Linear Industries, Inc.

GUI7001 Software User Manual

For the AT7001 Digital Exciter

Rev. E – October 2009

Revision History

REV	DESCRIPTION	DATE	BY
A	Initial Version	2008/10/08	Henry Douglas
B	Udated to new non-linear correction algorithm	2009/02/02	Henry Douglas
C	Crest Factor Reduction, Type A and Type B Models	2009/07/27	Henry Douglas
D	New layout, CCDF description correction	2009/09/09	Henry Douglas
E	Connection message changed	2009/10/19	Henry Douglas

How to Contact Linear

LINEAR INDUSTRIES INC. – NORTH AMERICA DIVISION

2531 Technology Drive

Suite 310

Elgin, IL 60124

Web site: www.linear-tv.com

Phone: (847) 428-5793

Toll Free: (847) 428-5793

Fax: (847) 428-5785

About this document

 *Indicates a hint.*

 *Indicates important information.*

1 Introduction

GUI7001 is the software developed by Linear Industries Inc. and is used to perform non-linear and linear pre-correction and signal measurements with the AT7001 ATSC 8VSB digital exciter.

2 Installation

System Requirements for Windows:

Table 1 – Minimum System Requirements.

Operating Systems	*Processors*	*Disk Space*	*RAM*
Windows XP (Service Pack 2 or 3) Windows Server 2003 (Service Pack 2 or R2) Windows Vista (Service Pack 1) Windows Server 2008	Intel Pentium (Pentium 4 and above) Intel Celeron** Intel Xeon Intel Core AMD Athlon 64** AMD Opteron AMD Sempron	466 MB	1024 MB (2048 MB recommended)

To install MCR perform the following steps:

1. Install the MATLAB COMPONENT RUNTIME. Execute the **MCRInstaller.exe** file located in the **MATLAB Component Runtime** folder.
2. Install the USB Driver. Execute the **CDM 2.04.06.exe** file located in the **USB Driver folder**. This is a Virtual COM Port driver Microsoft WHQL certified and compatible with the following operating systems:

- Windows Server 2008
- Windows Server 2008 x64
- Windows Vista
- Windows Vista x64
- Windows XP
- Windows XP x64
- Windows 2000
- Windows Server 2003
- Windows Server 2003 x64

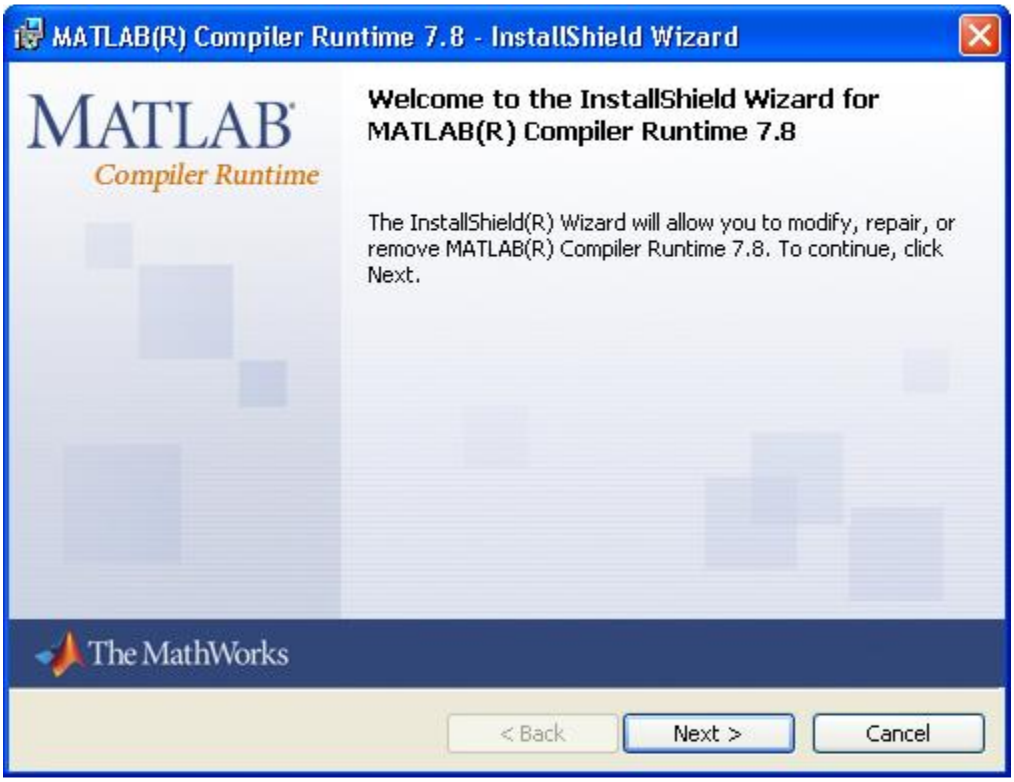

Figure 1 – MATLAB Component Runtime Installation Window.

3 Operation

Before running the software, be certain that the AT7001 is on and USB cable is connected between the exciter and PC.

☞ *The exciter USB Port is located at the rear panel.*

Run the executable file **GUI7001vXXX.exe** located in the **GUI7001** folder, where XXX indicates the version. The main screen will appear as follows.

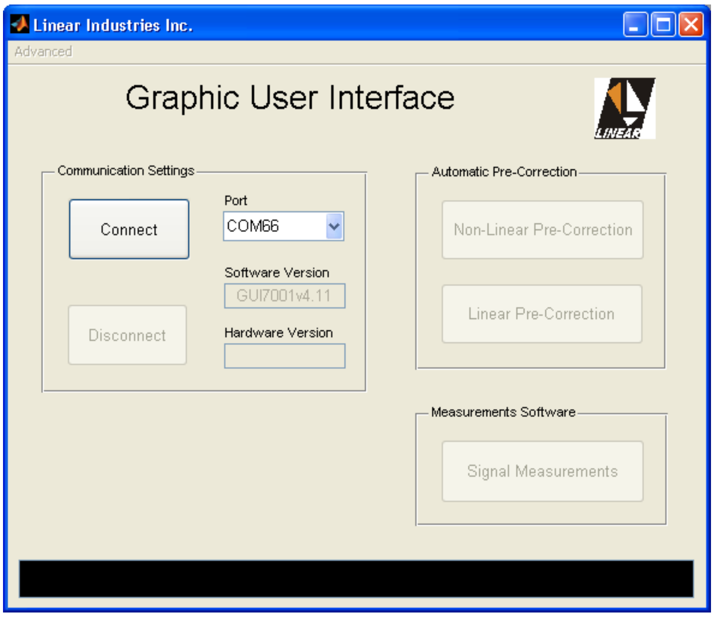

Figure 2 – GUI Software Main Window.

Choose the correct Serial **Port** number and Click on **Connect**. If the communication is ok, the information bar displays: *"Successfully Connected."* and **Hardware Version** Text Box is updated.

The Serial Port number may vary between computers.

All features in this software are optional. The prompt screen will show which options are included, which are not.

