

**Advanced Signal Integrity Design Kits  
reduced version  
(ADKmini)**

**User's Guide**

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## Advanced Signal Integrity Design Kits (ADK)

Advanced Signal Integrity Design Kits (or, ADK) is a collection of many signal integrity utility tools. It was designed to pre- and post-process signal integrity (SI) simulation and measurement data in an easy-to-use, mobile-apps-like package. It helps SI engineers identify and correct errors and correlate between simulation and measurement within a few mouse clicks. A system's design cycle time is greatly improved as a result.

The main window of ADK contains links to many utility functions. In most cases, executing these functions amounts to simply select an input file, and click "run".

ADKmini is a reduced version of ADK with a few customized features.

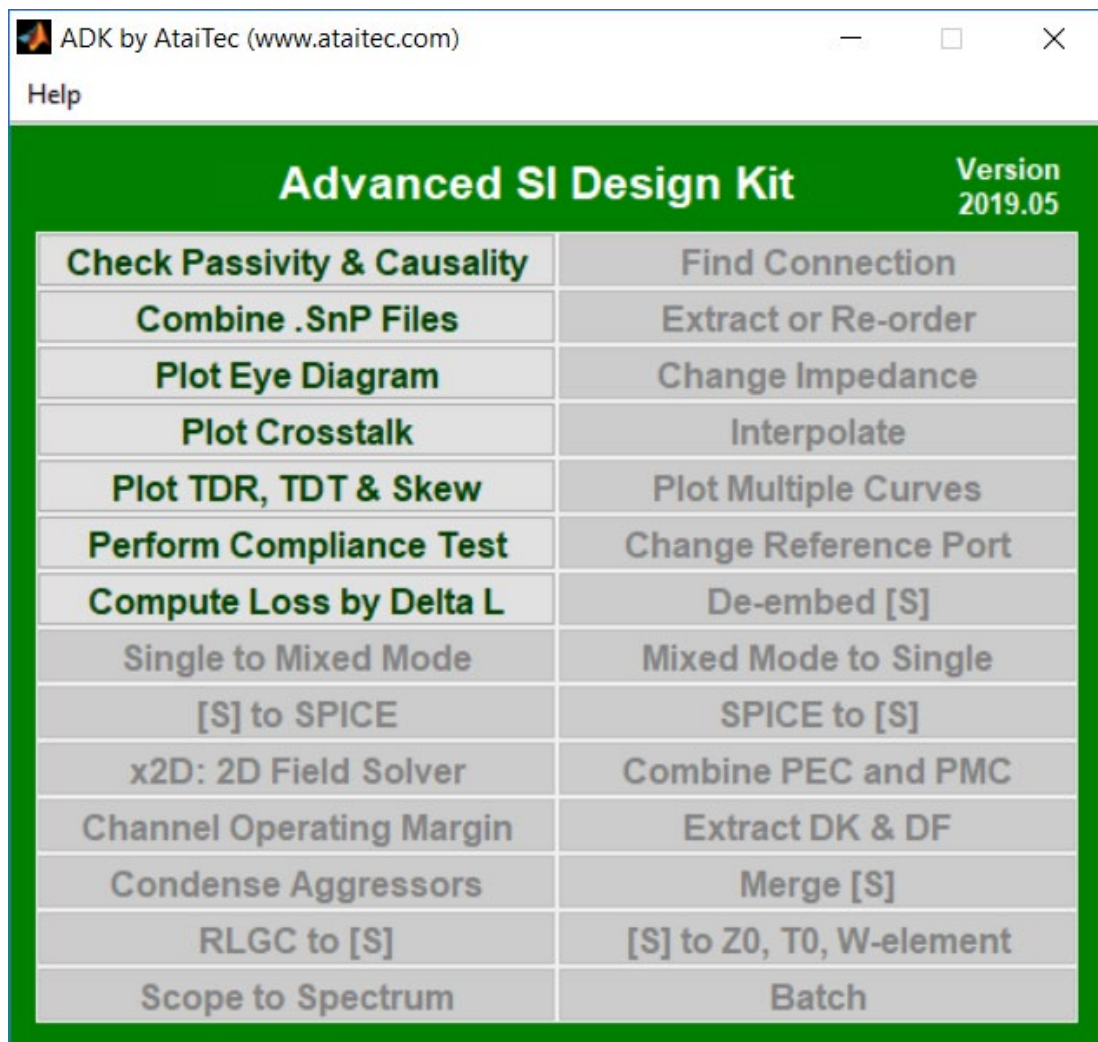


Figure 1

## Check Passivity & Causality (or Correct Passivity & Causality)

This utility lets the user correct a Touchstone file's reciprocity, passivity and/or causality. Depending on which button is enabled (see Figure 2), the newly created Touchstone file takes on one of the following names:

InputFileName\_sym.sxxp ("reciprocal" only)  
InputFileName\_pass.sxxp ("passive" only)  
InputFileName\_causal.sxxp (causal" only)  
InputFileName\_sym\_pass.sxxp ("reciprocal" + "passive")  
InputFileName\_sym\_causal.sxxp ("reciprocal" + "causal")  
InputFileName\_pass\_causal.sxxp ("passive" + "causal")  
InputFileName\_sym\_pass\_causal.sxxp ("reciprocal" + "passive" + "causal")  
InputFileName\_new.sxxp (none)

Where xx is the number of ports.

For point-to-point nets, DC resistance for both signals and ground can be entered to quickly fill in S parameters at DC. Multiple numbers (such as "0.5 0.3 0.1") can be used for different resistance in each signal. The user can also specify the order of port connection: Ports (1,2,3,...) to (n+1,n+2,n+3,...), or Ports (1,3,5,...) to (2,4,6,...), or random/no-thru connection.

For multi-drop nets, the user can bring in a resistive circuit file (see the syntax in "SPICE to [S]" of ADK full version) to create the S parameters at DC.

Because VNA measurements or 3D full-wave solvers do not provide [S] at DC, the user will find this utility rather convenient in filling in the missing DC values for later data processing.

The passivity and causality correction helps correlate simulation and measurement data by avoiding the situation of trying to correlate non-physical data. In addition, passivity and causality corrected Touchstone files will help convergence in SPICE simulation.

Using the utilities of "Plot TDR, TDT & Skew" and "Plot Multiple Curves on the Same Graph" (available in ADK full version), the user can compare the time-domain impedance profiles before and after causality correction (on the sample file: zCausal.s2p), as shown in Figure 3.

In another example (tCausal.s4p), the causality effect on the transmission curves can be clearly seen in Figure 4.

Theoretically, infinite bandwidth is needed for a causal response. Forcing finite-bandwidth S parameters to represent a causal response requires modification of original data. The user should check their data before and after causality correction to make sure the changes are

“reasonable”. In general, the user should apply causality correction only to larger structures (or S parameters with at least several wavelengths at the highest frequency).

The user has the option to apply causality correction to (1) insertion loss only and (2) single-ended or mixed-mode S parameters. It is recommended that the user select the correction in mixed mode when the following conditions are met:

1. The original Touchstone file has  $4*N$  ports (where N is an integer), and
2. The input port numbers are either sequential (1, 2, 3, ...) or odd (1, 3, 5, ...).

When the mixed-mode method is selected, this utility will automatically convert the single-ended data into mixed-mode data and apply causality correction to the mixed-mode data before converting the mixed-mode data back to the single-ended data.

### *Zero out $T<0$ and Kramers-Kronig*

---

The default of causality correction is to zero out time-domain response at  $T<0$  for all S parameters except insertion loss before enforcing the Kramers-Kronig criteria. Zeroing out waveform at  $T<0$  helps reduce the change to waveform at  $T>0$ . In some cases, the user can disable "Zero out  $T<0$ " if a large level shift is observed in TDR waveforms. In other cases, the user may want to enable "Zero out  $T<0$ " and disable "Kramers-Kronig" so the insertion loss is not perturbed. ("Kramers-Kronig" modifies the phase angle of insertion loss using the "minimum phase" methodology.)

### *Reverse polarity*

---

At times the polarity of certain ports can be found reversed because of improper assignment of from- and to- nodes in simulation or signal and ground probes in measurement. This can be observed by examining either TDR or the phase angle of insertion loss. (The phase angle of insertion loss should be 0 at DC instead of  $\pm 180$  degrees.) This utility lets the user easily correct the polarity error by entering those port numbers, separated by space, under "Reverse polarity".

Correct Passivity & Causality by AtaiTec (www.ataitec.com)

## Correct Passivity & Causality

**Select Input Touchstone File** Browse ...

D:\Demo\Examples\zCausal.s2p

**Correct [S] at DC**

- Set DC resistance for point-to-point net
 

Signals:  Ohm  
 Ground:  Ohm
- Set DC by resistive circuit file
 

Browse ...
- Extrapolate [S] at DC
- Use original value

**Causality Options**

- ☒ Reciprocal
- ☒ Passive
- ☒ Causal

**Method**

- ☐ Single-ended
- ☒ Mixed mode

**Reverse polarity**

Port number

**Port Connection**

- ☐ Default
- ☐ IN: 1, 2, 3, ...; OUT: n+1, n+2, n+3, ...
- ☐ IN: 1, 3, 5, ...; OUT: 2, 4, 6, ...
- ☐ Random or no thru

☒ Plot figures Run

Figure 2

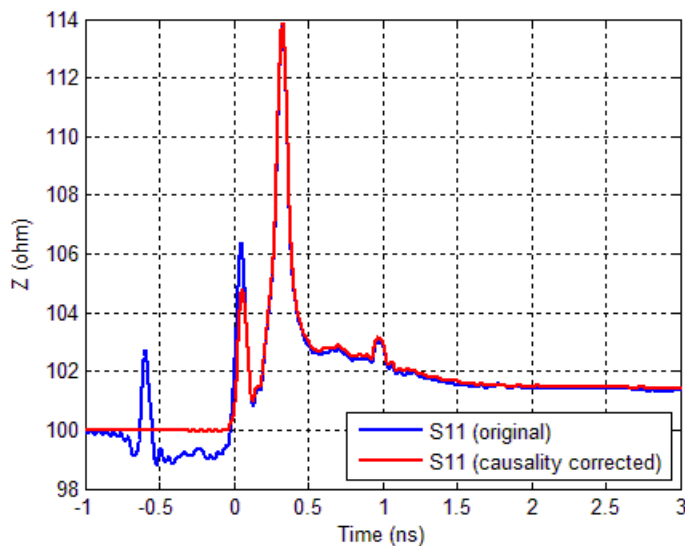
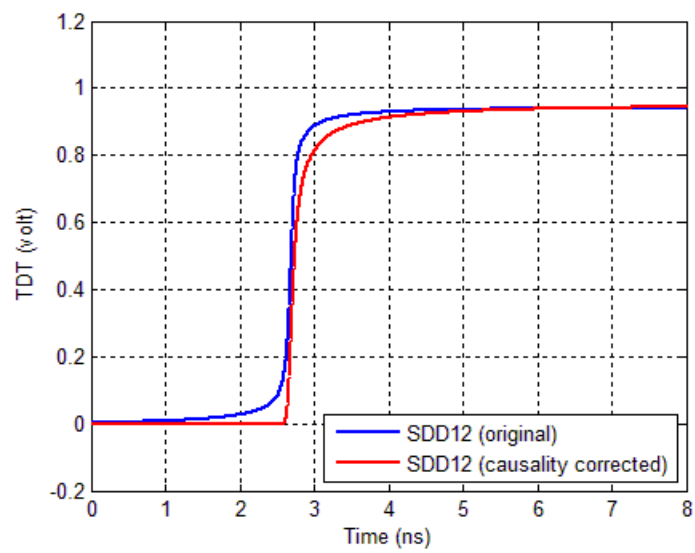


Figure 3



**Figure 4**

## Plot TDR, TDT & Skew

This utility allows [S] to be converted into impedance profile or TDR/TDT with matched terminations (Figure 5) . The user can select step, single-bit or impulse response. (The impulse response corresponds to the derivative of step response with zero rise time.) Zero is assumed for [S] above the Touchstone file bandwidth.

When step or single-bit response is selected, the input waveform is created by feeding a trapezoidal waveform through a Butterworth filter. When “TDR, TDT and Skew” is selected (Figure 6), the input waveform (VIN) is plotted, together with a summary of rise time, delay, skew and maximum crosstalk amplitude, etc.

The user has the option of applying TDR/TDT to single-ended, differential-mode or common-mode signals. Two types of port sequence are supported for differential- or common-mode signals: (1) 1 to N as inputs and N+1 to 2N as outputs (which is preferred) and (2) 1, 3, ..., 2N-1 as inputs and 2, 4, ..., 2N as outputs.

To reveal non-causal behavior, if any, all waveforms are plotted starting at -1 ns. Responses before time x (with  $x \geq 0$ ) can be indication of non-causality. The user has the option of adding delay to shift the waveform and observe responses before -1 ns. Figure 7 to Figure 8 show an example of differential impedance profile.



