Teranetics

10GBASE-T Transmitter specifications proposal

Sandeep Gupta, Teranetics

IEEE P802.3an, 26-28 January 2005

General methodology for linearity measurement

- Clause 55.4 text repeated here

The SFDR of the transmitter when subject to single tone inputs producing output with peak to peak transmit amplitude shall be:

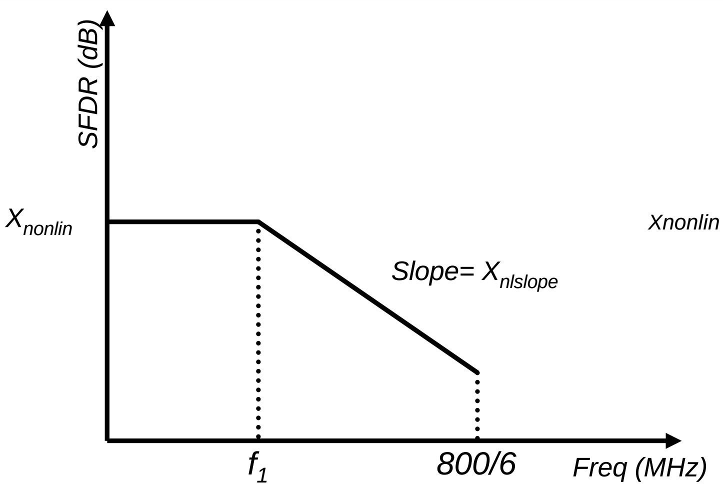
better than X_{nonlin} dB in the frequency range, f ε (0.1, f_1] MHz, f_1 is in MHz

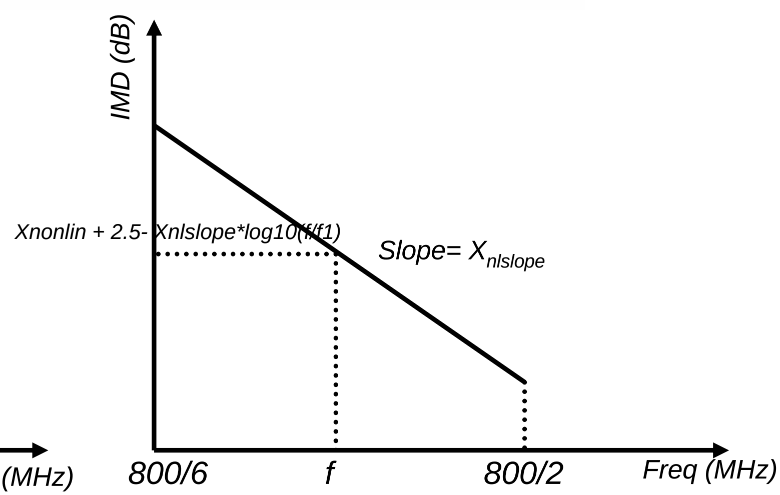
and better than [X_{nonlin}-$X_{nlslope}$*log10(f/f_1)] dB, for f ε (f_1, 800/6] MHz.

The Signal to Intermodulation distortion ratio of the transmitter, for dual tone inputs, producing output with peak to peak transmit amplitude, shall be better than:

[X_{nonlin} +2.5- $X_{nlslope}$*log10(f/f_1)] dB for f ε (800/6, 800/2]MHz

The specification on transmit linearity, is provided for the interoperability of the far end device. As a normative specification, the parameter X_{nonlin} = TBD *(Editor recommends 65)* dB, parameter f_1= TBD *(Editor recommends 25MHz)*, and parameter $X_{nlslope}$ = TBD *(Editor recommends 20dB)*. The recommended specification is X_{nonlin} = TBD dB and parameter $X_{nlslope}$ = TBD *(Editor recommends 0dB)*.





