By Perry Priestley
Linear Industries

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Oregon

DTV transmitter performance, correction and measurments

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GO DIGITAL

Contents

1. Introduction

DTV transmitter performance, correction and measurments

DTV transmitter performance, correction and measurments

Linear Corporate Overview

- USA factory created in 2005
- Local assembly
- Full test facility
- Marketing, Sales & Technical support
- Spare Parts inventory
- 30 Minutes from Chicago ORD Airport
- Most transmitters shipped in less than 10 days

- Linear in Brazil was established in 1978
- 28,000 Transmitter and Translator installations in 40 countries
- 350 Employees
- Largest supplier of Transmitters in South America and in 2006, 2007 and 2008 probably the world!
- Predominate supplier of digital TV equipment to the new South American digital market

"Flagship" products

DIGITAL EXCITER / TRANSMITTER

- VHF and UHF
- 20 – 120 Watts
- Transmitter or Exciter
- Air Cooled
- Linear and non-Linear correction
- Ideal for flash-cutting 1kW analog transmitters
- All metering on front panel
- Transport Stream measurement
- ASI or SMPTE 310M input
- Variable power control from front panel

DIGITAL EXCITER

- Frequency Agile
- 200 mW output
- Automatic linear and non-linear correction
- Ideal for flash-cuts - works with ANY OEM transmitter
- Includes measurement software option
- 14 different ATSC measurements
- ASI or SMPTE 310 input
- One-button correction

- UHF TV Transmitter
- 15 – 10,000 Watts
- Transmitters and Translators
- Gap Fillers
- Air Cooled
- Analog NTSC and Digital ATSC
- Linear and non-linear correction
- Unparallel performance
- 2 years warranty

Summary Of ATSC standard

- ATSC baseband signal is an MPEG-2 transport stream (TS)
  - Video signal coded as MPEG-2 - SD or HD
  - Audio signal coded to the Dolby Labs AC-3 format / 5.1 Audio

- 8VSB modulation scheme is a single-carrier technique employing eight-level trellis coding
- I (Real) Q (imaginary) modulation
- 8 VSB uses I axis with 8 level modulation constellation points equidistantly distributed
- Bandwidth reduced by lower sideband suppression (removing some of the Q component)
- As in analog TV – VSB filtering resulting; upper and vestigial sideband is employed
- Receiver contains Nyquist filtering to improve sideband filtering effectiveness
- Inherent 8 VSB advantage is power efficiency : ATSC Digital apparently uses only 25% power of NTSC analog signal to cover the same area

Main Causes Of Bit Errors in Transport Stream

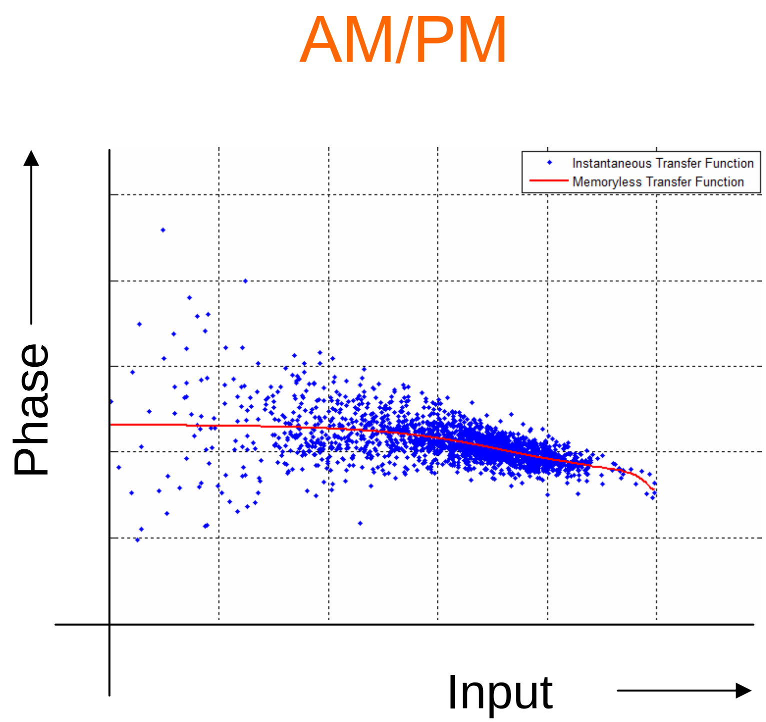
- Echoes* - External to Transmission system
- Interferers* – External to transmission system
- Amplitude distortion – typically non-linear amplifiers
- IQ errors – amplitude and phase errors in the modulator
- Group Delay errors – typically linear phase distortion
- Phase jitter – Poor oscillator stability, encoder phase errors or translator receiver phase errors
- Power spectrum “Shoulder” levels too high – Insufficient shoulder attenuation through non-linear correction and mask filter attenuation

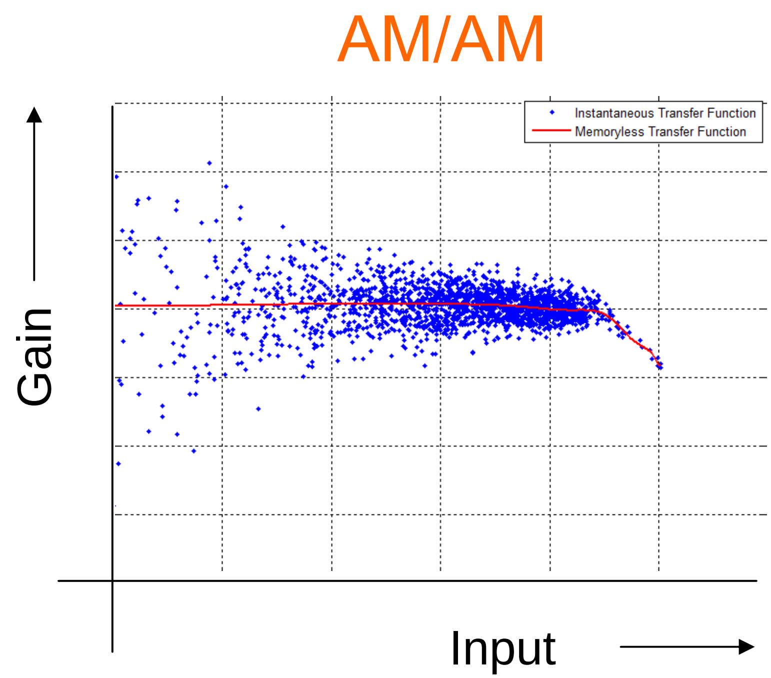
** Not covered in this presentation*

1. Explanation Of Key Test Measurements

Explanation of Key Test Measurements

Amplitude And Phase Distortion

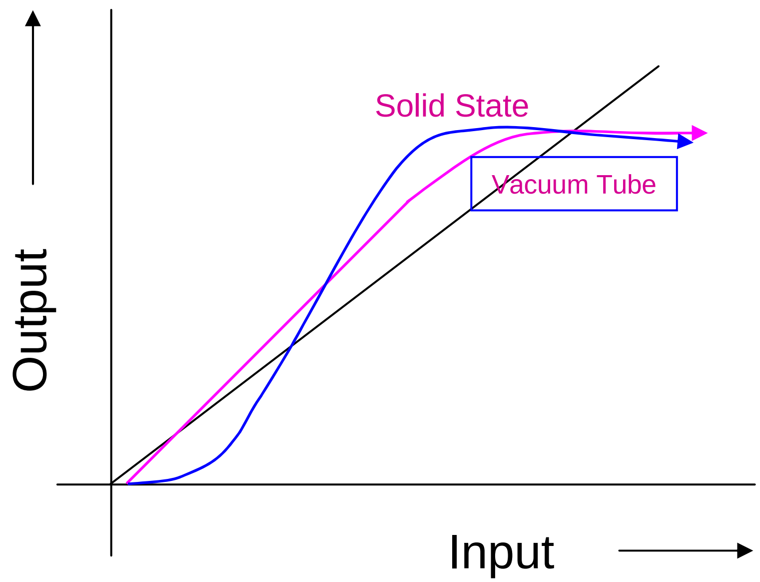




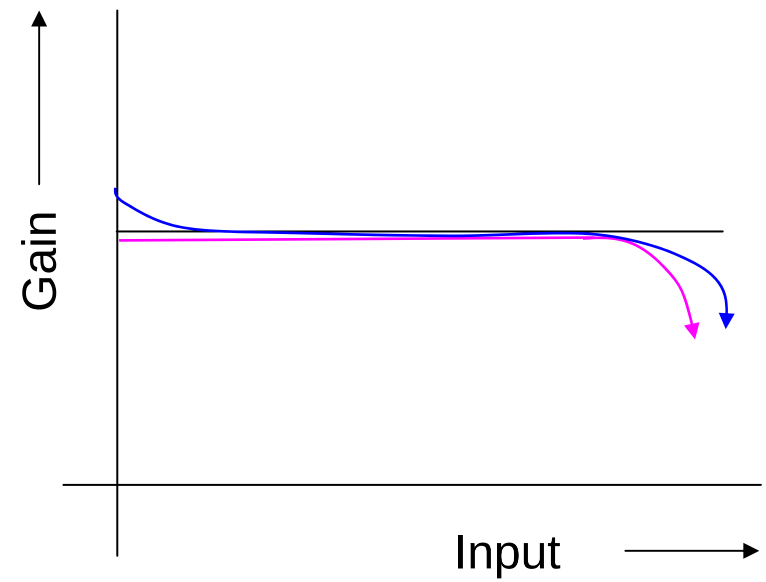
Explanation of Key Test Measurements

Amplitude distortion via AM/AM, AM/PM and CCDF

Gain (n) = Output / Input

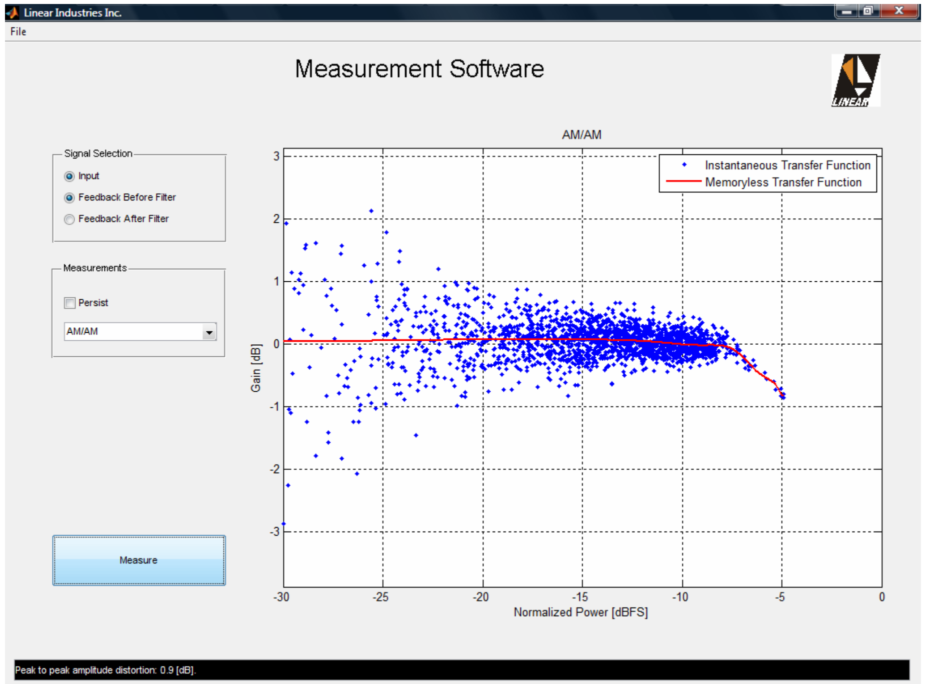


Gain (dB) = 10 $\log_{10}$ (Output/Input)



Explanation of Key Test Measurements

AM/AM

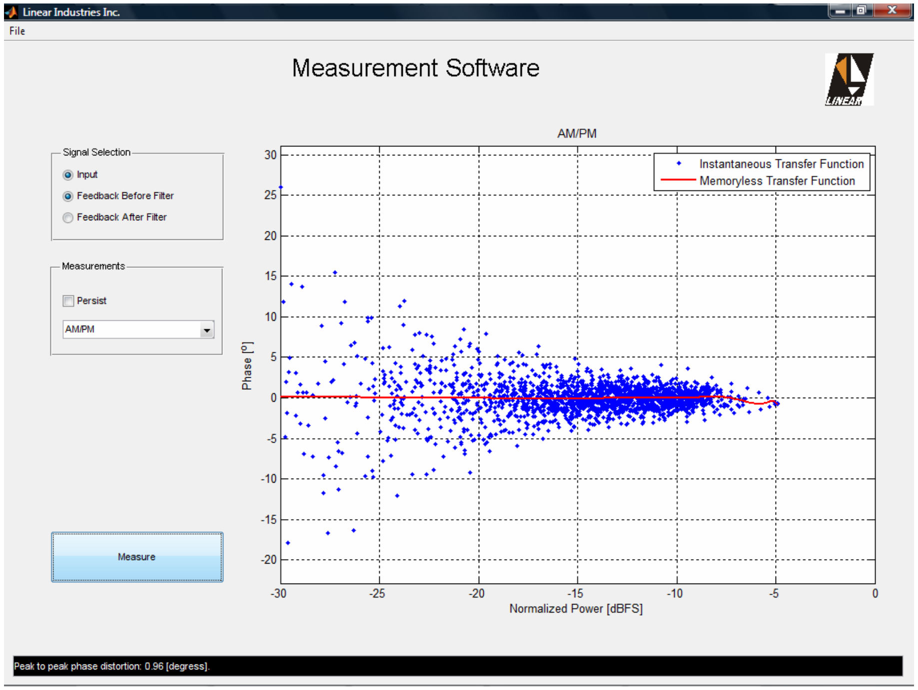


AM/AM: Amplitude Modulation / Amplitude Modulation.