Plot TDR, TDT and Skew by AtaiTec (www.ataitec.com)

## Plot TDR, TDT and Skew

**Select Input Touchstone File** Browse ...

D:\Demo\Examples\ISD\_SMA\_to\_SMA.s4p

☒ **Single-ended**
☐ **Differential mode**
☐ **Common mode**

**Input Waveform**

☒ **Step**
☐ **Single-bit**
☐ **Impulse**

**Rise Time**  
 (20% to 80%) 50 **ps**

**Total Time** 5 **ns**

**Resolution** 2 **ps**

**Delay** 0 **ns**

**Desired Outputs**

☐ **Impedance**  
☒ **TDR, TDT and Skew**

D:\Demo\Examples\ISD\_SMA\_to\_SMA.s4p.tdt.log

S24 min = -0.00109056 ; max = 0.988617 ; T(50) =  
 DELAY (S24) = 0.65005 ns  
 S31 min = -0.000192496 ; max = 0.989447 ; T(50) =  
 DELAY (S31) = 0.651201 ns  
 S42 min = -0.00140263 ; max = 0.98798 ; T(50) =  
 DELAY (S42) = 0.650099 ns  
**SKEW (S24-S13) = -1.17104 ps**

☒ **Plot figures** Run

Figure 5

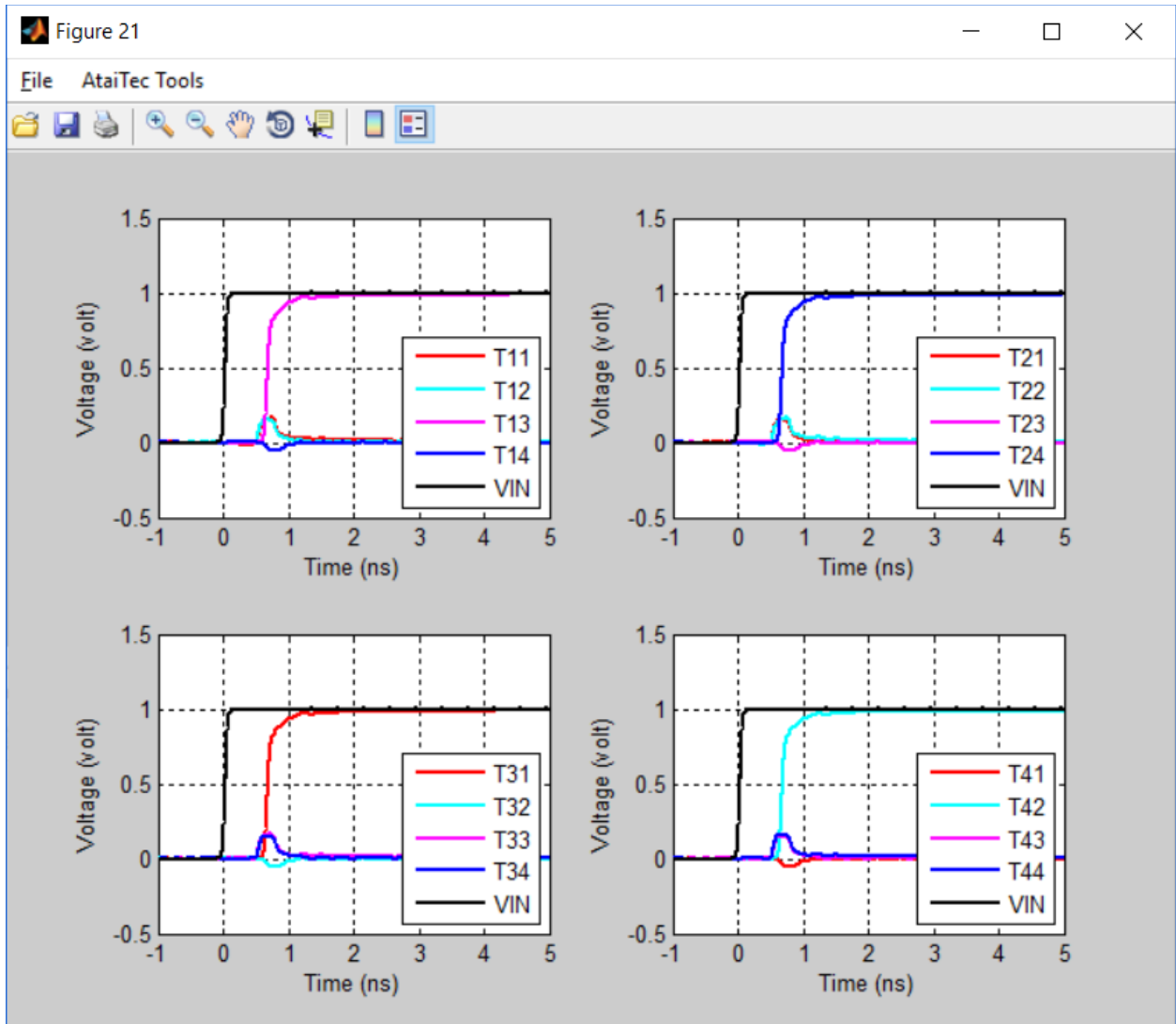


Figure 6

Plot TDR, TDT and Skew by AtaiTec (www.ataitec.com)

## Plot TDR, TDT and Skew

Select Input Touchstone File

D:\Demo\Examples\ISD\_SMA\_to\_SMA.s4p

☒ Single-ended ☐ Differential mode ☐ Common mode

### Input Waveform

☒ Step ☐ Single-bit ☐ Impulse

Rise Time (20% to 80%)  ps

Total Time  ns

Resolution  ps

Delay  ns

### Desired Outputs

☐ Impedance

☒ TDR, TDT and Skew

☒ Plot figures

Figure 7

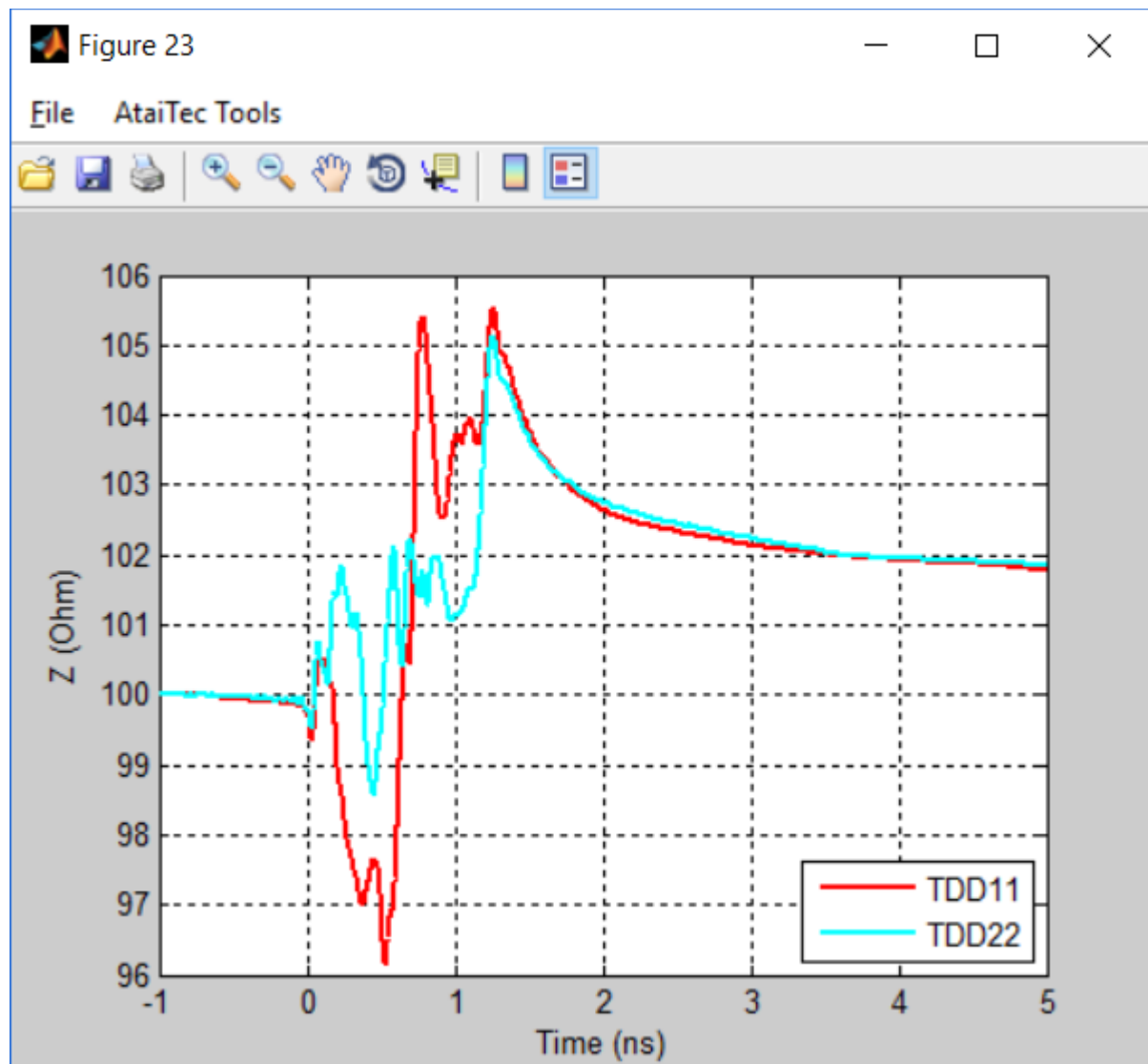


Figure 8

## Combine .SnP Files (or Combine [S])

With this utility, the user can combine several Touchstone files and expand it into a file with more ports. Zeros are inserted for un-specified [S]. One application is to combine many 4-port measurement files into a larger multi-port file. All Touchstone files will be synced automatically to the first file for the same frequencies and reference impedance.

Two methods are available: “Combine by [S]” and “Combine by [Z]”. The user should choose “Combine by [S]” if the un-measured ports are terminated and “Combine by [Z]” if the un-measured ports are open.

The following example shows how to combine six .s4p files into a complete .s8p file. Ports 1 to 4 are inputs and Ports 5 to 8 are outputs. The port sequence for six measurements is:

1-2-3-4 (NEXT)  
1-2-7-8 (FEXT)  
3-4-5-6 (FEXT)  
5-6-7-8 (NEXT)  
1-2-5-6 (THRU)  
3-4-7-8 (THRU)

Note that when there are duplicate port numbers, the data from the file specified later will override the data from the file specified earlier. For more accurate return loss, it’s usually a good idea to specify the file that contains the thru measurement (i.e., insertion loss) last.

To skip certain ports from a Touchstone file for combination, the user can assign to those ports a port number that is larger than the “total number of ports after combination”. Then, those “unwanted” ports will be dropped after combination.

“Reset Configuration” in the menu bar presets the port sequence and guides the user to combine six .s4p files into one .s8p file.

Combine .SnP Files by AtaiTec (www.ataitec.com) — □ ×

Reset Configuration

## Combine .SnP Files

Select number of files to combine

Method

☒ Combine by S ☐ Combine by Z

Touchstone Files

		Port Sequence
<input type="button" value="Browse ..."/>	D:\Demo\Examples\next1234.s4p	1 2 3 4
<input type="button" value="Browse ..."/>	D:\Demo\Examples\fext1278.s4p	1 2 7 8
<input type="button" value="Browse ..."/>	D:\Demo\Examples\fext3456.s4p	3 4 5 6
<input type="button" value="Browse ..."/>	D:\Demo\Examples\next5678.s4p	5 6 7 8
<input type="button" value="Browse ..."/>	D:\Demo\Examples\thru1256.s4p	1 2 5 6
<input type="button" value="Browse ..."/>	D:\Demo\Examples\thru3478.s4p	3 4 7 8

Total number of ports after combination

New Touchstone File Name

☒ Plot figures

Figure 9

## Plot Eye Diagram (or Channel Optimization)

With this utility, the user can easily import S parameters, select single-ended or mixed-mode IL, RL, NEXT and FEXT, run bit-by-bit simulation for NRZ or PAM-4 signals and plot waveform, eye diagram or spectrum with PRBS or fixed data pattern and TX FFE, RX CTLE and RX DFE tap coefficients.

### *Inputs and outputs*

---

In Figure 10, we import a .s4p file, select ports: “DD 2 1” (for differential insertion loss from Port 1 to Port 2), select optimized TX tap coefficients with 1 pre- and 1 post-cursor and plot a 2-bit eye (Figure 11).

The optimized tap coefficients, eye height, eye width and jitter are displayed on the screen (Figure 12). In addition, an output .log file (ISD\_SMA\_to\_SMA.s4p.log in this case, also shown in Table 1) that contains pertinent information is saved in the same directory as the input file.

