High Speed Link Simulator
Stateye and Matlab

EE689-606

Dr Samuel Palermo

PROCEDURES

1. Channel Model Download
   - STATEYE does not provide channel information, therefore we have to get touchstone type channel modeling files

Ex) http://www.t11.org/ftp/t11/models/index.html
http://grouper.ieee.org/groups/802/3/ap/public/channel_model/archive/index.html#Channel Model Material

2. Create STATEYE Script File

3. High Speed link Simulation will be done by STATEYE Simulator
   - STATEYE generate only MATLAB script files
   http://www.stateye.org/stateyev4/index.html

4. The Result Figure will be shown by MATLAB Simulator
   - Matlab 2007a and Stateye installed Lab 213B

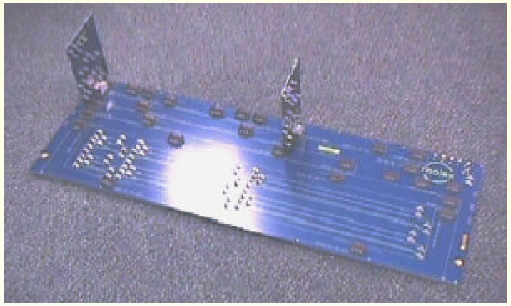
Stateye do not run at 2009 version

1. Download Channel

Channel Description

➢Backplane Channels:

- FR408 GBX Reference Backplane
- 15”, 25” and 30” channels (two connectors; 2.5” trace on each line card)
- Backdrilled, bottom routed and 185 mil via stub



➢SCA2 channel:

- Single channel (no Xtalk aggressors at this time), two measurement based connector models (thru-hole receptacle to straddle-mount SMT plug), 18” simulated FR408 backplane channel, 5 mm trace on each paddle card

Data Listing

What is provided:

- •Molex Case 1 (15” FR408 Backplane channel, bottom routed, moderate crosstalk)
- •Molex Case 2 (25” FR408 Backplane channel, backdrilled, moderate crosstalk)
- •Molex Case 3 (25” FR408 Backplane channel, backdrilled, high crosstalk)
- •Molex Case 4 (30” FR408 Backplane channel, backdrilled, moderate crosstalk)
- •Molex Case 5 (15” FR408 Backplane channel, via stub, moderate crosstalk)

Molex_Case2_F1
Molex_Case2_F2
Molex_Case2_F3
Molex_Case2_N1
Molex_Case2_N2
Molex_Case2_N3
Molex_Case2_N4
Molex_Case2_T

1. **Download Channel Model –We are using 25inches FR4 channel in this example.**
2. **Read Channel Description**

http://www.t11.org/ftp/t11/models/Molex_T11_Channels/Molex%20Backplane%20and%20SCA2%20Channel%20Test%20Cases.pdf

1. Download Channel

File Name Conventions

•S-parameter data for each channel comes in an accordingly named folder. The Thru channel data is designated by "_T" in the filename, NEXT aggressor data by "_N1" through "_N4", and FEXT by "_F1" through "_F3". For instance, Molex Case 1 data is found in the

Molex_Case1 folder and consists of:
Molex_Case1_T.s4p : Through Channel
Molex_Case1 _N1.s4p, Molex_Case1 _N2.s4p, Molex_Case1 _N3.s4p,
Molex_Case1_N4.s4p: NEXT Aggressors
Molex_Case1 _F1.s4p, Molex_Case1 _F2.s4p, Molex_Case1 _F3.s4p : FEXT Aggressors

•Data format is standard real/imaginary S-parameters
Ex) Molex_case2_T.s4p (touchstone file type)

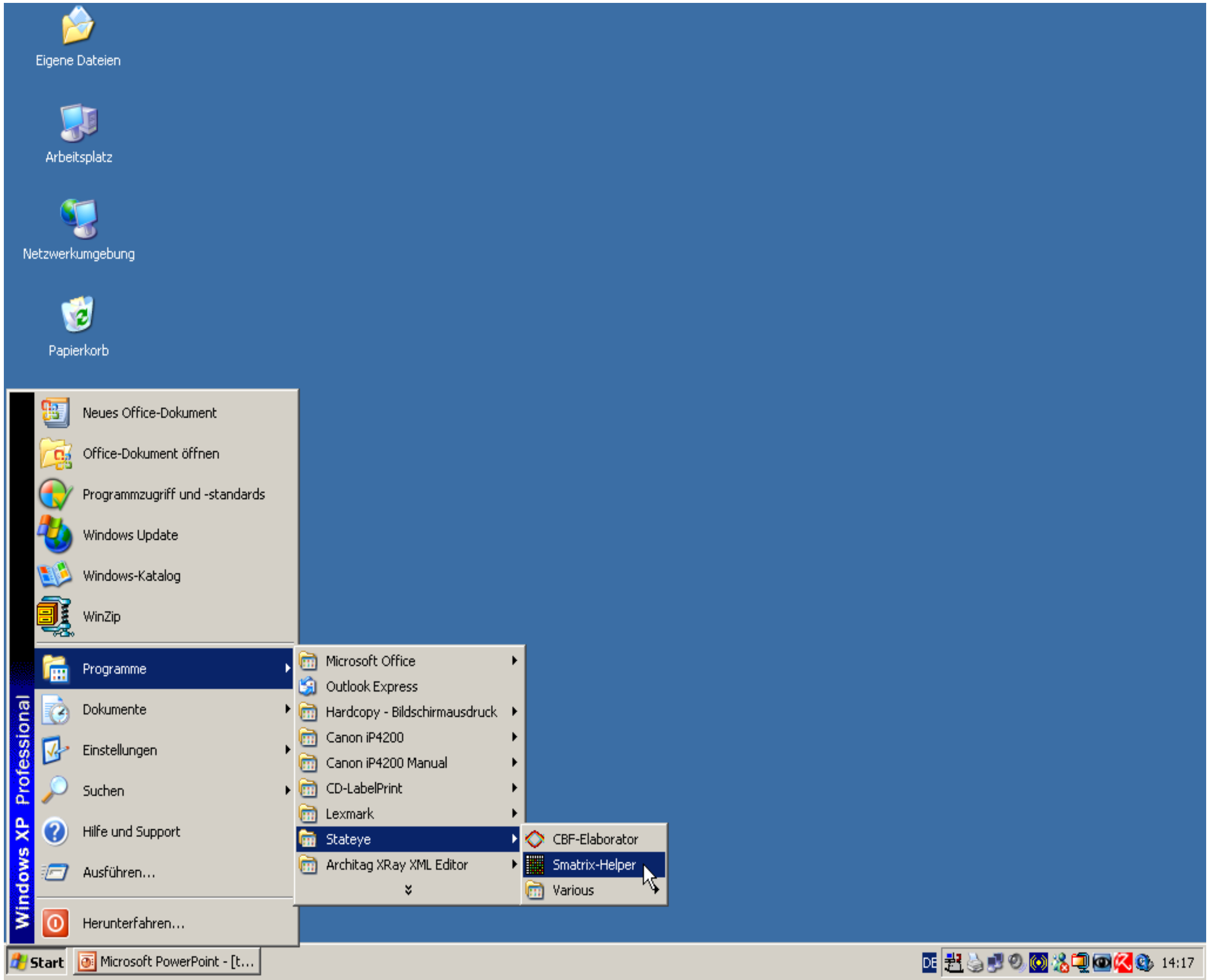
```
!
! FILE: D:\users\goganessyan\NEW 408 backplane S Parameters\Molex_T11_Channels\Molex_Case2\Molex_Case2_T.s4p
!
# MHz S DB R 50.00
!
! FREQ                S11                        S12                        S13                        S14
!                     S21                        S22                        S23                        S24
!                     S31                        S32                        S33                        S34
!                     S41                        S42                        S43                        S44
!
!                 DB          ANG            DB          ANG            DB          ANG            DB          ANG
  50.000     -17.468255   17.592245     -0.598598  -57.018001    -19.065630   32.411460    -34.953414  165.303432
              -0.593463  -57.648337    -17.269707   18.465607    -34.930167  164.884877    -19.084841   31.601300
             -19.119529   32.406244    -34.750492  165.762297    -17.108563   17.469597     -0.594390  -57.278942
             -34.760035  165.703378    -19.135560   31.918333     -0.585966  -57.499542    -17.052375   18.031386

  75.000     -16.364795   -4.619189     -0.694203  -85.248126    -17.499165    5.990685    -34.955757  117.894157
              -0.682937  -85.629148    -16.237144   -8.983909    -34.933093  118.035351    -17.511757    4.590984
             -17.526695    5.916828    -34.988549  117.530545    -15.994633   -4.286948     -0.697838  -85.188182
             -35.090696  117.086339    -17.537425    4.727861     -0.685963  -85.422054    -15.966294   -8.325409

 100.000     -17.167138  -28.089571     -0.723515 -113.154072    -17.816076  -19.699127    -37.925789   81.544340
              -0.717646 -113.488943    -17.193305  -32.088788    -37.673384   81.078617    -17.827793  -21.750163
             -17.853236  -19.727073    -37.841945   81.998876    -16.694223  -27.590234     -0.719680 -113.031183
             -37.915598   82.357265    -17.863863  -21.668177     -0.719750 -113.160992    -16.807415  -31.365738
```