- Should be measured after amplifier and before filter
- Represents normalized output/input amplitude ratio (amplifier gain) in [dB] vs. normalized input amplitude in [dB] full scale
- This evaluates a power amplifiers transfer function and linearity characteristics

Explanation of Key Test Measurements

AM/PM

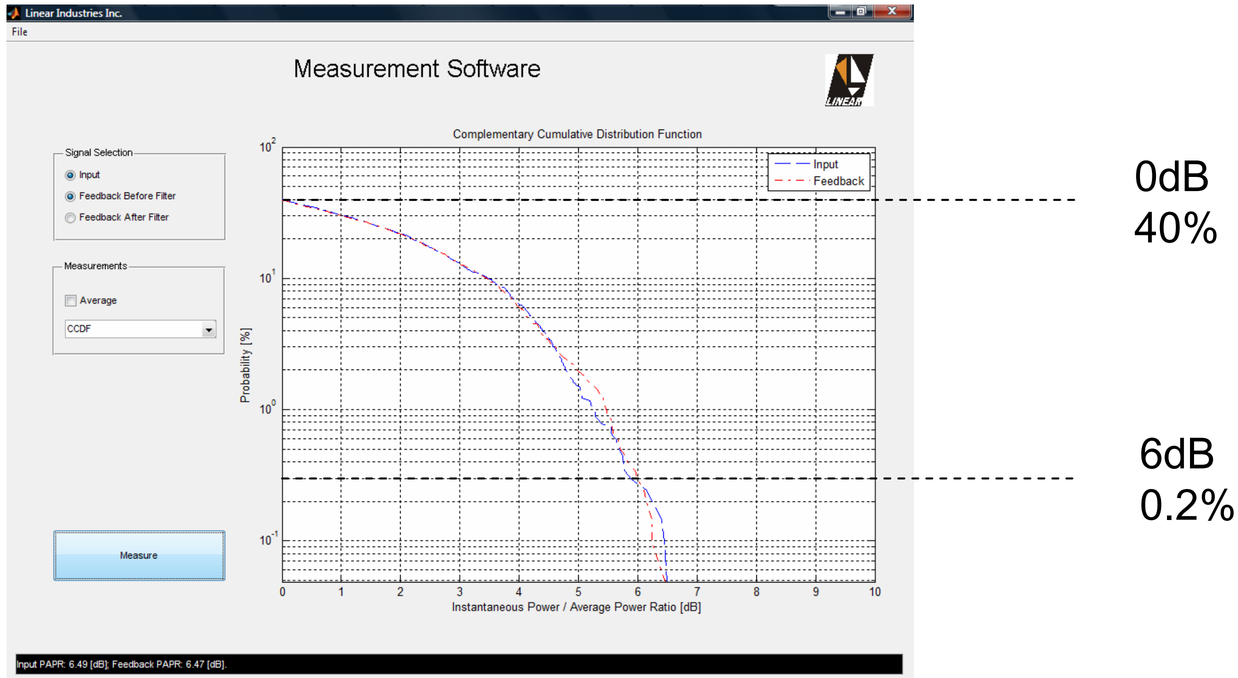


AM/PM: Amplitude Modulation / Phase Modulation

- Should be measured after amplifier and before filter
- Represents the phase deviation in [°] vs. normalized input amplitude in [dB]
- This evaluates a power amplifiers transfer function and its phase characteristics

Explanation of Key Test Measurements

CCDF



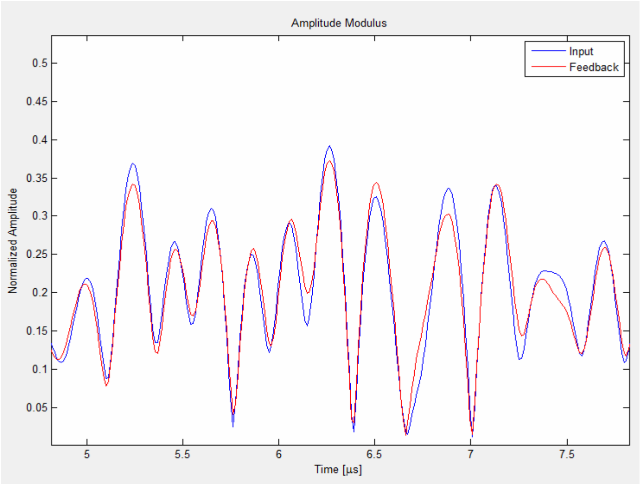
CCDF: Complementary Cumulative Distribution Function (CCDF)

- Represents the probability of instantaneous power to be above average power. If amplifier in compression, red line would be below blue line.
- Use this measurement to evaluate amplifier compressed or clipping PAPR (Peak to Average Power Ratio) measurement represents the ratio between the maximum peak power and average power
- Example: 0dB = 40 % of the time > 10kW or 60 % of the time < 10kW
  +6dB = 0.2 % of the time > 40kW or 99.8% of the time < 40kW

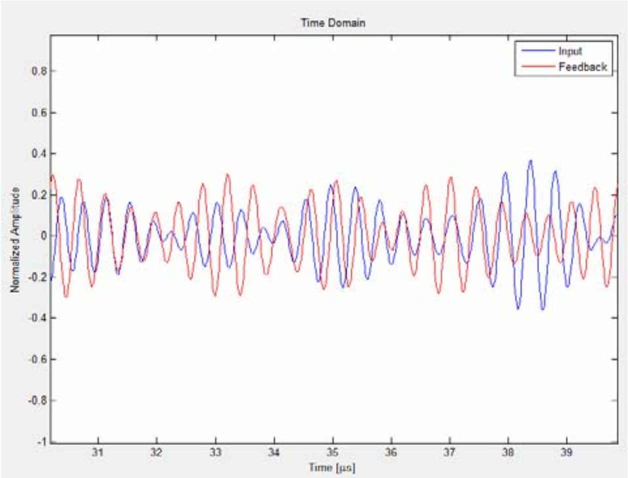
Explanation of Key Test Measurements

I and Q errors via

Amplitude Modulus



Time Domain



Explanation of Key Test Measurements

I and Q errors

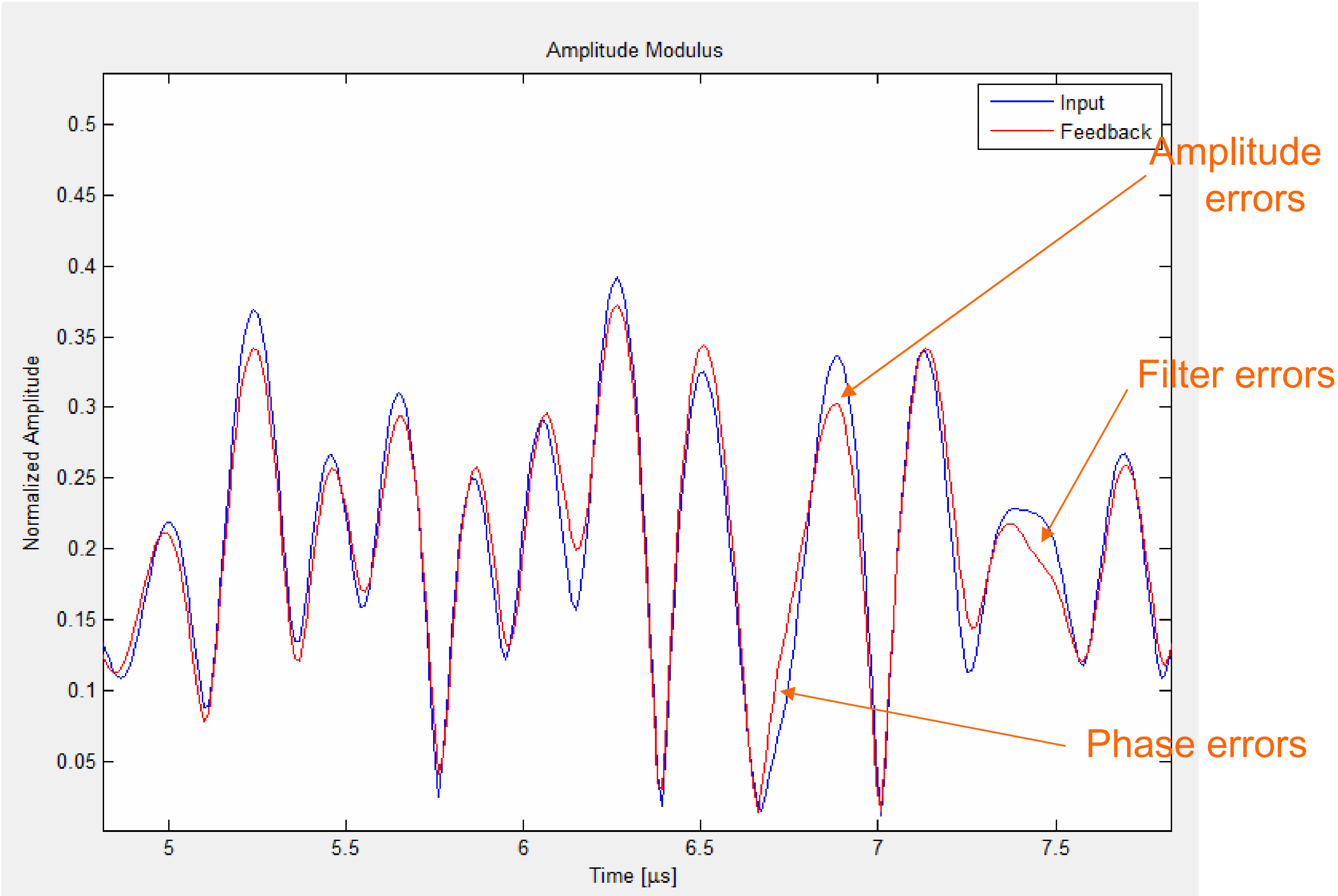
- I = real part (In-phase component)
- Q = imaginary part (quadrature component).
- Each sample as a vector on a plane, the amplitude modulus is the magnitude of this vector:

$$MOD = \sqrt{(I^2 + Q^2)}$$

- Two ways to represent a complex signal and the I Q errors:
  - Real part (I) of signal (Cartesian coordinates), wrt the imaginary part
    - Real and Imaginary (I and Q)
  - Polar coordinates Amplitude (Modulus) only
    - Modulus and Angle (I only)