### *Selected ports*

---

Multiple S parameters can be summed together, with their respective port indices separated by semicolon (;). In Figure 13 to Figure 14, we simulate the single-ended transmission (S31) with NEXT (S34) and FEXT (S32) included.

### *Random Jitter and Reference BER*

---

Random jitter, specified in unit interval (UI), is used in conjunction with reference BER. When non-zero random jitter ( $\sigma_{rms}$ ) is entered, the eye diagram will be shifted by  $\pm Q \cdot \sigma_{rms}$  where

$$Q = \sqrt{2} \cdot \operatorname{erfc}^{-1}(2 \cdot BER)$$

Random jitter must be between 0 and 0.1; BER must be between 1e-40 and 0.1

### *TX tap coefficients*

---

The user can select either optimized or fixed TX tap coefficients. When fixed TX tap coefficients are selected, the cursors are entered in a vector (such as “-0.02 -0.03 0.85 -0.08 -0.02”) where

- The main cursor takes on the largest value of input vector.

- The pre- and post-cursors are the numbers before and after the main cursor, respectively.
- Any number of pre- and post-cursors can be specified.

### Continuous time linear equalization (CTLE)

The transfer function of CTLE is defined by

$$H_{CTLE}(f) = f_b \cdot \frac{j \cdot f + 0.25 \cdot f_b \cdot 10^{\frac{G_{DC}}{20}}}{(j \cdot f + 0.25 \cdot f_b) \cdot (j \cdot f + f_b)}$$

where  $f_b$  is the baud rate (or data rate in the “Channel Optimization” window) and  $G_{DC}$  is the DC gain (in dB) which, using the syntax of -10:1:0, for example, is swept from -10 to 0 dB in 1 dB increment.

### Decision feedback equalizer (DFE)

The DFE output,  $y(t)$ , is defined by

$$y(t) = x(t) + \sum_{n=1}^N w_i \cdot y_d(t - nT_b)$$

where  $x(t)$  is the receiver input,  $w_i$ 's are the DFE tap coefficients,  $T_b$  is the bit time and  $y_d$  (=1 or -1) is the slicer's output.

DFE is turned off when # DFE taps is set to 0.

### TX filter

A TX Butterworth filter can be specified, with transfer function  $H(f)$  given by

$$H(f) = \frac{1}{G\left(j \frac{f}{f_c}\right)}$$

where



$$G(s) = \begin{cases} (s+1) \cdot \prod_{k=1}^{\frac{n-1}{2}} \left[ s^2 - 2s \cdot \cos\left(\frac{2k+n-1}{2n}\pi\right) + 1 \right] & n = \text{odd} \\ \prod_{k=1}^n \left[ s^2 - 2s \cdot \cos\left(\frac{2k+n-1}{2n}\pi\right) + 1 \right] & n = \text{even} \end{cases}$$

and  $n$  is order,  $f_c$  is bandwidth. It can be shown that

$$|H(f)| = \frac{1}{\sqrt{1 + \left(\frac{f}{f_c}\right)^{2n}}}$$

### ***RX filter***

---

An RX Bessel-Thomson filter can be specified, with transfer function  $H(f)$  given by

$$H(f) = \frac{G(0)}{G\left(j\frac{f}{f_c}\right)}$$

where

$$G(s) = \sum_{k=0}^n \frac{(2n-k)!}{2^{n-k} k! (n-k)!} s^k$$

and  $n$  is order,  $f_c$  is bandwidth.

### ***Eye mask***

---

An eye mask can be specified by a vector of “x1 y1 x2 y2 ...” with x in ps and y in volt. Multiple eye masks can be specified by several vectors separated by semicolon (;). To turn off the eye mask, this entry can be simply left blank. In Figure 15 and Figure 16, we plot a 2-bit PAM-4 eye with the following eye mask: “35 -0.2 40 -0.15 45 -0.2 40 -0.25 35 -0.2 ; 35 0 40 0.05 45 0 40 -0.05 35 0 ; 35 0.2 40 0.25 45 0.2 40 0.15 35 0.2”.

### ***Threshold voltage***

---

Threshold voltage is used as the reference voltage to measure eye height and width. Multiple threshold voltages can be entered in a vector such as “-0.2 0 0.2”. Table 2 shows the

output .log file that contains the measurements of eye height and width at various threshold voltages for the PAM-4 signals of Figure 15 and Figure 16.

### *Contour plot*

---

Besides plotting the eye diagram one curve at a time, the user has the option of choosing “contour plot” (see Figure 17).

For better efficiency, eye diagrams are displayed only in contour plot when PRBS is greater than 12.

### *Fixed data pattern*

---

The user can select either NRZ or PAM-4 signaling. A fixed data pattern for NRZ (or PAM-4) is specified in a character string of 0 and 1 (or 0, 1, 2 and 3) such as “0101110001” (or “102320132”).

### *# Repeated Pattern*

---

Either PRBS or fixed data pattern is assumed to be periodic. By default, “# Repeated Pattern” is set to follow “# Bits in an Eye” in order to fill the eye diagram. The user can override “# Repeated Pattern” if so desired.

### *Spectrum*

---

In Figure 18, we select ports: “CC 2 1” (for common-mode insertion loss from Port 1 to Port 2), select fixed cursors of “0 1 0” and plot its output spectrum (Figure 19). The discrete frequencies appear at  $0.19685 \text{ GHz} (= 1/(25\text{e}9*(2^7-1)))$  interval because of the 25 Gbps data rate and PRBS7 source. The maximum frequency that can be displayed is 20 GHz in this case, because it corresponds to the minimum of (a) the maximum frequency in this .s4p file (which is 20 GHz) and (b) one half of the inverse of sampling time resolution (which is  $125 \text{ GHz} = 1/(2/(25\text{e}9*10))$ ).

### *Restriction*

---

It is noted that, in order to limit the memory usage, the following restrictions are imposed:

- The maximum PRBS length is limited to 18.
- When “waveform” is selected, only the first 10,000 sampling points are plotted.

Channel Optimization
Reset Configuration

### Plot Eye Diagram

#### Channel's Touchstone File

Browse ...
D:\Demo\Examples\ISD\_SMA\_to\_SMA.s4p

Selected ports
DD 2 1

Reset port impedance (optional)
ohm

#### TX & RX

##### Waveform

Baud Rate
25.78125 Gbps

Rise Time (20/80)
10 ps

Amplitude (P-to-P)
1 volt

DC Offset
0 volt

Random Jitter
0.01 UI

##### TX FFE

☒ Optimized

# Precursors
1

# Postcursors
1

Min. Main Cursor
0.5

☐ Fixed

Cursors
0 1 0

##### Pattern

☒ PRBS

7

☐ Fixed

101010

# Repeated Pattern
2

##### Signaling

☐ NRZ
☒ PAM-4

##### TX Filter

☒ Butterworth Filter
☐ None

Bandwidth
25 GHz

Order
2

##### CTLE

☐ None

☒ Sweep GDC

-10 : 1 : 0 dB

##### DFE

# DFE taps
3

##### RX Filter

☒ Bessel Filter
☐ None

Bandwidth
25 GHz

Order
4

#### Run Control

☒ Eye diagram
☐ Waveform
☐ Spectrum

# Bits in an Eye
2

# Samples Per Bit
20

Shift Eye or Waveform
0 ps

Minimum Voltage
-0.4 volt

Maximum Voltage
0.4 volt

Threshold Voltage
0 volt

Eye Mask (x1 y1 x2 y2 ...)

☐ Contour Plot
Reference BER
1e-5

D:\Demo\Examples\ISD\_SMA\_to\_SMA.s4p.eye.log

```

=====
Eye height = 0.469299 volt
Eye width = 34.682 ps
Jitter = 4.10587 ps
>>> With RJ=0.01 UI, BER=1e-05, Q=4.26489:
*** Threshold voltage = 0 volt
Eye height = 0.442286 volt
Eye width = 31.191 ps
Jitter = 7.59686 ps

```

Plot Source
Run

Figure 10

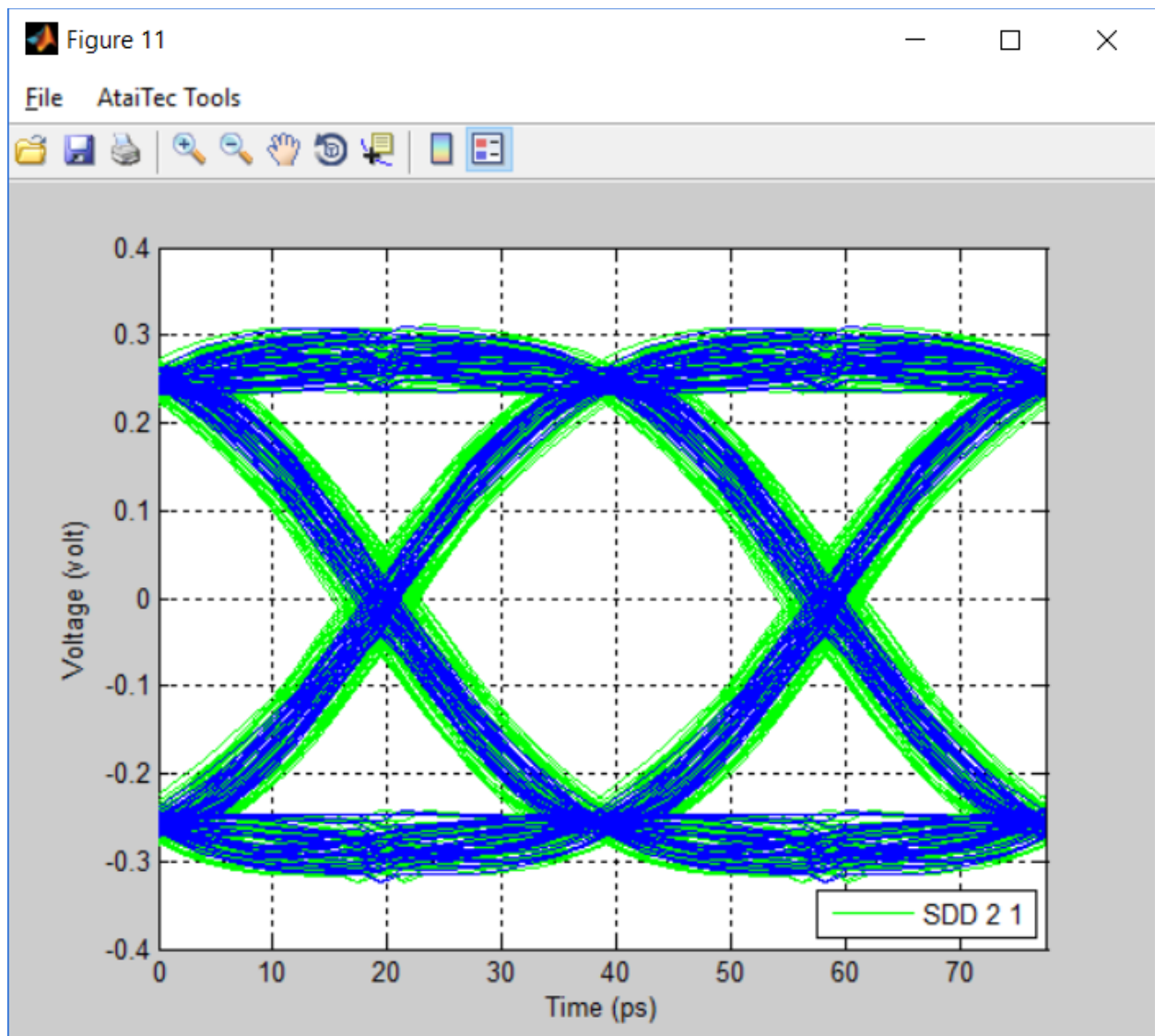


Figure 11

```
>>> Deterministic:
*** Threshold voltage = 0 volt
Eye height = 0.469299 volt
Eye width = 34.682 ps
Jitter = 4.10587 ps
>>> With RJ=0.01 UI, BER=1e-05, Q=4.26489:
*** Threshold voltage = 0 volt
Eye height = 0.442286 volt
Eye width = 31.191 ps
Jitter = 7.59686 ps
D:\Demo\Examples\ISD_SMA_to_SMA.s4p.eye.log is created.
Channel Optimization is completed.
```

Figure 12

```

----- Inputs -----
Input file = D:\Demo\Examples\ISD_SMA_to_SMA.s4p
Selected ports = DD 2 1
Data rate = 25.78125 Gbps
Rise time (20/80) = 10 ps
Fall time (20/80) = 10 ps
Amplitude (P-to-P) = 1 volt
DC offset = 0 volt
Random jitter = 0.01 UI
Reference BER = 1e-05
Signaling = NRZ
PRBS pattern = 7
TX Butterworth filter order = 2, bandwidth = 25 GHz
RX Bessel filter order = 4, bandwidth = 25 GHz

----- Outputs -----
Optimized TX tap coefficients = -0.0651823  0.89267  -0.0421475
Optimized gDC for CTLE = -3 dB
Optimized DFE coefficients =  0.00035264  0.00253746  -0.0127973
>>> Deterministic:
*** Threshold voltage = 0 volt
Eye height = 0.469299 volt
Eye width = 34.682 ps
Jitter = 4.10587 ps
>>> With RJ=0.01 UI, BER=1e-05, Q=4.26489:
*** Threshold voltage = 0 volt
Eye height = 0.442286 volt
Eye width = 31.191 ps
Jitter = 7.59686 ps

```

**Table 1**

Channel Optimization
Reset Configuration

## Plot Eye Diagram

**Channel's Touchstone File**  
Browse ...
D:\Demo\Examples\ISD\_SMA\_to\_SMA.s4p  
Selected ports
3 1 ; 3 4 ; 3 2  
Reset port impedance (optional)
ohm

**Run Control**  
☒ Eye diagram
☐ Waveform
☐ Spectrum  
  
# Bits in an Eye
2  
# Samples Per Bit
20  
Shift Eye or Waveform
0 ps  
Minimum Voltage
-0.6 volt  
Maximum Voltage
0.6 volt  
Threshold Voltage
0 volt  
Eye Mask (x1 y1 x2 y2 ...)
  
