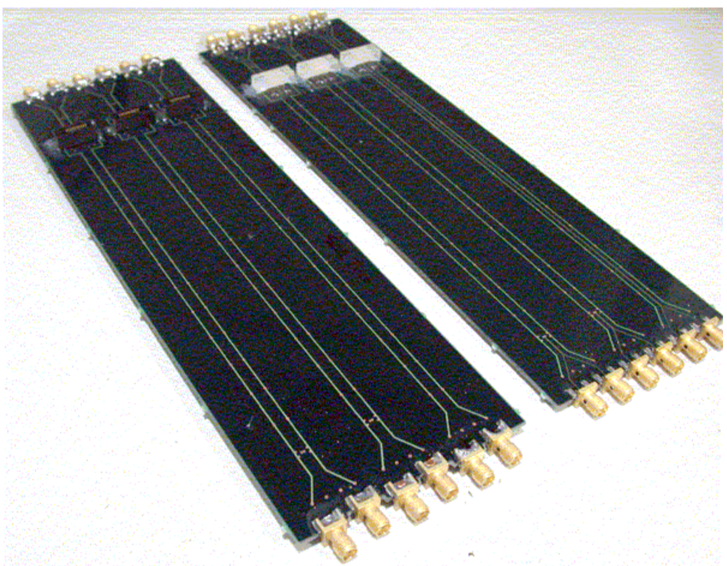
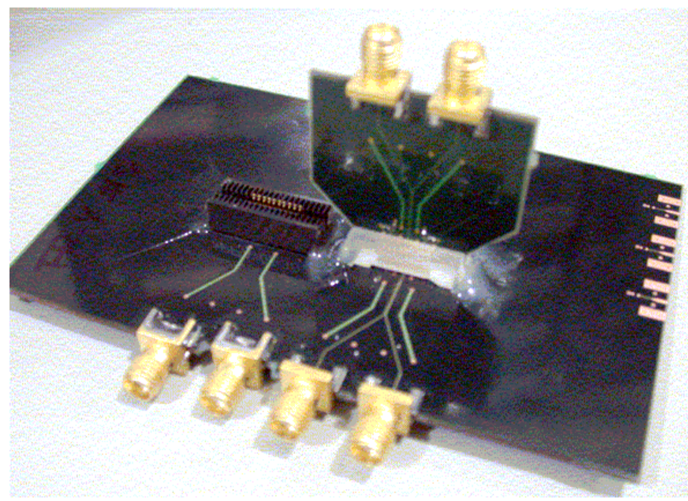
TEG Overview