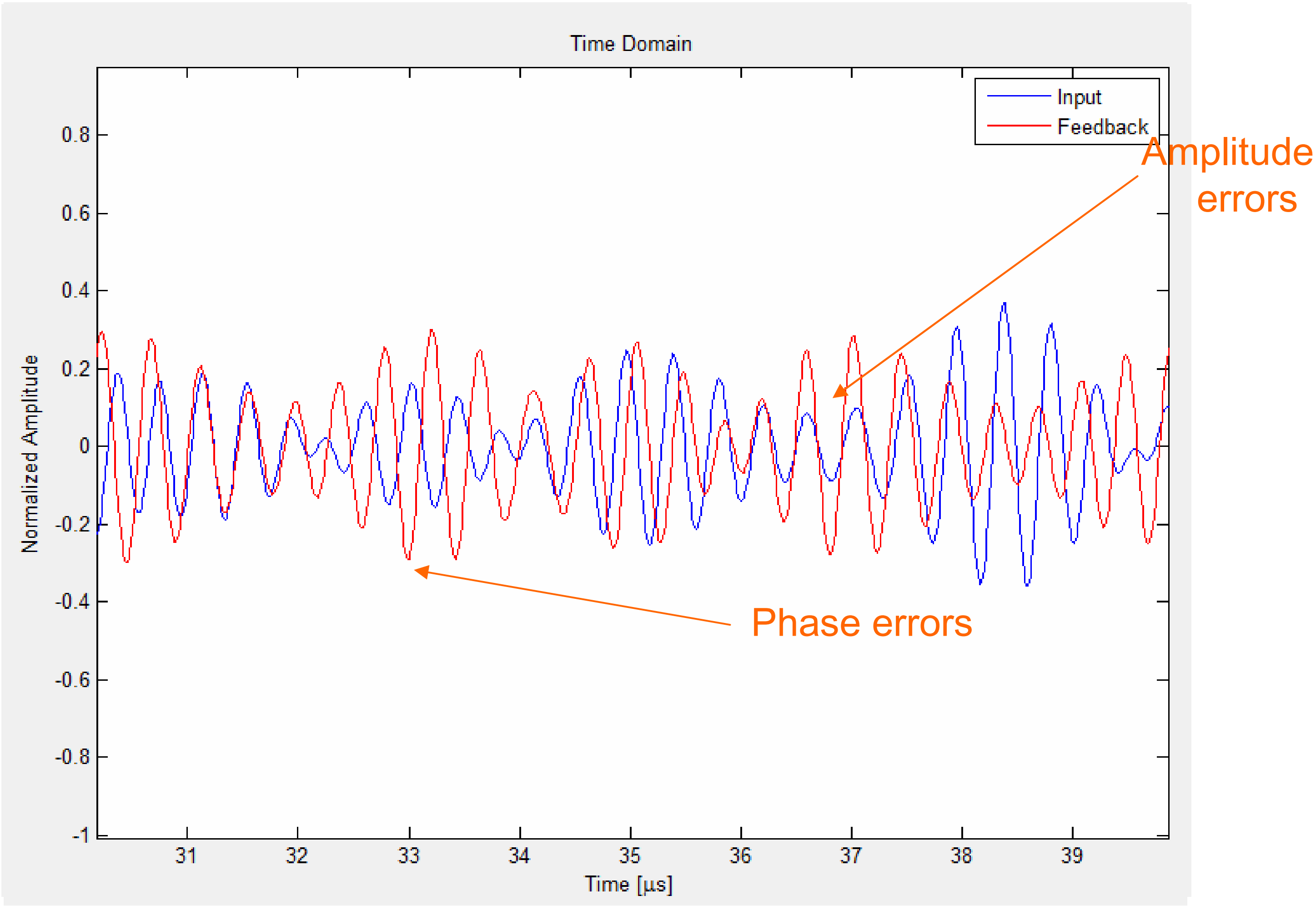
Explanation of Key TestMeasurements

I and Q Errors (Amplitude Modulus)



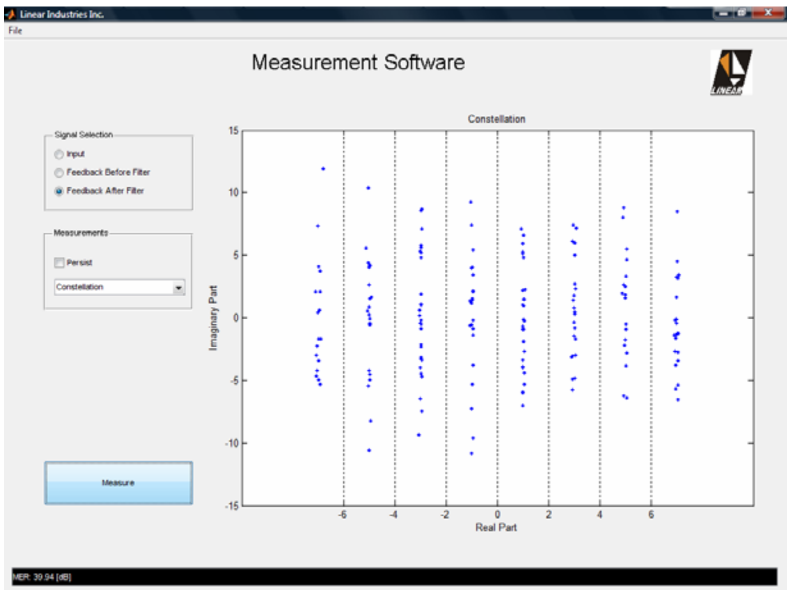
Explanation of Key Test Measurements

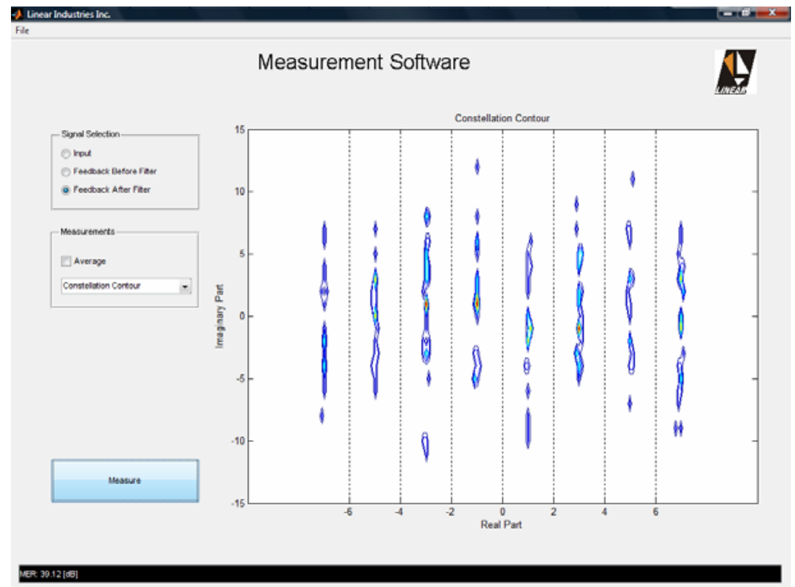
I and Q Errors (Time Domain)



Explanation of Key Measurements

ATSC Constellation and Constellation Contour





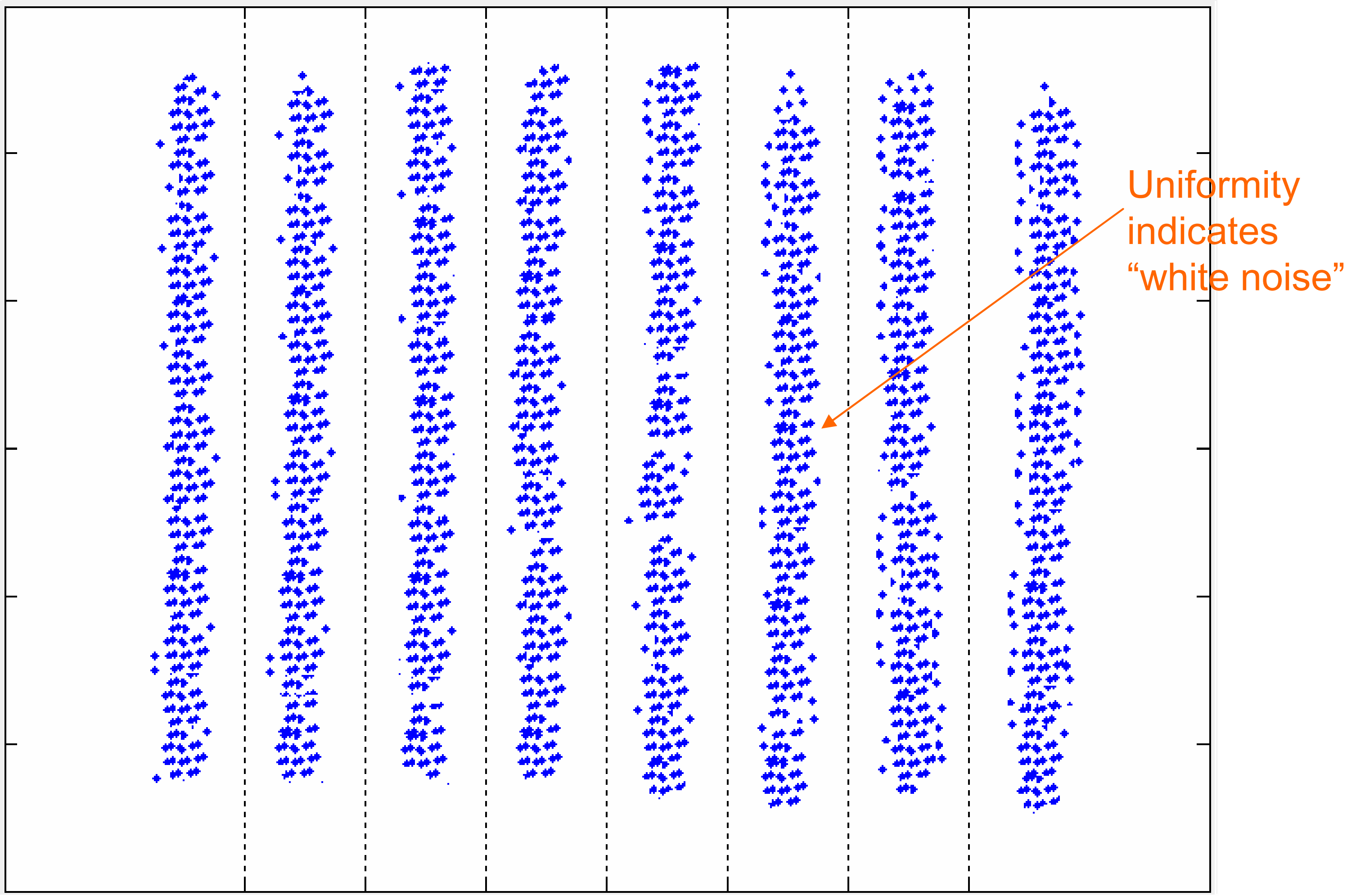
Explanation of Key Test Measurements

ATSC Constellation

- A two dimensional graphical representation of the 8-VSB RF carrier ampl. and phase at each sampling time
- The 8 VSB constellation diagram shows 8 lines (whereas 16 or 64 QAM would show 16 or 64 points)
- The 8VSB constellation diagram evaluates noise impairments such as SNR/MER.
- The thinner the lines the lower the distortion
- With "pure" noise impairment the lines are widened over their entire length
- The RMS value of the noise can be determined by constellation analysis and using a Gaussian (normal) distribution statistical function
- This determines the IQ "decision points" standard deviation from the ideal point

