Teranetics

10GBASE-T Transmitter Key Specifications

Sandeep Gupta, Jose Tellado

Teranetics, Santa Clara, CA

sgupta@teranetics.com

1000BASE-T Transmitter spec. overview

Teranetics

- Differential voltage at MDI output ~ 2V peak to peak as defined by Transmitter test mode 4
  - **Fig. 40-21, IEEE Std 802.3-2002, Section Three**

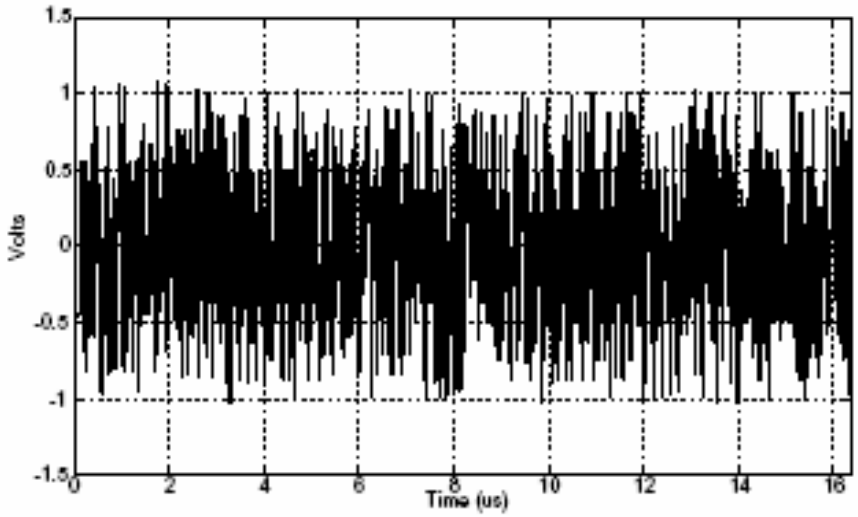


Figure 40–21—Example of Transmitter Test Mode 4 waveform (1 cycle)

- Transmitter distortion specified at the MDI output with
  - **PHY transmitting sequence of symbols generated by the scrambler generator, in presence of a sine wave disturber of 5.4V Peak to Peak differential through a series 100 ohm resistor.**

10GBASE-T transmitter

Teranetics

- Nonlinearity of transmitter has a transfer function of 1 (without a magnetic hybrid)
- Transmit linearity has to be high
  - **Echo canceller cannot cancel the nonlinear component**
  - **Tough specification to meet in 10GBASE-T system.**
- Transmit linearity required is highest at maximum cable length
  - **In this situation, the far end transmitter signal is significantly attenuated**
- Transmit linearity requirement relatively independent of the frequency.