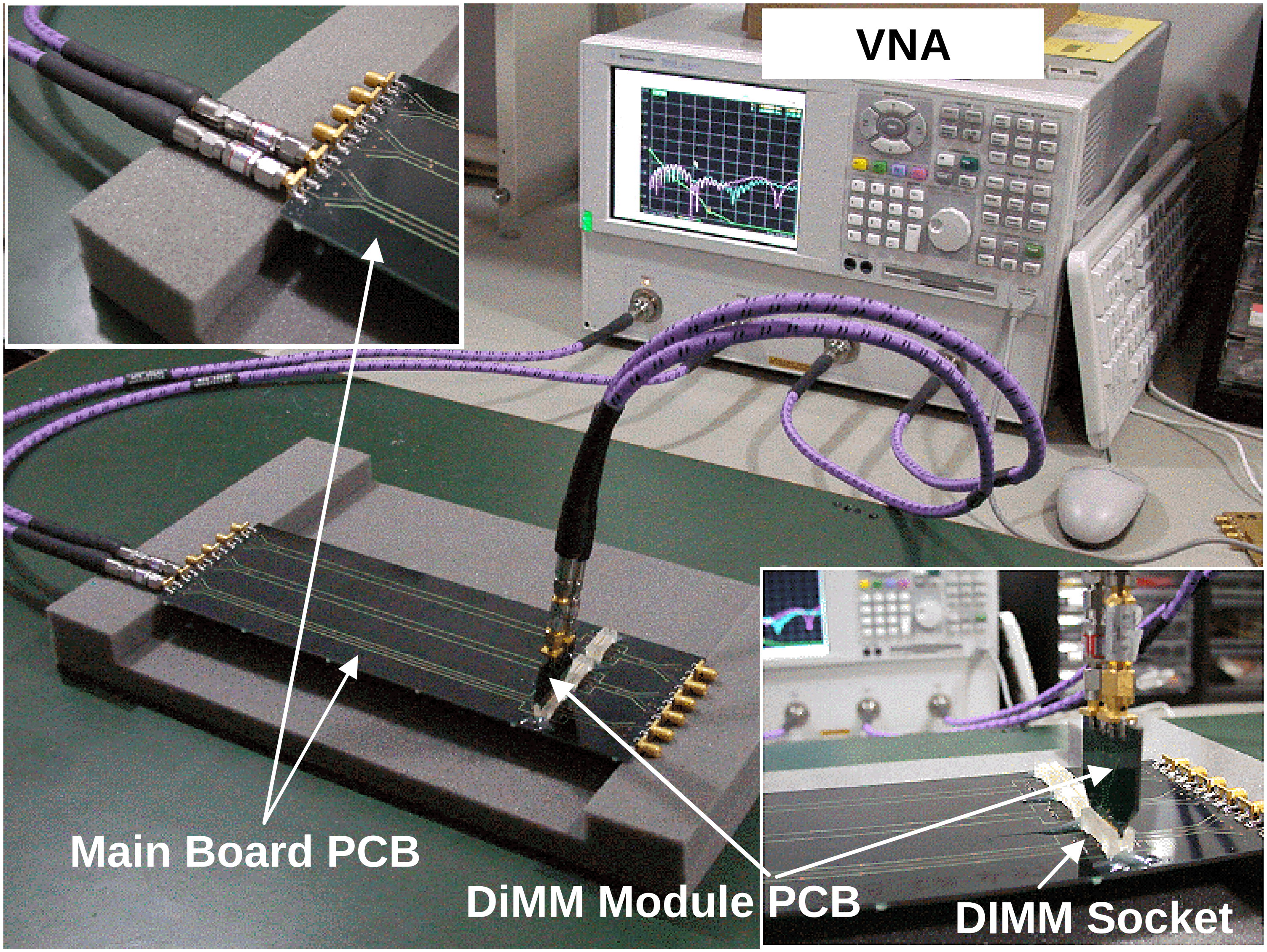




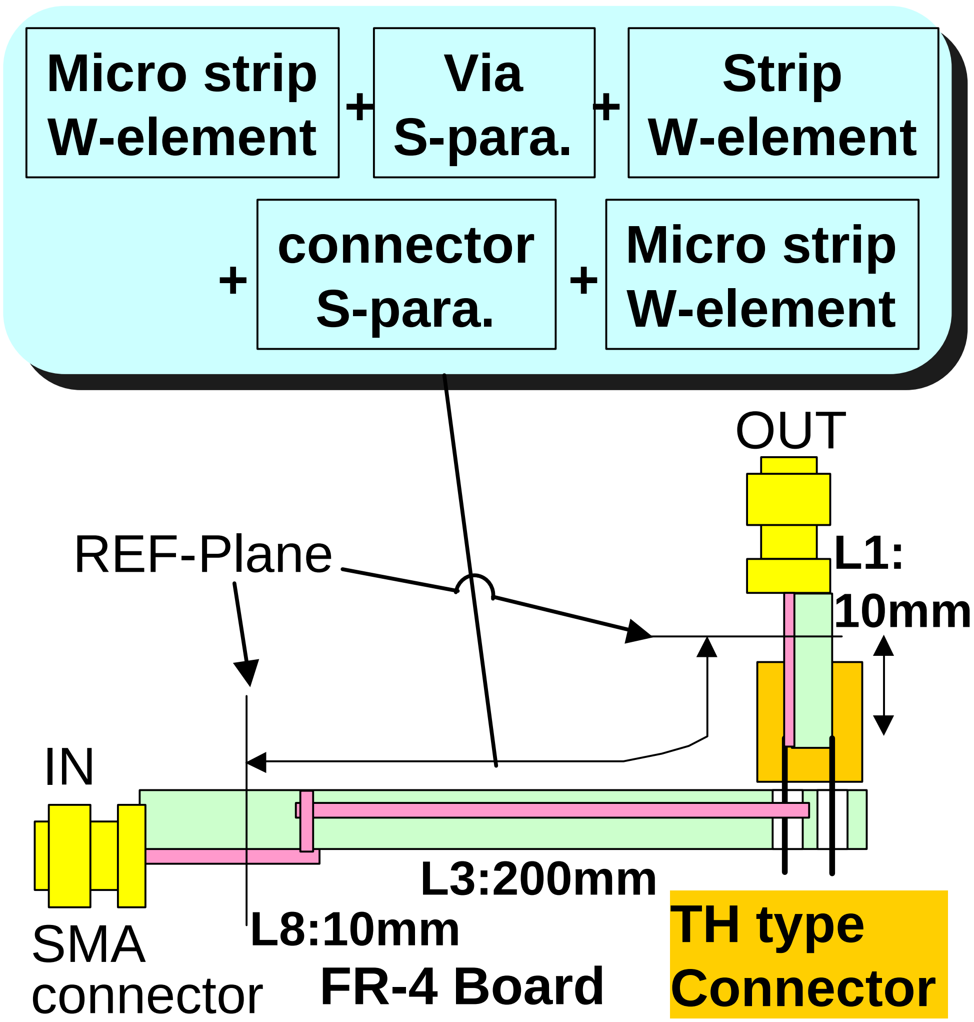


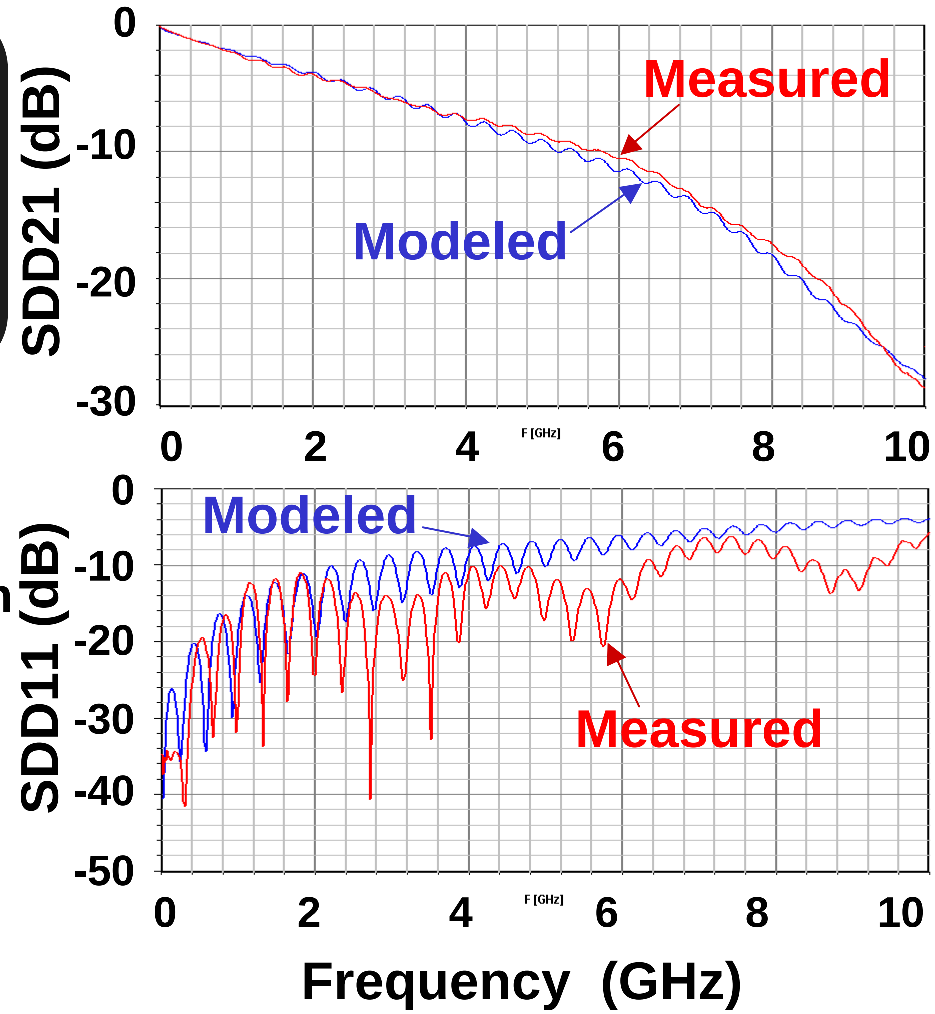


S-parameter measurement overview

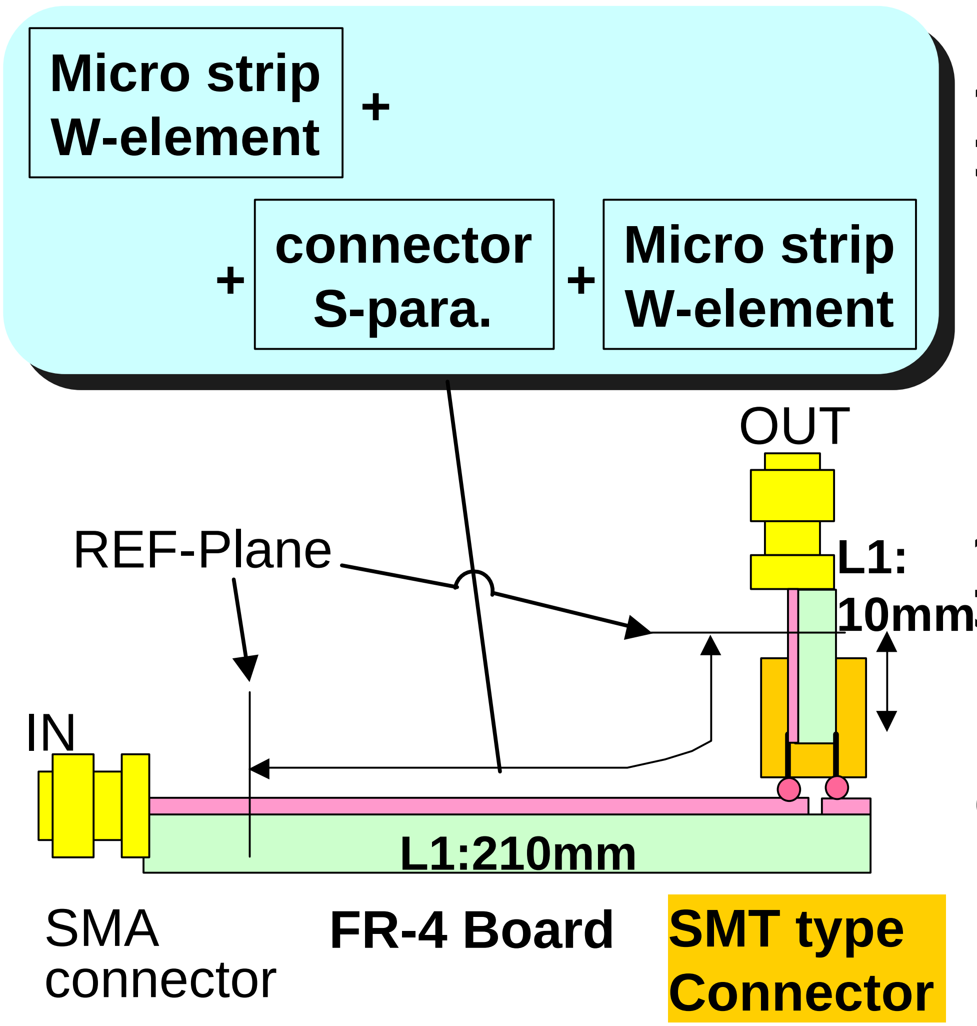


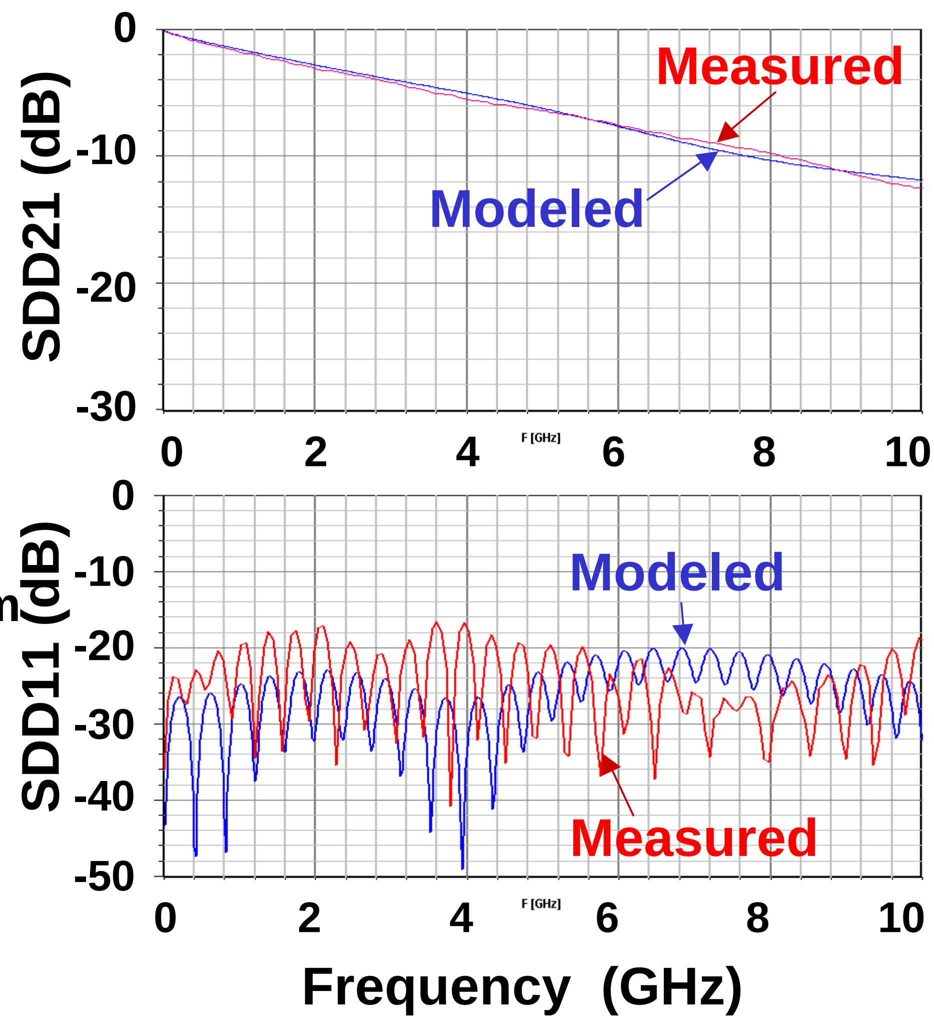
Example of Measured S-parameter and Simulation (TH type connector)





Example of Measured S-parameter and Simulation (SMT type connector)





S-parameter Modeling vs. measurement

(FR-4 Board case)		SDD21 (transmission Loss)			
Condition / Frequency		@4.8GHz	error	@9.6GHz	error
Micro Strip Line case	Measure	-6.5dB	0.1dB	-11.9dB	0.0dB
	Sim.	-6.6dB		-11.9dB	