General methodology for linearity measurement

- Frequency domain measurement of linearity because of ease of measurement.
- Transmit linearity and PSD to be measured with a spectrum analyzer as shown in transmit test fixture 2, figure 55-23 in Draft D1.2.
- Clause 55.5.2, test mode 4, repeated here.

When test mode 4 is enabled, the PHY shall transmit, with the THP turned off, transmitted symbols, timed from an F_S clock in the MASTER timing mode, defined as follows:

Symbols corresponding to a single frequency tone, with frequencies of TBD.

*Editor's Note: Recommended frequencies are (800MHz/1024)*13, (800MHz/1024)*23, (800MHz/1024)*53, (800MHz/1024)*101, (800MHz/1024)*167*.

Symbols corresponding to dual frequency tones in the pairs of TBD.

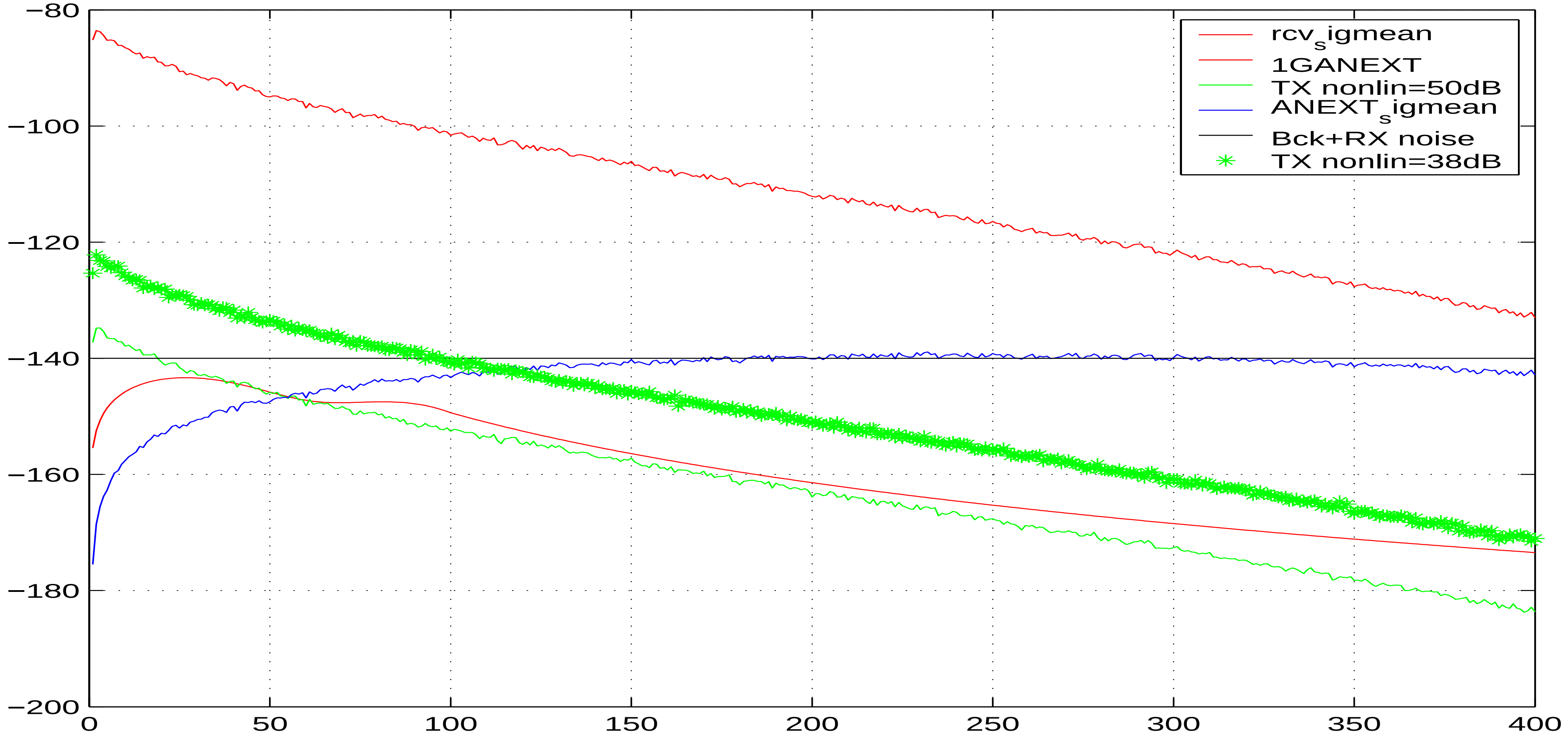
*Editor's Note: Recommended frequencies are: [(800MHz/1024)*179, (800MHz/1024)*181], [(800MHz/1024)*277, (800MHz/1024)*281], [(800MHz/1024)*397, (800MHz/1024)*401], [(800MHz/1024)*499, (800MHz/1024)*503].*

