Subject: Typical Channel Characteristics and Displays

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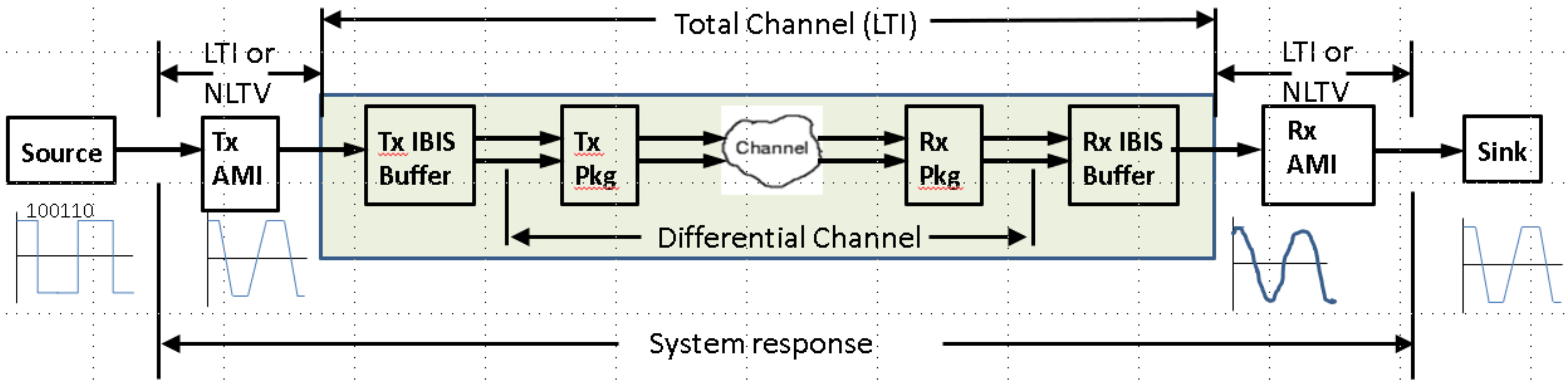
This paper discusses features on the web site: **https://www.serdesdesign.com**

The Channel Simulation Tool analyzes a channel used with a SerDes system that has a typical structure shown in this figure.



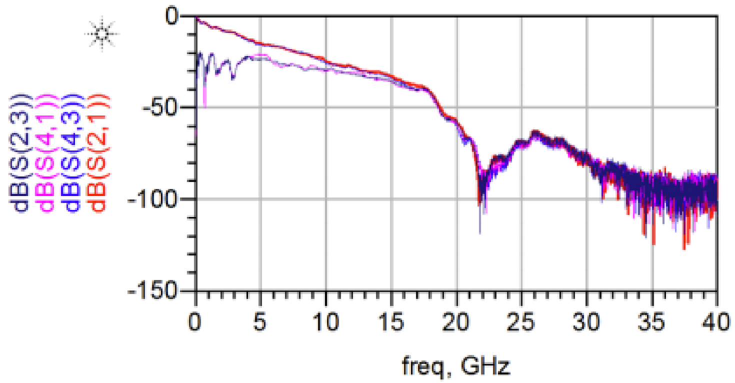
The differential channel often includes a transmit (Tx) package and a receive (Rx) package.

See discussion in 'About the Channel Simulation Tool'.

This section discusses typical channel characteristics and displays. Let us know if you would like the tool enhanced with additional capability.

A typical SerDes channel, with about 18 nsec time delay, defined for use with serial data at a bit rate of 25 Gbps has its hardware 4-Port S-parameters measured from 10 MHz to 40 GHz in steps of 3.125 MHz as shown here:

Figure 1: S-parameters magnitude response versus frequency; only S21, S41, S23, S24 are displayed.



