TPC pad simulation for wide dynamic range application

2011-01-12

Workshop on advanced detector technology for nuclear physics @RIKEN

Tokyo Metropolitan Industrial Technology Research Institute

Electronics Group

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Outline

1. Brief introduction of TIRI
2. Development motivation
3. Development steps of a TPC pad
4. Crosstalk measurement
5. Impedance measurement
6. New TPC pad development
7. Summary

1. Introduction of TIRI

We are established for small and medium-sized enterprises (SME) .

Support for product development
- Open use of instruments
- Custom-made development support

Technical Assistance
- Requested test
- Technical Consultation

Research & development
- Collaborative research
- Base research

Industrial human Resource development
- Custom-made seminar

Publication of industrial information

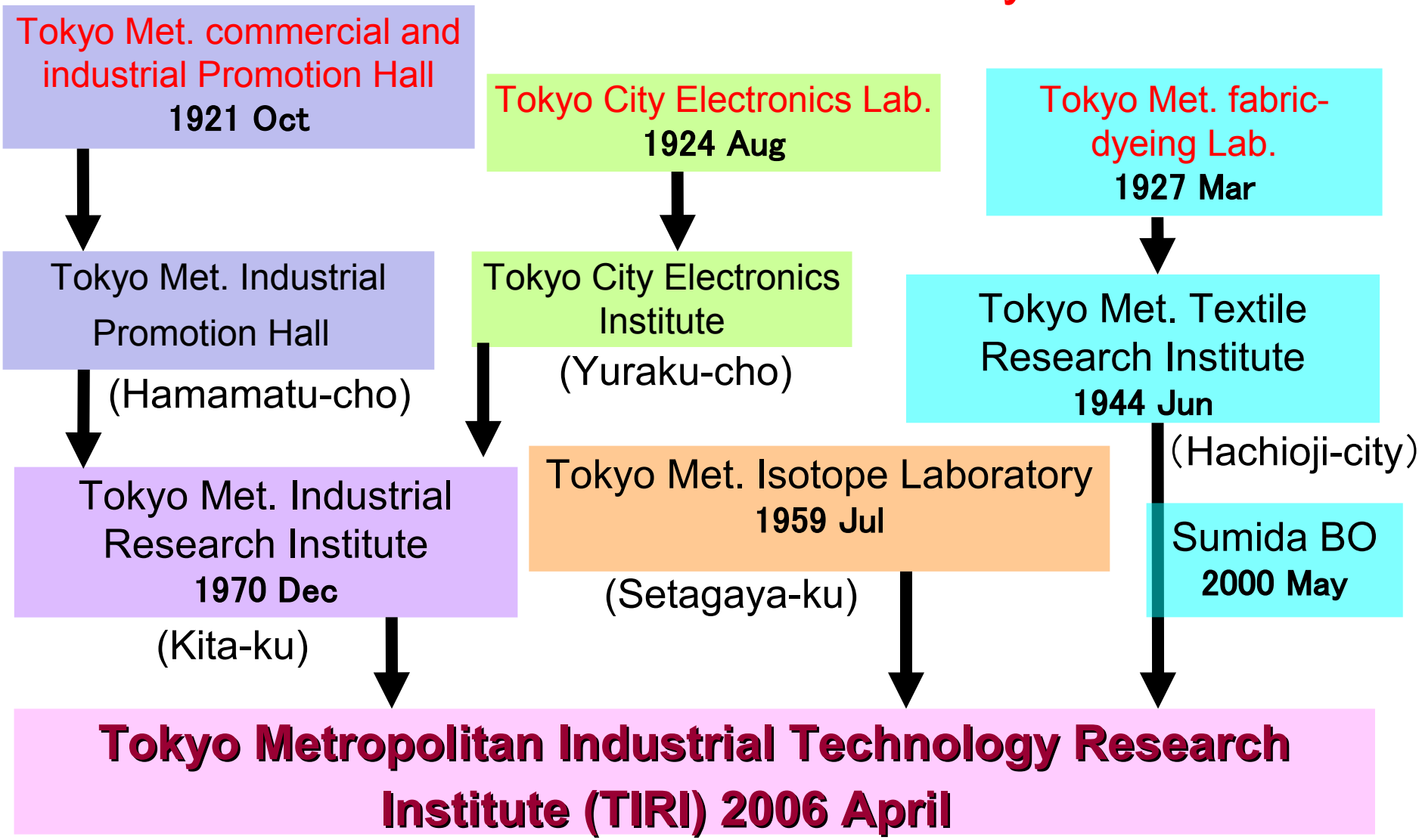
Support for technology management
- Technical review
- Using Intellectual Property

Cooperation and collaboration for industry
- Industry-Government-Academia cooperation

Increase competitiveness of goods and services

Our History

We were established before 90 years.



2. Development motivation

- Pulse height induced in a detector $\propto Z^2$
- Target of the range of Z is Z~10.

In order to obtain the detection dynamic range, the crosstalk level should be less than 0.5%.

3. Development steps of a TPC pad

We are developing a new TPC pad with RIKEN.

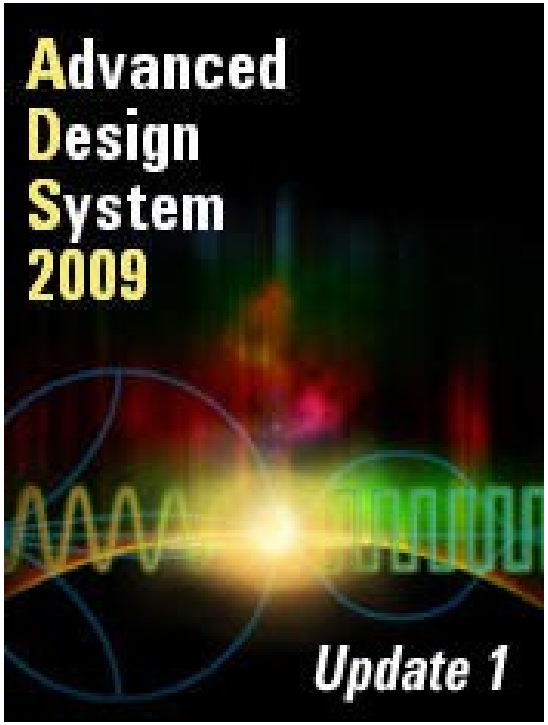
1. Electromagnetic simulation
   - Design lower crosstalk pattern and transmission line.
   - Layer structure, physical parameters
   - Current distribution, S-parameter calculation
2. Circuit Simulation for crosstalk

   Calculate crosstalk level in an adjacent line

   -> Required crosstalk level is less than 0.5%.
3. Making Test board for crosstalk evaluation
4. Design TPC pad

Development Software for the simulation

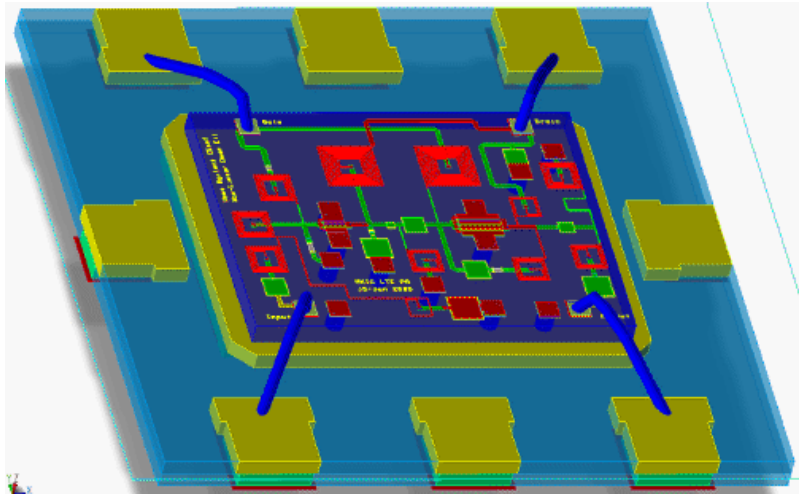
Agilent Technology: Advanced Design System (ADS)



