A Practical Method for 3D-Modeling of Glass Weave

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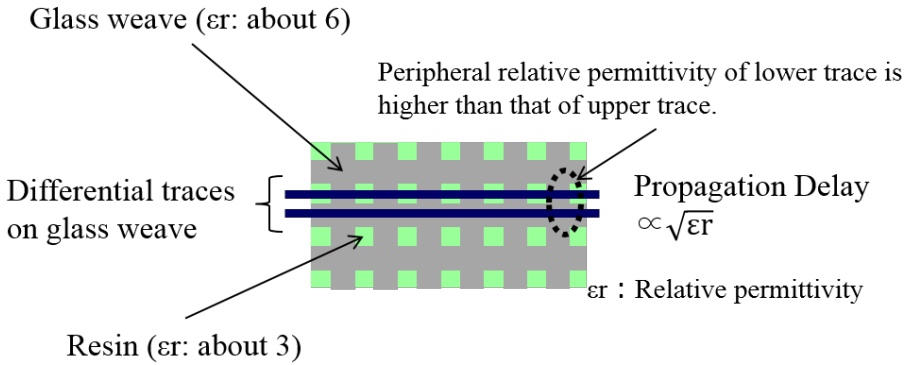
Contents

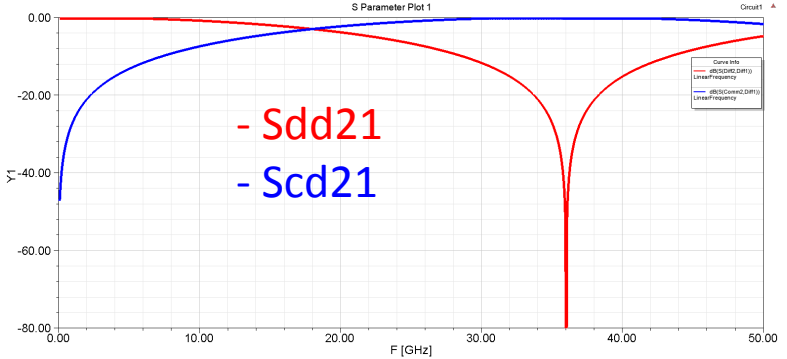
Introduction : Glass Weave Effect

- **Glass Weave Effect**

Feature of relative permittivity of glass epoxy



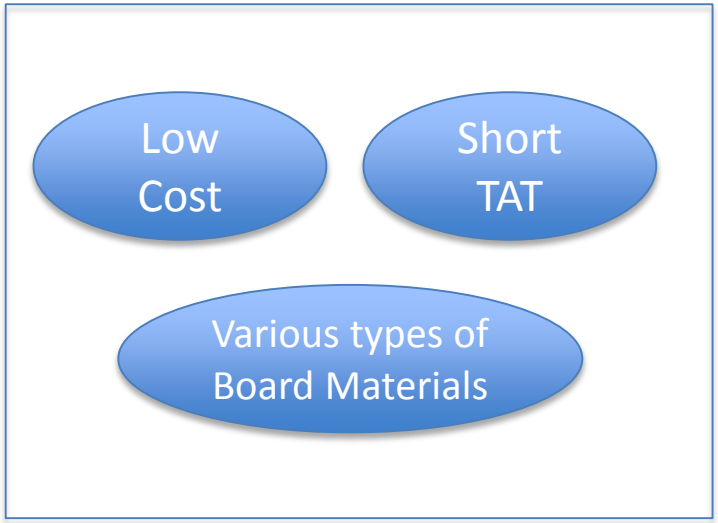
Sdd21 / Scd21 is particularly affected at high frequency.



We need to design PCB with consideration of glass weave effect.

Introduction : Feature of our modeling method

Requests to us
on the consumer product design



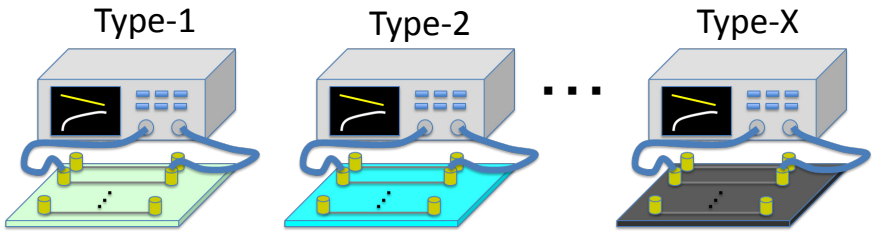
Our Needs

- **"Short TAT" and "A Simple Verification Method" for glass weave**

Introduction : Related Work

- **Some methods based on measurement**

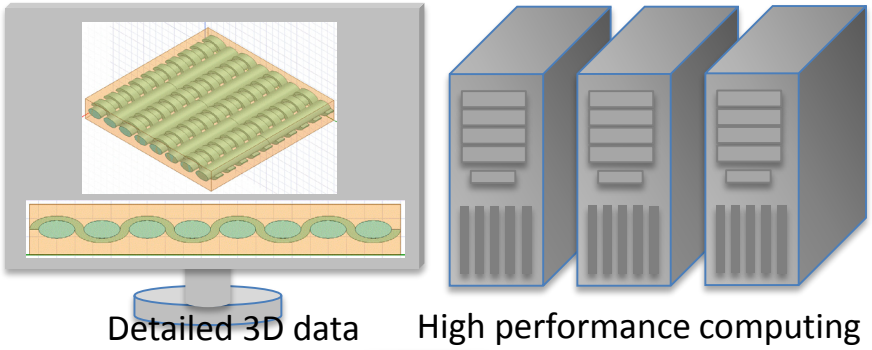
Test Boards & Measurement



- Accuracy is OK
- It requires long time and high cost

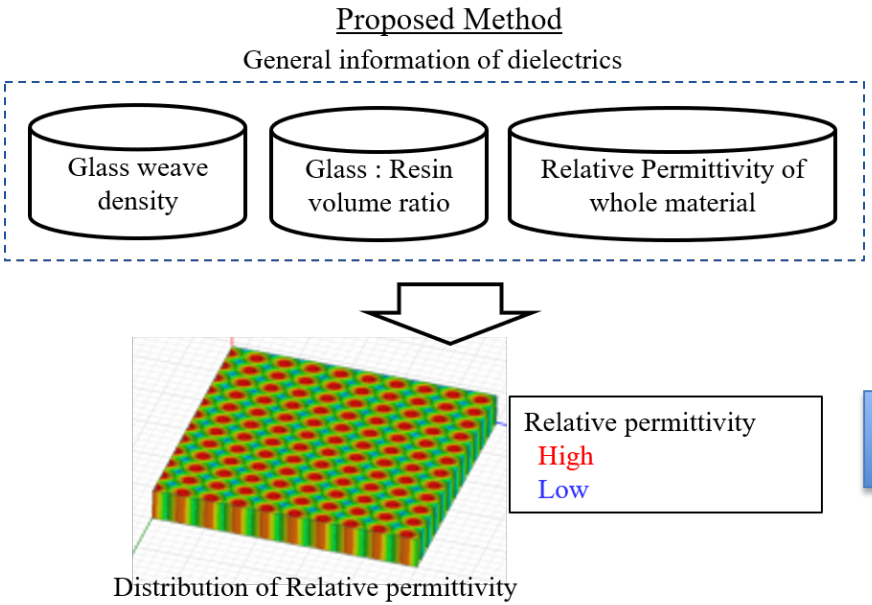
- **The simulation with glass weave**

Simulation model of physical glass weave



- Accuracy is OK
- It requires large scale computing resource and long simulation time

