INTT BusExtender

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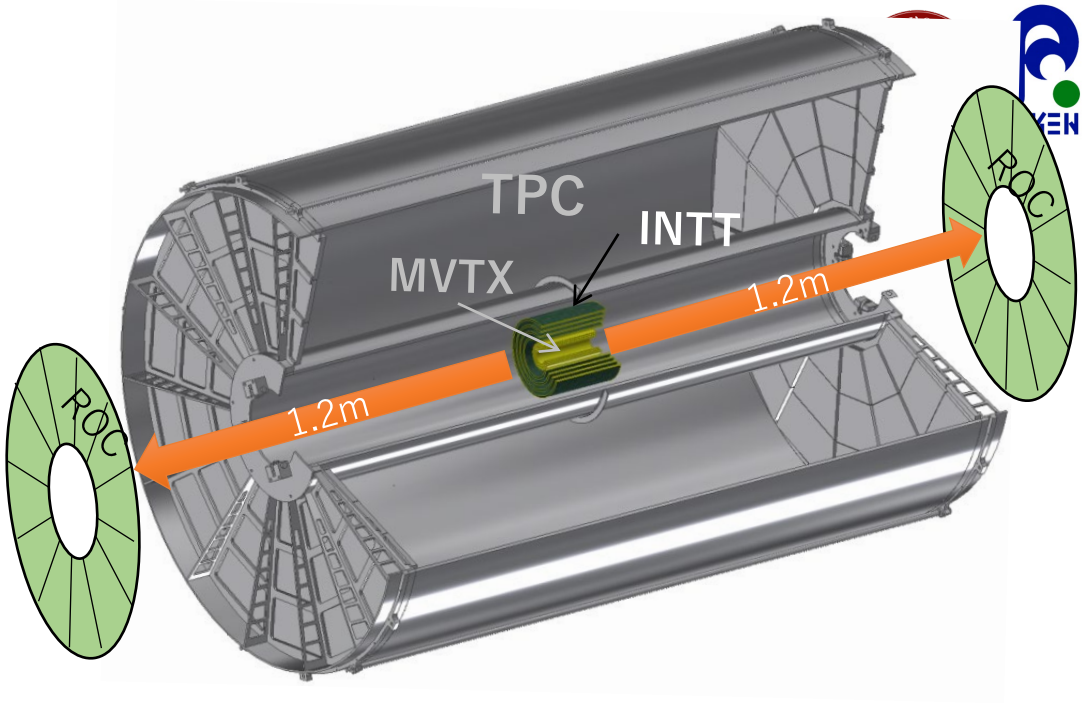
sPHENIX-INTT

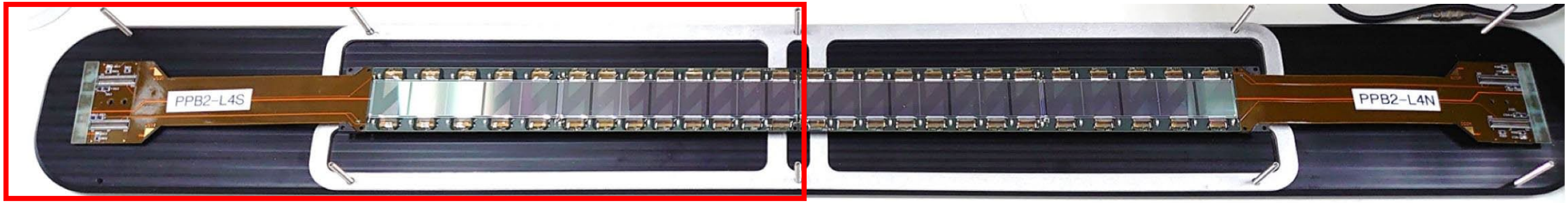
INTermediate Si-Tracker, INTT

- a 2 layer barrel tracker w/ Si-strip
  - R~7, 10cm

INTT half ladder

- Electrically isolated into two halves
- Speed : ~200Mbps for a LVDS pair
- Half ladder = 26 RO ASIC = 56 LVDS pairs