Development for:

- RF circuit, High Speed RF circuit
- Monorisic Microwave IC (MMIC), RFIC
- Transmission Line, Antenna

Example of MMIC design

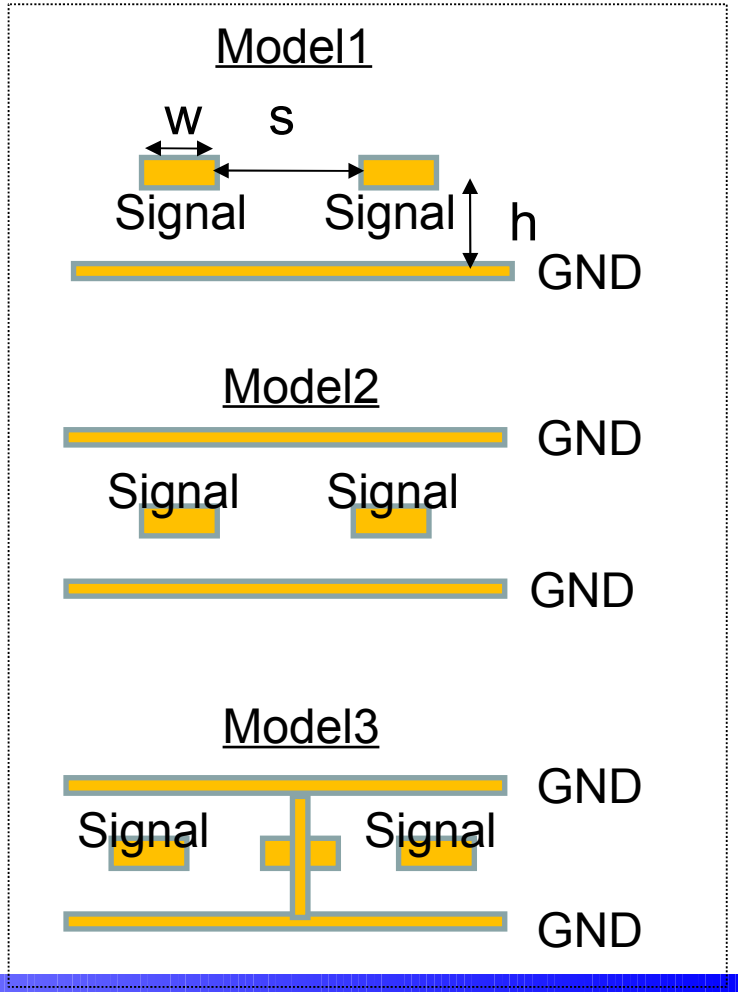


Electromagnetic simulation models

First, development of low crosstalk transmission line in TPC pad

- 3 types of transmission line
- Line width (w): 0.1 mm
- Space (s): 0.1 mm
- Line length:36 mm
- Thickness (h):43 μm
- Substrate: FR-4 (er=4.2, tanδ=0.015)
- Conductivity: 5.8 x10^8 S/m

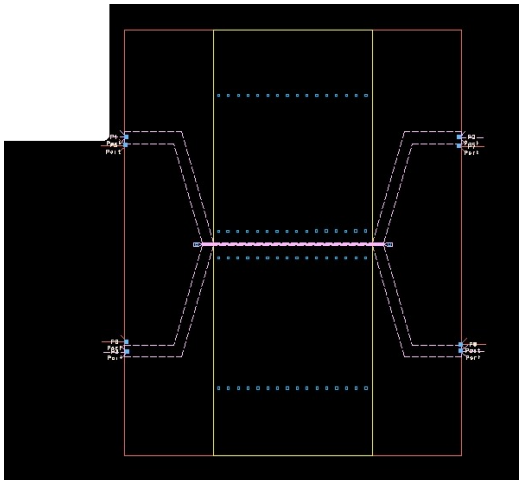
Simulation Models



Result of electromagnetic simulation

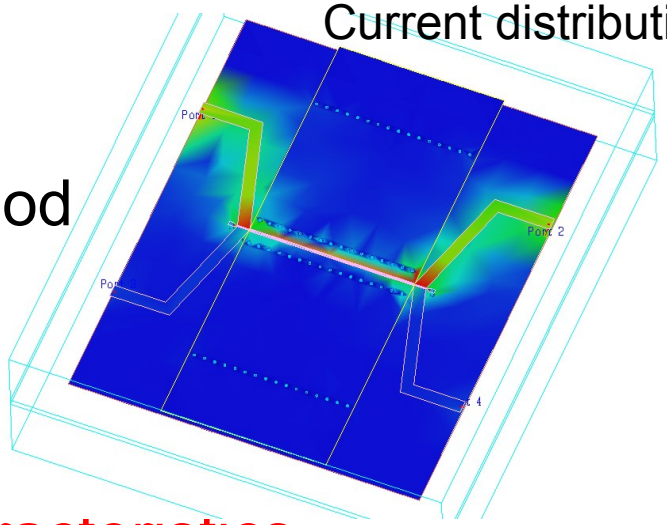
Calculating the S-parameters from 10 MHz to 2.5 GHz.