Introduction : Outline of proposed method



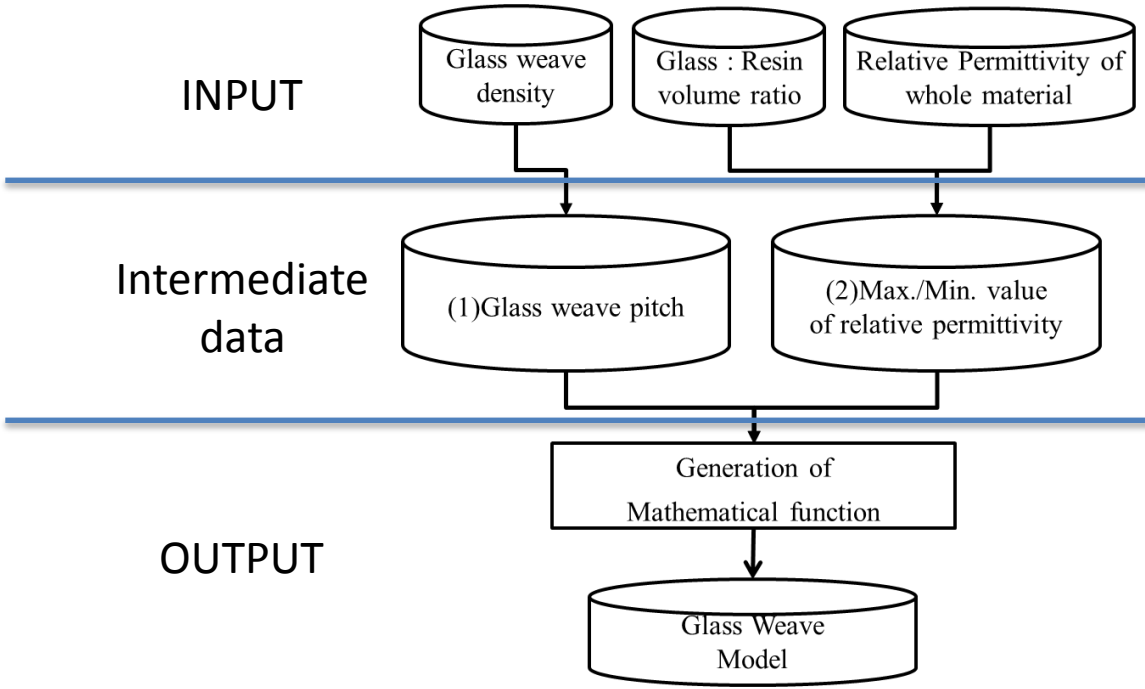
- **Simulation time is as short as the conventional method.**
- **Appropriate correlation between measurement and simulation**

Expressed mathematics distribution of relative permittivity

Contents

Modeling Flow

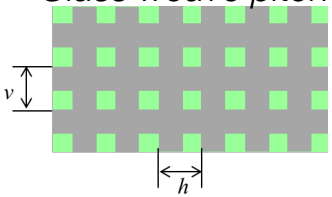
- **The flow of proposed method for modeling glass weave**



General information of dielectrics

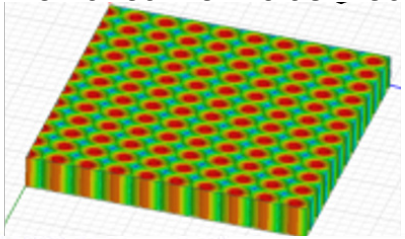
Type	Weave Density [bundle/inc]	Glass/resin Ratio	Relative permittivity
Type-A	60 x 47	33:67	4.0
Type-B	60 x 58	49:51	4.4

Glass weave pitch



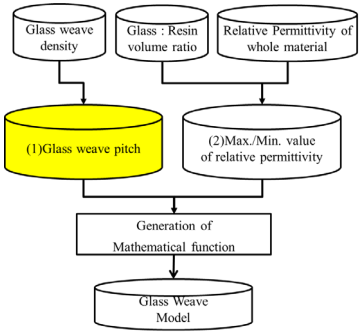
$\varepsilon_{max}, \varepsilon_{min}$

Mathematical Formulas Model



Calculation of glass weave pitch

- **60 bundles of glass fibers exist per one inch horizontally and 47 bundles vertically in Type-A case below.**



Type	Weave Density [bundle/inch]	Glass/resin Ratio	Relative permittivity
Type-A	60 x 47	33:67	4.0
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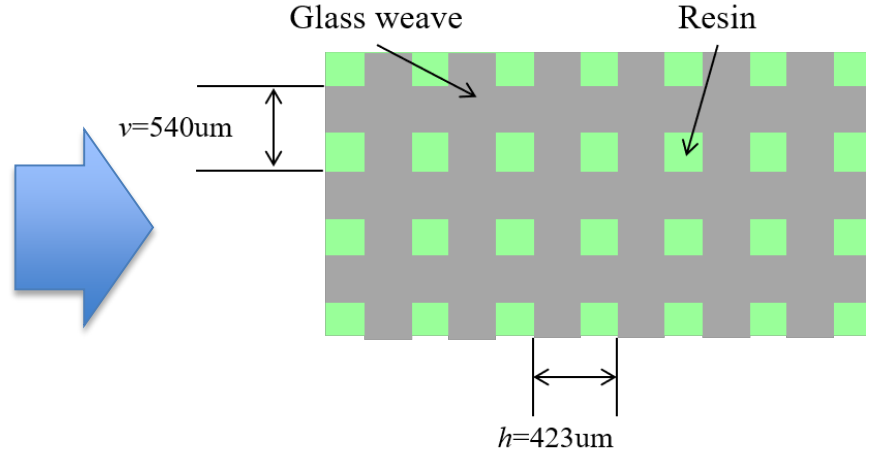
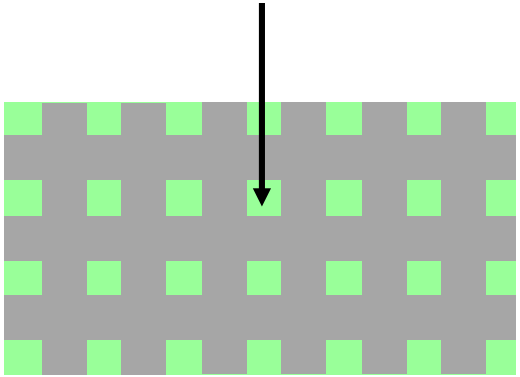


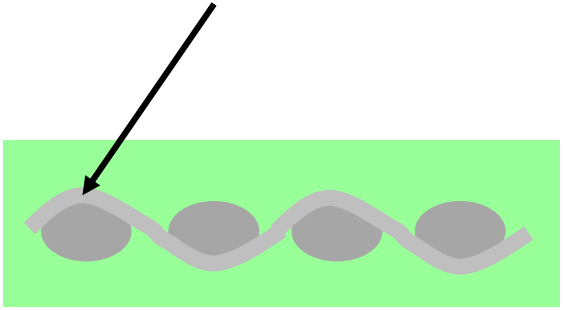
Min, max value of relative permittivity

ε_{min} is found here.
(where only resin exists.)