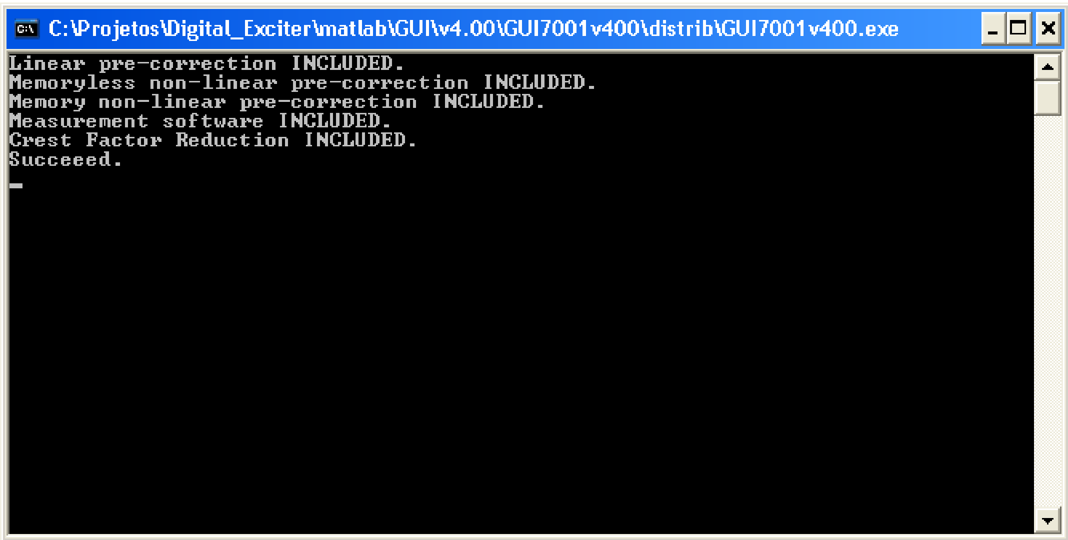

Figure 3 – Prompt Window.

If an option is included, the corresponding button is enabled.

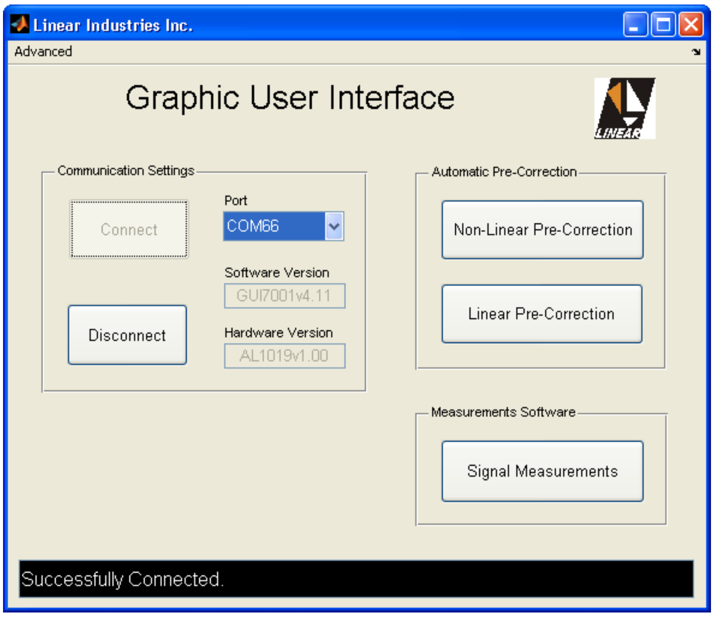

Figure 4 – AT7001 connected with all options enabled.

3.1 Non-Linear Pre-Correction

This is the process is used to compensate for the power amplifier non-linearity, in order to reduce the intermodulation at the output signal and thus improve PA efficiency. With the automatic non-linear digital pre-correction the PA linearity is improved and extended so that the PA can be operated at higher power. This means that a lower-power lower-cost linearized PA can be used in place of a higher-power higher-cost PA. Furthermore, the linearized PA operates more efficiently since it is operated closer to saturation. The benefits are compounded because a lower-power PA operating more efficiently consumes substantially less power than an inefficient higher-power PA.

When the Non-Linear Pre-Correction screen is opened, the software read and display the pre-correction curves stored on the non-volatile memory. The Memory Effects Compensation checkbox is not going to be enabled if this option is not included.

The Figure 5 shows the non-linear pre-correction main window.

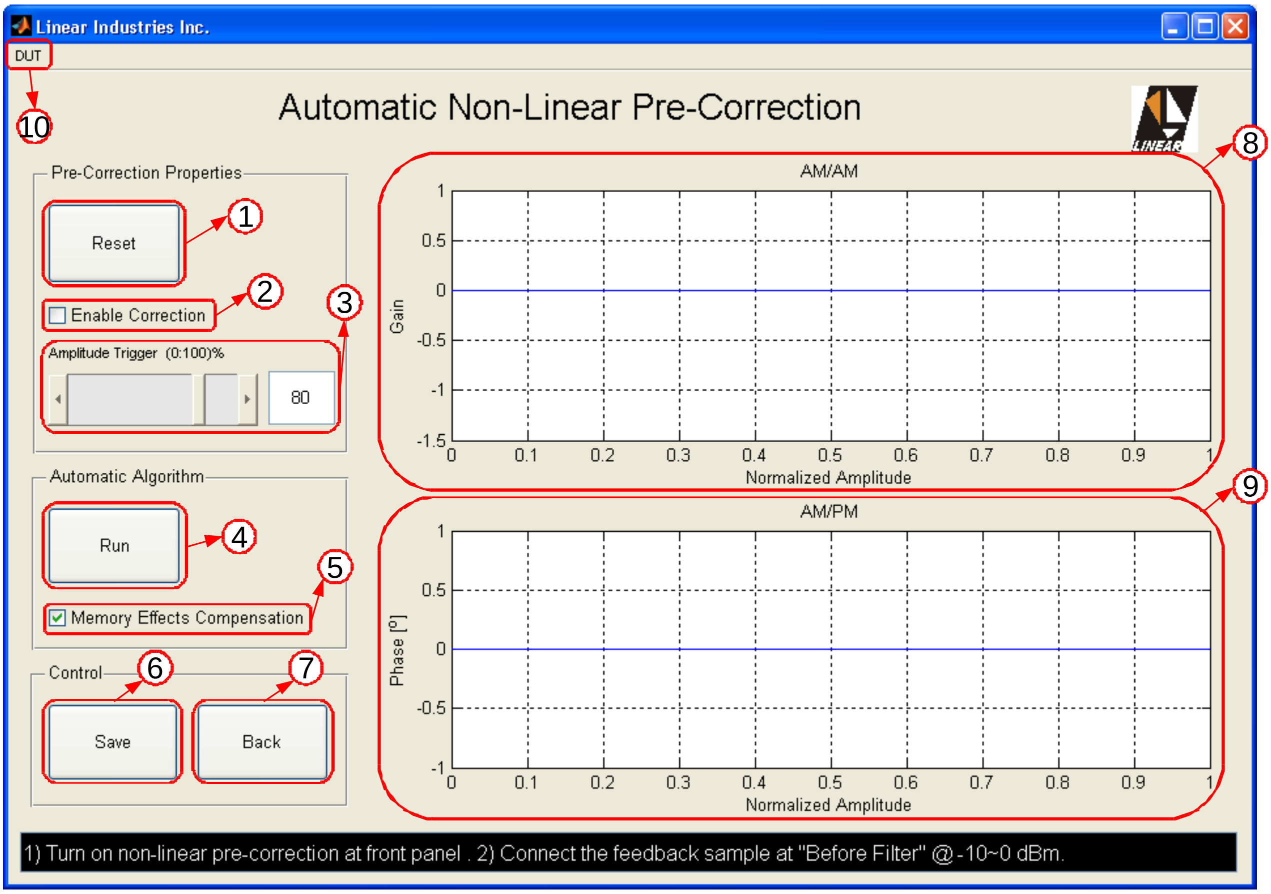

Figure 5 – Non-Linear Pre-Correction Window.