Its differential transmission characteristic is defined as the differential response from the input differential pair of ports to the output differential pair of ports (positive side: port 1 -> port 2; minus side: port 3 -> port 4):

The S-parameters, though measured on actual hardware, actually deviate from the constraints for physical realizability such as passivity, reciprocity, and causality or include noise in the measured S-parameters for various reasons. For physical realizability, the S-parameters should ideally be measured continuously from 0 Hz to infinity and with no noise or distortion. For practical reasons, the S-parameters are band limited, are tabulated only at discrete frequencies, and are corrupted by measurement noise. These measurement limitations typically cause the S-parameters to be non-causal, non-reciprocal, and non-passive.

Thus, to achieve a physically realizable transmission characteristic, the S-parameters must have corrections applied. The total channel, inclusive of the S-parameters, is then converted to an equivalent single ended impulse response.

See channel impulse response detail in References > **Channel Time-Domain Response**

The typical approach involves zero-padding the S-parameters for the time domain SampleRate (SampleRate = BitRate * SamplesPerBit) for a maximum frequency of SampleRate/2.0 and applying the constraints for physical realizability which include meeting the mathematical aspects of the Kramers-Kronig relations applied to linear time invariant (LTI) systems. This zero-padding approach often results in high frequency aliasing.

SerDesDesign.com uses a proprietary algorithm to obtain the causal channel impulse response which inherently does not result in any high frequency aliasing. Direct use of the S-parameter data inherently introduces errors.

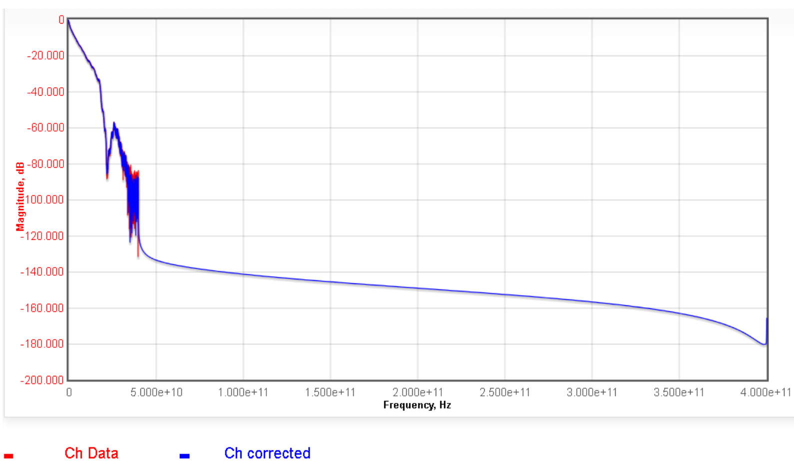
See Causal S-Parameters detail in: **About the Generate Causal S-Parameters Tool**

See also discussion below on **'Obtaining the Differential Channel Frequency Domain Characteristic'.**

With physical realizability corrections applied, various measurements are made.

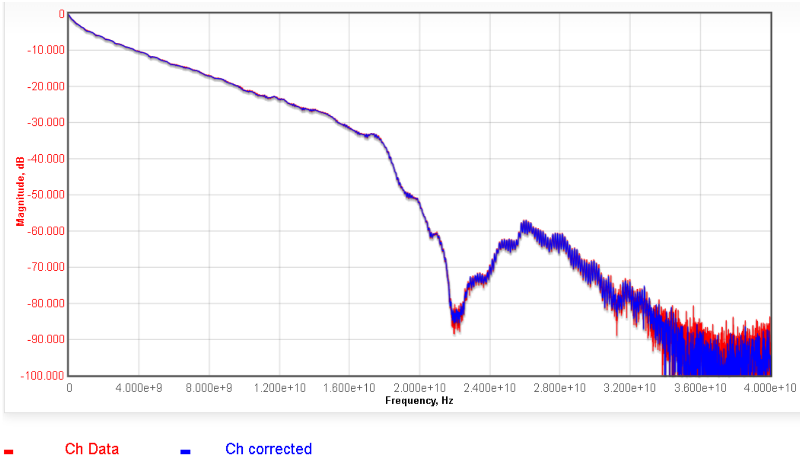
1A. Channel spectrum magnitude

The data (red) and corrected (blue) differential transmission magnitude (in dB) characteristic is shown in the frequency domain up to the maximum sample rate frequency of SampleRate/2.0 = 400 GHz. Observe no high frequency aliasing in the corrected data.