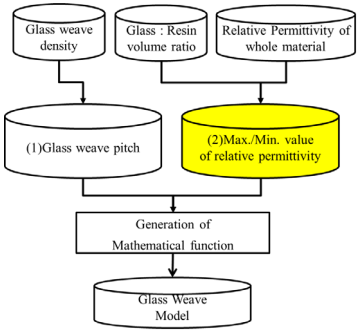


Top View

ε_{max} is found here.
(where glass weave is thickest)



Cross section



- We need to know the relative permittivity of resin and glass respectively to calculate ε_{min} and ε_{max} .

Equation about relative permittivity

- **The relative permittivity of resin and glass can be calculated from the equation below.**

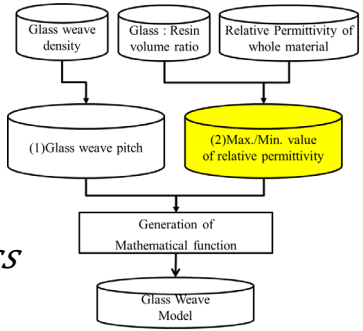
$$\varepsilon r\_board = \varepsilon r\_resin \times volume\_ratio\_resin + \varepsilon r\_glass \times volume\_ratio\_glass$$

Unknown

Unknown

Type	Weave Density [bundle/inc]	Glass/resin Ratio	Relative permittivity
Type-A	60 x 47	33:67	4.0
Type-B	60 x 58	49:51	4.4

Calculation of ε_{min}



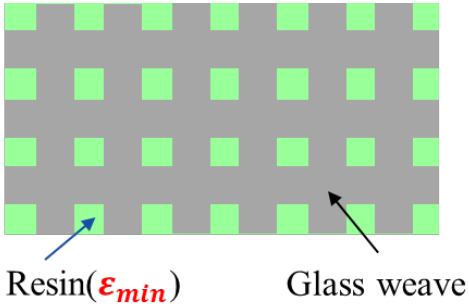
- **Calculation of ε_{min} values = εr_resin**
  - Using at least two types of board structures with same materials, the relative permittivity of resin and glass can be calculated.
    - $\varepsilon r\_board = \varepsilon r\_resin \times volume\_ratio\_resin + \varepsilon r\_glass \times volume\_ratio\_glass$

$\varepsilon r\_resin \times 0.67 + \varepsilon r\_glass \times 0.33 = 4.0$

$\varepsilon r\_resin \times 0.51 + \varepsilon r\_glass \times 0.49 = 4.4$

$\varepsilon r\_resin = 3.175(\varepsilon_{min})$

$\varepsilon r\_glass = 5.675$



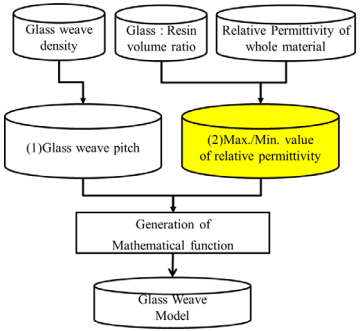
Type	Weave Density [bundle/inc]	Glass/resin Ratio	Relative permittivity
Type-A	60 x 47	33:67	4.0
Type-B	60 x 58	49:51	4.4

Calculation of ε_{max}

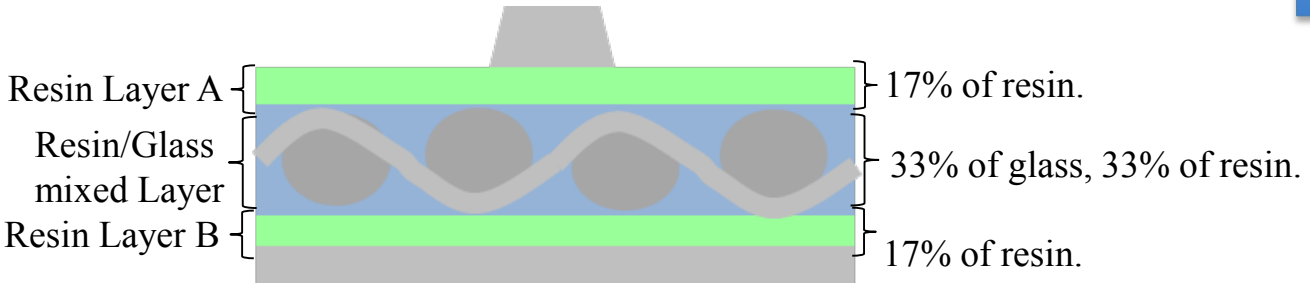
Understanding cross-sectional structure

Determine cross-sectional dimensions

Volume Ratio
Resin：Glass = 67:33



Calculation of max. values of the relative permittivity

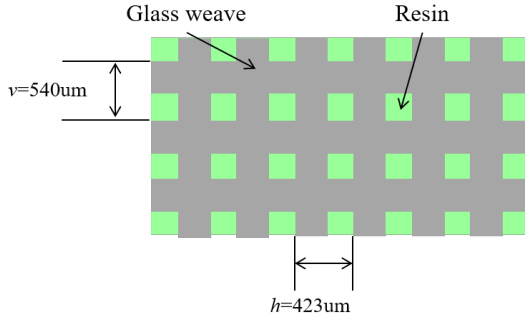


ε_{max} = 3.175 × 0.17*2 + 5.675 × 0.66

ε_{max} = 4.825

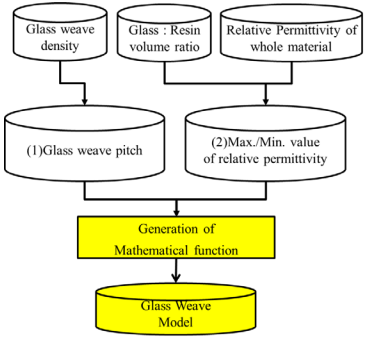
Distribution of relative permittivity

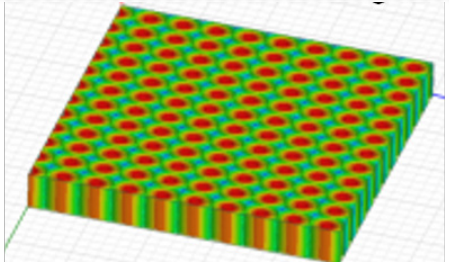
- Calculation of glass weave pitch



- Calculation of ε_{min}, ε_{max} values
  - ε_{min} = 3.175
  - ε_{max} = 4.825

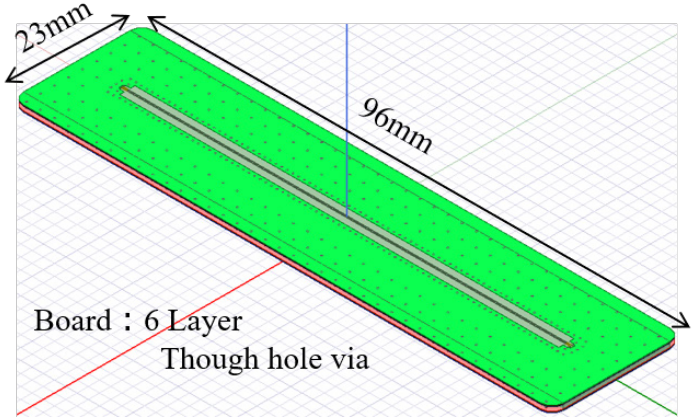
A mathematical formula of the position dependent relative permittivity distribution