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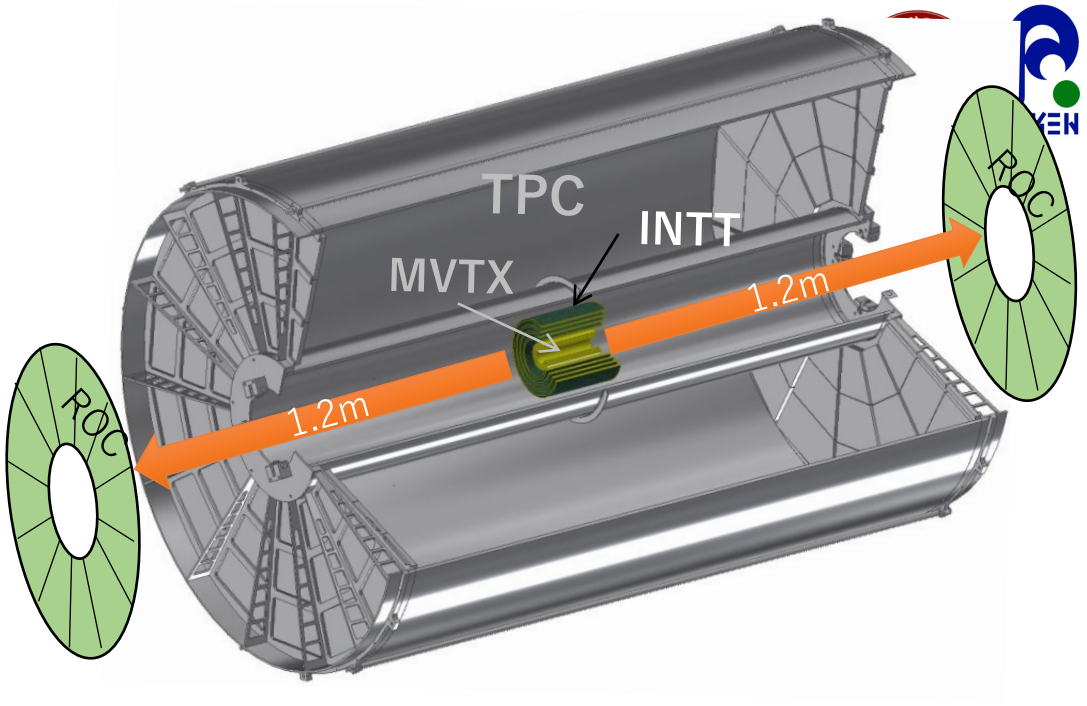
Bus-Extender : Long and high signal-density cable

- ROC board : 1.2 m away from INTT
- Space is tight (only a few cm btw TPC and MVTX)

Requirements

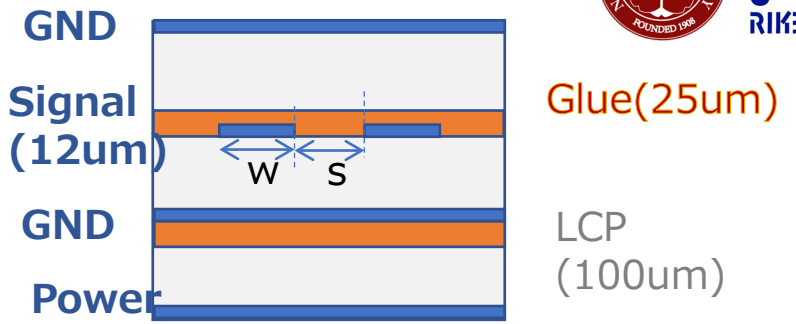
- Length: ~ 120cm
- Line density = 62 LVDS pairs and + Power/GND
- **Data speed = 200 Mbps LVDS (Z_{diff}=100Ω)**
- Space : less than ~5cm width w/ flexibility



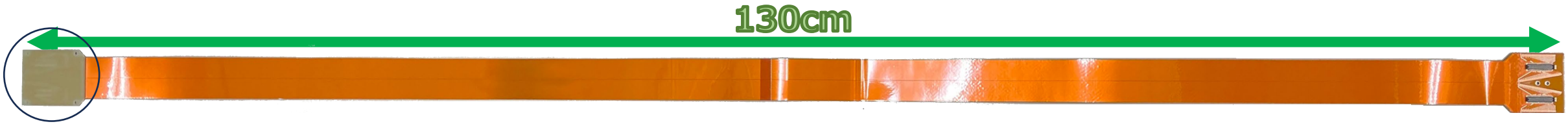
No commercial cable available in the market. We developed

Bux-Ext development

- We adopt Flex PCB technology because of fine wiring and flexibility
- Bus-Ext prototype :
  - Structure
    - 130 x 3.5 cm^2、
    - 4 layers including signal, power, GND layers
    - 62 LVDS pairs （Line and space : 130 & 130 μm)
  - Impedance control : Z_{diff} : 100Ω w/ strip line
  - Substrate : Liquid Crystal Polymer (LCP)
    - Signal loss smaller than Polyimide for Hi freq (small dissipation-tangent)
  - Connector at both side
  - Final design was determined using EM SIM for PCB



They are laminated w/ glue sheet



Transmission loss w/ freq

- LCP has a smaller tangent
  - Normal FPC is made from Polyimide(Capton)
- BuxExt used LCP+Cu(12um)

	LCP	Polyimide
Dielectric Constant	3.0@2GHz	3.2@ 1GHz
Dissipation tangent	0.0008 @ 2GHz	0.0085@1GHz