☐ Contour Plot
Reference BER
1e-5

**TX & RX**  

**Waveform**  
Baud Rate
25 Gbps  
Rise Time (20/80)
10 ps  
Amplitude (P-to-P)
1 volt  
DC Offset
0 volt  
Random Jitter
0 UI

**TX FFE**  
☒ Optimized  
# Precursors
1  
# Postcursors
1  
Min. Main Cursor
0.5  
☐ Fixed  
Cursors
0 1 0

**Pattern**  
☒ PRBS
7  
☐ Fixed
101010  
# Repeated Pattern
2

**CTLE**  
☐ None  
☒ Sweep GDC
-10 : 1 : 0 dB

**Signaling**  
☐ NRZ
☒ PAM-4

**DFE**  
# DFE taps
0

**TX Filter**  
☒ Butterworth Filter
☐ None  
Bandwidth
25 GHz  
Order
2

**RX Filter**  
☒ Bessel Filter
☐ None  
Bandwidth
25 GHz  
Order
4

D:\Demo\Examples\ISD\_SMA\_to\_SMA.s4p.eye.log  
----- Outputs -----  
Optimized TX tap coefficients = -0.0694177 0.92  
Optimized gDC for CTLE = -4 dB  
>>> Deterministic:  
\*\*\* Threshold voltage = 0 volt  
Eye height = 0.221221 volt  
Eye width = 22.4667 ps  
Jitter = 17.5333 ps

Plot Source
Run

Figure 13

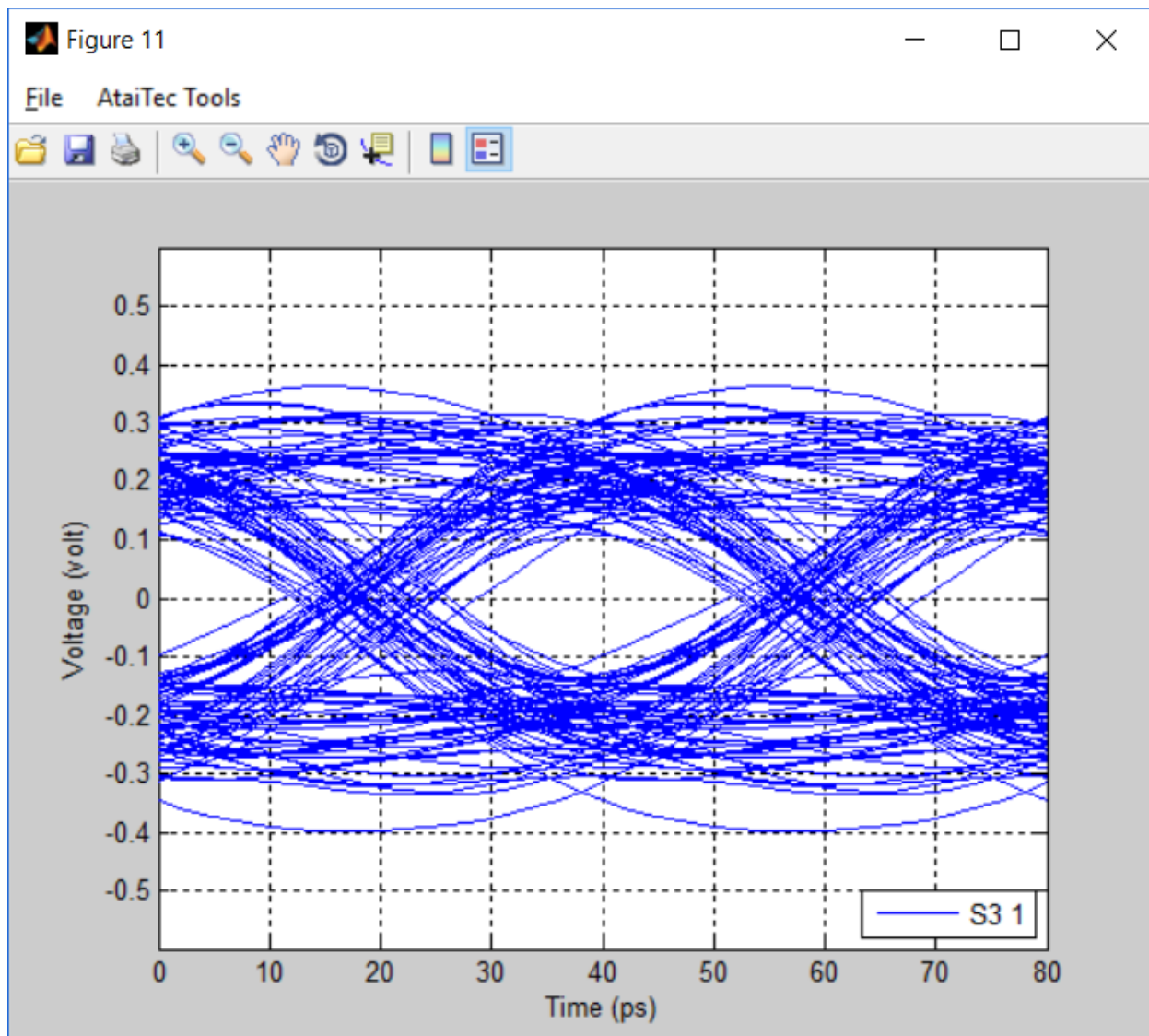


Figure 14

Channel Optimization
Reset Configuration

## Plot Eye Diagram

**Channel's Touchstone File**  
Browse ... D:\Demo\Examples\ISD\_SMA\_to\_SMA.s4p  
Selected ports DD 2 1  
Reset port impedance (optional) ohm

**Run Control**  
☒ Eye diagram
☐ Waveform
☐ Spectrum

**TX & RX**  

**Waveform**  
Baud Rate 25 Gbps  
Rise Time (20/80) 10 ps  
Amplitude (P-to-P) 1 volt  
DC Offset 0 volt  
Random Jitter 0 UI

**TX FFE**  
☒ Optimized  
# Precursors 1  
# Postcursors 1  
Min. Main Cursor 0.5  
☐ Fixed  
Cursors 0 1 0

**Pattern**  
☒ PRBS 7  
☐ Fixed 101010  
# Repeated Pattern 2

**CTLE**  
☒ None  
☐ Sweep GDC -10 : 1 : 0 dB

**Signaling**  
☐ NRZ
☒ PAM-4

**DFE**  
# DFE taps 0

**TX Filter**  
☒ Butterworth Filter
☐ None  
Bandwidth 25 GHz  
Order 2

**RX Filter**  
☒ Bessel Filter
☐ None  
Bandwidth 25 GHz  
Order 4

# Bits in an Eye 2  
# Samples Per Bit 20  
Shift Eye or Waveform 0 ps  
Minimum Voltage -0.4 volt  
Maximum Voltage 0.4 volt  
Threshold Voltage -0.2 0 0.2 volt  
Eye Mask (x1 y1 x2 y2 ...) 5 0.2 40 0.15 35 0.2  
☐ Contour Plot
Reference BER 1e-5

D:\Demo\Examples\ISD\_SMA\_to\_SMA.s4p.eye.log  

```

*** Threshold voltage = 0 volt
Eye height = 0.157537 volt
Eye width = 19.8503 ps
Jitter = 20.1497 ps
*** Threshold voltage = 0.2 volt
Eye height = 0.156588 volt
Eye width = 16.0715 ps
Jitter = 23.9285 ps

```

Plot Source
Run

Figure 15



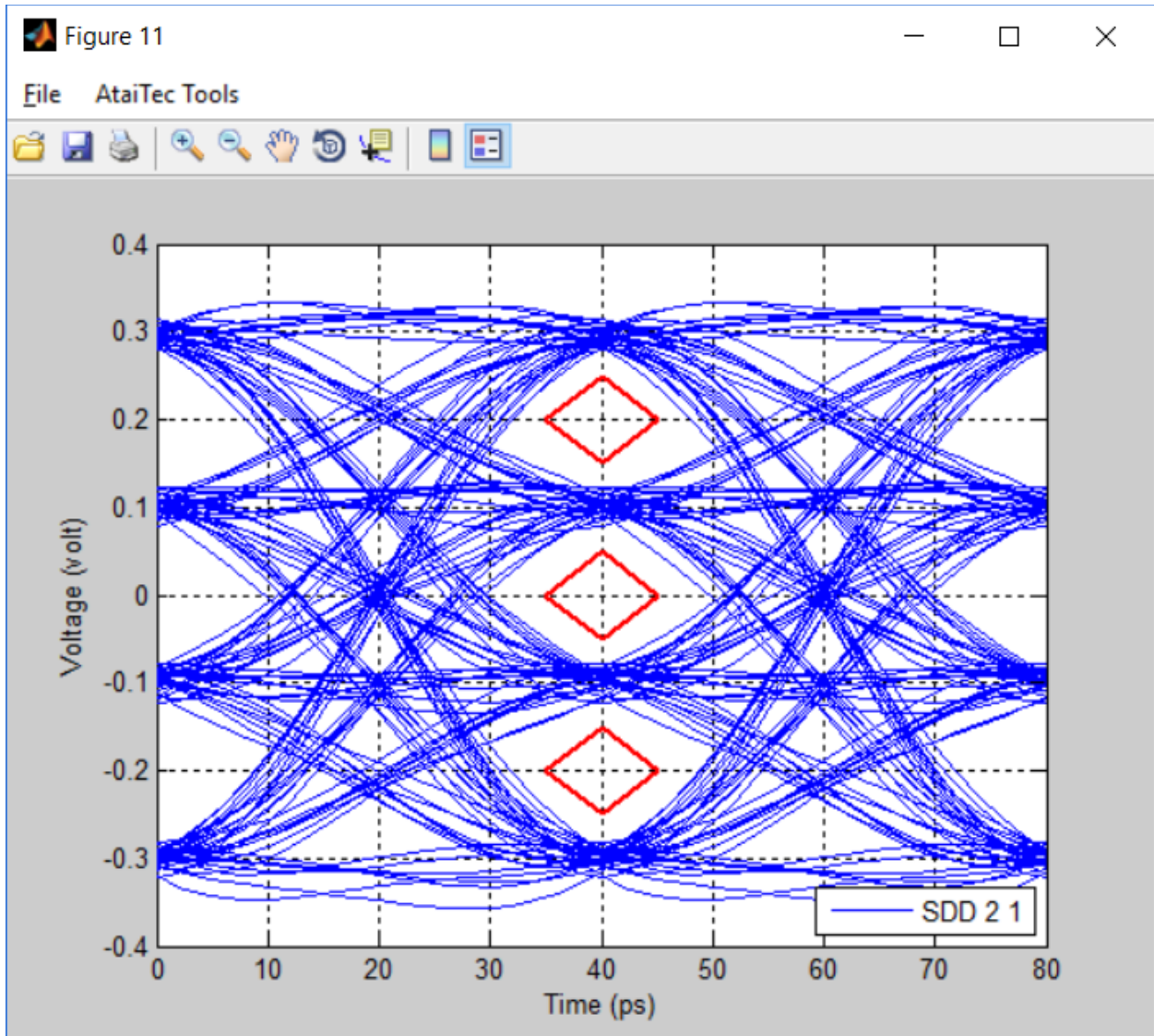


Figure 16

```

----- Outputs -----
Optimized TX tap coefficients =  -0.0570849  0.838403  -0.104512
>>> Deterministic:
*** Threshold voltage = -0.2 volt
Eye height = 0.158592 volt
Eye width = 16.9354 ps
Jitter = 23.0646 ps
*** Threshold voltage = 0 volt
Eye height = 0.157537 volt
Eye width = 19.8503 ps
Jitter = 20.1497 ps
*** Threshold voltage = 0.2 volt
Eye height = 0.156588 volt
Eye width = 16.0715 ps
Jitter = 23.9285 ps