1. **Reset** – Download linear LUTs (Look-Up Tables). Used to bypass the corrections.
2. **Enable Non-Linear Pre-Correction** – Used to bypass the corrections or not without downloading linear LUTs.
3. **Amplitude Trigger** – Adjust the amount of peak power used to trigger the signal capture.
4. **Run** – Single iteration algorithm to compensate for non-linear distortions.
5. **Memory Effects Compensation** – Check this box to compensate for memory non-linear distortions. Uncheck to compesante for memoryless distortions only.
6. **Save** – Push this button to save the result on the non-volatile memory.
7. **Back** – Close current window.
8. **AM/AM** – Figure that shows the AM/AM behavior for the pre-correction.
9. **AM/PM** – Figure that shows the AM/PM behavior for the pre-correction.
10. **DUT** – If the Memory Non-Linear Pre-Correction option is enabled, two PA memory models may be selected: Type A and Type B. try both to compare which one fits better.

Memoryless vs. Memory Pre-Correction – Non-linearity is present when the AM/AM and AM/PM transfer functions are not straight lines, i.e., when the DUT (Device Under Test) has not a constant gain and a constant output phase delay with respect to the input amplitude. When such distortions don't change with time they're called memoryless non-linearity, or static non-linearity. It means the output signal at the present moment depends only on the input signal at the present moment also. However, some amplifiers present a dynamic behavior. Their AM/AM and AM/PM behavior change with time in a short time range (nano / micro seconds). It happens because the output signal at the present moment doesn't depend on the input signal at the present moment only, but also on its previous values. It generates more distortion, and a memoryless pre-corrector is not able to compensate for these memory effects.

This pre-correction is an automatic procedure. It uses a signal taken from a feedback sample located between the power amplifier output and the mask filter input. Perform the following steps to run the pre-correction:

1. Connect the AT7001 RF output to the amplifier to be linearized. If an output filter is used, run the algorithm with the filter connected to the amplifier because the reflected signal coming from the filter may change the amplifier behavior.
2. Set the desired power.
3. Take the **Before Filter Feedback Sample** and make sure is connected the AT7001 rear panel before running the pre-correction.

The coupler used for the sample must be directional, with isolation greater than 15 [dB] in order avoid miscalculation created by a reflected signal. The coupling port must have 50 [Ω] impedance in order to avoid a linear distortion in the feedback path. Also the coupling port response must be as flat as 0.3 [dB] in a 30 [MHz] range. The feedback sample level must be between -10 and 0 dBm. You can use the Signal Measurements software to check if the feedback sample is present.

4. Press **Reset** to bypass the last correction.
5. Check or uncheck the **Memory Effects Compensation** checkbox.
6. If **Memory Effects Compensation** is checked, select between **Type A** or **Type B** at the **DUT** menu. This option is not available if the memoryless pre-correction is selected (Memory Effects Compensation unchecked).

There differences between IOT and Solid State amplifiers regarding its memory non-linearities. As a rule of thumb Type A achieves better results for IOT amplifiers and Type B for Solid State.

7. Click on **Run**. The whole process consists of single iteration. After a few seconds the results will be applied automatically. Both algorithms works independently.

Crest Factor Reduction will be automatically bypassed when the algorithm is running.

8. Once the correction performed satisfied results, click on **Save** push-button to save the curves on the non-volatile memory.

After running the algorithm, the presence of unbalanced shoulders means that there are memory effects left.

9. If **Crest Factor Reduction** option is enabled, make it active on AT7001 front panel and set a reduction level. When the amplifier operates above the saturation level, i.e., clipping the signal peaks, the CFR may reduce intermodulation. However, be aware there is a trade-off between intermodulation reduction and MER using CFR. The more the reduction the worst the MER.

The next Figure shows typical results using the Memoryless and the Memory Pre-Correction. Usually the Memory correction achieves better results than the Mermoryless correction.

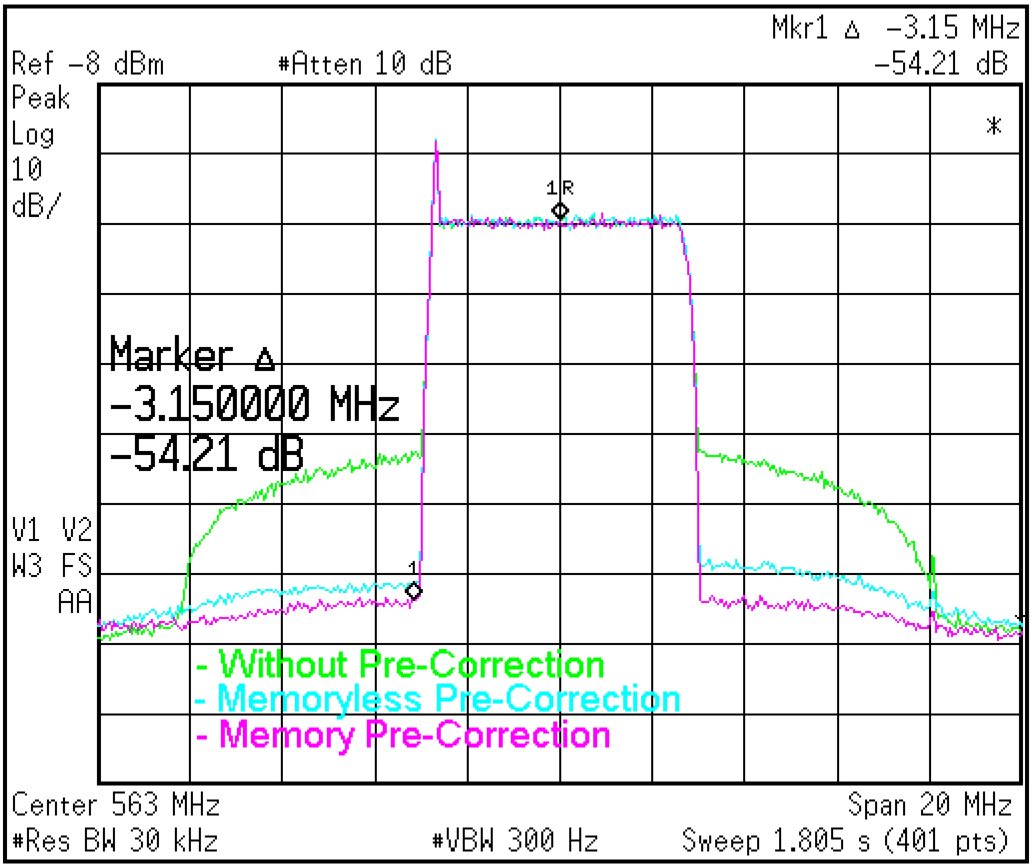

Figure 6 – Memoryless vs. Memory Comparison.

