X2D2

The new 2D field solver with causal dielectric and surface roughness models

Dr. Ching-Chao Huang

huang@ataitec.com

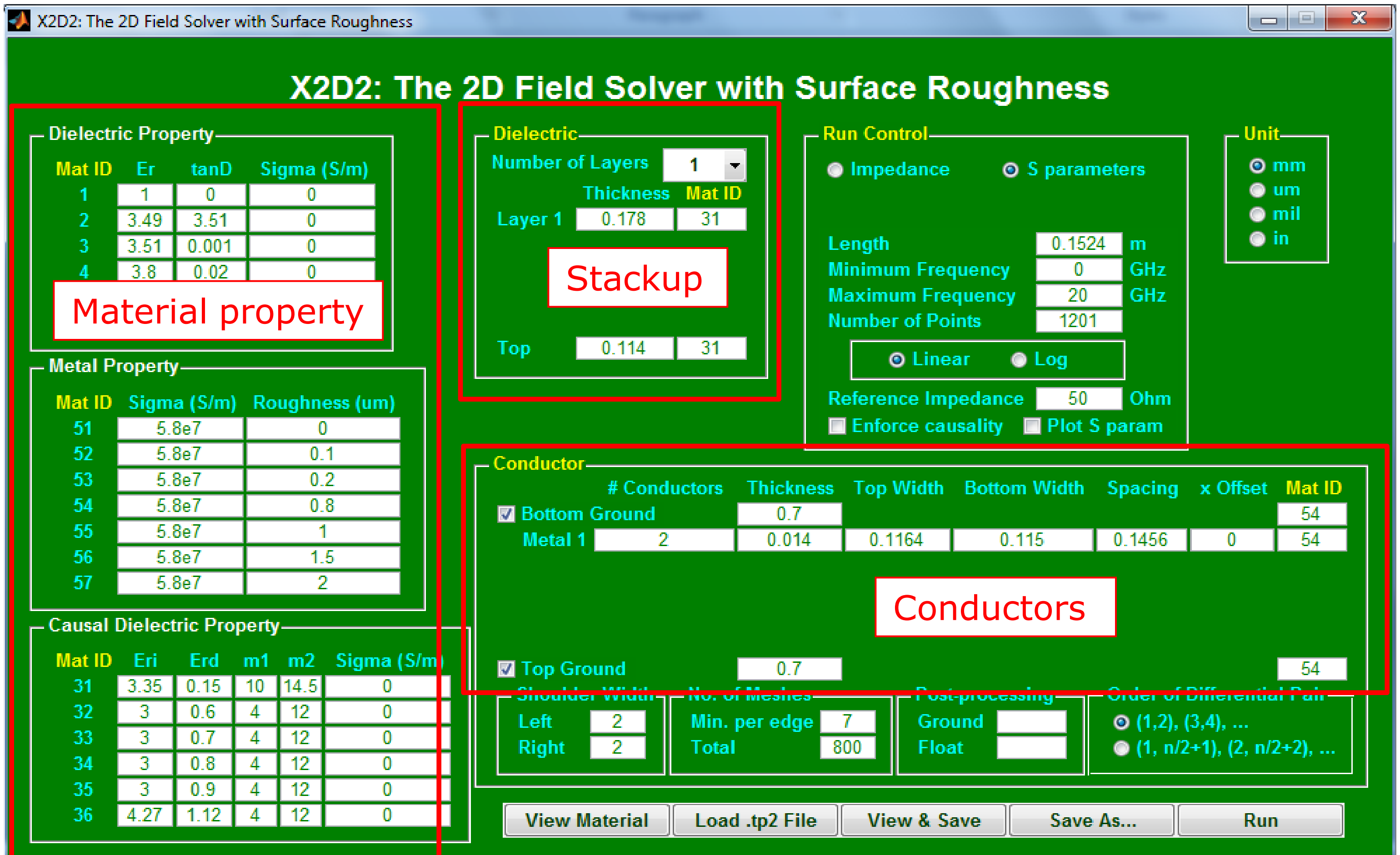
AtaiTec Corporation

Outline

- What is X2D2
- Causal dielectric model
- Surface roughness model
- PCB extraction and modeling methodology
- Measurements for 6” differential trace extraction
- In-situ de-embedding (ISD)
- Extraction of material property (DK, DF, roughness)
- Summary

What is X2D2

- A new 2D solver that creates S parameters with causal dielectric and surface roughness models.