Strip Line case	Measure	-9.0dB	0.5dB	-19.4dB	0.8dB
	Sim.	-8.5dB		-18.6dB	
TH type Connector + Board (use L8)	Measure	-6.8dB	0.2dB	-17.7dB	0.0dB
	Sim.	-6.6dB		-17.7dB	
TH type Connector + Board (use L3)	Measure	-8.6dB	0.3dB	-26.6dB	0.7dB
	Sim.	-8.9dB		-25.9dB	
BGA type Connector + Board (use L1)	Measure	-6.2dB	0.3dB	-12.1dB	0.5dB
	Sim.	-5.9dB		-11.6dB	

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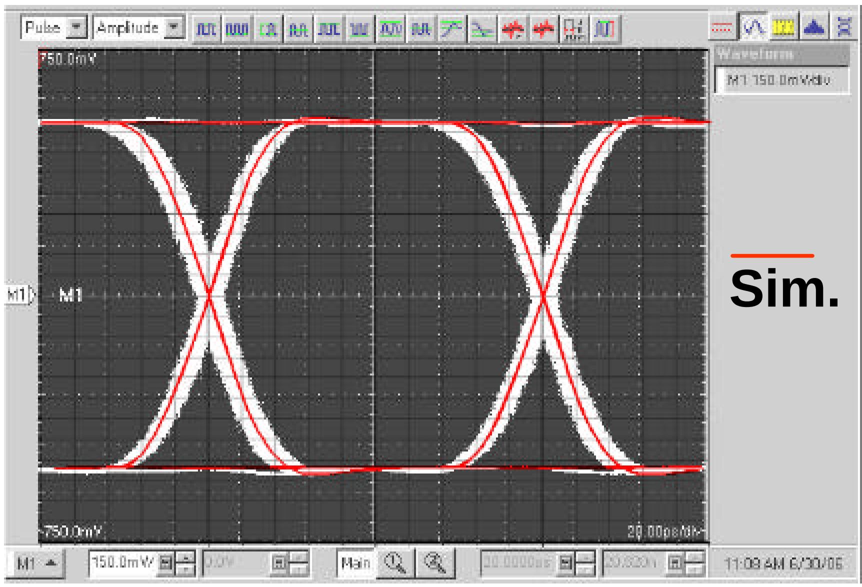
Trap – Transient simulation

Transient simulator using S-parameter model and W-Element model is in development stage as for the accuracy over few GHz operating range.