```

Table 2

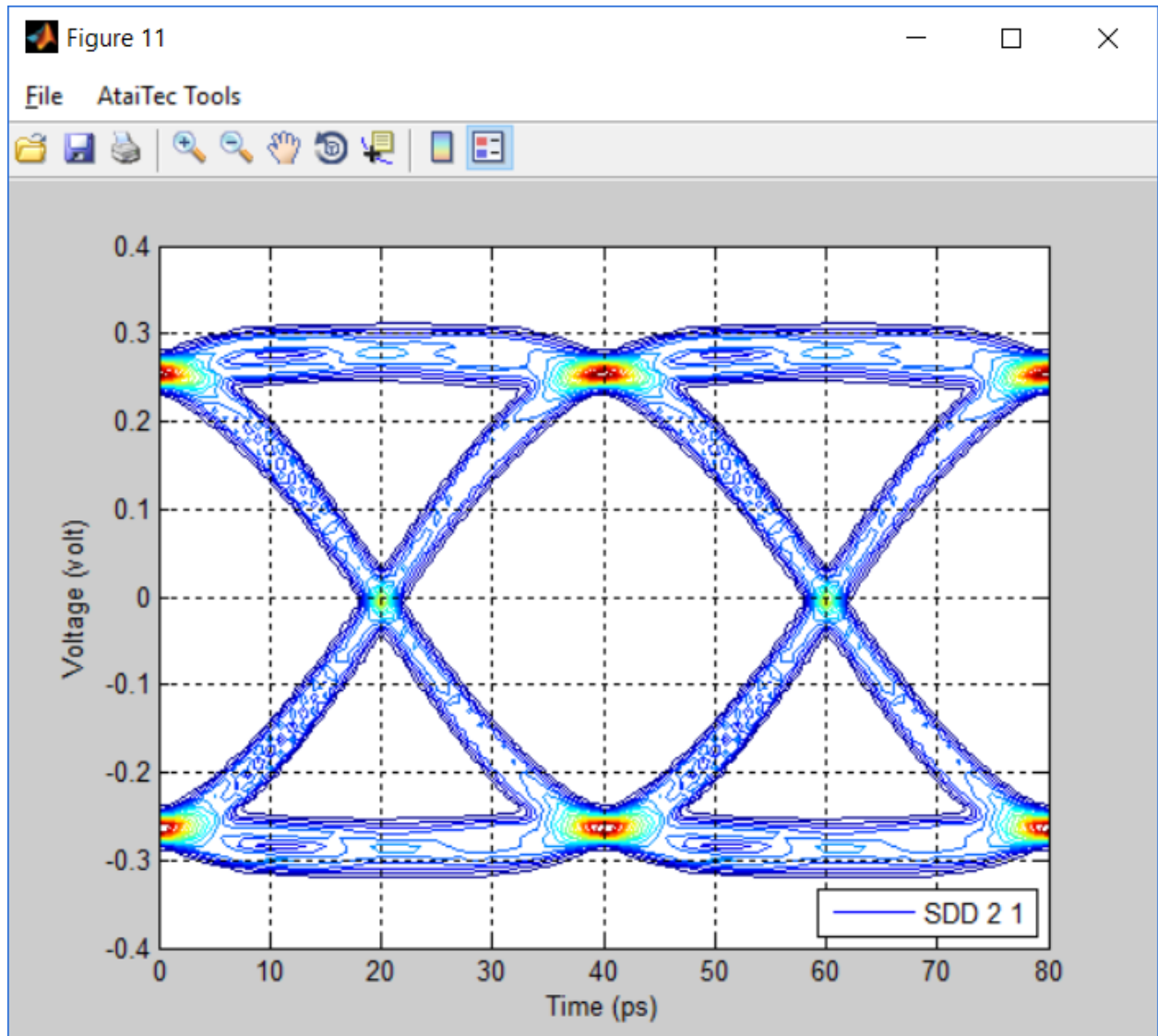


Figure 17

Channel Optimization
Reset Configuration

## Plot Eye Diagram

**Channel's Touchstone File**  
Browse ...
D:\Demo\Examples\ISD\_SMA\_to\_SMA.s4p  
Selected ports
cc 2 1  
Reset port impedance (optional)
ohm

**Run Control**  
☐ Eye diagram
☐ Waveform
☒ Spectrum  
☒ Linear
☐ Log  
Minimum Frequency
0.01 GHz  
Maximum Frequency
20 GHz  
☒ Bar Graph
☐ DB Plot

**TX & RX**  
**Waveform**  
Baud Rate
25 Gbps  
Rise Time (20/80)
10 ps  
Amplitude (P-to-P)
1 volt  
DC Offset
0 volt  
Random Jitter
0 UI  
**Pattern**  
☒ PRBS
7  
☐ Fixed
101010  
# Repeated Pattern
1  
**Signaling**  
☐ NRZ
☒ PAM-4  
**TX Filter**  
☒ Butterworth Filter
☐ None  
Bandwidth
25 GHz  
Order
2  
**TX FFE**  
☒ Optimized  
# Precursors
1  
# Postcursors
1  
Min. Main Cursor
0.5  
☐ Fixed  
Cursors
0 1 0  
**CTLE**  
☐ None  
☐ Sweep GDC
-10 : 1 : 0 dB  
**DFE**  
# DFE taps
0  
**RX Filter**  
☐ Bessel Filter
☒ None  
Bandwidth
25 GHz  
Order
4

Plot Source
Run

Figure 18

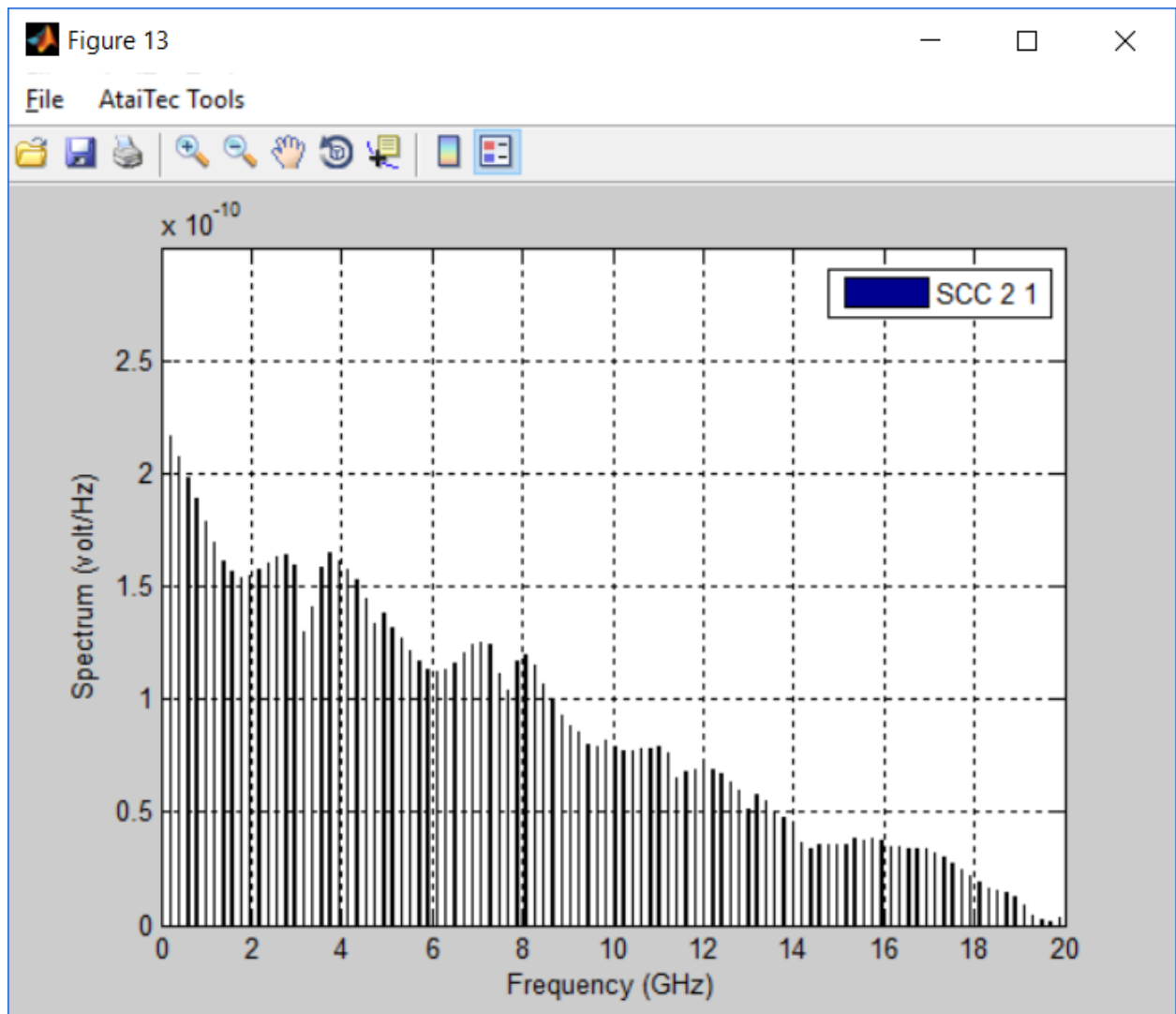


Figure 19

## Plot Crosstalk

This utility lets the user easily plot single-ended and/or differential crosstalk for a .s4p or .s8p file. All the user needs to do is to import a .s4p or .s8p file and select (1) the port sequence, (2) single-ended or differential crosstalk and (3) victim port number. The program will then automatically display near-end crosstalk (NEXT), far-end crosstalk (FEXT) and their power sum (see Figure 20 to Figure 25). The user can override/repeat each port number or leave NEXT or FEXT blank to customize the power sum (Figure 26 to Figure 27).

Plot Crosstalk by AtaiTec (www.ataitec.com)

### Plot Crosstalk

**Select Input Touchstone File** Browse ...

D:\Demo\Examples\ISD\_SMA\_to\_SMA.s4p

**Port sequence**

- ☐ 1, 2 to 3, 4
- ☒ 1, 3 to 2, 4

**Crosstalk**

- ☒ Single-ended

**Port number**

Victim	1
NEXT	2
FEXT	4

Run

Figure 20

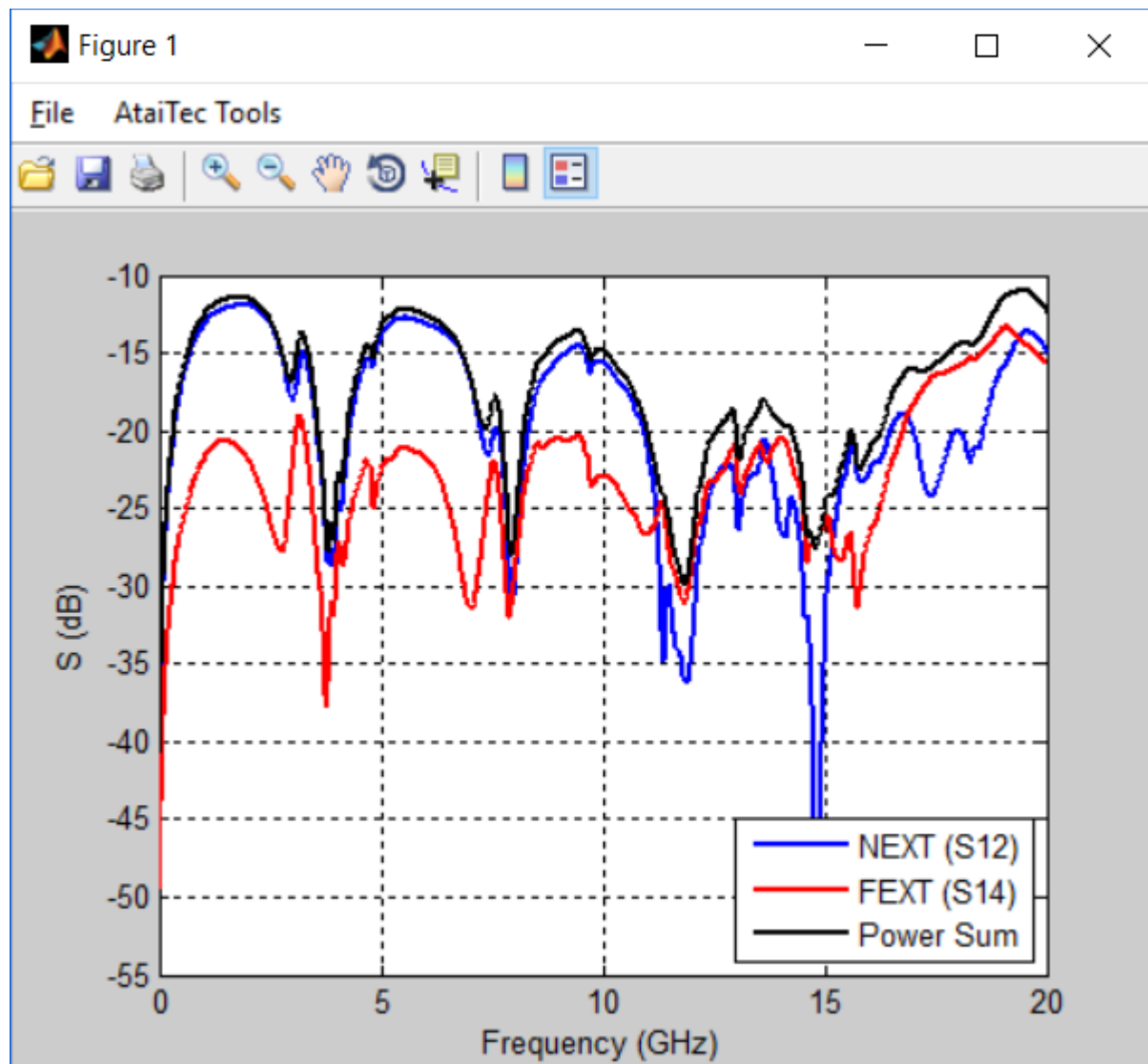


Figure 21

Plot Crosstalk by AtaiTec (www.ataitec.com)

# Plot Crosstalk

Select Input Touchstone File Browse ...