The peak to peak symbols used in this test, for both single and dual frequency tones correspond to ± 16.

"Recommended", "Normative" specification

- Local or own transmitter's nonlinearity can limit the capacity on own receiver, in absence of nonlinear echo cancellation
- "**Recommended**" spec (**compliance not required**) essentially a spec on nonlinearity of local transmitter.
- **"Normative" spec (compliance required)**: This should ensure that the nonlinearity of a ***far end*** transmitter does not cause the receiver to lose "much SNR margin".
  - **Therefore in doing so, an *assumption* needed for the receiver recovering this far end transmitter data.**
  - ***Assumption*:**
    - Receiver with all noise sources added up-to -140dBm/Hz. This is a loose assumption (though commonly used) representative of the sum total of
      - » Background noise
      - » Receiver's fixed noise
      - » Local transmitter's noise and residual nonlinear echo
      - » Noise due to ADC and transmitter jitter.
    - Channel 1 model impairments, ANEXT, IL and ANEXT of 1GBASE-T
    - No implementation loss assumed.

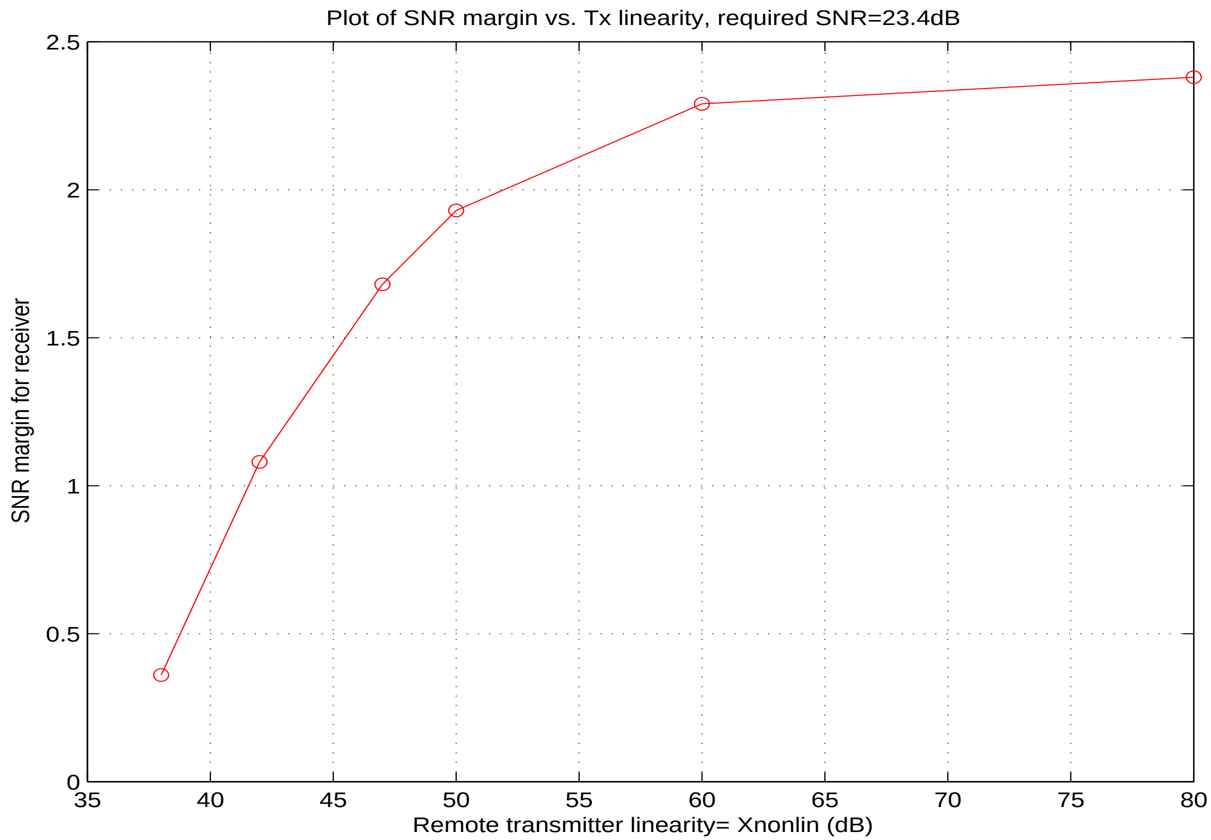
System impairments example plot



- *Two green lines represent the far end TX nonlinearity, varying from 38dB to 50dB, and the severe impact on SNR of the receiver at 38dB linearity.*
- *The lower the linearity, the more, that is, further out in frequency it impacts SNR.*
- *If linearity >50dB, it does not impact SNR beyond 50MHz, if >60dB, no impact >25MHz*

How to choose Normative spec.

