SNDR Target in Transmit Linearity Test

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July 2019

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Overview

- A MGBASE-T1 transmitter has to maintain a minimum level of linearity to ensure proper operation of the far-end receiver
- Test mode 4 and linearity test (clause 149.5.2.2) are to ensure compliance of transmitter to the distortion requirement as defined by a minimum transmit SNDR
- This limit, as currently defined in D2.0, is too low resulting in considerable reduction in the operating margin of the far-end receiver
- New SNDR targets are proposed, for each data rate, to limit the loss in margin

Linearity Test - Background

There has been minimal discussion within 802.3ch task force on how to measure the nonlinearity and what the passing bar should be

- There has been only one presentation on this topic correlating linearity test in 1000BASE-T1 with link performance and interoperability
  http://www.ieee802.org/3/ch/public/mar19/Donahue_3ch_01_0319.pdf

Options considered are:

- No test
- Similar to 1000BASE-T1
- Similar to 100GBASE-KP4 – adopted

Linearity Test - Procedure

- Transmit a known PRBS test pattern and measure at MDI
- Do a linear fit and find the pulse response $P(k)$
- Calculate the nonlinearity σ_e^2 as the power of the difference of MDI signal and the linear fit
- Measure random noise power σ_n^2 by measuring the variance of repeated patterns
- Calculate SNDR as $10 \times log_{10}\left(\frac{P_{max}^2}{\sigma_e^2+\sigma_n^2}\right)$
- Pass criterion: SNDR > 31 dB

Linearity Test - Concerns

- Definition of the test is scattered across many clauses (149, 94, 85, 92, 75) which makes the specification prone to misinterpretation
- Multiple test patterns which are not provisioned in test mode 4
- Main test pattern is designed based on the transmit machinery of 100GBASE-KP4 which may not be readily fitting MGBASE-T1
- Designed for simplex system (100G-KP4) and not duplex (MG-T1)
- SNDR, as defined, does not represent the true signal-to-noise ratio
- SNDR limit is too low resulting in considerable loss of SNR in far-end receiver
- SNDR limit is the same for all rates

SNDR Definition

- SNDR is defined as $\text{SNDR}_{\text{TM}} = 10 \times log_{10}\left(\frac{P_{max}^2}{\sigma_e^2+\sigma_n^2}\right)$
- While the denominator is a reasonable representation of the noise power, the numerator is not signal power

$$\text{Signal power} = \frac{\sum P^2(k)}{M} \times \frac{5}{9}$$

PAM4 power (-2.6 dBFS) ← $\frac{5}{9}$

Over-sampling factor ← M

$$P_{max}^2 \leq \frac{\sum P^2(k)}{M}$$

$$\text{SNDR}_{\text{real}} \leq \text{SNDR}_{\text{TM}} - 2.6\ \text{dB}$$

SNDR Limit

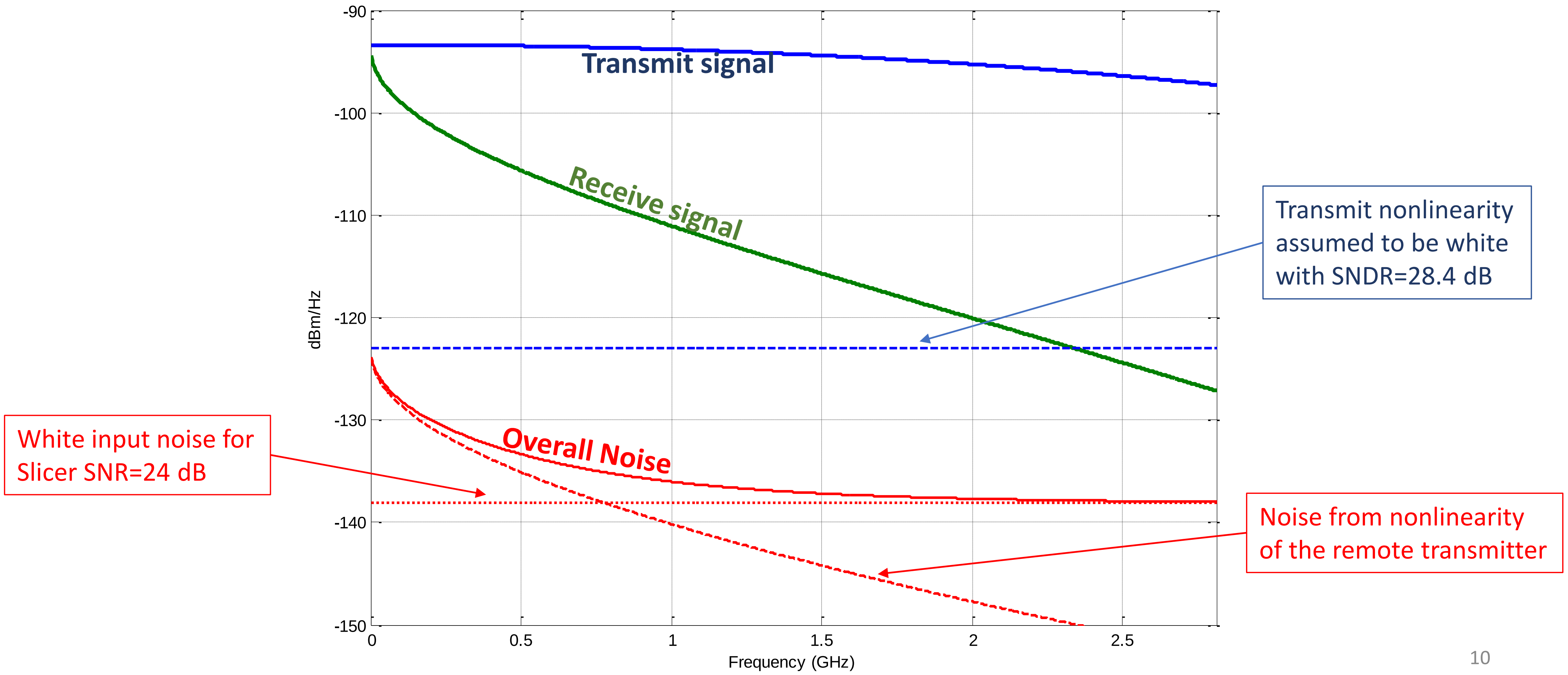
- The *pass* limit for $SNDR_{TM}$ is 31 dB
- This means that a compliant transmitter can have a transmit $SNDR_{real}$ of as low as 28.4 dB
- A compliant transmitter can reduce the operating margin of the far-end receiver significantly

SNR Requirements for MGBASE-T1

- Target bit-error rate: 10^{-12}
- Modulation: PAM4
- Assuming the coding gain from Reed-Solomon covers for implementation margin and non-Gaussian input noise sources such as
  - Impulse noise
  - DFE error propagation
  - EMI effects

Required SNR at slicer = 24 dB

Signal and Noise PSD – 10GBASE-T1



Transmitter Nonlinearity and SNR Loss

Current limit of $SNDR_{TM}$ =31 dB results in nearly 3 dB loss in receiver SNR

Proposed transmit $SNDR_{TM}$ levels that limit the SNR loss to less than 1 dB:

10G: 38 dB

5G: 36 dB

2.5G: 35 dB