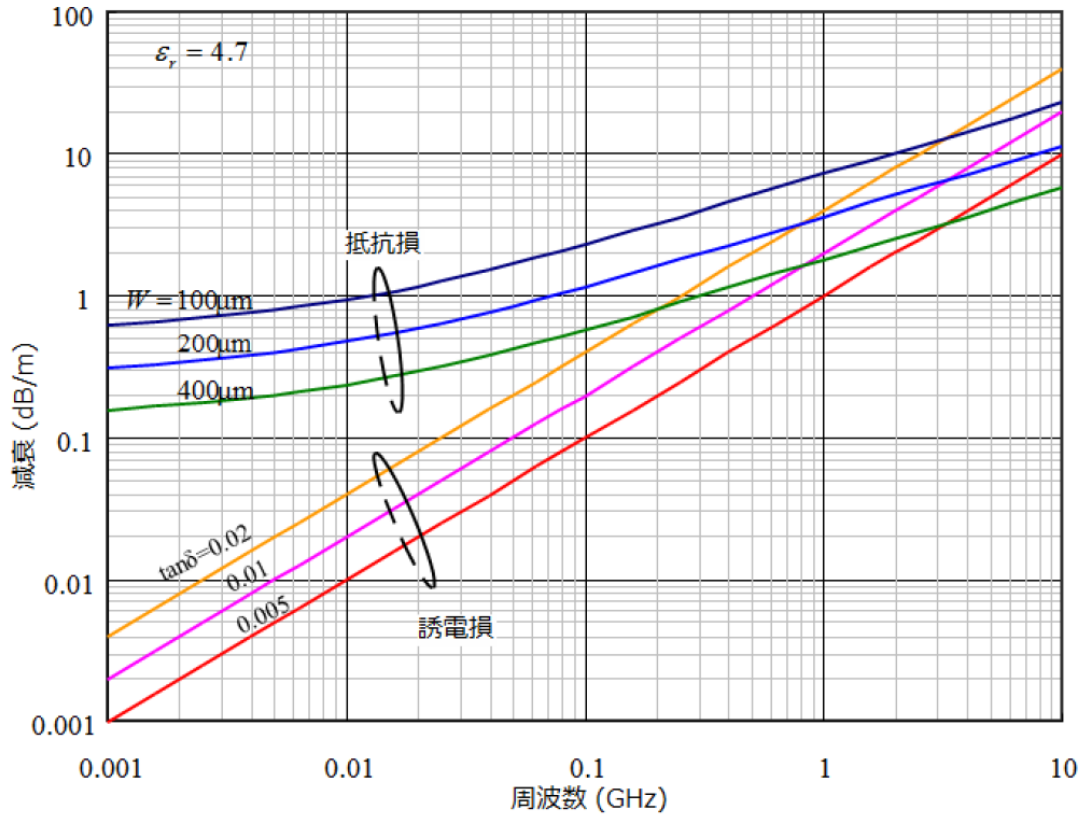
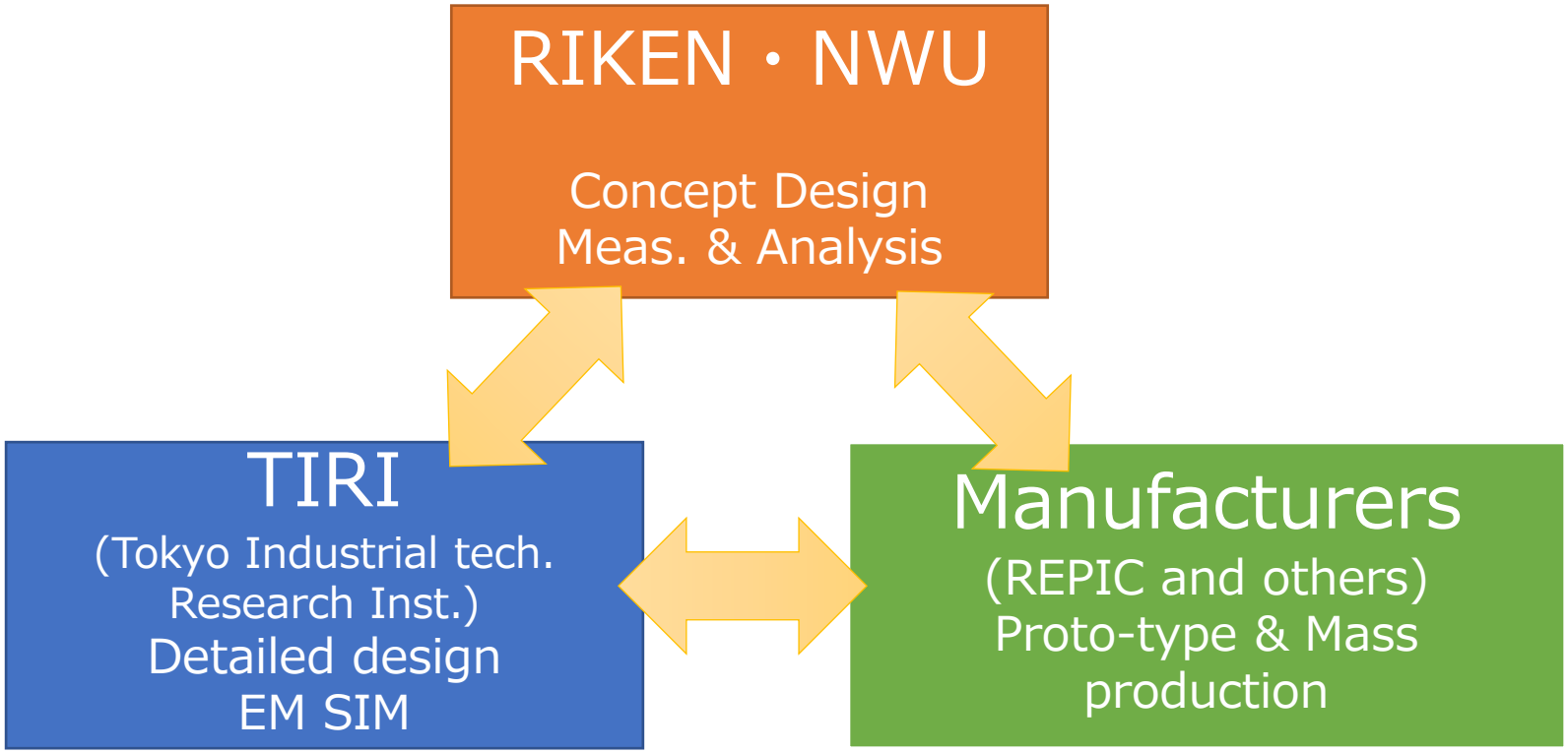