2. Create STATEYE Script File

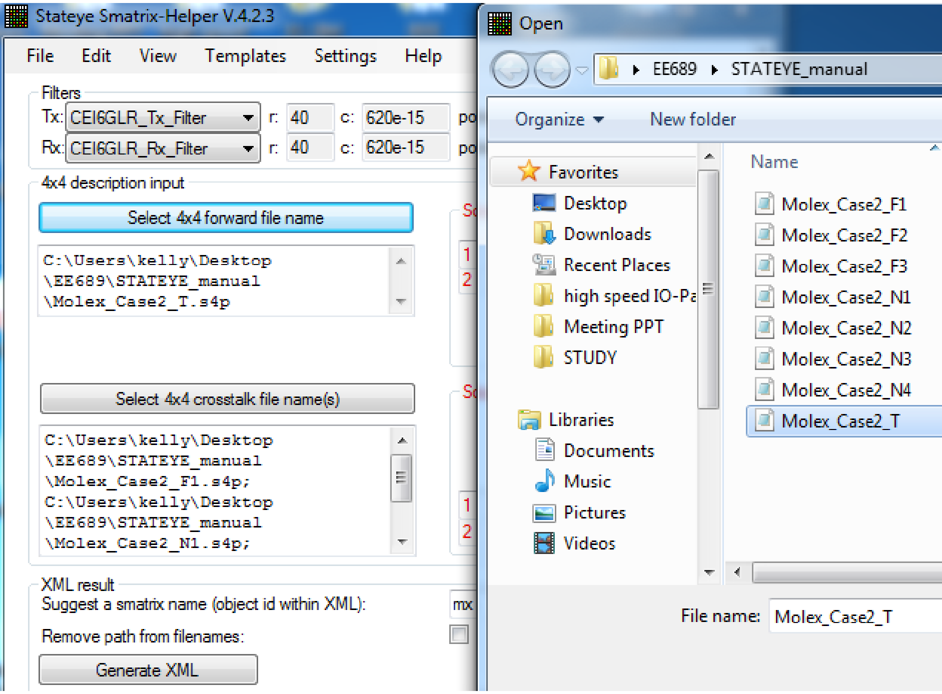
❑ Starting SmatrixHelper



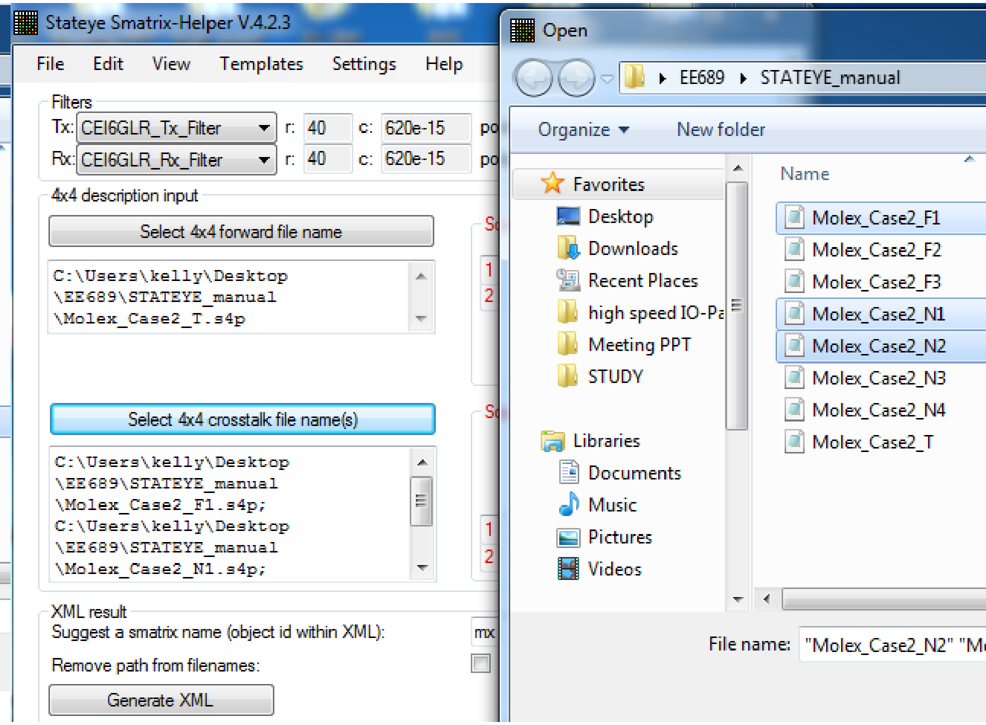
We will now show how to analyse a single channel using the default settings of Stateye. Firstly we recommend for entry of the touchstone files the use of smatrixhelper

2. Create STATEYE Script File

1. Through Channel Add

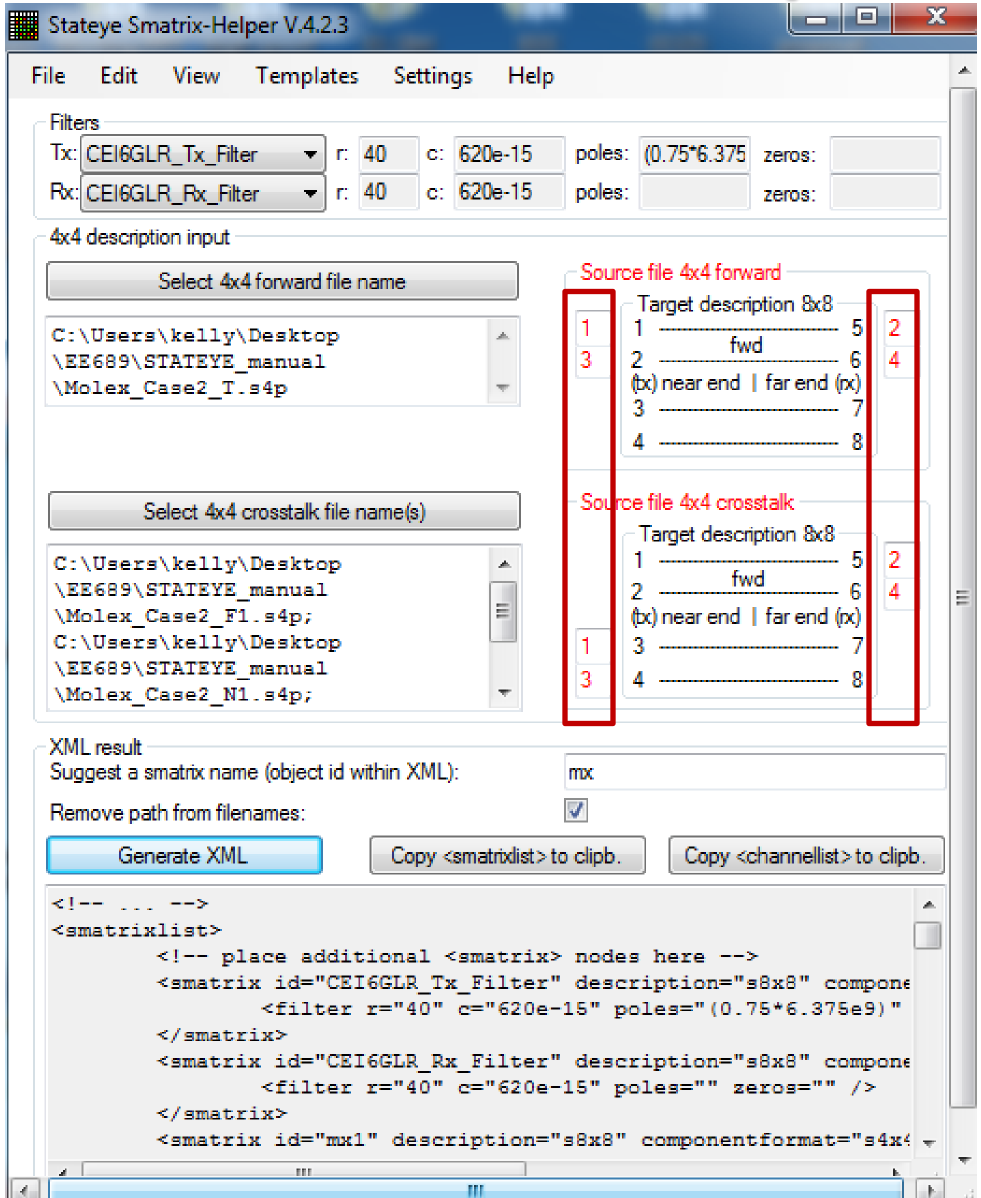


2. Cross Talk Channel Add



1. we select the transmit and receiver linear filter that is to be cascaded with the touchstone files. Note we select the same OIF standard for tx and rx Please note that the filter is only defining the return loss, plus transmit filter, and time continuous filters. Decision Feedback Equalisation is performed later, during the selection of the receiver type in the XML definition files.
2. we select the touchstone file for the forward channel. In this case a 4x4 matrix is selected by pressing the appropriate button