Electromagnetic simulation model

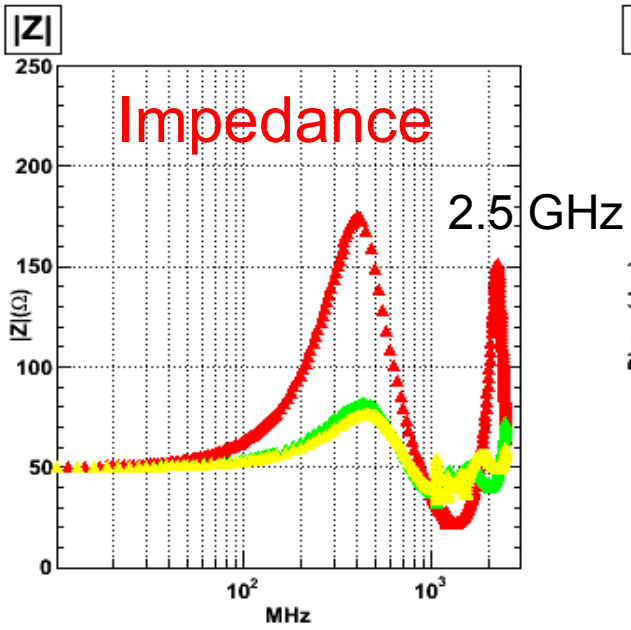


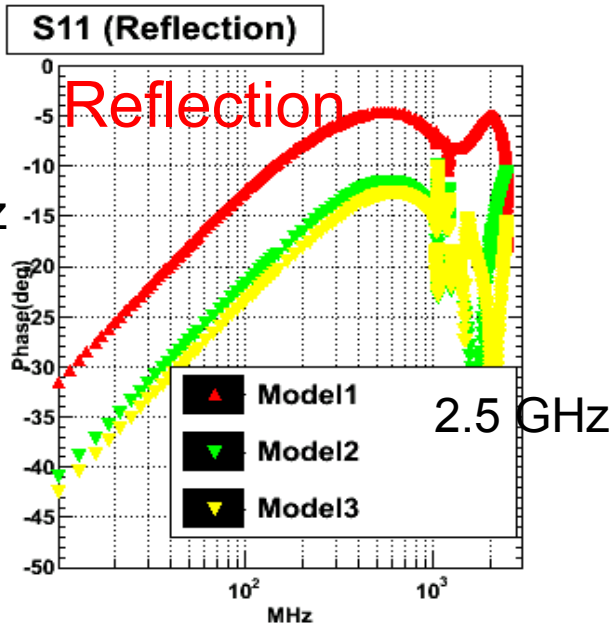
Momentum Method

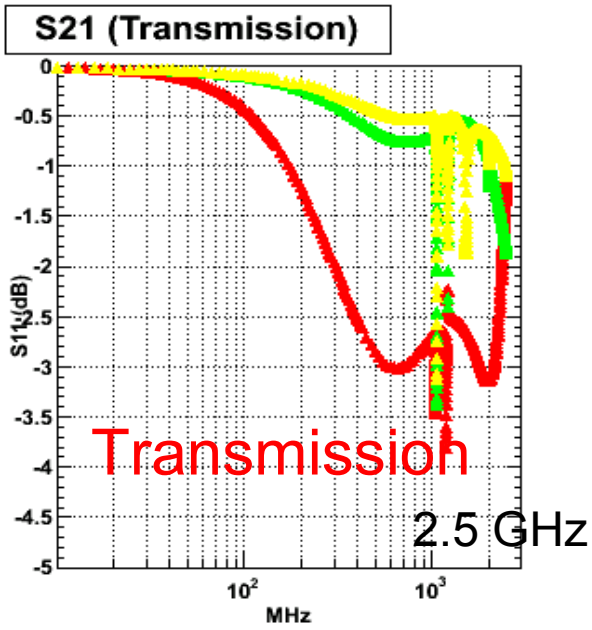
Current distribution



Model3 has the best characteristics.



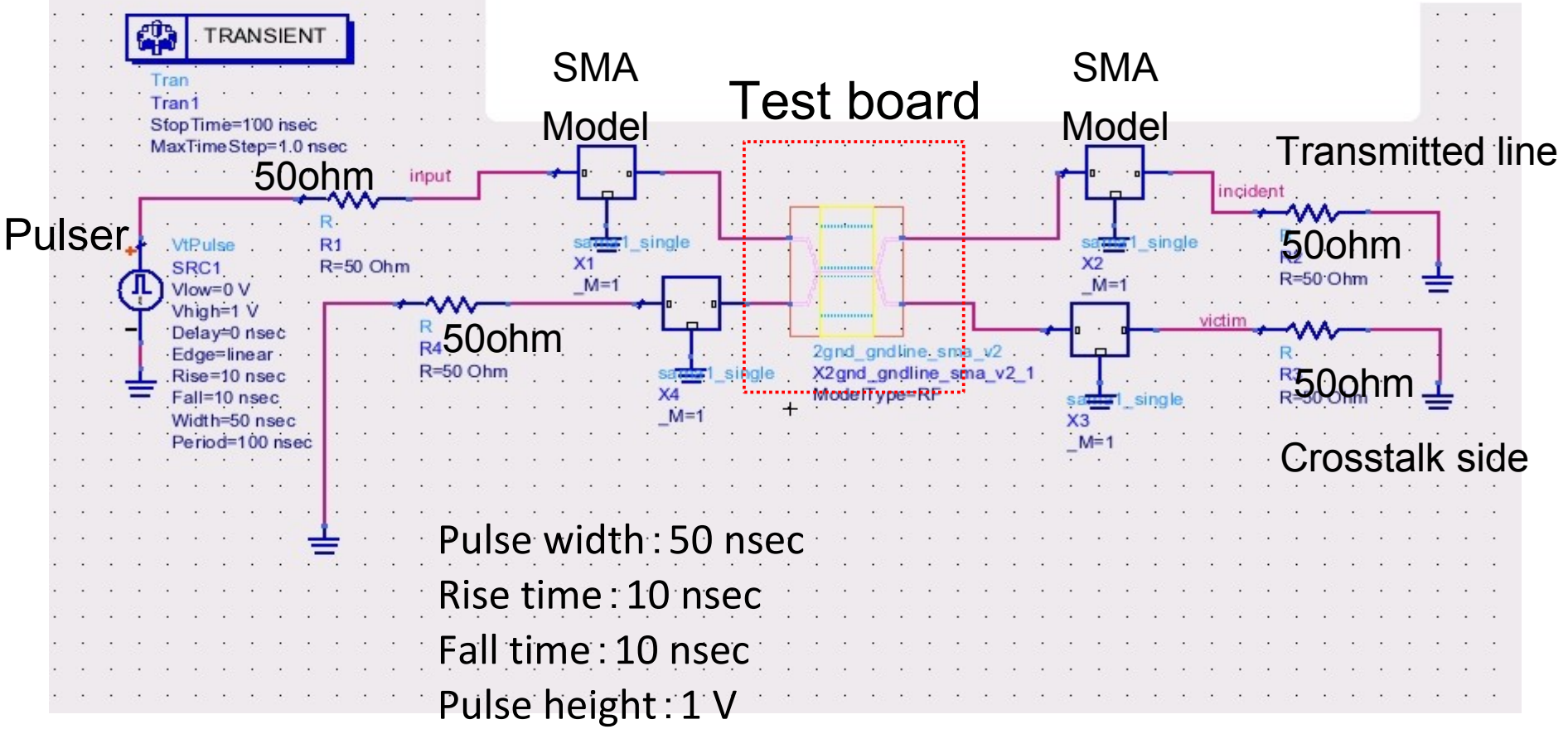




Calculation model for crosstalk evaluation

SMA connector model is included to make a realistic model.

Without connector model is also prepared.