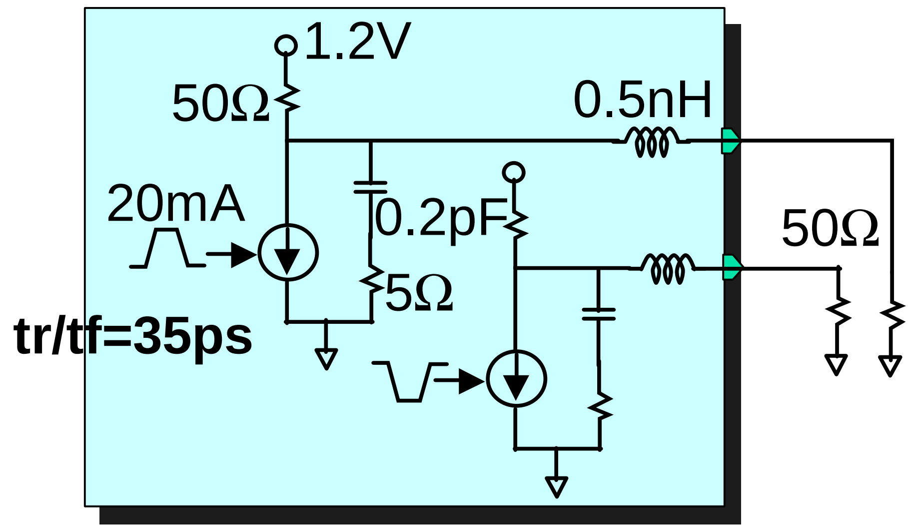
- **Not all the simulator output the same result.**
- **Even the same simulator, output the different waveform by software version difference.**
- **Even the same simulator, output the different waveform by optional setting difference.**
- **Transient simulation result getting closer to measurement result using newer program revision and newer optional setting.**

Driver waveform and model for simulation



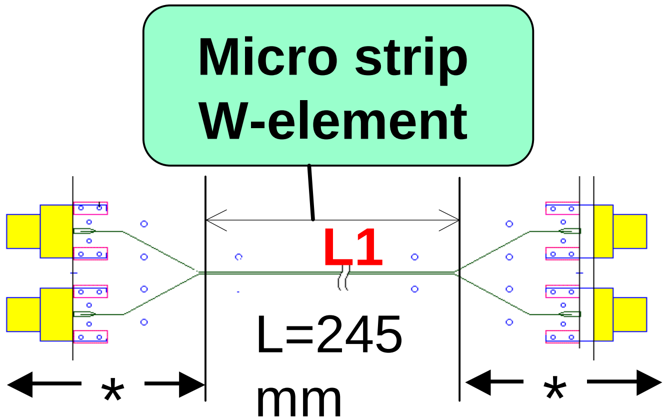
Signal: 10Gbps 2^7-1 PRBS

Driver model for simulation

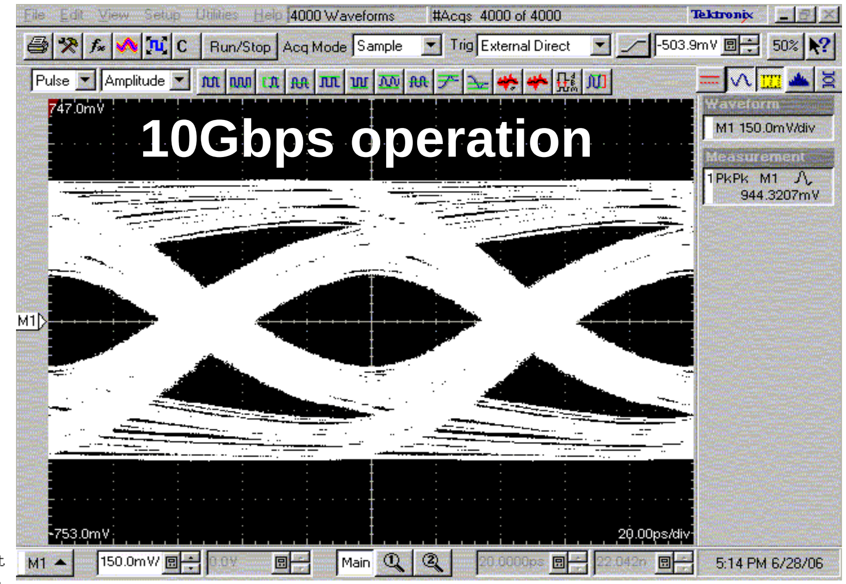


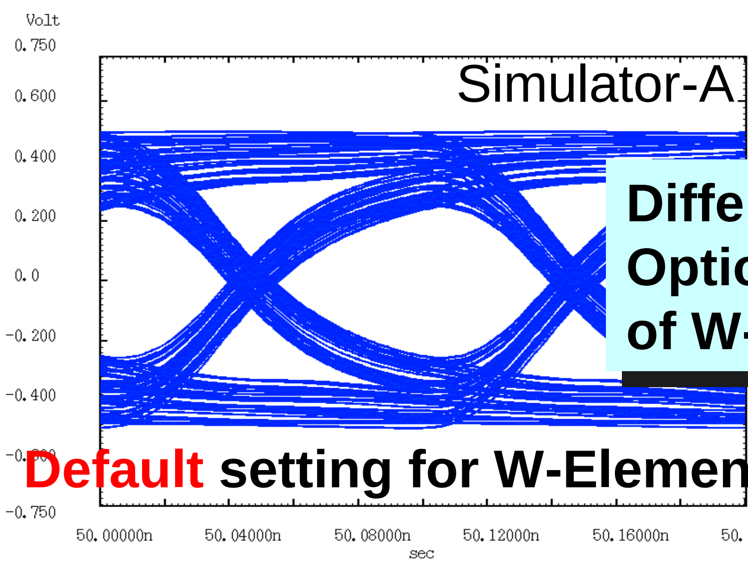
Caution: ±5ps jitter included in Measurement data. But jitter is not include in transient simulation waveform.