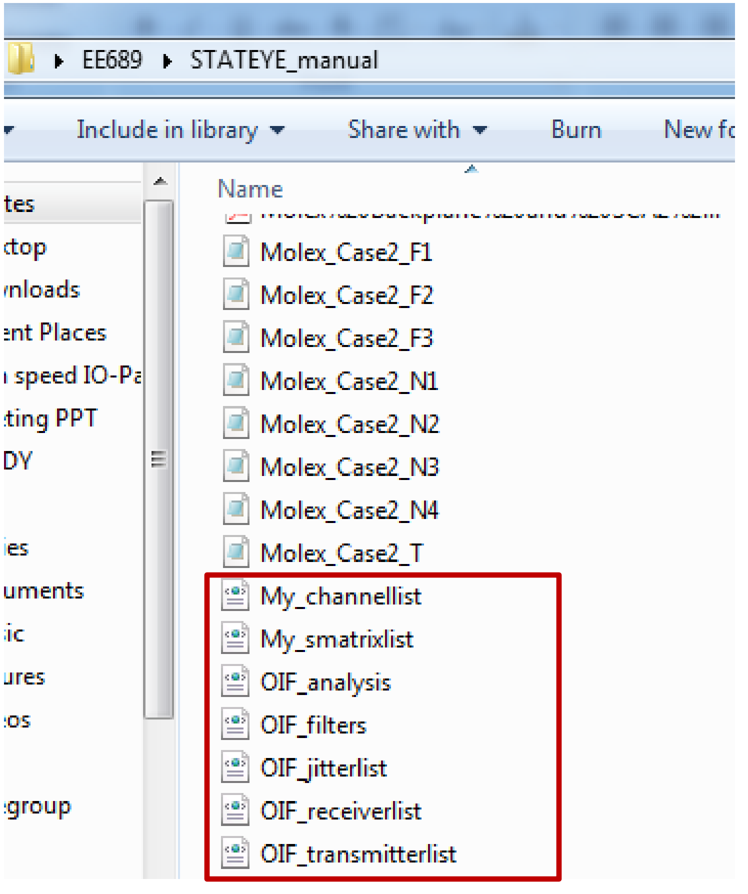
2. Create STATEYE Script File



Each touchstone file has its own definitions for the ports connected to the transmitter and receiver. For this example we must swap ports 2 and 3. Clearly if this is wrong then the results will also be wrong.

2. Create STATEYE Script File

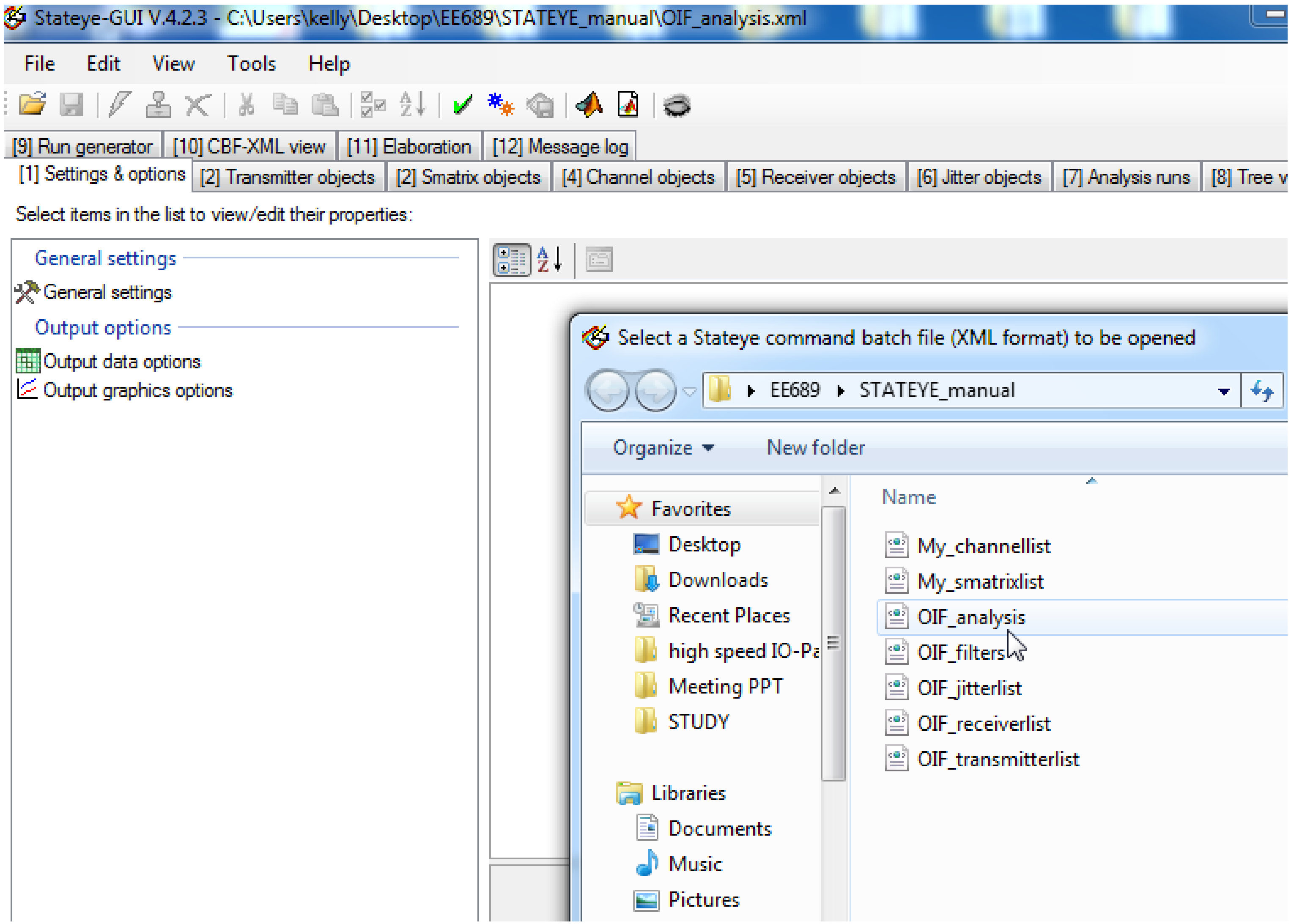
1. We will now leave the other options as default and generate the XML code for the matrices and channels in two seperate definition files
2. smatrixhelper will ask if you wish to copy the oif templates from the installation directory also to this directory. Say yes as we will need these files to generate the final matlab script



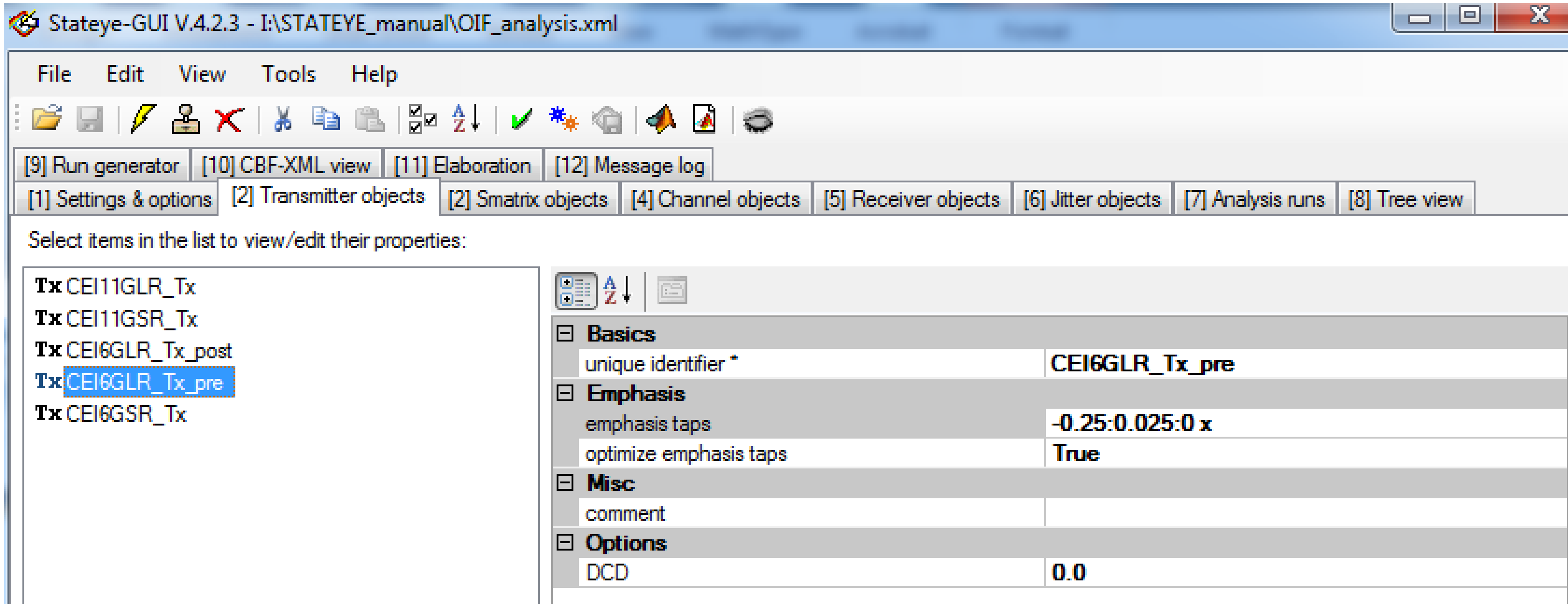
Main ref : [Stateye V.4.0 training - Getting started (slides)]