Teranetics

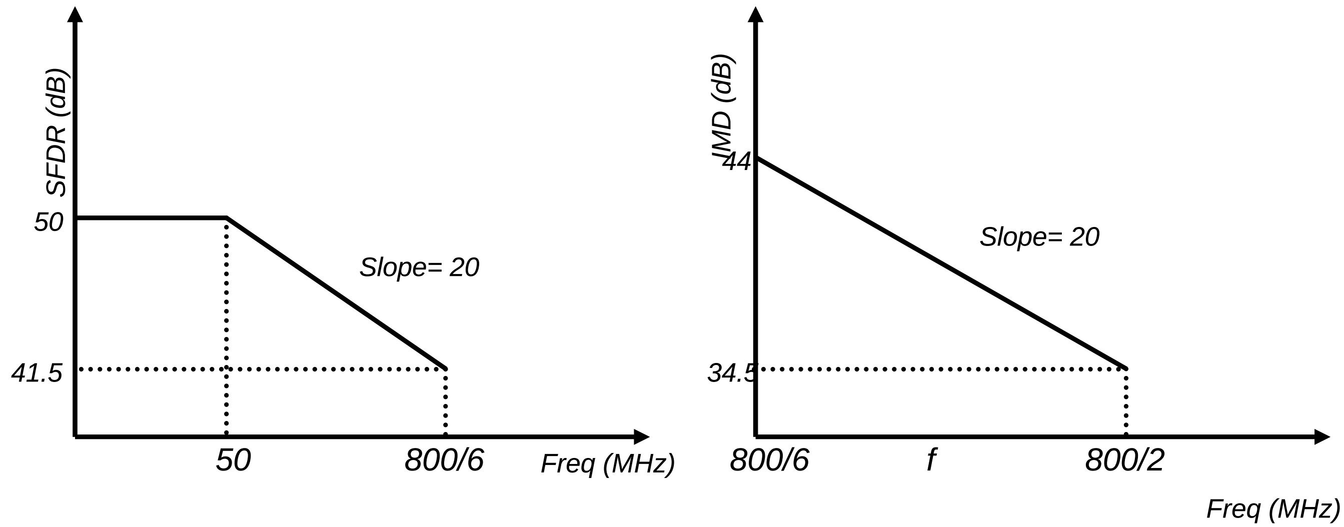


- For 38dB linearity, we lose 2dB SNR margin JUST due to this impairment.
- ANY other assumptions set, for real receiver losses, same 2dB loss at 38dB
- **For 0.5dB SNR loss, the linearity of far end transmitter X_{nonlin}> 50dB.**
- **The linearity could scale down after f1=50MHz, at a rate of 20dB/dec**

Normative, recommended spec proposal

Teranetics

- **NORMATIVE SPEC PROPOSAL (compliance required)**: X_{nonlin}=50dB, $X_{nlslope}$=20dB, f_1=50MHz, for equations represented as general in clause 55.4, and repeated in slide 9



- For the "recommended" spec: Similarly, the SNR margin loss due to local transmitter linearity
  - **68dB causes 0.5dB SNR margin loss**
  - **65dB causes ~1dB SNR margin loss.**