Simulation Accuracy (Simulator-A)

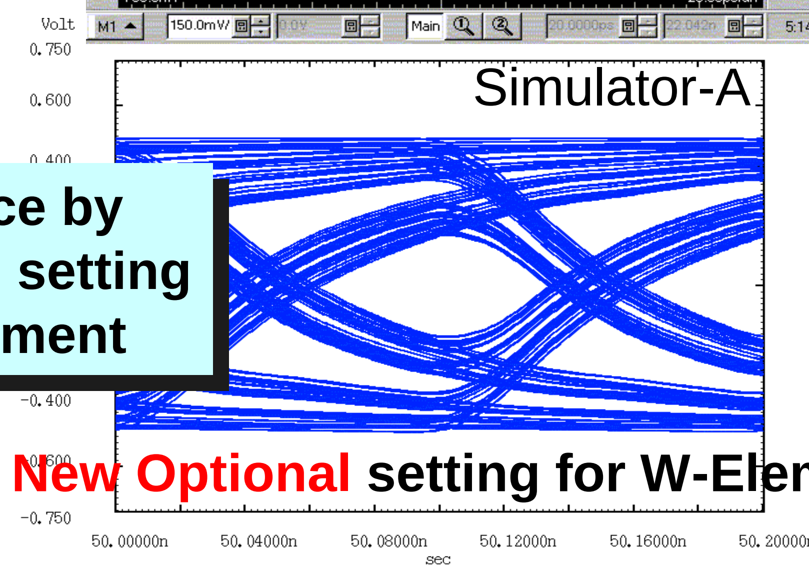


***: Model for De-embedding was used.**





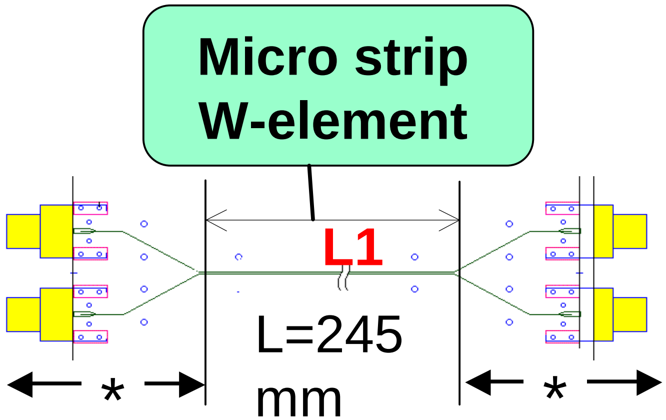
Difference by Optional setting of W-Element



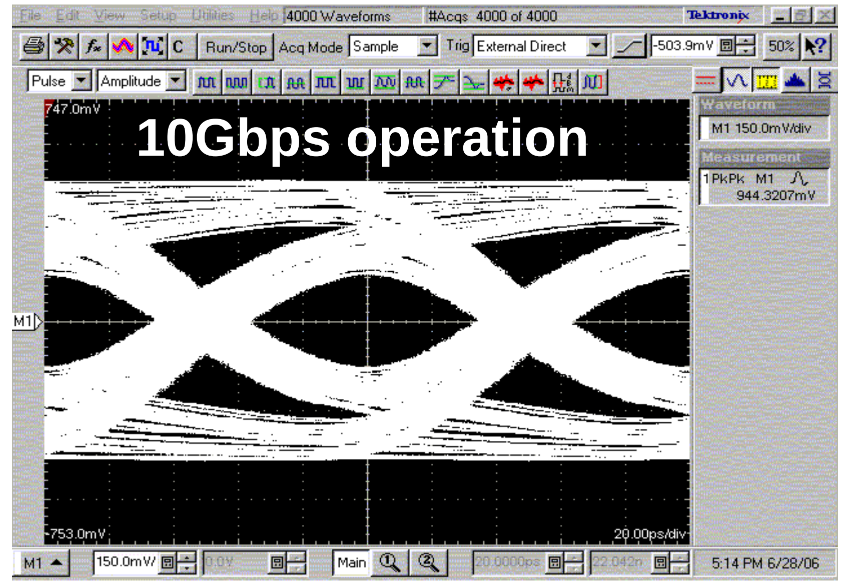
Default setting for W-Element

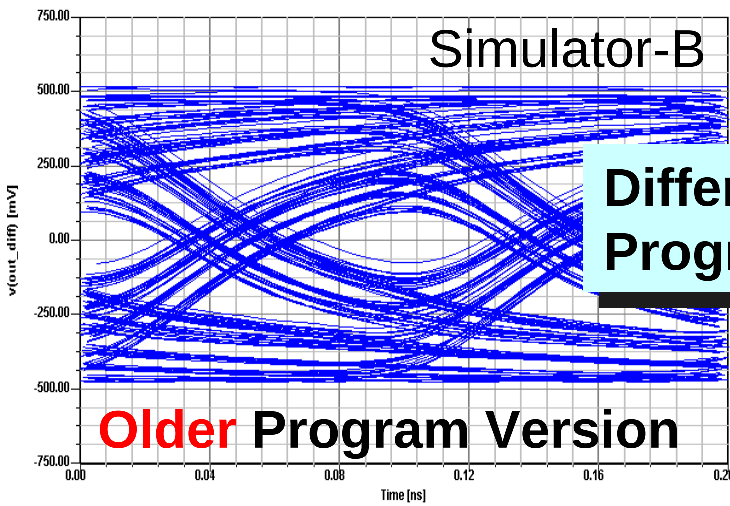
New Optional setting for W-Element

Simulation Accuracy (Simulator-B)

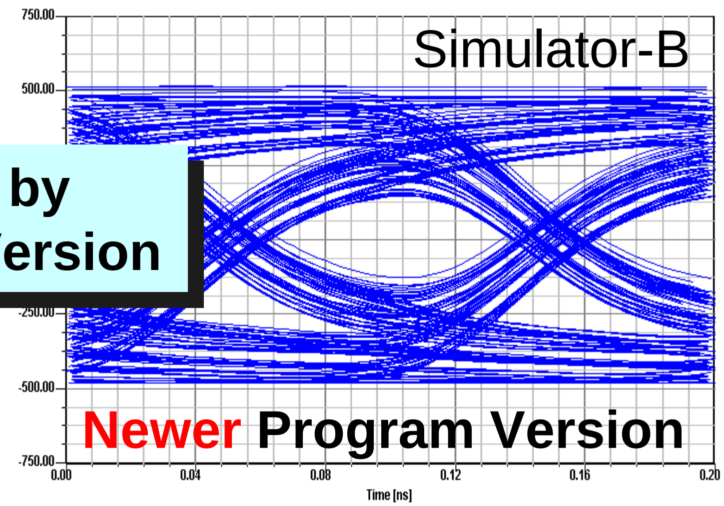


*: Model for De-embedding was used.