3. Create Matlab Script File

1. **Run Stateye Gui**
2. **Open OIF_analysis**



1. CEI6GLR_TX_Pre

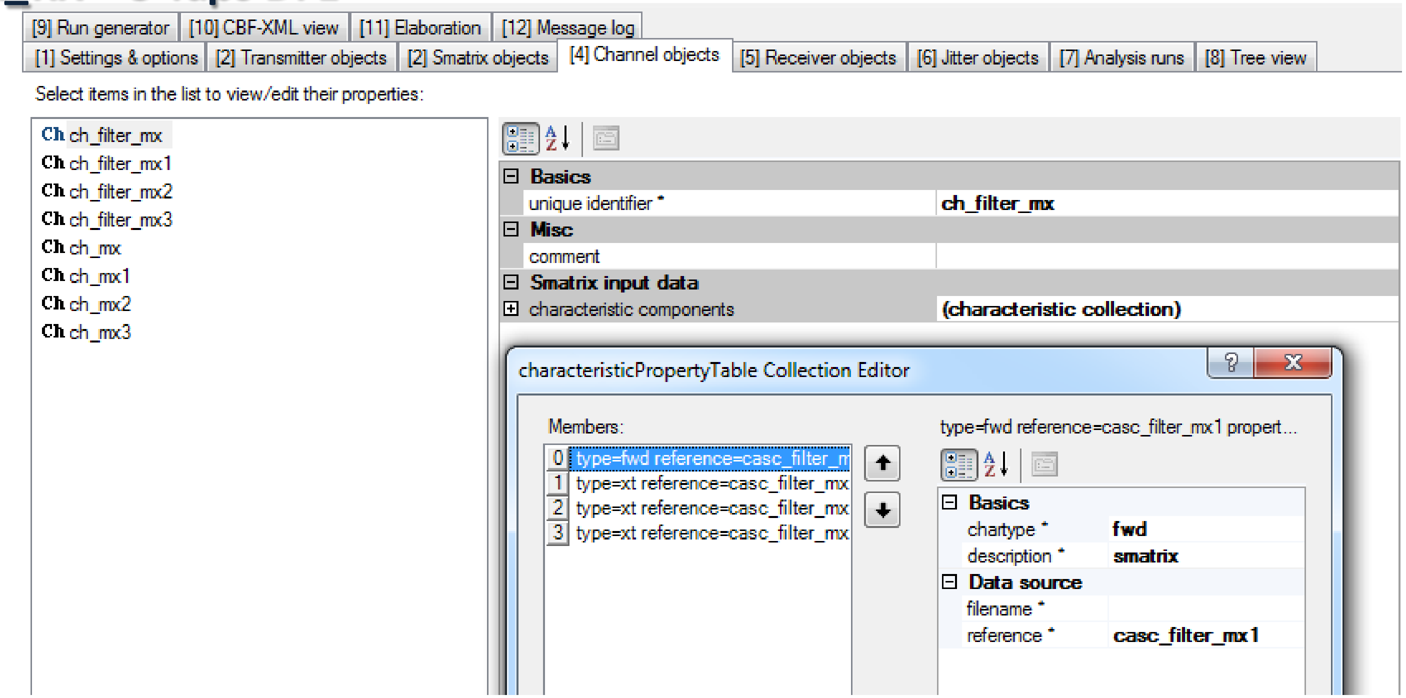


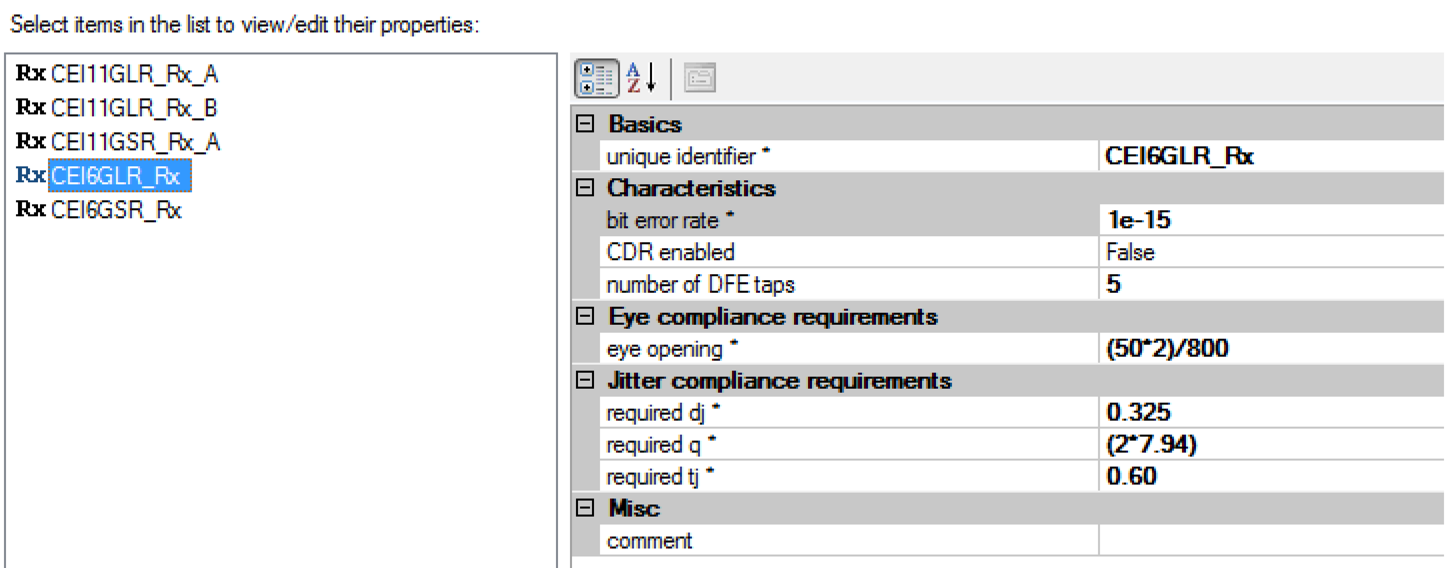
Examples:

- `emphasis=""` : equivalent to `emphasis="1"` (i.e. no specific emphasis to be applied)
- `emphasis="-0.05 0.85 -0.10"` : fixed pre-tap -0.05, main tap 0.85, post-tap -0.10
- `emphasis="-0.05 x -0.10"` : will be converted to `emphasis="-0.05 0.85 -0.1"` (see above)
- `emphasis="x -0.3"` : will be converted to `emphasis="0.7 -0.3"`
- `emphasis="0:-0.05:-0.1 x -0.1"`: will be converted to `"0 0.9 -0.1"` and `"-0.05 0.85 -0.1"` and `"-0.1 0.8 -0.1"` (sweep)

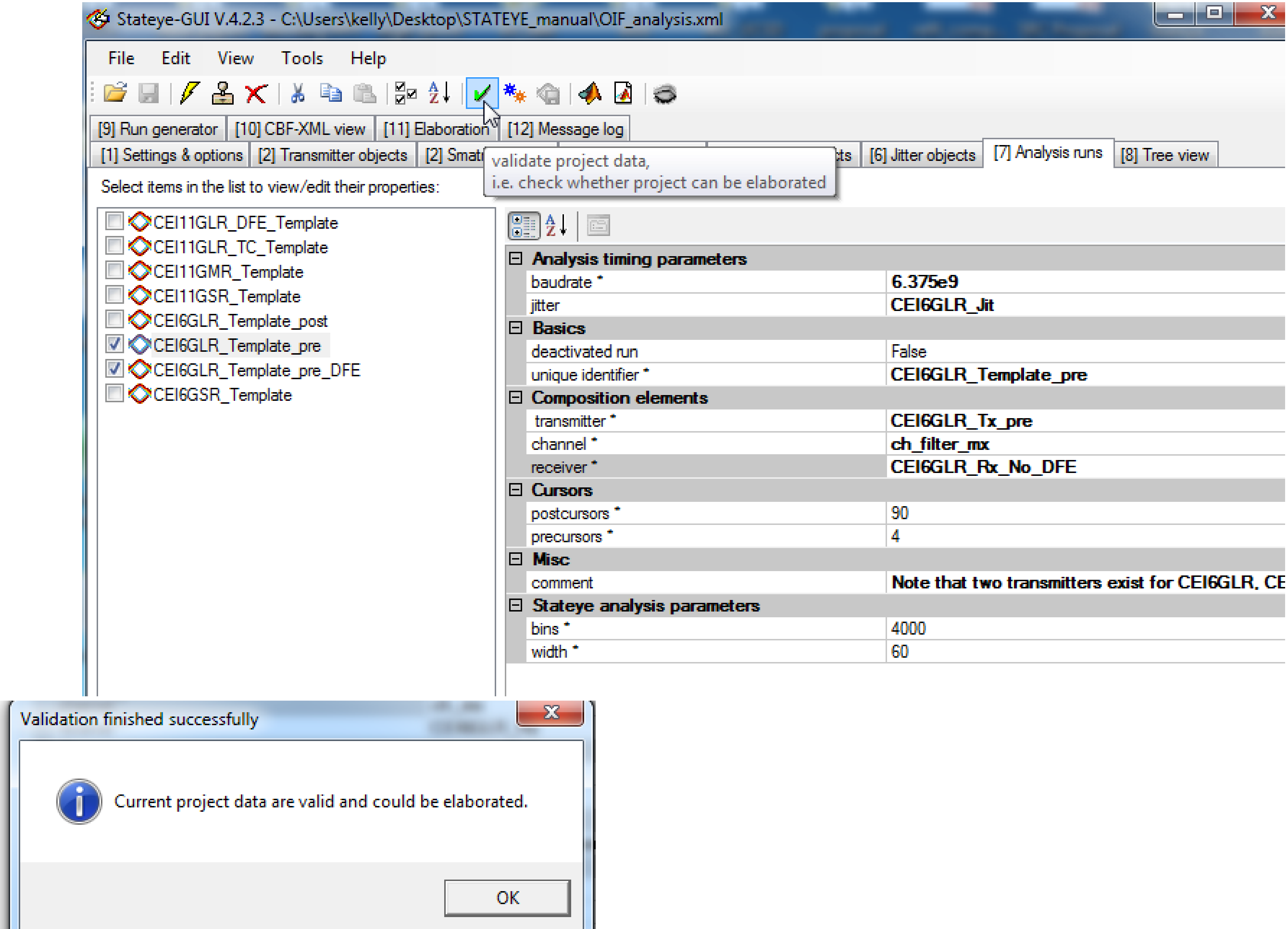
Either a single pre or post tap transmitter, with ≤ 6dB of emphasis, with infinite precision accuracy.

