Advanced SI Design Kit (ADK)

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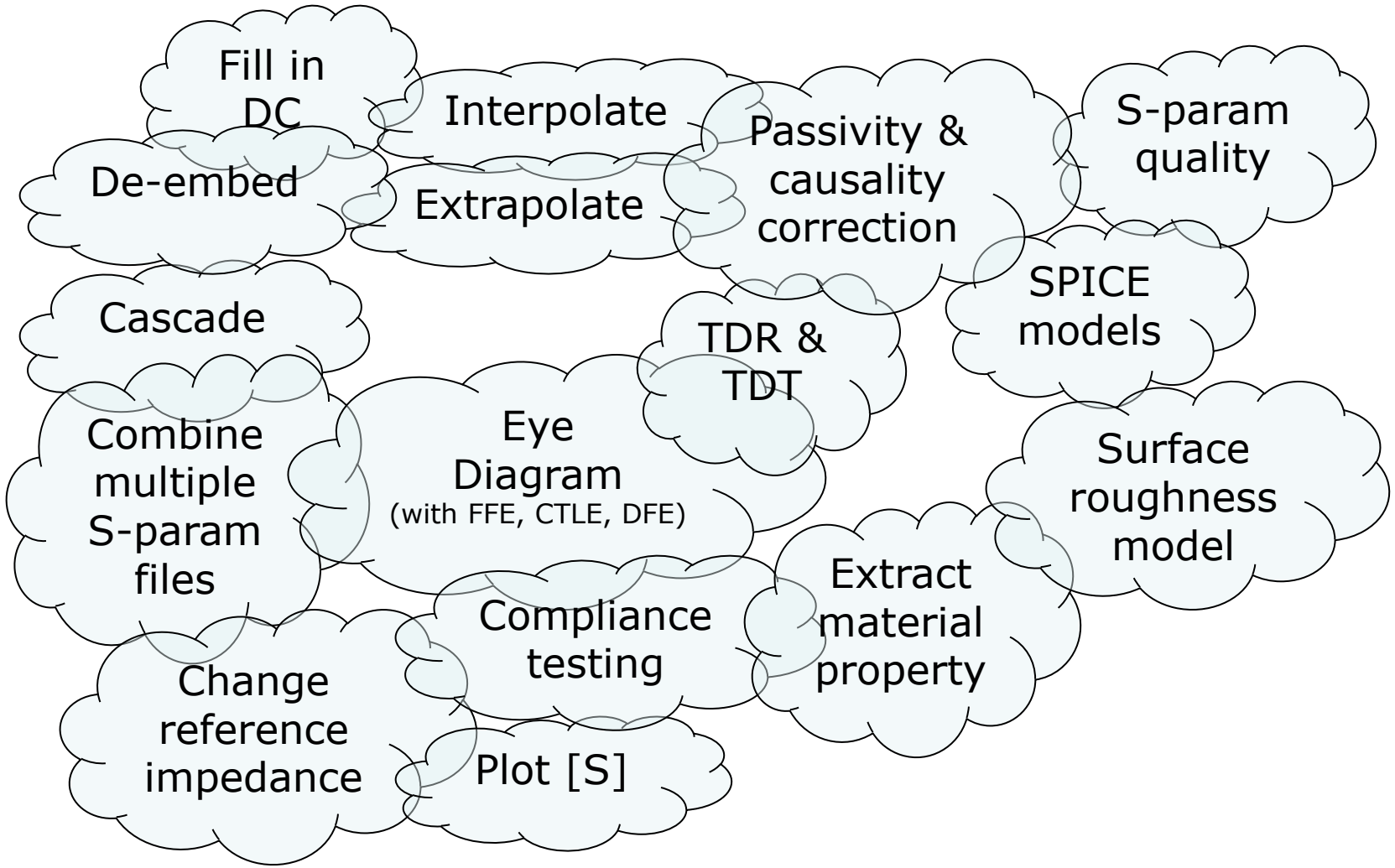
Outline

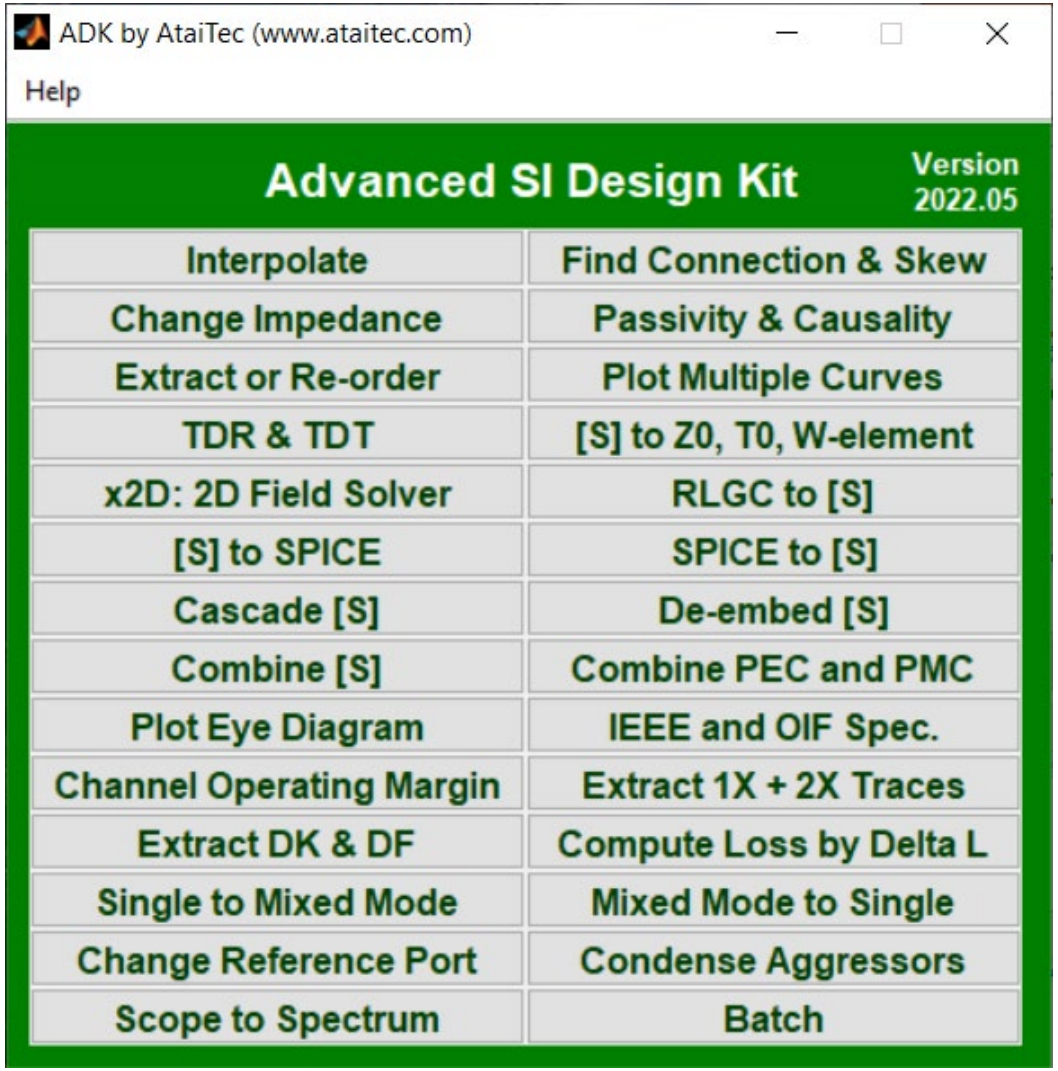
- Can SI tools be made like mobile apps?
- Advanced SI Design Kit (ADK)
  - Many mobile-apps-like SI tools in one place: causality correction, eye diagrams, TDR/TDT, compliance testing, DK/DF extraction, Delta L, Channel Operating Margin (COM), …
  - Complex SI operations in ~3 mouse clicks.
  - Significantly increase productivity.
- Advanced 2D solver (X2D2)
  - Model DK, DF and roughness.

