TRANSMITTER POWER SPECTRAL DENSITY NOISE IMPACT FOR 200 GB/S PAM 4 PER LANE

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For IEEE802.3 devices, transmitter devices are tested with a test fixture. The test fixture ideally is a transmission line extension from the balls of a device to instrument quality test connection where an oscilloscope is attached. Noise in the transmitter may originate from power delivery, out of band chip activity, thermal, and in-band crosstalk as well as other mode conversion noise. Limiting noise out of the transmitter is required to ensure devices will interoperate. However, the amount of noise is in relation to the transmitter signal. Signal distortion is interpreted by the receiver as noise reducing the signal to noise ratio (SNR). SNR is directly ties to a perceived bit error ratio (BER) and thus performance. The ratio of a transmitted signal to a grouping of physical and distortion noise sources is called signal to noise distortion ratio (SNDR). What are the signal and noise underlying assumptions?

SNDR was introduced in 2014 ethernet standards [1], where a signal was defined as the ratio of the peak power of a transmitter fitted pulse response to the measured noise power which was assumed to be white (wide broadband) and Gaussian. Developments in 2024 for the IEEE project to define 200 Gb/s per lane signaling propose [2] defining SNDR using the sampled signal power density in place of the peak of the pulse suggest spectral coloring should be considered. Expanding spectral content beyond just the signal towards colored noise is discussed.

Measurement of SNDR in IEEE Std 802.3-2014 [1] implies the value of SNDR is independent of any attached channel. In other words, SNDR would be the same regardless of the fixturing being used acquire it. This makes usage in COM, simulation, and measurement simple and straight forward. The noise variance used in the COM receiver from the transmitter was found by multiplying the voltage at the pulse response sampled point time the value of SNR computed from SNDR.

A presentation [2] in IEEE P802dj showed that SNDR is not attached channel independent but could be made so with spectrally aware loss correction factor (LCF) which seems to compensate for the signal spectral density. Usage of SNDR in COM is discussed. The power spectral compensation seemed to work well by adjusting the voltage uses as a signal in the SNDR calculation. SNDR is basically the dB ratio of transmitted signal power to transmitted noise power which includes Tx nonlinearity converted to variance. A thought comes to mind. If the spectral density is important for the signal, is it important for the noise? If the noise is frequency dependent how does this change SNDR computation and usage in COM? This paper will explore if the noise spectral content is important here.

Simple experiments with noise injected at a pattern generator instrument to emulate noise sources will be used to compare SNDR to performance metrics Channel Operating Margin (COM), vertical eye closure (VEC), and eye height (EJ). Noise filters are introduced to emulate noise from power supply (low frequency), out of band buses (like PCIe), and various types of crosstalk. A variety of "added" channels such as ISI board and test fixtures help paint a clear picture of how to use SNDR when non-white noise sources are present.

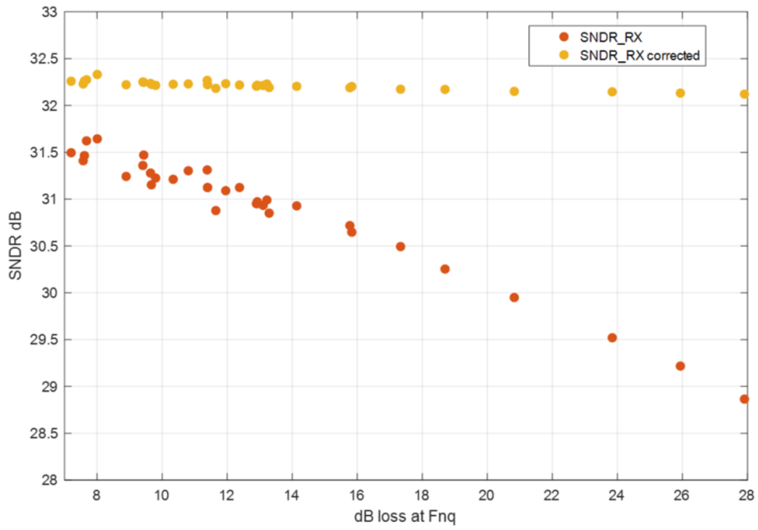

Fig. 1. Original and after correction SNDR

[1] "IEEE Standard for Ethernet Amendment 2: Physical Layer Specifications and Management Parameters for 100 Gb/s Operation", IEEE Std 802.3bj™-2014 (Amendment to IEEE Std 802.3™-2012 as amended by IEEE Std 802.3bk™-2013) Over Backplanes and Copper Cables".

[2] R Mellitz, "SNDR Insertion Loss Adjustments", May 2024 IEEE802.3 Interim Meeting, Annapolis, MD USA https://www.ieee802.org/3/dj/public/24_05/mellitz_3dj_02_2405.pdf

[3] B. Gore, R. Mellitz, A. Josephson, F. de Paulis, L. Boluna, J. Calvin, R. Rabinovich, M. Resso, "Transmitter Power Spectral Density Noise Impact for 200 Gb/s PAM 4 per Lane", in *Proc. DesignCon 2025*, Santa Clara (CA), Jan. 28 – Feb. 30, 2025.