Transmit power vs. voltage

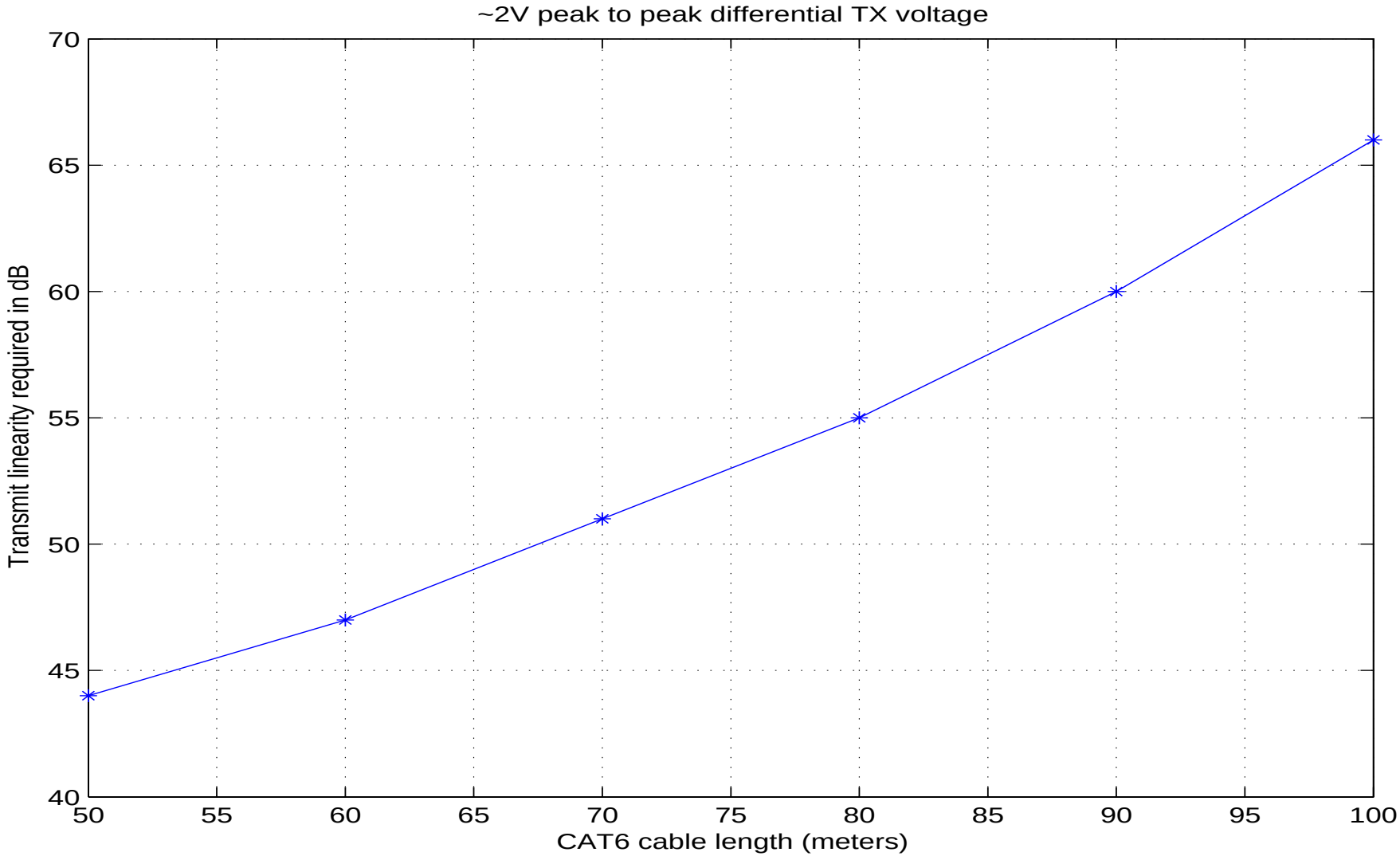
Teranetics

- Spec. for the transmitter in terms of peak-to-peak output voltage
  - **Output power level depends on the assumptions for filter and modulation scheme.**
- Assumptions:
  - **PAM8-PAM12 modulation scheme**
    - For a given differential output, output power level from PAM8 to PAM12 changes by < -0.5dB.
  - **Continuous time filter at the output of the DAC with -3dB frequency around fs/2 (similar assumption to Gigabit)**
- 2V peak to peak differential output (similar to gigabit) corresponds to 4.5-5dBm power level, ~ 4V peak-to-peak differential (twice as Gigabit) corresponds to 10.5-11dBm power level
  - **Digital filter similar to Gigabit ($0.75+0.25z^{-1}$) reduces output power level for a given voltage by another ~2dB.**