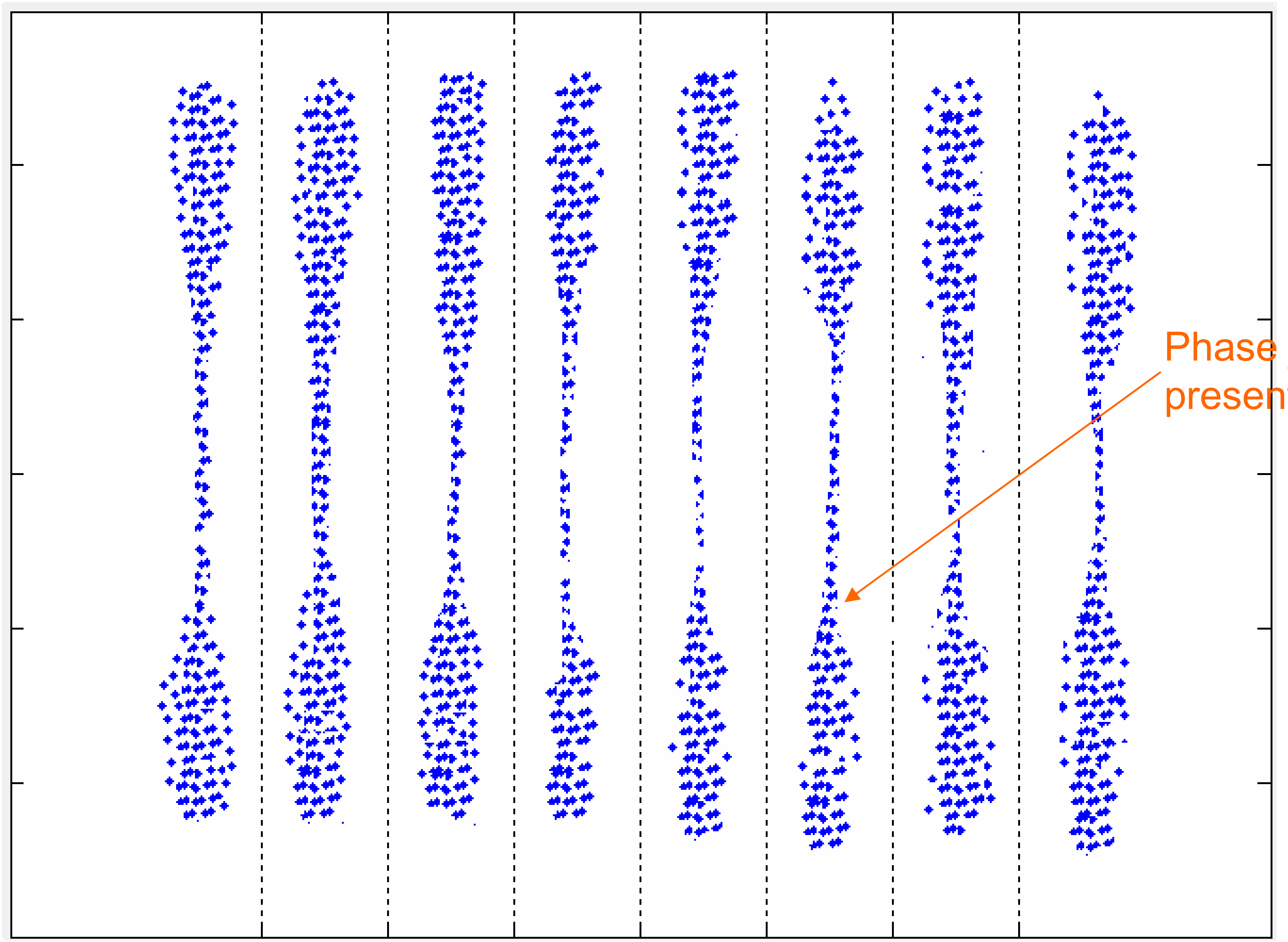
Explanation of Key Measurements

ATSC Constellation



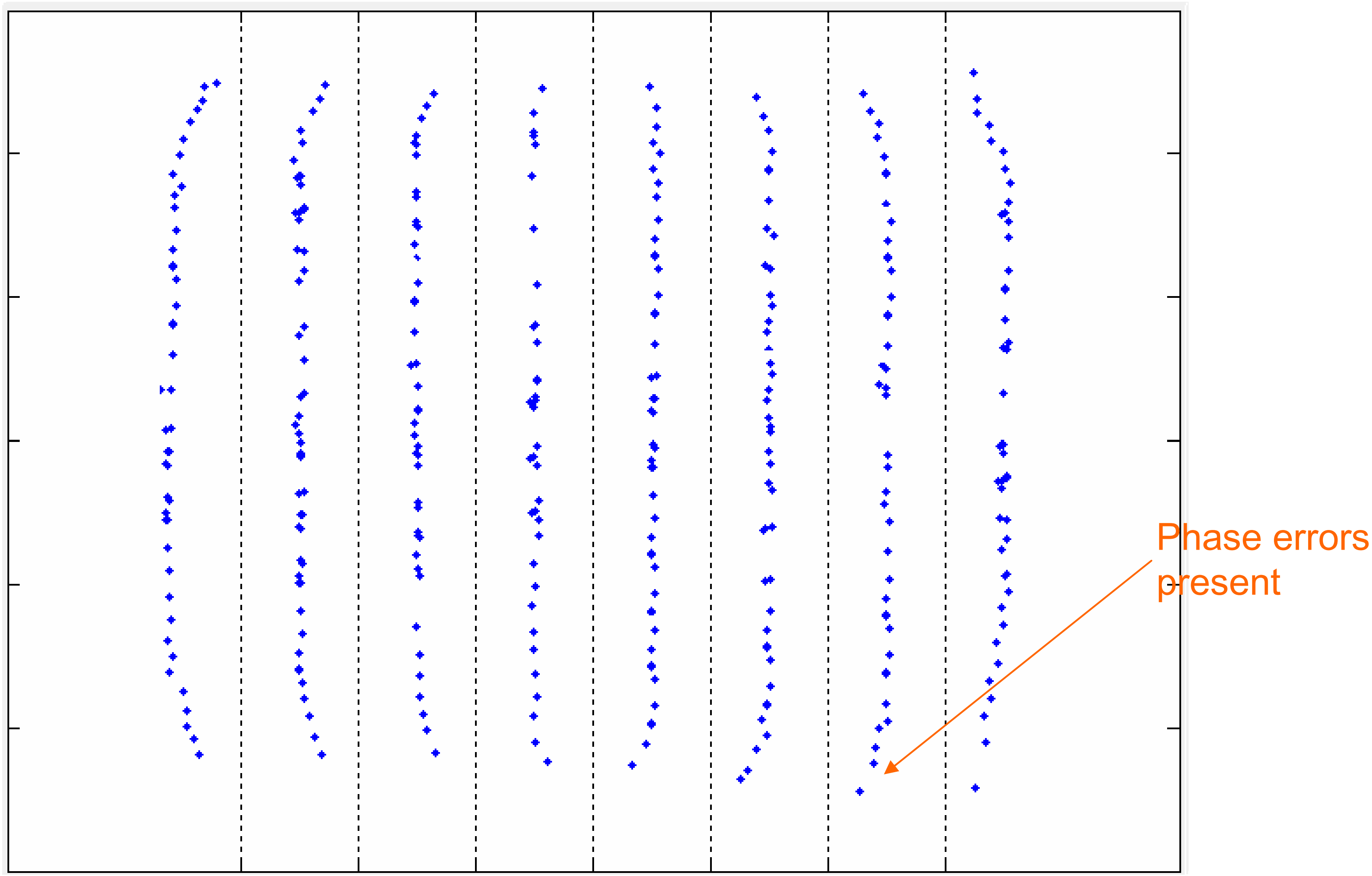
Explanation of Key Measurements

ATSC Constellation



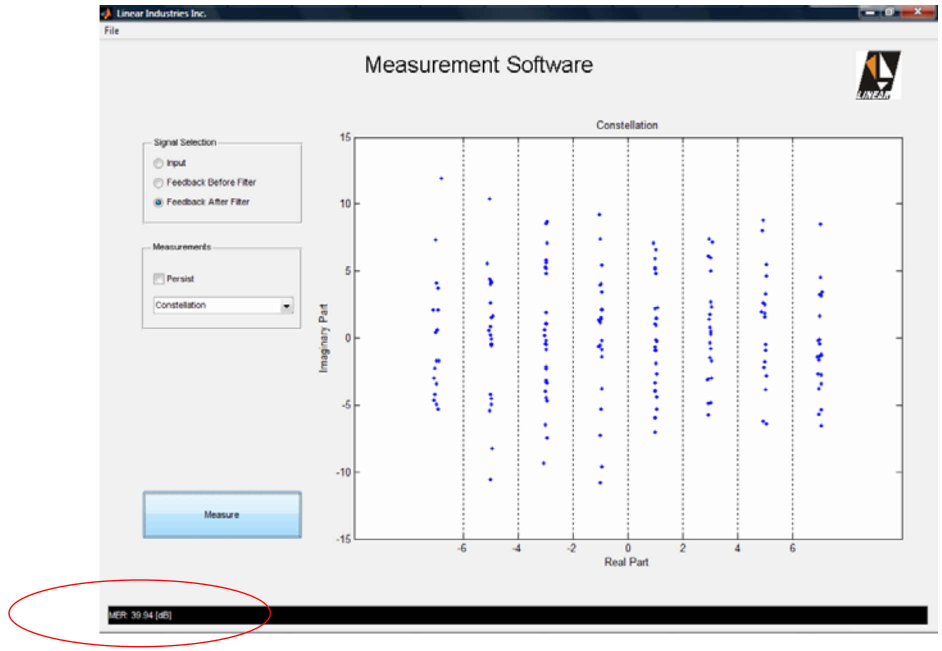
Explanation of Key Measurements

ATSC Constellation



Explanation of Key Measurements

ATSC Constellation

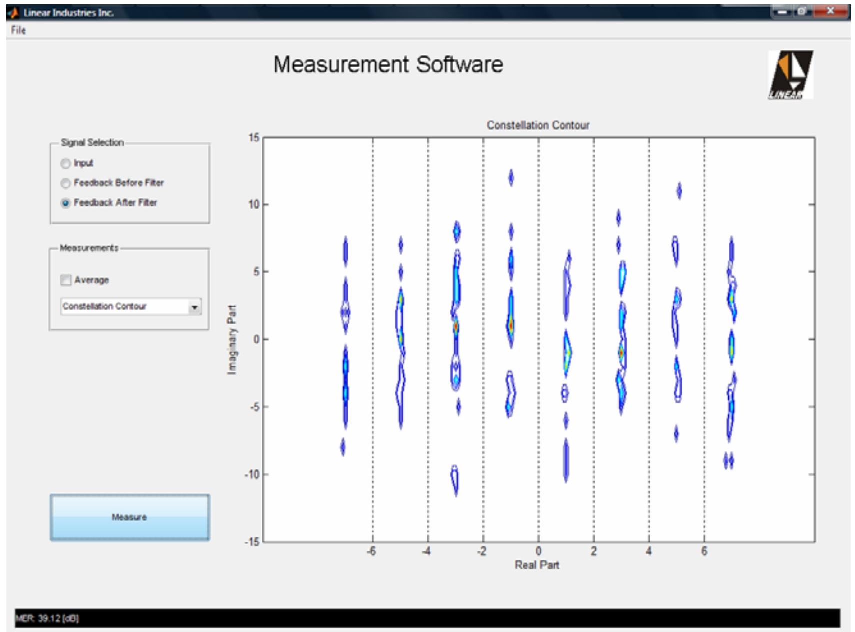


Constellation

- A representation of the sampled baseband modulating symbols, where the Cartesian plan is plotted by its real vs. imaginary part. The real part (in-phase) of the sampled symbols carry the transmitted information while the imaginary part (quadrature) carries the necessary information to generate the vestigial side band. For 8VSB modulation the eight regions represent the eight possible symbols and the seven dashed lines indicate the decision threshold.
- The Modulation Error Ratio (MER) is provided in [dB]

Explanation of Key Measurements

ATSC Constellation Contour

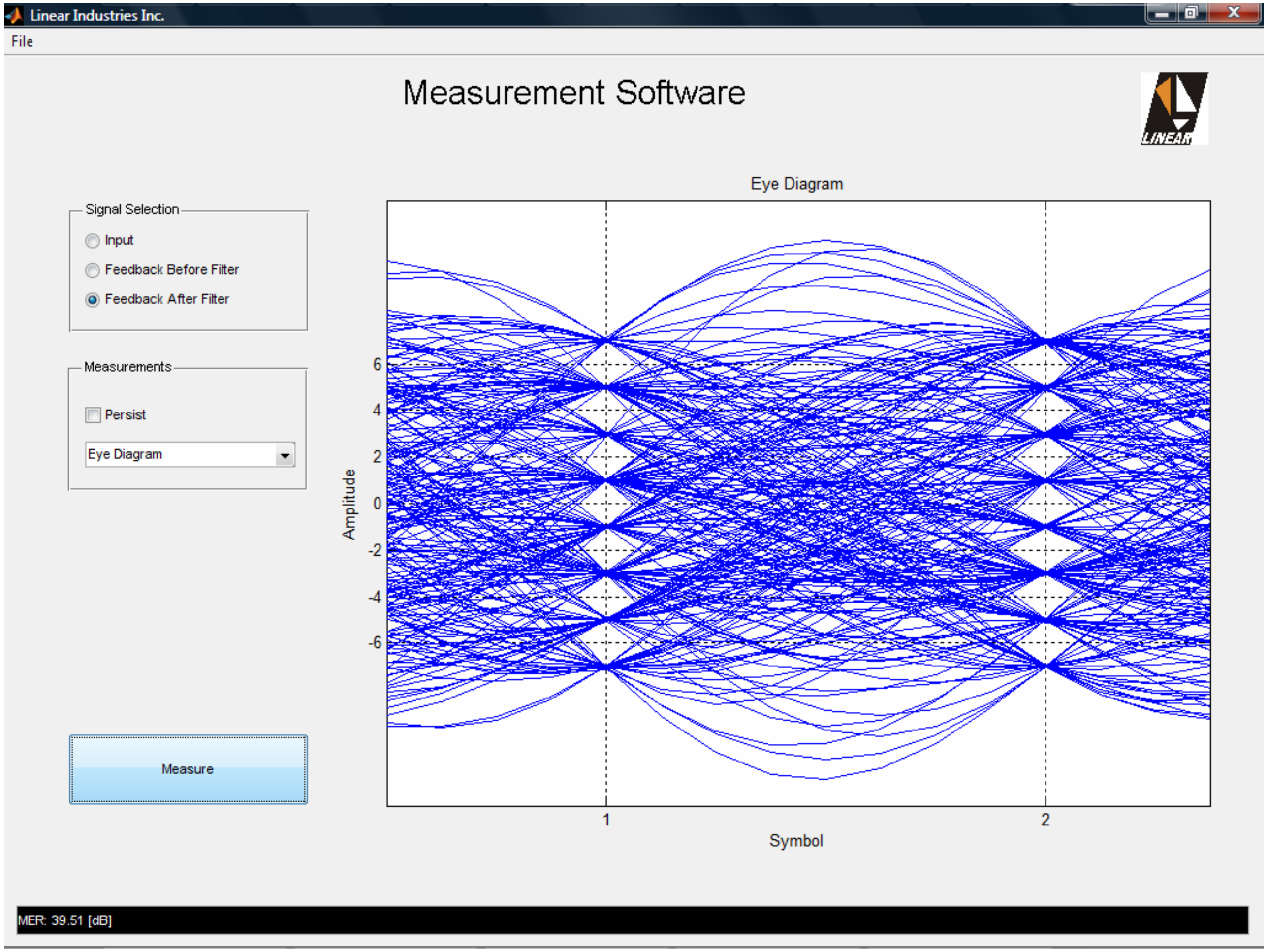


Constellation Contour

- Shows probability regions for a demodulated symbol to fail in coded in colors. A red area means low probability of failure, the blue area means higher probability of failure
- This measurement reflects the signal quality. Use it to measure non-linear, linear and amplitude distortions
- MER is the mean squared error in [dB] assuming the perfect symbol as the reference signal