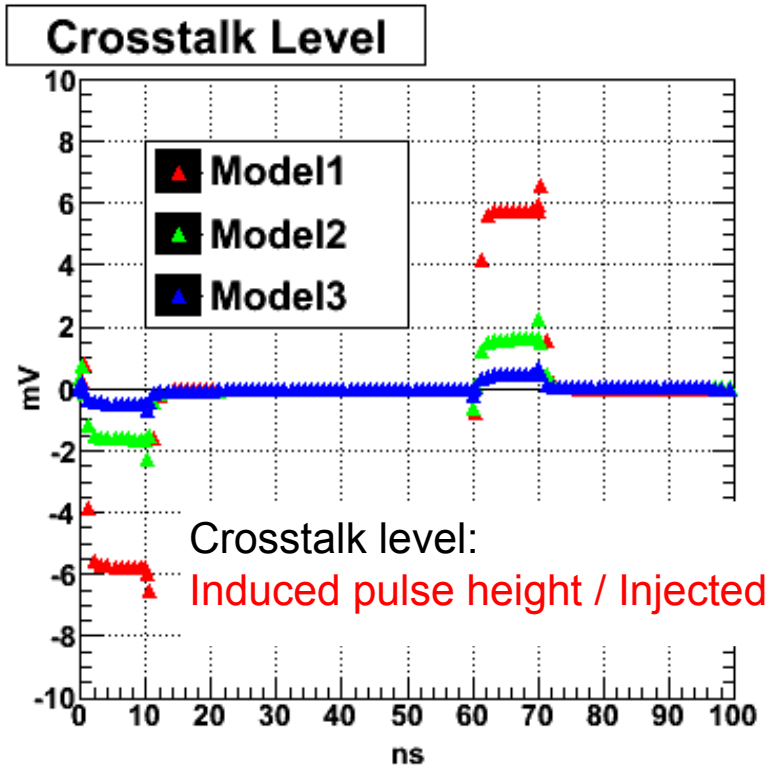
Pulse width : 50 nsec

Rise time : 10 nsec

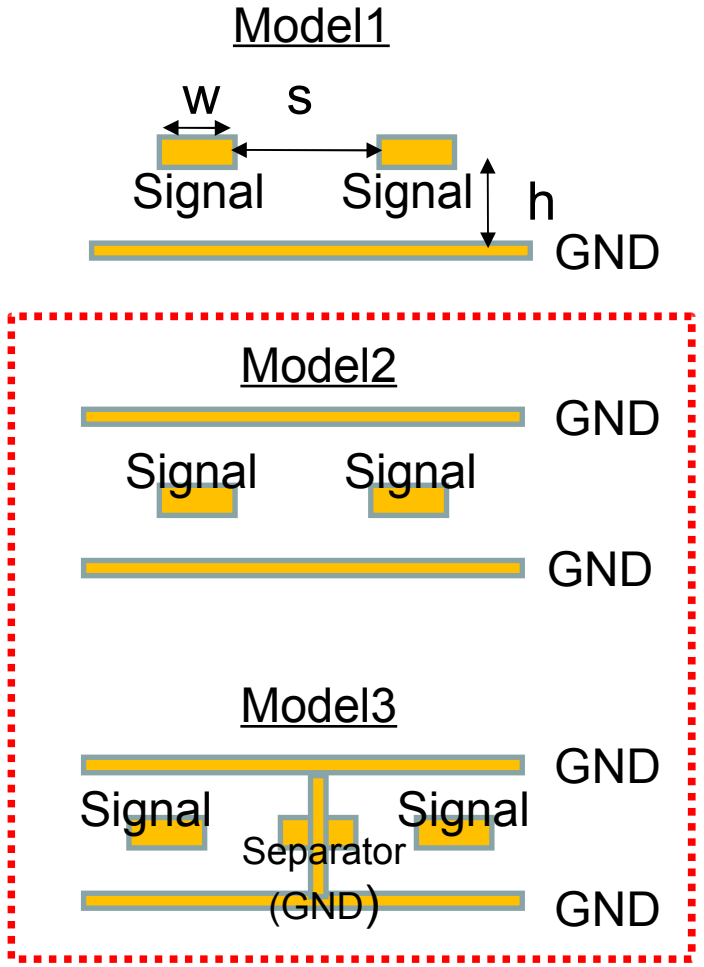
Fall time : 10 nsec

Pulse height : 1 V

Crosstalk level in each models



Crosstalk level:
Induced pulse height / Injected pulse height

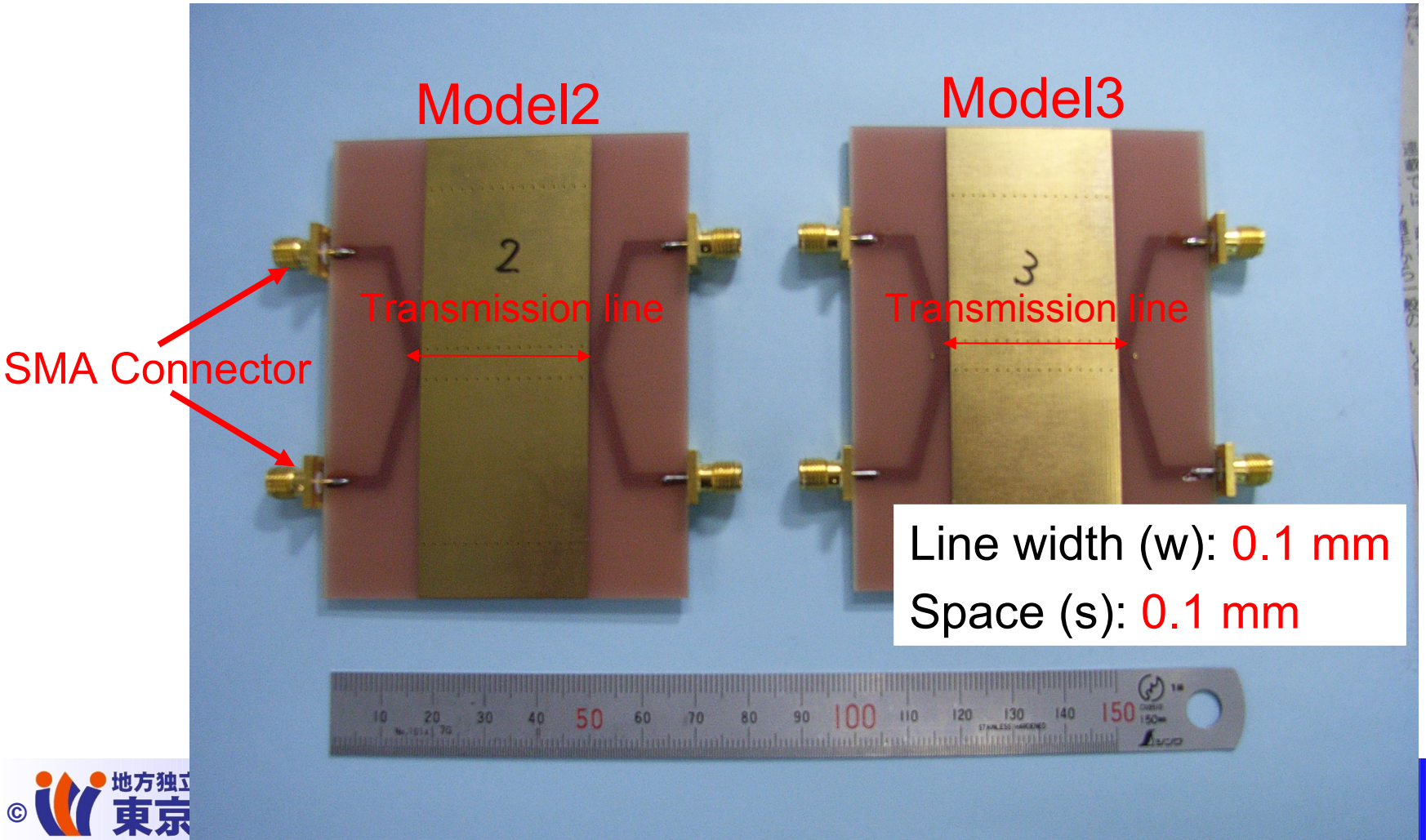


	Crosstalk Level (no SMA)	Crosstalk Level (with SMA)
Model1	1.67%	1.70 %
Model2	0.31%	0.33%
Model3	0.08%	0.08%

Crosstalk level of Model3 is also the best.