- **RECOMMENDED SPEC PROPOSAL (Compliance not required, just recommended)**: Keep the "recommended" spec X_{nonlin}=65dB, as this is much harder to meet, especially since here $X_{nlslope}$=0, f1=don't care(=400MHz)

Proposal for transmitter linearity

Teranetics

- Adopt the measurement test fixture 2.
- Adopt the methodology, the exact frequencies suggested in 55.5.2, test mode 4.
- Adopt the formulas for SFDR and IMD tests copied from section 55.4.
- Adopt the spec of X_{nonlin}=65dB, $X_{nlslope}$=0 for the “recommended” spec of the transmitter.
- Adopt the spec of X_{nonlin}=50dB, $X_{nlslope}$=20dB, f_1=50MHz for the “normative” spec of the transmitter.

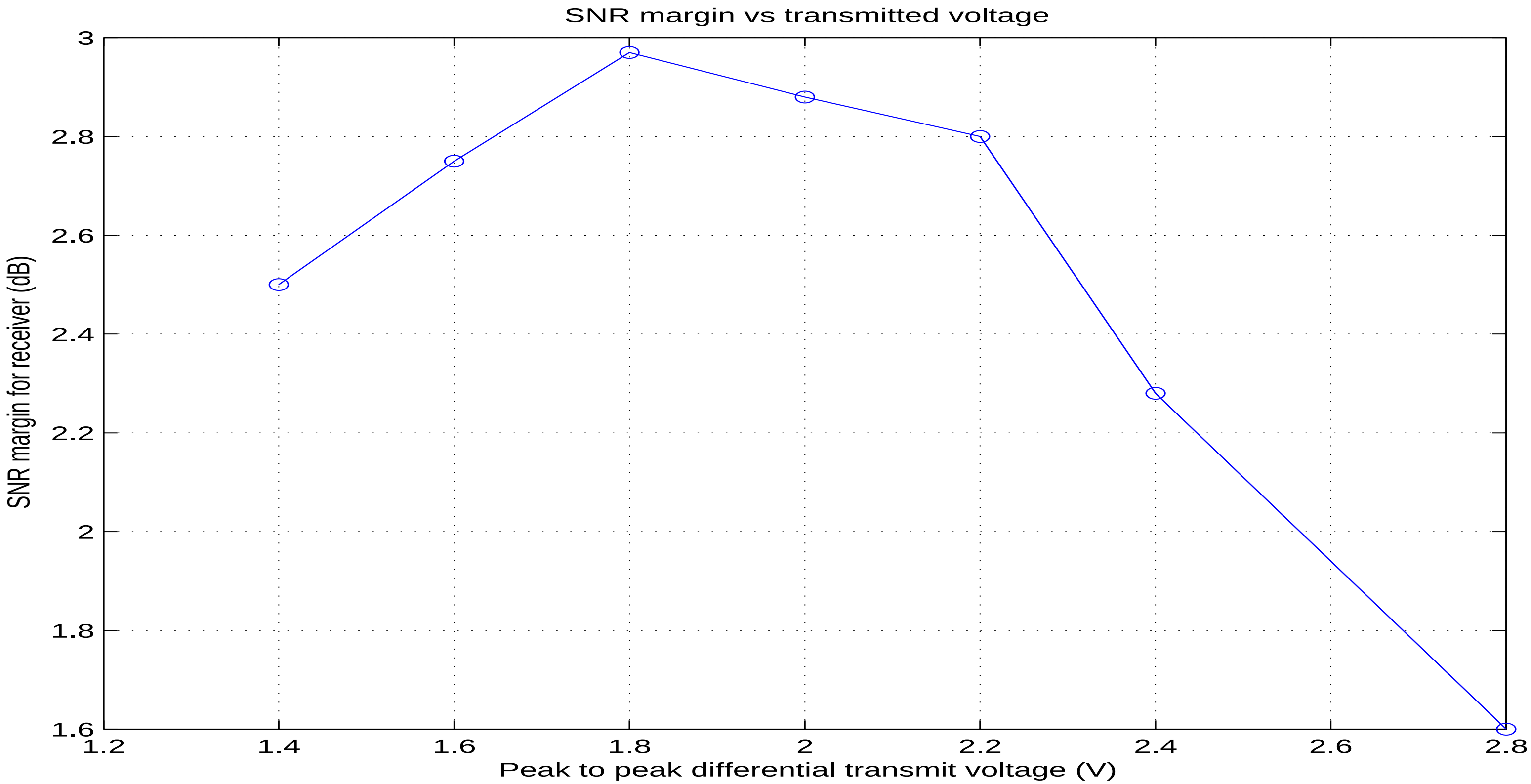
Impact on receiver capacity by TX voltage, power