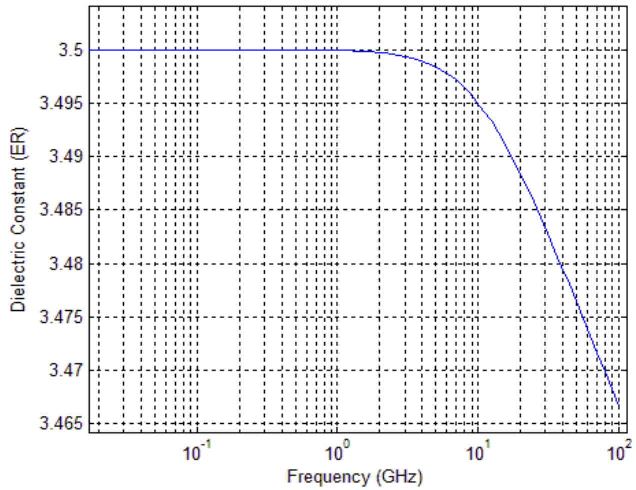


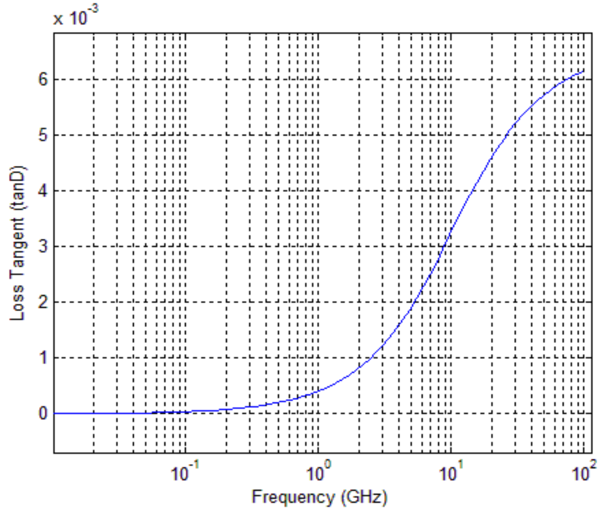
Causal dielectric model

- Wideband Debye (or Djordjevic-Sarkar) model
  - Need only four variables: ε_∞ , $\Delta\varepsilon$, m_2 , m_1

$$\varepsilon = \varepsilon_\infty + \Delta\varepsilon \cdot \frac{1}{m_2 - m_1} \cdot \log_{10}\left(\frac{10^{m_2} + i \cdot f}{10^{m_1} + i \cdot f}\right)$$

$$= \varepsilon_r \cdot \left(1 - i \cdot \tan\delta\right)$$





$$\varepsilon_\infty = 3.35 \ , \ \Delta\varepsilon = 0.15 \ , \ m_2 = 10 \ , \ m_1 = 14.5$$

ataitec

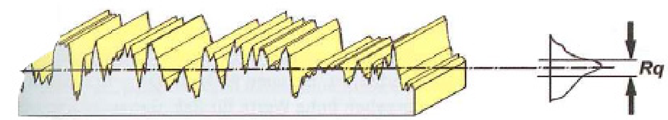
Surface roughness model

- Effective conductivity (by G. Gold & K. Helmreich at DesignCon 2014) needs only two variables: σ_{bulk} , R_q

