On PCB with 50Gbps for ATE board, Characteristic improvement Approach

Takahiro Yagi
OKI Circuit Technology Co., Ltd.

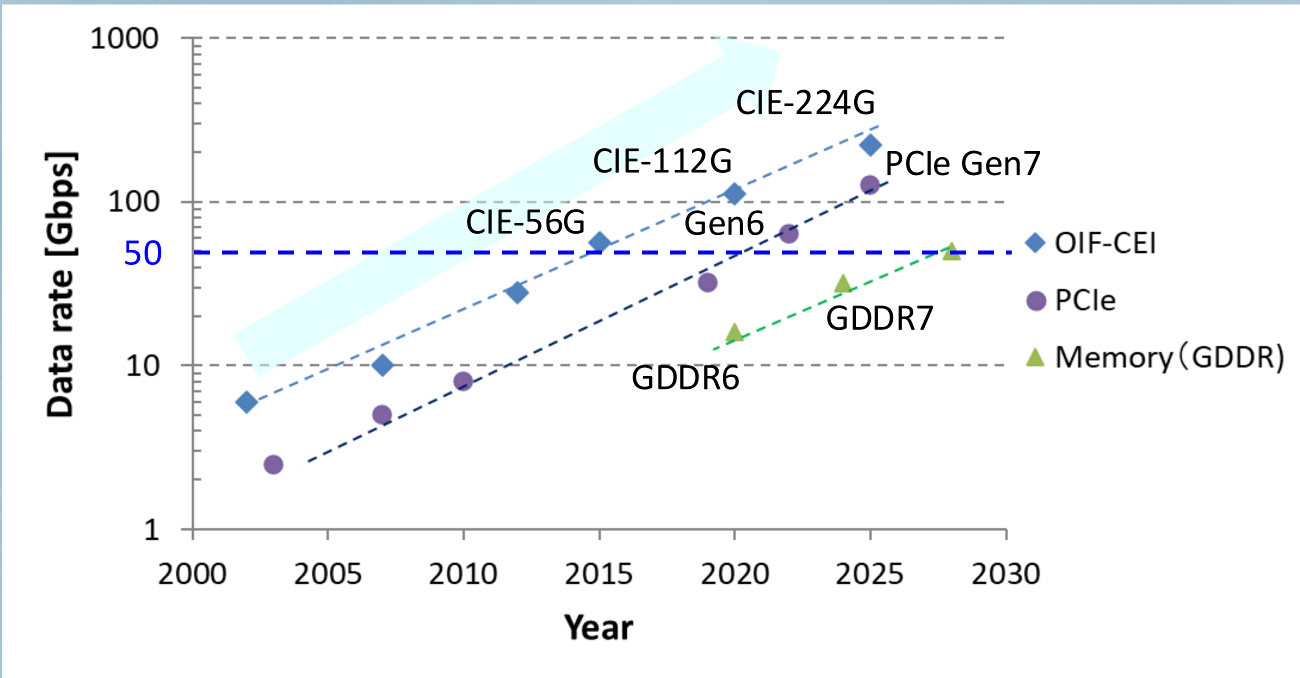
Overview

- Background
- High-speed PCB trends
- Challenges for High-Speed PCB
- Flow for development of High-Speed PCB
- PCB characteristic improvement
- Development examples
- Correlation between Simulation and measurement
- Conclusion

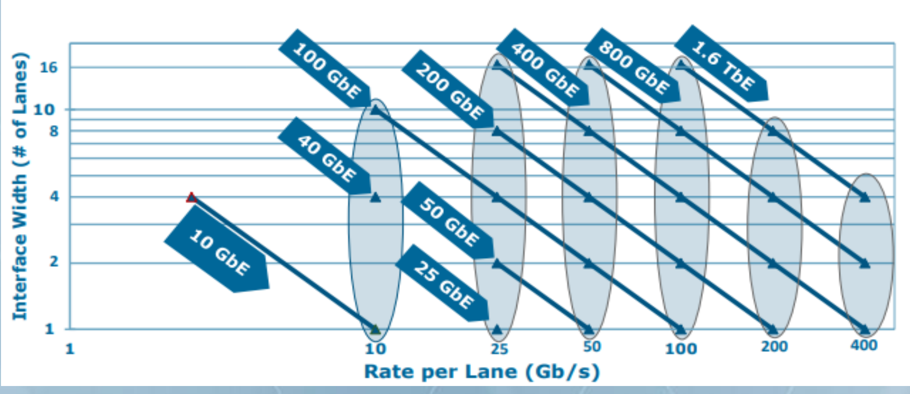
Background

- Data Rate Doubled in 3 to 4 years : exceeding 56Gbps
- PCB are also required to perform at 50GHz or more

Ex:
- Nyquist frequency of 56G-PAM4 : 14GHz
- The 3rd harmonic : 42GHz



The Relationship Between Ethernet & Signaling Rates



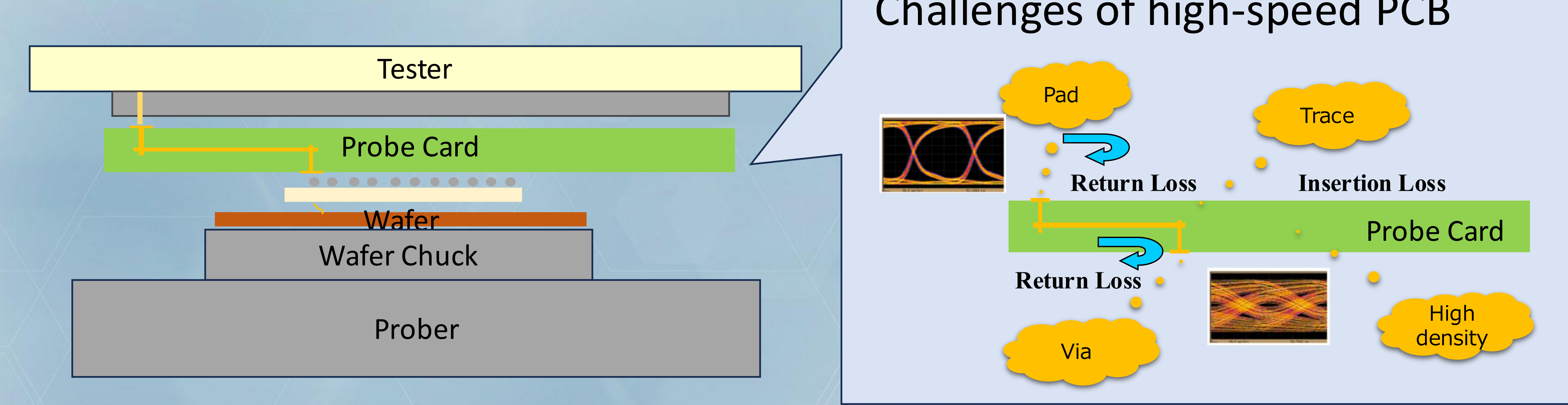
Source: IEEE 802.3 Beyond 400 Gb/s Ethernet Study Group

Data rate and Nyquist frequency

Data Rate	Encoding	Nyquist Frequency
56Gbps	PAM4	14GHz
64Gbps	PAM4	16GHz
56Gbps	NRZ	28GHz
112Gbps	PAM4	28GHz
128Gbps	PAM4	32GHz
224Gbps	PAM4	56GHz

Background

- Signal speed in wafer testing is increasing
  Probe Card also required to support high-speed signal
  → Reducing loss and reflection of pads and vias



・Increased loss and reflection
・Eye pattern does not open

Background

- Three factors of PCB Performance : Material, Manufacturing, and Design
  → These factors must be balanced with performance and cost