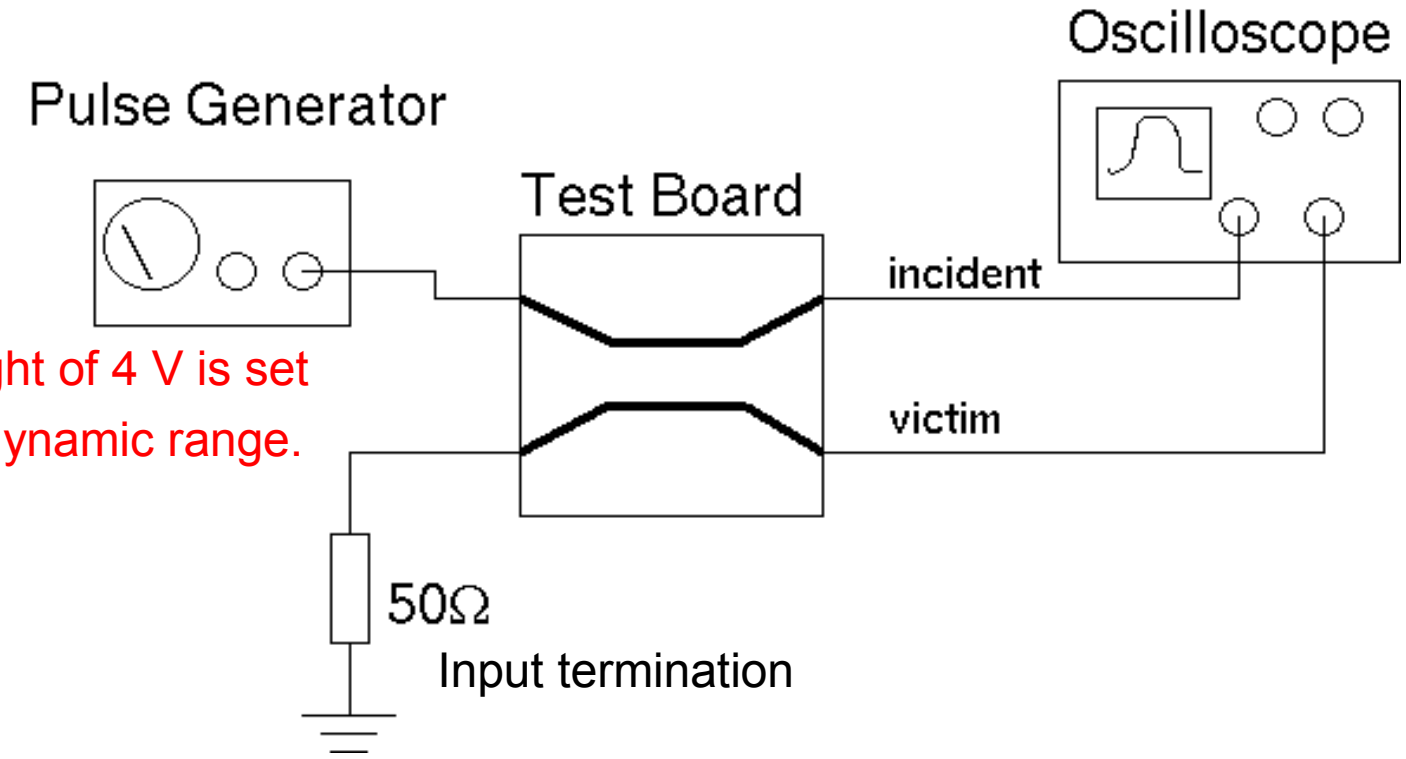
Test boards

- To evaluate transmission line in Model2 and Model3.
- Measured cross talk level, impedance are compared with simulation result.



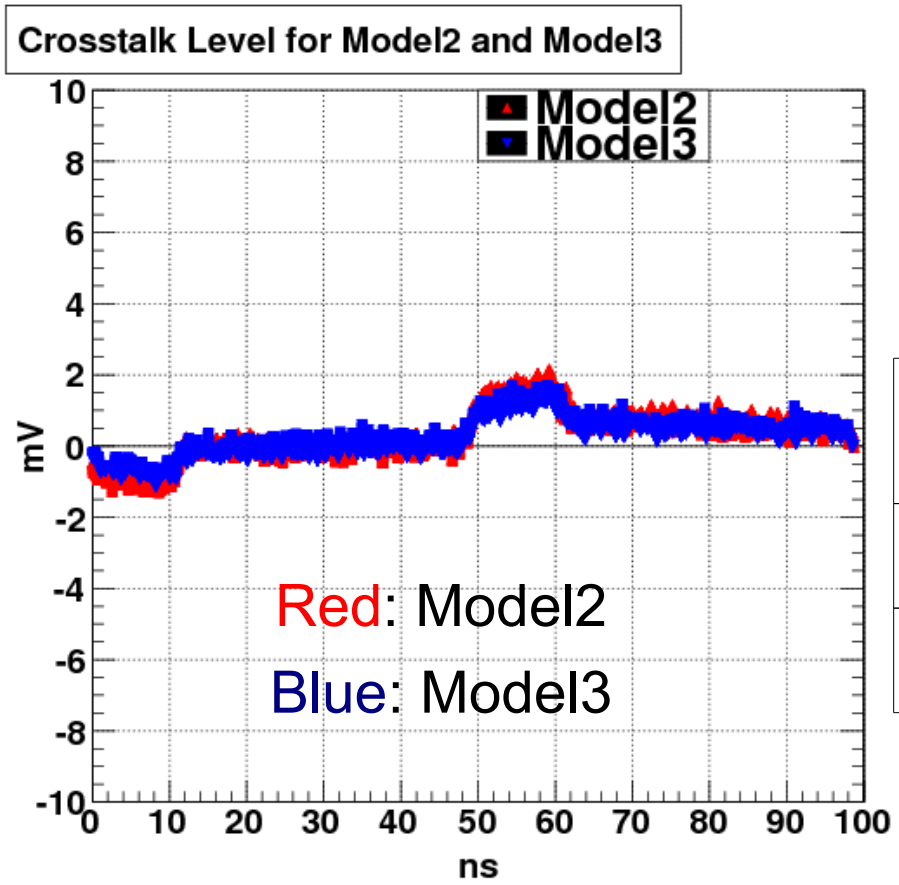
4. Crosstalk level measurement

- Crosstalk measurement setup
  - 3 GHz analog bandwidth oscilloscope
  - Pulse Generator (Pulse height=4 V)



Pulse Height of 4 V is set to obtain dynamic range.

Crosstalk level measurement result



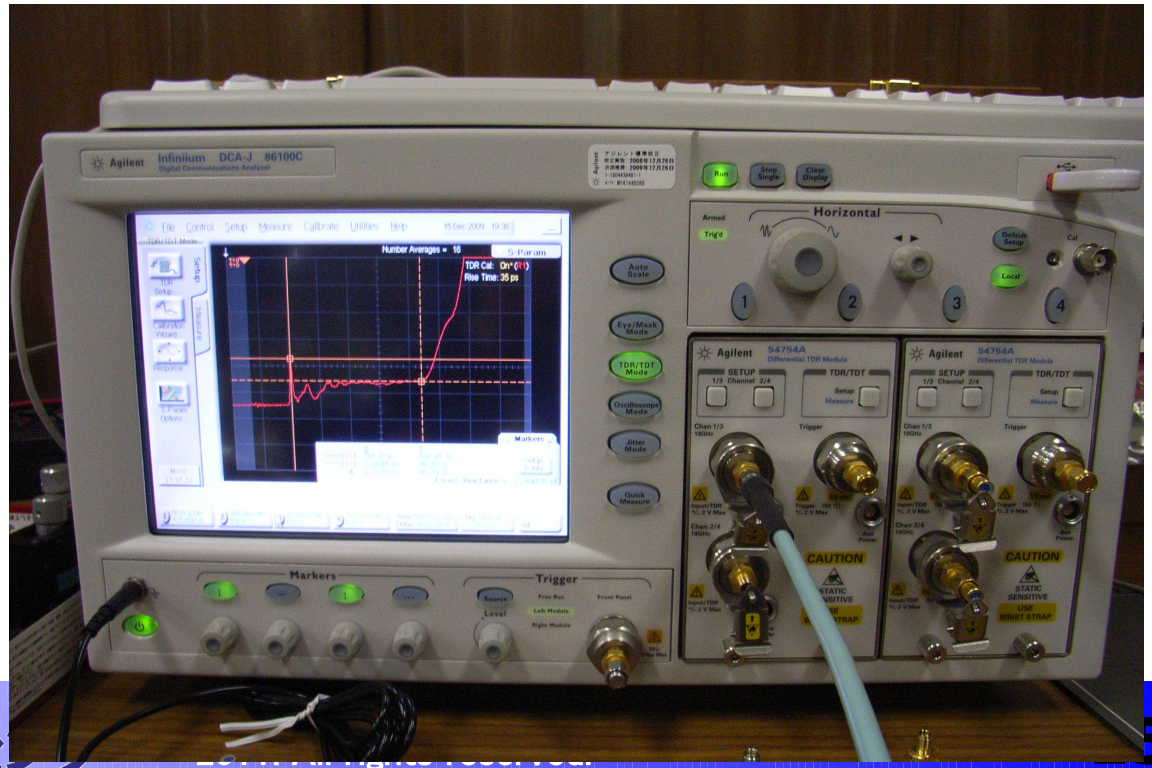
	Crosstalk Level (Simulated)	Crosstalk Level (Measured)
Model2	0.33%	0.05%
Model3	0.08%	0.04%

Crosstalk level in Model3 is improved than the simulation.

→ It might be reason of SMA connector frequency characteristics.