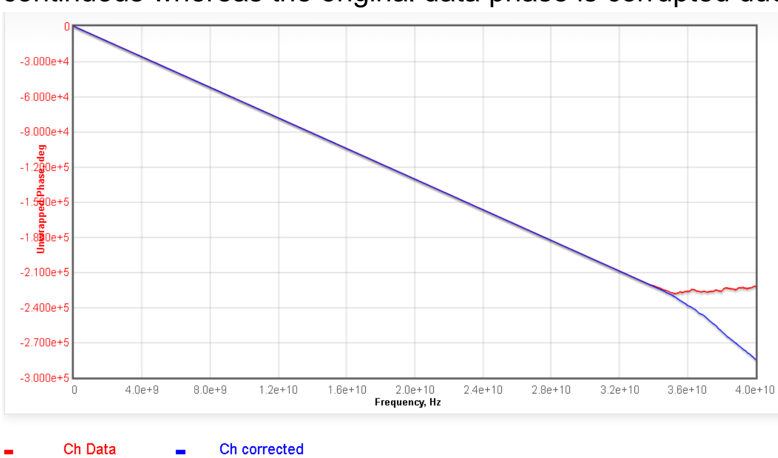
1B. Channel spectrum magnitude zoomed

The data (red) and corrected (blue) differential transmission magnitude (in dB) characteristic is shown in the frequency domain up to the maximum data frequency of 40 GHz. Observe that the corrected data tracks the suck out between 20 GHz and 24 GHz and reduces the noise in the original data.



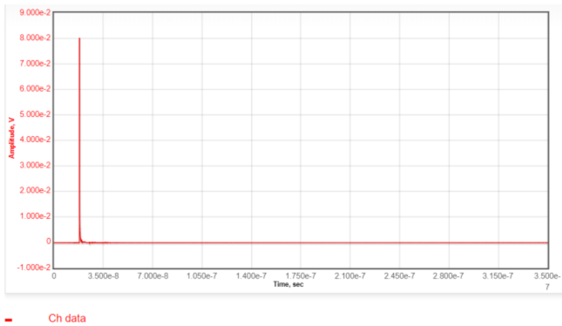
2. Channel spectrum phase

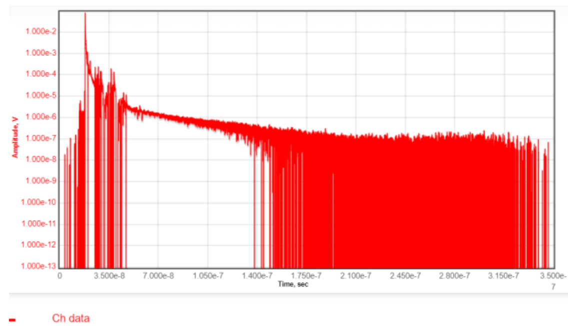
The data (red) and corrected (blue) differential transmission unwrapped phase (in deg) characteristic is shown in the frequency domain up to the maximum sample rate frequency of SampleRate/2.0 = 400 GHz. Observe that the corrected data phase is continuous whereas the original data phase is corrupted due to noise.



3. Channel data impulse response

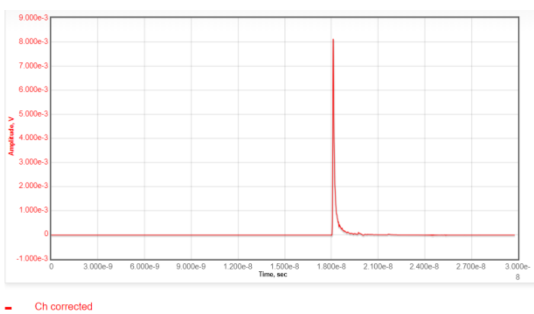
The data differential transmission impulse response is shown here along with a view with a logarithmic y-axis. The total time duration is about 350 nsec. With the logarithmic view, the non-causal artifacts are visible before the 18 nsec transit time of the channel.