PCB Performance

Material

Greatest impact on PCB properties and cost

Manufacturing

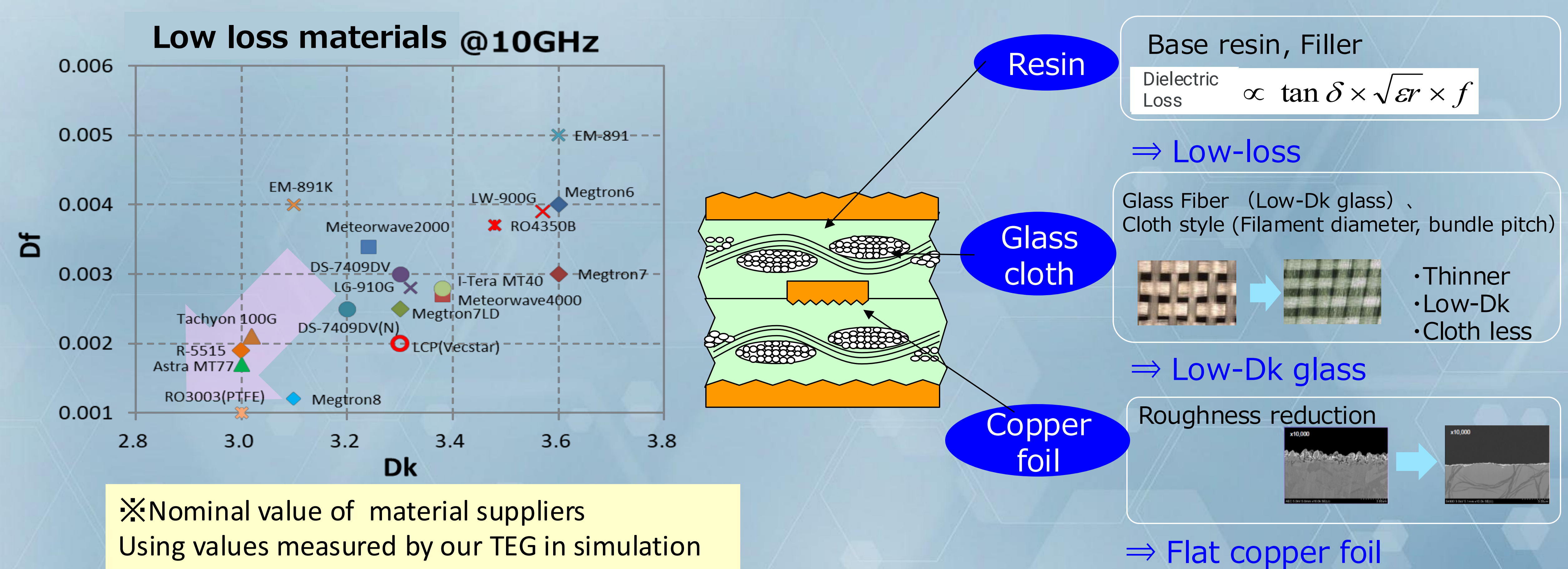
Must meet designed specifications with minimal variation
Process differences can affect characteristics

Design

Critical for high-speed PCB
Simulation is needed because poor design can degrade performance.

High-speed PCB trends

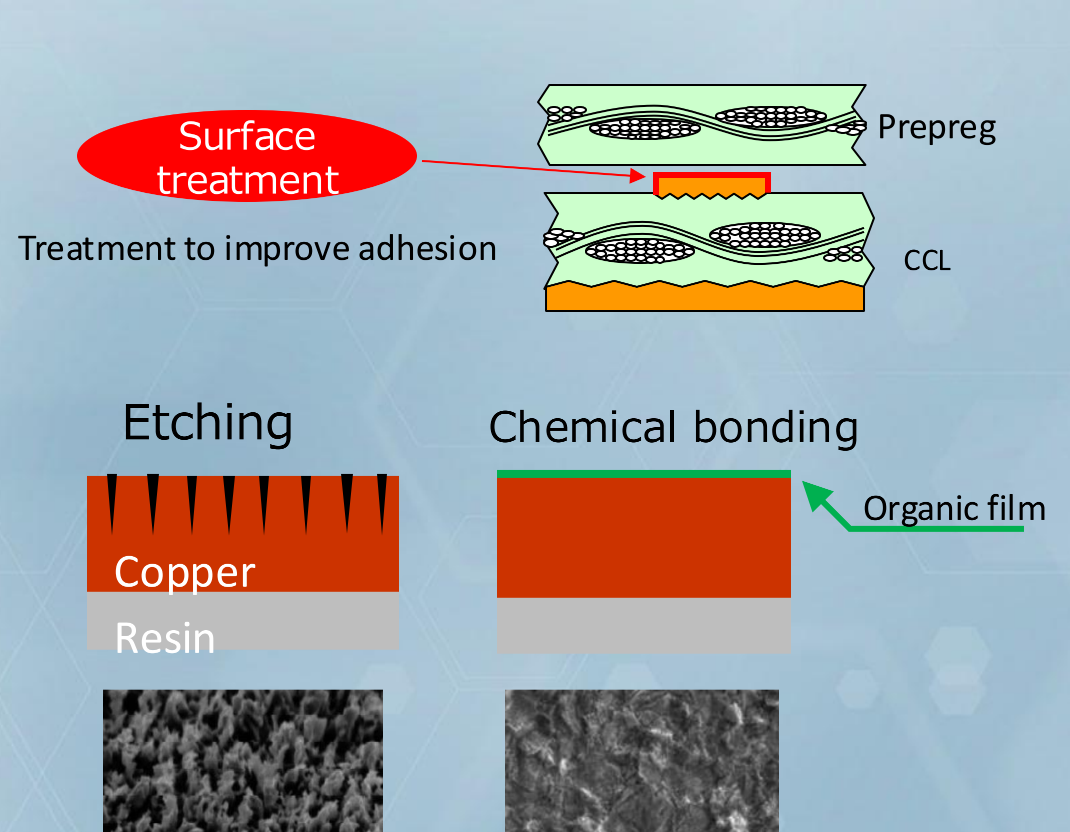
- Approach by materials
  Evolution to Low-Dk/Df （Dk : 3.0, Df : 0.001 and less）



※Nominal value of material suppliers
Using values measured by our TEG in simulation

High-speed PCB trends

- Approach by manufacturing process -1
  High speed PCB require flat surfaces → Chemical bonding



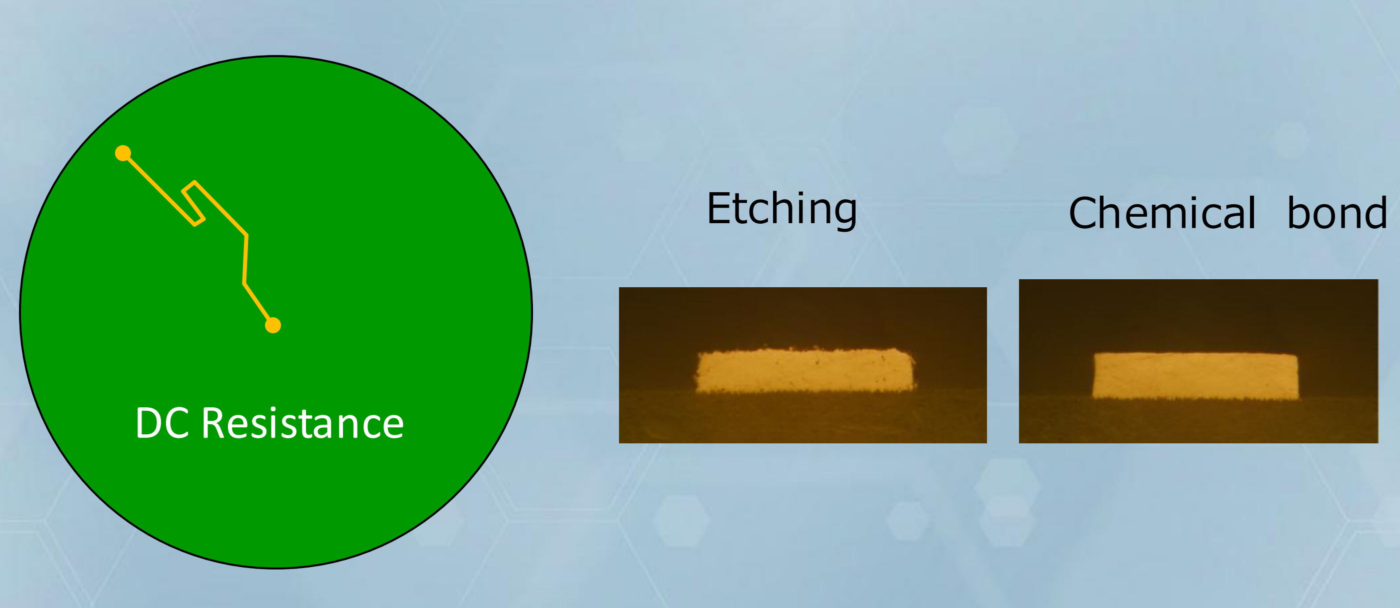
Etching process increases roughness impact due to skin effect

