Proposal for Transmitter Linearity Specification (SNDR Method)

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Overview

- Current State of SNDR Specification
- Objectives
- Performance Analysis Results
- Proposed Specification
- Conclusion

State of SNDR Linearity Specification

- Transmitter Linearity Specification is Based on SNDR Measurements of Single-Tone and Two-Tone Test Signals
  - Overall measure of jitter, noise, and distortion
  - PHY developers can optimally allocate transmitter impairments
  - Measurement accuracy maximized through use of precision analog measurement equipment (spectrum analyzers)

State of SNDR Linearity Specification

- SNDR Specification Based on Frequency Dependent Requirement of the Form:

$$\mathrm{SNDR} \geq \min\left\{\mathrm{A}, \mathrm{B} - 20 \cdot \log\left(f_{\mathrm{MHz}} / 25 \right) \right\}$$

  - Specification allows distortion and noise to increase with increasing frequency
  - High frequency noise and distortion has minimal channel capacity impact
  - High frequency noise and distortion has major impact on analog circuit design complexity

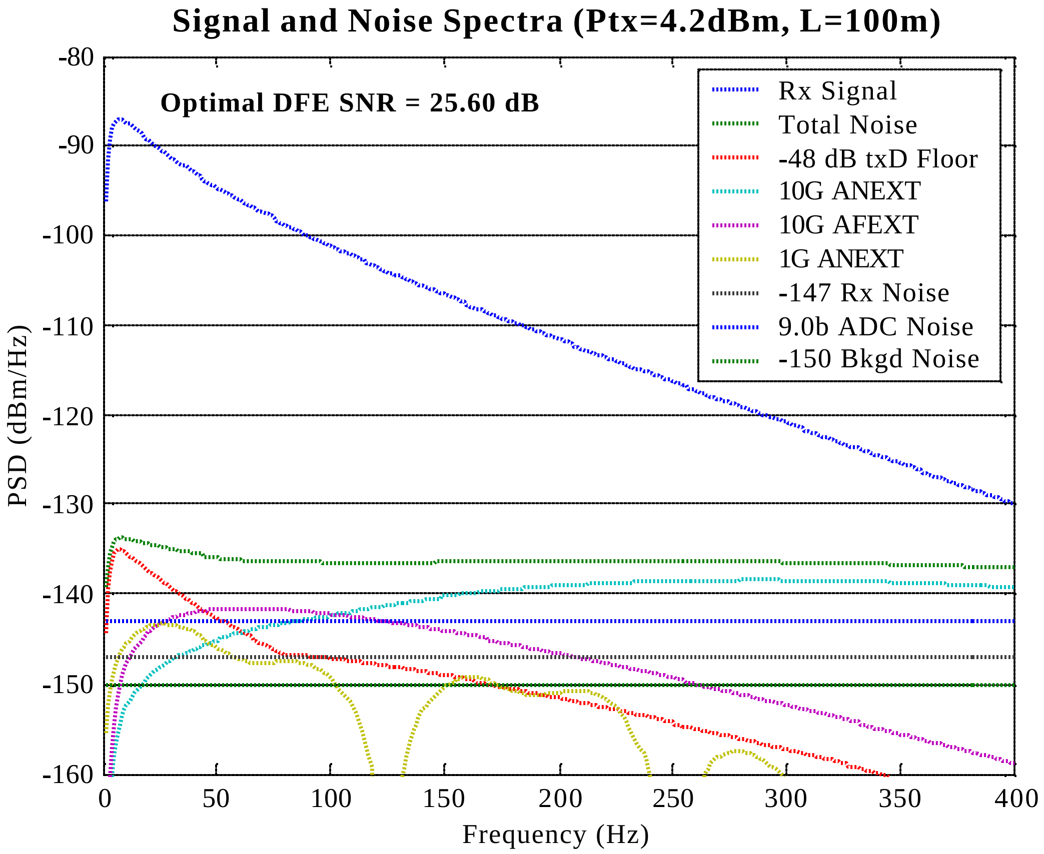
Objectives

- Base Transmitter Linearity Specification on Interoperability Requirements
  - Local receiver requirements are vendor discretionary
  - Specification must not preclude innovation in the area of distortion/noise cancellation
- Base Transmitter Linearity Specification on Judicious Allocation of Implementation Loss
  - Optimal allocation is <u>Not</u> to require a perfect transmitter