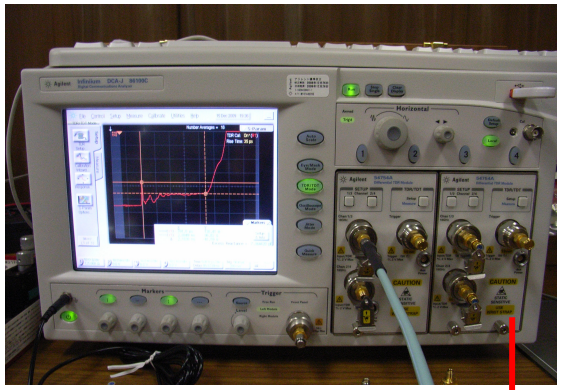
5. Impedance measurement

- Time Domain Reflectometry (TDR)
- Agilent 86100C
  - TDR Module 54754A x 2
- Minimum pulse rise time:10 ps
- To evaluate characteristic impedance in time domain.
  - Transmission lines
  - Finding failure point
    - Lines
    - Wire-bonding…



Impedance measurement setup

TDR (B.W=18 GHz)



Oscilloscope

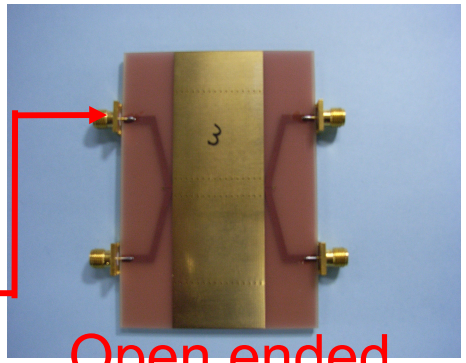
+

Pulser

35 ps Injection step pulse

Reflected pulse

Test Board



Open ended

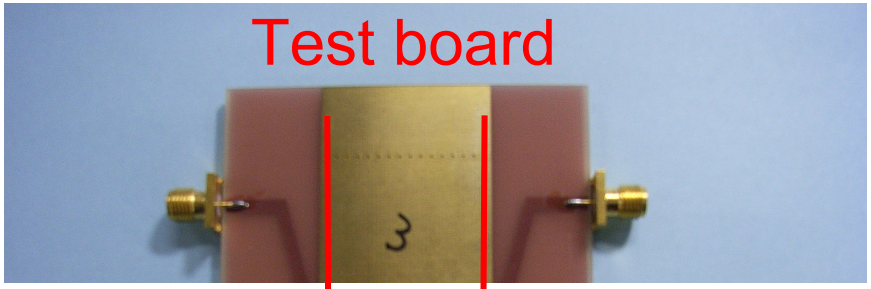
Composing

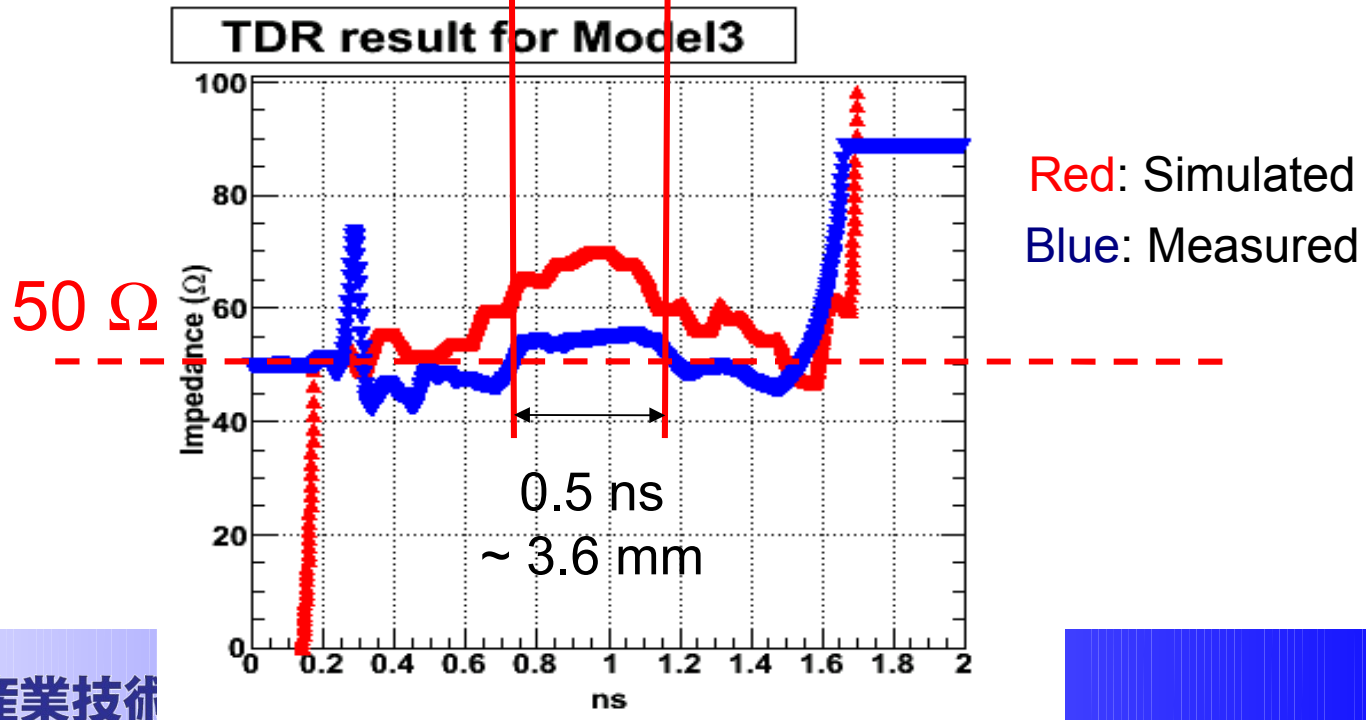
Injection + Reflection pulse

Impedance measurement result 1

Test board of Model3 has better impedance characteristics.

- Z ~ 55 Ω
- Line length by TDR measurement: ~ 36 mm
  - It is consistent with the real length.