High-speed PCB trends

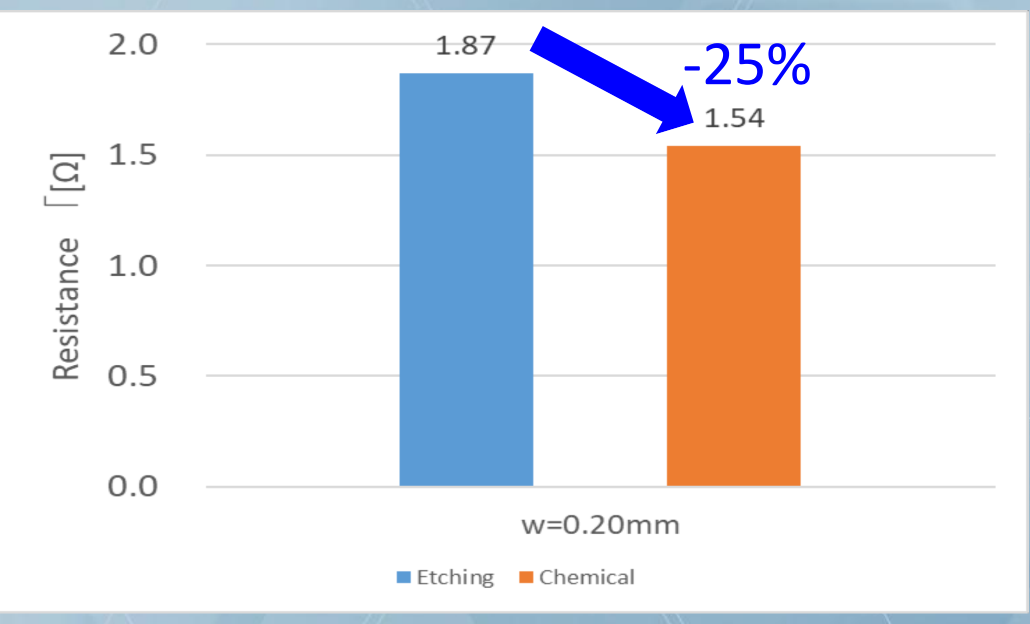
- Approach by manufacturing process -2

Chemical bonding is also effective in DC resistance

Resistance is reduced by 25%, especially effective for power wiring



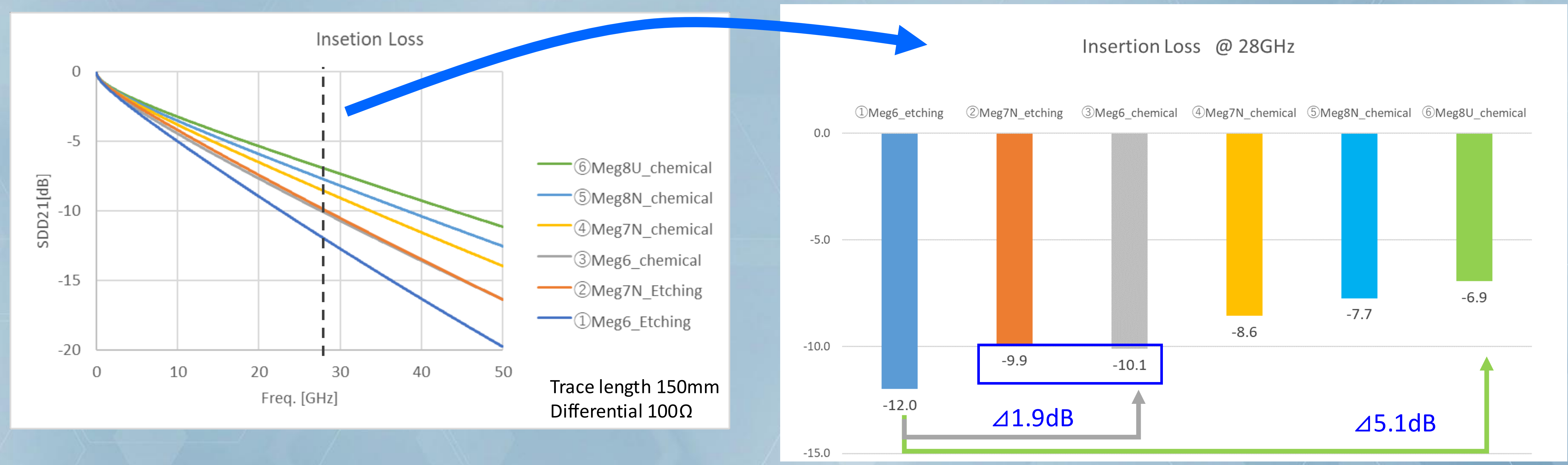
<Probe Card>



0.5oz
L=250mm

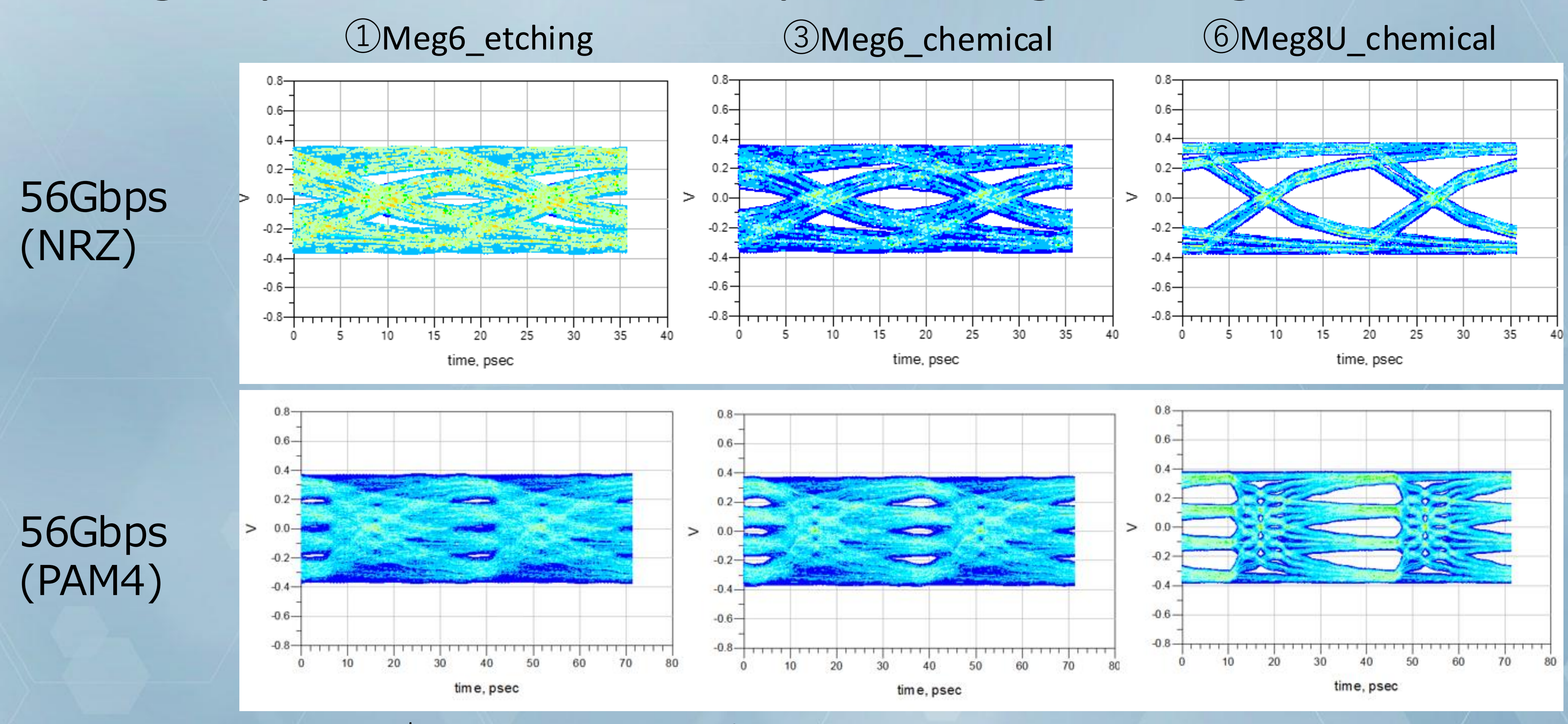
High-speed PCB trends

- Effect of material & surface treatment
- ③ improves 1.9dB by the effect of chemical bonding
  ③ and ② are similar → Chemical bond improves loss and cost
- Most Effective is ⑥ : Megtron8U and Chemical bonding: 5.1dB improvement



High-speed PCB trends

- Eye pattern comparison： ① < ③ < < ⑥
  → High-speed materials and processing show great effects

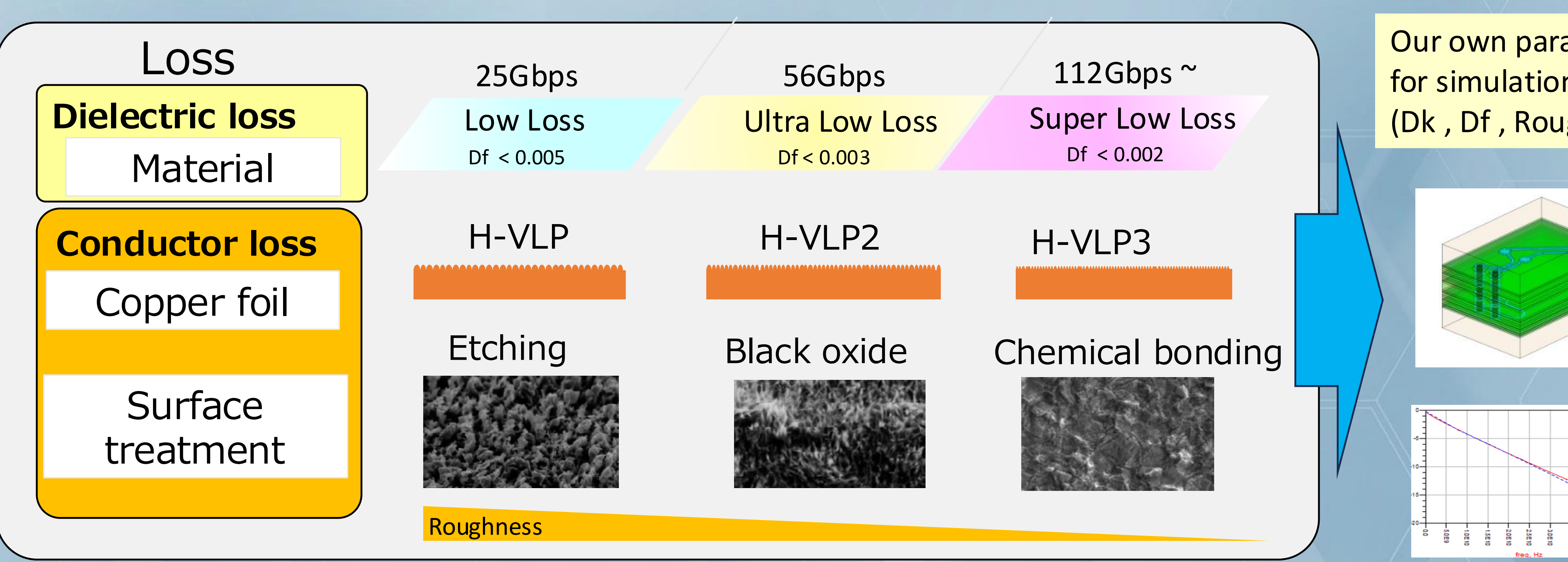