Performance Impact of TX SNDR

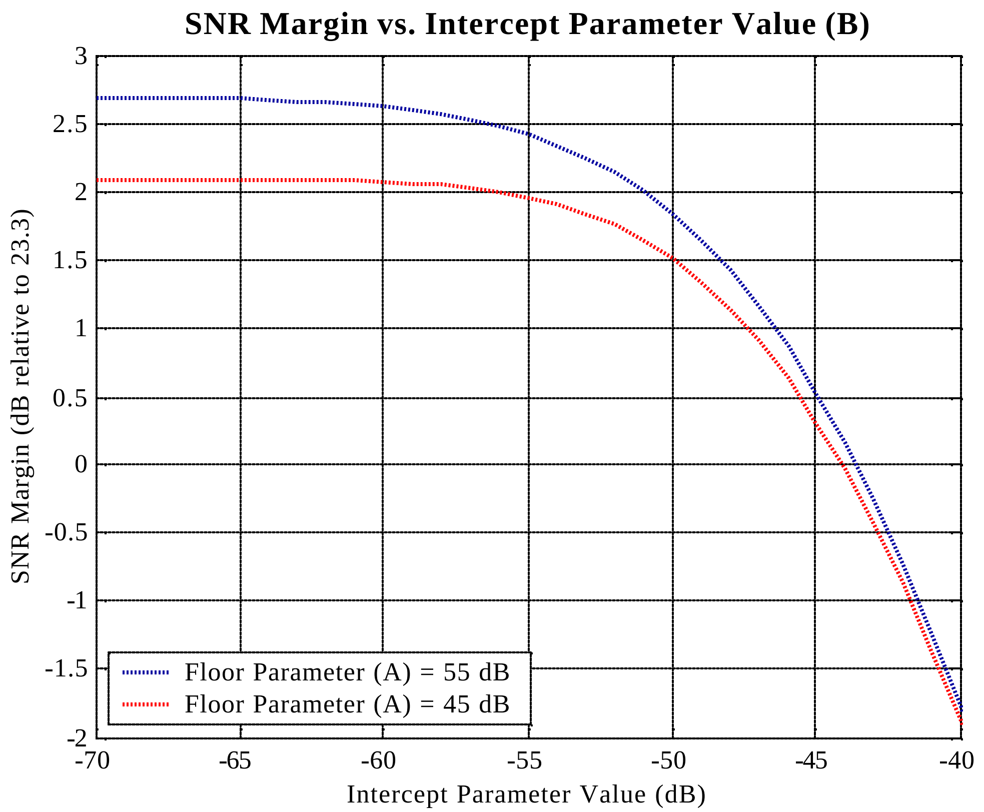
- Basis for SNDR Performance Impact is Optimal DFE (Saltz) SNR
  - Cat6e Insertion Loss Model (100 meters)
  - Class E Power Sum ANEXT Model
  - 100m Power Sum AFEXT Model at –41 dB Level
  - 1G ANEXT (coupling per Class E ANEXT model)
  - Nominal TX Power (4.2 dBm, 5 MHz-450 MHz BW)
  - -141 dBm/Hz Effective Receiver Noise
    - 9-bit ADC (ENOB)
    - -150 dBm/Hz background noise
    - -147 dBm/Hz AFE noise (white)

Typical Signal and Noise Spectra



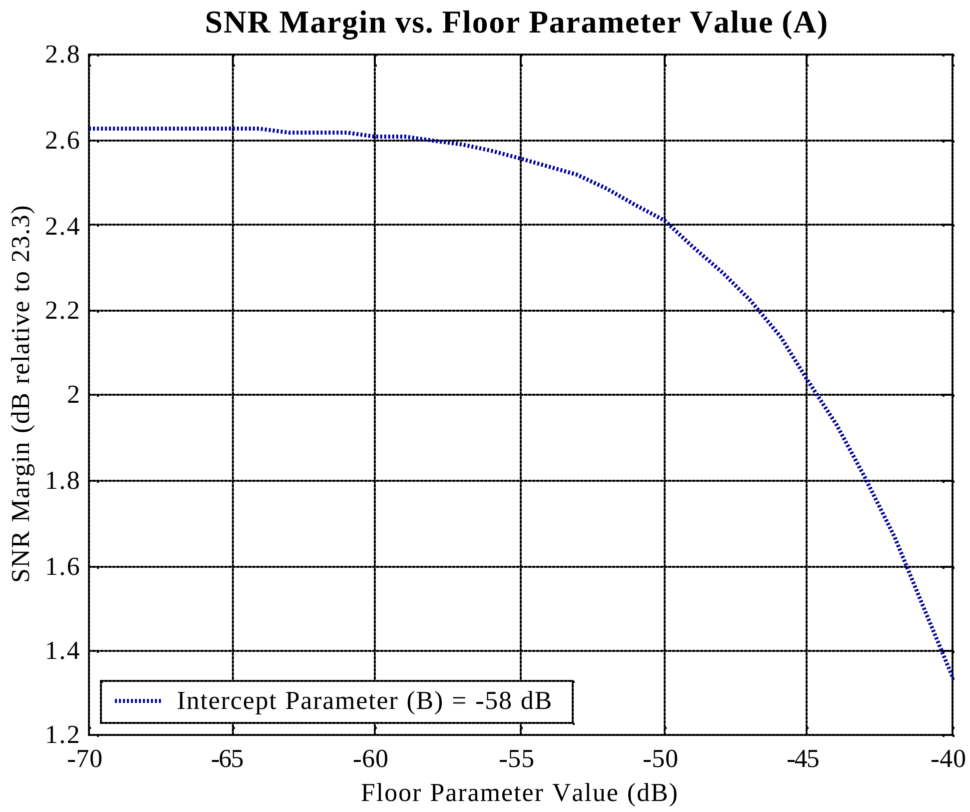
- Baseline Conditions for Optimal DFE Analysis