Explanation of Key Measurements

MER and the "Eye" diagram



Explanation of Key Measurements

MER and the "Eye" diagram

- An overlay of many received RF amplitude signal traces at the instant of sampling – the RF signal must attain one of 8 levels
- Can be used to evaluate many types of errors
- The convergence of "perfect" signal traces forms seven "eyes" that coincide with the occurrence of the receiver clock pulses
- Errors can be caused by noise, low-image rejection ratio, phase noise, carrier suppression and non linear and linear distortion

Explanation of Key Measurements

MER and the "Eye" diagram

- For each type of error, an error vector is continually calculated, and the sum of the squares (RMS value) of all error vectors is calculated
- The ratio of the error-vector RMS value to the signal amplitude produces the value is the MER [specified in dB]
- The quality of the in-channel emitted signal can be specified and measured by determining the departure from 100 percent "eye" opening
- The departure, or error, has four identifiable components: 1) circuit or "white" noise, 2) inter-modulation noise caused by non-linearity, 3) inter-symbol interference, and 4) phase noise

Explanation of Key Measurements

MER and the "Eye" diagram

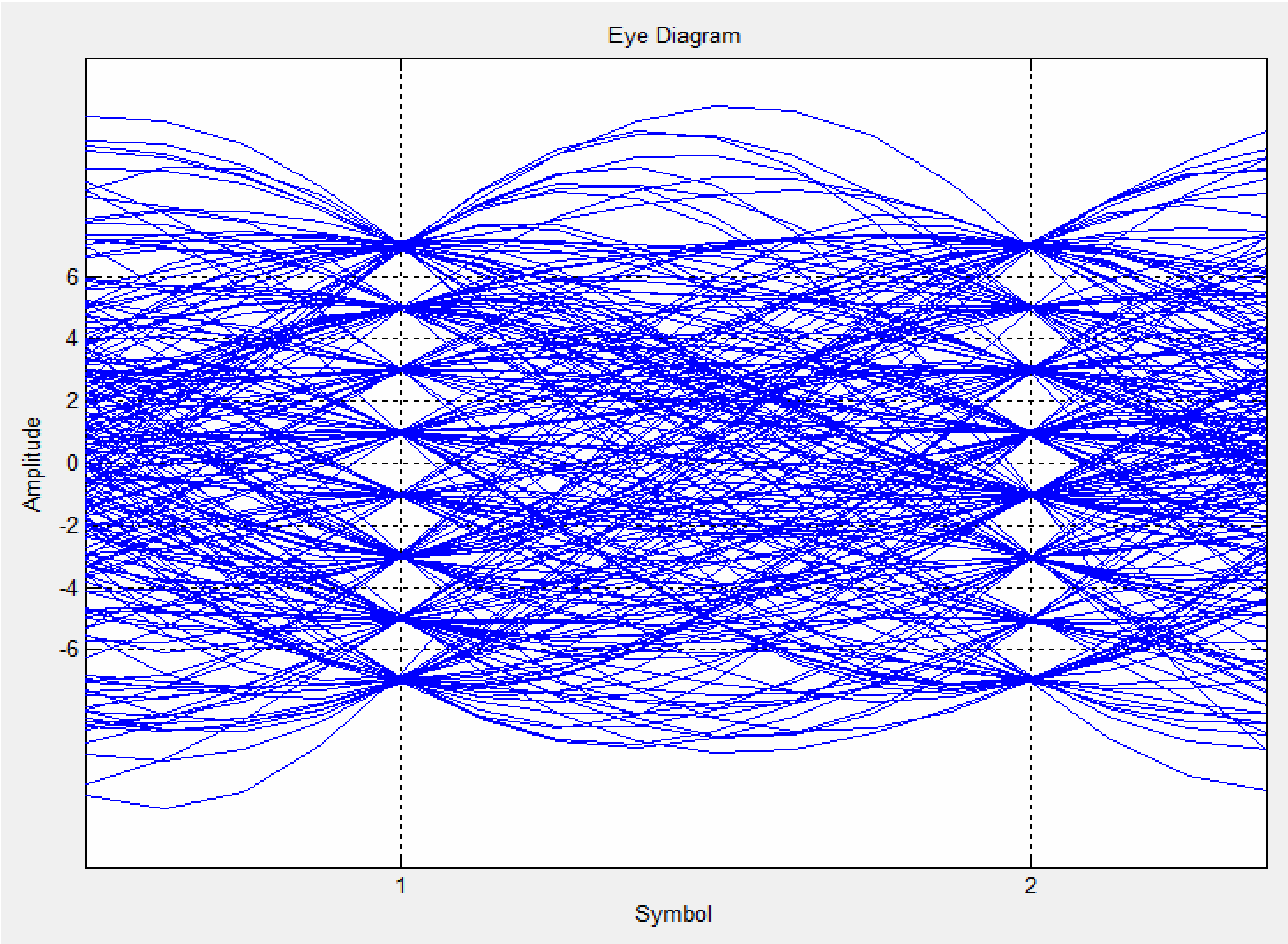
- The combination of all of these effects can be specified and measured by an error (or noise) magnitude power. The error magnitude power for a DTV signal should be no greater than – 27 dB relative to the authorized signal power.

- An error power of this level will increase the received DTV error threshold by a maximum value of about 0.25 dB, which for UHF assignments corresponds to a reduction of approximately 1/4 mile in coverage distance from the transmitter

- The error is the total power of all the above errors along the in-phase demodulation axis, and is considered as "noise" when measuring signal-to-noise ratio

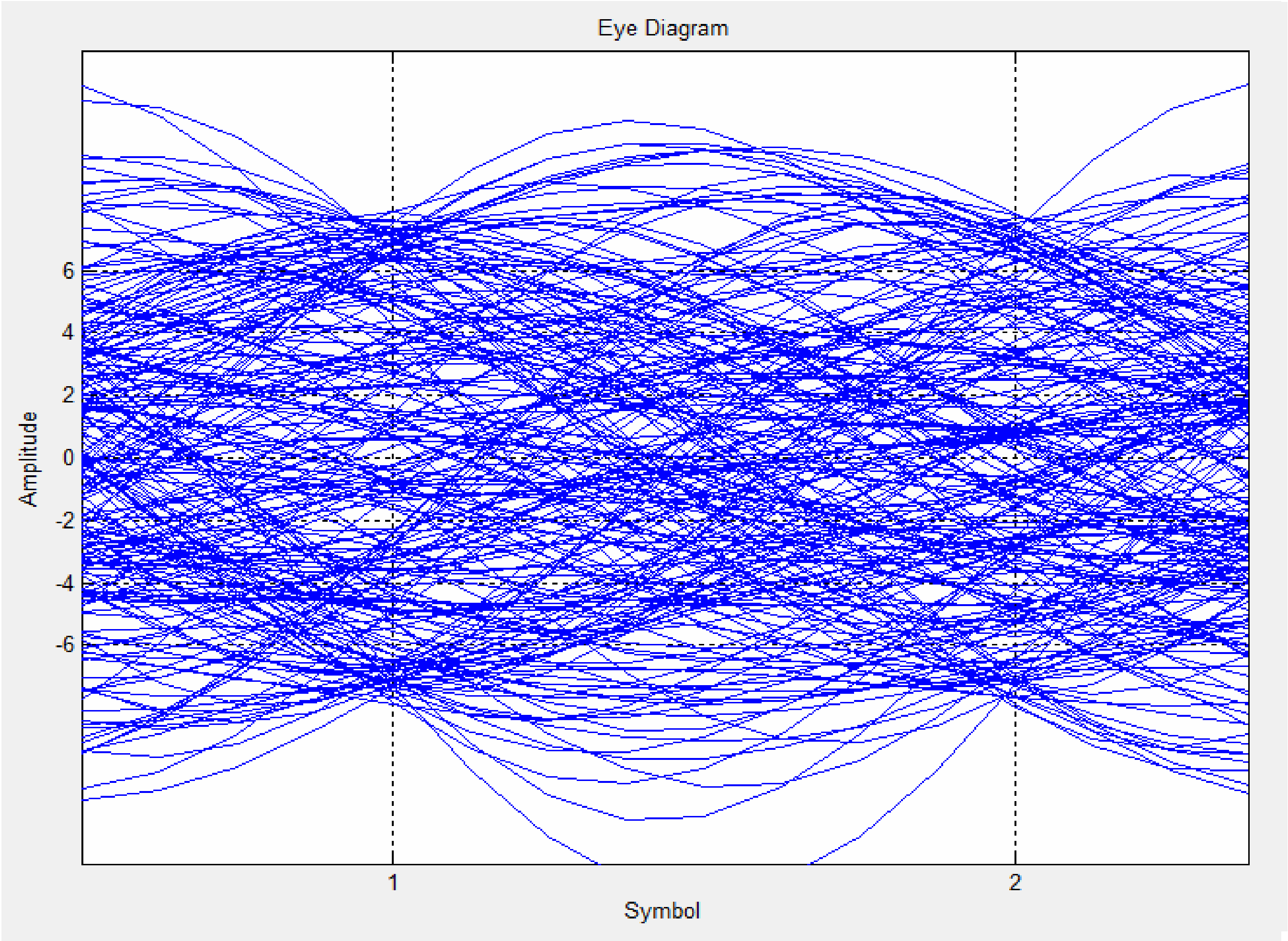
Explanation of Key Measurements

MER and the "Eye" diagram



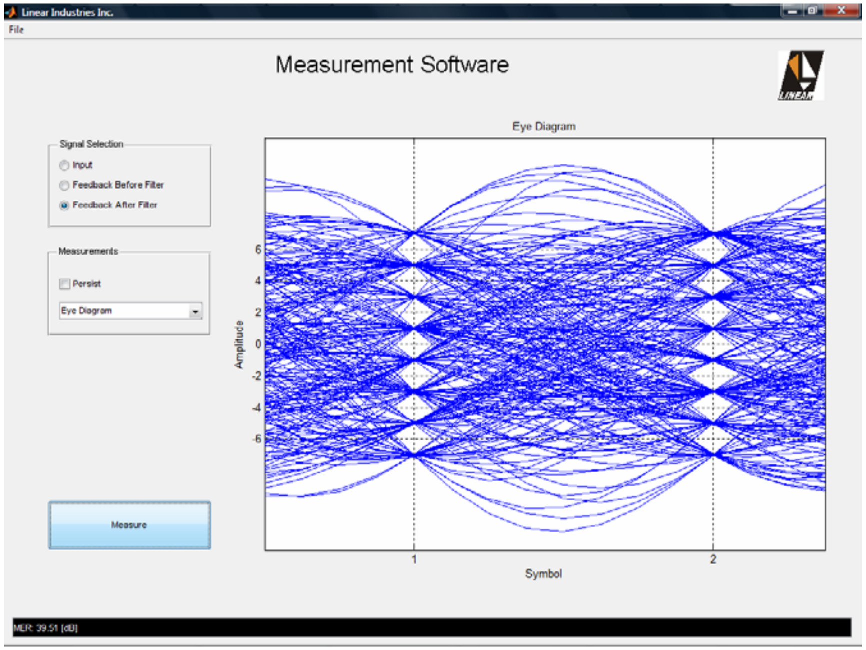
Explanation of Key Measurements

MER and the “Eye” diagram



Explanation of Key Measurements

MER and the “Eye” diagram



Eye Diagram :

- Represents the pure “real” modulating symbols filtered with a raised cosine filter and persisted with a symbol period multiple. The open “eyes” indicate the exact moment for the receiver to sample and decide the level of the symbol in order to extract its value
- Use it to realize non-linear, linear and amplitude distortions. It can be measured before and after the filter to understand the individual and cumulative distortions of both parts of the system