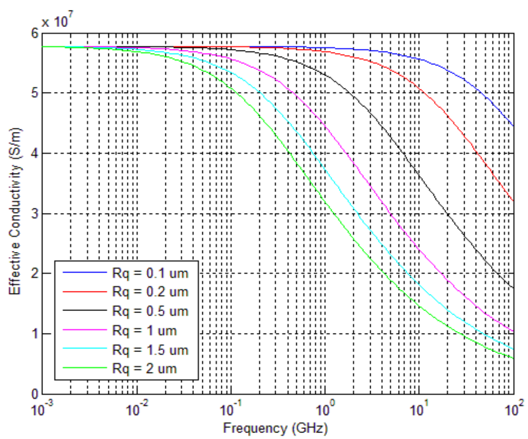
Parameter	Description	Standard
R_q	root mean square	DIN EN ISO 4287
R_a	arithmetic average	DIN EN ISO 4287, ANSI B 46.1
R_k	core roughness depth	DIN EN ISO 13565
R_z	average surface roughness	DIN EN ISO 4287

Table 1: *Statistical parameters to describe surface roughness*

$$\sigma(x)=\sigma_{bulk}\cdot CDF(x)=\sigma_{bulk}\cdot\int_{-\infty}^{x}PDF(x)du=\sigma_{bulk}\cdot\int_{-\infty}^{x}e^{-\frac{u^2}{2R_q^2}}du$$



- Numerically solving $\nabla^2\overline{B}-j\omega\mu\sigma\overline{B}+\frac{\nabla\sigma}{\sigma}\times\left(\nabla\times\overline{B}\right)=0$ and equating power to that of smooth surface gives σ_{eff}

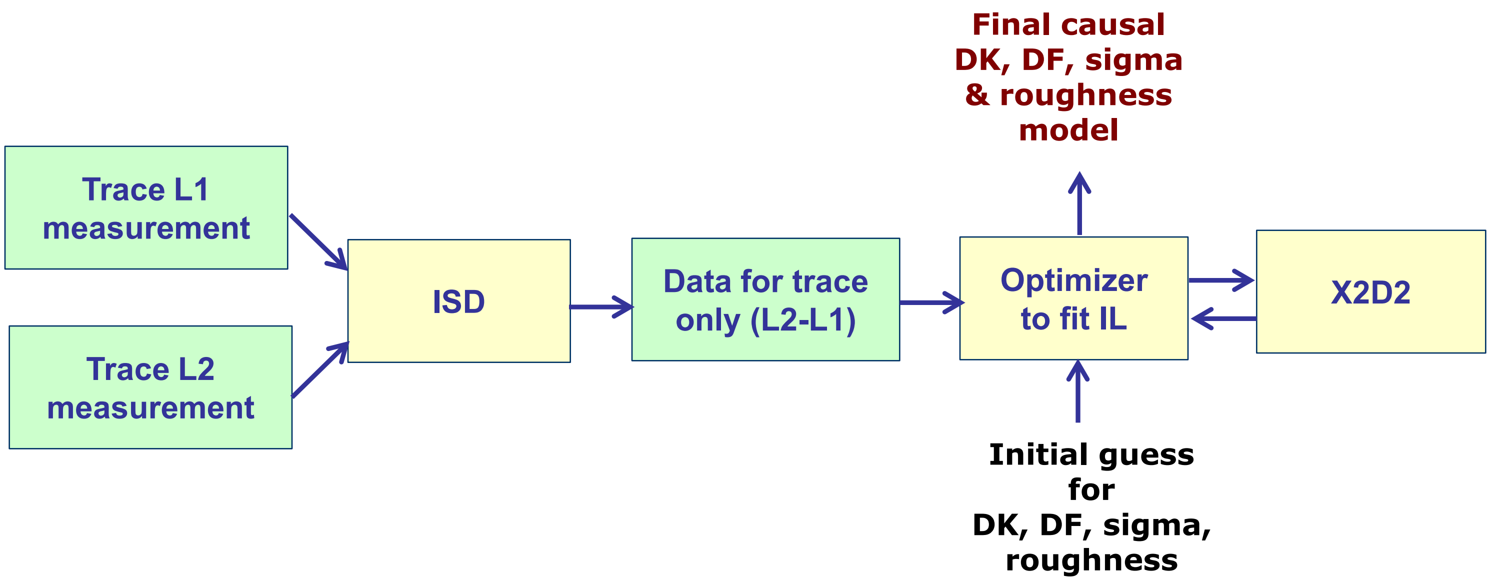


$\sigma_{bulk}=5.8\times10^{7}$ s/m

- ❖ Simple
- ❖ Work well with field solver
- ❖ Give effect of roughness on all IL, RL, NEXT and FEXT