High-speed PCB trends

- Dielectric loss is the dominant factor

  At High frequency, the effect of conductor loss has increased

  → Realize required characteristic by combinations

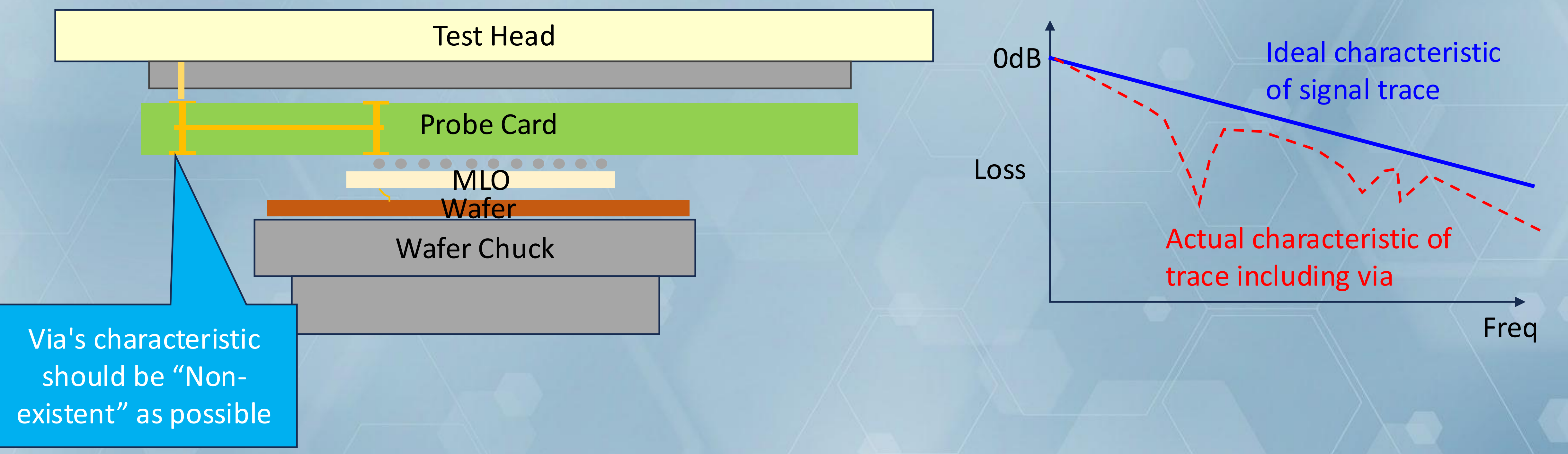


Our own parameters for simulations (Dk , Df , Roughness)

High-speed PCB trends

Structural challenges

- In Probe card, via is necessary for connection from top to bottom
  That via becomes the cause of loss of PCB performance
- Controlling via characteristics at high frequencies is so challenging



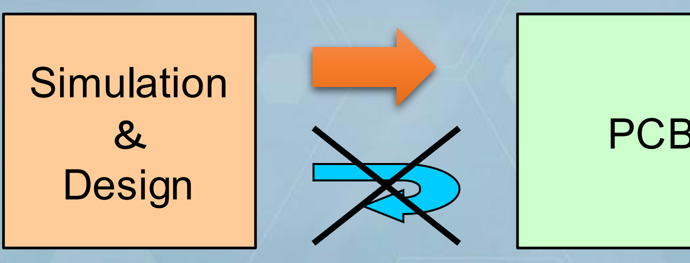
Challenges for High-Speed PCB

■Goal

- Achieve well-balanced cost and characteristics
- "Via characteristic control" to achieve the targeting characteristics