Teranetics

- Among main impairments limiting capacity/SNR on receiver
  - **1. What scales with voltage/power is**
    - A) ANEXT of 10GBASE-T
    - B) local and far end transmitter's and receiver's jitter noise and TX device noise
    - These **DO NOT** contribute to appreciable SNR loss/gain w.r.t. TX voltage/power.
  - **2. What remains constant with voltage/power is**
    - A) Background noise + a portion of total receiver noise, excluding the portion 1(B)= (~ -145dBm/Hz, for this exercise)
    - B) 1GBASE-T ANEXT.
    - These two contribute **MINOR SNR** gain at higher TX voltage/power
  - **3. What scales inversely and that too inversely as square, cubed, even quad…**
    - Local and far end transmitter nonlinearity.
    - For a given implementation, consider $(x+ \alpha_2 x^2 + \alpha_3 x^3)$ nonlinearity
      - ≈ α_2 and α_3 remain fixed, which is a fair assumption for ANY given implementation.
      - » Raising voltage by x dB, Signal/Nonlinearity ratio can degrade by 2x dB.
    - These contribute to SIGNIFICANT SNR loss at higher TX voltage/power for ANY fixed implementation complexity.

SNR margin to 10G net rate vs. TX voltage

Teranetics



- *Based on this, optimal to choose ~ 2V center voltage as explained before in my presentations, **certainly NOT 2.25V or 2.5V.***
  - *Other reasons are "possible to design" implementation, power and area, ESD.*
- *Based on filtering pole variations, there can be easily 1dB variation in transmitter power level, so restrict the voltage range to be 2V+/-5%. **PROPOSAL = 2V+/-5% at low freq**.*
- *This is compatible with TX power levels of **3.2-5.2dBm, (2dB range) , with 4.2dBm center**.*