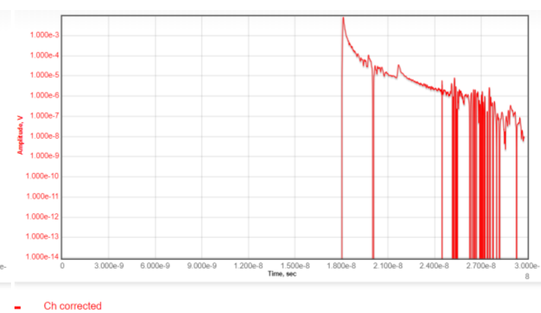




4. Corrected channel impulse response

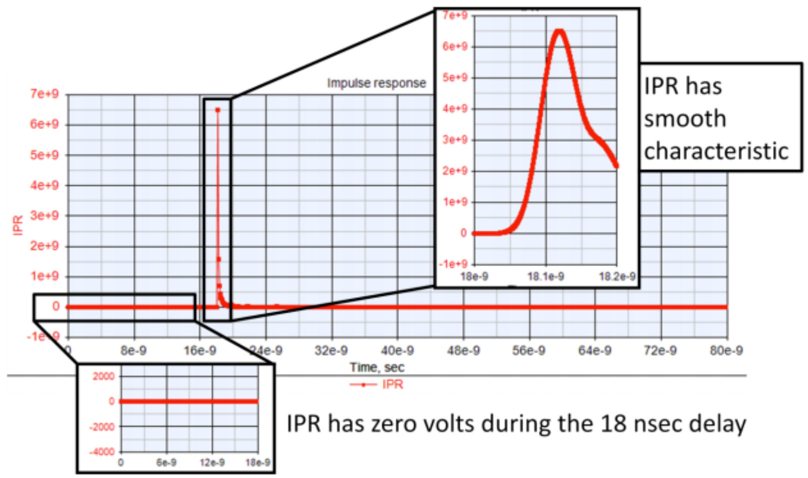
The corrected differential transmission impulse response is shown here along with a view with a logarithmic y-axis. The total time duration is about 30 nsec, which is 10x shorter than the impulse response based on the un-corrected data. With the logarithmic view, one can see that the corrected impulse response has no non-causal artifacts are visible before the 18 nsec transit time of the channel.





The corrected channel impulse response can be downloaded and reused in future analyses so that the channel corrections do not need to be recalculated thereby eliminating the simulation time needed to do these calculations.

Additional detail on the causal corrected impulse response.