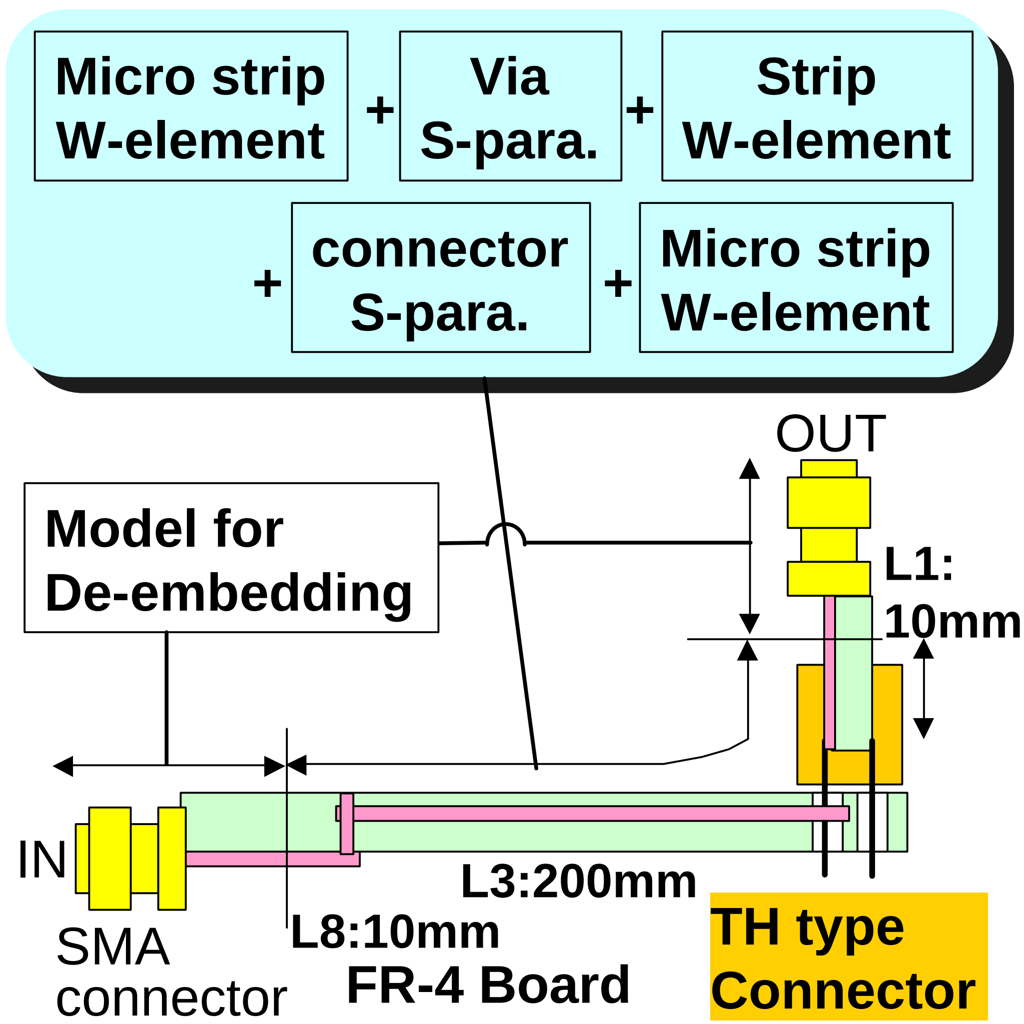


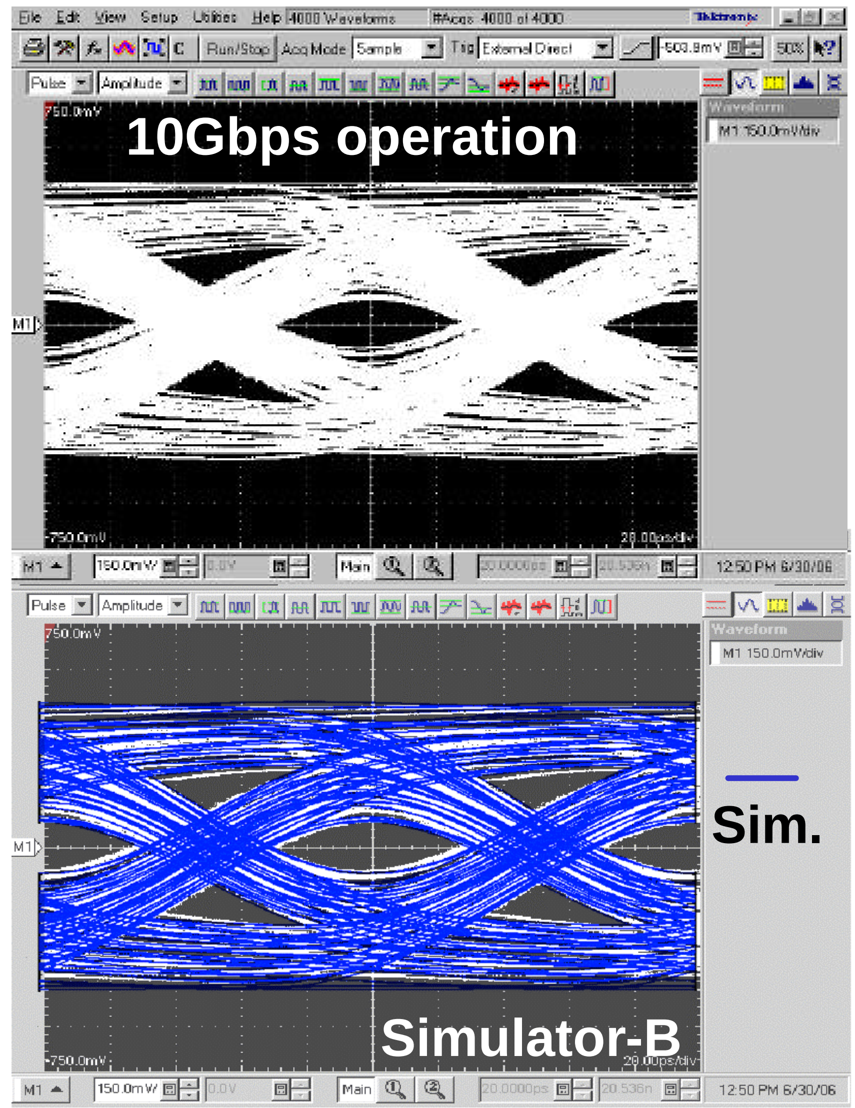


Difference by Program Version

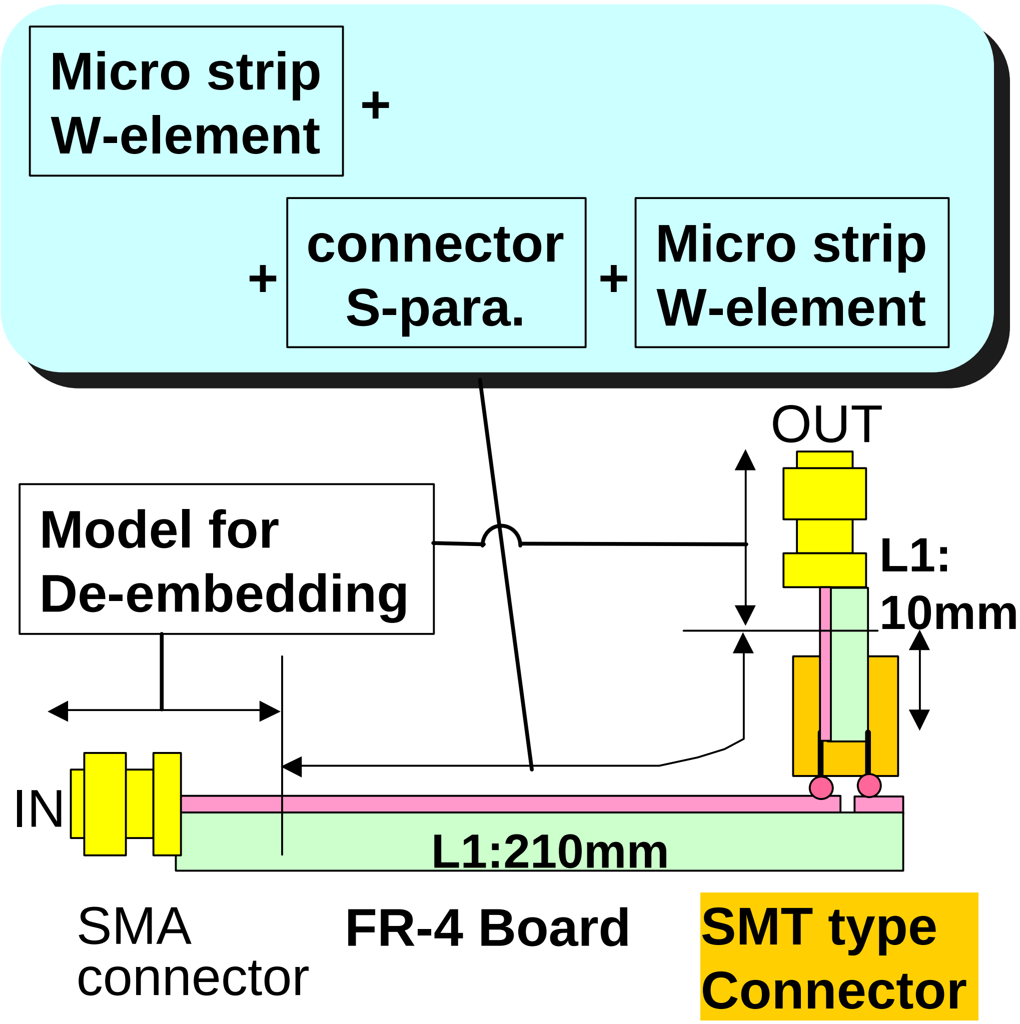


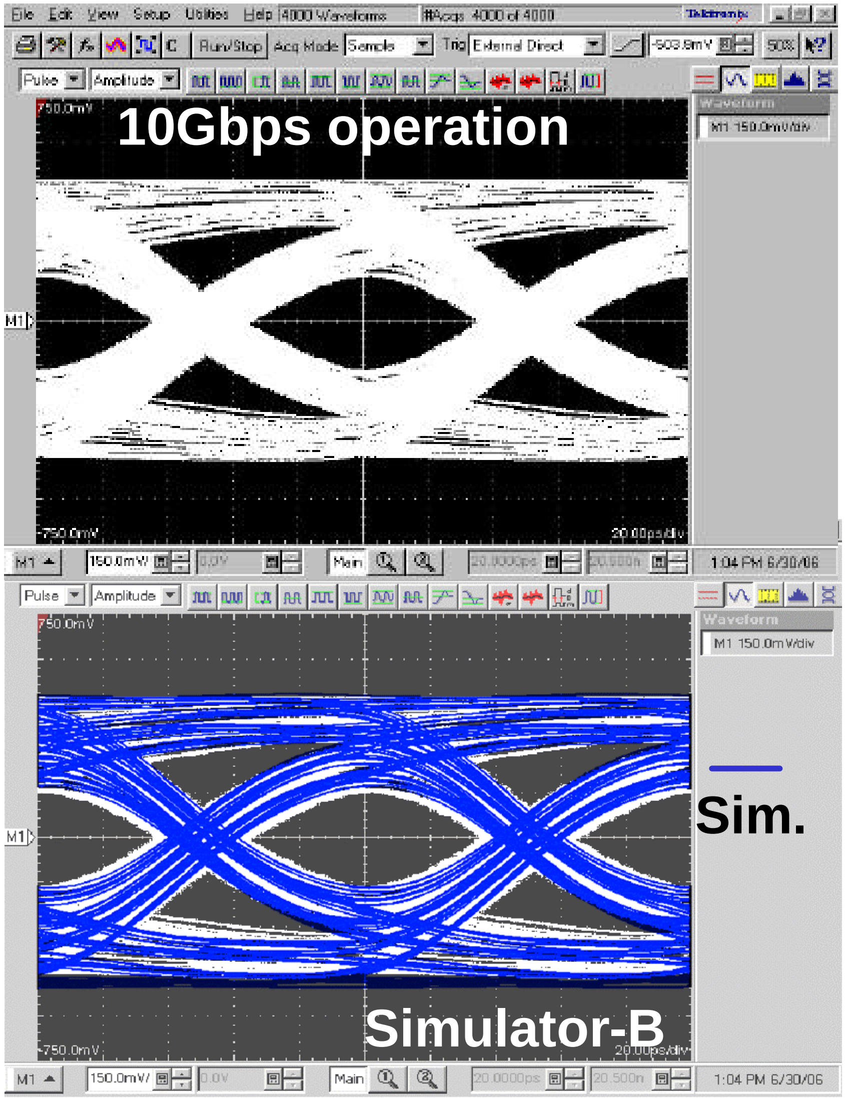
Measured Eye pattern (TH type connector)





Measured Eye pattern (SMT type connector)





Eye height simulation vs. Measurement

(Simulator-B case)

Condition		Eye height @10Gbps	error
Micro Strip Line case	Measure	305mV	0.1dB
	Sim.	300mV	
Strip Line case	Measure	159mV	0.8dB
	Sim.	175mV	
TH type Connector + Board (use L8)	Measure	242mV	2.0dB
	Sim.	306mV	
TH type Connector + Board (use L3)	Measure	156mV	0.1dB
	Sim.	155mV	
BGA type Connector + Board (use L1)	Measure	311mV	0.5dB
	Sim.	330mV	