1. **Previous SmatrixHelper already generate cascade Channel model, however we can customize**
2. **CEIGLR_RX – 5 Taps DFE**

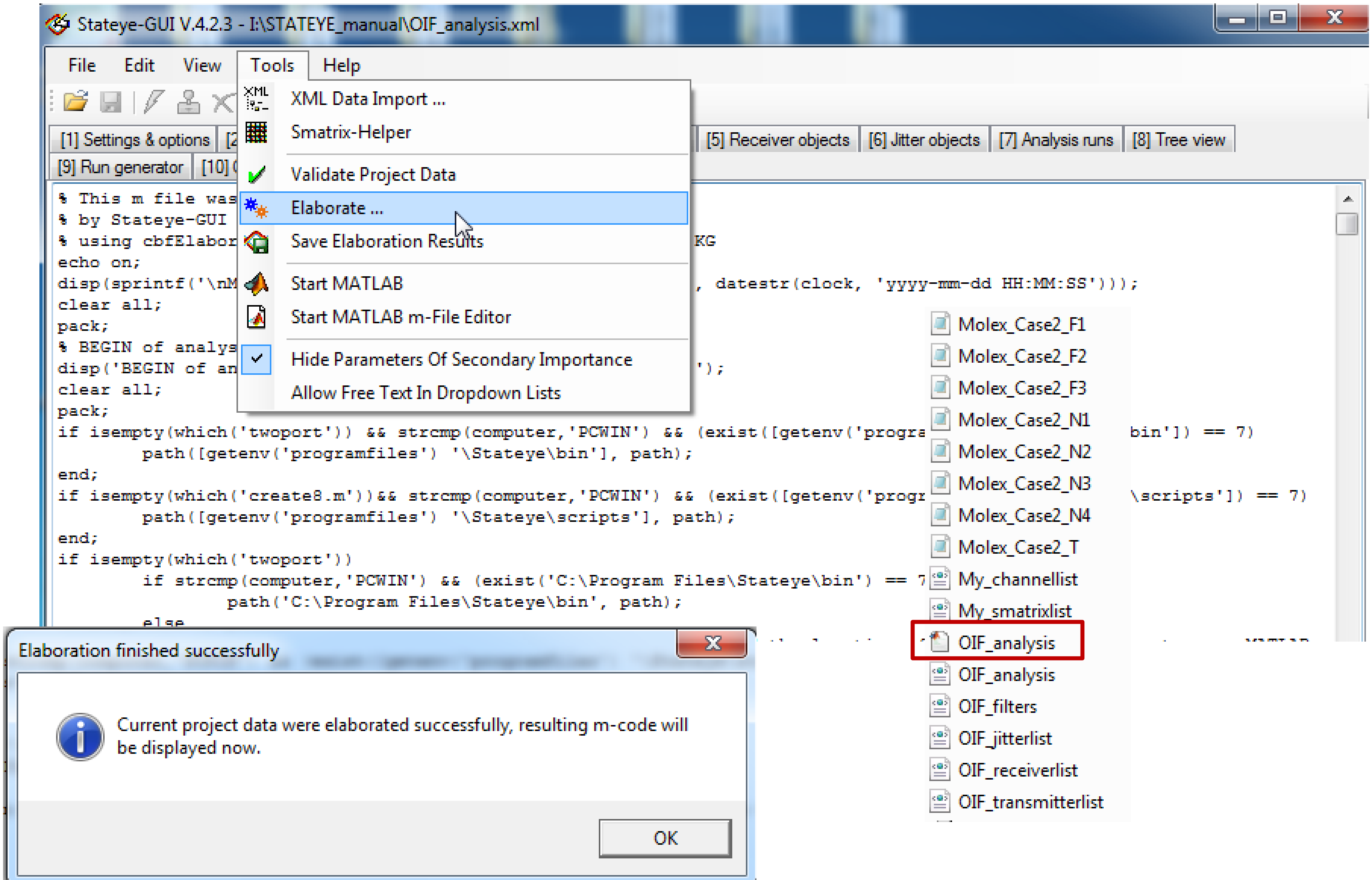




1. **Analysis runs, we will do CEI6GLR_post simulation.**
2. **Validate Project Data**



1. **Elaborate**
2. **After Elaborate, save elaboration results, however make sure you save this file at directory which have channel model files**
3. **Further information – download manual in stateye website**



3.1 Link Characteristic –StatEye Sim

CEI-6G-SR Short Reach Interface

6.2 Requirements

1. Support serial baud rate from 4.976Gsym/s to 6.375Gsym/s.
2. Capable of low bit error rate (required BER of 10^{-15}).
3. Capable of driving 0 – 200mm of PCB and up to 1 connector. 200mm = 7.9 inch
4. Shall support AC coupled operation and optionally DC-coupled operation.
5. Shall allow multi-lanes (1:N).
6. Shall support hot plug.

CEI-6G-LR Long Reach Interface

7.2 Requirements

1. Support serial baud rate from 4.976Gsym/s to 6.375Gsym/s.
2. Capable of low bit error rate (required BER of 10^{-15}). 1m = 39.9 inch
3. Capable of driving 0 – 1m of PCB (such as IEEE 802.3 XAUI/TFI-5 compliant backplane) and up to 2 connector.
4. Shall support AC coupled operation and optionally DC-coupled operation.
5. Shall allow multi-lanes (1:N).
6. Shall support hot plug.

3.1 Link Characteristic –StatEye Sim

- CEI-11G-SR Short Reach Interface

8.1 Requirements

1. Support serial data rate from 9.95 Gsym/s to 11.1 Gsym/s.
2. Capable of low bit error rate (required BER[1] of 10^{-15}).
3. Capable of driving 0 – 200 mm of PCB and up to 1 connector.
4. Shall support AC-coupled and optionally DC-coupled operation.
5. Shall allow multi-lanes (1 to n).
6. Shall support hot plug.

- CEI-11G-LR/MR Long/Medium Reach Interface

9.1 Requirements

1. Support NRZ coded serial data rate from 9.95 Gsym/s to 11.1 Gsym/s.
2. Capable of low bit error rate (required BER $< 10^{-15}$).
3. Capable of driving 0 — 1 meter (39 inches) of PCB and up to 2 connectors.
4. Capable of driving 0 — 600 mm of PCB and up to 2 connectors for low-power applications.
5. Shall support AC-coupled and optionally DC-coupled operation.
6. Shall allow multi-lanes (1 to n).
7. Shall support hot plug.

3.1 Link Characteristic –StatEye Sim

❑ CEI-6G-LR Long Reach Interface

- Main Template in this manual

Table 7-2. CEI-6G-LR Transmitter Output Electrical Specifications

Characteristic	Symbol	Condition	MIN.	TYP.	MAX.	UNIT
Baud Rate	T_Baud	See 7.4.1.2	4.976		6.375	Gsym/s
Output Differential voltage (into floating load Rload=100Ω)	T_Vdiff	See 7.4.1.3 & Note 1	800		1200	mVppd
Differential Resistance	T_Rd	See 7.4.1.5	80	100	120	Ω
Recommended output rise and fall times (20% to 80%)	T_tr, T_tf	See 7.4.1.4	30			ps
Differential Output Return Loss (100MHz to 0.75*T_Baud)	T_SDD22	See 7.4.1.5			-8	dB
Differential Output Return Loss (0.75*T_Baud to T_Baud)						
Common Mode Return Loss (100MHz to 0.75 *T_Baud)	T_S11	See 7.4.1.5			-6	dB
Transmitter Common Mode Noise	T_Ncm				5% of T_Vdiff	mVppd
Output Common Mode Voltage See Notes 2, 3 & 4 See also 3.2.2	T_Vcm	Load Type 0 See Note 2	100		1700	mV
		Load Type 1 See Note 3 & 4	630		1100	mV

NOTES:

1. The Transmitter must be capable of producing a minimum T_Vdiff greater than or equal to 800 mVppd. In applications where the channel is better than the worst case allowed, a Transmitter device may be provisioned to produce T_Vdiff less than this minimum value, but greater than or equal to 400 mVppd, and is still compliant with this specification.
2. Load Type 0 with min T_Vdiff, AC-Coupling or floating load.
3. For Load Type 1: R_Zvtt ≤ 30Ω; T_Vtt & R_Vtt = 1.2V +5%/-8%
4. DC Coupling compliance is optional (Load Type 1). Only Transmitters that support DC coupling are required to meet this parameter.