■Challenges

Providing PCBs that meet required characteristics without re-spin
→ Design & Simulation with link to “MONOZUKURI” technology



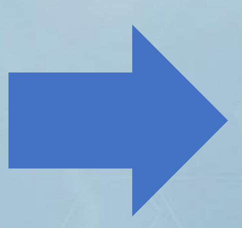
- Simulation technology that reflecting manufacturability
- Correlation b/w simulation and measurement

Development flow of High-Speed PCB

Manage design, manufacturing, and inspection consistently

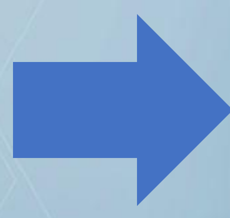
Design & Simulation

Optimize the targeted performance through Simulation



Manufacturing

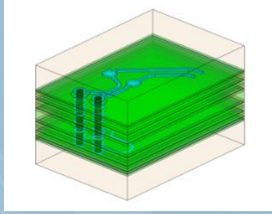
Manufacture with minimal variability

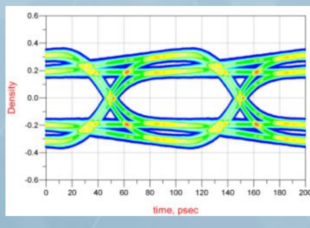


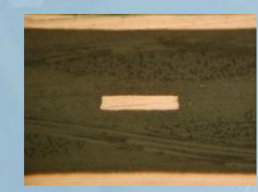
Inspection

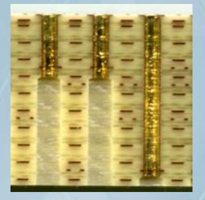
Verify target characteristics

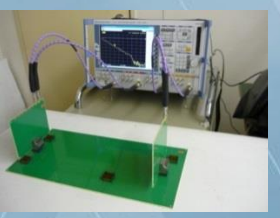
- Impedance
- S-parameter







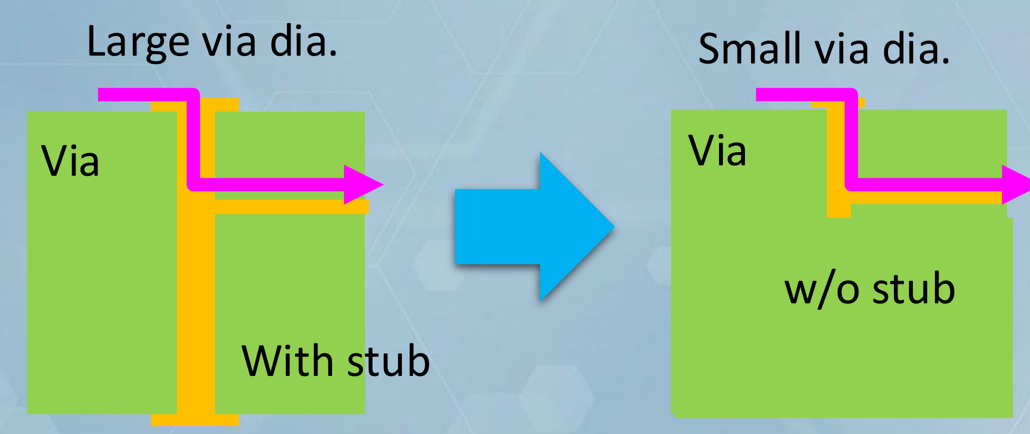




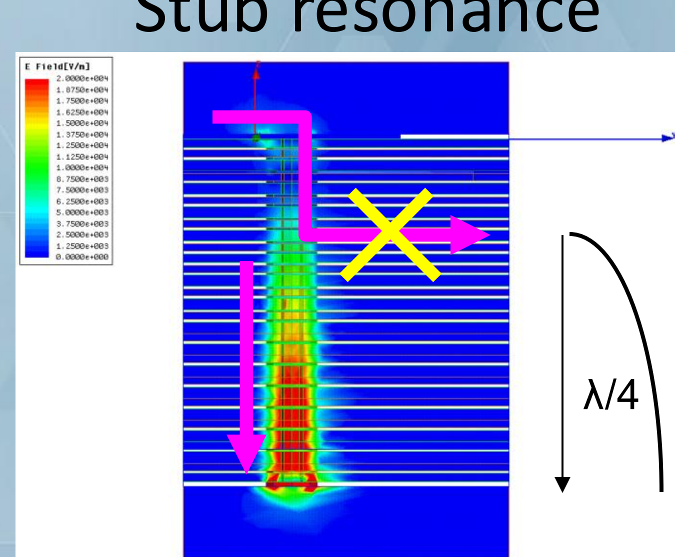
PCB characteristic improvement by design

Improved via's characteristic

1) Apply smaller hole and via diameter as possible
   ⇒ Reduce parasitic capacitance
2) Not exist stub
   ⇒ Not cause resonance