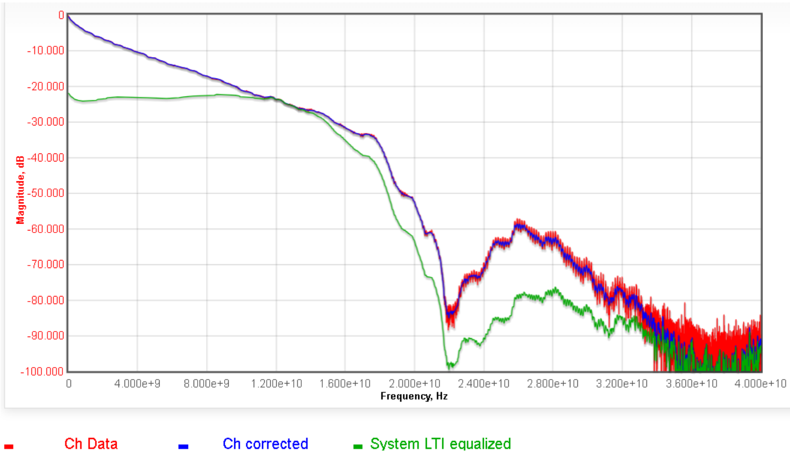


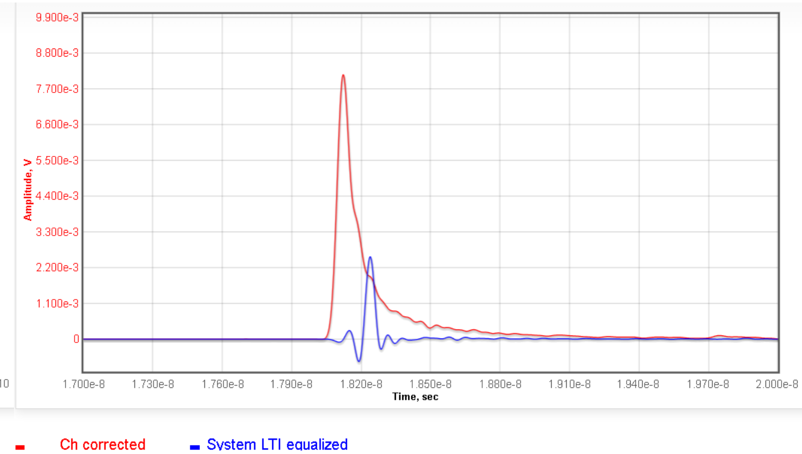
For the 25 Gbps data rate, one unit bit time interval (UI) is 40 psec. Thus, the transmission 18 nsec delay is equal to 450 UI time intervals. Notice that the impulse response has a zero value for this time delay interval, has a sharp turn on after the time delay, and has a realistically smooth characteristic. Most tools in the Electronic Design Automation (EDA) industry do not generate such a good IPR response from S-parameter data. In fact, any impulse response that is derived from S-parameters and has non-zero values during the transmission delay is inherently a non-causal impulse response. Also, any impulse response that is derived from S-parameters and has a non-smooth peaking value inherently has a problem with aliasing.

5. Channel with Tx IBIS-AMI model with FFE equalization: Impulse response

From the equalized channel impulse response, the impulse response can be obtained in the time and frequency domains.

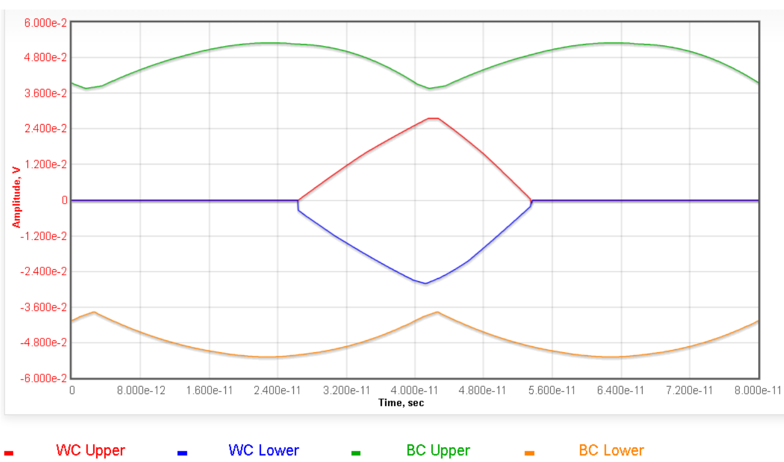
See Channel Pulse Model detail in References > **Channel Pulse Model**





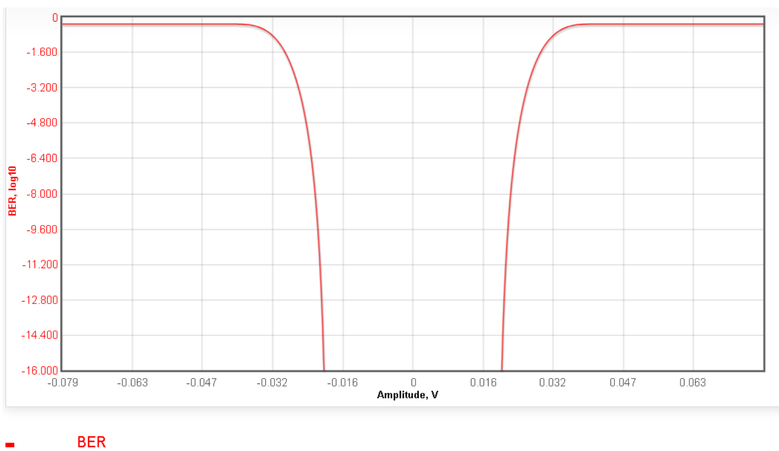
6. Channel with Tx IBIS-AMI model with FFE equalization: Worst/best case eye contours