Transmit linearity to meet 10G net rate

Teranetics

- Fixed Receiver input referred noise



Transmit linearity measurement

Teranetics

- Transmit linearity specified in 1000BASE-T in the presence of a disturber.
  - **Specification requires peak distortion to be less than 10mV (post processing the output to remove disturber)**
  - **Disturber magnitude at transmitter output ~ 5.4V/2 =2.7V peak to peak differential sine wave at fs/6**
    - chosen to mimic far end transmit signal peak amplitude in presence of baseline wander assuming a short cable
  - **Disturber causes ~8dB increase in the output amplitude.**
    - Makes the third order circuit nonlinearity ~16dB larger.
- Overkill specification for 10GBASE-T because cable loss is high
  - **At longer cable lengths, nonlinearity dominated by the local transmitter peak voltage, disturber magnitude being small (~< 0.5V peak to peak differential) compared to 1000BASE-T.**
  - **At short cable lengths, system margin can tolerate higher non-linearity.**
- Linearity specification to be defined in presence of a small disturber (0.5v peak to peak differential, sine wave ~fs/8 frequency), in terms of the peak distortion based on a transmitted sequence of symbols.

Tradeoffs on transmit voltage

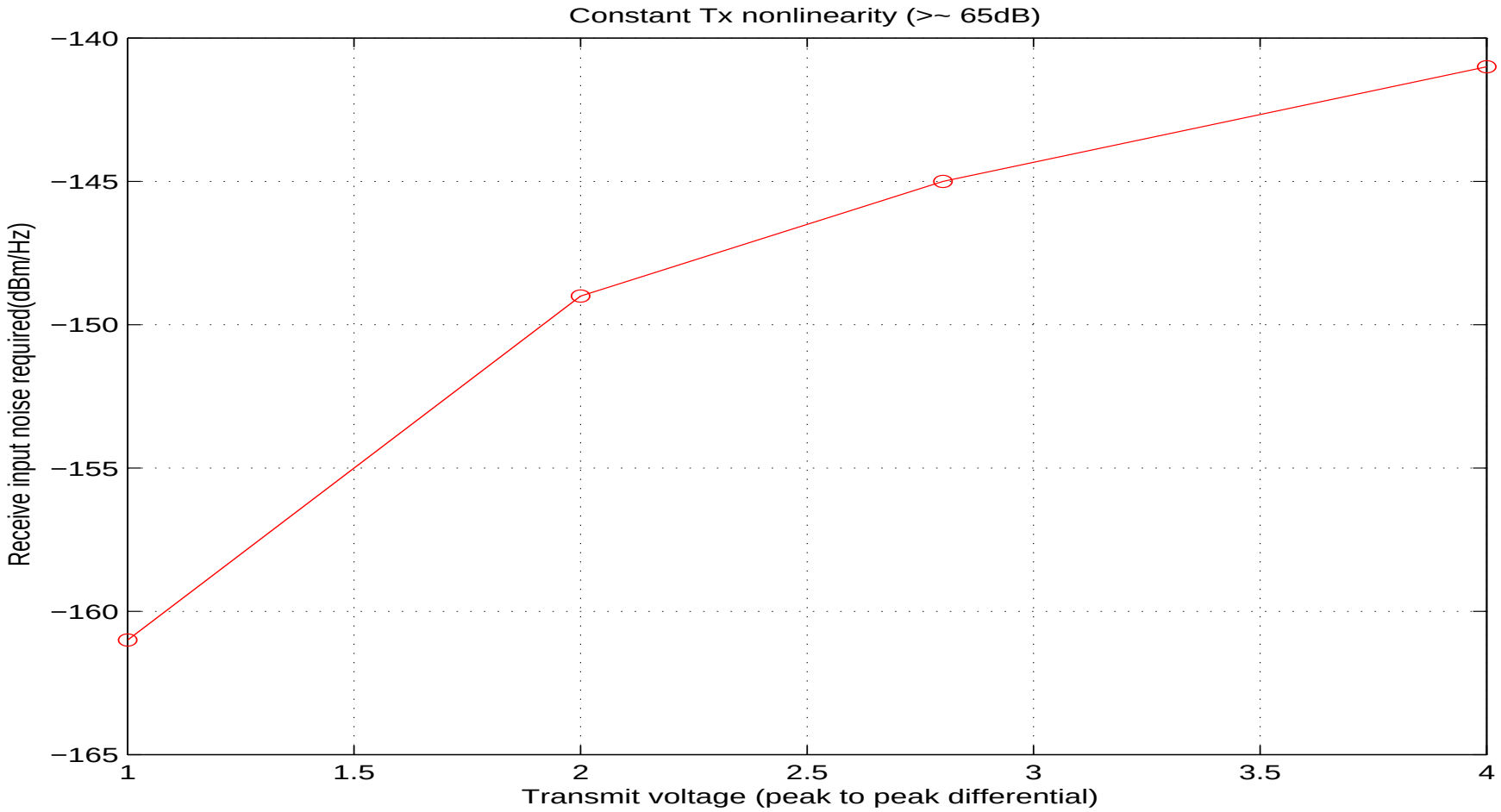
Teranetics

- At the same spec as Gigabit Ethernet, i.e. 2V peak-to-peak differential output voltage at MDI port
  - **Transmit linearity spec. ~ 65dB for channel models #1 and #3**
  - **In 1000BASE-T, the peak distortion spec would translate to ~48dB transmit linearity.**
- Including baseline wander, and full duplex operation, worst case voltage at MDI port for 2V peak to peak differential output ~ 4.8V peak to peak differential.
- For 4V peak to peak differential output, the swing is 9.6V peak-peak differential !
- Given state of the art CMOS processes (90nm, 1v/2.5v, 0.13um, 1.2/2.5V, 0.18um, 1.8/3.3V), difficult to achieve this for any reasonable power

Tradeoffs on transmit voltage

Teranetics

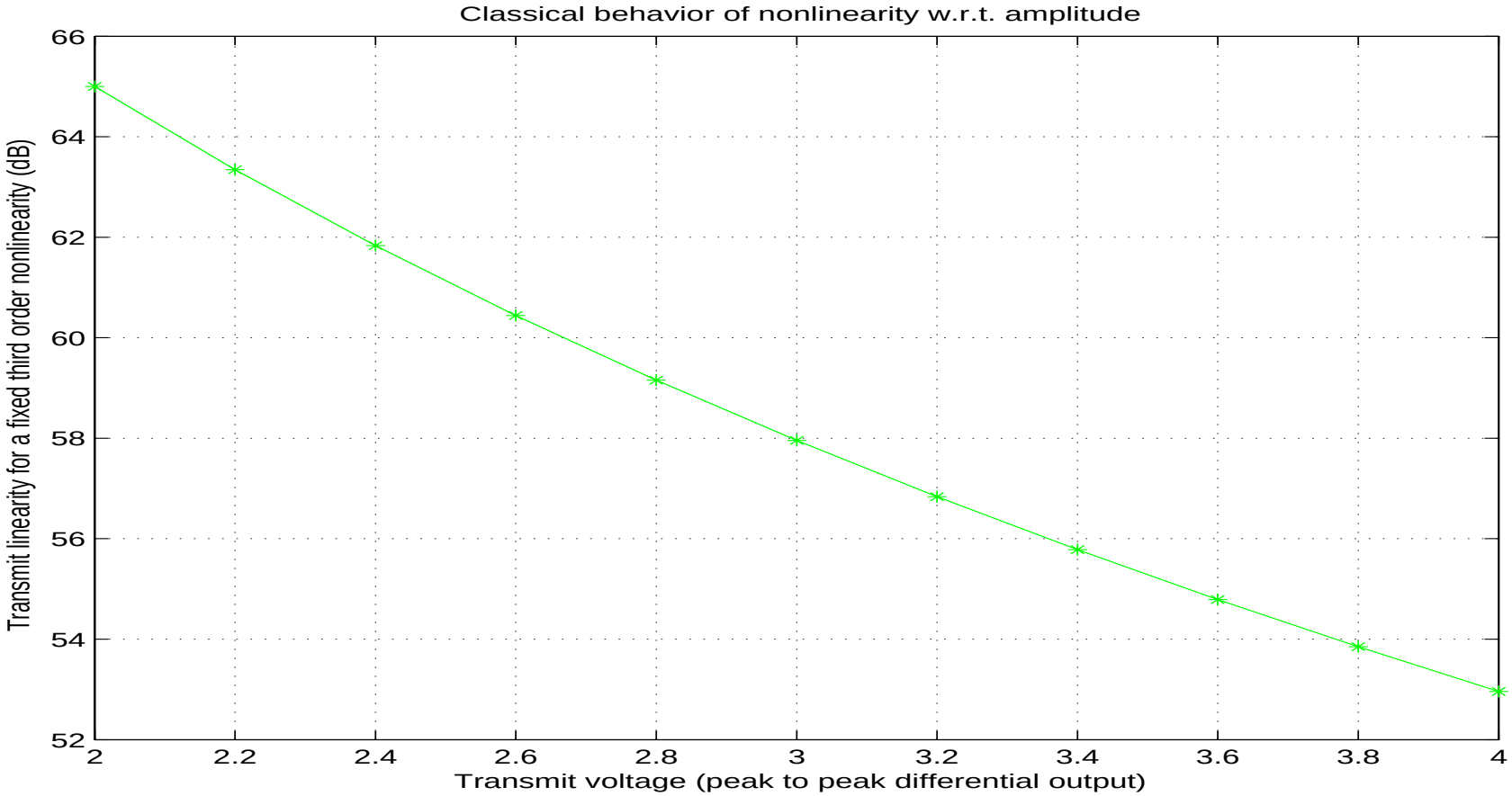
- As the transmit output voltage is raised by x dB, the input referred noise of the receiver circuits reduces x dB
  - **At low enough transmit output voltage, input referred noise has to go down significantly because large reductions cause very little advantage when other noise sources (background, ANEXT) limit SNR.**