Sensitivity of Intercept Parameter B



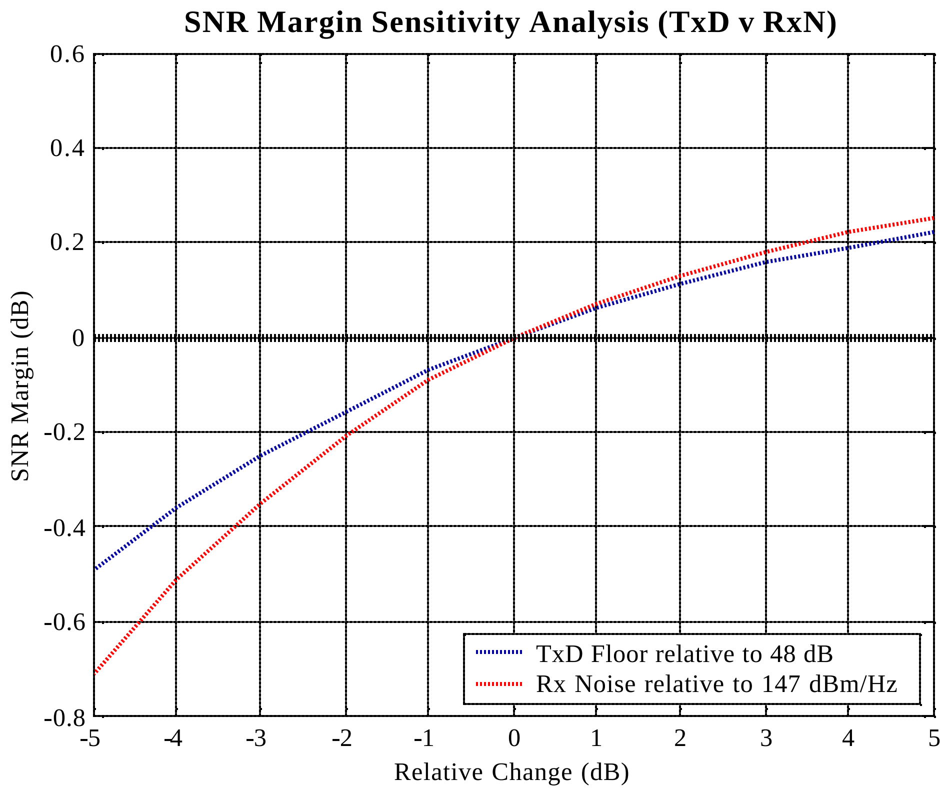
- Increasing the Intercept Parameter beyond 58 dB has negligible SNR Margin benefit (<0.12 dB)

Sensitivity of Floor Parameter A



- Increasing the Floor Parameter beyond 48 dB has only marginal SNR Margin benefit (<0.33 dB)

Sensitivity of Tx Distortion v Rx Noise



- Improving Rx Noise yields greater SNR Margin benefit than improving Tx Distortion for Floor Parameter > 48 dB

Transmitter SNDR Specification

- Base Specification on a Transmitter Linearity Requirement of

$$\mathrm{SNDR} \geq \min\left\{48, 58 - 20 \cdot \log\left(f_{\mathrm{MHz}} / 25\right)\right\}$$

- Maximum SNDR Limit of 48 dB Reached at Frequencies Below 79 MHz
  - SNDR measurements at ~41 MHz and ~79 MHz ensure that 48 dB SNDR maximum is reached
  - Measurements at lower frequencies not required