From the equalized channel impulse response, a statistical analysis can be performed to determine what is the associated eye diagram peak (and minimum) distortion characteristics. For this channel, due to its large loss, the peak distortion (Worst Case Upper and Worst Case Lower) results in a closed eye. With Tx FFE equalization, the eye is opened.



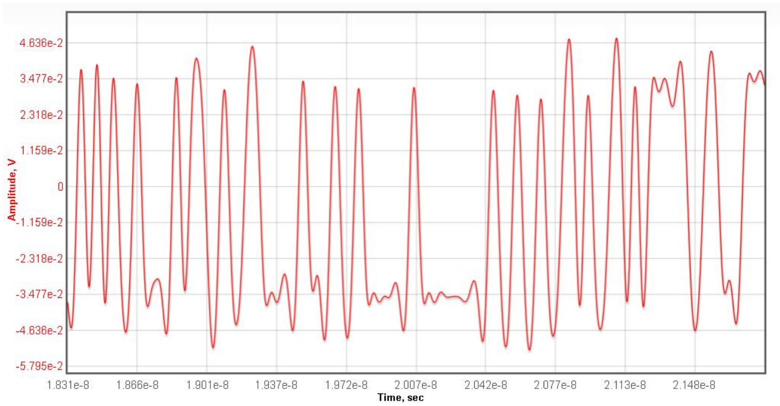
7. Channel with Tx IBIS-AMI model with FFE equalization: Amplitude bathtub BER

From the equalized channel impulse response, a statistical analysis can be performed to determine the BER amplitude bathtub curve vs eye time. Since the channel eye is equalized, the BER for this equalized channel will also show a low minimum BER (log10) at the eye center sampling time instant.



8. Channel with Tx IBIS-AMI model with FFE equalization: Waveform

From the equalized channel impulse response, a statistical analysis can be performed to determine the channel waveform response. The channel waveform specification are based on the Analysis Setup Options: **Setup Options**

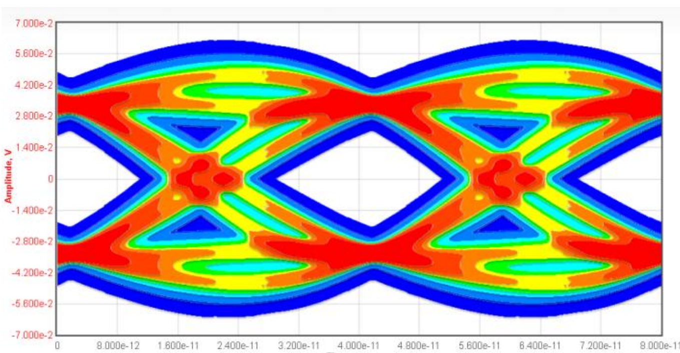


9. Channel with Tx IBIS-AMI model with FFE equalization: Eye Density Plot

For detail channel eye analysis, including jitter and BER characteristics, use the Eye Analysis Tool after analyzing a channel. See detail discussion at: About_the_Eye_Analysis_Tool. These displays are available:

1. System eye worst/best case contours; no additional applied jitter	Open
2. Applied jitter PDF	Open
3. System eye amplitude PDF	Open
4. System eye timing PDF	Open
5. System eye density plot	Open
6. System eye amplitude bathtub BER	Open
7. System eye timing bathtub BER	Open
8. System BER vs eye height	Open
9. System BER vs eye width	Open
10. System constant BER eye contours	Open

Here is the detail Eye Density Plot.



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