There is no guarantee to achieve better results using the Memory Pre-Correction. It depends on the amplifier to be linearized.

Figure 7 presents the corresponding curves used to compensate for the non-linearities of Figure 6. Those curves holds the inverse DUT characteristic, i.e., the necessary characteristic to compensate for the distortion.

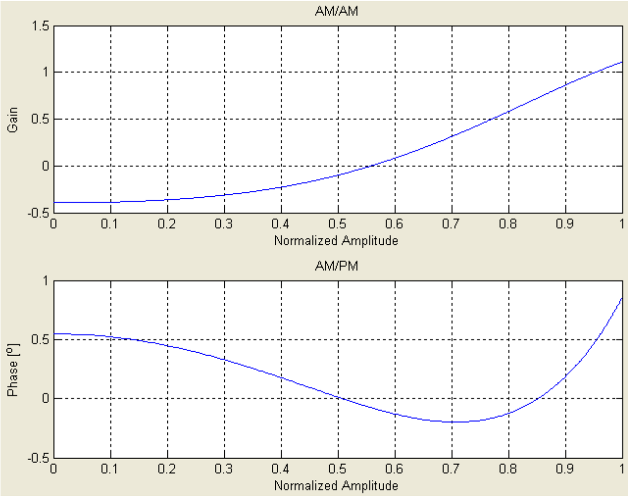

Figure 7a – Memoryless curves.

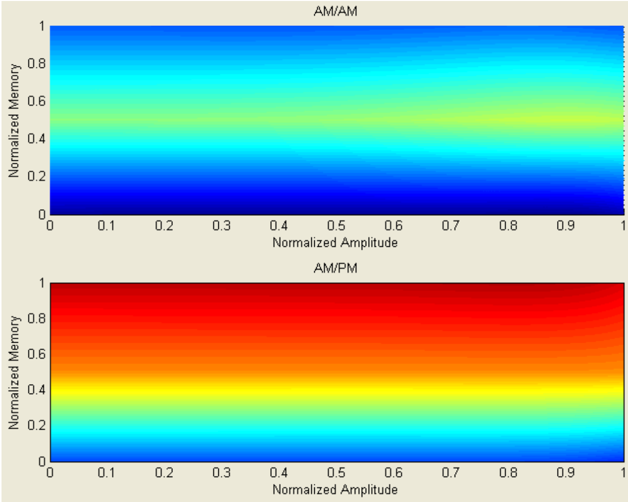

Figure 7b – Memory curves.

The memory curves (Figure 7b) are three dimensional plots, where the color means amplitude (in [dB]) for AM/AM and phase (in [°]) for AM/PM. A distortion is present when horizontal parallel lines present different colors.

When Crest Factor Reduction is used, intermodulation may be reduced. However there is a trade-off with three collateral effects:

- MER reduction
- Frequency response distortion
- Image frequency rejection

Figure 8 represents typical results when Crest Factor Reduction is used.

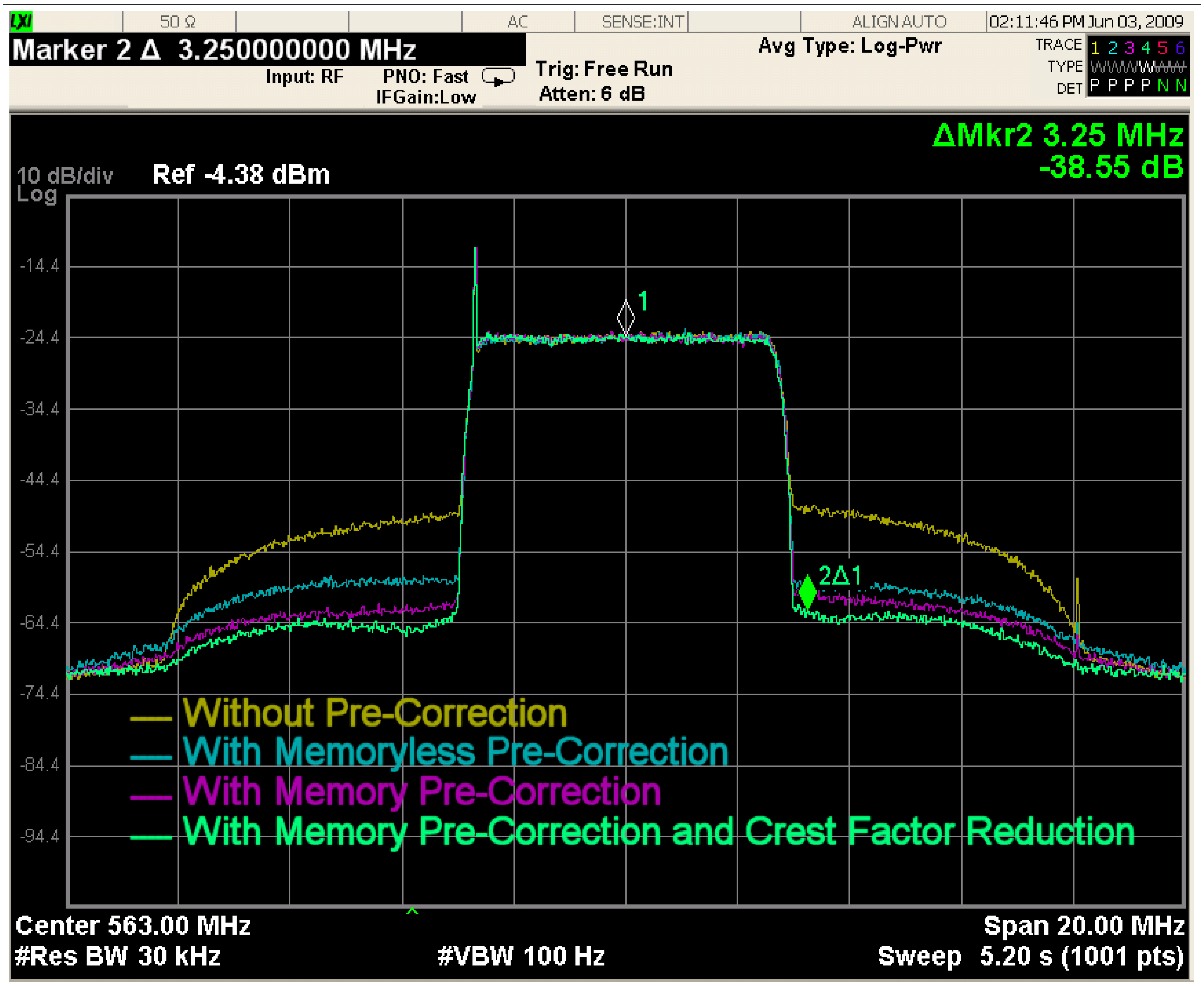

Figure 8 – Crest Factor Reduction.

3.2 Linear Pre-Correction

This is the process is used to compensate for linear distortions, for example not constant frequency response and group delay inside the channel. A Mask Filter is used at a transmitter output to limit the signal bandwidth and comply with an emission mask. The sharper it is the greater the group delay distortion. A small amount of attenuation is also introduced at channel edges. Linear pre-correction is used to compensate for these effects.