If it takes more than 5 seconds to do any of these, it is too long…



Advanced SI Design Kits (ADK)

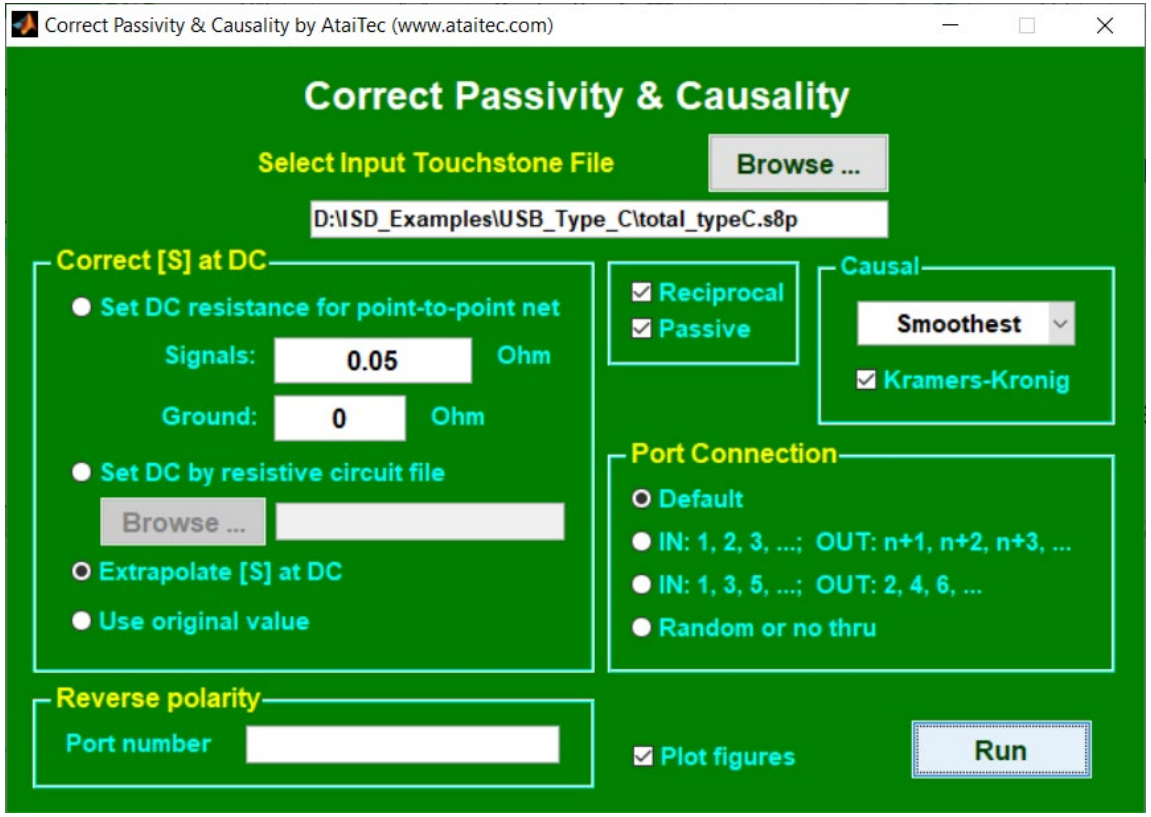
Many mobile-apps-like SI tools in one place



- Complex SI operations, from causality correction to eye diagrams, TDR/TDT, compliance testing, DK/DF extraction, Channel Operating Margin, … in a few mouse clicks.
- Everything you want to do with S parameters in one place.
- Increase productivity.

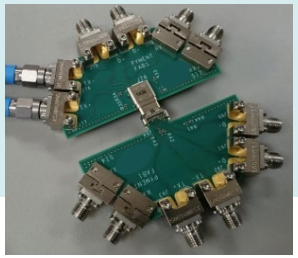
Passivity & causality correction

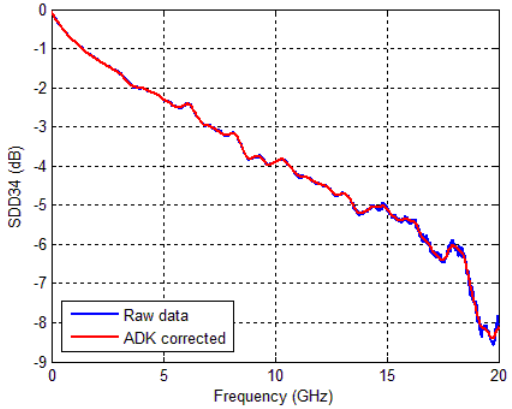
The only tool that can correct measurement error

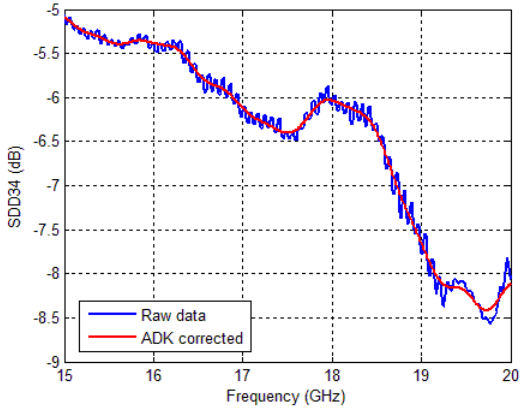


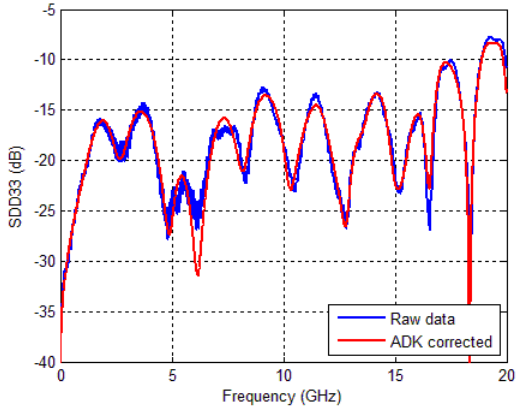
- Proprietary algorithm to smooth S-param magnitude and phase and correct causality error for any noisy data.
- Popular vector-fitting method can only correct small error for simulation data.
- Multiple ways to fill in DC data.