Transmitter SNDR Specification

55.5.4 Transmitter signal to noise plus distortion

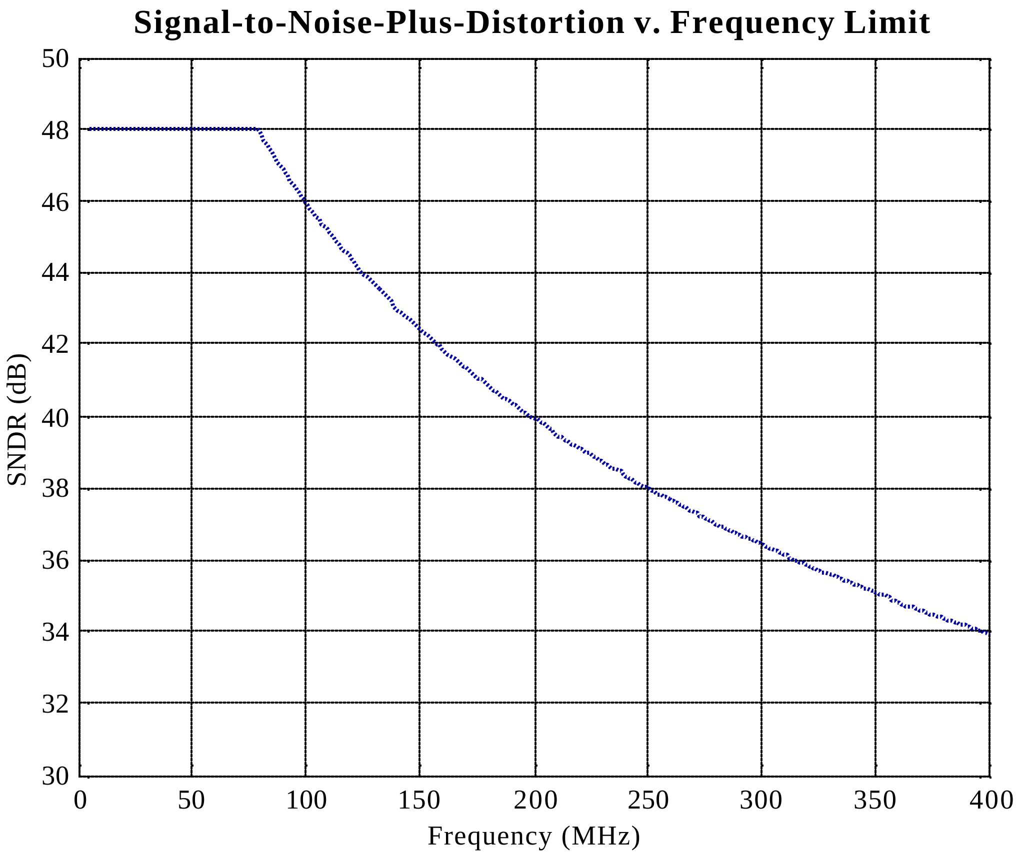
When in Test mode 4 and transmitting on a single pair into a 100Ω differential resistive load per the test configuration shown in Figure 55-22, the signal to noise plus distortion ratio of the differential signal at the MDI output shall be greater than the limit specified in Figure 55-x, which corresponds to:

$$\min\left\{48,\ 58-20\cdot\log\left(f_{\mathrm{MHz}}/25\right)\right\}\mathrm{dB},\ 5\le f_{\mathrm{MHz}}\le 400$$

Measurements of signal to noise plus distortion ratio shall be made with sinusoidal output waveforms (single-tone and two-tone).

Transmitter SNDR Specification

55.5.4 Transmitter signal to noise plus distortion (cont.)



Transmitter SNDR Specification

55.5.4 Transmitter signal to noise plus distortion (cont.)

For sinusoidal measurements, the MDI shall be configured to output single-tone and two-tone waveforms at the frequencies specified for the six test cases given in Table 55-x, such that the peak-to-peak output of the sinusoidal signal corresponds to $\pm$16 with respect to a DSQ output signal. The measured signal to noise plus distortion ratio shall be greater than the values specified in Table 55-x. For two-tone waveforms, signal power shall be defined as the total (sum) power of both tones. Signal to noise plus distortion ratio measurements shall be made across a 5 MHz to 400 MHz band, using a resolution bandwidth of less than or equal to 100 kHz.

Transmitter SNDR Specification

Table 55-x: Signal to Noise Plus Distortion Requirements

Output Waveform Frequencies	**SNDR Specification (dB)**
Single tone:	
(53/1024)*800 MHz	48
(101/1024)*800 MHz	48
(167/1024)*800 MHz	44
Two tone:	
(179/1024)*800 MHz, (181/1024)*800MHz	43
(277/1024)*800 MHz, (281/1024)*800MHz	39
(397/1024)*800 MHz, (401/1024)*800MHz	36

Conclusion

- Proposed Transmitter SNDR Specification Meets Outlined Objectives for:
  - Compatibility with Interoperability Requirements
  - Frequency Dependency, and
  - Judicious Allocation of Implementation Losses
- Proposed Transmitter SNDR Specification is Based on Overall SNDR Requirement of

$$\mathrm{SNDR} \geq \min\left\{48, 58 - 20 \cdot \log\left(f_{\mathrm{MHz}} / 25\right)\right\}$$