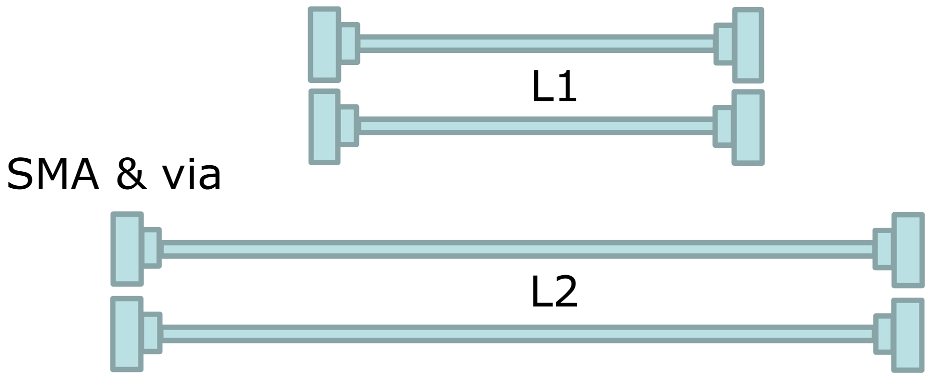
PCB extraction and modeling methodology

- Measure two traces of different length (L1 & L2).
- Use ISD to extract trace-only data.
- Extract causal DK, DF and surface roughness model by running multiple X2D2 to fit IL in both magnitude and phase.

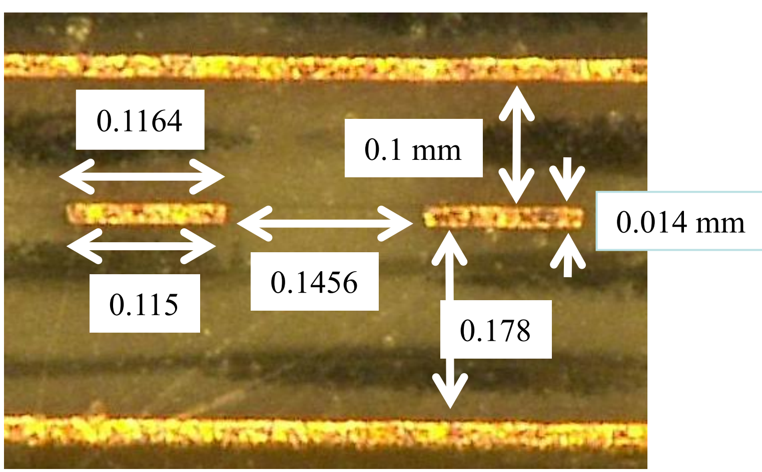


Example

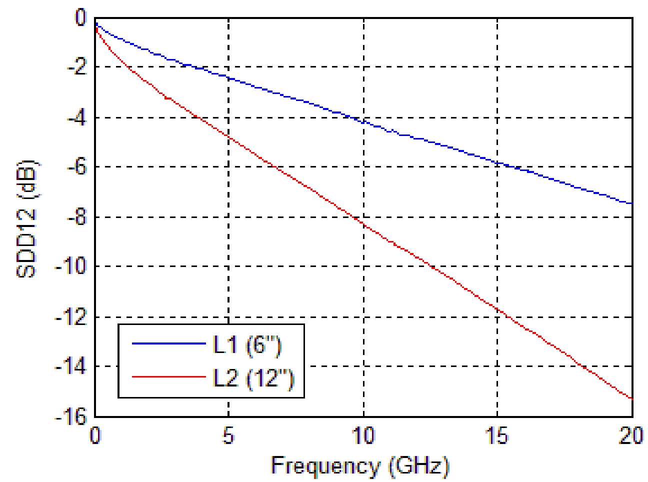
- Two differential stripline traces of different length (L1 & L2) are measured.



