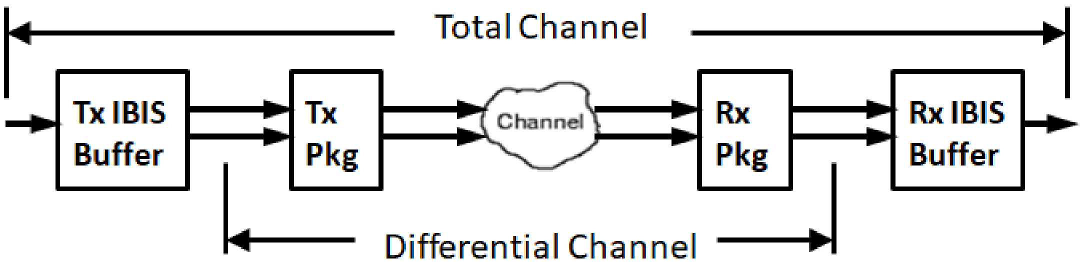
Subject: About the Generate Causal S-Parameters Tool

Author: John Baprawski; John Baprawski Inc. (JB)

Date: Jan 3, 2019

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

The Generate Causal S-Parameters Tool analyzes a channel used with a SerDes system that has a typical structure shown in this figure.



The differential channel is often represented with an S-Parameter file and that file may include characteristics for a differential transmit (Tx) package and a differential receive (Rx) package.

- The differential channel represents a hardware SerDes channel and is typically characterized by measuring its N-port S-parameters and is typically a 4-port. The 4-port differential input ports are typically port 1 (+) and port 3 (-). The associated differential output ports are typically port 2 (+) and port 4 (-). The differential characteristic (Port 1 – Port 3 vs. Port 2 – Port 4) is the channel transmission characteristic and is observed versus frequency.
- See S-parameter detail in References > **S-Parameter Channel Examples**
- The S-parameters may also be obtained from various simulators.
- A high speed digital SerDes channel typically has substantial high frequency attenuation at and beyond the bit/symbol rate Nyquist frequency and requires compensation using equalizers at the transmit and/or receive side of the channel.

S-Parameters inherently have problems when used in a time domain simulation. S-parameters, though measured on actual hardware, actually deviate from the contraints 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. These corrections must be achieved when converting S-Parameters to equivalent impulses in the time domain.

All SerDes system channel simulators convert the frequency domain S-parameter characteristics into time domain impulse characteristics. While doing this, all such simulators attempt to correct for all impairments in the S-parameters. However, some are less successful than others.

In fact, all of the top 6 EDA channel simulation tools have problems in doing this. As has been observed by many and especially reported by Romi Mayder of Xilinx Inc. at the 2015 DesignCon conference, Jan 27-30, Santa Clara Convention Center, Santa Clara CA, the top 6 EDA Channel Simulators in the industry give widely varying impulse modeling of S-parameters as well as widely varying channel BER performance. See this link: > **IBIS-AMI Model Simulations over Six EDA Platforms**

The key to obtaining consistent S-Parameter use with any time domain based tool, including any channel simulator, is to convert S-Parameter data to what is called on this web site “Causal S-Parameters”. Causal S-Parameters for an N-port are based on the frequency domain equivalent of the NxN causal impulse responses generated from the original NxN S-Parameters. Causal S-Parameters will typically provide better eye and BER results while also provide close agreement with the frequency domain response of the original S-Parameters. Causal S-parameters will typically provide faster simulations. Causal S-parameters typically result in impulse responses that have a smaller number of data points. A 2x shorter impulse length results in 4x faster convolution times.

The typical approach to convert S-parameters to an impulse response 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.

To use the Generate Causal S-Parameters Tool, follow the steps on the web page.

1. Define the system

   - Upload an S-parameter file, name must begin with an alpha character, and identify the number of ports in the S-parameter file.

2. Setup the analysis.

   - Define the analysis name.
   - Define the bit (symbol) rate in bits (symbols) per second.
   - Define the number of samples per bit (symbol).
   - Define whether the file represents a differential channel.
   - Define the input and output ports for the file.

3. Generate the Causal S-Parameters for the S-Parameter file.

   - After the file generation is done, the conversion log file is displayed.
   - Look at the bottom of the file to see that the generation was successful:

     Writting Causal S-parameter file

     Writting Causal Impulse file

     Exiting Causal SParameters Analysis with success; run time = 130 sec.

4. Download the causal S-parameter file.

   - Use this file in other Channel Simulators to achieve consistent processing of S-Parameters among the various Channel Simulators.

5. Run an Analysis to compare the converted S-Parameters against the original S-Parameters.

   - Look at the bottom of the file to see that the analysis was successful:

     Writting Impulse files.

     Writting Spectrum files.

     Exiting Compare SParameters with success; run time = 39 sec.
   -

6. Display results of the comparison.

   - For more detail on the data and graphs available from this web site, see the article: > **Typical Causal SParameters Characteristics and Displays…**

Terms & Conditions | Privacy Policy