Simulation using 3D EM solver

- **Comparison of analysis time between A and B**
  - Case1 and case2 is almost same both analysis time and used memory
    - *Our request is satisfied.*



Case	Glass weave model	Analysis Time	Used Memory
1	None	8 hours 02 minutes	43.5GB
2	Proposed method	7 hours 35 minutes	41.0GB

Contents

- **Introduction**
  - Glass weave effect
  - Features of our modeling method
  - Related Work
  - Outline of proposed method
- **A practical method for 3D-modeling of glass weave**
  - Proposed method for modeling glass weave
- **Experimental board and Measurement**
  - Modeling of surface roughness of copper foil
  - Experimental board considering the influence of glass weave
  - Comparison between measurement and simulation
- **Conclusion**

Verification Flow

- **The following 2 processes for verification of proposed method**

First Step

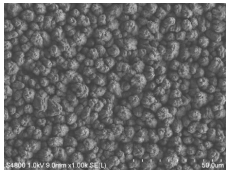
Verification of
Modeling of Loss Factors

Using single-End trace

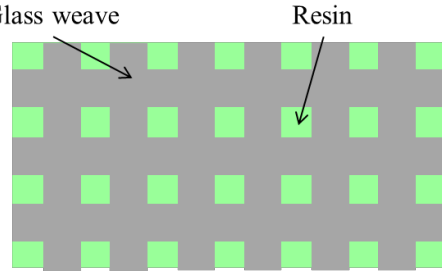
Second Step

Verification of
Modeling of Glass weave

Using differential traces



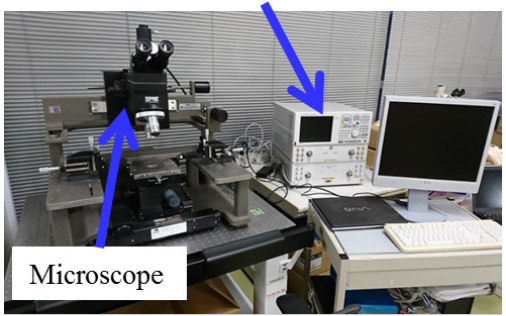
Key factor :
Surface Roughness



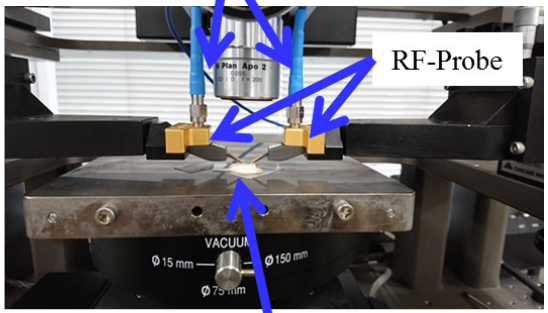
Measurement environment

- **Network Analyzer, Coaxial Cable, RF Probe**
- **Frequency range for measurement : 10MHz-30GHz**
- **Calibration was used SOLT method.**
- **The calibration plane was placed on the edge of RF probes.**

Network analyzer
(Keysight E8364/10MHz-50GHz)

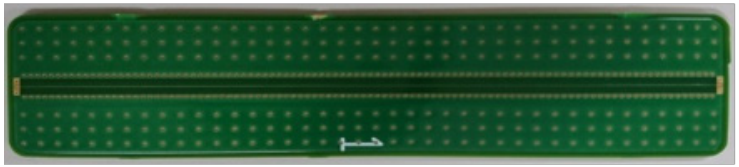


Coaxial Cable



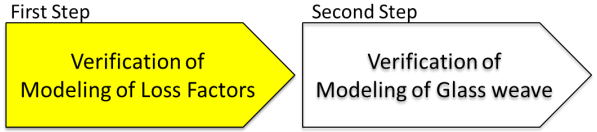
Calibration Board/DUT

Experimental board of single-end trace



- Board: Six-Layer Through hole via
- Relative permittivity: 4.4 (1 GHz)
- Tanδ: 0.01 (1 GHz)
- Microstrip Line
- Line Length: 100 mm

Modeling methods of surface roughness



- **The following main three methods were checked comparison between measurement and simulation.**

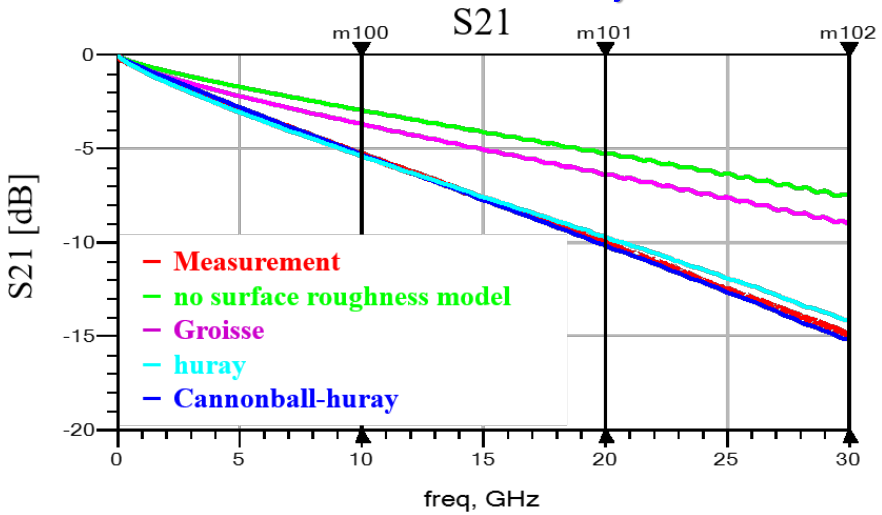
Modeling Method	Input information	Feature
Groisse	Rq (Root mean square of surface roughness)	Getting input information is easy. Accuracy is not high.
Huray	Radius of particle Surface Area Index	Getting input information is difficult. Accuracy is high.
Cannonball-Huray	Rz(Max height of surface roughness)	Getting input information is easy. Accuracy is high.