When the Linear Pre-Correction screen is opened, the software read and display the pre-correction curves stored on the non-volatile memory.

The next figure shows the linear pre-correction main window.

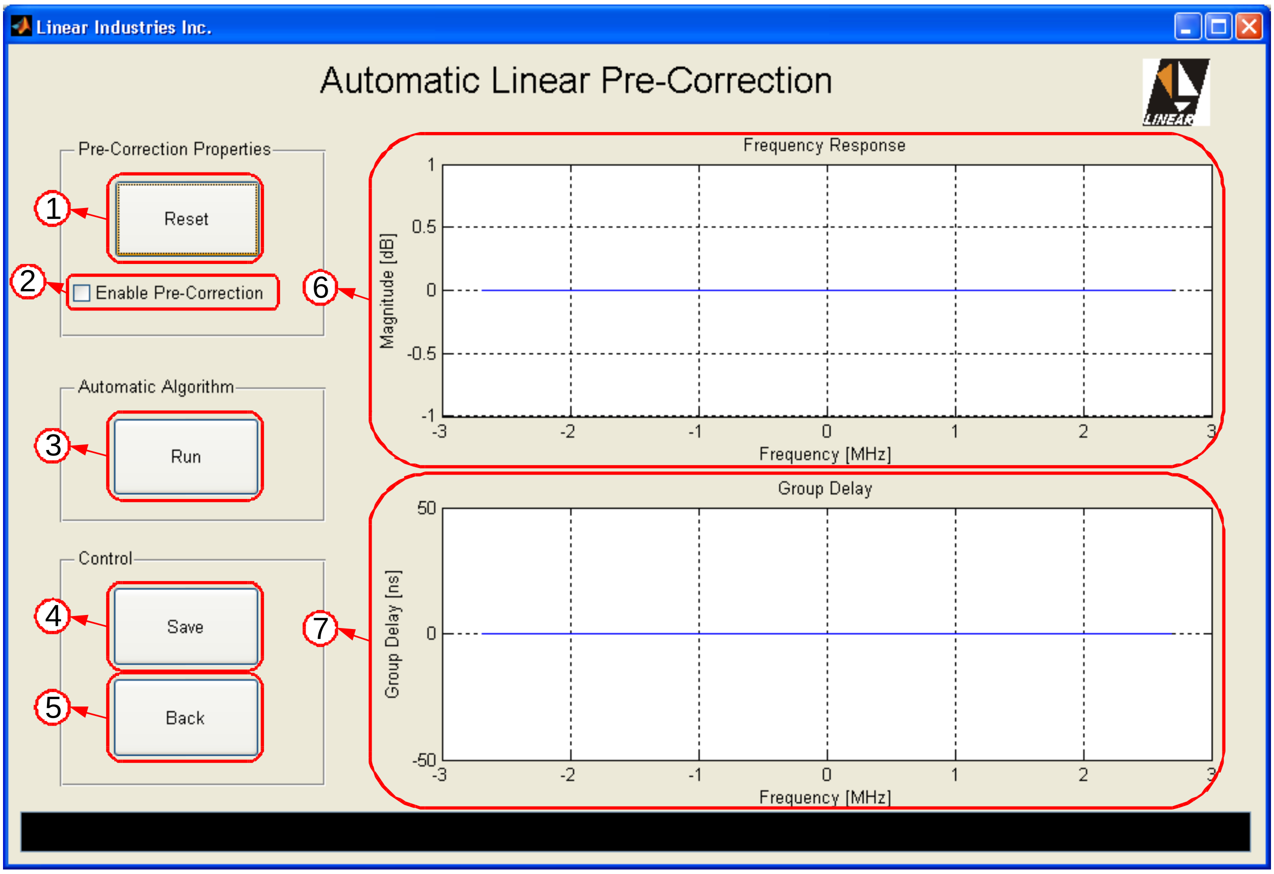

Figure 9 – Linear Pre-Correction Window.

1. **Reset** – Download an all-pass filter. Used to bypass the linear correction.
2. **Enable Linear Pre-Correction** – Used to bypass the linear correction or not without downloading an all-pass filter.
3. **Run** – Single iteration algorithm to compensate for linear distortions.
4. **Save** – Button used to save the result on the non-volatile memory.
5. **Back** – Close current window.
6. **Frequency Response** – Figure that shows the pre-correction frequency response, which is the inverse filter response.
7. **Group Delay** - Figure that shows the pre-correction group delay, which is the opposite filter group delay.

This pre-correction is an automatic procedure. It uses a signal taken from a feedback sample located at the mask filter output. Perform the following steps to run the pre-correction:

1. Connect the AT7001 RF output to the DUT.
1. Set the nominal power.
2. If an amplifier is used, run the non-linear pre-correction first, and then the linear pre-correction. This will make linear calculation more accurate.
3. Make sure the **After Filter Feedback Sample** is connected the AT7001 rear panel before running the pre-correction.

The coupler used for the sample must be directional, with an isolation greater than 15 [dB] in order avoid miscalculation created by a reflected signal. The coupling port must have a 50 [Ω] impedance in order to avoid a linear distortion in the feedback path. Also the coupling port response must be as flat as 0.5 [dB] in a 30 [MHz] range. The feedback sample level must be between -10 and 0 dBm. You can use the Signal Measurements software to check if the feedback sample is present.

4. Click on **Run**. The whole process consists of single iteration. After a few seconds, the results will be applied automatically.

Crest Factor Reduction will be automatically bypassed when the algorithm is running.

5. Once the correction achieves satisfying results, click on **Save** push-button to save the curves on the non-volatile memory.

   Figure 10 presents the corresponding curves used to compensate a mask filter.

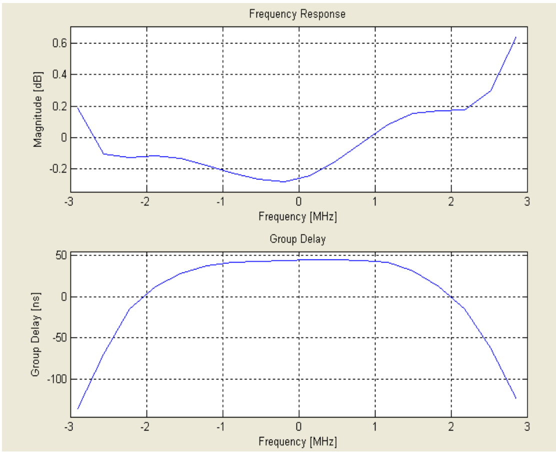

Figure 10 – Typical Linear Pre-Correction Curves.

3.3 Signal Measurements

This software is used to perform measurements at the signals generated by the AT7001 Digital Exciter. There are fourteen measurements avaiable.