L2 – L1 = 6″



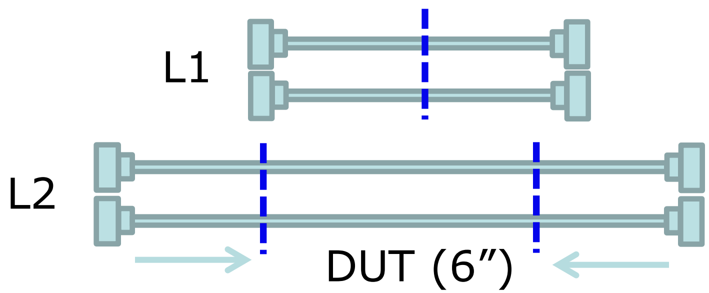
Cross section

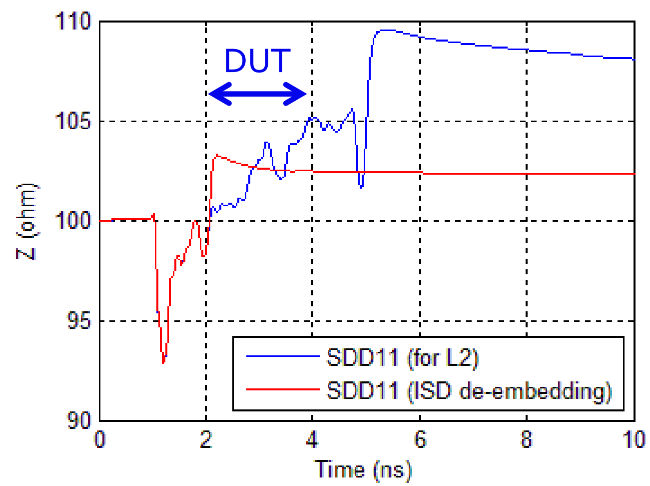


ataitec

In-situ de-embedding (ISD) is used to extract trace-only data

- ISD uses L1 as 2x thru and matches L2 impedance to extract DUT (6” trace).