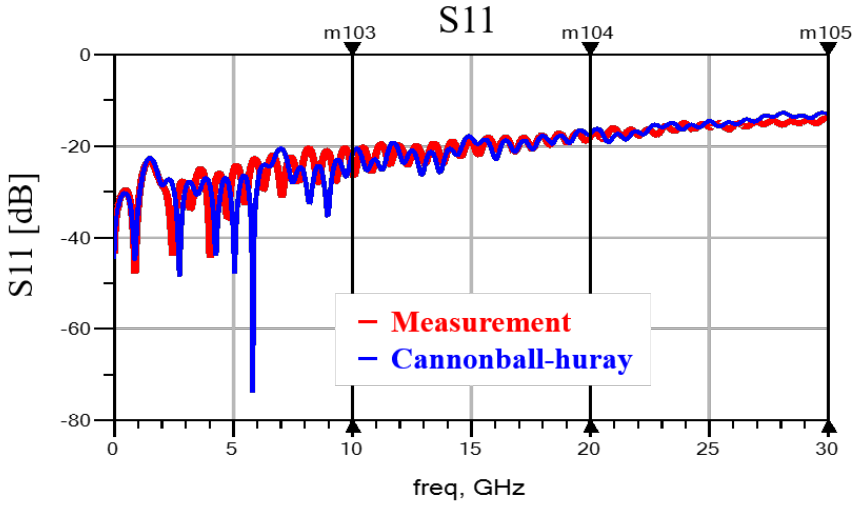
Simulation accuracy for single-end trace

First Step: Verification of Modeling of Loss Factors

Second Step: Verification of Modeling of Glass weave

- **The comparison between measurement and simulation**
  - The accuracy of *Huray* and *Cannonball-Huray* is very good.
  - The accuracy of *Groisse's* method is not good.
  - We selected Cannonball-Huray method.





Verification Flow

- **The following 2 processes for verification of proposed method**

First Step

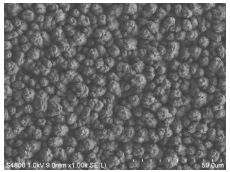
Verification of
Modeling of Loss Factors

Using single-End trace

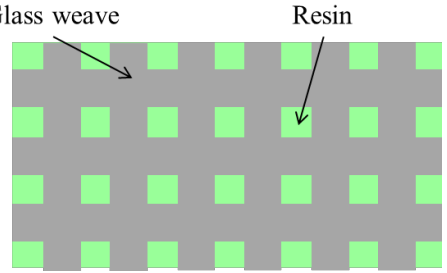
Second Step

Verification of
Modeling of Glass weave

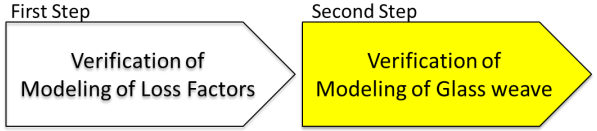
Using differential traces



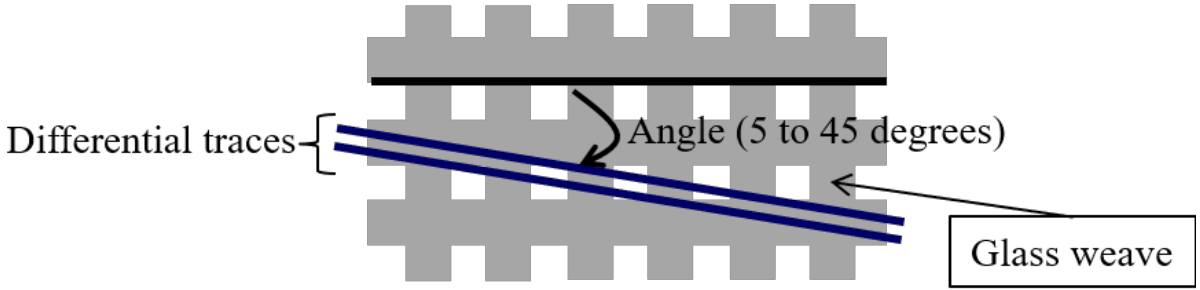
Key factor :
Surface Roughness



Diagonal differential traces



- **Measurement and simulation accuracy check for 3D-modeling of glass weave**
  - We did two kinds of experiments.
    - *The first experiment was to check the effect of diagonal traces.*

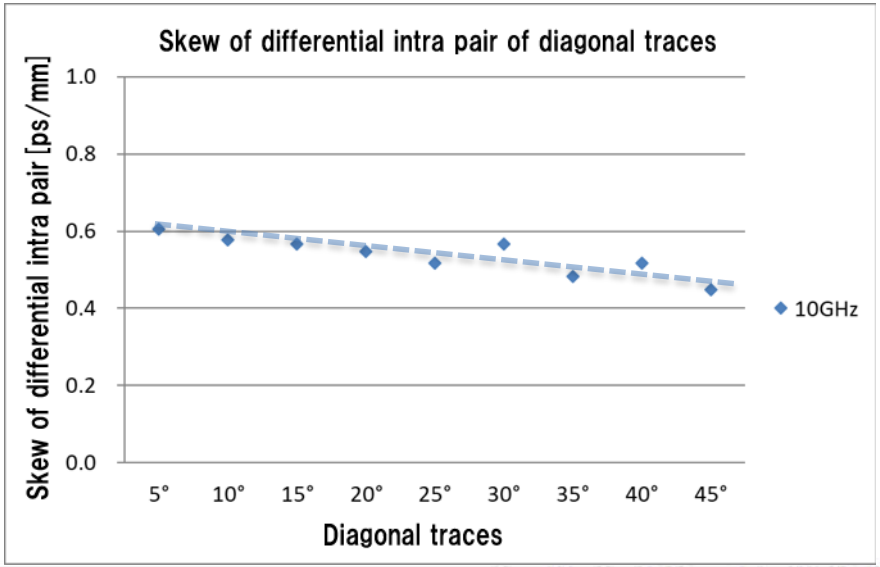


Measurement results of diagonal traces

First Step: Verification of Modeling of Loss Factors

Second Step: Verification of Modeling of Glass weave

- **The skew tends to decrease as the trace angle becomes bigger.**
- **The result is as expected.**