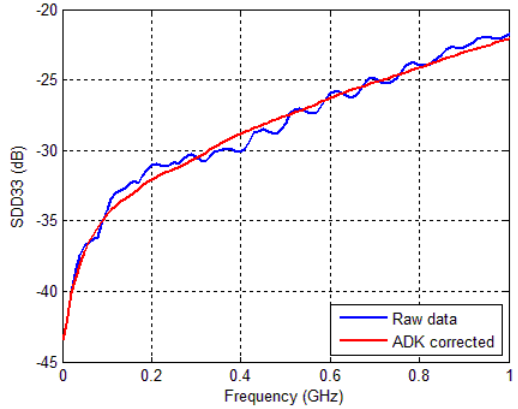
USB Type-C raw measurement





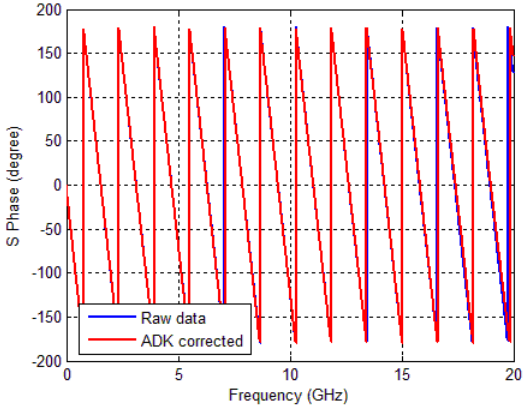


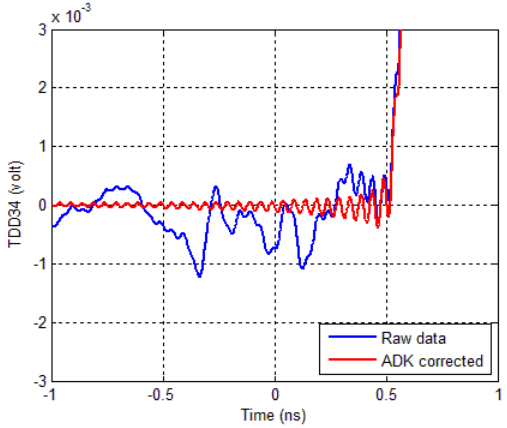


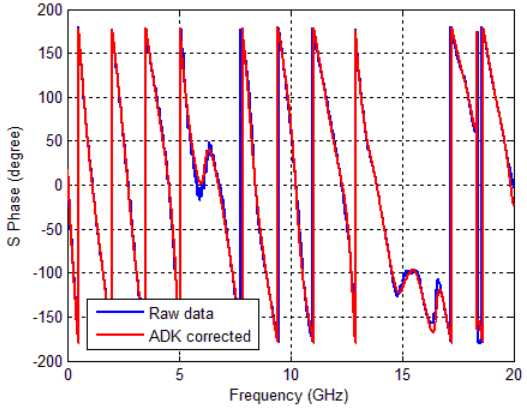


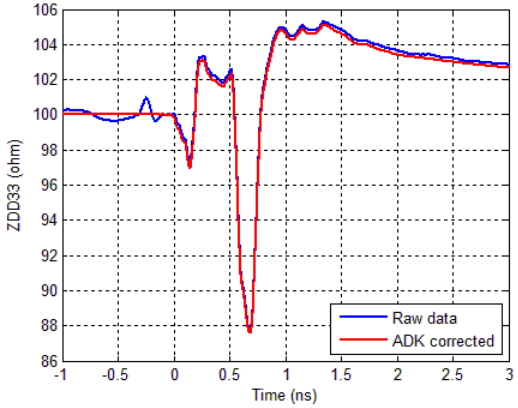
Insertion loss

Return loss



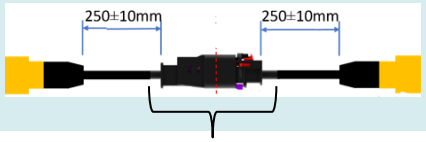




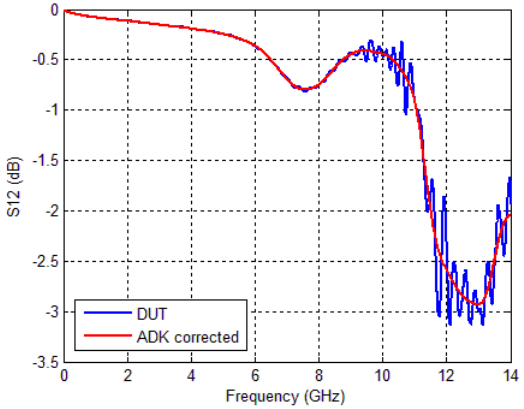


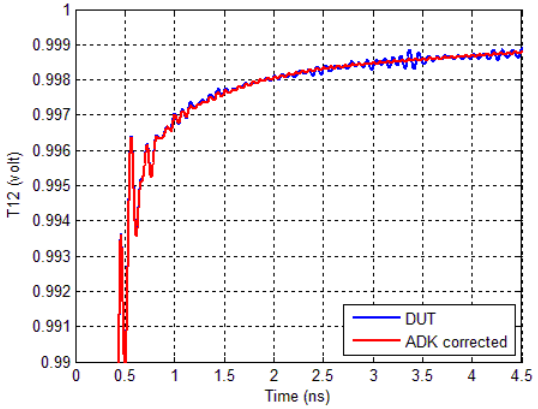
Rise time (20/80) = 50ps

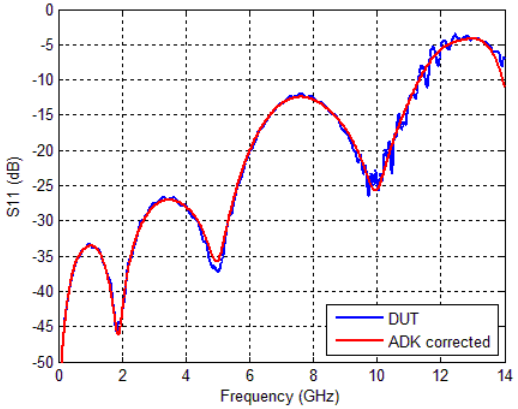
SAE/USCAR-49 inline connector

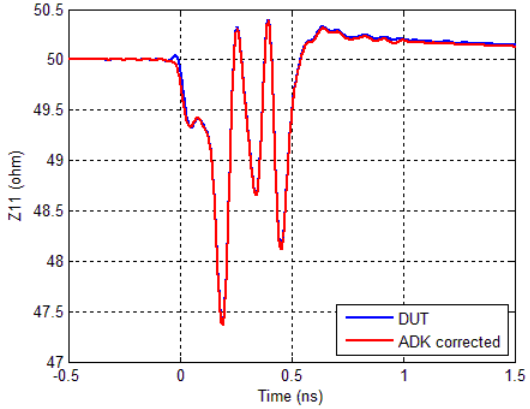


DUT



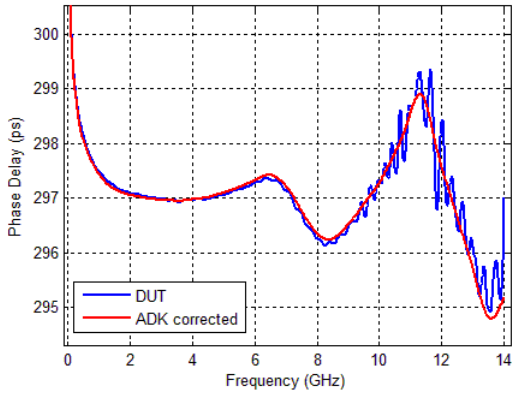


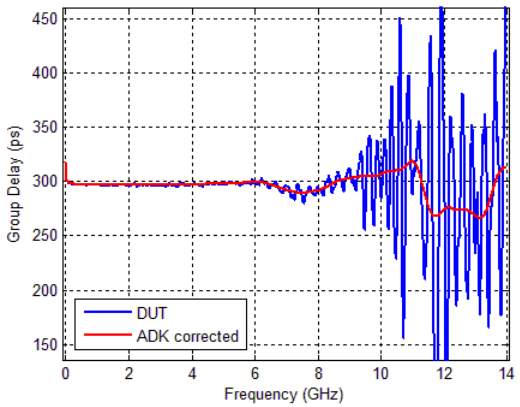