D:\Demo\Examples\example3\_passivity.s8p

**Port sequence**

- ☒ 1, 2, 3, 4 to 5, 6, 7, 8
- ☐ 1, 3, 5, 7 to 2, 4, 6, 8

**Crosstalk**

- ☒ Single-ended
- ☐ Differential

**Port number**

Victim	1
NEXT	2 3 4
FEXT	6 7 8

Run

Figure 22

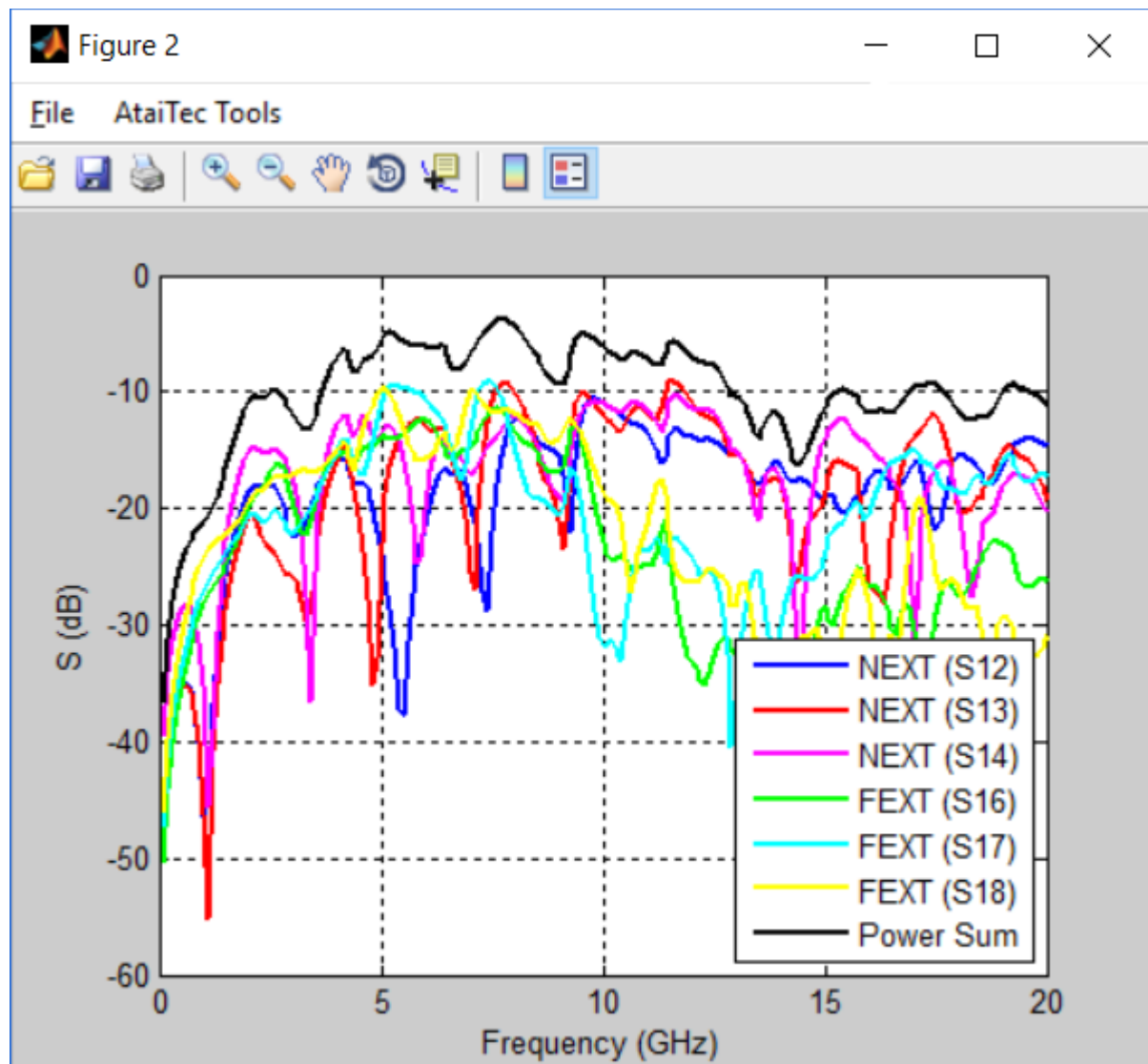


Figure 23



Plot Crosstalk by AtaiTec (www.ataitec.com)

# Plot Crosstalk

**Select Input Touchstone File** Browse ...

D:\Demo\Examples\example3\_passivity.s8p

**Port sequence**

- ☐ 1, 2, 3, 4 to 5, 6, 7, 8
- ☐ 1, 3, 5, 7 to 2, 4, 6, 8

**Crosstalk**

- ☐ Single-ended
- ☐ Differential

**Pair number**

Victim	1
NEXT	2
FEXT	4

Run

Figure 24

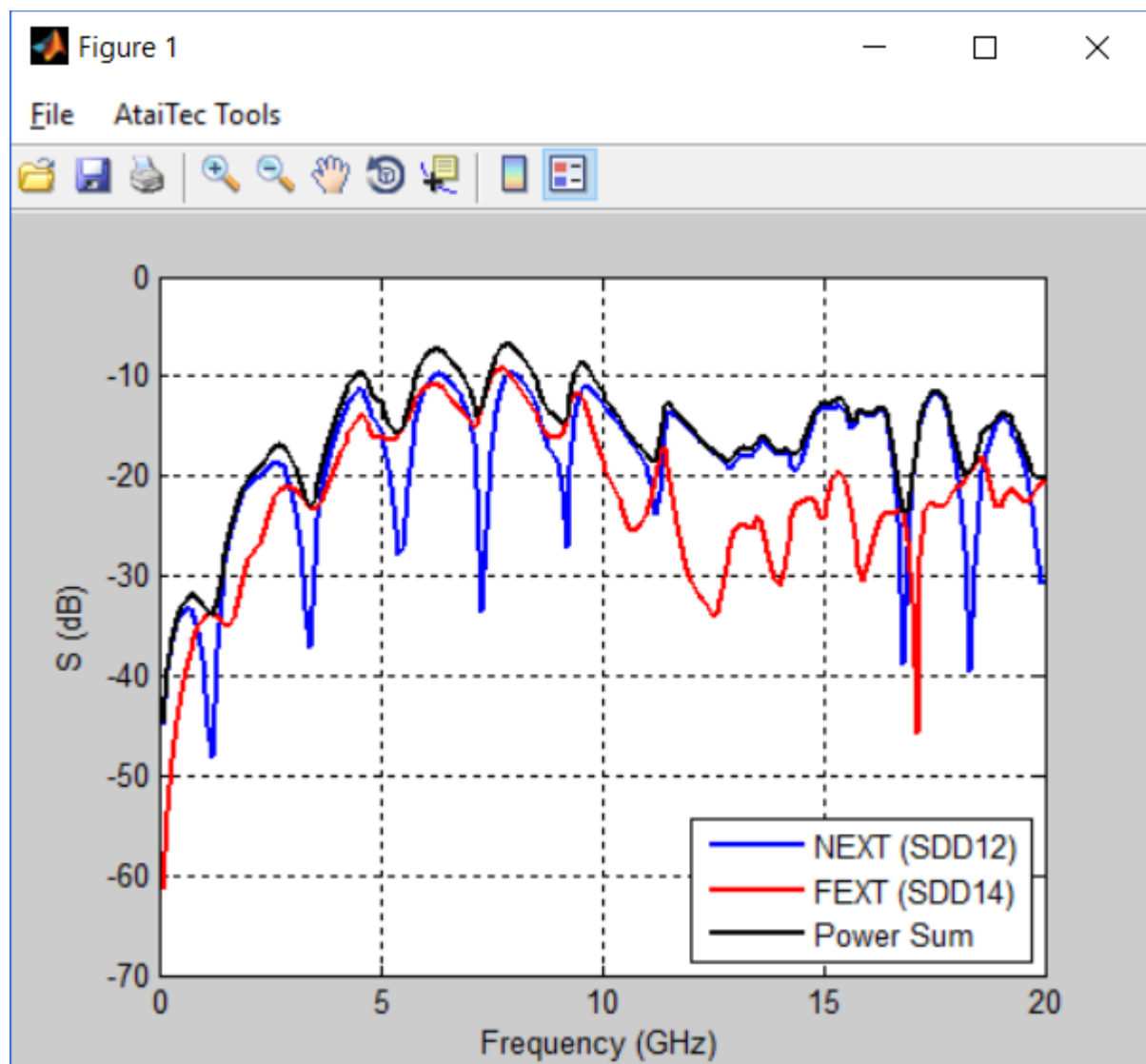


Figure 25

Plot Crosstalk by AtaiTec (www.ataitec.com)

# Plot Crosstalk

Select Input Touchstone File Browse ...