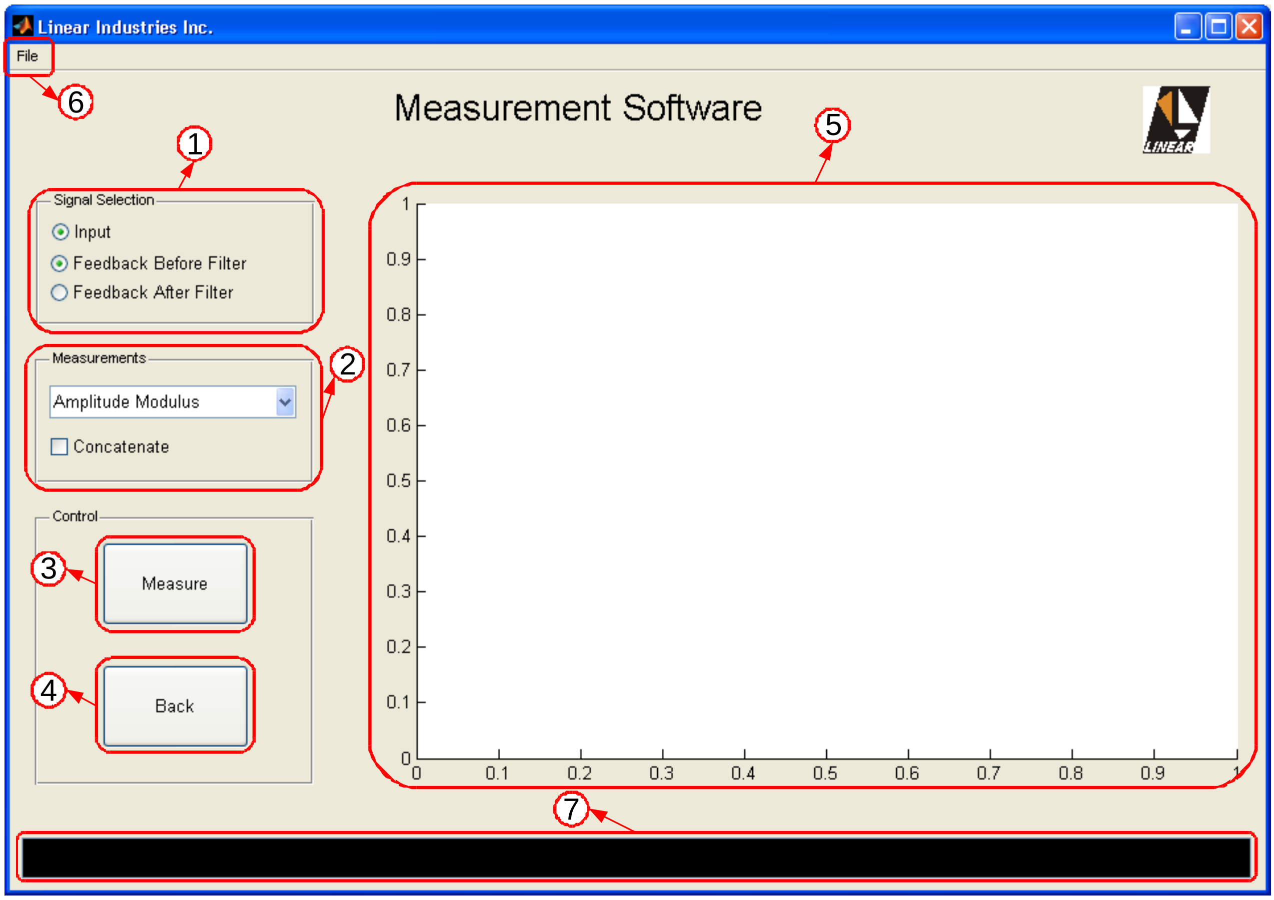

Figure 11 – Signal Measurements Window.

1. **Signal Selection** – Select which signal is going to be measured. "Input" is the signal at the DUT input, or the modulator output. The Input signal is always the reference. Both feedback samples are also available. Some measurements allow just one signal selection. In order to make a comparison, others allow two signals at the same time.
2. **Measurements** – This pop-up menu shows all fourteen measurements available. For each measurement there is an additional option like Concatenate, Persist, or Average the consecutive measurements.
3. **Measure Push-Button** – Click once to start measuring. Click again to stop.
4. **Back** – Close current window.
5. **Measurement Window** – This Figure shows the last active measurement.
6. **File => Export** – Use this option to export the measurement to one of the following formats:
   - .emf => Enhanced Metafile.
   - .eps => Encapsulated Postscript.
   - .jpeg => Joint Photographic Experts Group.
   - .pdf => Portable Document Format.
7. **Information Bar** – This bar shows additional information regarding the last measurement.

Amplitude Modulus – Shows the normalized complex envelope modulus for the Input and a Feedback signal, where $\sqrt{I^2(n)+Q^2(n)}$ is the modulus for a complex signal with real part $I(n)$ and imaginary part $Q(n)$.

It is useful to evaluate the signal compression caused by the amplifier non-linearity, as it gets close to the saturation region. Perform this measurement using the **Feedback Before Filter** sample. Figure 12 shows a signal that has been compressed at the saturation level and expanded at the turn-on region, typical in class AB amplifiers.

The information bar will show two additional important pieces of information:

- Error: Shows the Mean Squared Error between the Input and Feedback signals.
- Peak Compression: shows in [dB] how much the maximum peak found was compressed.

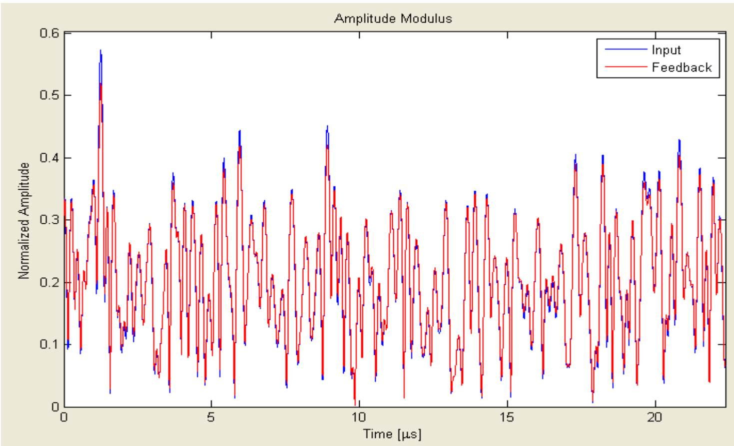

Figure 12 – Amplitude Modulus Measurement.

AM/AM – AM/AM stands for Amplitude Modulation / Amplitude Modulation, it represents the normalized output/input amplitude ratio (amplifier gain) in [dB] vs. normalized input amplitude in [dB] Full Scale. The blue points show the Instantaneous Transfer Function, as it has a dynamic behavior. Their spread characteristic is caused by noise and memory effects. The red line is the Memoryless Transfer Function that best fits the blue points.

This is a powerful tool to evaluate a power amplifier transfer function, and thus its linearity. Check how spread the blue points are in order to realize how much memory effects the amplifier has. Always perform this measurement using **Feedback Before Filter** sample.

The information bar will show the additional information:

- Peak to peak amplitude distortion: Shows the Memoryless Transfer Function peak to peak value.