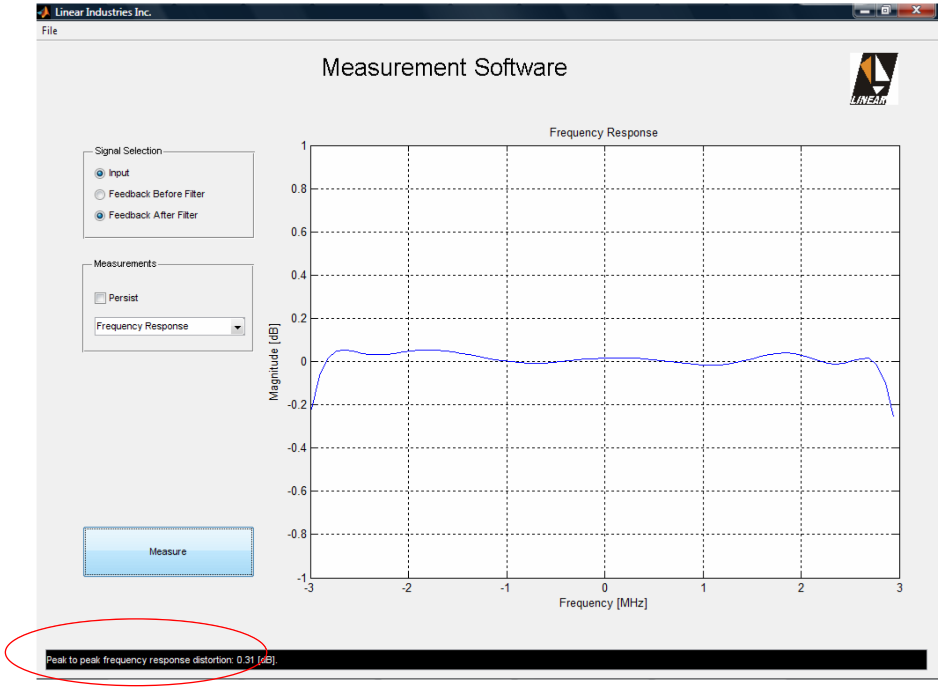
Explanation of Key Measurements

Amplitude Response and Group Delay

- The 8VSB signal has no pilot signals that provide information about channel quality – however...
- Amplitude response and group delay can still used to align a modulator or transmitter or determine where a fault may be present
- A in band frequency response and Group delay spectrum are valuable tools to evaluate the characteristics of an 8VSB signal
  - Shoulder attenuation
  - Amplitude frequency response
  - Pilot carrier amplitude

Explanation of Key Measurements

Amplitude Frequency Response

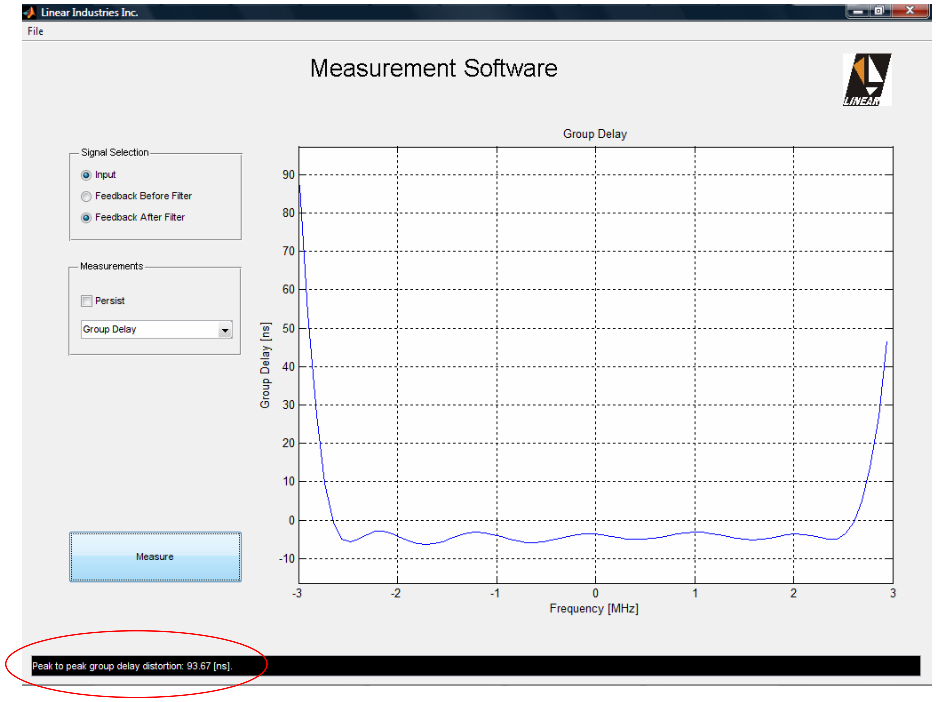


Frequency Response

- This measurement will show the in-band frequency response of the device under test (DUT). This measurement can be used to measure amplitude versus frequency distortions of such devices as amplifiers, combiners, couplers, filters and feedback systems.
- **Peak to peak frequency response distortion:** difference in amplitude in [dB] (p-p). Ideal response should be less than 1.5[dB].

Explanation of Key Measurements

Group Delay



Group Delay

- This measurement will show the in-band Group delay response of the device under test (DUT). This measurement can be used for linear distortion of devices such as combiners, feedback circuits and filtering networks. Typically most linear distortion is caused by the output mask filter and therefore the measurement should be taken after filter
- **Peak to peak group delay:** difference in the delay in [dB] (p-p). Ideal delay should be less than 150[nS].

Explanation of Key Measurements

Shoulder Measurement via the Power Spectrum

• The DTV emission mask was adopted in FCC Memo O/R requires that:

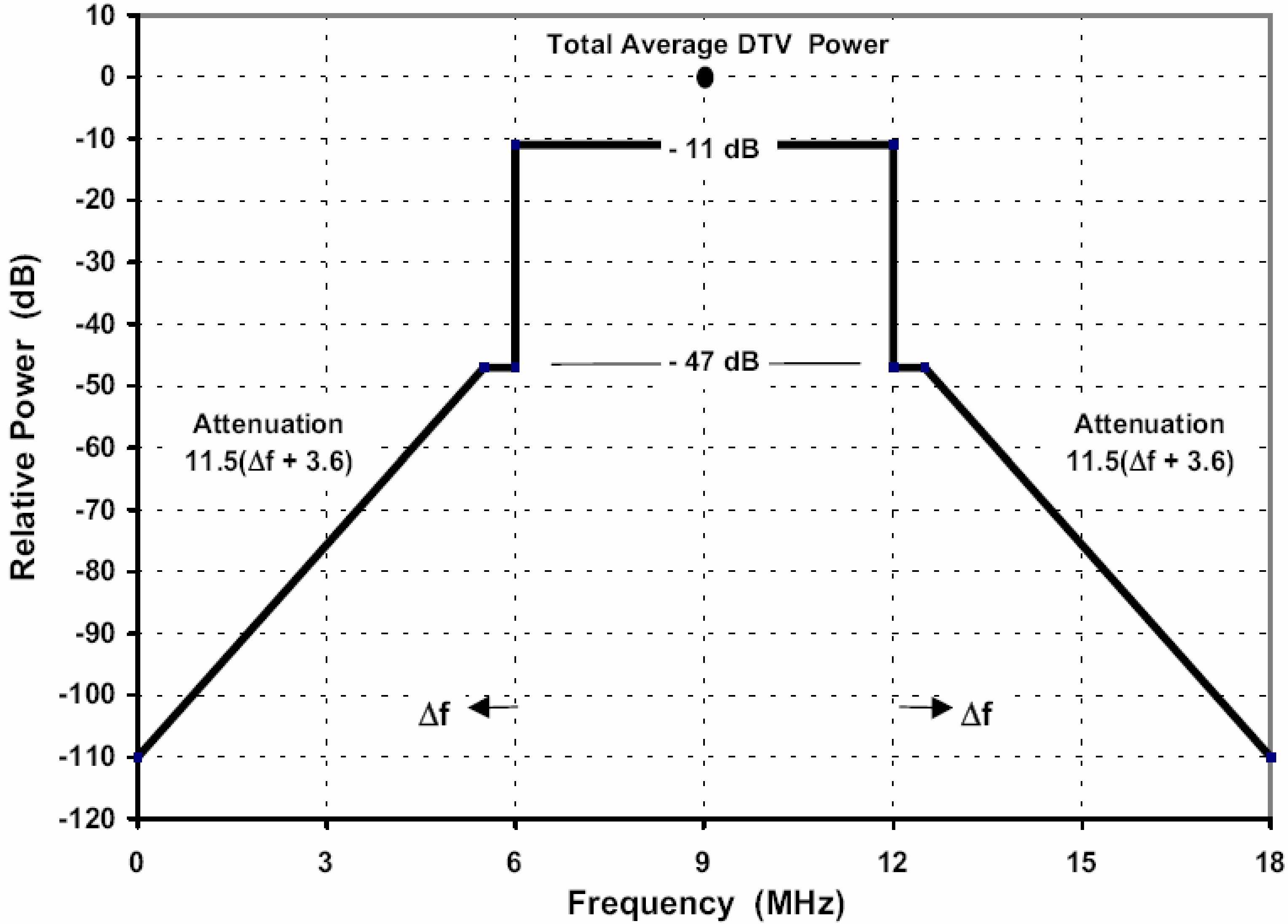
• In the first <u>500 kHz</u> from the authorized channel edge, transmitter emissions must be attenuated no less than <u>47 dB</u> below the average transmitted power;

• More than **6 MHz** from the channel edge, emissions must be attenuated no less than <u>110 dB</u> below the average transmitted power;

• At any frequency between 0.5 and 6 MHz from the channel edge, emissions must be attenuated no less than the value determined by the following formula: Attenuation in dB = 11.5 (Δ f + 3.6) where Δ f = frequency difference in MHz from the edge of the channel

Explanation of Key Measurements

Power Spectrum Density



Explanation of Key Measurements

Linear Industries Inc.