図 1： 抵抗損失と誘電損失の周波数特性（碓井有三氏から引用）

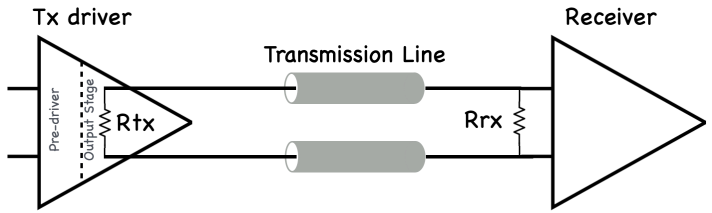
BusExt Collaboration

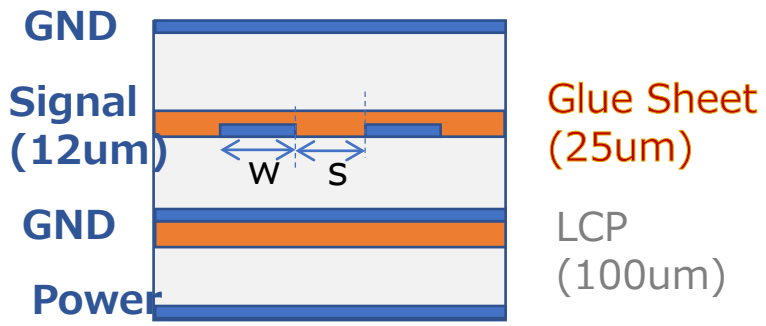


- Study what is the technical limits
- Evaluate about electrical characteristics by simulation prior the prototype production
- Prote-type, Pre-Production, Mass production

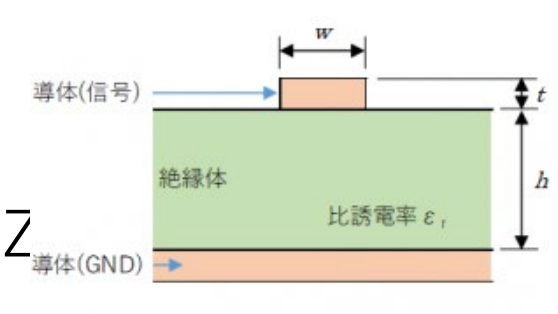
Impedance control Z

- Diff –Z should be 100Ω for LVDS transmission (Z=50Ω for single)