D:\Demo\Examples\example3\_passivity.s8p

**Port sequence**

- ☒ 1, 2, 3, 4 to 5, 6, 7, 8
- ☐ 1, 3, 5, 7 to 2, 4, 6, 8

**Crosstalk**

- ☒ Single-ended
- ☐ Differential

**Port number**

Victim	2
NEXT	
FEXT	5 7 8 5 7 8

Run

Figure 26

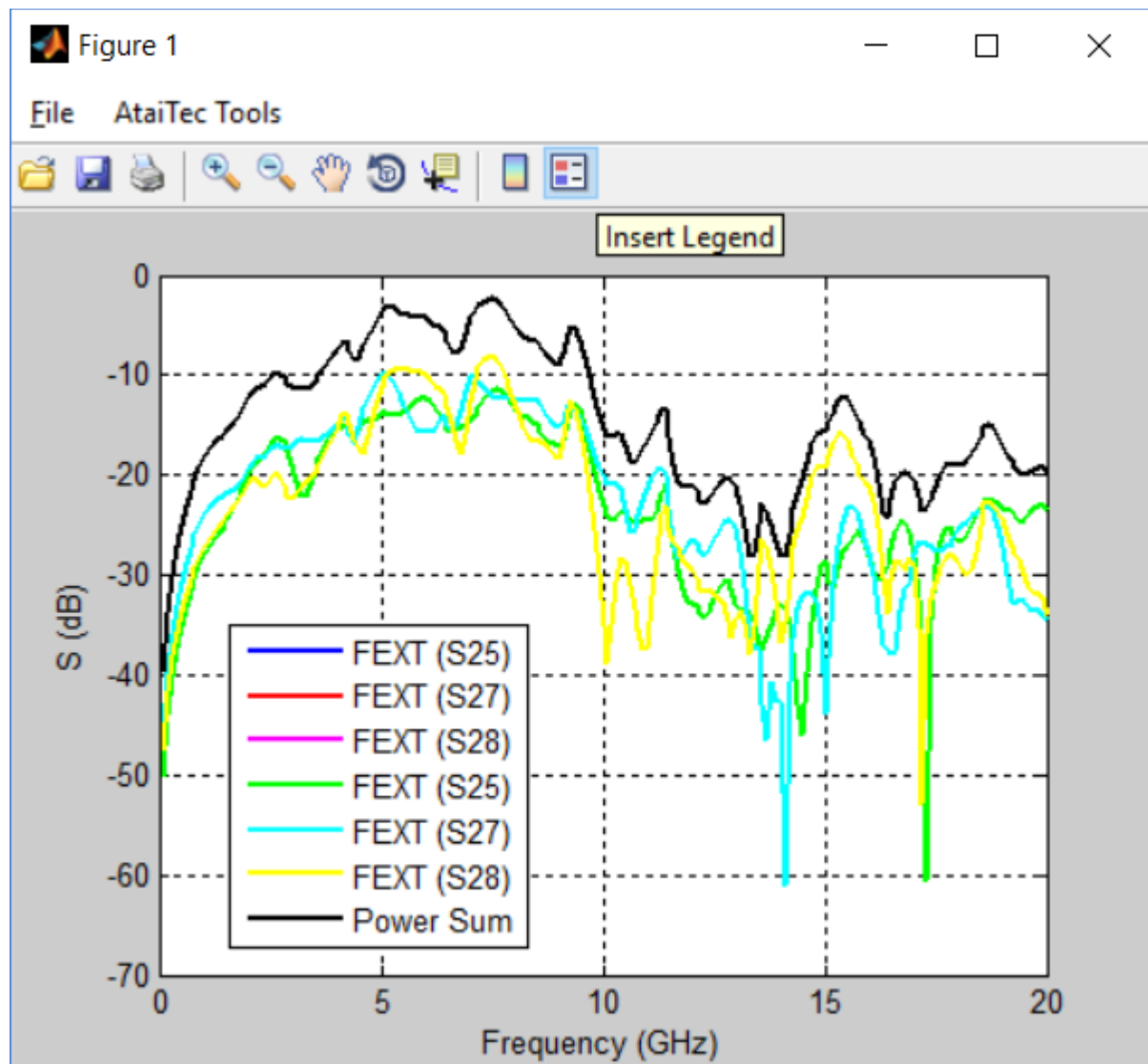


Figure 27

## Perform Compliance Test (or IEEE and OIF Spec.)

With this utility, the user can choose among several IEEE and OIF specs, and compare the power sum of coupled noises, insertion loss crosstalk ratio (ICR), insertion loss, insertion loss deviation (ILD), and integrated crosstalk noise (ICN), etc. (See Figure 28 to Figure 30.)

By default, the button: “Convert to Differential Signals” is enabled to convert single-ended S-param into differential S-param. Two types of port sequence are supported: (1) 1 to N as input and N+1 to 2N as output (which is preferred) and (2) 1, 3, ..., 2N-1 as input and 2, 4, ..., 2N as output.

The 10Gbase-KR standard is for NRZ signaling. It is of interest to extend 10Gbase-KR's ICR spec. to PAM4 signaling. When PAM4 is selected, 9.54dB ( $=20 \cdot \log_{10}(3)$ ) is added to the NRZ's ICR spec.

IEEE and OIF Spec.  
Reset Configuration

### Perform Compliance Test

**Select Input Touchstone File** Browse ...  
D:\Demo\Examples\example4\_condense.s28p  
☒ **Convert to Differential Signals**  
**Number of Crosstalk Curves** 5

[S] Indices for crosstalk	
Curve 1	1 9
Curve 2	1 10
Curve 3	1 11
Curve 4	1 12
Curve 5	1 13

☐ 10GBASE-KR ☐ 40GBASE-CR4  
☐ OIF CEI-25G-LR ☐ OIF CEI-28G-MR  
☐ OIF CEI-28G-SR ☐ OIF CEI-28G-VSR  
Baud Rate 10.3125 Gsym/s

**Insertion-loss-to-crosstalk ratio (ICR)**  
☒ Log Plot  
☒ Fitted ICR from 0.1 GHz to 5.15625 GHz  
ICR Spec  
Constant ICR spec above 5 GHz  
☐ NRZ ☒ PAM4

Insertion loss index 18  
Return loss index 11 Run

Figure 28

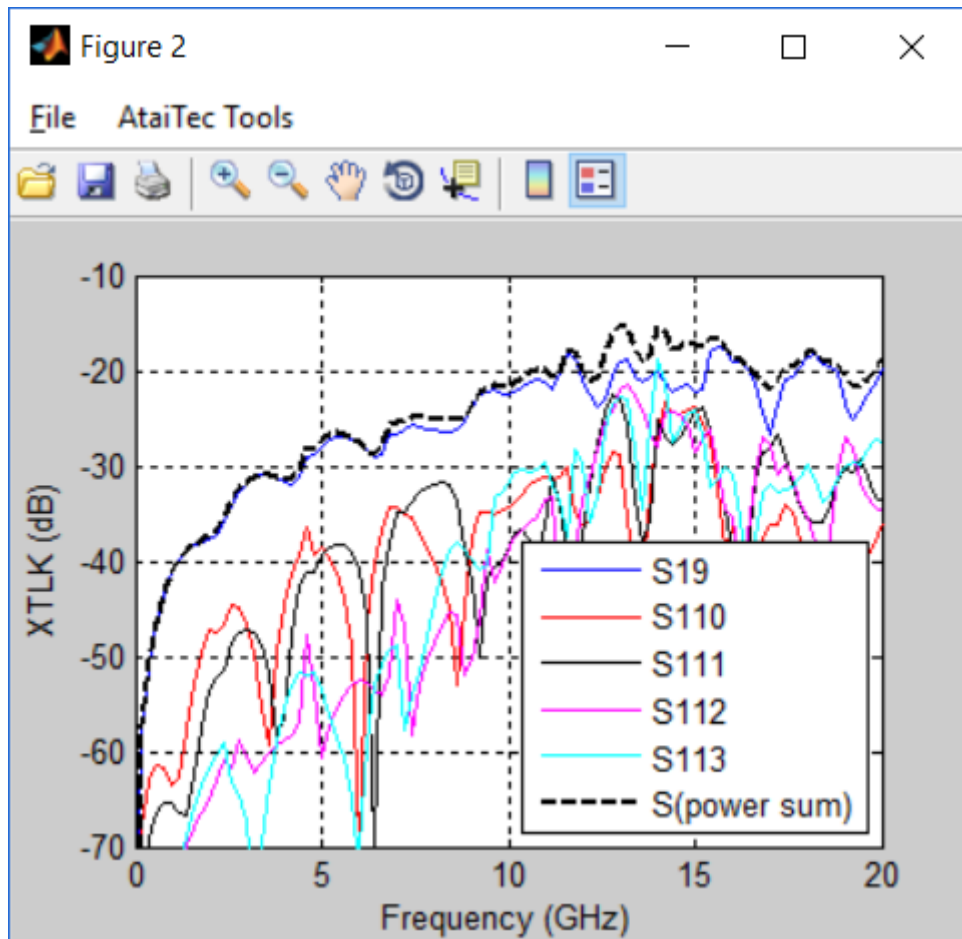


Figure 29 Power sum of far-end crosstalk (FEXT)

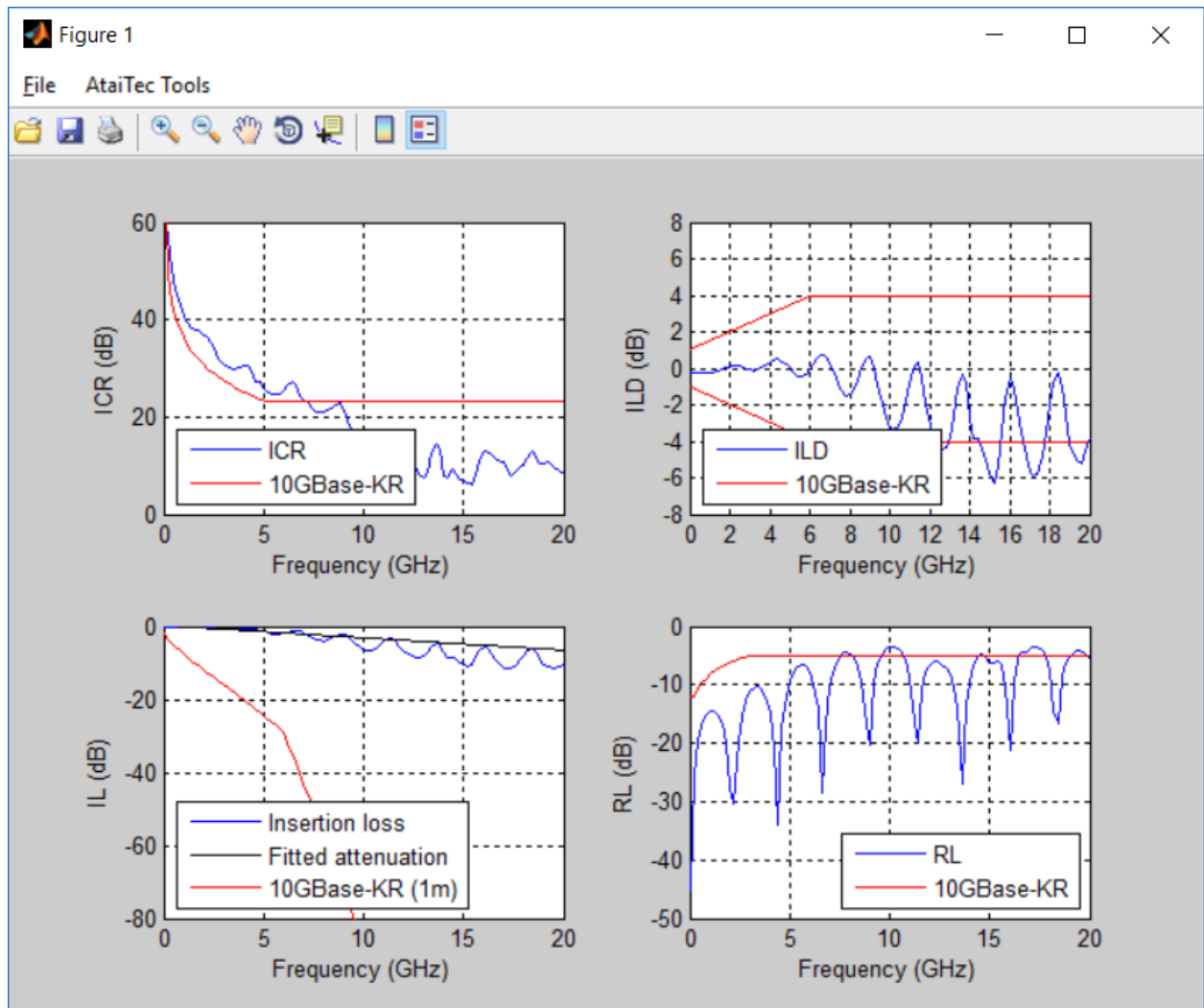


Figure 30

## Compute Loss by Delta L

This utility computes PCB trace loss by Delta-L 3.0 (i.e., eigenvalue solution). Up to seven Touchstone files (in either .s2p or .s4p) of different length + launch can be entered. The program then calculates the trace-only (= long trace – short trace) attenuation in dB/in between every two files by eigenvalue solution, plots them in the same graph, curvefits their average values and outputs a summary in ...ADK\_DeltaL.log. When only one file is entered, the short trace is equated to a perfect short (of zero length) and the eigenvalue of that input file's corresponding T parameter is computed.

Shown in Figure 31, the eigenvalue solution:

1. converts each S parameter into T parameter,
2. assumes that the launch structures for both short and long traces are identical,
3. assumes that the DUT (i.e., remaining trace-only portion) is a uniform transmission line, and
4. writes trace-only attenuation in one equation.

Spikes are often observed due to the assumptions of (2) and (3) above. For more details, see: [http://ataitec.com/docs/In-Situ\\_De-embedding.pdf](http://ataitec.com/docs/In-Situ_De-embedding.pdf)

### *Frequencies of interest*

---

Frequencies of interest, separated by space, can be entered (in GHz) to place markers on the fitted curve. Those fitted numbers are shown in ...ADK\_DeltaL.log

### *Figure Property*

---

By default, the figure properties are left as blank and the program automatically plots the entire x and y ranges. The user has the option to enter a specific x, y range to plot and override the default label, legend, line color, line width and font size, etc. Valid line colors are in b (blue), r (red), k (black), m (magenta), c (cyan), g (green), y (yellow). Valid font size is between 6 and 60. The default of "brkmcg" corresponds to that the 1<sup>st</sup> curve is in blue and the 2<sup>nd</sup> curve is in red, etc. Certain publications (such as patent, journal, ...) require that all graphs be in black and white. The user can just enter "k" in this case and the program will plot all curves in black with solid line, dashed line, ..., etc.

### *Auto de-skew*

---



An option of "Auto de-skew" is available to de-skew .s4p files before computing the loss. De-skewing is crucial for getting unbiased reading of differential loss. When enabled ( - the default is on), each file will be de-skewed and new file is generated in:

<file name>\_noskew.s4p

Figure 32 to Figure 34 show an example with "Auto de-skew" turned on where the .s4p files of 2", 3", 5" and 7" trace + launch are entered to compute the dB/in differential loss. (The differential loss is automatically displayed for .s4p input.) The same example is repeated in Figure 35 to Figure 37, but with "Auto de-skew" turned off. It is apparent that the latter results gave more variation.