File

Measurement Software

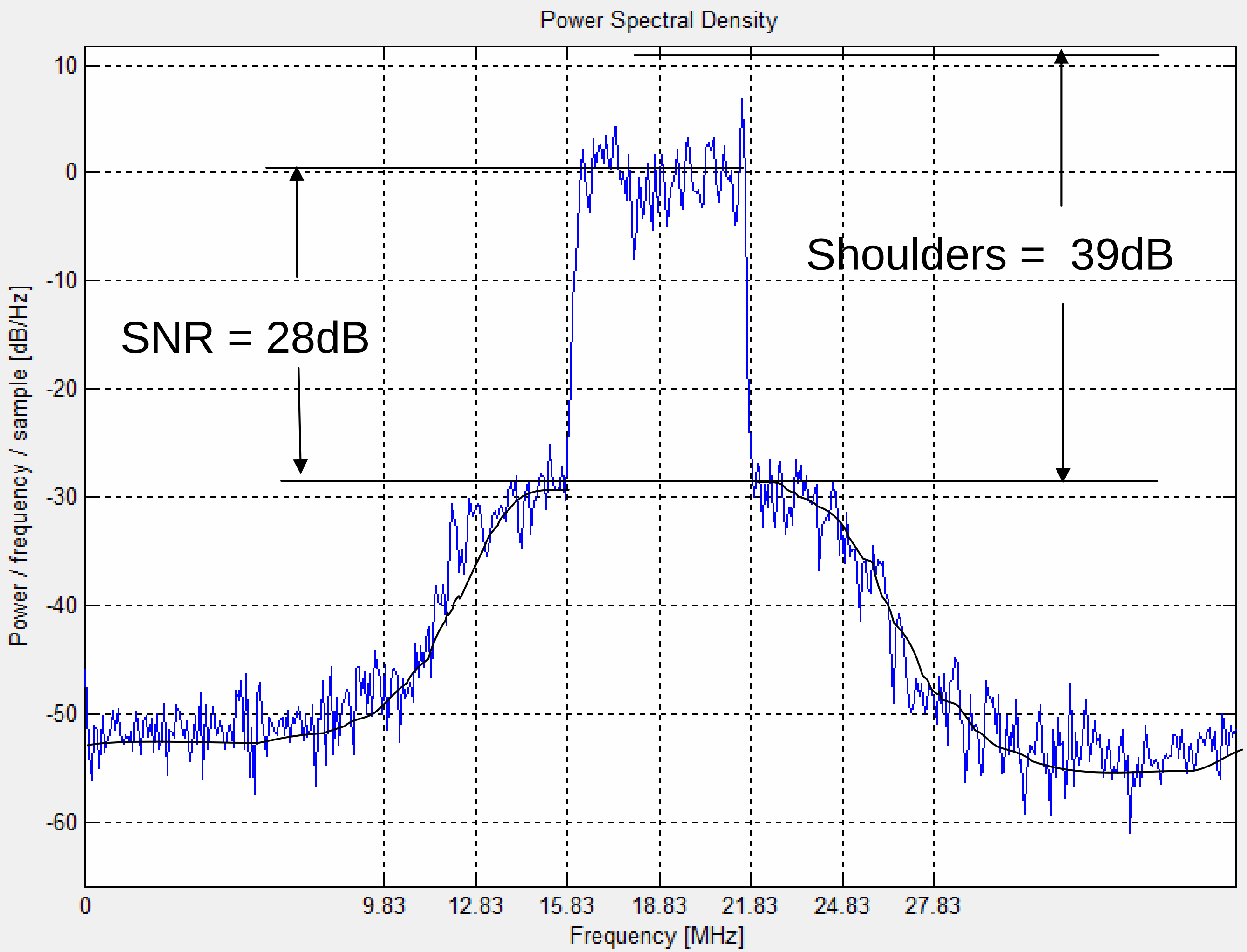
Power Spectrum Density

Signal Selection
- Input
- Feedback Before Filter
- Feedback After Filter

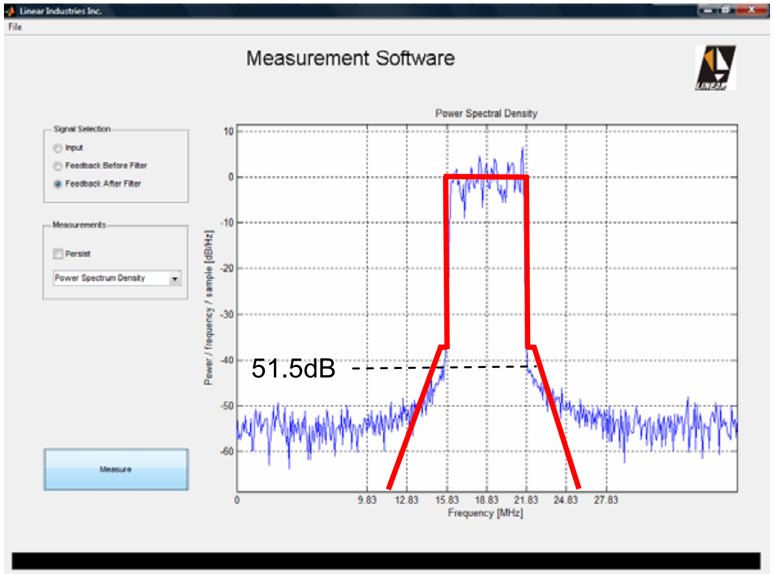
Measurements
- Persist

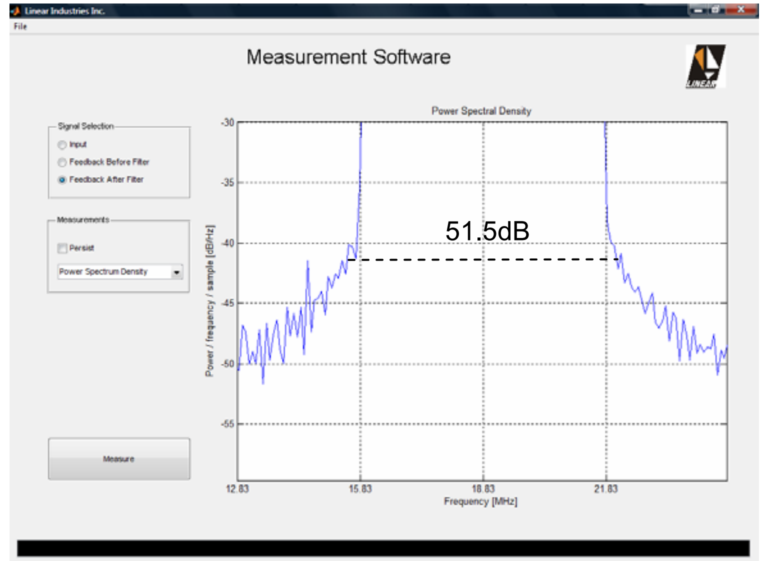
Power Spectrum Density

Measure



Power Spectrum Density measurement



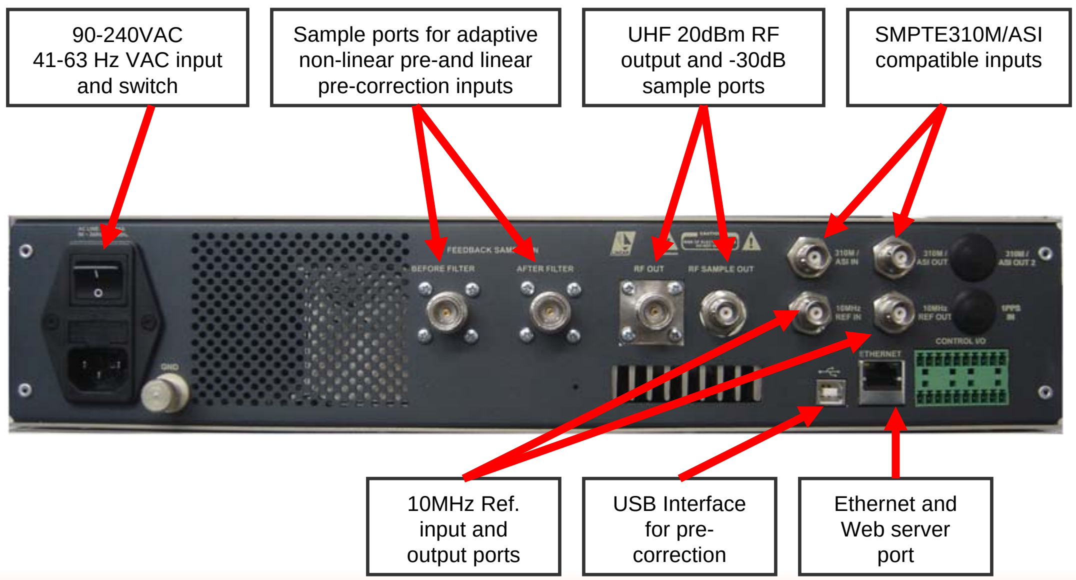


Power Spectrum Density

- This is a spectral analysis using the Power Spectrum Density estimation of the output signal. The in-band signal is normalized to be 0 [dB] point. The shoulders can be measured at +/- 3MHz from the authorized channel edges. The Average power measured in the first 500kHz must be less than -47dB with respect to -11dB at 500kHz resolution.

2. Correction demonstration

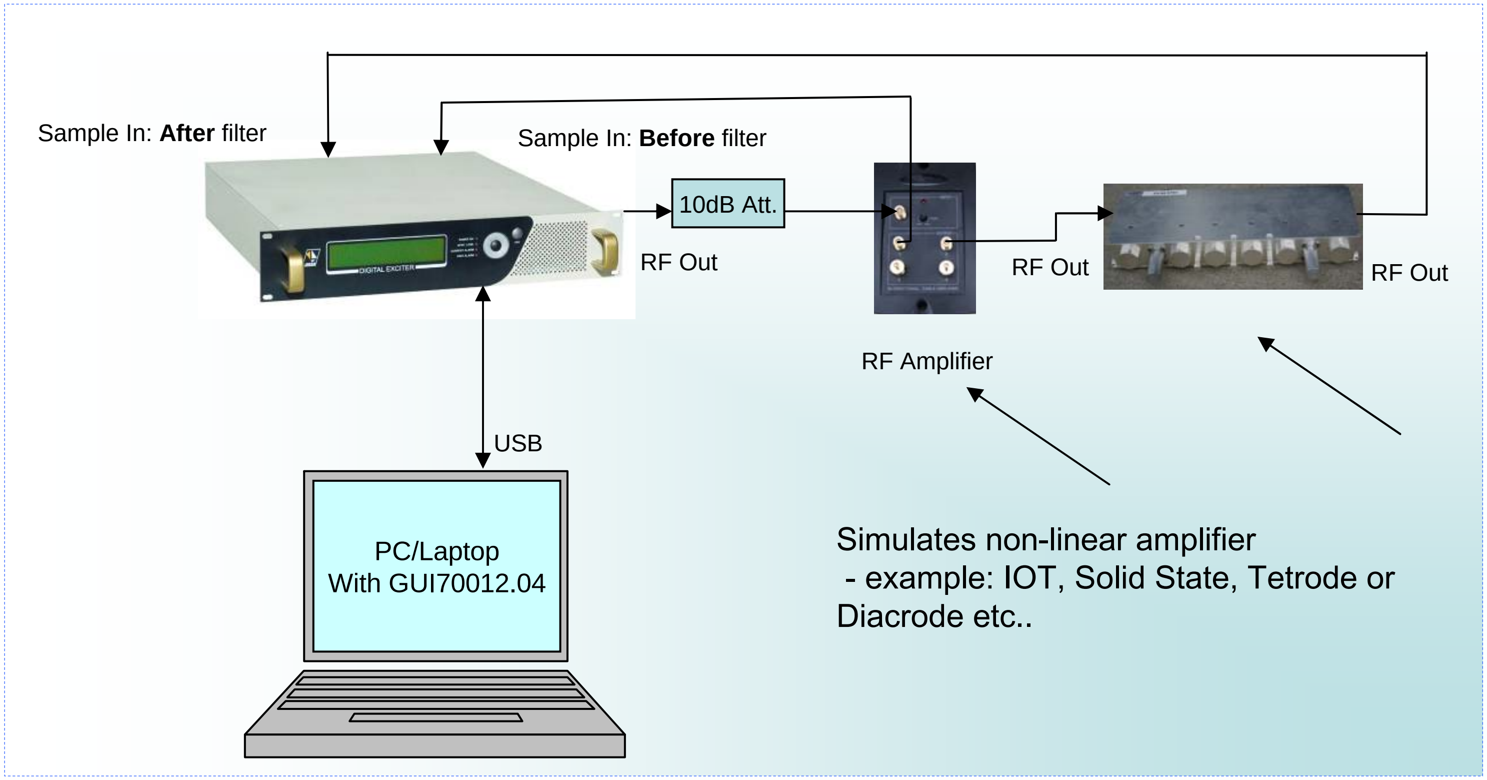
Digital Pre-Correction Demonstration



Digital Pre-Correction Demonstration

<u>Conditions</u>

Exciter Channel: 44
RF Output: +1dBm
Amplifier: RS Cable
ATSC Mask Filter channel 44
Laptop PC with Windows Vista and GUI7xxx.xx software



Digital Pre-Correction Demonstration

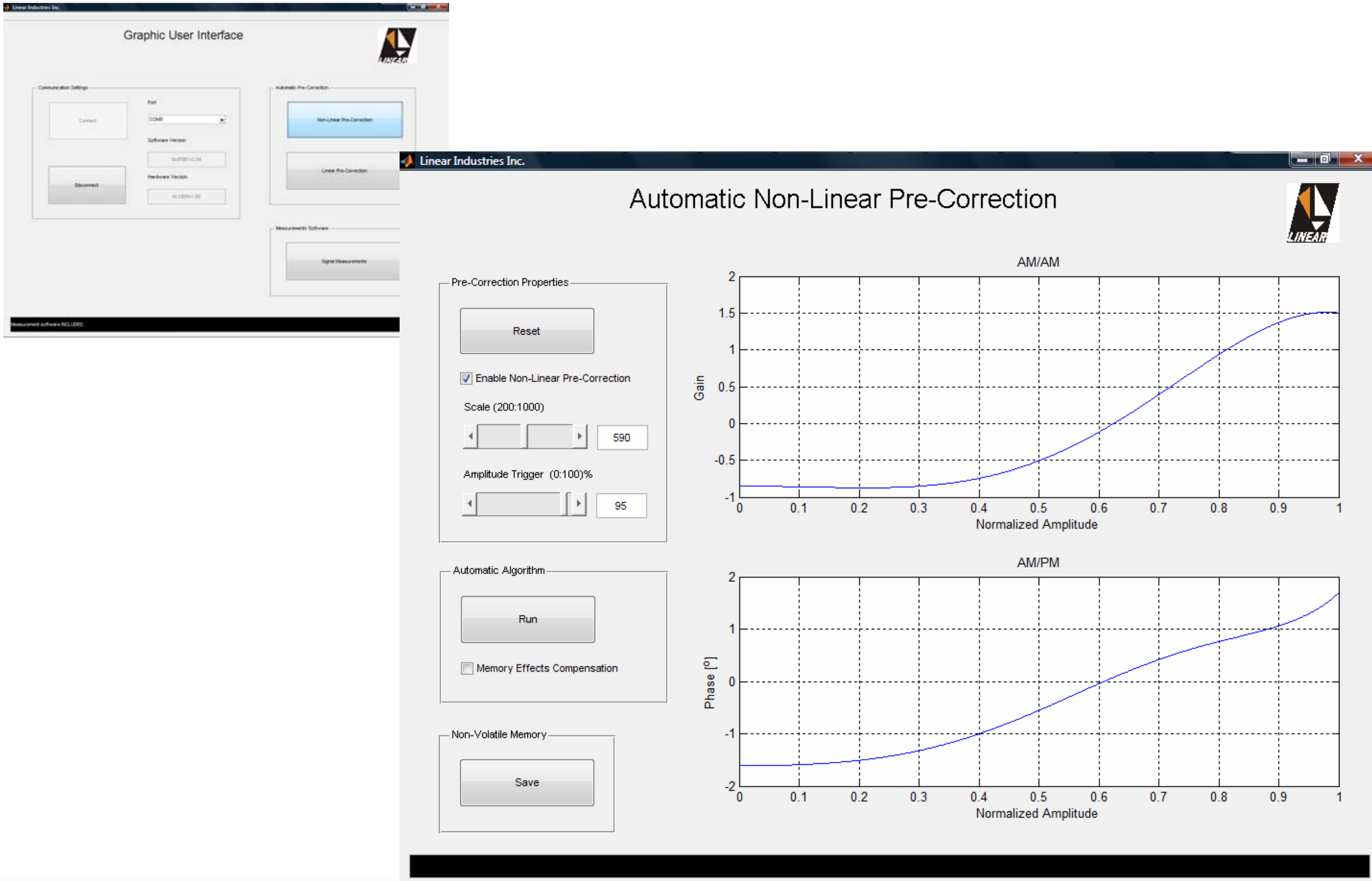
Amplifier Performance @ min. and Max. gain