3.1 Link Characteristic –StatEye Sim

❑ CEI-6G-LR Long Reach Interface

Table 7-7. CEI-6G-LR Receiver Electrical Input Specifications

Characteristic	Symbol	Condition	MIN.	TYP.	MAX.	UNIT
Rx Baud Rate	R_Baud	See 7.4.2.1	4.976		6.375	Gsym/s
Input Differential voltage	R_Vdiff	See 7.4.2.3			1200	mVppd
Differential Resistance	R_Rdin	See 7.4.2.7	80	100	120	Ω
Bias Voltage Source Impedance (load type 1)	R_Zvtt	See Note 1			30	Ω
Differential Input Return Loss (100MHz to 0.75*R_Baud)	R_SDD11	See 7.4.2.7			-8	dB
Differential Input Return Loss (0.75*R_Baud to R_Baud))						
Common Mode Input Return Loss (100MHz to 0.75 *R_Baud)	R_SCC11	See 7.4.2.7			-6	dB
Input Common Mode Voltage See Notes: 1, 2 & 3	R_Vfcm	Load Type 0 See Note 2	0		1800	mV
		Load Type 1 Notes: 1 & 3	595		R_Vtt - 60	mV
Wander divider (in Figure 2-27 & Figure 2-28)	n			10		

NOTES:
1. DC Coupling compliance is optional (Load Type 1). Only receivers that support DC coupling are required to meet this parameter.
2. Load Type 0 with min T_Vdiff, AC-Coupling or floating load. For floating load, input resistance must be ≥ 1kΩ
3. For Load Type 1: T_Vtt & R_Vtt = 1.2V +5%/-8%.

3.1 Link Characteristic –StatEye Sim

❑ CEI-6G-LR Long Reach Interface

Reference Receiver:

1. Rx equalization: 5 tap DFE, with infinite precision accuracy and having the following restriction on the coefficient values:

   Let W[N] be sum of DFE tap coefficient weights from taps N through M where

   N = 1 is previous decision (i.e. first tap)
   M = oldest decision (i.e. last tap)
   R_Y2 = T_Y2 = 400mV
   Y = min(R_X1, (R_Y2 - R_Y1) / R_Y2) = 0.30
   $Z = {}^{2}/_{3} = 0.66667$

   Then $W[N] \leq Y * Z^{(N-1)}$

   For the channel compliance model the number of DFE taps (M) = 5. This gives the following maximum coefficient weights for the taps:

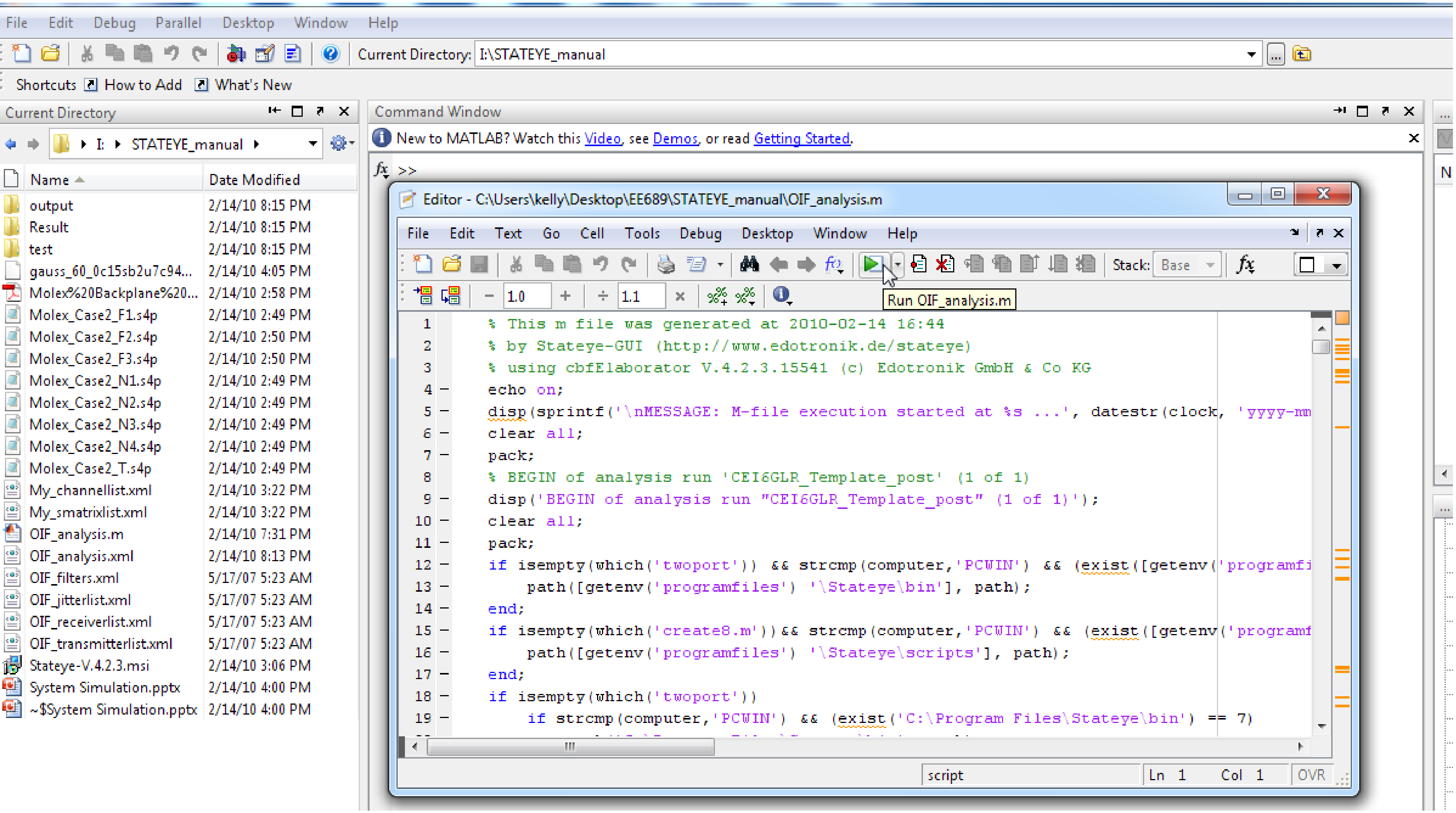
   $W[1] \leq 0.2625$ (sum of taps 1 to 5)
   $W[2] \leq 0.1750$ (sum of taps 2 to 5)
   $W[3] \leq 0.1167$ (sum of taps 3 to 5)
   $W[4] \leq 0.0778$ (sum of taps 4 and 5)
   $W[5] \leq 0.0519$ (tap 5)

   Notes:
   - These coefficient weights are absolute assuming a T_Vdiff of 1Vppd
   - For a real receiver the restrictions on tap coefficients would apply for the actual number of DFE taps implemented (M)

Common Electrical I/O (CEI) Electrical and Jitter Interoperability agreements for 6G+ bps and 11G+ bps I/O IA # OIF-CEI-02.0 28th February 2005

4. Run Matlab – High speed link Simulation

1. **Open OIF_analysis.m by Matlab simulator**
2. **Run OIF_analysys.m**



1. **Previously Stateye simulator – created CEI6LR_pre_DFE**
2. **As we can see, in matlab simulation result is shown**

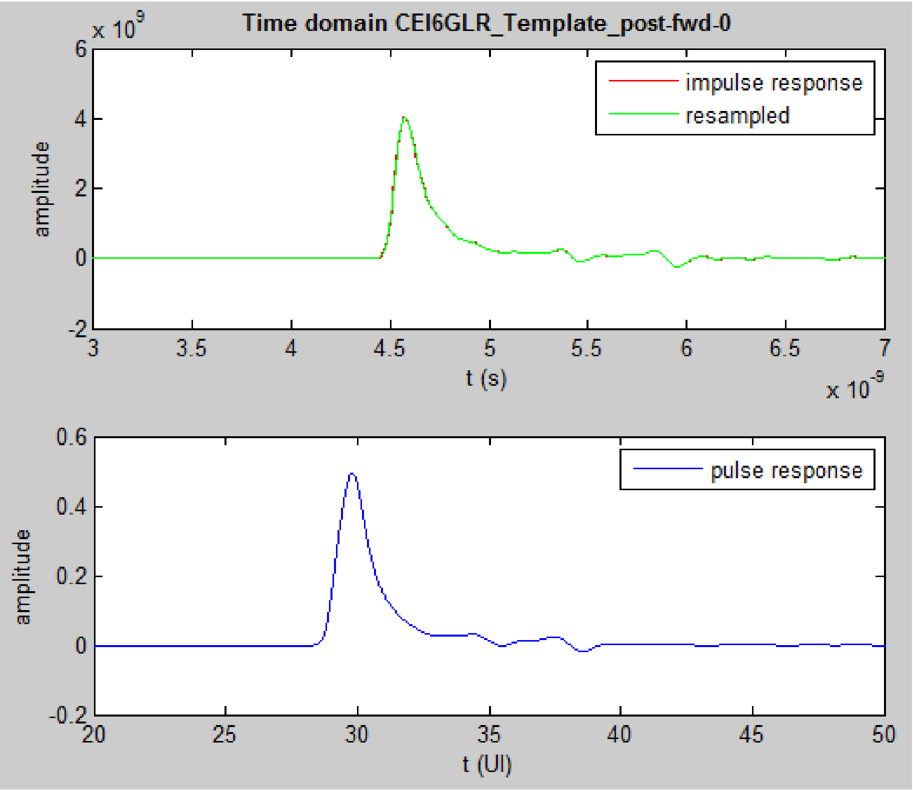
- bathtub_20100407T022211
- charFD-fwd-0_20100407T022211
- charFD-xt-1_20100407T022211
- charFD-xt-2_20100407T022211
- charFD-xt-3_20100407T022211
- diary_20100407T022211
- eye_20100407T022211
- optimizationlog_20100407T022211
- results_20100407T022211