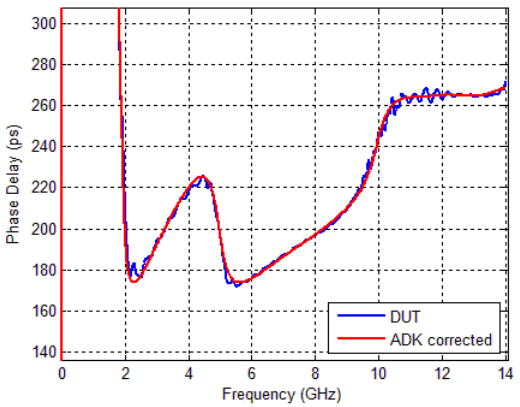


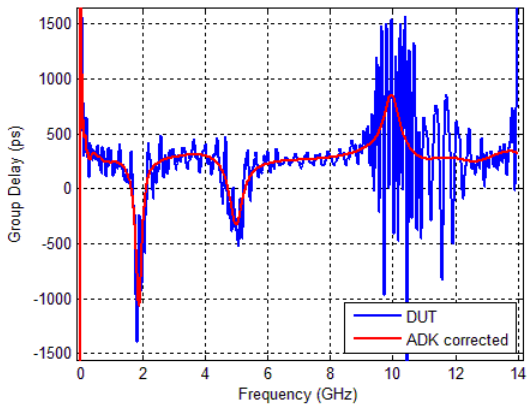
Insertion loss

Return loss





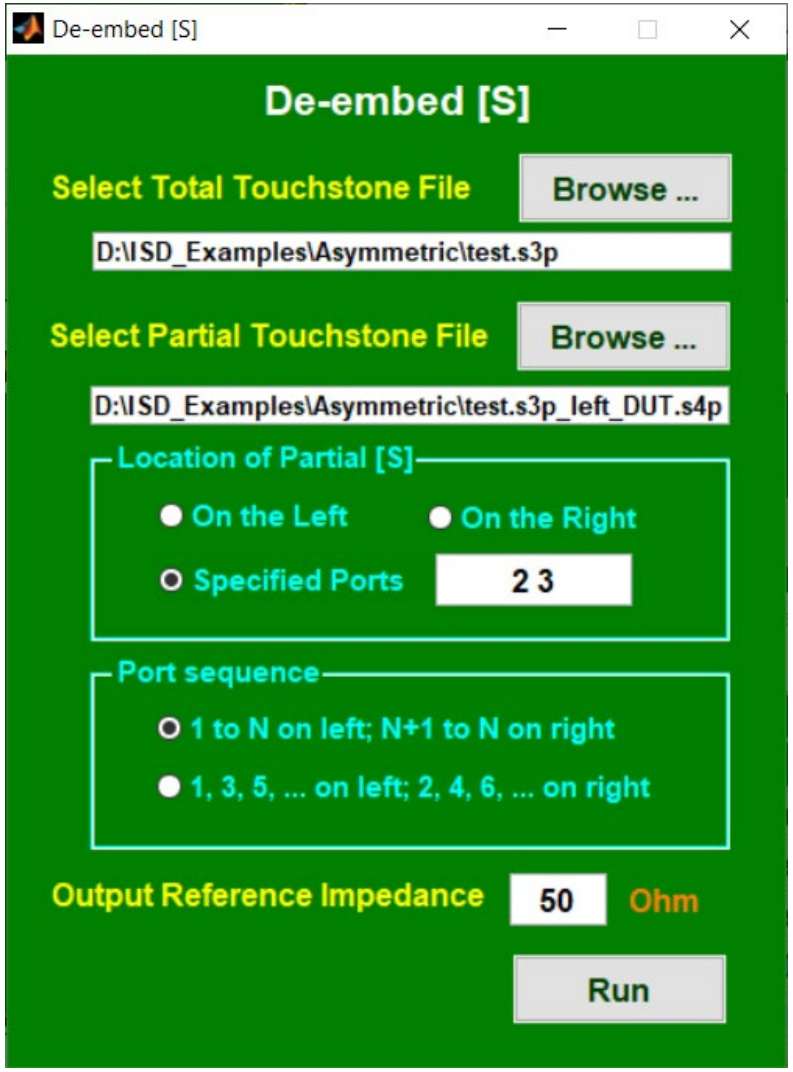


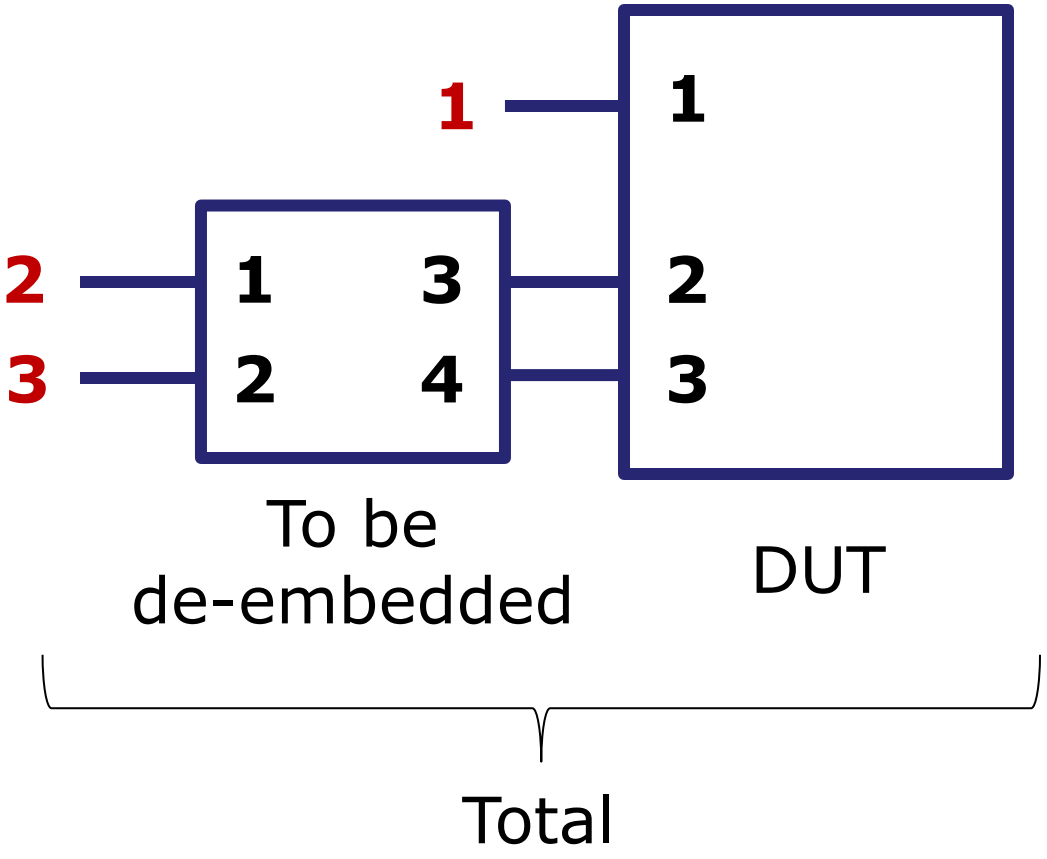


Rise time (20/80) = 50ps

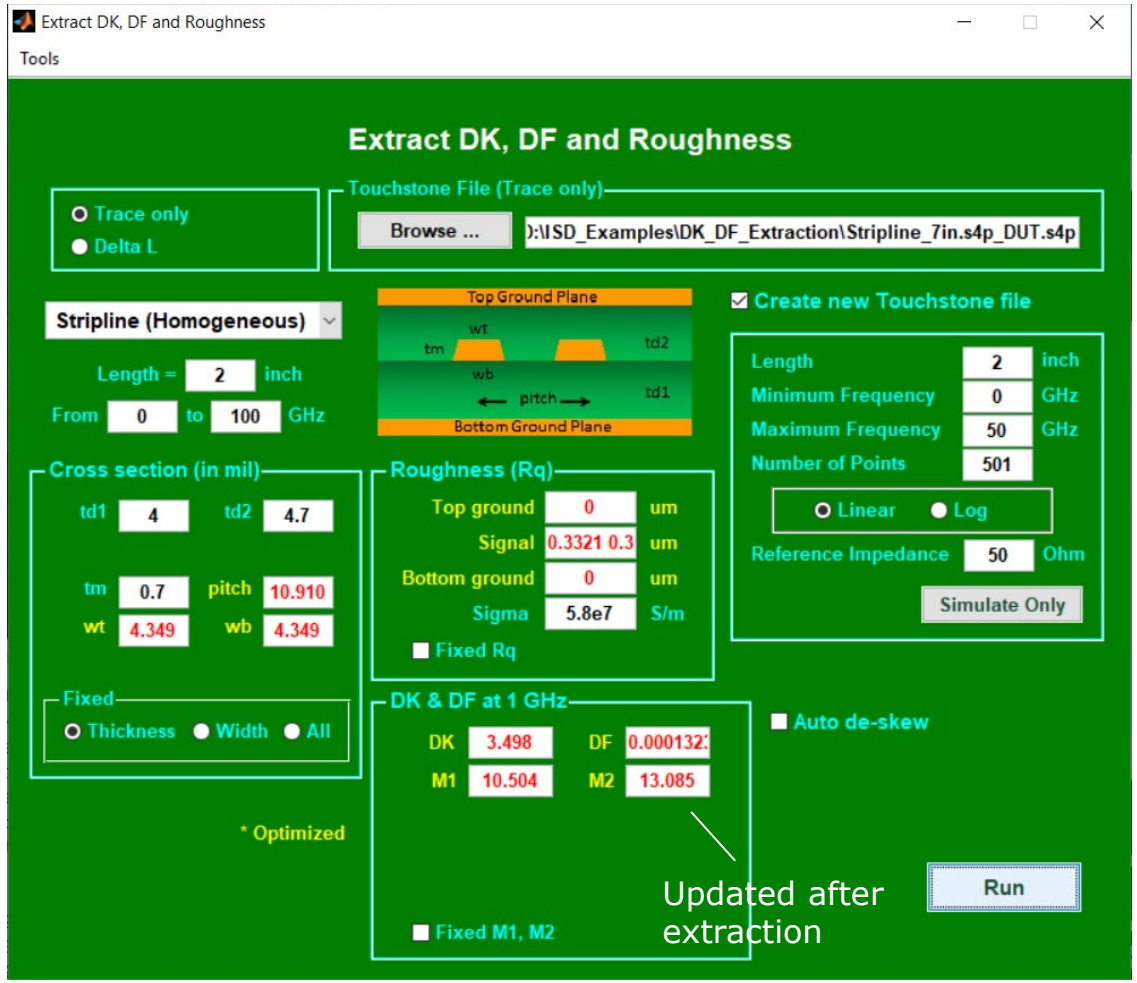
De-embed [S]

The only tool that can de-embed arbitrary N ports from M ports





Robust DK/DF/SR extraction

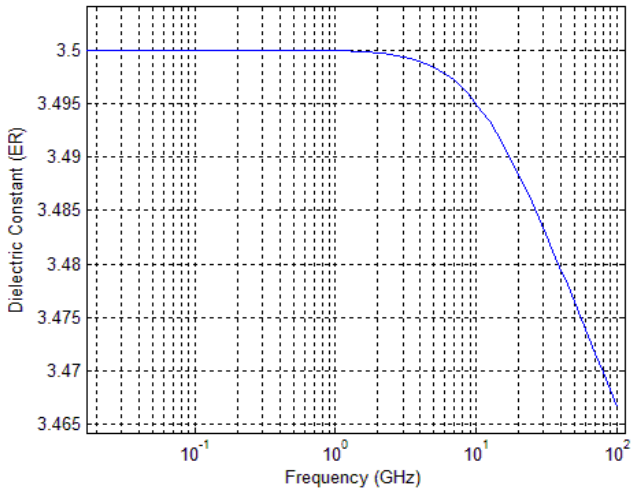


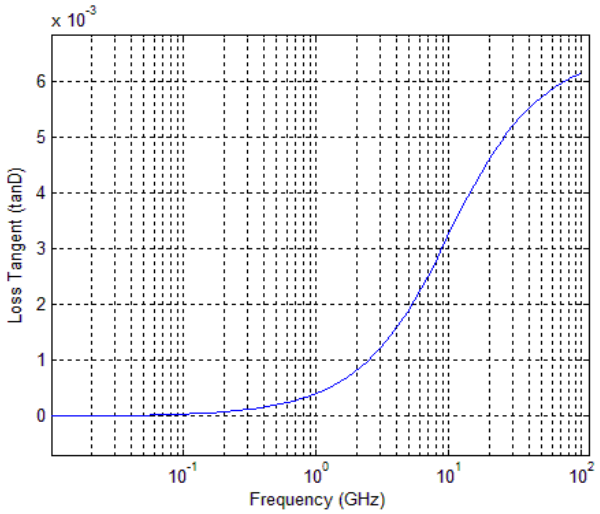
- Interactive GUI
- Multiple templates
- Different roughness for each surface
- Simulate directly
- Huray model conversion
- Compatible HFSS models