Measurement of transmitter voltage

- Measure this for a periodic sequence of {10 +16, 10 -16} symbols, as the voltage measured at least 10ns (8 symbol periods) after a zero crossing of the waveform.
  - **Note: This peak to peak specification therefore is not the “absolute” peak to peak but rather a measure of the settled intended voltage.**
- Transmitter test fixture 1 as proposed in PMA electrical draft 1.2 to be used for measuring this

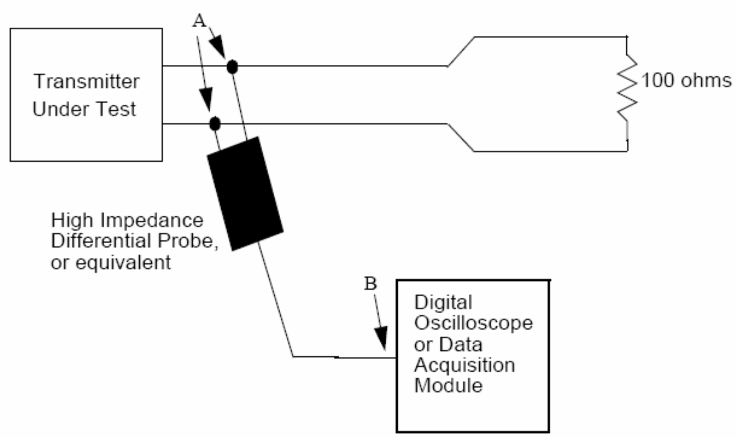


Figure 55–22—Transmitter test fixture 1 for peak to peak voltage measurement and Transmitter droop measurement