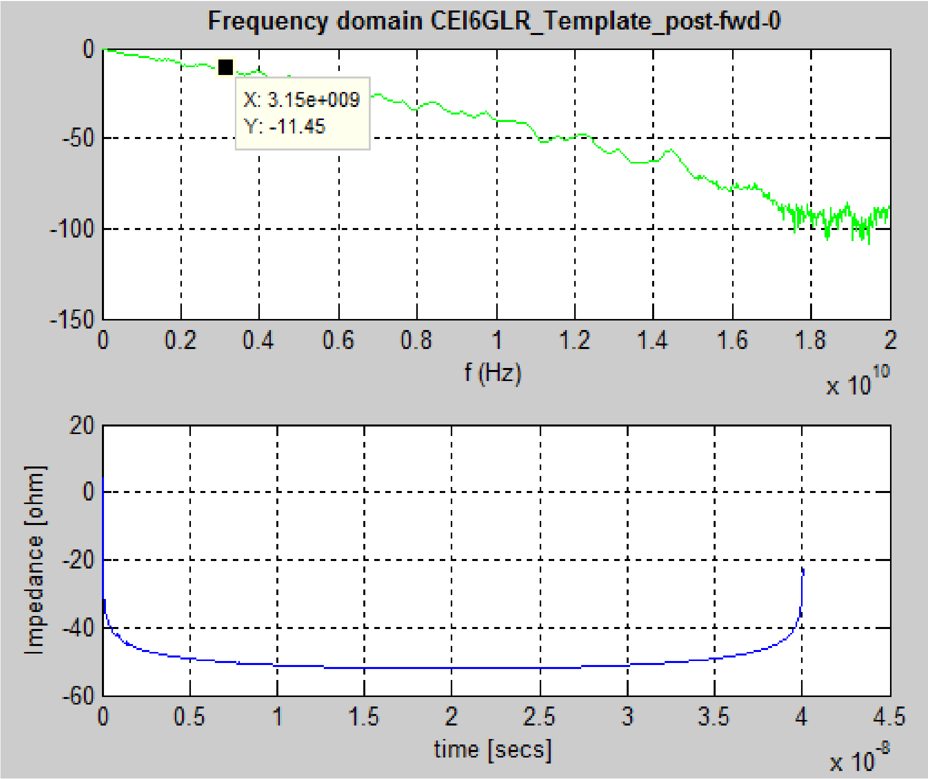
```
transmitterId =CEI6GLR_Tx_pre
emphasis =-0.00625    0.99375
optemphasis =1 [-0.25:0.025:0 x ]
dcd =0
channelId =ch_filter_mx
receiverId =CEI6GLR_Rx
ber =1e-015
dfetapsNumber =5
dfetapsFound =0.203113 0.0775882 0.0311997 0.0267718 0.0201809
cdrEnabled =0
tjRequired =0.6
djRequired =0.325
qRequired =15.88
eyeRequired =0.125
jitterId =CEI6GLR_Jit
jitterTemplate =gauss
jitterDj =0.15
jitterRj =0.00944584
precursors =4
postcursors =90
width =60
baudrate =6.375e+009
bins =4000
mustIncreaseBins =0
tictoc =265.928
dj =0.2027
rj =0.0146271
tj =0.434979
statMiddle =0
```

Result.txt

4. Channel Characteristic

- ❑ **Channel time domain and Frequency domain analysis (also we can see cross talk channel information)**

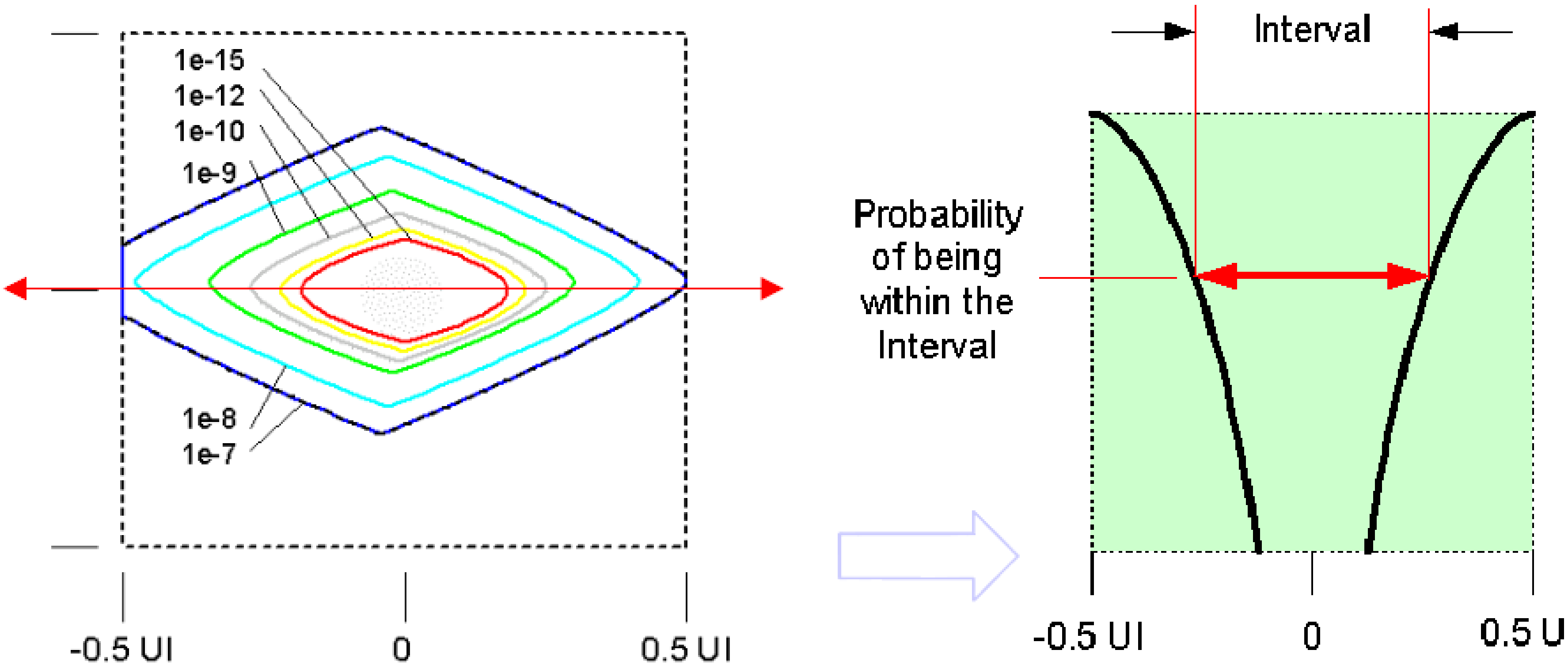




- ❑ **This can be done by Matlab simulator with touch stone file without STATEYE.**