Causal dielectric model

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

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





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

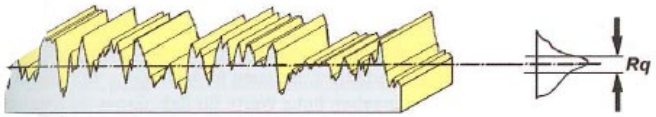
Surface roughness model

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

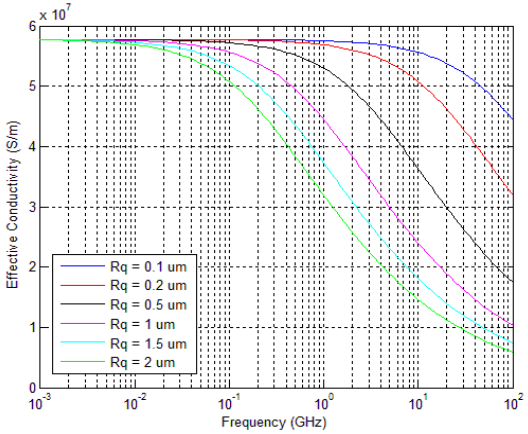
Parameter	Description	Standard
R_q	root mean square	DIN EN ISO 4287
R_a	arithmetic average	DIN EN ISO 4287, ANSI B 46.1
R_k	core roughness depth	DIN EN ISO 13565
R_z	average surface roughness	DIN EN ISO 4287

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

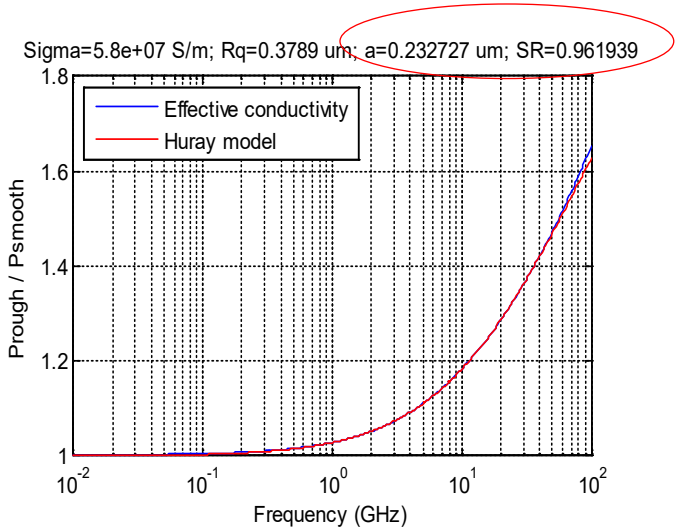
Convert effective conductivity to Huray model

- Huray model

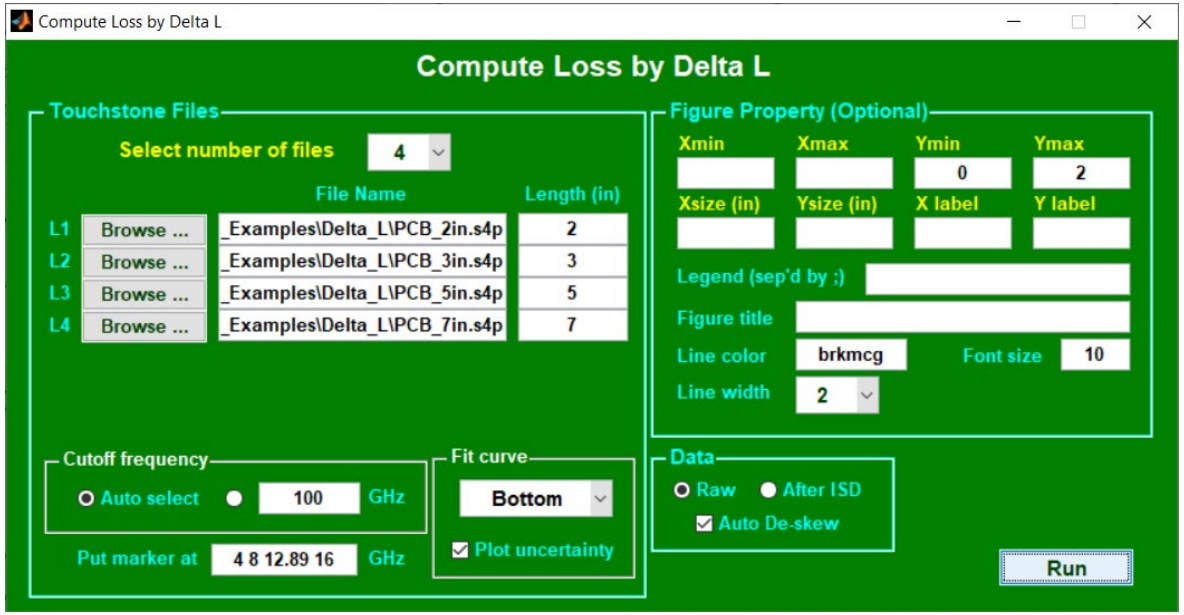
$$\frac{P_{rough}}{P_{smooth}} \approx 1 + \frac{3}{2} \cdot SR \cdot \left(\frac{1}{1 + \frac{\delta(f)}{a} + \frac{1}{2}\left(\frac{\delta(f)}{a}\right)^2} \right)$$

$$\delta(f) = \sqrt{\frac{1}{\pi f \mu \sigma}} \quad ; \quad a = \text{radius} \quad ; \quad SR = \text{surface ratio}$$

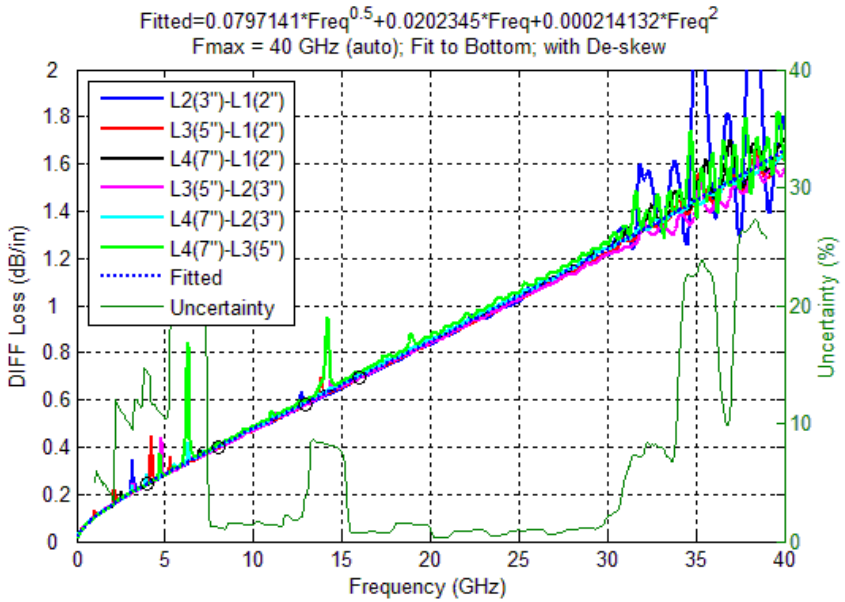
- Curvefit Prough / Psmooth to convert σ_{bulk} , R_q to a , SR