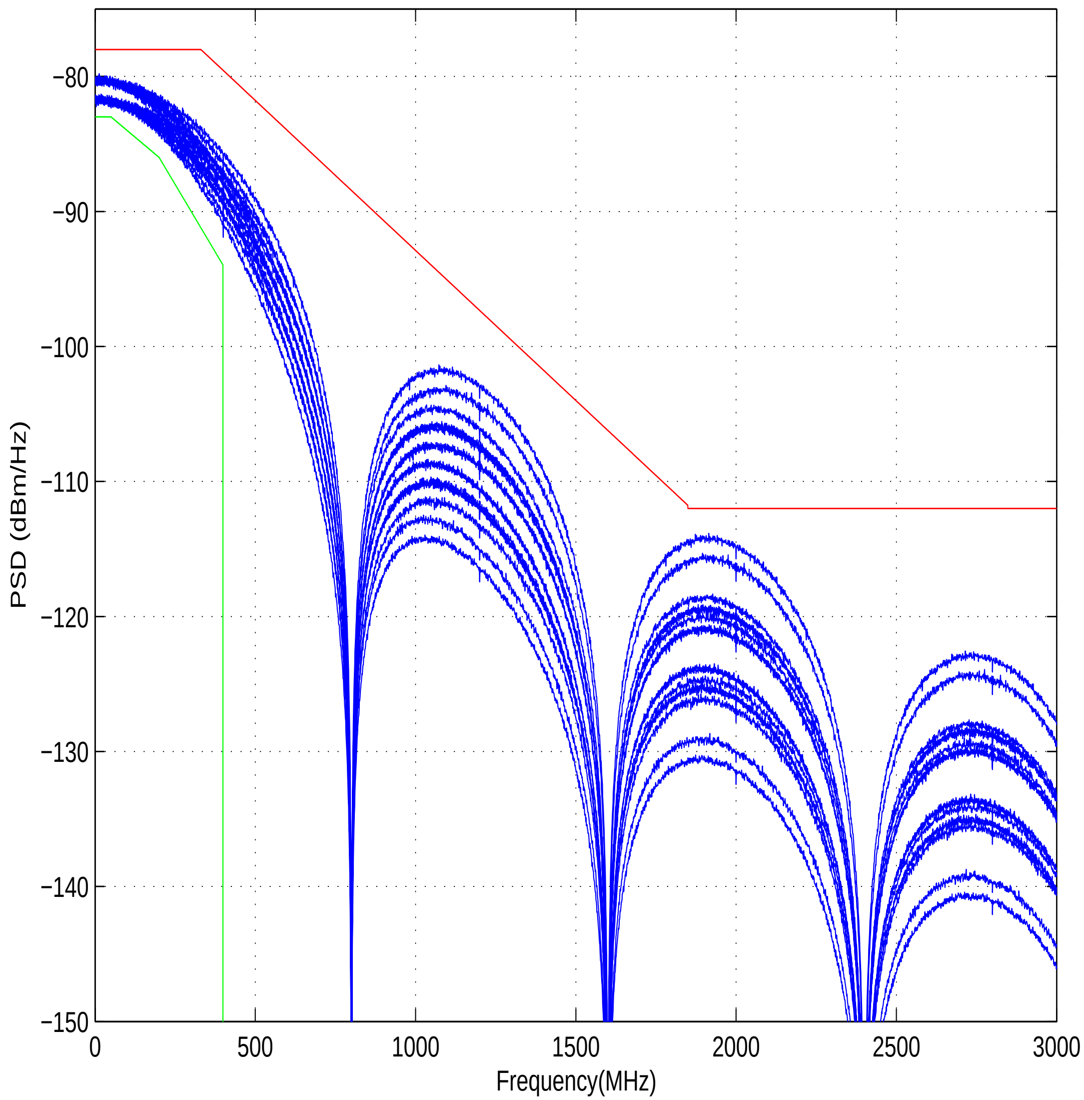
Transmit PSD mask

Teranetics

- Complete PSD mask requires maximum and minimum definition.
- Designed to be compatible with >1dB margin on either side for 1.9-2.2V.
- To specify the PSD maximum and minimum, substantial tolerance of the poles assumed
  - **Transformer 1st pole at ~100kHz**
  - **Transformer pole f1 with substantial tolerance of 750MHz +/-33%**
  - **Transmitter pole f2 with substantial tolerance for different implementations 750MHz +/- 33%**
  - **Transmitter and board "parasitic" pole f3 with substantial tolerance for different implementations, 1200MHz +/- 33%.**
  - **Sinc roll-off, contributing majority of the band limitation.**

PSD mask proposal

Teranetics



- *PSD mask defined as two boundaries, PSDmax and PSDmin*
- *Upper mask already decided.*
- ***The upper mask proposed to be modified only slightly, with a slope of "45" between 330-1850MHz instead of 40, as it can be too restrictive at ~2GHz frequency with even 3-4 pole with tolerances, for as low as 2.2V.***
- *PSDmax(f) = -78 dBm/Hz, f<330MHz*

  -78-(f-330)/45 dBm/Hz, f ε [330,1850) MHz

  -112 dBm/Hz, f >= 1850MHz
- *PSDmin(f) = -83 dBm/Hz, f<50MHz*

  -83 – (f-50)/50 dBm/Hz, f ε [50,200) MHz

  -86 – (f-200)/25 dBm/Hz, f ε [200,400) MHz

  - infinity, f >= 400MHz.
- *PSD mask maximum range at low frequencies = 5dB*

Proposal for TX voltage, power, PSD

Teranetics

- Neither transmit power nor transmit voltage ALONE, coupled with such a huge PSD mask range are sufficient to uniquely specify the transmit filtering.
- Proposals:
  - **1. Narrow down the already agreed time domain voltage spec, "settled" voltage range to be 2V+/-5% as in slide 10.**
  - **2. Choose the settled transmit peak to peak differential voltage, to be measured for {10 +16, 10 -16} symbols as in slide 11.**
  - **3. Choose the PSD mask as in slide 13.**
  - **4. Based on the same huge range of filtering tolerance as assumed in the PSD plots, specify, if considered necessary, the transmit power to be between 3.2 - 5.2dBm (2dB range)**