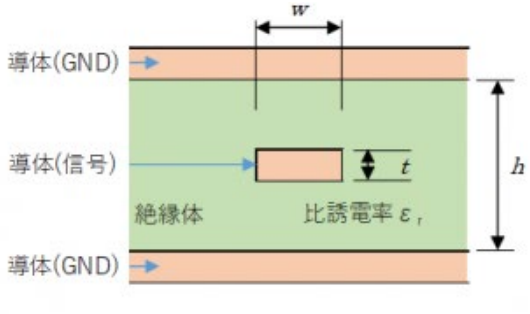
- BusExt used “strip-line” structure to control Z
  - Difficulties in manufacturing
    - hard to make “narrow” signal line uniformly for 130cm
    - 130um width is minimum (said). Then substrate should be thick (100um thick)
    - Why it is hard
      - In the FPC production, line uniformity is limited by each Light exposure and Etching process
    - Standard FPC
      - 50um line width + 50um thick Polyimide



$$Zo = \frac{87}{\sqrt{(\varepsilon_r + 1.414)}} \times \ln\frac{5.98h}{0.8w + t}$$

図１．マイクロストリップライン断面図

Micro strip-line



$$Zo = \frac{60}{\sqrt{\varepsilon_r}} \times \ln\frac{4h}{0.67\pi w\left(0.8 + \frac{t}{w}\right)}$$