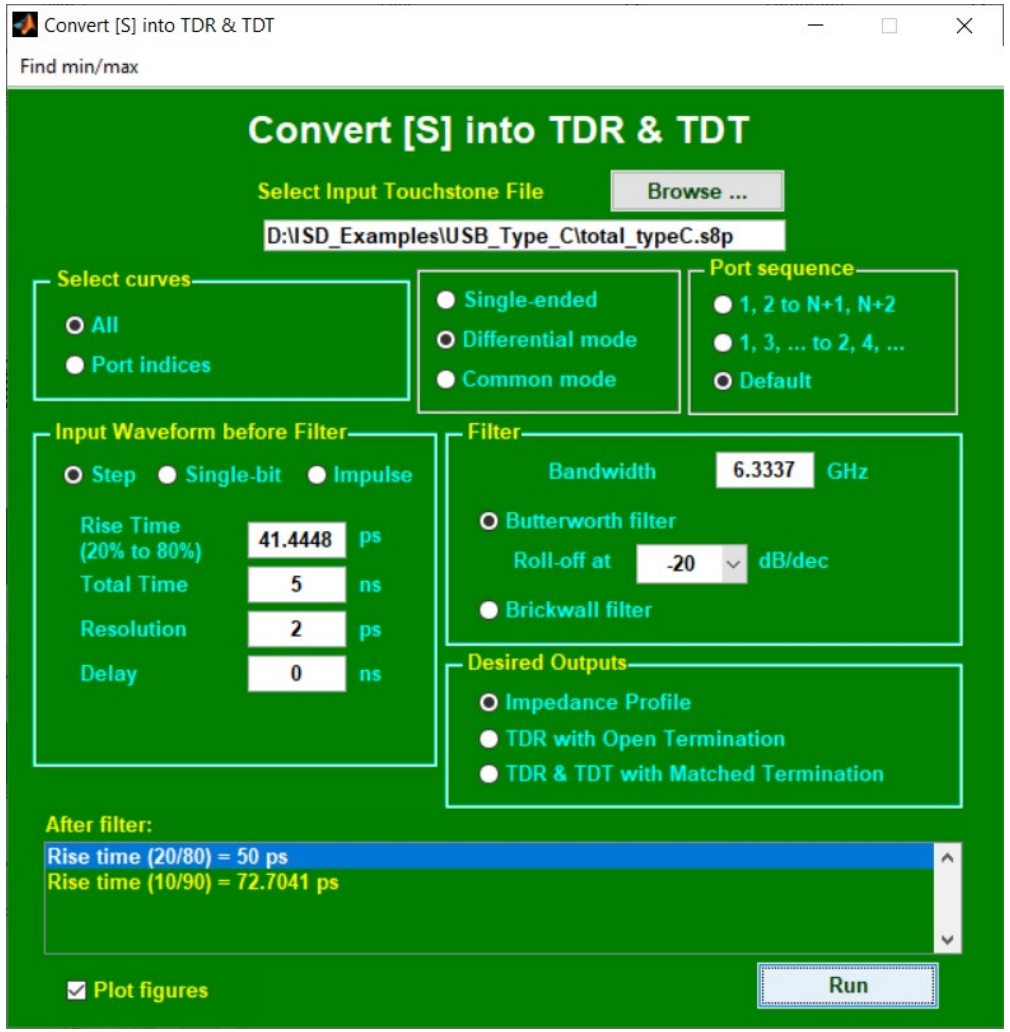
Compute loss by Delta L



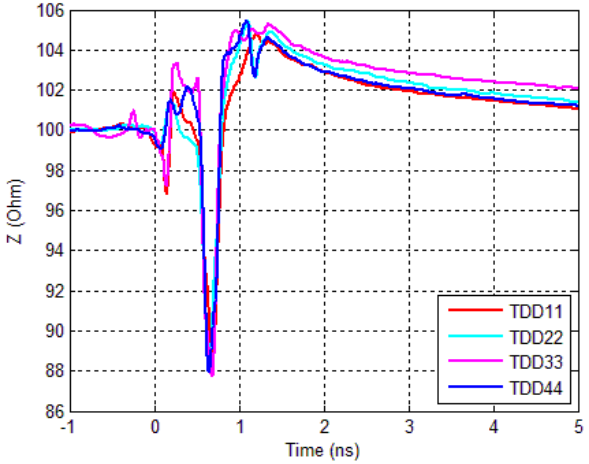
- Curvefitted equation for loss per inch with uncertainty
- Auto de-skew
- Fit data to bottom, middle or top



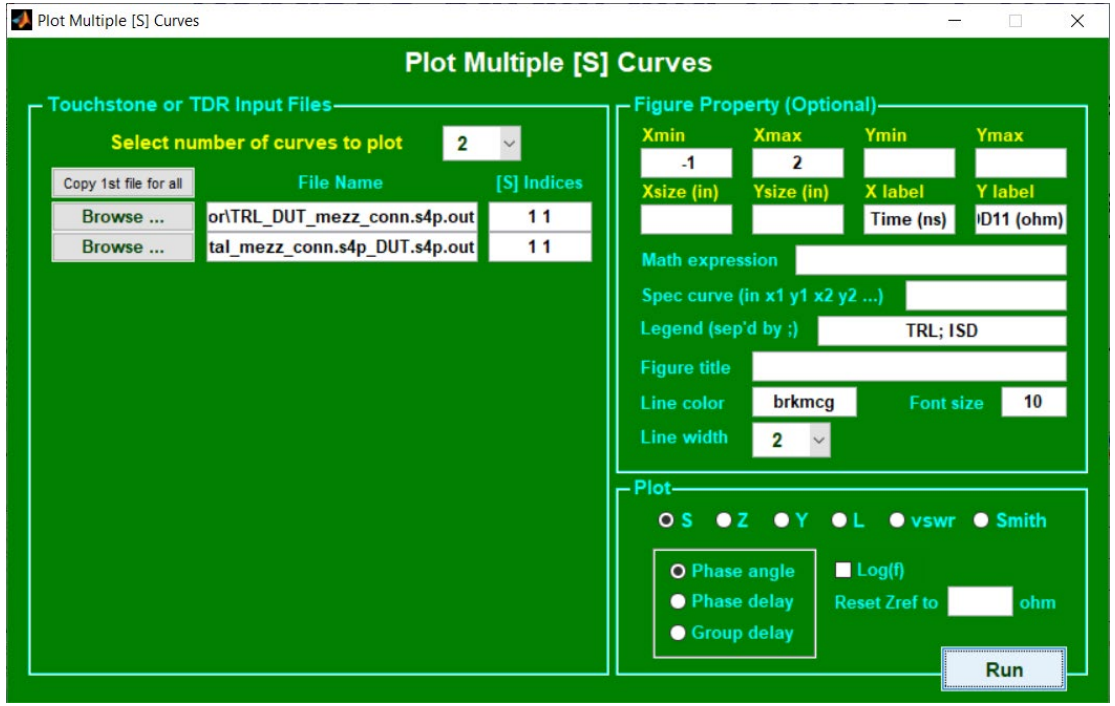
[S] to TDR & TDT



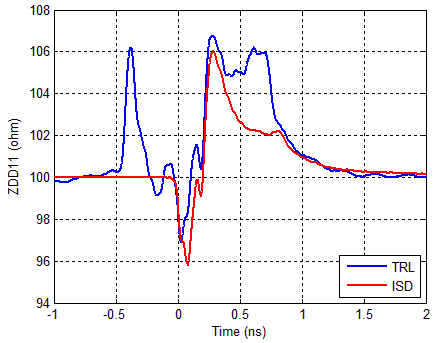
- Built-in filter & IFFT.
- Single-ended, differential or common mode.
- Step, single-bit or impulse response.
- Correlated with TDR equipment.

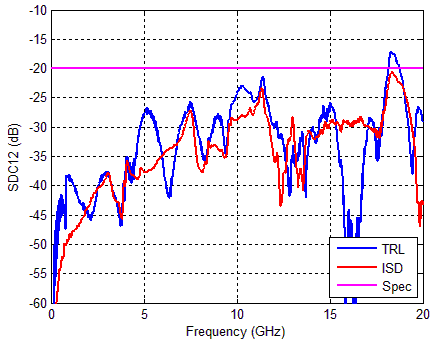


Robust S-param and TDR/TDT viewer

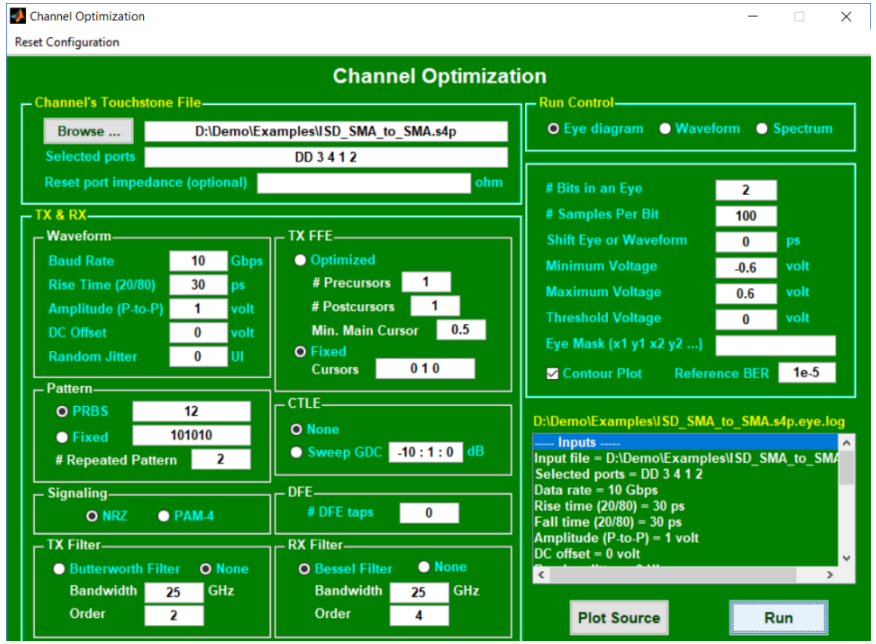


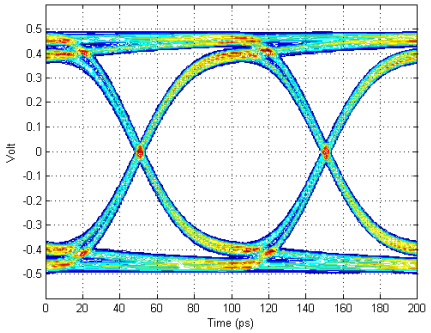
- Add math expression, spec curves, figure title/legend.
- Display delay or DK, VSWR, Smith Chart.
- Reset impedance.
- Flexible port index.