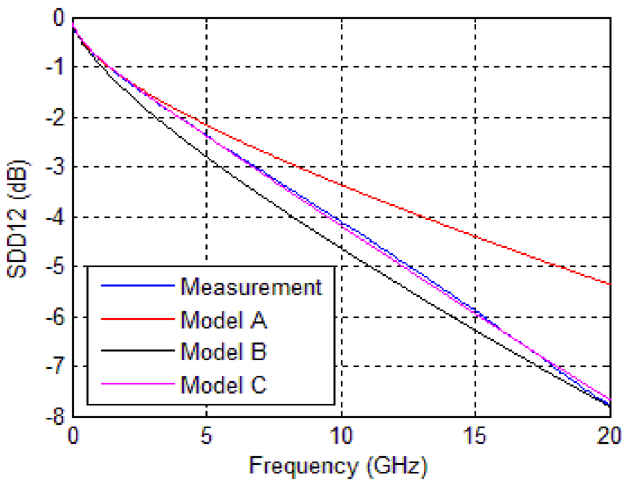


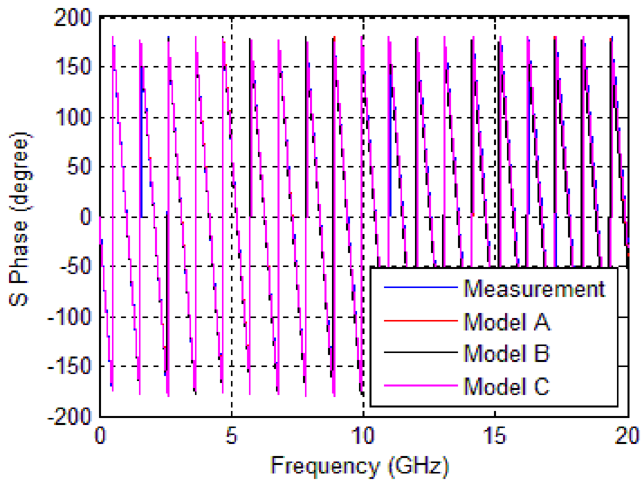
Rise time (20/80) = 50 ps

atatec

X2D2 is used to compare different models

- Model A (manufacturer's) – DK=3.51, DF=0.004, $\sigma_{bulk} = 5.8 \times 10^7$ s/m, $R_q = 0$
- Model B (intermediate) – DK=3.51, DF=0.004, $\sigma_{bulk} = 5.8 \times 10^7$ s/m, $R_q = 1\ \mu m$
- Model C (optimized) – $\varepsilon_\infty = 3.35$, $\Delta\varepsilon = 0.15$, $m_2 = 10$, $m_1 = 14.5$, $\sigma_{bulk} = 5.8 \times 10^7$ s/m, $R_q = 0.8\ \mu m$

