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## File Format for Channels Frequency Responses

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# Channel Responses

- Channel responses and noise characteristics are the fundamental requirements for modeling and simulation, link performance analysis, and to derive PHY specifications
- Main channels frequency responses for a single-pair cable:
  - Insertion loss
  - Return loss (echo)
- Other interesting channel responses:
  - Crosstalk channel between adjacent cables
  - Common-mode-to-differential loss for EM immunity
  - Differential-to-common-mode loss for EM emission

# Channel Response in Time and Frequency Domains

- Channel response is usually measured in frequency domain as gain over discrete frequency values
- The channel response may have to be converted to time-domain for certain types of analyses, modeling, and simulations
  - The measurement in frequency should include both magnitude and phase, or both real and imaginary components
  - The measurements should be over uniformly-spaced frequencies so that simple transforms can be used without a need for interpolation
  - The measurements should ideally cover the full span of frequency from DC to the maximum to avoid any need to extrapolation

# Maximum Measurement Frequency

- While the bandwidth of interest is up to Nyquist frequency (half the baudrate), the measurement should cover beyond Nyquist so that the effect of non-ideal front-end LPF can be analyzed
  - For instance, 25% excess bandwidth has been considered for 10GBASE-T over Cat6a
- In a baseband system, the baud-rate is higher when a sparser constellation is used for signal modulation
- To support a data-rate of 10 Gbps with a simple PAM2 constellation
  - Baud-rate = 10 Gbaud
  - Nyquist frequency = 5 GHz
- To support 25% excess bandwidth: maximum frequency = 6.25 GHz
- To support 25% of overhead for FEC, control/management channel, etc:

Maximum Measurement Frequency = 7.5 GHz

# Frequency Steps of Measurements

- The frequency steps in measurement of channel response limits the time span of the impulse response
- Echo channel has typically the longest impulse response:
  - For cable length of 15 m, the echo response should be confined to 200 ns
  - Maximum frequency steps should be 5 MHz

Measurement Frequency Step = 1 MHz

# Unified File Format

- A standard file format for measurements is very important
  - Prevents error due to misunderstandings of data format
  - Prevents error due to conversion one format to another
  - Streamlines and speeds up the analysis for various measurements from different sources
- CSV file format: human readable, and easily imported in Matlab, Python, C, etc.
- 1 channel response per file
- Each file consists of 3 columns: frequency, real value of channel gain, imaginary component of channel gain
- Filenames associated with a single cable should have a common prefix and suffix to identify the measured channel
  - Insertion loss seen by first end of the cable is identified by IL1: XyzCable\_IL1.csv
  - Return loss seen at port 2 is identified by RL2: XyzCable\_RL2.csv

# Unified File Format

- Frequency should be expressed in MHz
- Channel gain should be expressed in linear value (not dB) and is represented in *Engineering* format (e.g.  $-1.275e-3$ )
- It is encouraged to include lines of human-readable comments at the top of the file with information such as
  - The measured channel (IL, RL, etc)
  - The type of cable
  - The measurement instrument
  - The date of measurement
  - The source (or company) that has provided the measurement
- All lines of comments should precede the data and start with ‘%’ as the first character in each line

# Summary

- Proposed a unified CSV file format for channel frequency response
- Separate file for each channel consisting of 3 columns:
  - Frequency in MHz starting from 0 to 7.5 GHz in 1 MHz increments
  - Real component of channel gain
  - Imaginary component of channel gain
- The gain should be expressed in linear value (not dB) and in *Engineering* format
- The filename should have standard suffix to identify the measured channel (IL2, RL1, etc)
- Each comment line should start with ‘%’
- All comments should be confined to the top of the file before measurement data



Thank you.

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