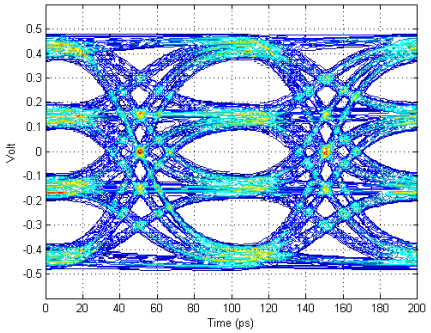


Plot eye diagram





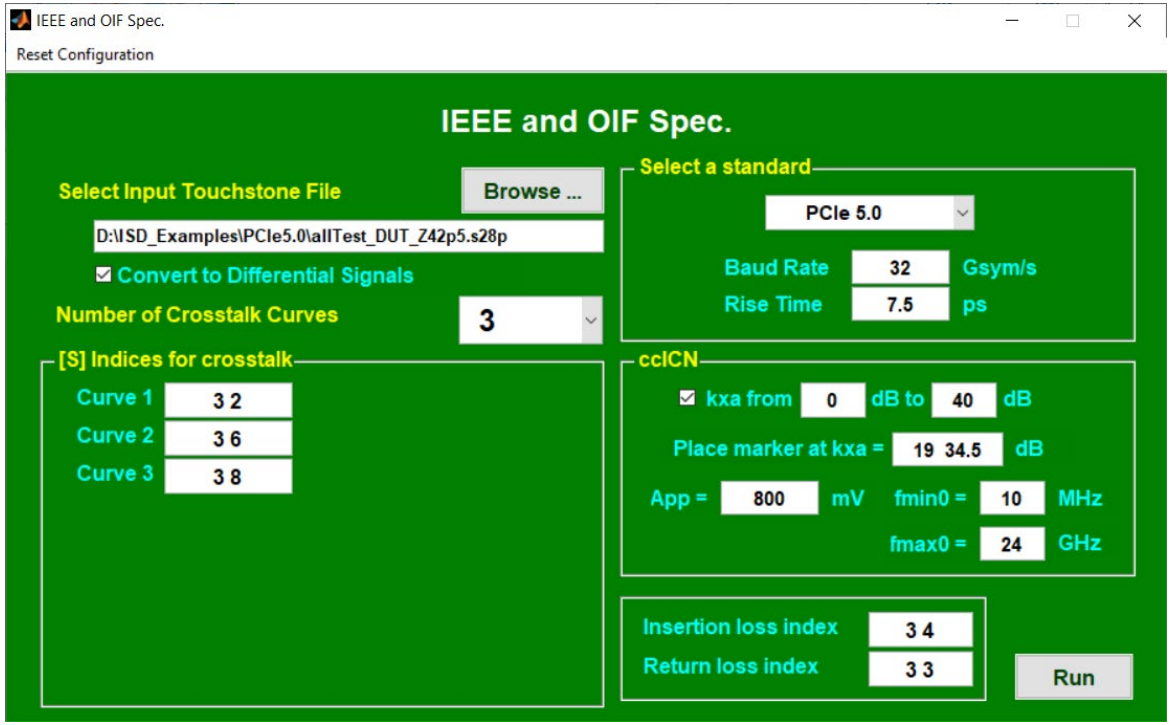
NRZ



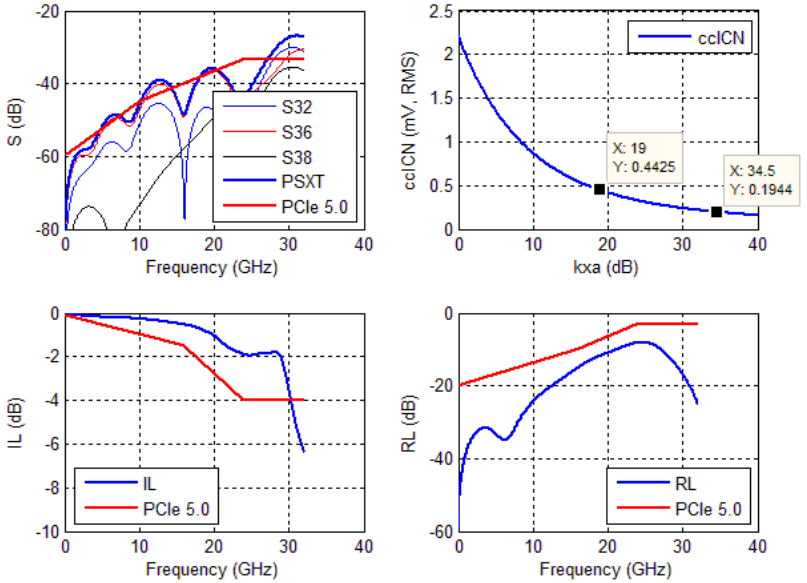
PAM4

- [S] to eye diagram, waveform or spectrum.
- Single-ended, differential or mixed-mode.
- With or without NEXT and FEXT.
- With or without TX FFE, RX CTLE and DFE.
- Fixed or PRBS patterns.
- NRZ or PAM4

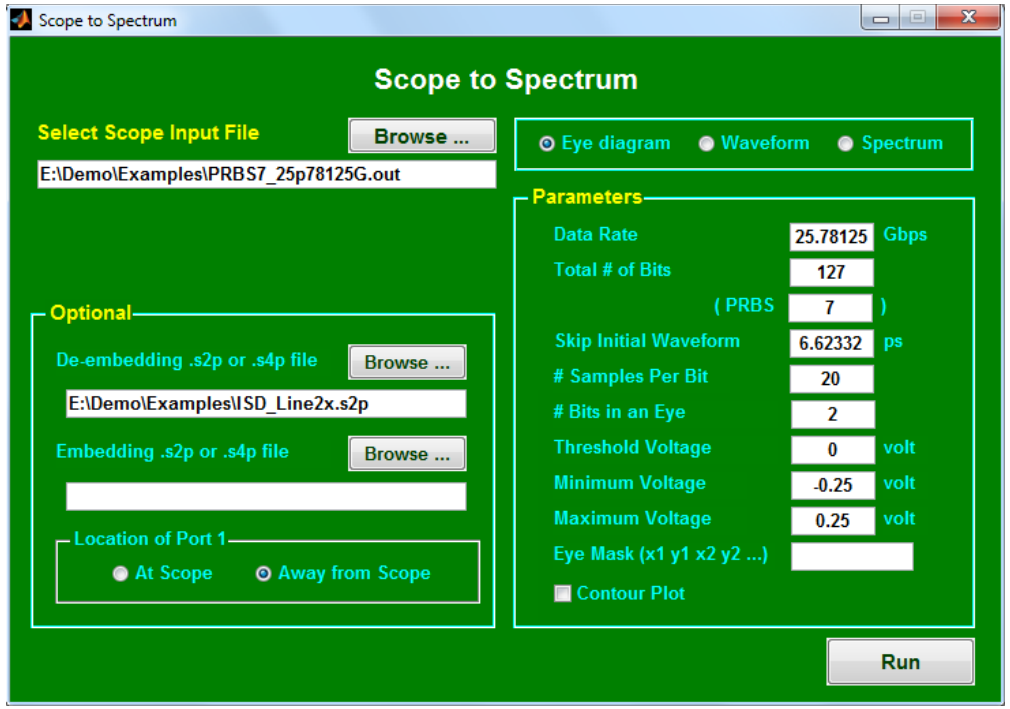
IEEE, OIF and PCIe Spec.



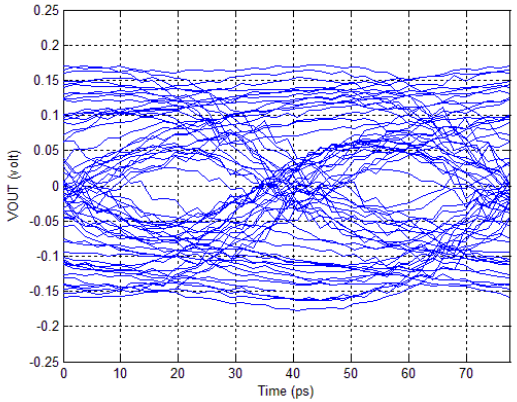
- Compare IL, RL, crosstalk, ICR, ICN, ccICN with various compliance spec.



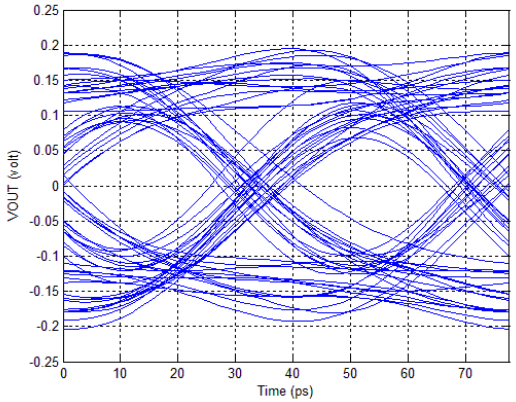
Scope embedding & de-embedding



- Plot scope data in waveform, eye diagram or spectrum.
- Embed and/or de-embed [S] from scope data.