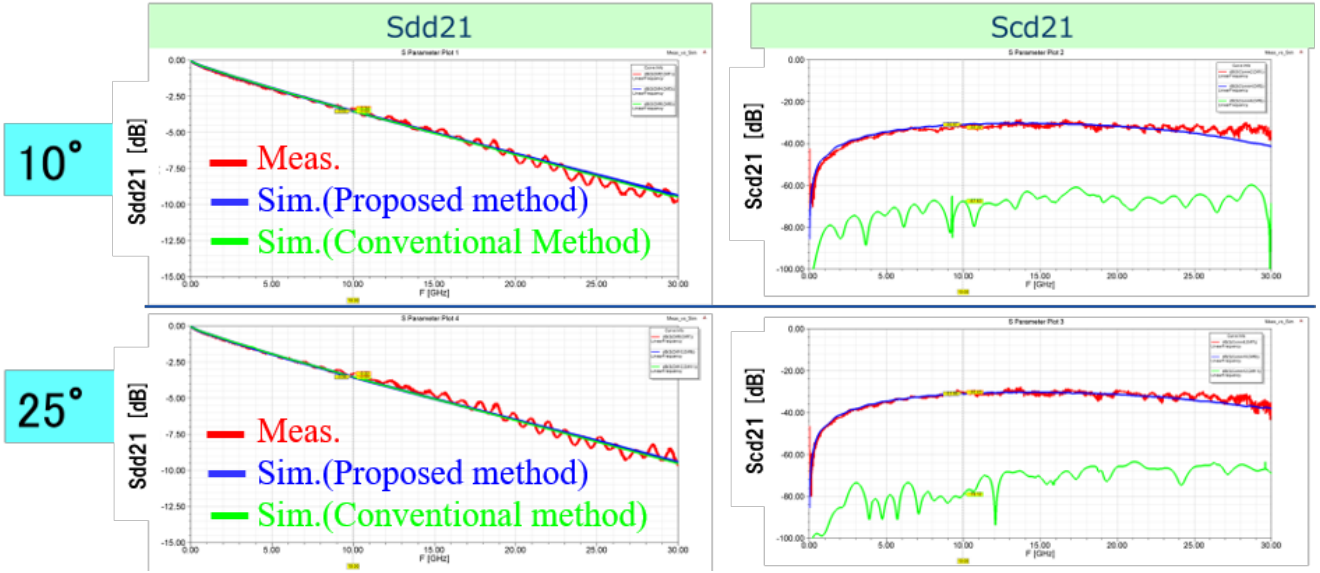


Simulation accuracy for diagonal traces

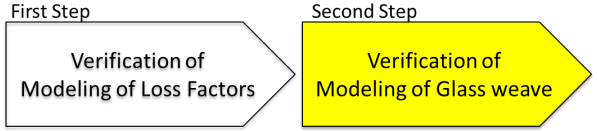
First Step: Verification of Modeling of Loss Factors

Second Step: Verification of Modeling of Glass weave

- **The comparison between measurement and simulation for diagonal traces**
  - Good correlation between measurement and proposed method, especially about Scd21.

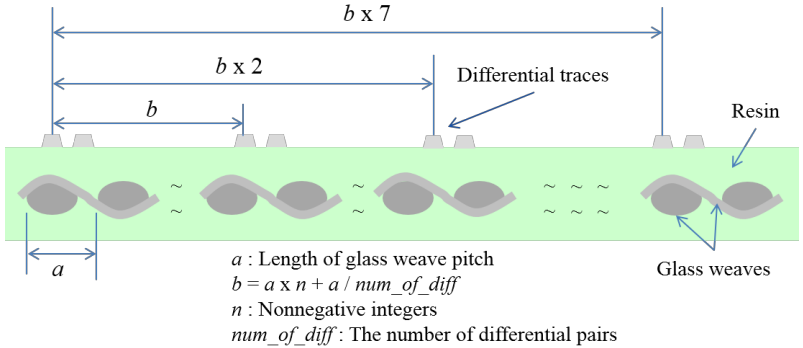


Position-shifted traces



- **Measurement and simulation accuracy check for differential trace**
  - We did two kinds of experiments.
    - *The second experiment was to check the skew variation when the positional relationship between glass weave and differential pairs changed.*

The second experiment

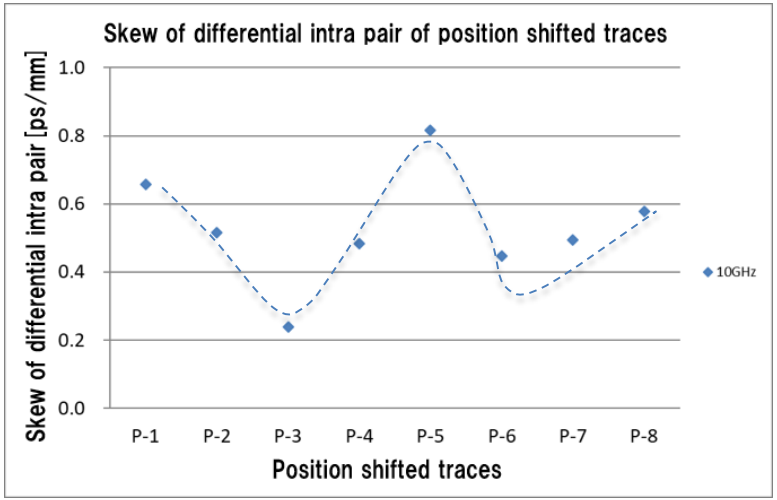


Measurement results for position-shifted traces

First Step: Verification of Modeling of Loss Factors

Second Step: Verification of Modeling of Glass weave

- **The results of experimental boards**
  - Each differential pair has different skew, and the change of skew looks like periodic.

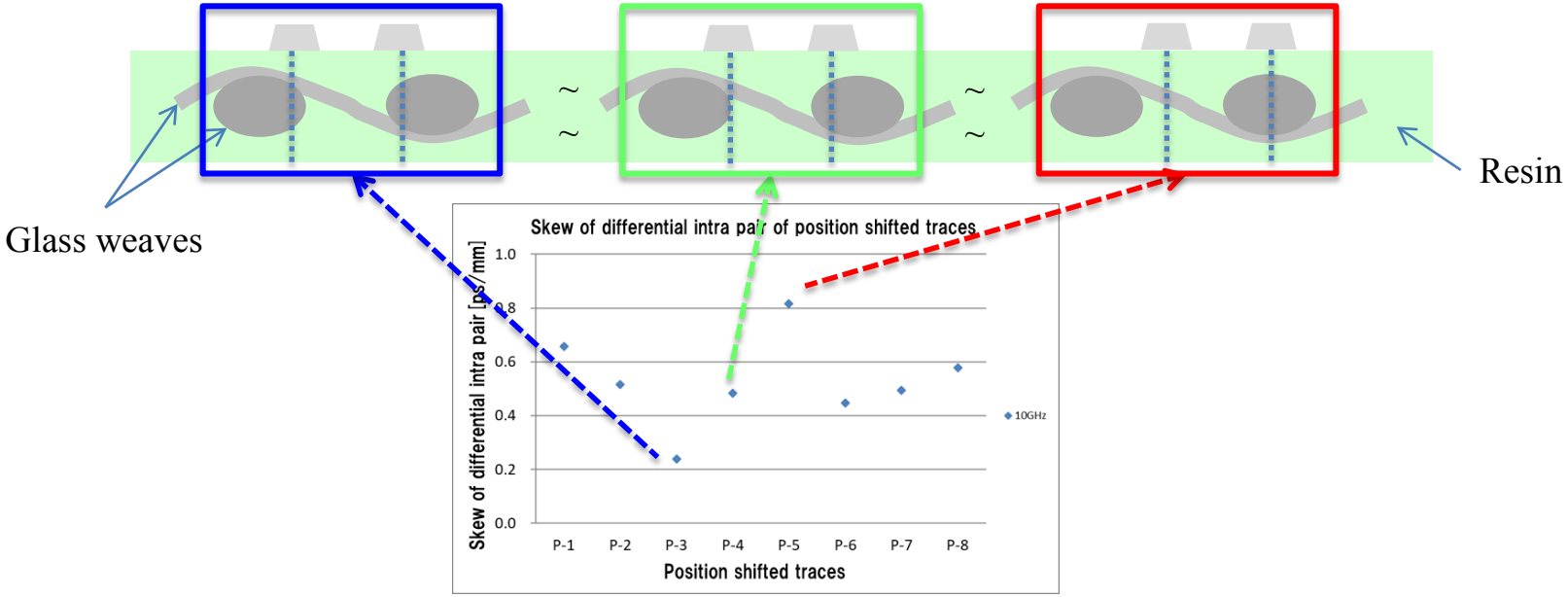


Positional relationship between glass and traces

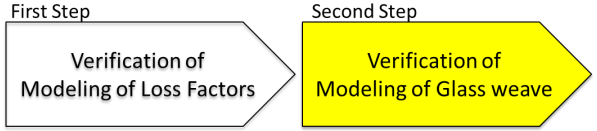
- **The difference of relative permittivity between POS and NEG makes the intra-pair skew.**