4. High Speed Link Simulation Result

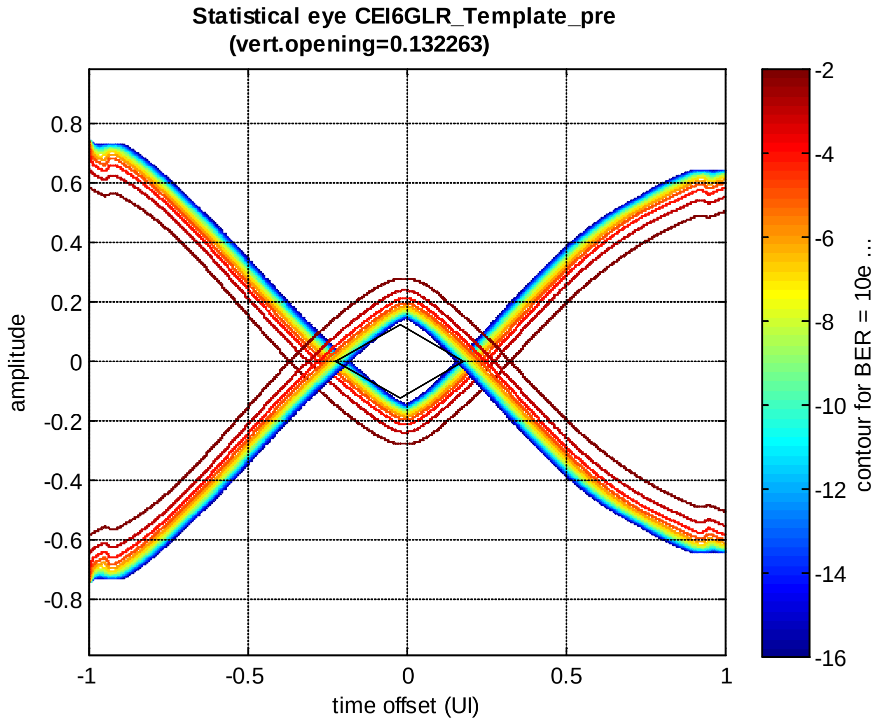
- Stat Eye to Bathtub

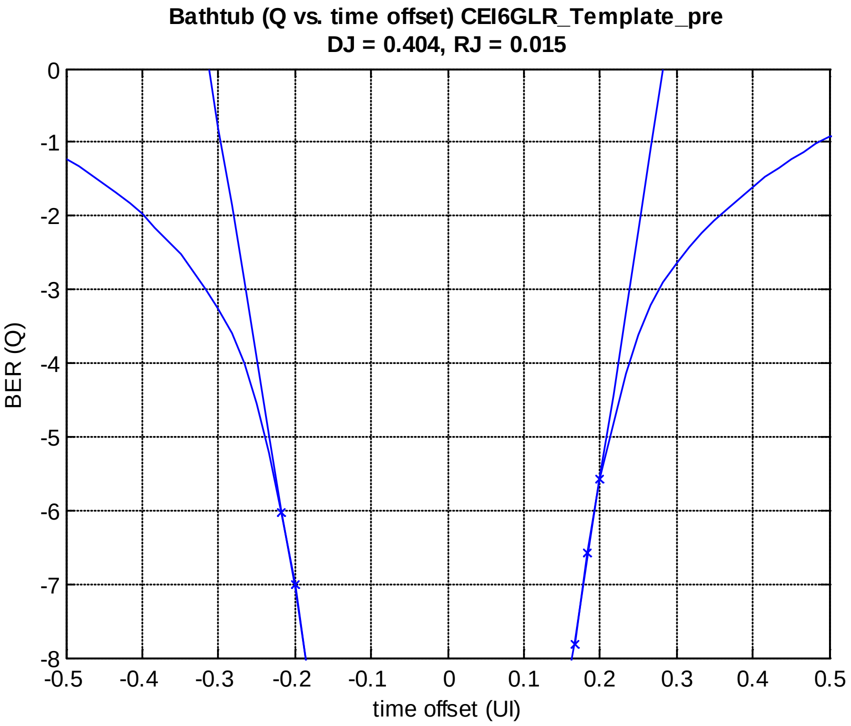


Slice Through Contours along Horizontal Axis of Stat Eye = Bert Scan
Note: Not the same as Bert Scan Calculated from RJ, DJ

4. High Speed Link Simulation Result

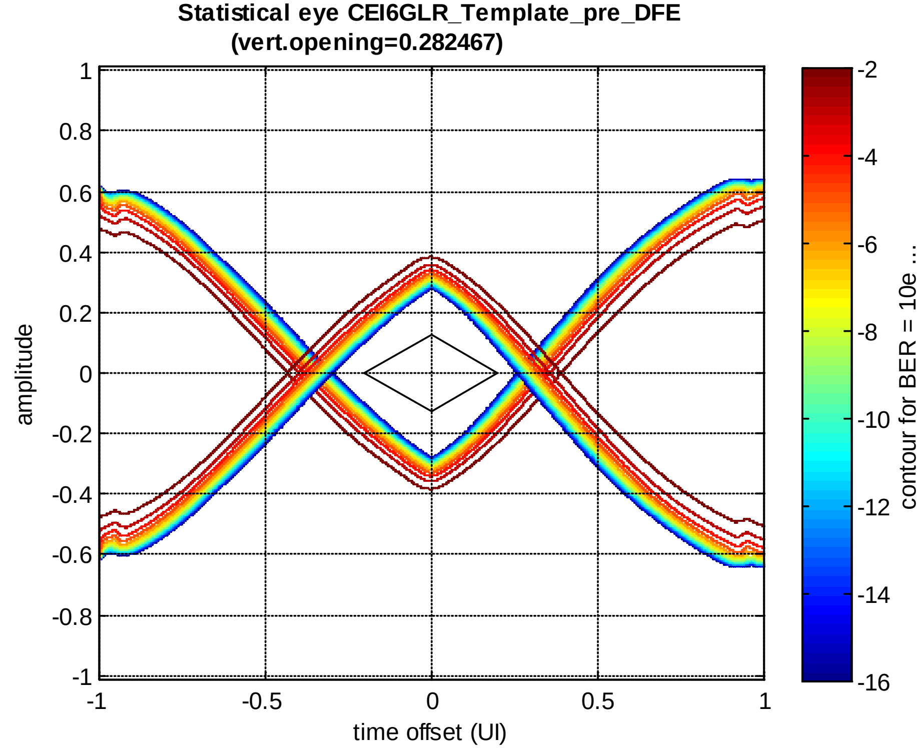
- CEI6GLR_Template_Pre_1 tap TX
- Q=7.94 => BER = 10^-15

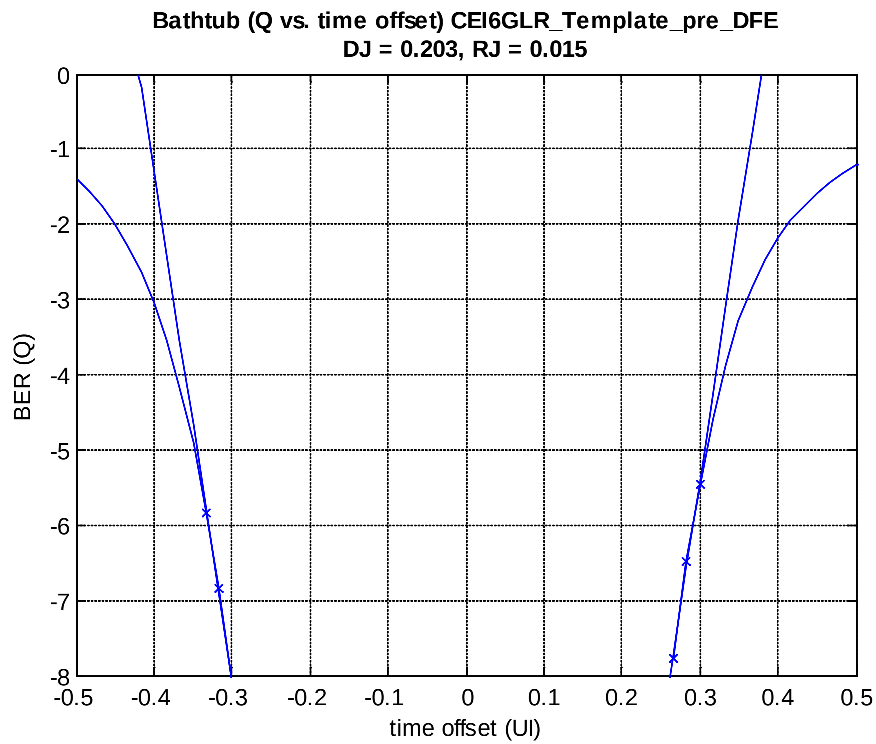




4. High Speed Link Simulation Result

- CEI6GLR_Template_Pre_1 taps TX and 5 taps DFE RX
- Q=7.94 => BER = 10^-15





❑ From Reference

Results (2) – Contents

- Depending on the output settings of the project, a data file (csv format by default) and one or more graphic files (default: fig format) will be written during the execution of the analysis m file:
  - The data files contain one row per run with general data, input parameters and the calculated results:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	runId	runCounter	startedAt	computer	machinename	lastWarning	lastError	transmitterId	emphasis	optemphasis	dcd	channelId	receiverId	ber	dfetapsNumber
2	runIdealTermWithRealLoad	1 of 4	24.07.2006 21:59	PCWIN	ALEXANDER-SMS			CEI11GSR_Tx	1	0	0	chIdealTermWithRealLoad	CEI11GSR_Rx_A	1,00E-15	0
3	runRealTerm	2 of 4	24.07.2006 22:03	PCWIN	ALEXANDER-SMS			CEI11GSR_Tx	1	0	0	chRealTerm	CEI11GSR_Rx_A	1,00E-15	0
4	runRealTermWithFilter	3 of 4	24.07.2006 22:07	PCWIN	ALEXANDER-SMS			CEI11GSR_Tx	1	0	0	chRealTermWithFilter	CEI11GSR_Rx_A	1,00E-15	0
5	runThrough	4 of 4	24.07.2006 22:10	PCWIN	ALEXANDER-SMS			CEI11GSR_Tx	1	0	0	chThrough	CEI11GSR_Rx_A	1,00E-15	0

P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	
dfetapsFound	cdrEnabled	tjRequired	djRequired	qRequired	eyeRequired	jitterId	jitterTemplate	jitterDj	jitterRj	precursors	postcursors	width	baudrate	bins	mustIncreaseBins	tictoc	dj	rj	tj
n/a	1	0.65	0.45	15.88	0.306666	CEI11GSR_Jit	gauss	0.15	0.00944584	4	90	60	1.11e+010	4000	0	256.579	0.142184	0.0101142	0.30
n/a	1	0.65	0.45	15.88	0.306666	CEI11GSR_Jit	gauss	0.15	0.00944584	4	90	60	1.11e+010	4000	0	242.05	0.145686	0.00977256	0.30
n/a	1	0.65	0.45	15.88	0.306666	CEI11GSR_Jit	gauss	0.15	0.00944584	4	90	60	1.11e+010	4000	0	155.613	0.139804	0.0118022	0.32
n/a	1	0.65	0.45	15.88	0.306666	CEI11GSR_Jit	gauss	0.15	0.00944584	4	90	60	1.11e+010	4000	0	125.913	0.145691	0.00977234	0.30

  - Graphic files contain the desired diagrams, e.g. a ststistical eye: