Results of a Practical Measurement System for the TP3 Comprehensive Stressed Receiver Sensitivity and Overload Test

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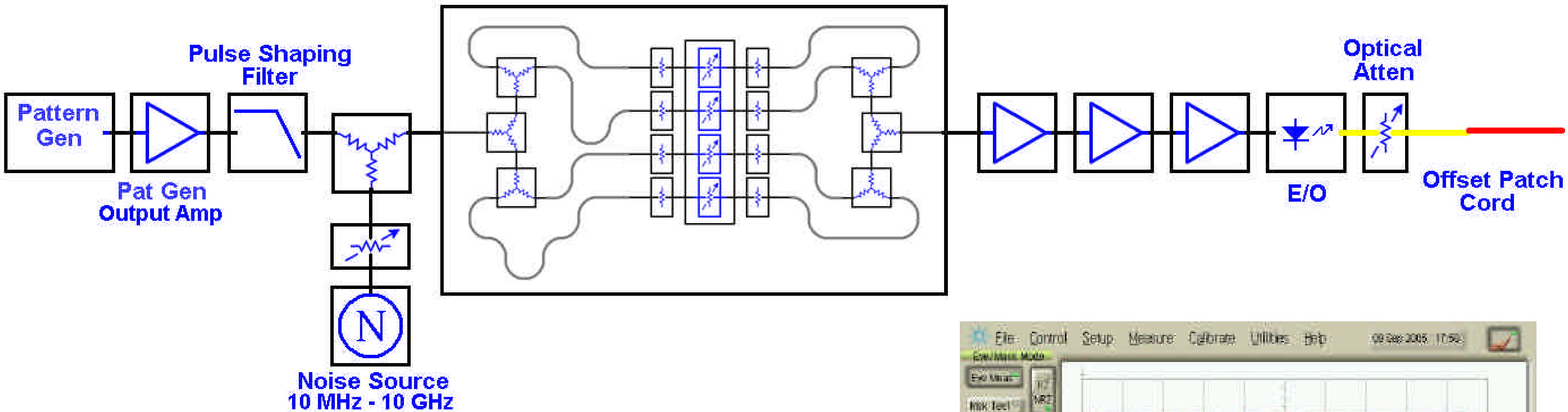
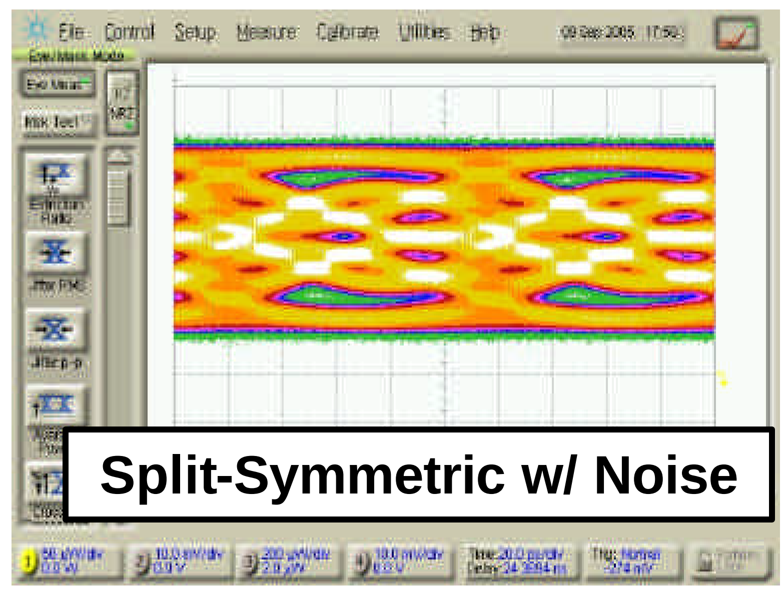
Introduction

- IEEE 802.3aq D2.2 68.6.9 Comprehensive Stressed Receiver Sensitivity and Overload Test specifies an optical signal for testing receivers
  - Signal has specified pulse shape, noise, and OMA characteristics
  - Comments 66 and 87 on D2.2 have raised questions about the practical feasibility of accurately generating the required test signal
- Finisar previously reported on a TP3 tester which was under development http://www.ieee802.org/3/aq/public/mar05/mcvey_1_0305.pdf
  - Electrical only; No E/O in place
  - Suffered from many unwanted reflections due to limitations of the components
- TP 3 tester has been improved
  - Produces an optical output
  - Unwanted reflections sufficiently under control
  - Accuracy and Repeatability investigated and appear very good

TP3 Tester Block Diagram





Accuracy and Repeatability Issues

- Time Domain
  - Tap spacing
  - Pulse Shape
- Frequency Response
  - Signal (includes pattern generator spectrum)
  - Noise (includes noise source spectrum)
- PIE-D as measured by TWDP
- Noise
  - Signal-to-Noise Ratio
  - Peak-to-average Ratio (Crest Factor)
- OMA & ER

Tap Spacing Accuracy

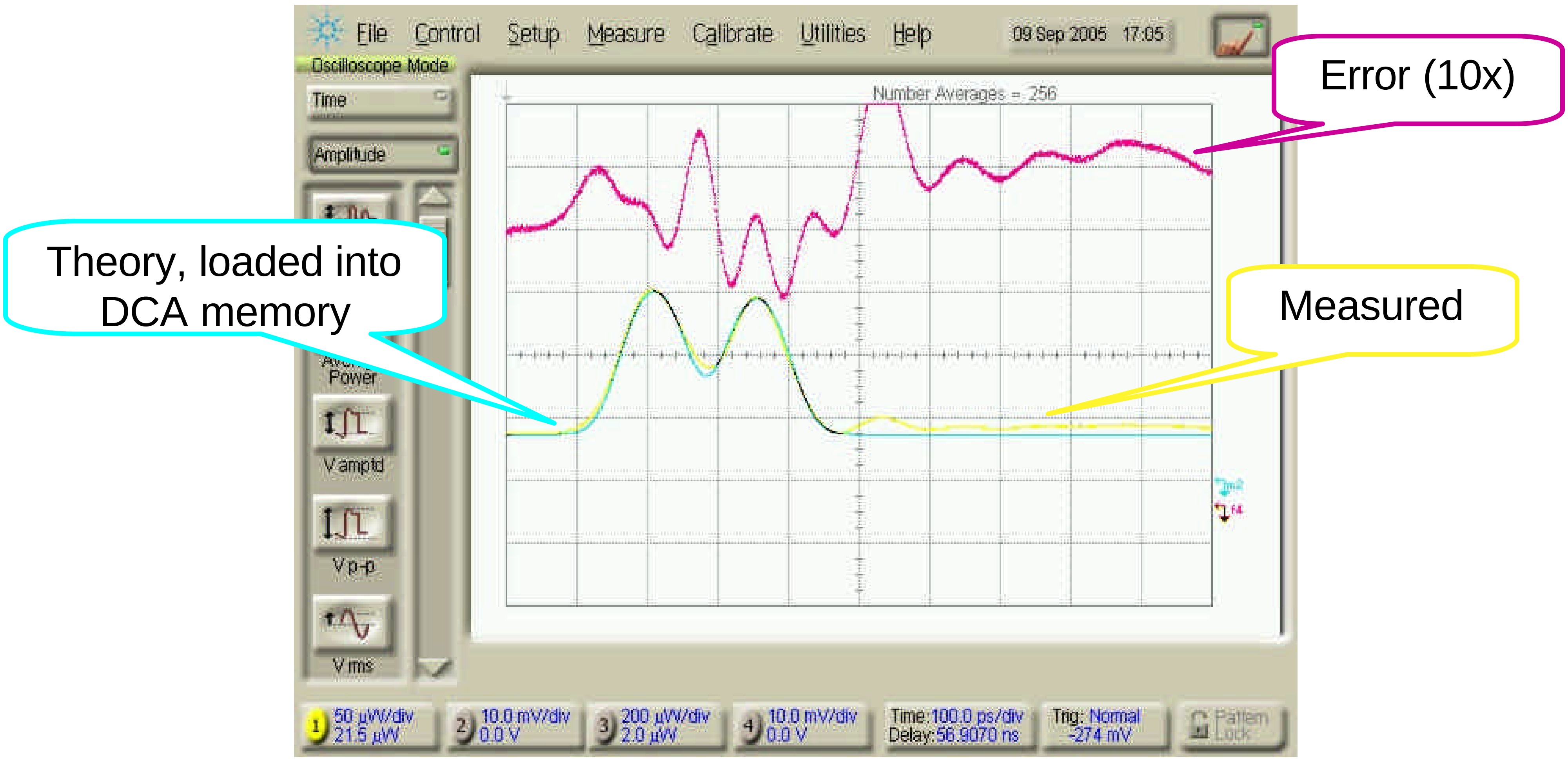
Tap	1	2	3	4	
Delay (from tap 1)	0	0.75	1.50	2.25	UI
Measured Delay	0	0.721	1.534	2.259	UI
Error	0	-0.029	0.034	0.009	UI
Error	0	-2.81	3.30	0.87	ps

- Measured two ways:
  - Time domain; define pulse center of 50% points on rise and fall
  - Frequency domain; Set two equal power taps and observe notch frequency
- Good agreement. Results above are from frequency method

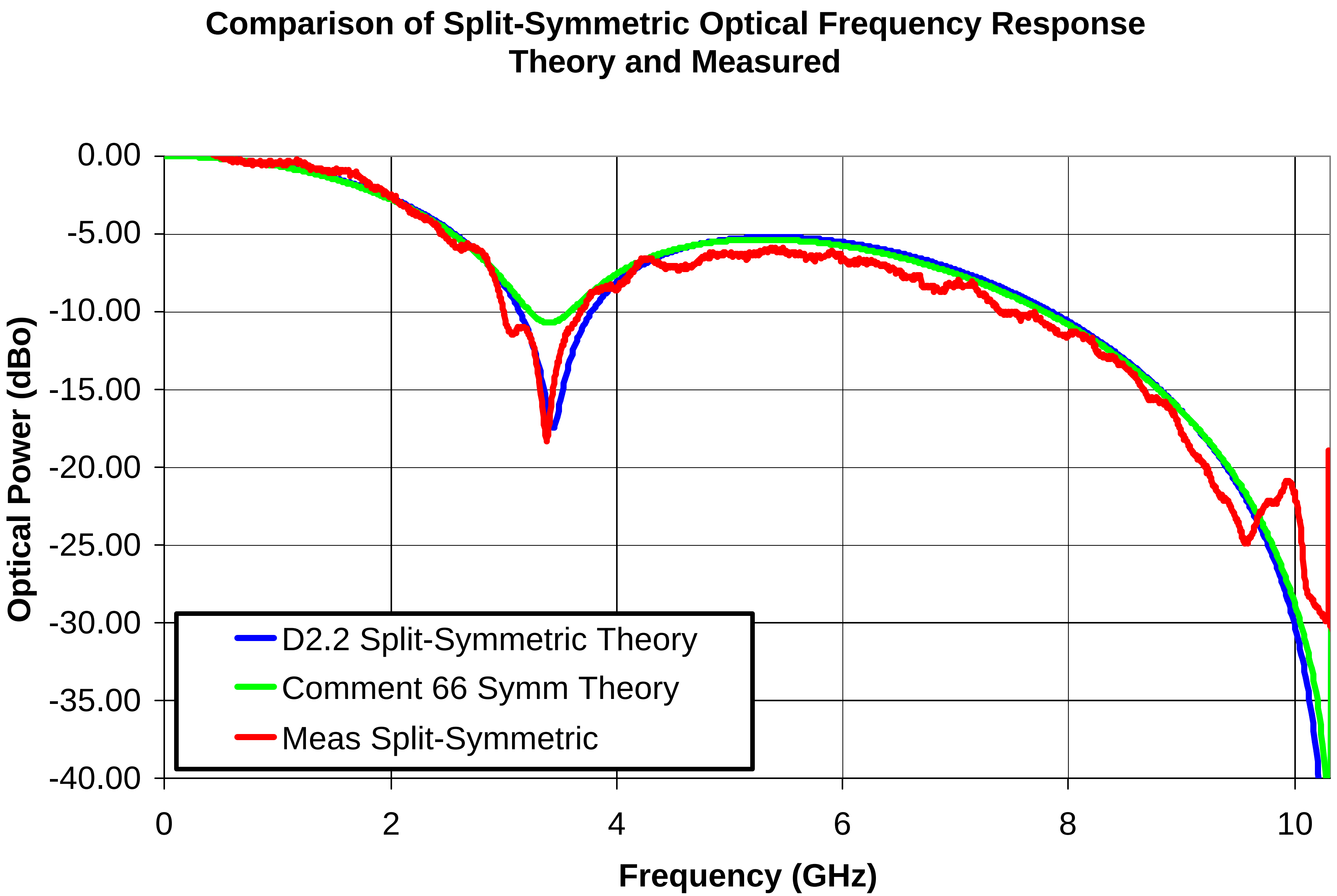
Pulse Shape Split-Symmetric per 802.3aq D2.2

Target PIE-D = 3.83 dBo, Actual PIE-D = 3.70 dBo

7.5 GHz 4th BT RX filter

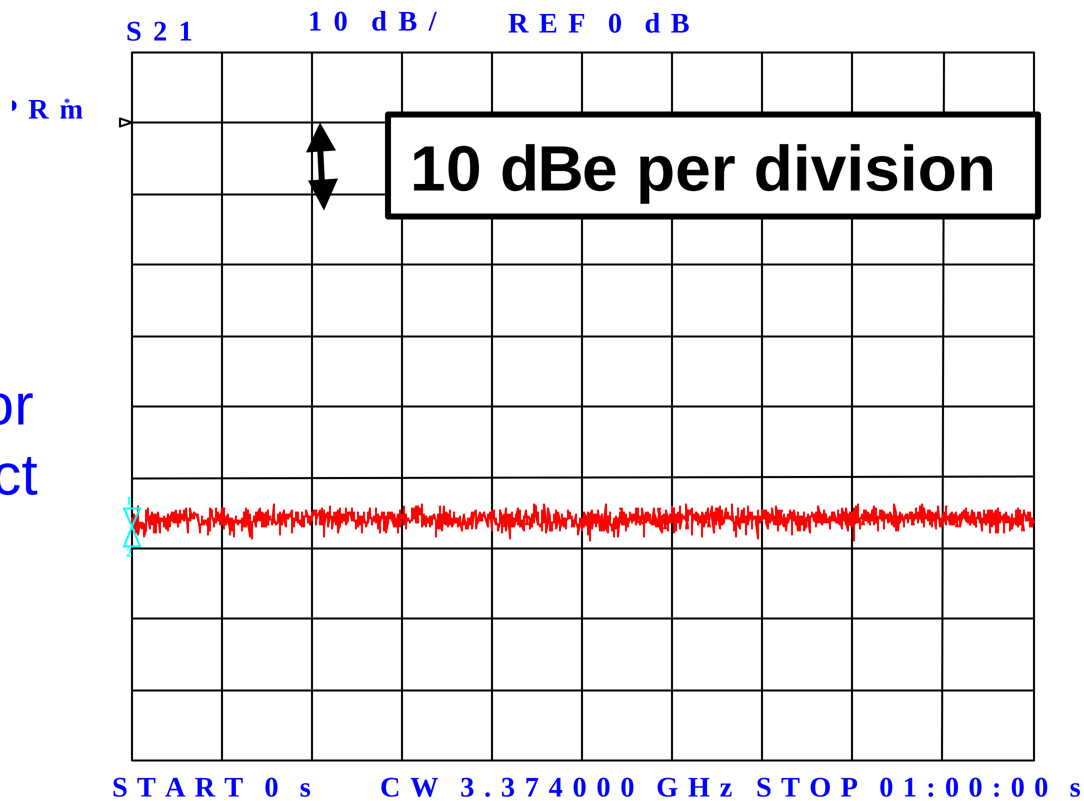


Signal Spectrums



Signal Stability

- Bottom of Split-Symmetric notch measure in CW mode on network analyzer
  - Electrical measurement
  - Swept over a one hour period
  - Measurement un-calibrated for absolute amplitude, but correct for change in signal level
  - Notch depth is very stable indicating very little drift in amplitude or phase of the ISI generator taps

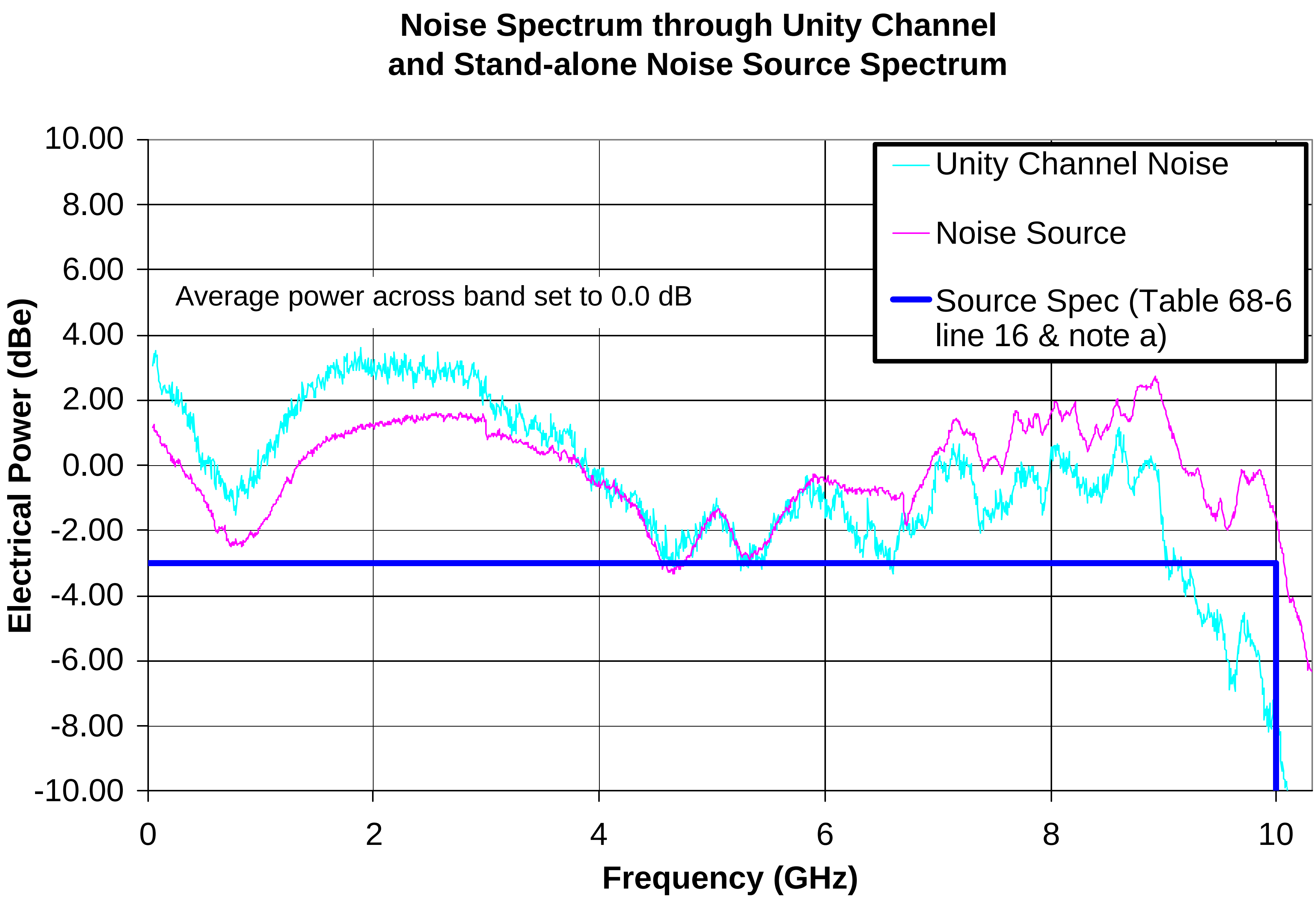


PIE-D as measured with TWDP

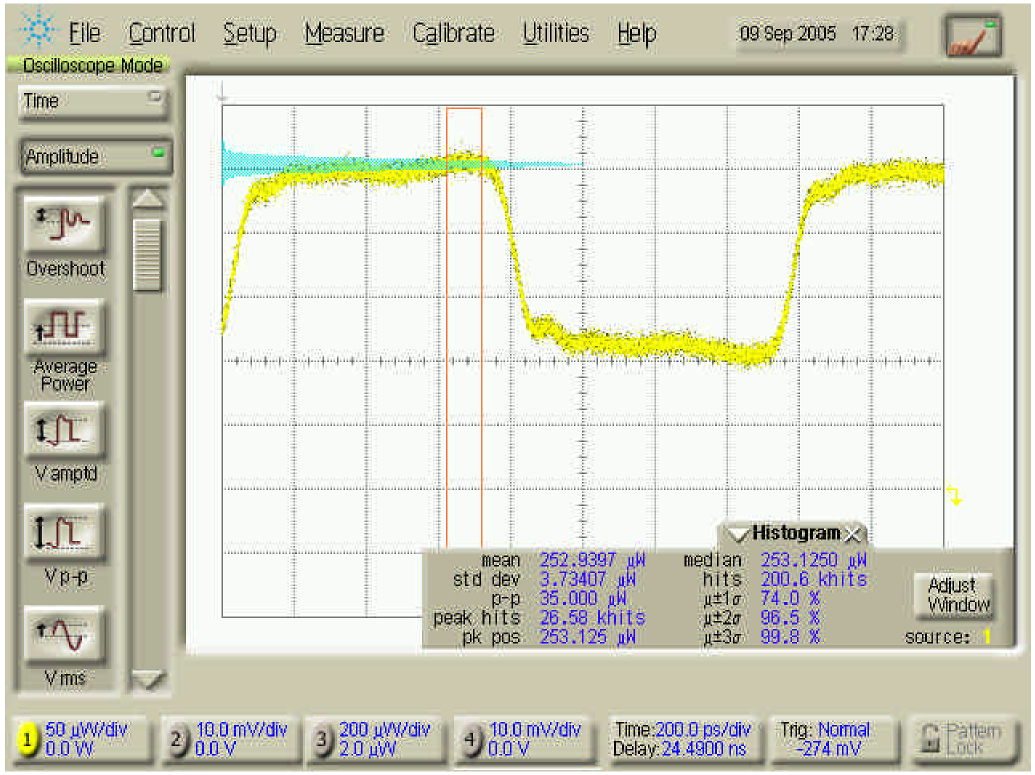
- Sampled on Agilent 86100A DCA, 86105C, PRBS9 pattern; Piers Dawe’s code of 2 August 2005, unity fiber channel [1, 0, 0, 0]
- Measurement includes 7.5 GHz 4^{th} BT filter

Stressor	Theory PIE-D	Measured PIE-D	
Precursor	**4.03**	**3.90**	**dBo**
Split-symmetric	**3.83**	**3.70**	**dBo**
Post-cursor	**4.20**	**4.30**	**dBo**

Noise Spectrums



Signal-to-Noise Calibration



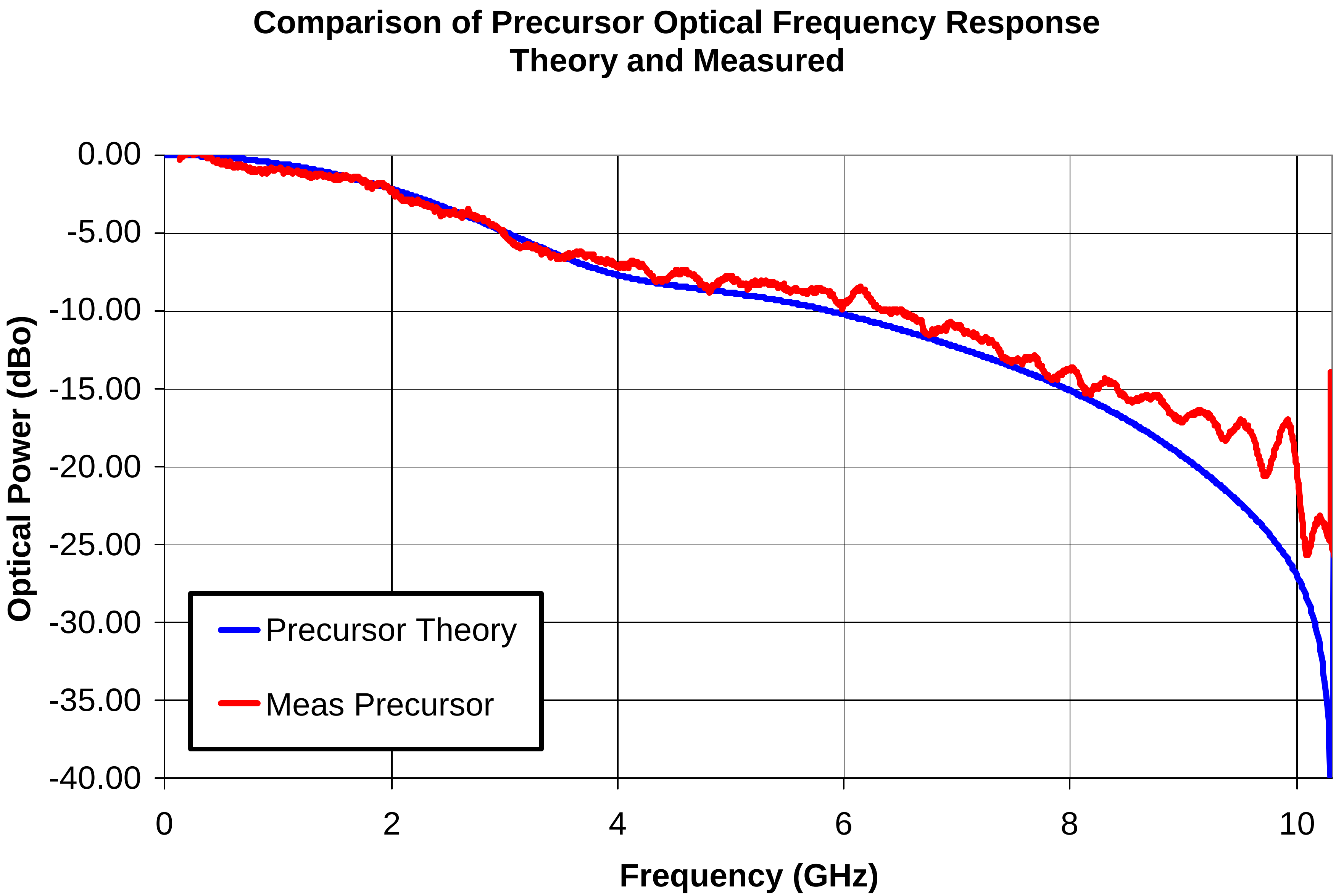
- Very easy to set Signal-to-Noise ratio
- Qsq value (i.e. 22.5) needs a small compensation
  - For calibration system noise (68.6.7 line 28)

Summary

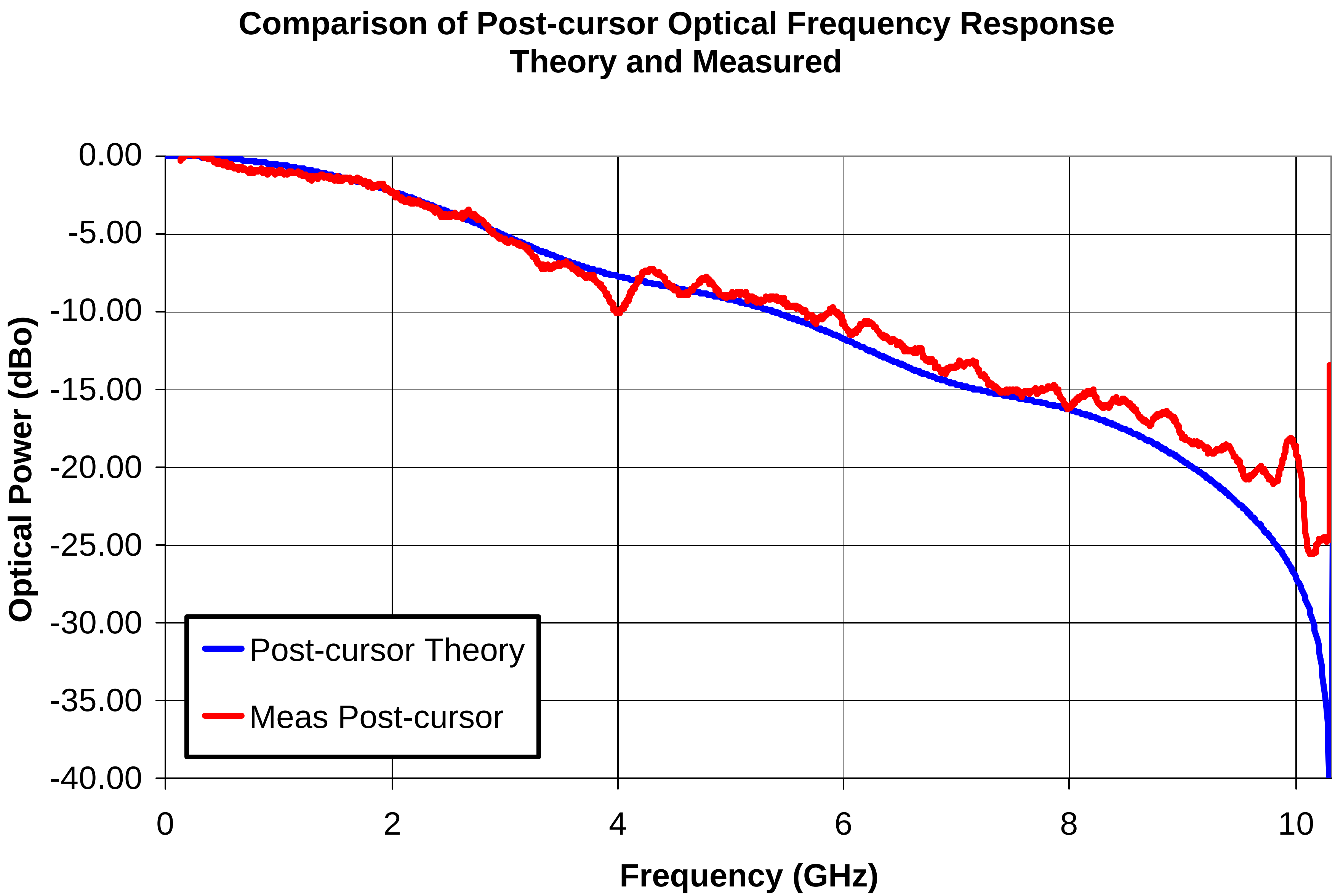
- Measured results Comprehensive Stressed Receiver Sensitivity and Overload test is practical to implement.
- System shown is inherently very accurate and can be calibrated using simple methods and equipment to improve accuracy.
- Measured results demonstrate that the system is stable.
- The change suggested by comment 66 is not needed for TP3 tester requirements.

Back Up

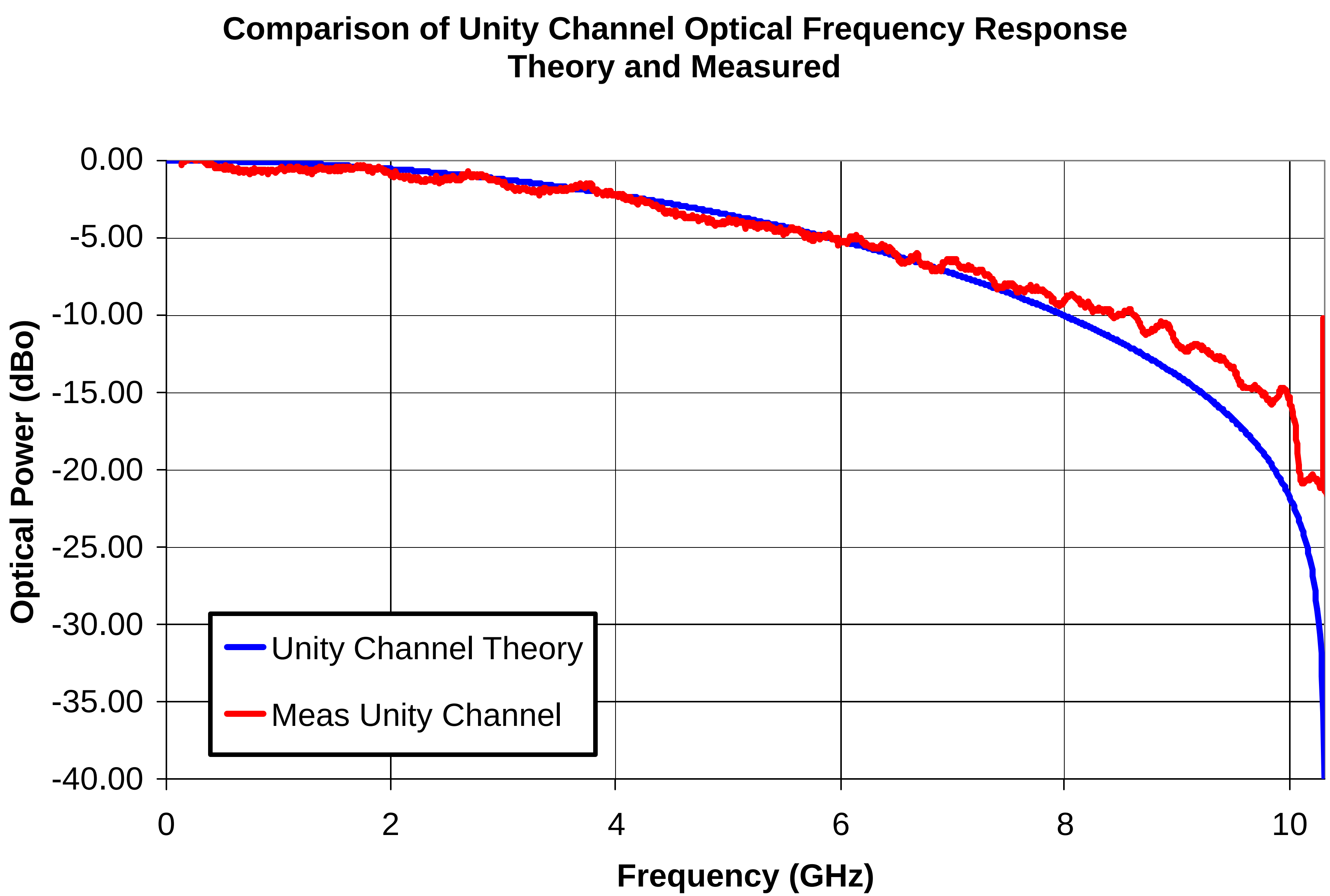
Precursor Signal Spectrum



Post-cursor Signal Spectrum



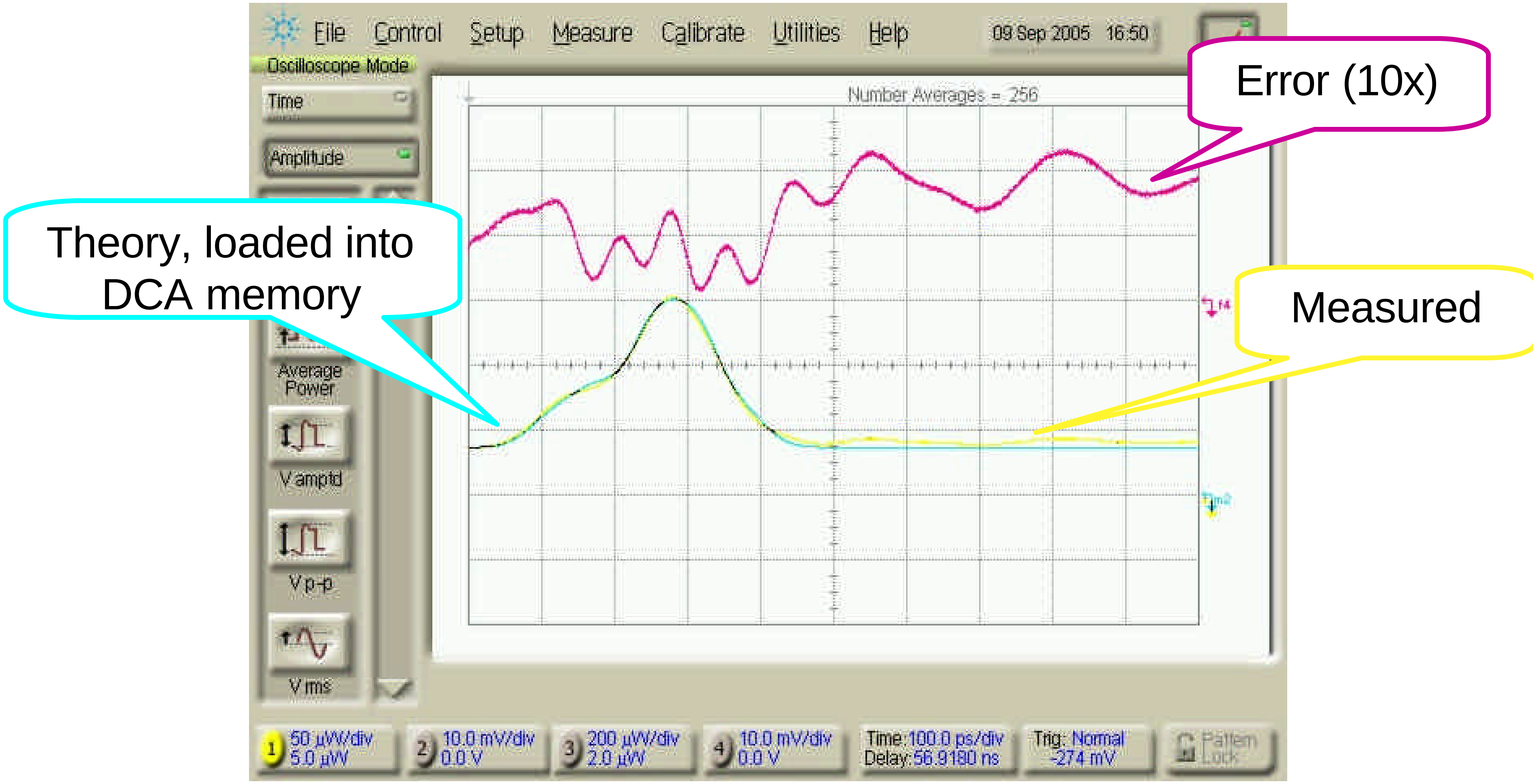
Unity Channel Signal Spectrum



Pulse Shape Precursor per 802.3aq D2.2

Target PIE-D = 4.03 dBo, Actual PIE-D = 3.90 dBo

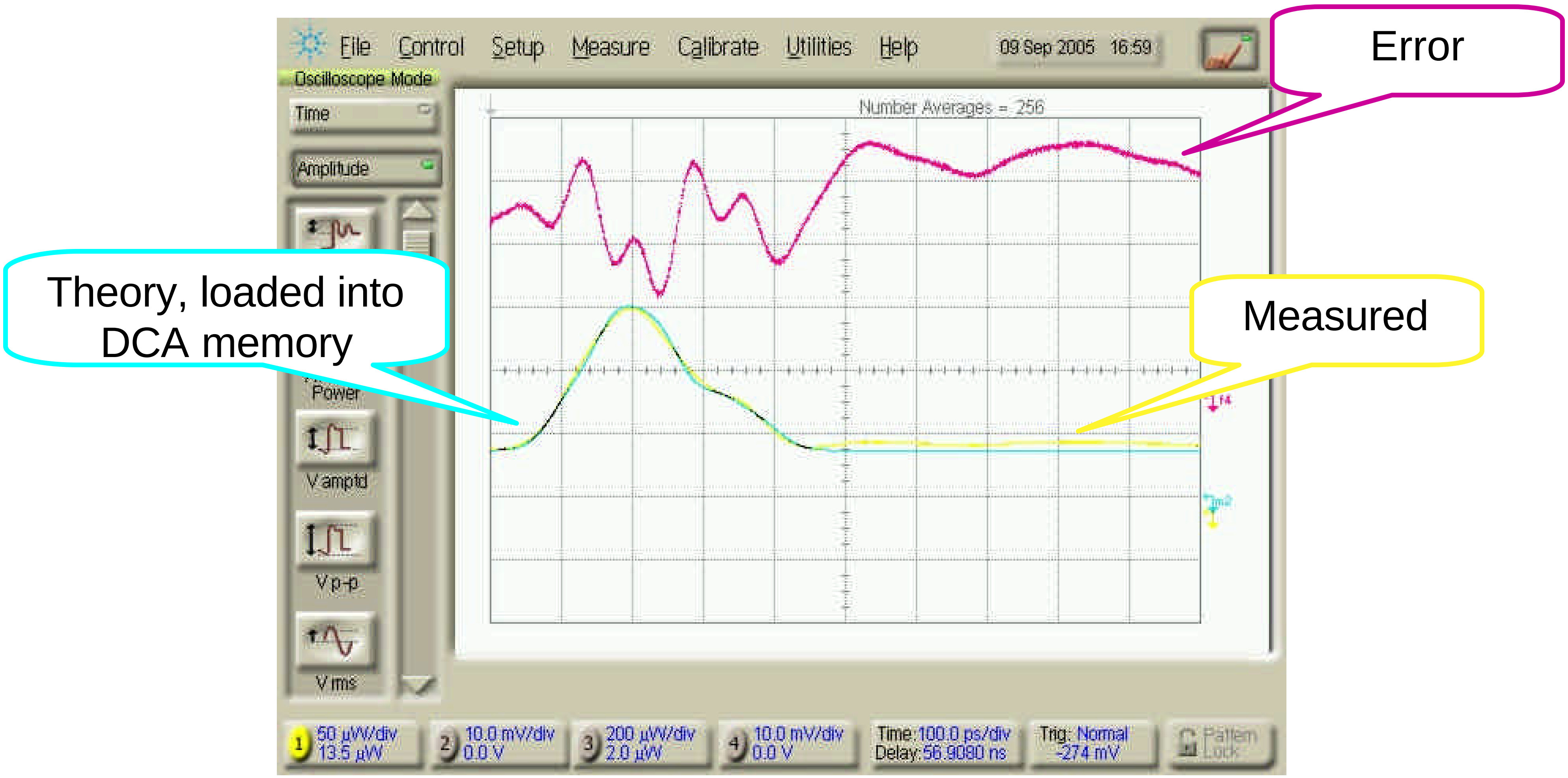
7.5 GHz 4th BT RX filter



Pulse Shape Post-cursor per 802.3aq D2.2

Target PIE-D = 4.20 dBo, Actual PIE-D = 4.30 dBo

7.5 GHz 4th BT RX filter

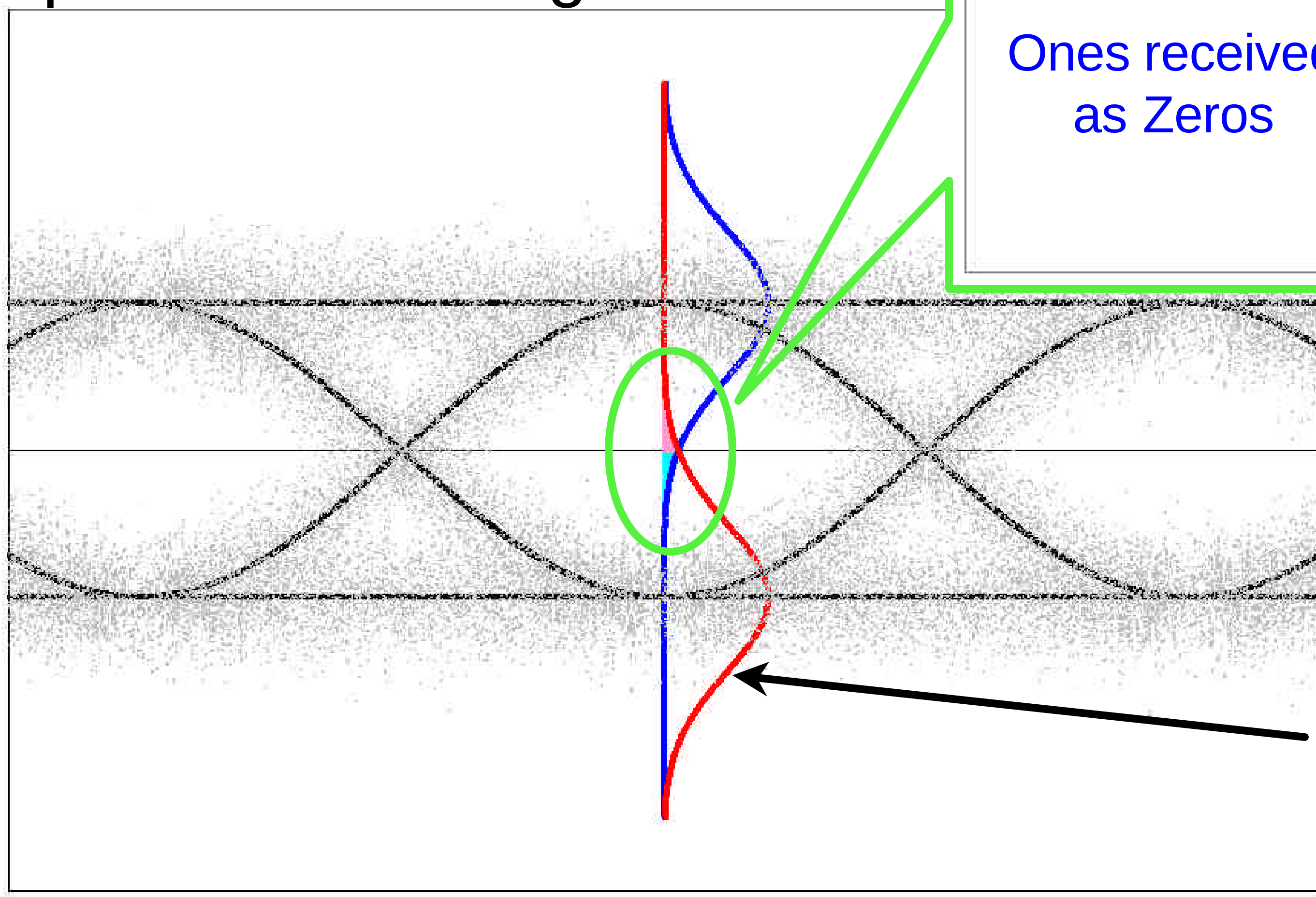


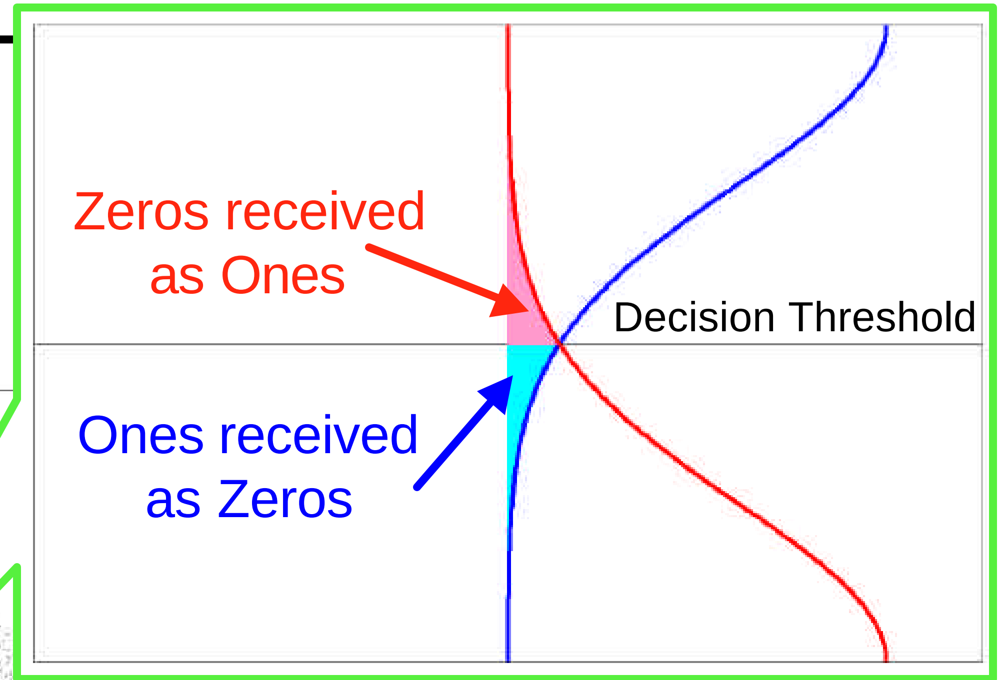
Noise Statistics

- Noise is specified as Gaussian, but real system has non-ideal statistics.
- Distortion (primarily compression in amplifiers) can truncate the tails of the Gaussian distribution leading to overly optimistic BER measurements
  - This system uses amplifiers with 1 dB compression point of +13 dBm
  - Noise power is nominally –32 dBm during calibration. This is 45 dB below compression, but…
  - Must account for distortion of signal plus noise
- D2.2 68.6.9.1 line 29 note calls for peak-to-rms of 7
- Have not yet verified noise statistics by measurement

Idealized Additive Gaussian Noise Statistics

For Gaussian electrical noise, σ (“sigma”) is the “standard deviation” and equals RMS voltage





$$\frac{1}{s\sqrt{2p}}\, e^{\left(\frac{-x^{2}}{2s^{2}}\right)}$$

Noise statistics, cont.

- **Noise signal can be specified using voltage "peak-to-average" (x-to-s) ratio**
  - **This is sometimes called "crest factor" and my be expressed as $20\log_{10}$(peak voltage/RMS voltage)**
- **Some commercial noise sources specified "crest factor" = 20log(Vpeak/Vrms) = 18 dB. Vpeak/Vrms = 7.94. Qfunc(7.94) = 9.8E-16**
- **Real systems do not hard limit at the peak value. There is gradual signal compression which distorts the Gaussian statistics**
  - **Component (*e.g.* amplifier) transfer function can be approximated using a polynomial:**

$$Vout(t) = a_0 + a_1 Vin(t) + a_2 Vin^2(t) + a_3 Vin^3(t) + a_4 Vin^4(t) + a_5 Vin^5(t) \ldots$$

  - **Coefficients can be derived from component specifications like Third-Order Intercept point, 1 dB compression point, etc.**
  - **Distortion effects are slightly different for noise-only (probability density function centered around zero Volts) versus signal plus noise.**

Noise Distortion

- **Differences in CPDF (Cumulative Probability Density Function): Distorted needs more "sigmas" to reach target BER**