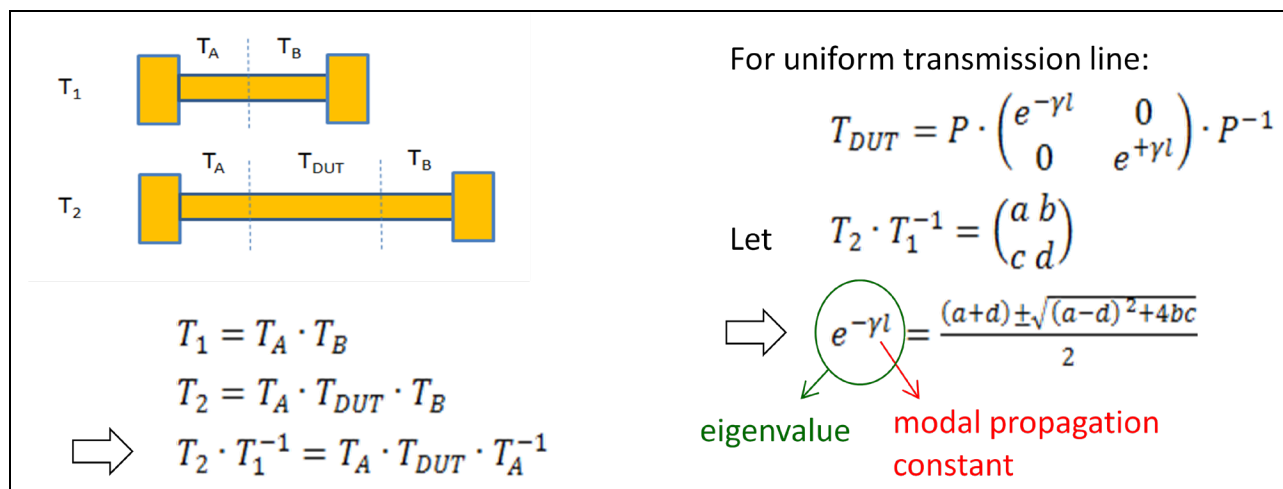


Figure 31

Compute Loss by Delta L

**Touchstone Files**

Select number of files: 4

	File Name	Length (in)
L1	Browse ... D:\Delta_L\PCB_2in.s4p	2
L2	Browse ... D:\Delta_L\PCB_3in.s4p	3
L3	Browse ... D:\Delta_L\PCB_5in.s4p	5
L4	Browse ... D:\Delta_L\PCB_7in.s4p	7

Frequencies of interest: 4 8 12.89 16 GHz

**Figure Property (Optional)**

Xmin: Xmax: Ymin: Ymax:

Xsize (in): Ysize (in): X label: Y label:

Legend (sep'd by ;):

Figure title:

Line color: brkmcg Font size: 10

Line width: 2

☒ Auto De-skew

Run

Figure 32

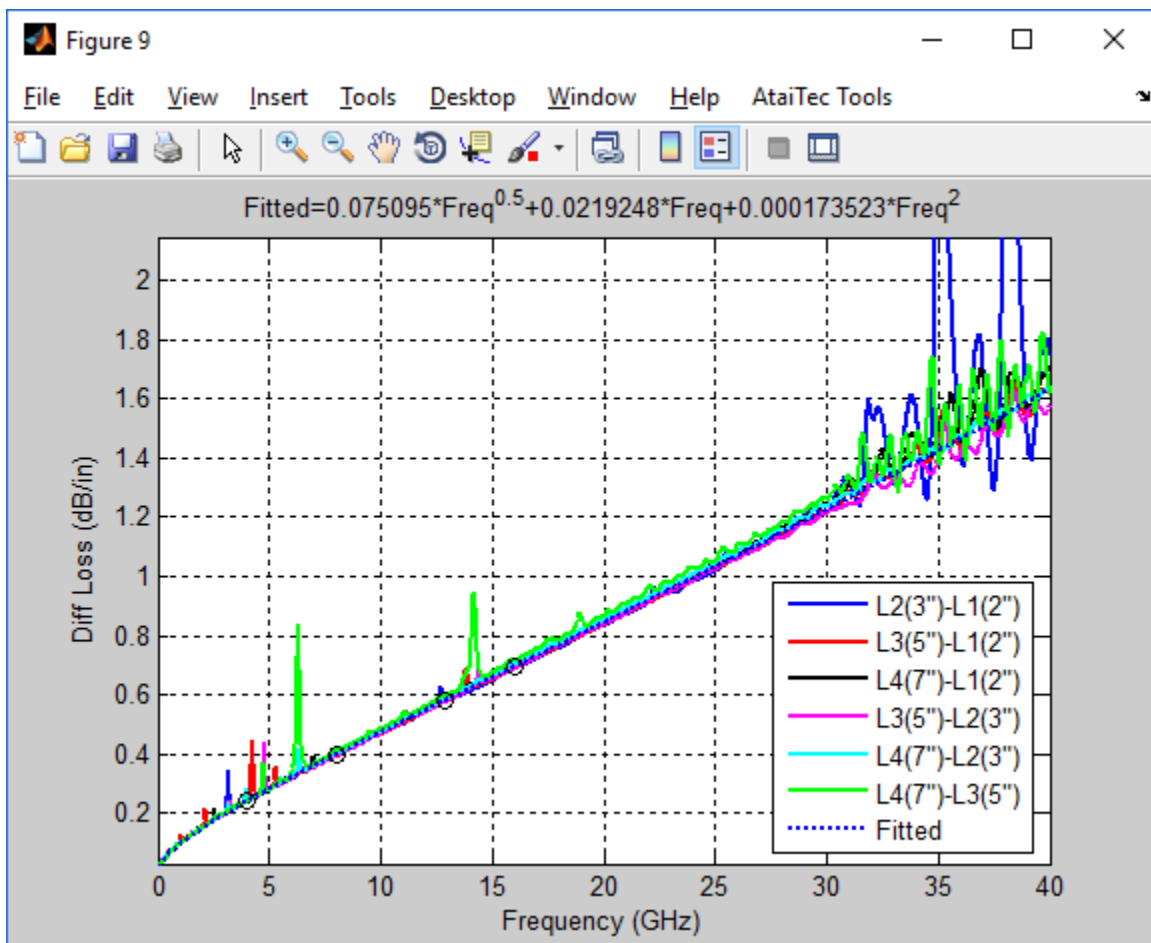


Figure 33

Input files:

L1 (2") -> D:\Delta\_L\PCB\_2in.s4p\_noskew.s4p

L2 (3") -> D:\Delta\_L\PCB\_3in.s4p\_noskew.s4p

L3 (5") -> D:\Delta\_L\PCB\_5in.s4p\_noskew.s4p

L4 (7") -> D:\Delta\_L\PCB\_7in.s4p\_noskew.s4p

De-skew: Yes

Fitted equation (Freq in GHz):

$$\text{Loss (dB/in)} = 0.075095 * \text{Freq}^{0.5} + 0.0219248 * \text{Freq} + 0.000173523 * \text{Freq}^2$$

Loss (dB/in):

GHz	Original	Fitted
4	0.243512	0.240666
8	0.400784	0.398905
12.89	0.583575	0.581053
16	0.699449	0.695599

Loss (dB/in), expanded table:

GHz	Original	Fitted
1	0.101949	0.097193
2	0.152865	0.150744
3	0.199874	0.197404
:		
38	1.748430	1.546627
39	1.572497	1.587964
40	1.649641	1.629572

**Figure 34**

Compute Loss by Delta L

**Touchstone Files**

Select number of files:

	File Name	Length (in)
L1	Browse ... D:\Delta_L\PCB_2in.s4p	2
L2	Browse ... D:\Delta_L\PCB_3in.s4p	3
L3	Browse ... D:\Delta_L\PCB_5in.s4p	5
L4	Browse ... D:\Delta_L\PCB_7in.s4p	7

Frequencies of interest:  GHz

**Figure Property (Optional)**

Xmin	Xmax	Ymin	Ymax
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Xsize (in)	Ysize (in)	X label	Y label
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

Legend (sep'd by ;)

Figure title

Line color  Font size

Line width

☐ Auto De-skew

Figure 35

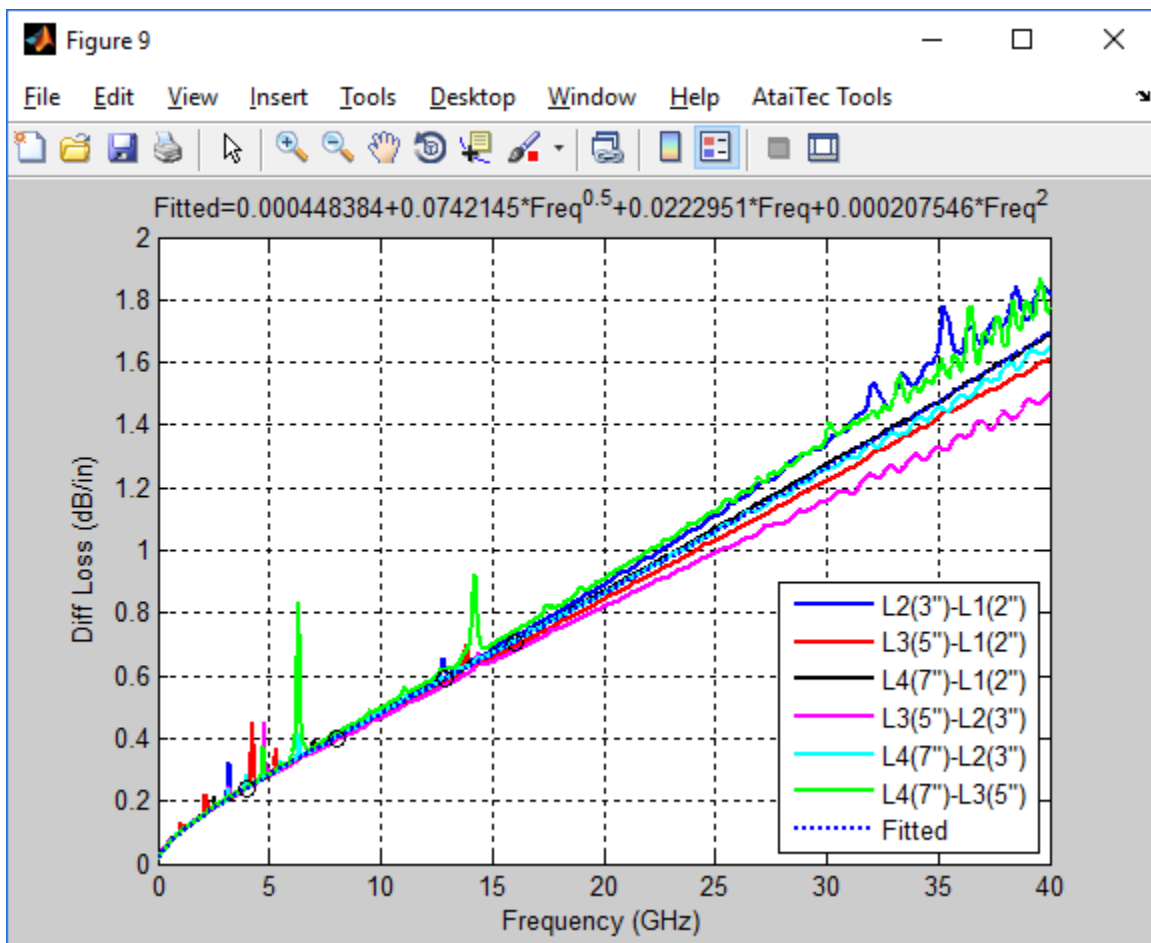


Figure 36

Input files:

L1 (2") -> D:\Delta\_L\PCB\_2in.s4p

L2 (3") -> D:\Delta\_L\PCB\_3in.s4p

L3 (5") -> D:\Delta\_L\PCB\_5in.s4p

L4 (7") -> D:\Delta\_L\PCB\_7in.s4p

De-skew: No

Fitted equation (Freq in GHz):

$$\text{Loss (dB/in)} = 0.000448384 + 0.0742145 * \text{Freq}^{0.5} + 0.0222951 * \text{Freq} + 0.000207546 * \text{Freq}^2$$

Loss (dB/in):

GHz	Original	Fitted
4	0.244466	0.241379
8	0.403700	0.402002
12.89	0.593407	0.588766
16	0.713276	0.707160

Loss (dB/in), expanded table:

GHz	Original	Fitted
1	0.102005	0.097166
2	0.153061	0.150824
3	0.200228	0.197745
:	:	:
38	1.590775	1.604848
39	1.644633	1.649105
40	1.672864	1.693700

**Figure 37**