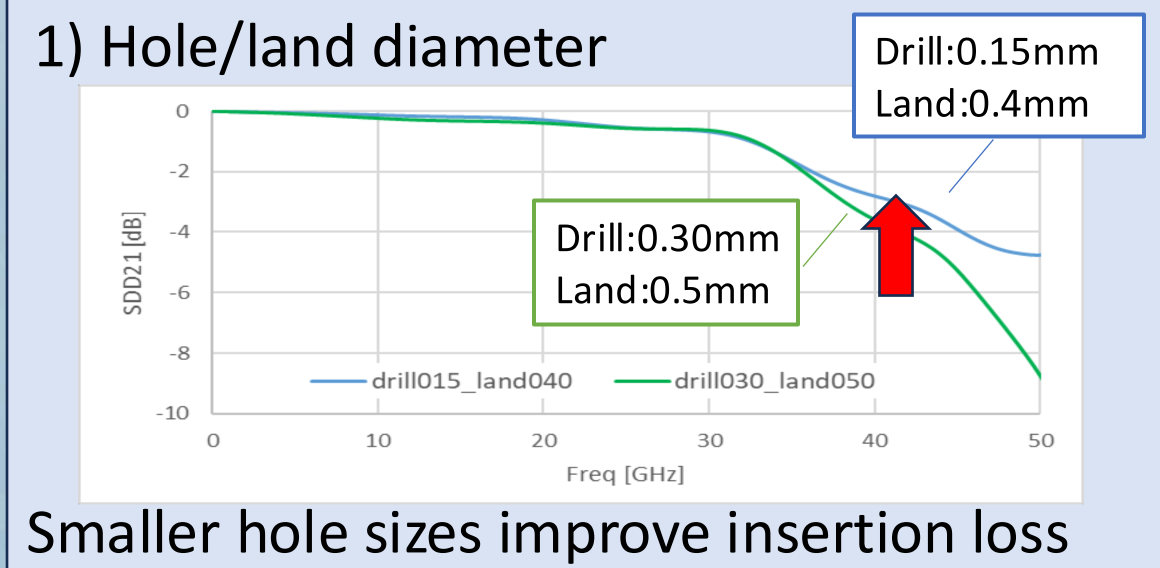
Stub resonance

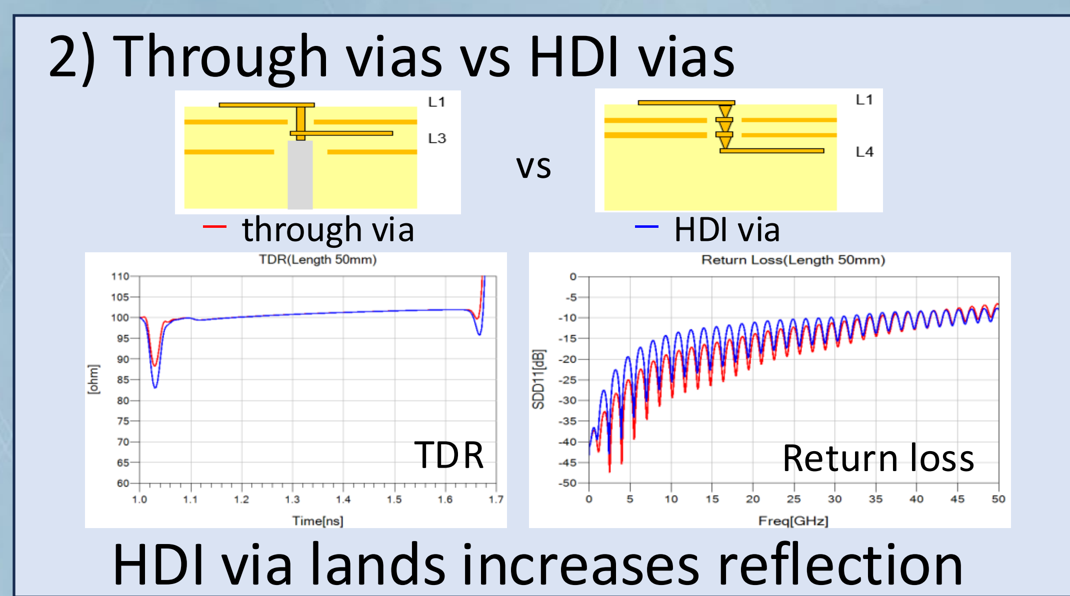


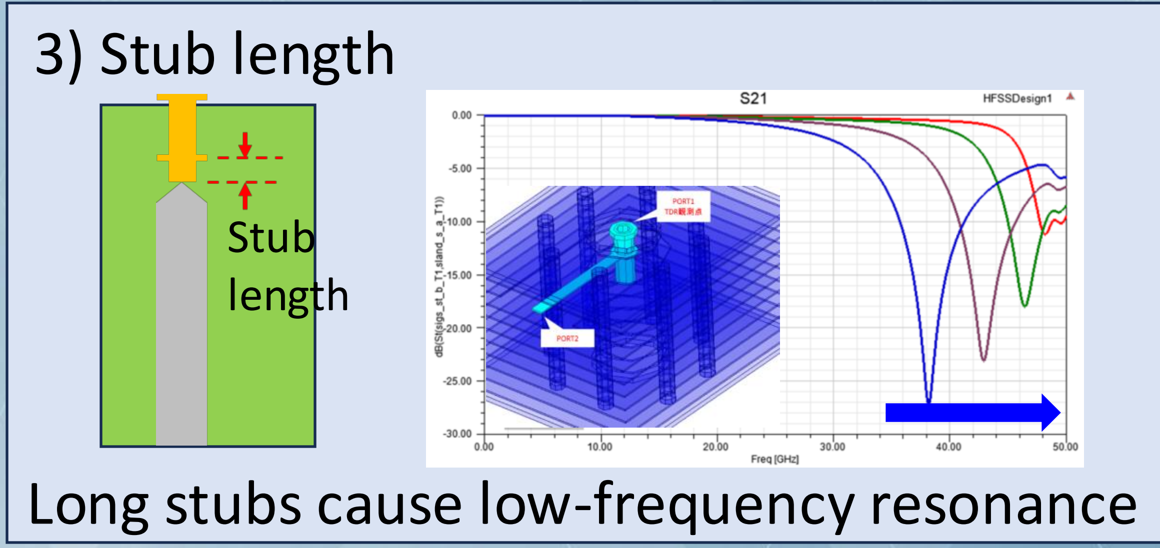
PCB characteristic improvement by design

Effects of dimensional changes

1) Hole and land diameters
2) Via structure
3) Stub length







PCB characteristic improvement by process

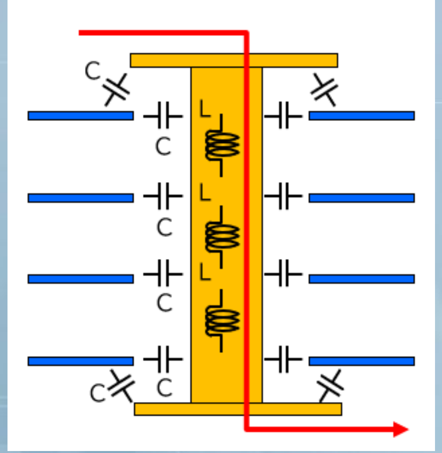
Manufacturing variations impact

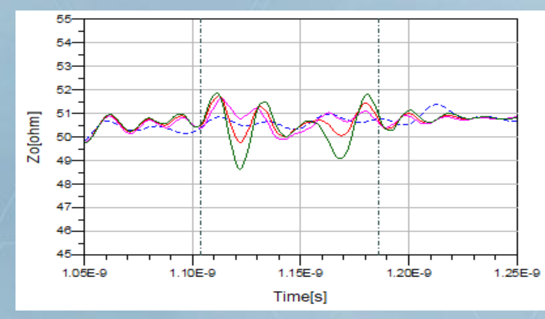
So many variable factors in PCB manufacturing

→ which is key factor ?

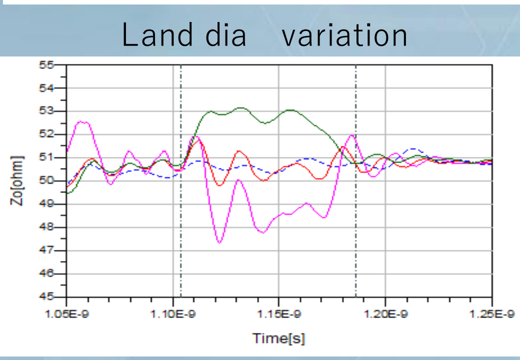
→ Definition of manufacturing tolerances