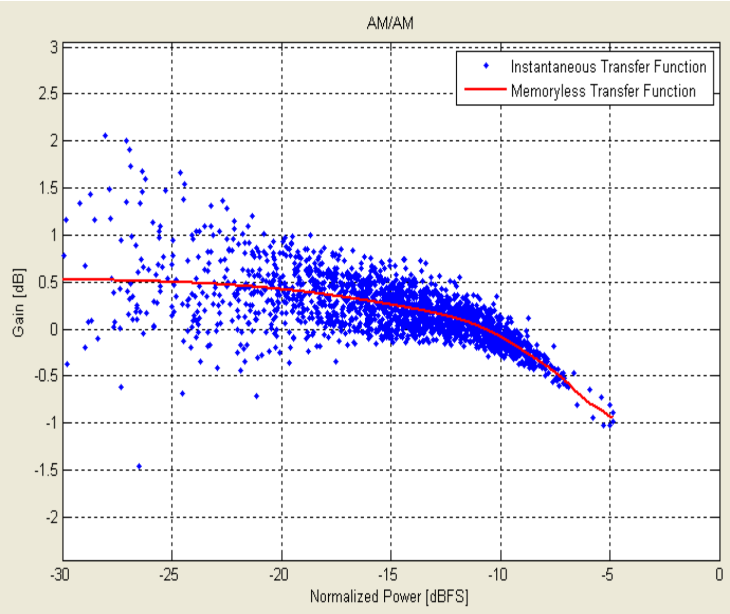

Figure 13 – AM/AM Measurement.

AM/PM – AM/PM stands for Amplitude Modulation / Phase Modulation, it represents the phase deviation in [°] vs. normalized input amplitude in [dB] Full Scale. The blue points show the Instantaneous Transfer Function, as it has a dynamic behavior. Their spread characteristic is caused by noise and memory effects. The red line is the Memoryless Transfer Function that best fits the blue points.

This is a powerful tool to evaluate a power amplifier transfer function, and thus its linearity. Check how spread the blue points are in order to realize how much memory effects the amplifier has. Always perform this measurement using **Feedback Before Filter** sample.

The information bar will show the additional information:

- Peak to peak amplitude distortion: Shows the Memoryless Transfer Function peak to peak value.

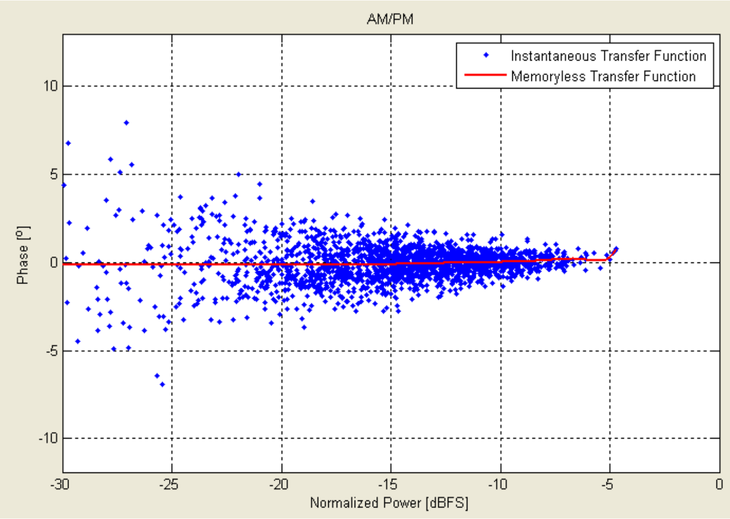

Figure 14 – AM/PM Measurement.

CCDF – CCDF stands for Complementary Cumulative Distribution Function. It represents the probability (vertical axis) of the Instantaneous Power be "x" [dB] above the average power, where "x" is the value in the horizontal axis. For example, suppose an amplifier is driving 1 [kW] into a dummy load, and the Feedback Sample was taken from its output. In the measurement below (Figure 15), the 0 [dB] point has a probability around 40 [%]. It means 40 [%] of time the Instantaneous power is above 1 [kW] (or 0 [dB]) and thus 60 [%] of time the Instantaneous power is below the average power (1 [kW]). Now another example: the 6 [dB] point for the Feedback signal (red dashed line), has a probability of 0.07 [%]. It means that 99.93 [%] of time, the Instantaneous Power is below 4 [kW] (6 [dB]), but for very few time, or 0.07 [%] of time, the amplifier will drive a power above 4[kW]. It is clear that the amplifier compressed the high amplitudes, because the red line is below the blue one.

Use this measurement to evaluate how much an amplifier has compressed or clipped a signal.

The information bar will show the additional information:

- PAPR: Stands for Peak to Average Power Ratio and represents the ratio between the maximum peak power found and the average power. Shown for both Input and Feedback signals.

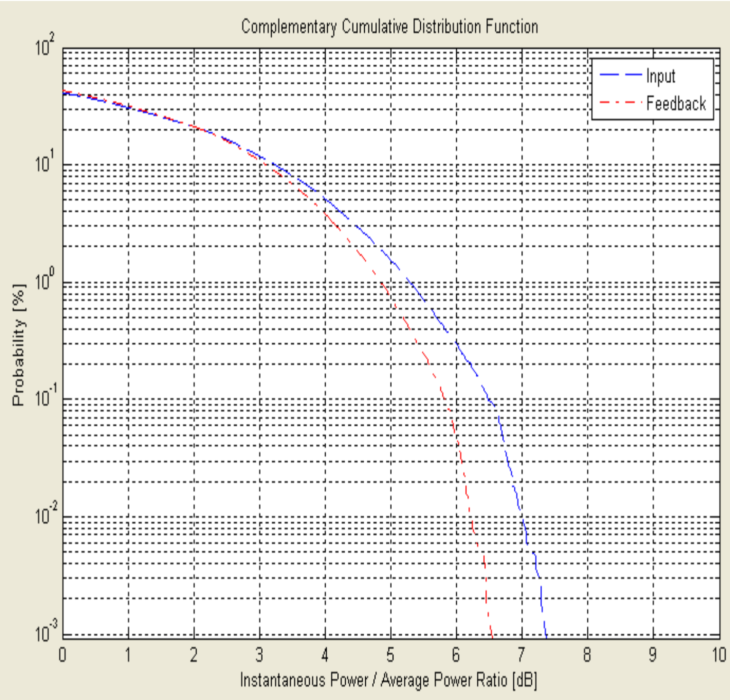

Figure 15 – CCDF Measurement.

Constellation – the constellation is a diagram of the sampled baseband modulating symbols, where the Cartesian plane is plotted by its real vs. imaginary part. The real part (In Phase) of those sampled symbols carry the transmitted information while the imaginary part (Quadrature) carry the necessary information to generate the vestigial side band. For 8VSB modulation, the eight regions represents the eight possible symbols, and the seven dashed lines indicates the decision threshold.

This measurement reflects the signal quality. Use it to realize non-linear, linear and amplitude distortions.

The information bar will show the additional information:

- MER: Modulation Error Rate. It is the mean squared error in [dB] considering the perfect symbol as the reference signal.