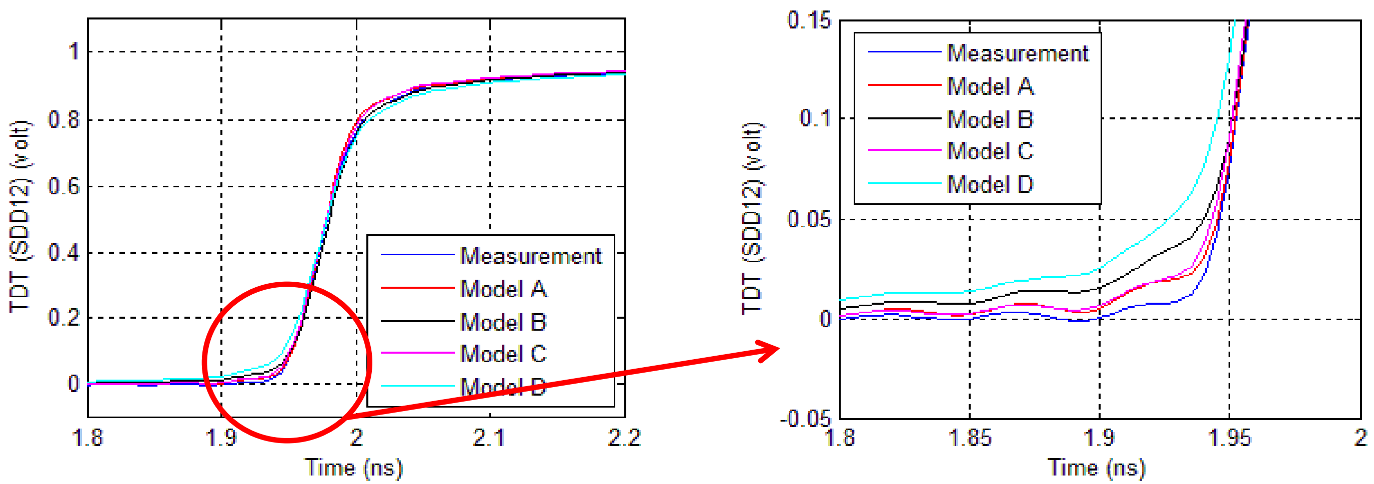




Fitting differential IL in both magnitude and phase

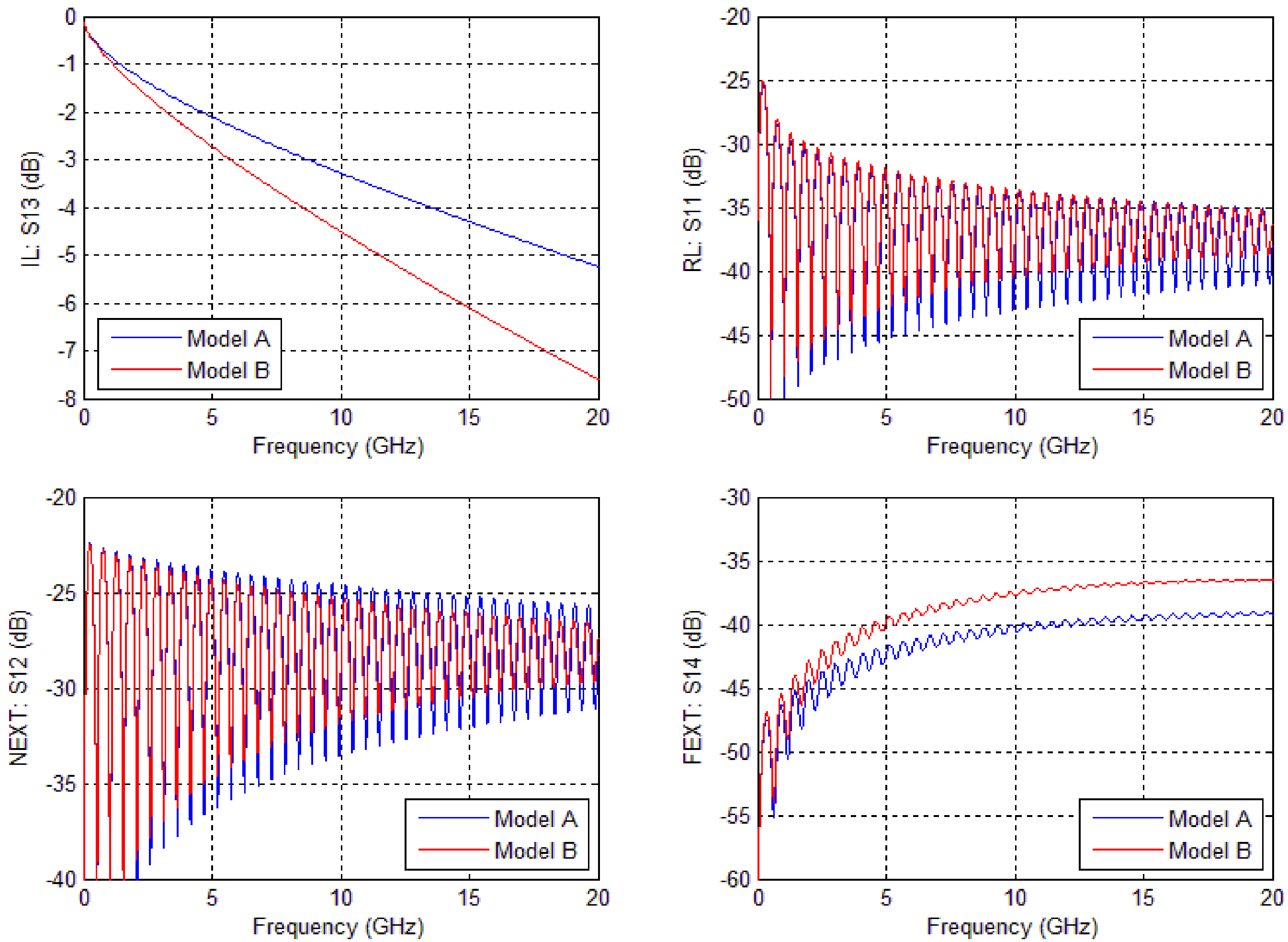
Causality

- Model A appears okay due to low loss (DF=0.004).
- Model D changes Model A's DF to 0.014 and it gives more non-causal response.
- Model C looks good with wideband dielectric model and surface roughness included.



Rise time (20/80) = 25 ps

X2D2 gives surface roughness effect on all IL, RL, NEXT and FEXT



ataitec

Summary

- Causal dielectric model is made simple through wideband Debye model.
- Surface roughness model is made simple through effective conductivity.
- Extraction of causal dielectric and surface roughness models is made simple through AtaiTec's ISD and X2D2.
- The proposed methodology constructs causal and correlated PCB trace models that help predict 50+ Gbps system performance more precisely.