The impact of random changes must be considered

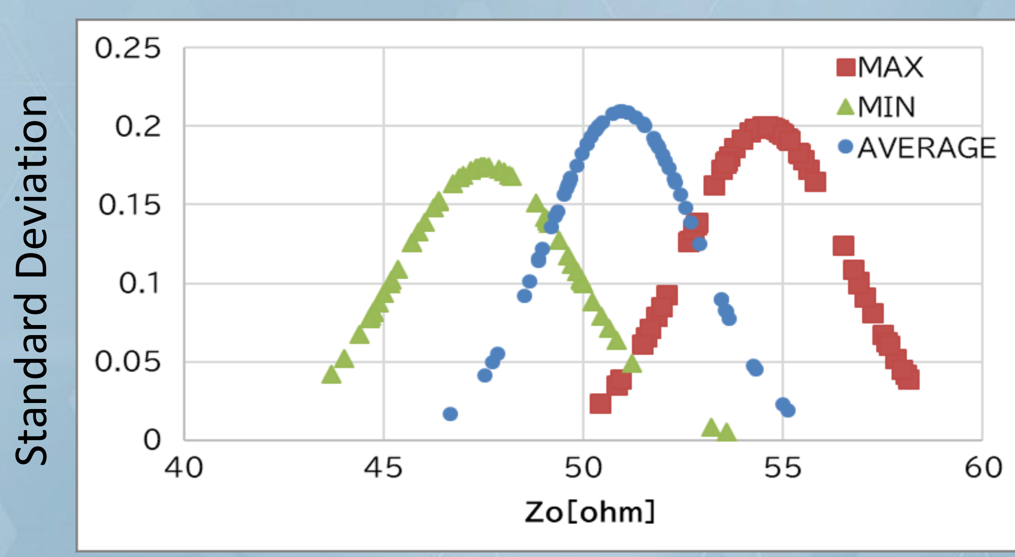




Land dia variation



Anti-pad variation

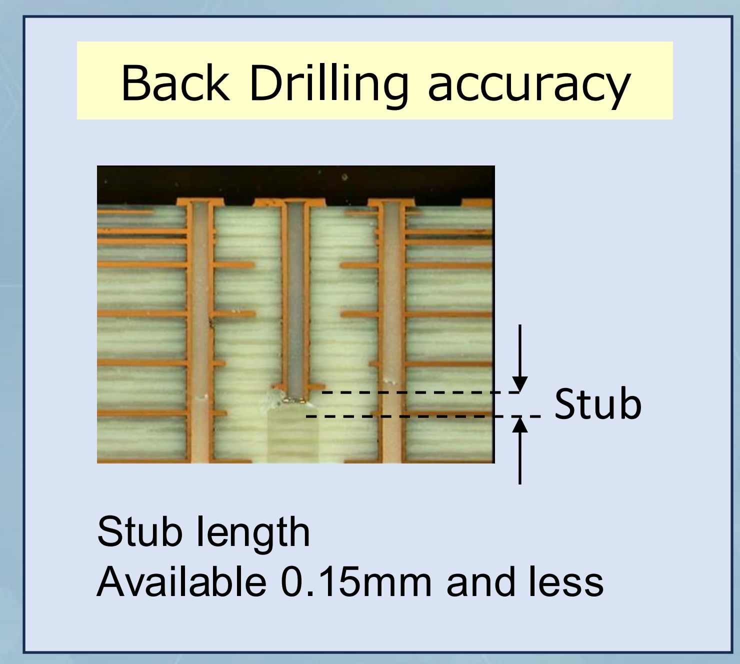


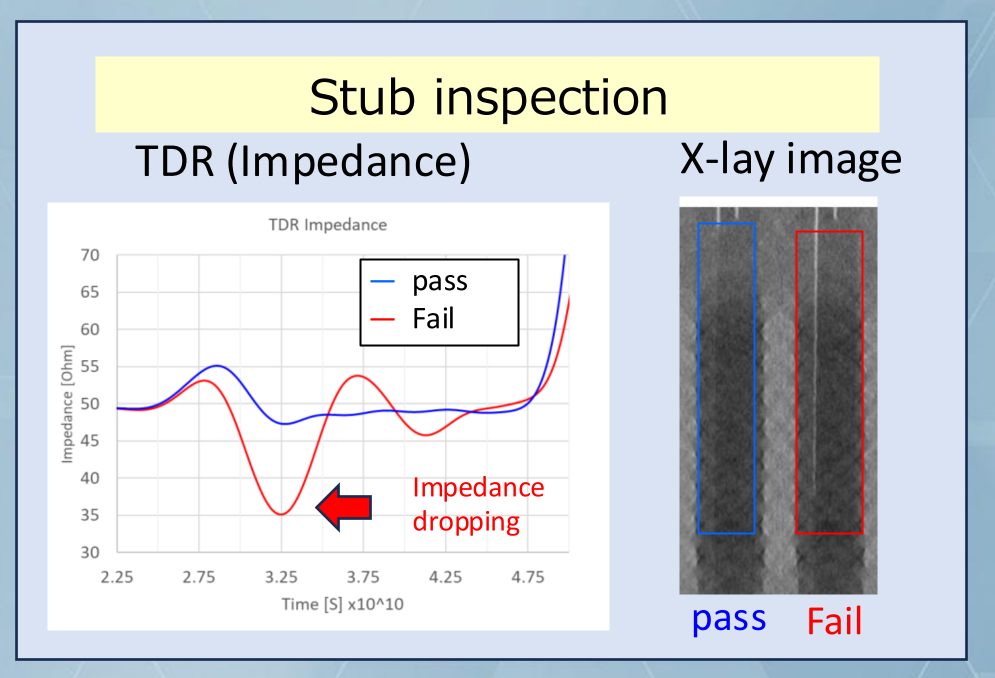
■Variable factors

- Board thickness
- Hole Dia
- Land Dia
- Anti-pad Dia
- Hole alignment
- Layer alignment
- Dk
- Stub length

PCB characteristic improvement by process

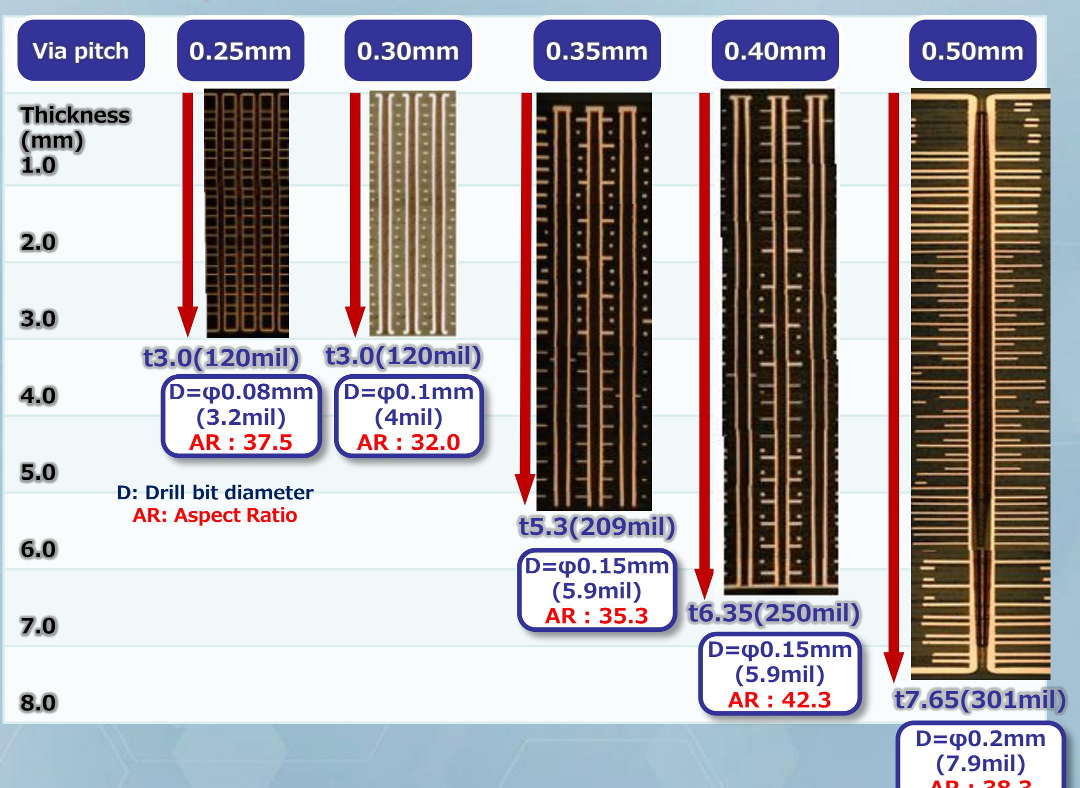
- Stub accuracy control and inspection
  - High-speed PCB achieve a stub accuracy in 0.15mm or less
  - TDR inspection detects remaining stubs