図２．ストリップライン断面図

strip-line

Production process

Single layer

Multi-layers

Thru-hole

Surface

Make Photo-Mask

Light-Exposure to print

Etching to make lines

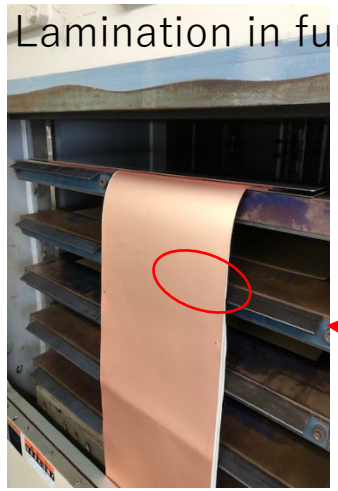
Laminate / heat and pressure

Drill + Plating to make electrical contact

Mounting conn. and cleaning

used high precision printer ± 3 um

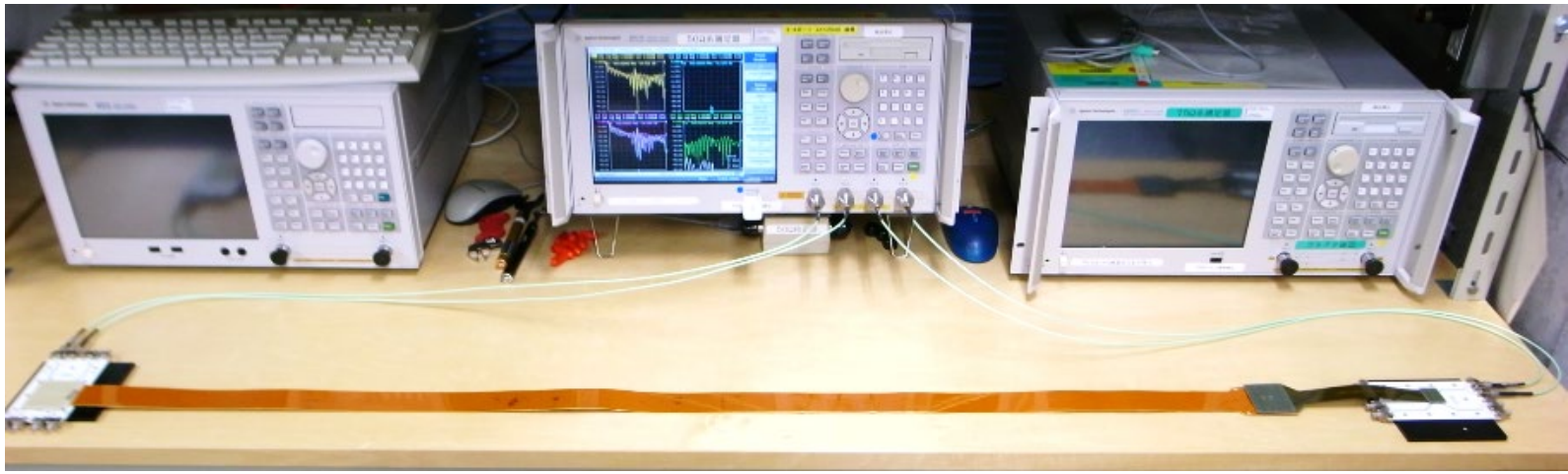
Lamination in furnace

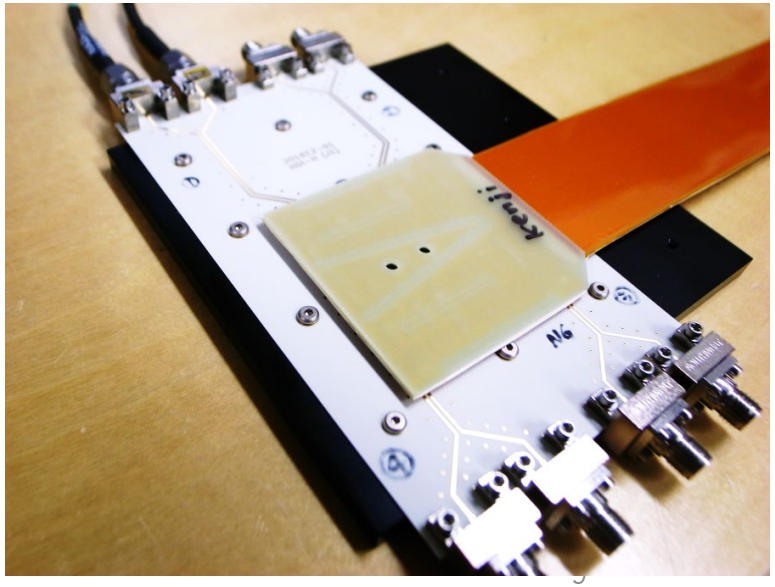


- No single manufacturer can make this.
  - No manufacturing equip. available for long FPC （ standard FPC size is upto 50x50cm^2)
  - We asked 4 manufacturers (FPC, drill, plating, surface treatment)
- All the processes was done in Japan