First Step: Verification of Modeling of Loss Factors

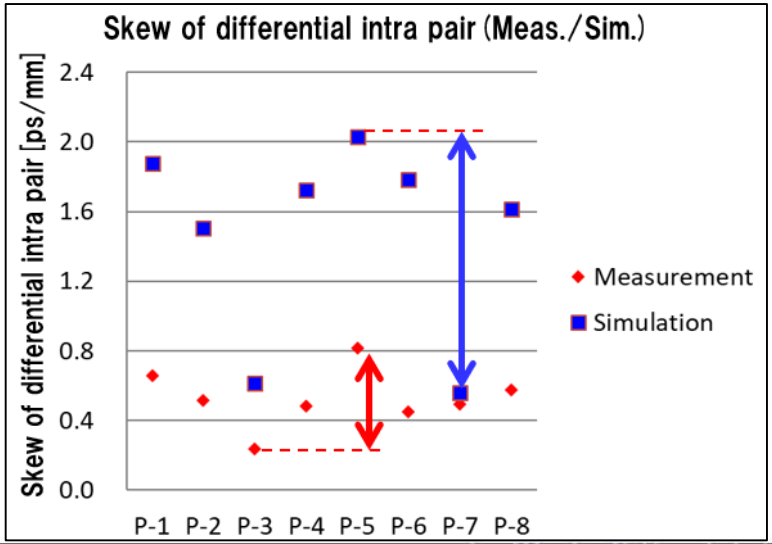
Second Step: Verification of Modeling of Glass weave



Difference between measurement and simulation



- **The comparison between measurement and simulation for position-shifted traces**
  - The range of skew change by position shift is different between measurement and simulation.
  - The measured skew is smaller than expected.



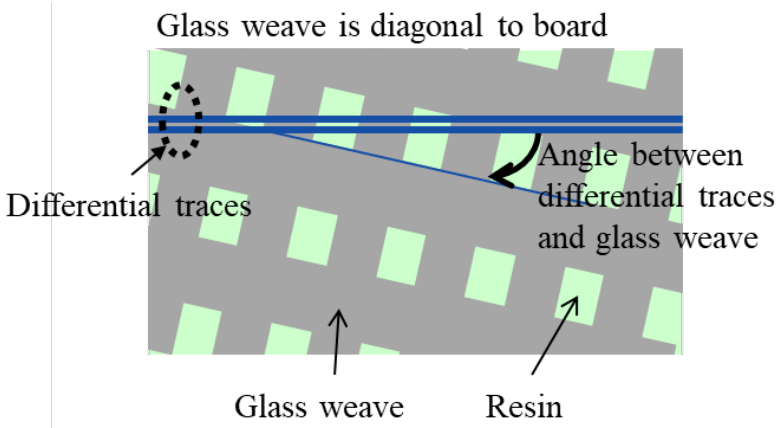
A hypothesis for the cause of difference

First Step: Verification of Modeling of Loss Factors

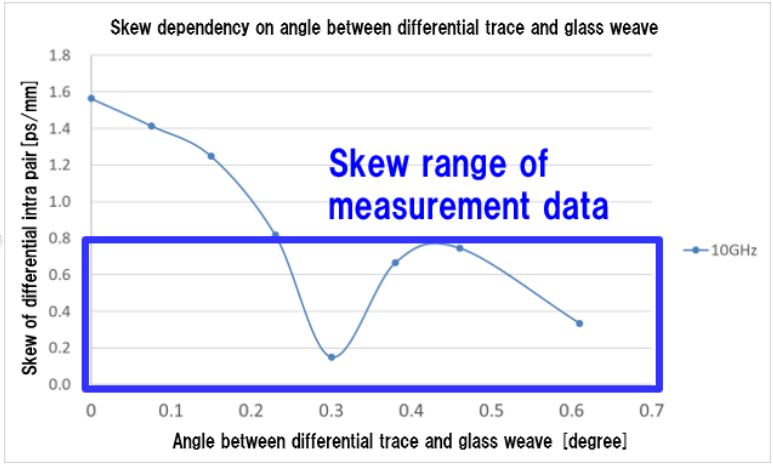
Second Step: Verification of Modeling of Glass weave

- **A hypothesis**
  - The small angle between glass weave and test board itself can be a main cause of this difference.

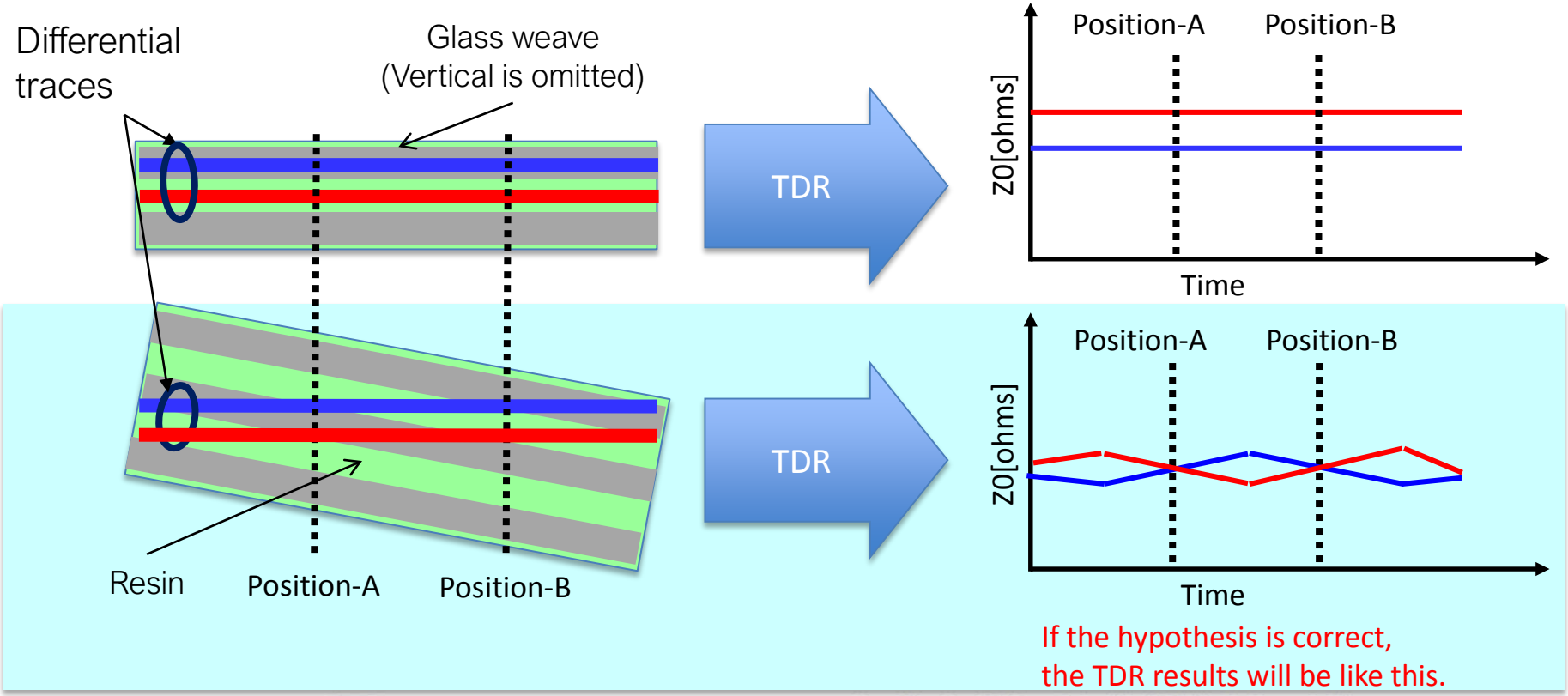
The small angles was able to make the intra-pair skew as small as the measurement results.