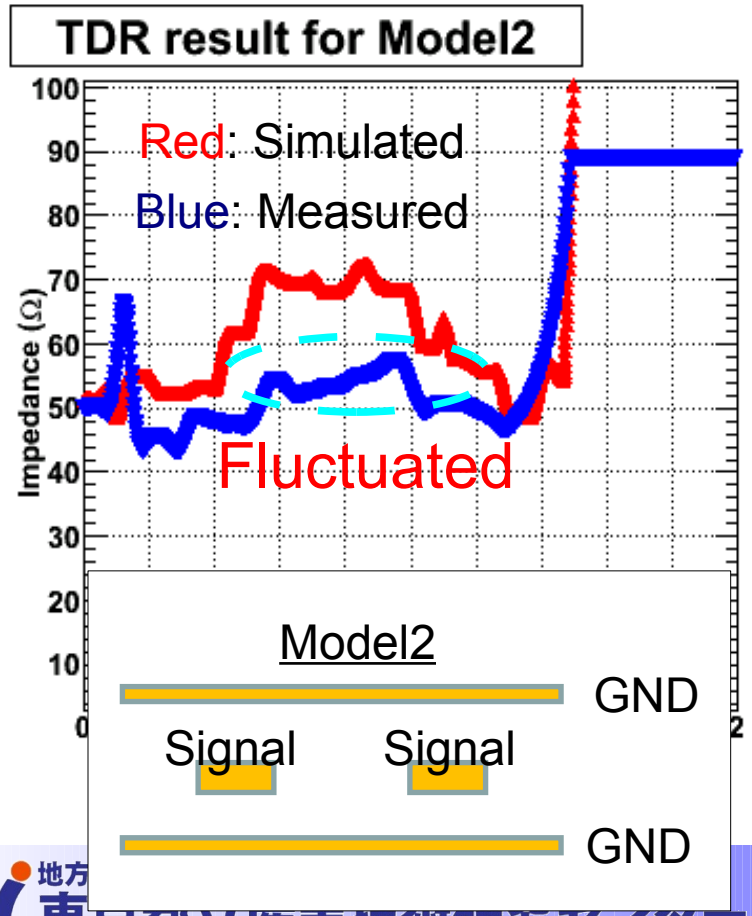


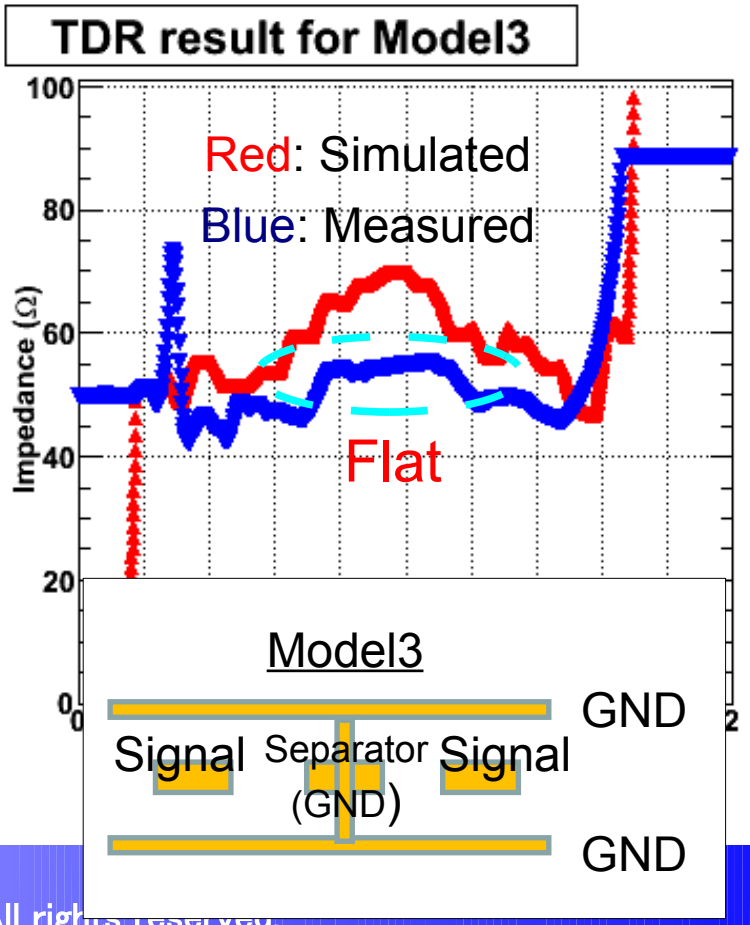
Impedance measurement result 2

It seems Model3 has better impedance characteristics.

- Line impedance of transmission region in Model3 is flat than Model2.
- Good result by separator (GND line) in Model3

  → Electric force line can be shielded.

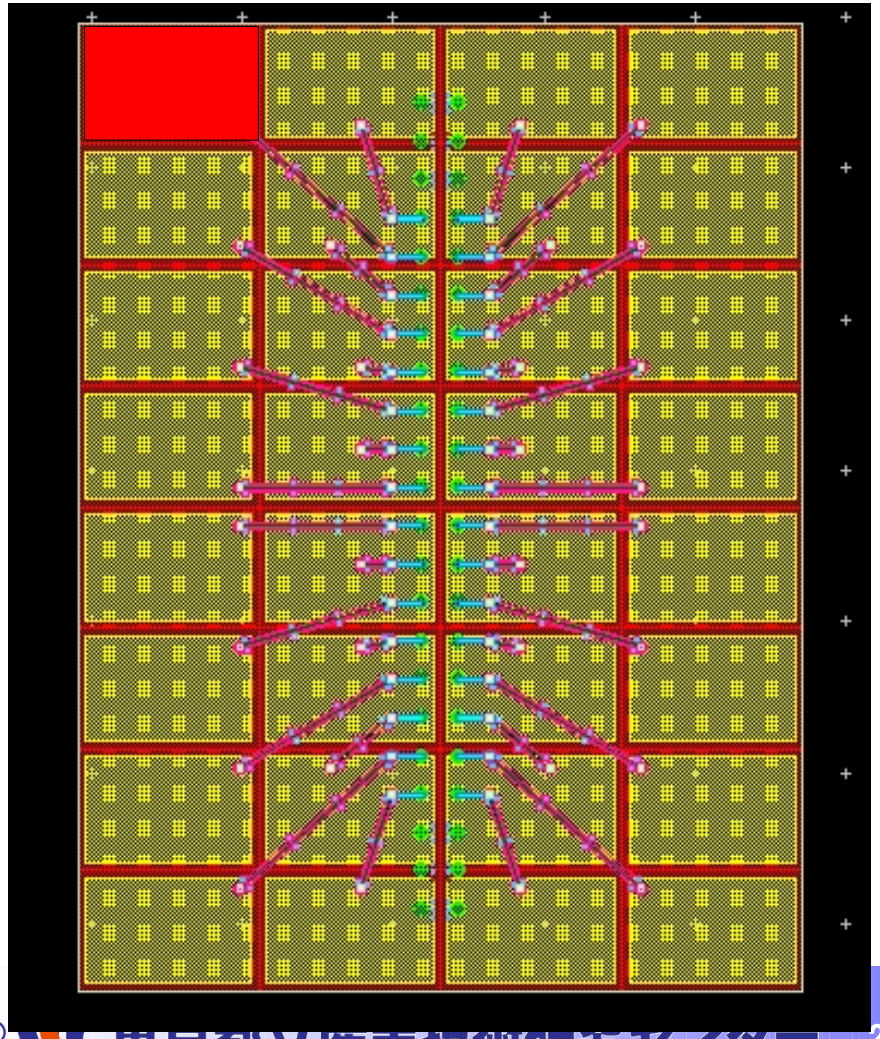




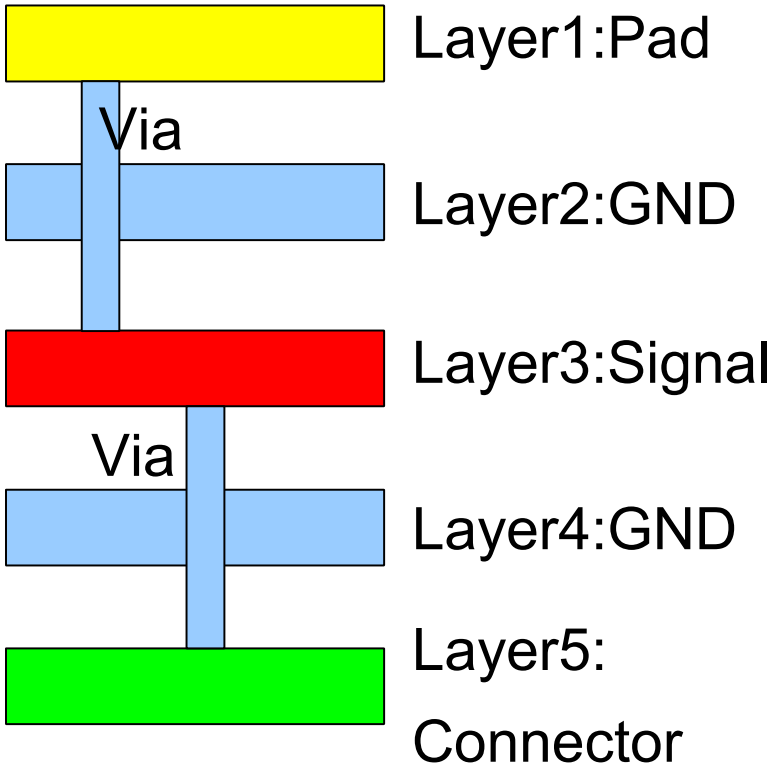
6. New TPC pad

5 Layers structure

- 1 Pad area: 11 mm x 7 mm



Cross Section



7. Summary

- We are developing lower crosstalk TPC pad including transmission line.
  - Crosstalk level by simulation: 0.08%
  - Crosstalk level by measurement: 0.04%
  - Requirement: <0.5%, it is satisfied.
- Line impedance stability is confirmed by TDR.
  - Model3 has has good stability.
- Starting new TPC pad simulation and design.
  - 1 Pad area: 11 mm x 7mm.
  - 5 Layers structure
- Do simulation including TPC capacitance (~10pF) including transmission line.