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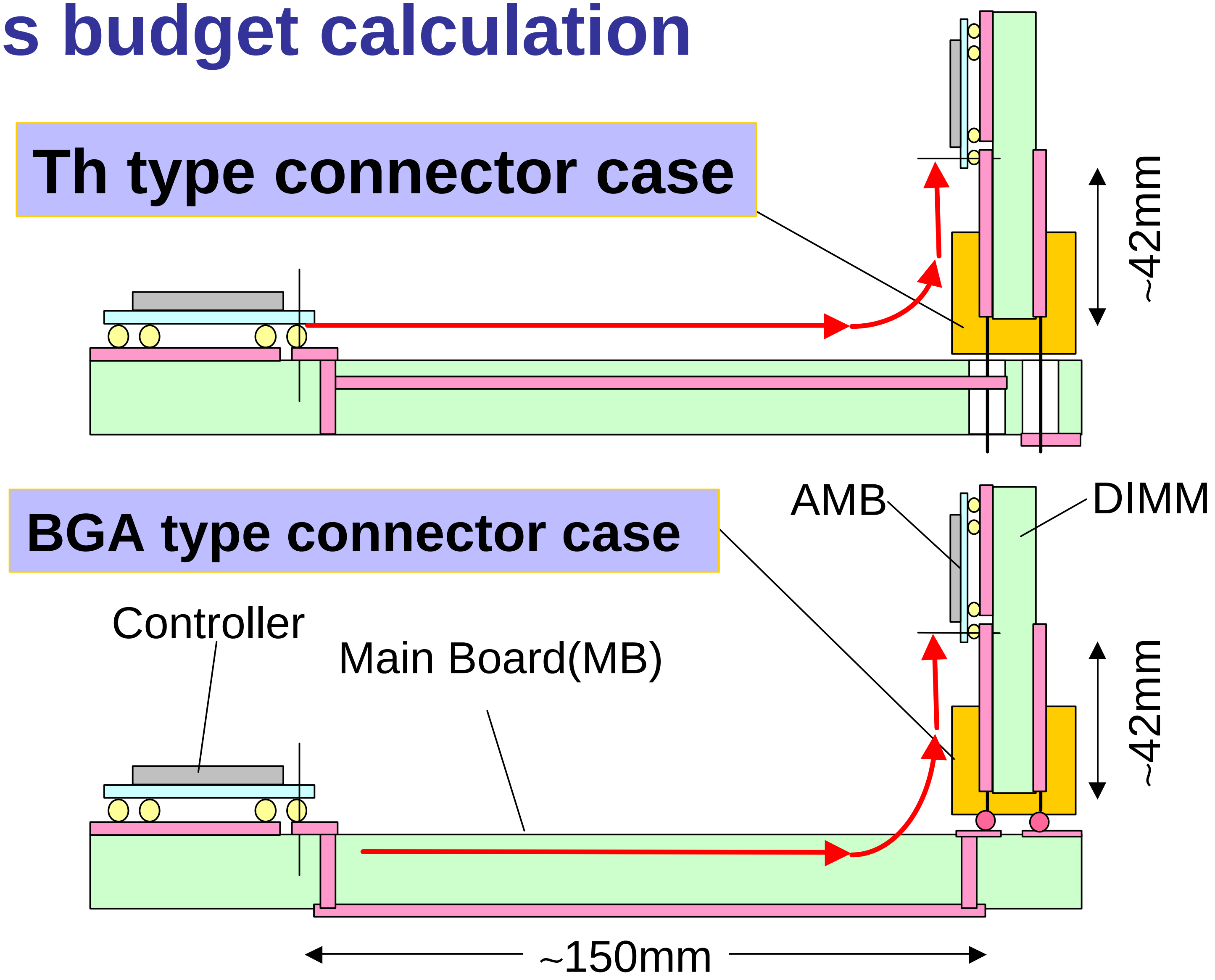
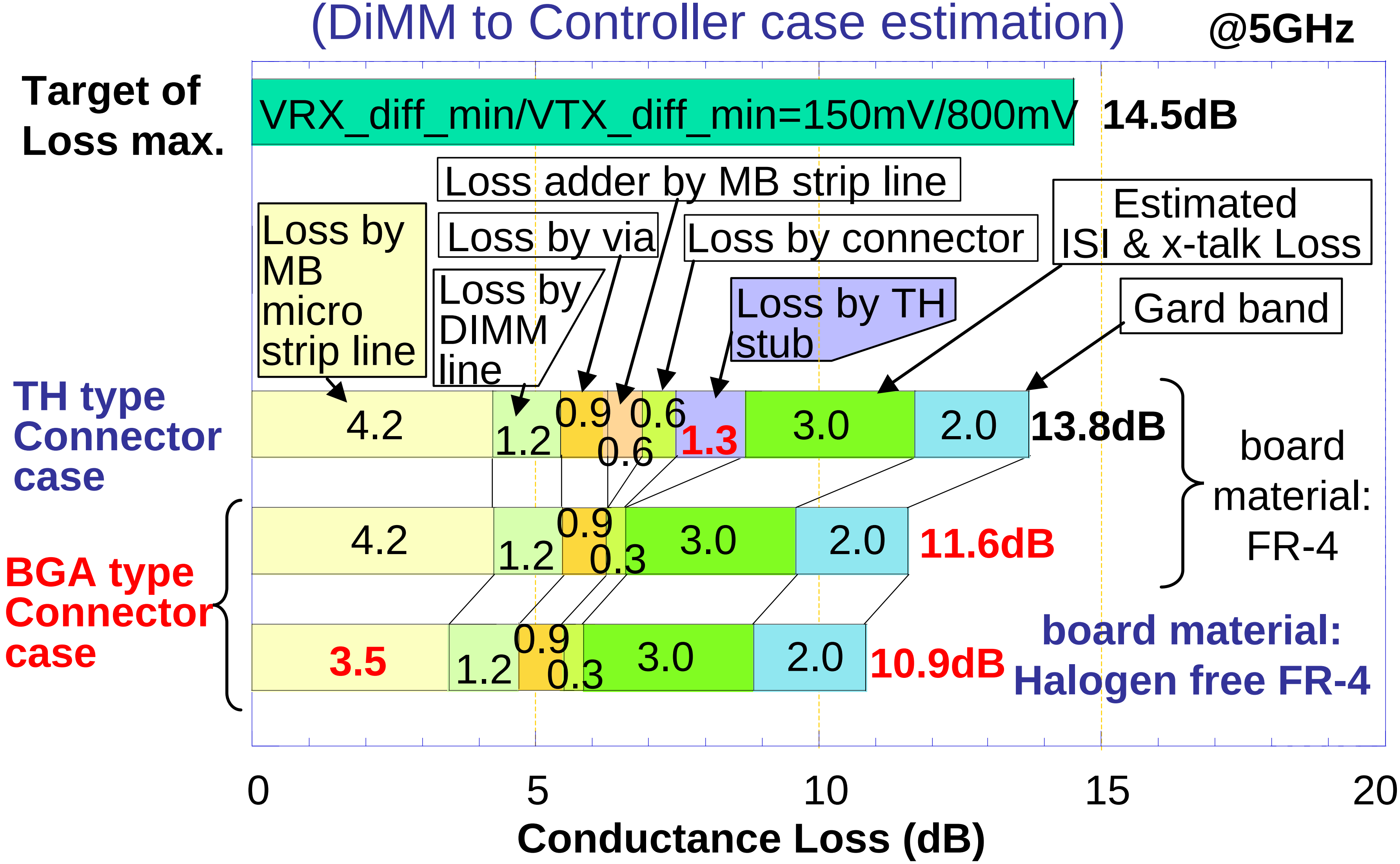
FB-DiMM High-speed channel example for Loss budget calculation



Connector type and comparison of total Conductance Loss

(DiMM to Controller case estimation)



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Summary

1. SMT type connector exhibit smaller Insertion/Return loss than conventional through hole type connector. Because, stub effect is minimized.
2. Cutting out the reference plane at DiMM edge finger part improve impedance matching and exhibit smaller Insertion/Return loss .
3. Lower tand dielectric material than FR-4 is Preferable to preserve proper loss in long line case. (ex. Length>200mm)
4. Via connecting layer difference cause Insertion/Return loss difference.
5. Selecting the Model type and simulator, we get good relation between modeling and measurement in S-parameter.
6. Selecting the simulator and condition, we get fairy well relation between simulation and measurement in transient eye waveform.
7. Example case calculation of system total conductance loss show a smaller loss than target even the FR-4 main board and through hole type connector case.

Conclusion

- **Transmission loss by through hole stub under connector and long line length in main board is fairly big. But we judged that, conventional FR-4 main board and through hole type DiMM socket can accommodate up to 9.6Gbps operation.**

Recommendation

1. **Change the connector like surface mounts type.**
2. **Change to lower dielectric loss material than usual FR-4 for main board. Halogen free FR-4 seems to be a suitable choice.**