Simulation



Verification of the hypothesis



If the hypothesis is correct,
the TDR results will be like this.

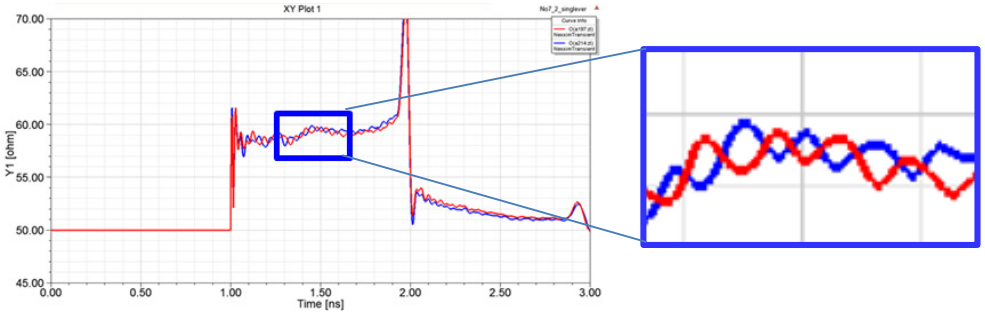
TDR results for 5 degrees angled traces

First Step: Verification of Modeling of Loss Factors

Second Step: Verification of Modeling of Glass weave

- **At first, we confirmed the TDR results with 5 degrees traces.**
  - The characteristic impedance reverses about 30 times.

TDR result of 5 degrees diagonal traces



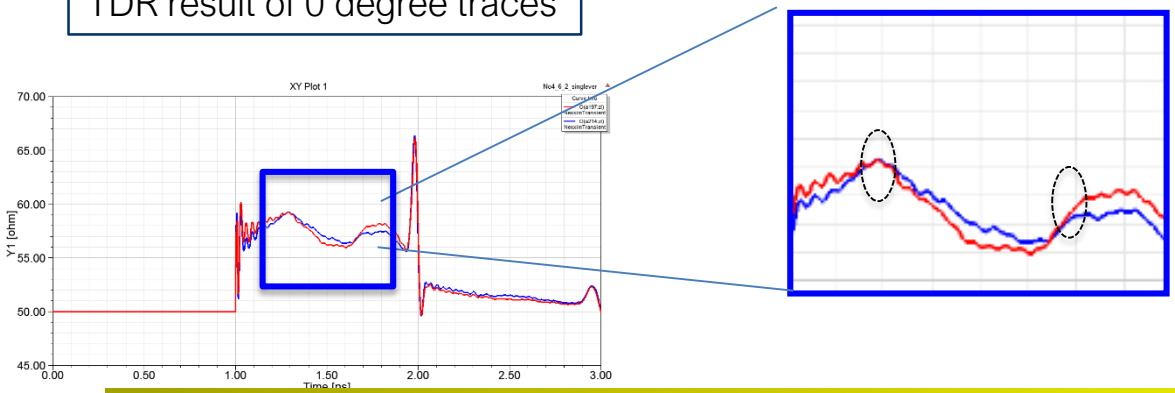
TDR results for 0 degree traces

First Step: Verification of Modeling of Loss Factors

Second Step: Verification of Modeling of Glass weave

- **We confirmed the TDR results with 0 degree traces.**
  - The angle is approximately 0.5 degrees.
    - *This value can be calculated by the length of the traces and the period of impedance reversing.*

TDR result of 0 degree traces



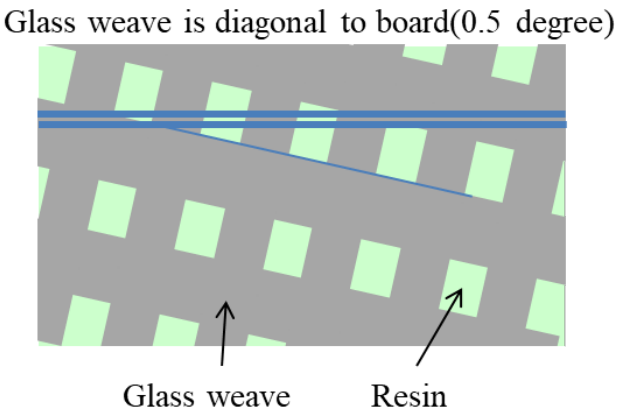
The hypothesis that there is small angle between board and glass weave looks like correct.

Simulation accuracy with small angle

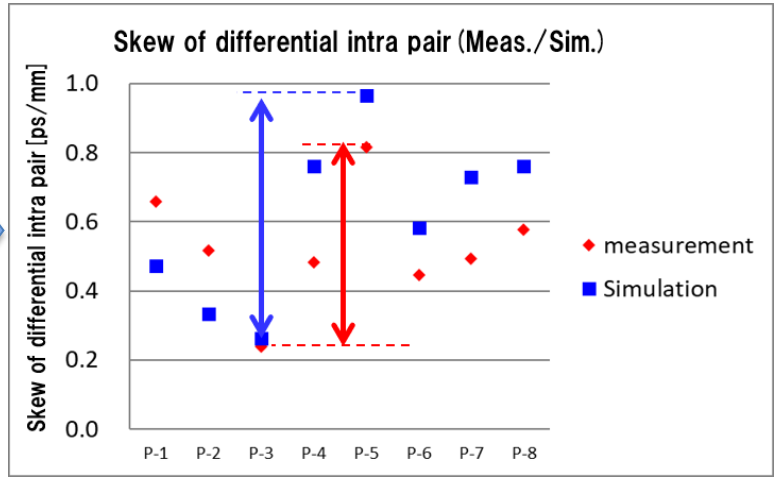
First Step: Verification of Modeling of Loss Factors

Second Step: Verification of Modeling of Glass weave

- **The simulation results becomes much closer to the measurement results by applying small angle between the traces and glass weave.**



Simulation



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Conclusion

- We proposed a practical method to make models of glass weave for 3D EM solver.
- In this method, the required information can be obtained easily from board material manufacturers.

- The analysis time of EM solver is not increased when the proposed method is applied.
- We also confirmed there was enough correlation between simulation and measurement result.

Thank you!

QUESTIONS?