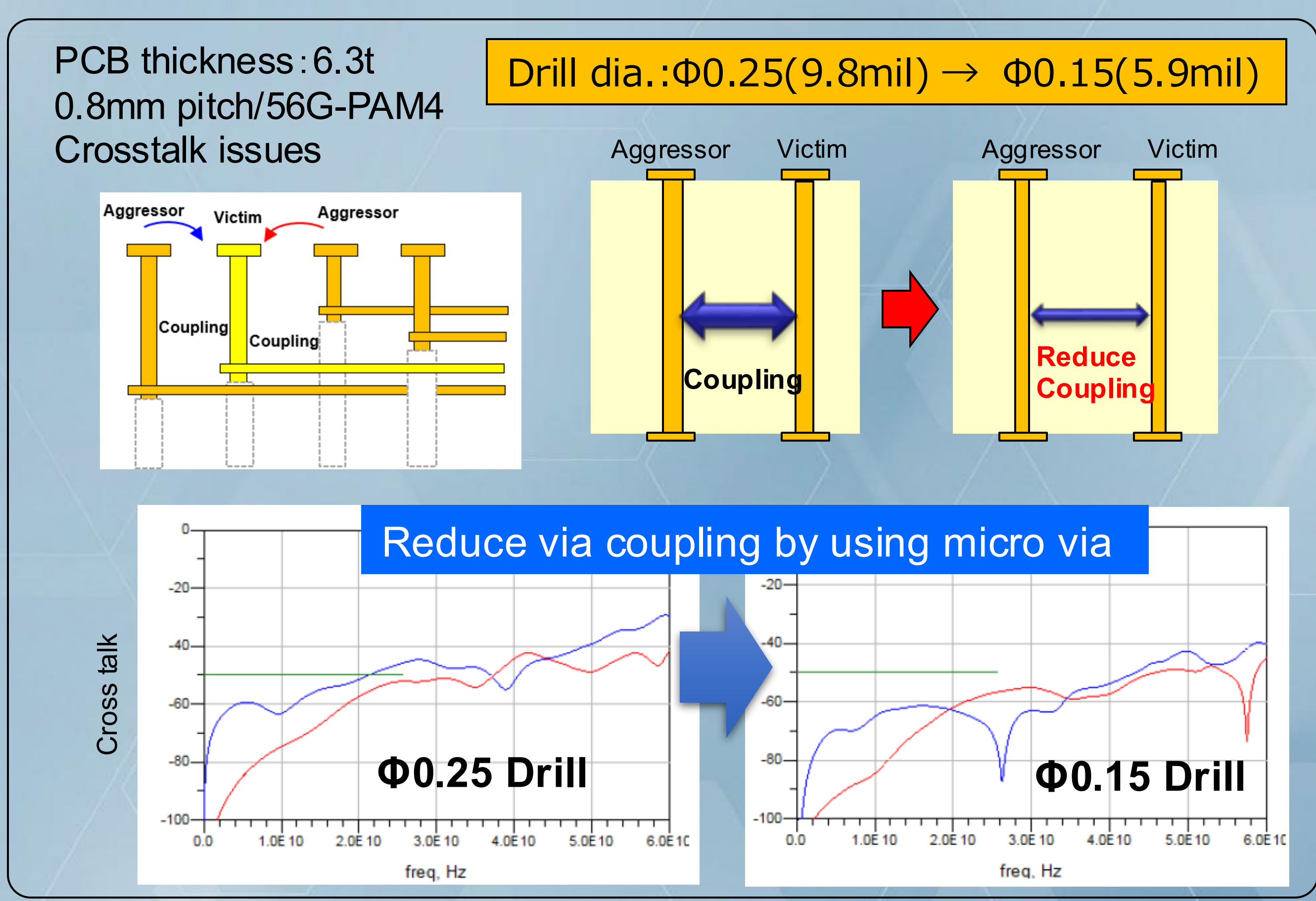




Development examples

- "Fine pitch Through via Technology" reduces crosstalk for 56G-PAM4
  ⇒ Smaller 0.15mm drill is used to reduce coupling in the Z direction





Correlation between measurement and simulation

- Characteristics control of high-speed trace including via

  Target spec：Insertion loss： -3dB@20GHz

  Impedance：50Ω±3Ω（Tr=25ps）

- Board thickness 6.3mm
- 50 Layer / Megtron6
- Via dia. ϕ0.2

PORT1

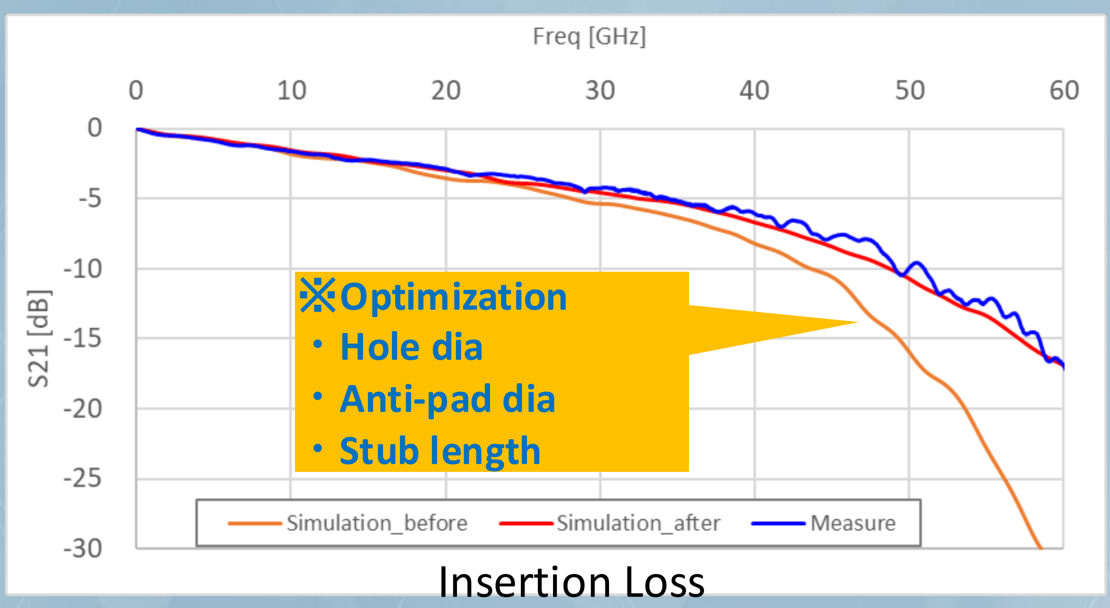
Deembed

Deembed

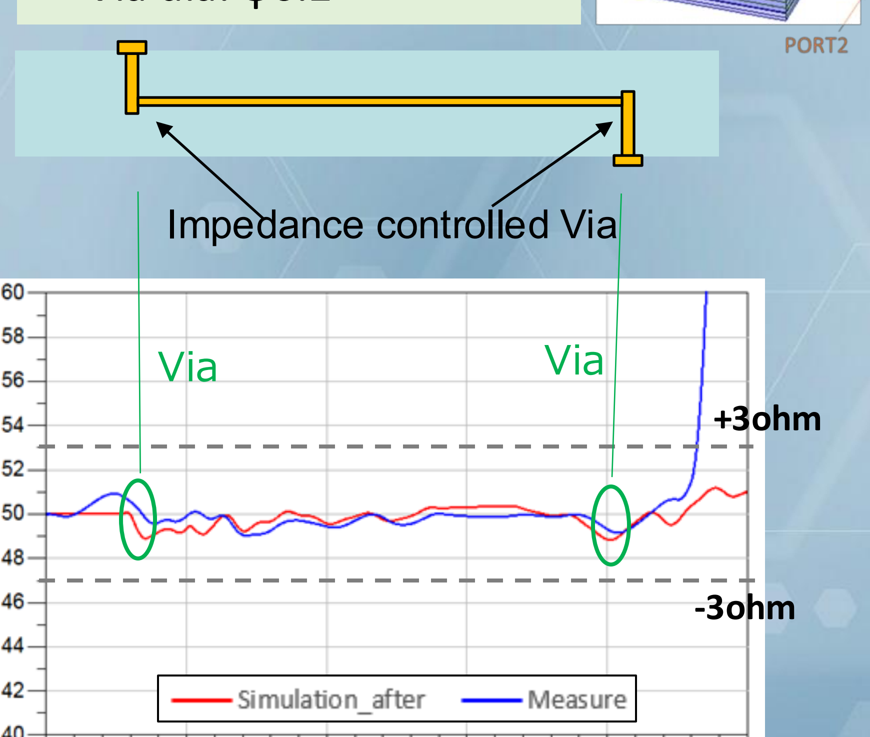
PORT2

Impedance controlled Via

Good correlation between via TDR (impedance) and Insertion loss up to 60GHz



Insertion Loss



TDR (Impedance)

Conclusion

・Achieve the development of high-speed PCB efficiently by controlling materials, processes, and design

・Via's characteristic control is the effective technology for high-speed transmission

・Through the simulation with high correlation up to 50GHz, realize the required characteristic with proper cost

・Aim correlation on 100 GHz as next step

Thank You