Measurement		@ min. Gain	@ max. Gain	Diff.
Compression	dB	0.54	1.96	-1.42
Amplitude Distortion	dB	0.54	3.07	-2.53
Phase Distortion	Degrees	1.62	3.79	-2.17
PAPR Difference	dB	0.21	1.92	-1.71
MER	dB	33	26	-7
Frequency Response	dB	0.93	2.03	-1.1
Group Delay	nS	121	224*	-103
Shoulder Levels	dB	47	39	-8

* After MASK filter

Digital Pre-Correction Demonstration

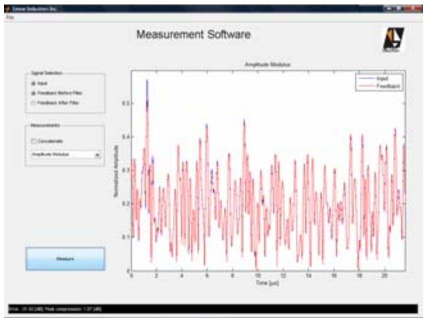
Run non-linear correction ("at the push of a button")



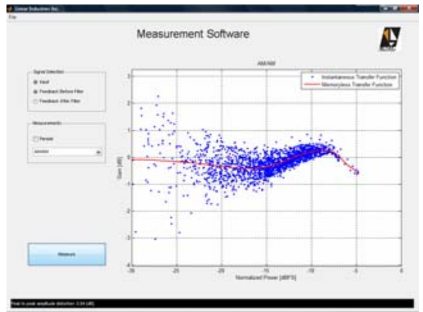
Digital Pre-Correction Demonstration

Performance before filter after non-linear correction

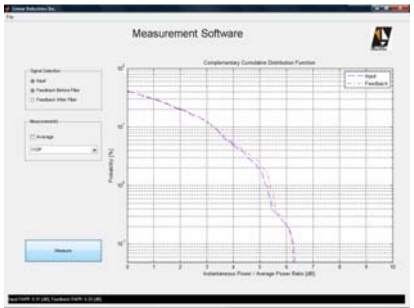
0.68dB compression



0.83dB amplitude distortion

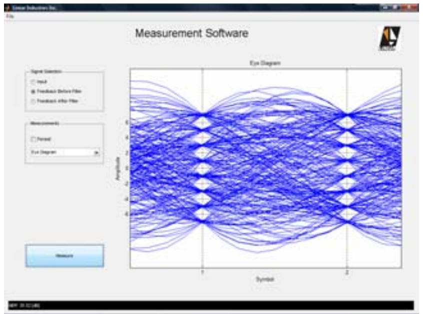


6.31/6.25dB PAPR

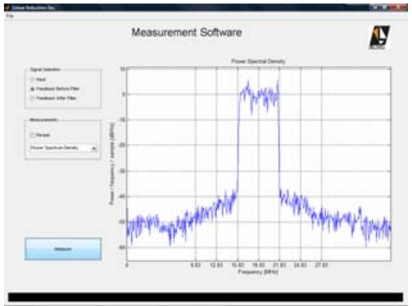


35.86dB MER

35.86dB MER



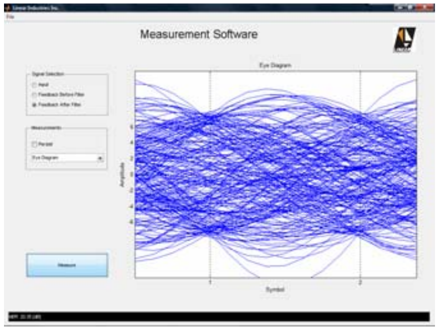
48dB Shoulders



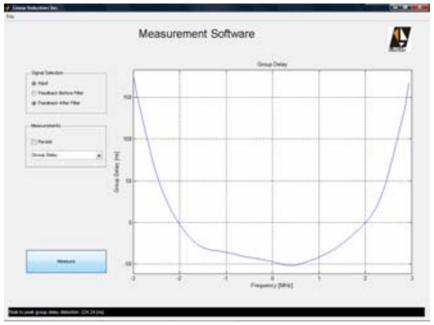
Digital Pre-Correction Demonstration

Performance after filter without linear correction

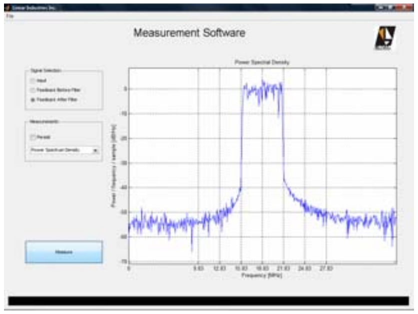
20.35 MER



224nS Group Delay

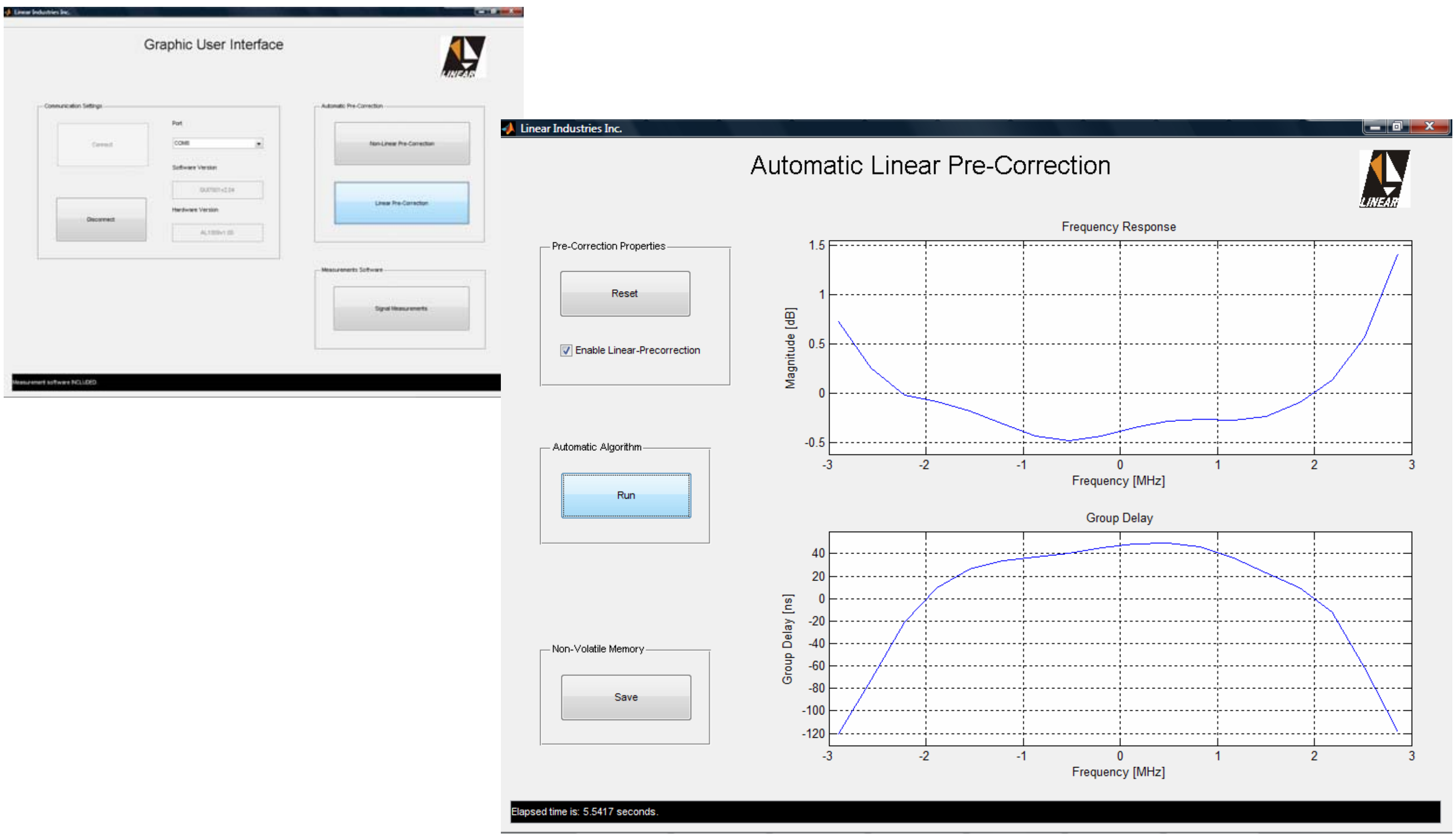


48dB Shoulders



Digital Pre-Correction Demonstration

“Run” linear correction (“at the push of a button”)



▶ *lin·e·ar – direct, to the point; advanced technology, cost-efficient economics.*

~ *Delineation - clarity, distinctness, exactness*

Digital Pre-Correction Demonstration

Final Performance results

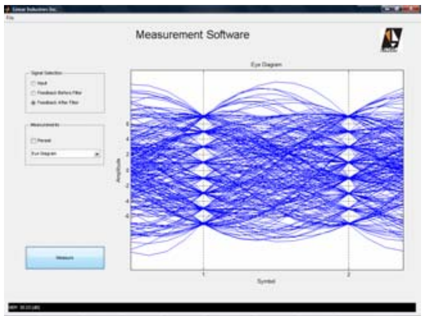
Measurement		@ max. Gain Before Correction	@ max. Gain After Correction	Improvement.
Compression	dB	1.96	0.32	1.64
Amplitude Distortion	dB	3.07	0.4	2.53
Phase Distortion	Deg.	3.79	0.51	3.28
PAPR Difference	dB	1.92	0.24	1.68
MER	dB	26	38	12
Frequency Response	dB	2.03	0.6	1.43
Group Delay	nS	224*	79	145
Shoulder Levels	dB	39	51	12

* After MASK filter

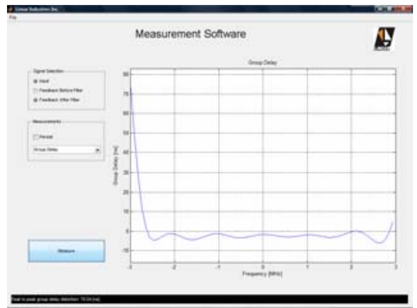
Digital Pre-Correction Demonstration

Final Performance results

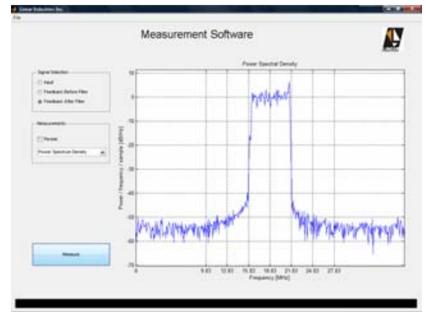
38.03dB MER



79nS Group Delay



51dB Shoulders



Summary

- With automatic correction almost any OEM transmitter and any OEM filter can be corrected to meet the FCC recommended performance
- Shoulders of 50+ dB and MER of 36+ dB obtainable (well within spec!)
- Not necessary to spend $50,000+ on an ATSC automatic correcting exciter
- One product corrects, monitors and measures the performance of any the transmitter for less than $25k*
- Low power solid state transmitters can be upgraded to digital for less than $10k*

*price exclusive of taxes, shipping and handling. Additional options available

AT7001

AT7001

Thank you for your attention

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