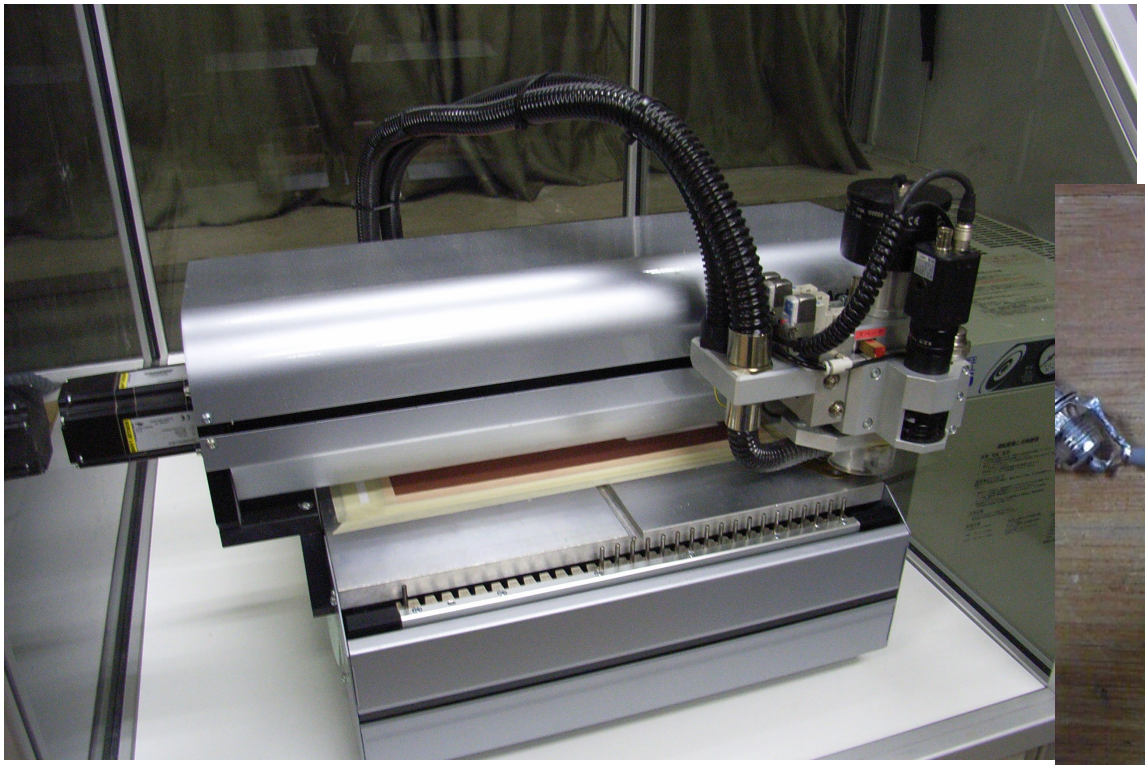
Backup slides

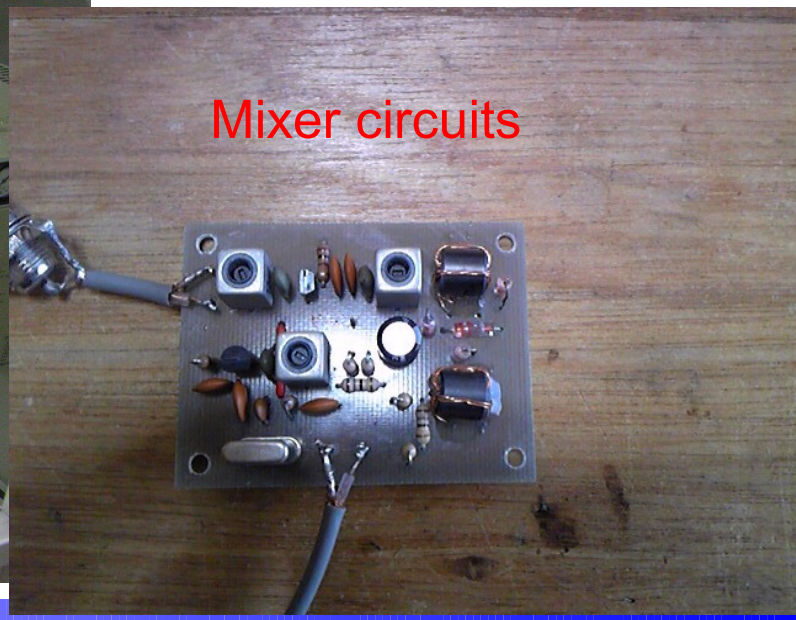
Impedance Analyzer

- Aglient 4395A (10-500MHz), 4396B (10-1.8 GHz)
- Impedance, Network, Spectrum Analyzer (Combined type)
- Evaluate signals, RF networks, impedance…

PCB milling machine

- ProtoMat H100 LPKF (Germany)
- Making PCB patterns by milling
- For prototyping use
- Need Gerber and drill data file





Measurement Instruments for transmission evaluation

Vector Network Analyser (VNA)

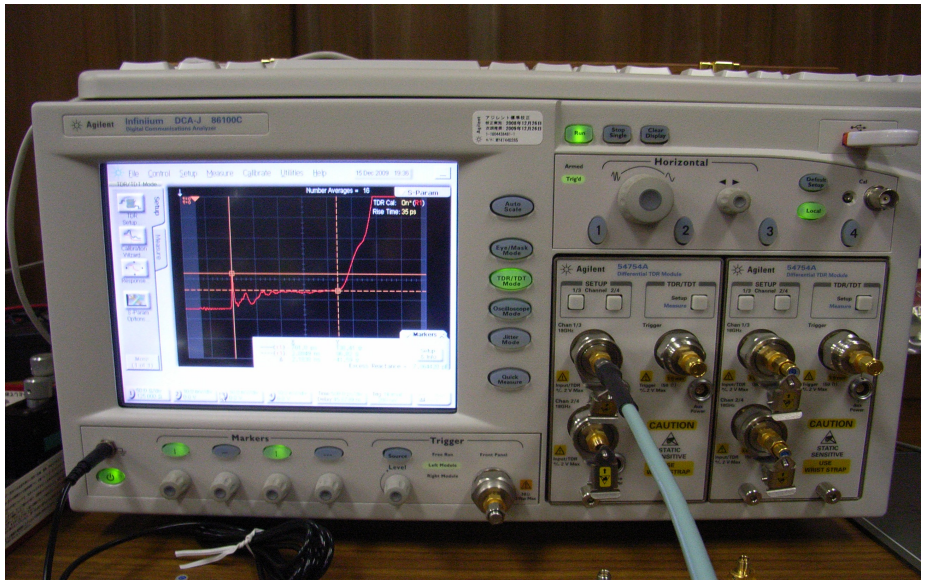
- Frequency response in complex
- Impedance, Refection, Transmission

Aglient 4396B (100 kHz-1.8 GHz)

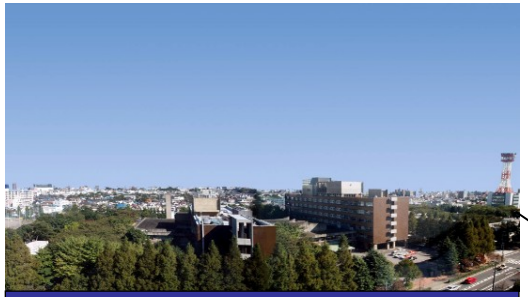
Time Domain Reflectometry

- Impedance in time domain

Agilent 86100C+54754A



Our bases (1 Headquarters, 6 Branches)



Nishigaoka HQ

1970 (S.45)

Joto BO

1991 (H.3)

Sumida BO

2000 (H.12)

RIKEN
Wako

Hachioji BO

1960 (S.35)

Tama BO

2002 (H.14)

Komazawa BO

1959 (S.34)

Jonan BO

1996 (H.8)

294 persons
(H.21 April)

Simulation with or without SMA