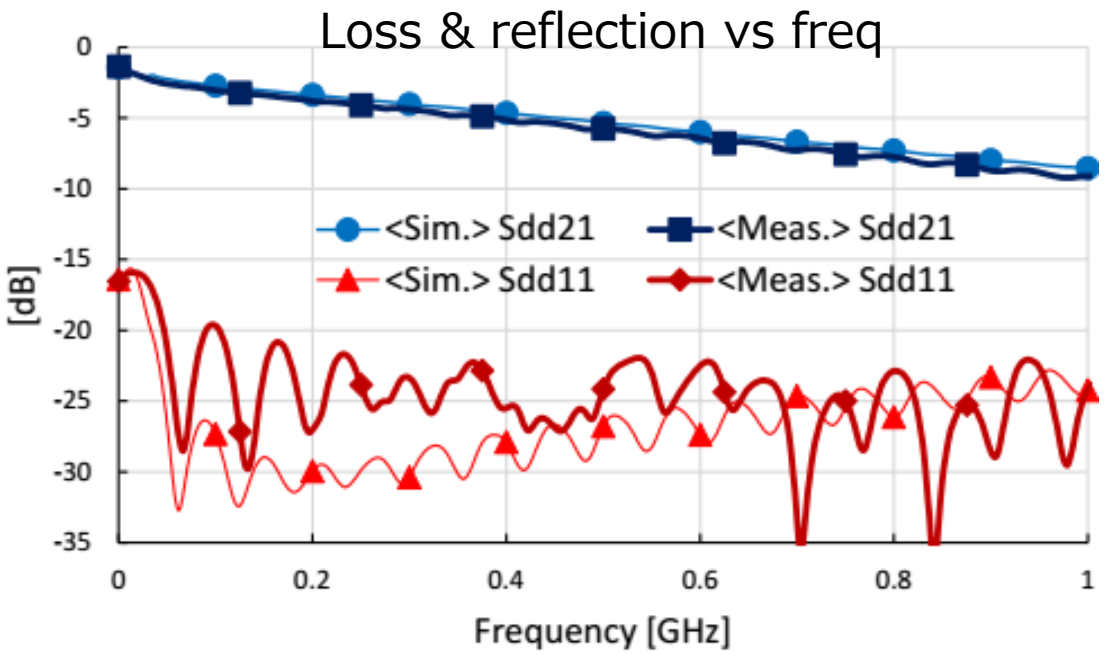
Bus Extender Performance

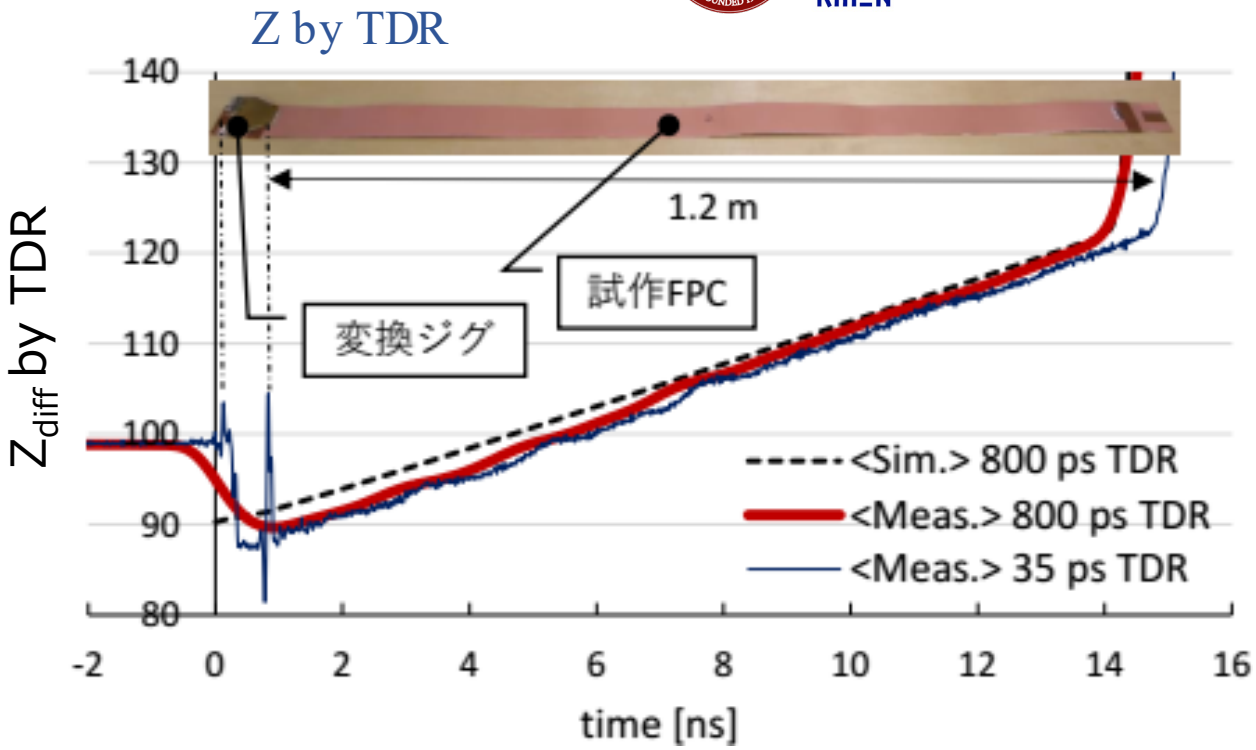
- Electrical properties
  - Signal loss vs freq. ,
  - Z_{diff} by TDR
  - Eye diagram
- Mechanical property
  - Accuracy of line & space
- Aging test
- Radiation hardness





Electrical Performance





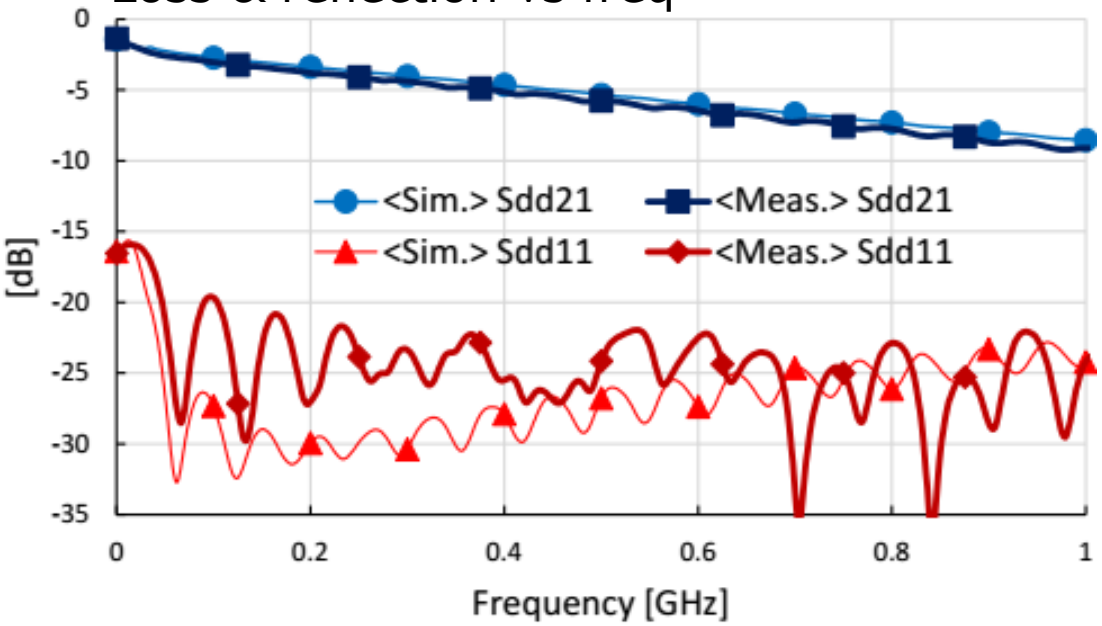
- Freq. dependence(s-parameter)
  - Signal loss : ~30%、
  - Reflection: < 10%

- Zdiff by TDR
  - Z ~ 90Ω　(slight smaller than 100Ω)