Tradeoffs on transmit voltage

Teranetics

- Transmit linearity specification ***does not change*** as we raise the transmitted power or voltage.
  - **Differential circuits, nonlinearity dominated by HD3, HD3 2x dB worse for x dB higher transmit amplitude.**
  - **With 4V peak-to peak differential, HD3 of the transmitter for the same circuit gets worse by 12dB (higher order harmonics like HD4, HD5, worse by ~ 18-24 dB as compared to 2V peak to peak differential)**



MDI Return loss

Teranetics

- MDI return loss
  - **Reflection due to differential signals incident upon the MDI from the cable**
  - **Different specification than the link segment return loss**
- Specified in 1000BASE-T, with respect to a balanced cabling with an impedance of 100ohms +/-15%, as
  - **-16dB over the frequency range of 1MHz to 40MHz**
  - **- [10-20log10(f/80)] over the frequency range of 40MHz to 100MHz (f in MHz)**
- Initial Proposal for MDI return loss for 10GBASE-T
  - **Based on**
    - The advancement in CMOS technology.
    - Available Wideband 10G transformer data.
    - Backward compliance with Gigabit Ethernet.
  - **Reflections with respect to a balanced cabling with an impedance of 100ohms +/- 15% should be attenuated by**
    - 16dB over the frequency range of 1MHz to 40MHz
    - At least 16-10log10(f/40) over the frequency range of 40MHz to 625MHz (To be better than 1000BASE-T by around 4dB at 100MHz)

Summary

Teranetics

- Transmit linearity of ~65dB needed for operating over specified channel models
- Transmit linearity measured in presence of small disturber (~0.5V peak to peak differential)
- Transmit peak to peak differential voltage ~ 2V
  - **higher than 2V peak to peak, circuit nonlinearities and state of the art CMOS processes limit reasonable power implementation.**
  - **lower than 2V peak to peak, input referred noise required on the receiver stringent, limiting reasonable power implementation.**
- Initial proposal for MDI return loss, -16dB from 0-40MHz, -[16-10log10(f/40)] from 40MHz to 625MHz