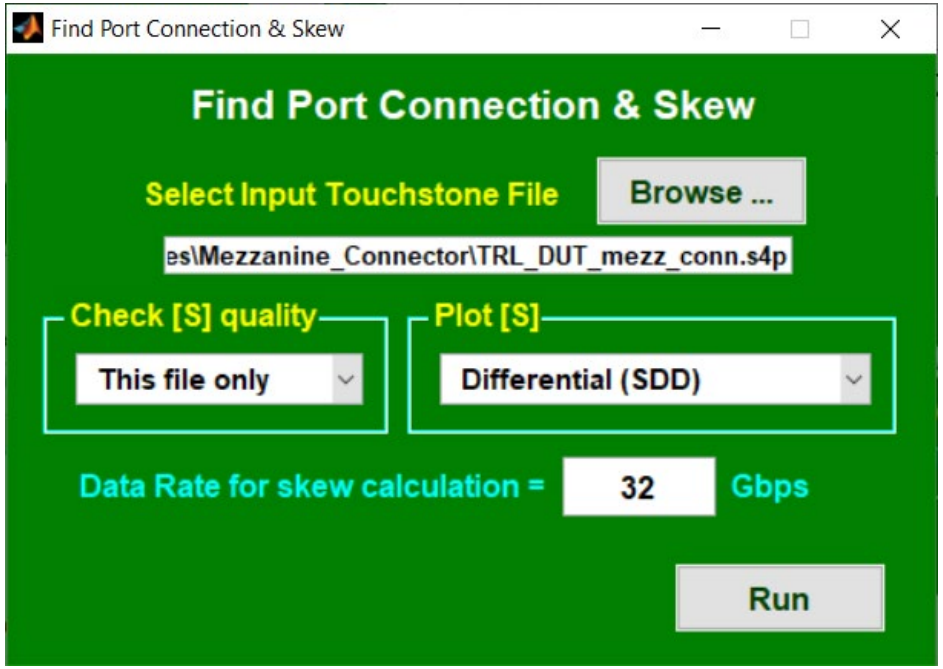


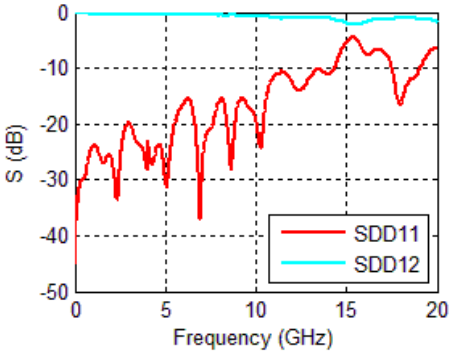
Original

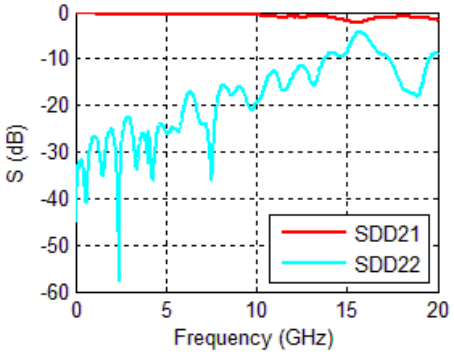


After de-embedding

Find connection





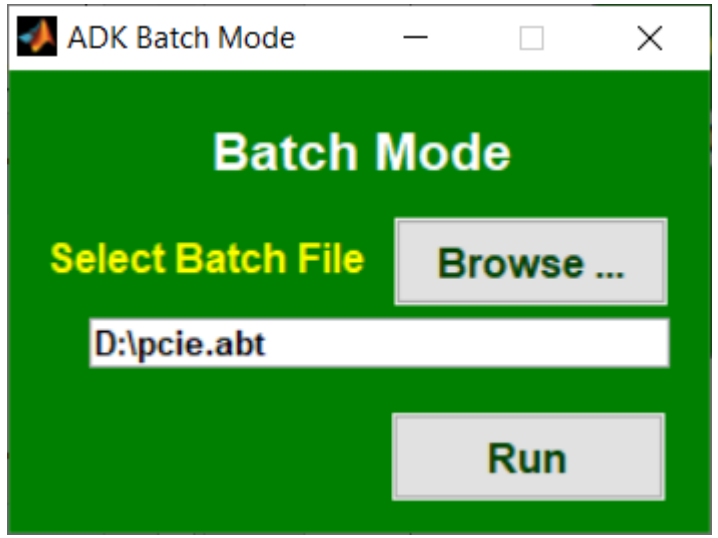


- Quickly examine [S].
- Identify from-to connection.
- Compute quality metrics.
- Compute delay and skew.

```
File name: D:\ISD_Examples\Mezzanine_Connector\TRL_DUT_mezz_conn.s4p
  Total 800 points from 0.025 GHz to 20 GHz with 50 ohm Zref.
  Reciprocity metric =  99.04 %
  Passivity   metric =  92.90 %
  Causality   metric =  62.48 %
  Causality metric for each S(i,j):
   67.44  84.47  64.01  89.27
   86.39  73.68  89.13  62.48
   63.05  88.40  67.03  92.20
   89.08  66.11  92.36  70.97
  From-To Connections:
    Port 1 -> 3
    Port 2 -> 4
    Data rate set to 32 Gbps --
    L1: Median phase delay (1 to 3) = 132.159 ps
    L2: Median phase delay (2 to 4) = 131.107 ps
    Median skew (L1-L2) = 0.974904 ps
    Effective Intra-pair skew (EIPS: L1-L2) = 0.9157 ps
```

Batch mode

- Run multiple jobs through batch file in GUI or command line.



"C:\Program Files (x86)\AtaiTec\ADK\adk2.exe" adkc D:\pcie.abt

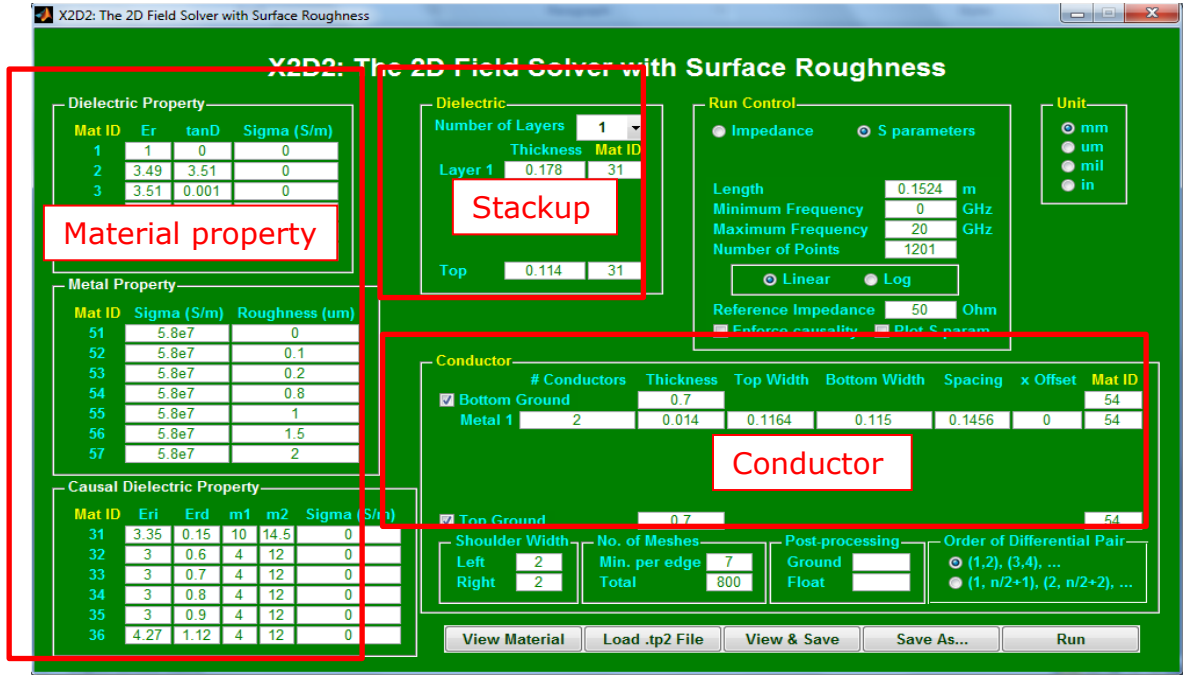
- Most ADK functions are available through batch file.

```
# standard
infile D:\PCIeCEM5\allTest.s28p_Z42p5.s28p_DUT.s28p
spec_no 7
differential 1
ccicn 1
il 3 4
rl 3 3
xtalk 3 2
xtalk 3 6
xtalk 3 8
figure_tag ccICN_FEXT
csv_tag ccICN_FEXT

# passive
infile D:\Demo\examples\ISD_SMA_to_SMA.s4p
symmetric 0
causal 0
plot 0
dc_method 1
resistance 0.05

# s2mix
infile D:\Demo\examples\ISD_SMA_to_SMA.s4p_pass.s4p
mixed 1
order 0
```

X2D2
Advanced 2D solver for surface roughness modeling



- Accurate 2D BEM field solver with causal dielectric and effective-conductivity surface roughness models.
- Compute impedance, RLGC matrices and S parameters.
- Create Touchstone file and tabular W-element model