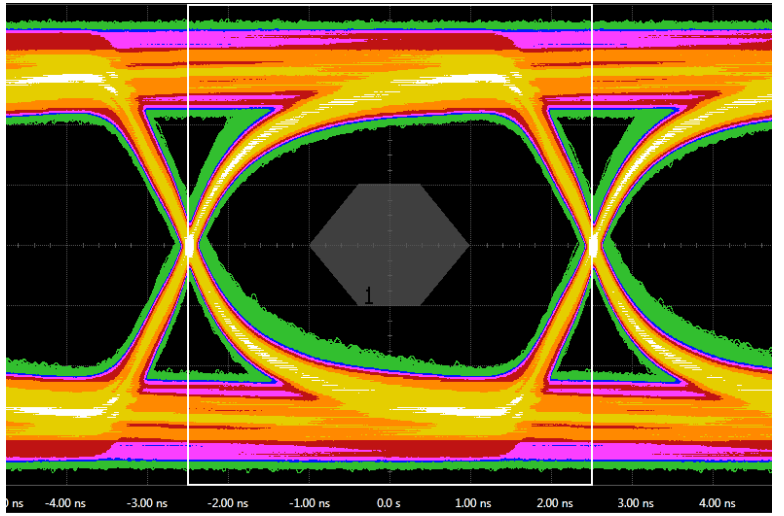
Data is consistent with the EM field simulation

Electrical Performance

Loss & reflection vs freq



Eye-Diagram



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- Freq. dependence(s-parameter)
  - Signal loss : ~30%、
  - Reflection: < 10%
- Eye-diagram： Accumulated pulse shape for 1 bit
- Found good opening

We did aging test and rad-hardness test. It was good shape

Issues we found was fixed

- For Bus-Extender
  - Line uniformity → Fixed
  - Thru-hole prodution → Fixed
  - Aging test (by Thermal sheck test) → Fixed
  - Rad-hardness(by gamma ray) → Checked
  - Yield rate → Fixed(30%→100%)

  - It took long time (~4 or 5 years)
- We hope we can be of help for ePIC TOF

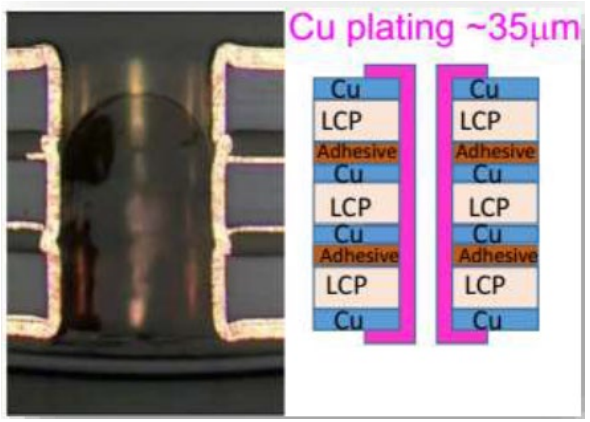
Aging Test

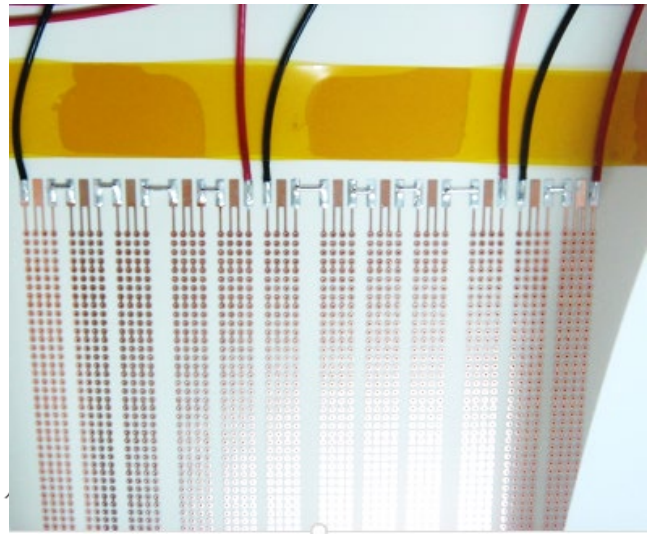
- Keep healthy at least 3 year operation

- Mechanical stress by temperate
  - LCP is expanded and shrunk
  - Thru-hole could be damaged.

- Temperature cycle
  - -15 (30min.) ~ 75°C (30min.) with 1~2min. transition.
  - 1000 cycles (40 days)

- Test FPC sample
  - 4 layers, same as bus extender
  - 400, 1000, 1000 throu-holes are daisy chained and its resistance monitored .
- Results
  - Resistances changed with temperature
  - All FPC samples are healthy after 1000 cycles.





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