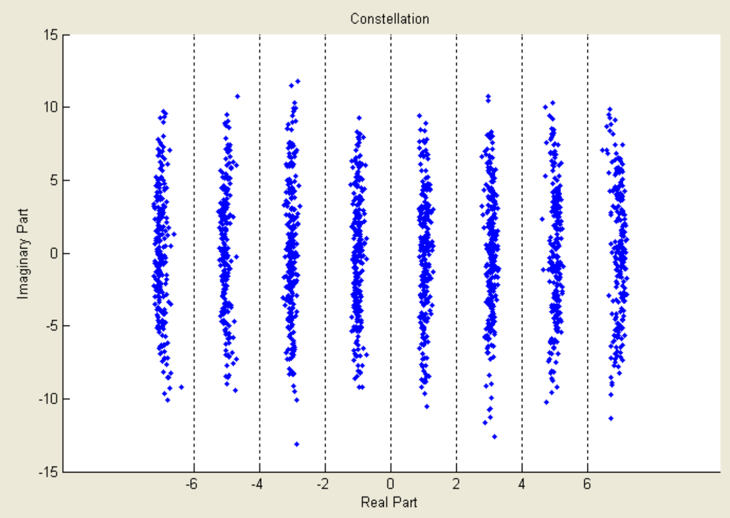

Figure 16 – Constellation Measurement.

Constellation Contour – the constellation is a diagram of the sampled baseband modulating symbols, where the Cartesian plan is plotted by its real vs. imaginary part. The real part (In Phase) of those sampled symbols carry the transmitted information while the imaginary part (Quadrature) carry the necessary information to generate the vestigial side band. For 8VSB modulation, the eight regions represents the eight possible symbols, and the seven dashed lines indicates the decision threshold. The Constellation Contour differs from the Constellation in the sense it shows probability regions for a demodulated symbol to fall in coded in colors. A red area means high probability, as the blue area means low probability.

This measurement reflects the signal quality. Use it to realize non-linear, linear and amplitude distortions.

The information bar will show the additional information:

- MER: Modulation Error Rate. It is the mean squared error in [dB] considering the perfect symbol as the reference signal.

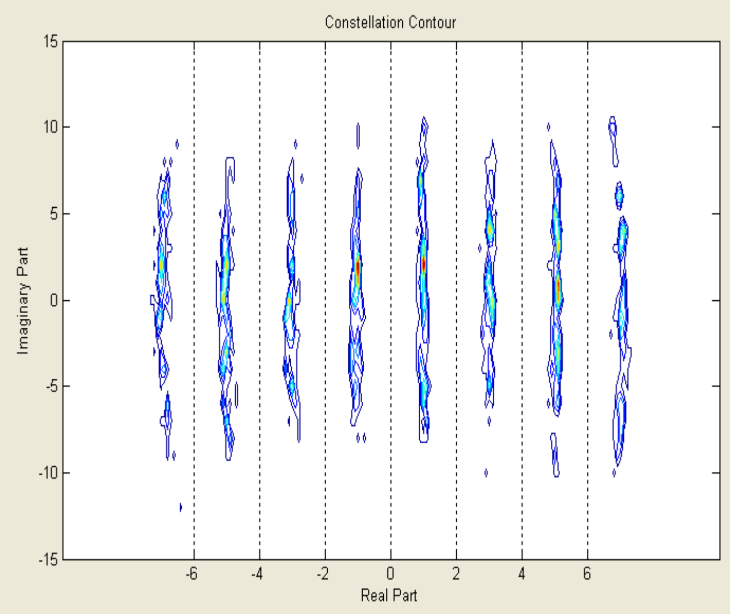

Figure 17 – Constellation Contour.

Eye Diagram – The Eye Diagram is the purely real modulating symbols filtered with a raised cosine filter and persisted with a symbol period multiple. The open eyes points indicates the exact moment for the receiver to sample and decide in order to extract the message. Eyes wide open are desired.

This measurement reflects the signal quality. Use it to realize non-linear, linear and amplitude distortions.

The information bar will show the additional information:

- MER: Modulation Error Rate. It is the mean squared error in [dB] considering the perfect symbol as the reference signal.

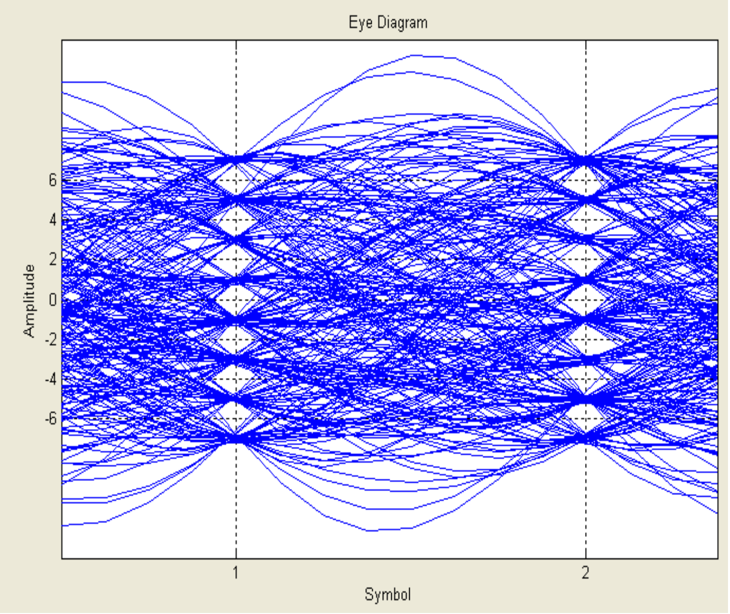

Figure 18 – Eye Diagram Measurement.

Frequency Response – This measurement will show the Frequency Response existent on your device under test, typically a filter. Use it to measure linear distortions.

The information bar will show the additional information:

- Peak to peak frequency response distortion: self explained.

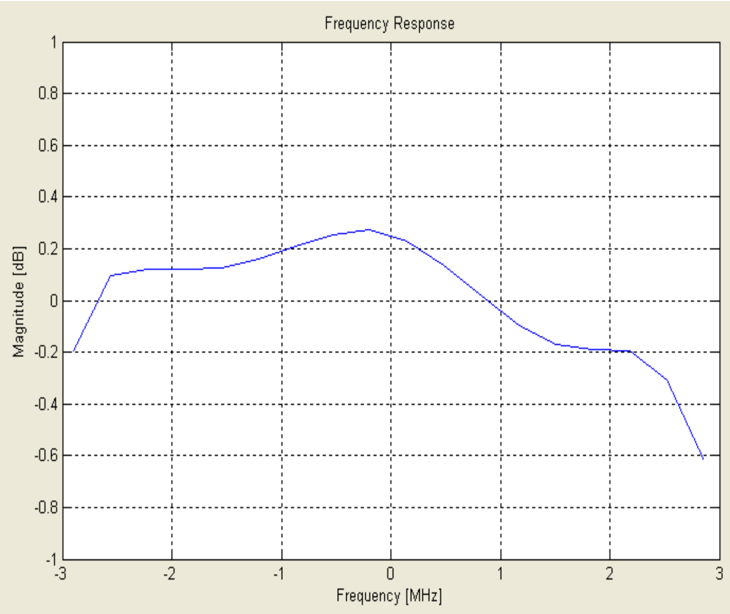

Figure 19 – Frequency Response Measurement.

 *Crest Factor Reduction will be automatically bypassed when this measurement is being performed.*

Group Delay – This measurement will show the Group Delay existent on your device under test, typically a filter. Use it to measure linear distortions.

The information bar will show the additional information:

- Peak to peak group delay distortion: self explained.

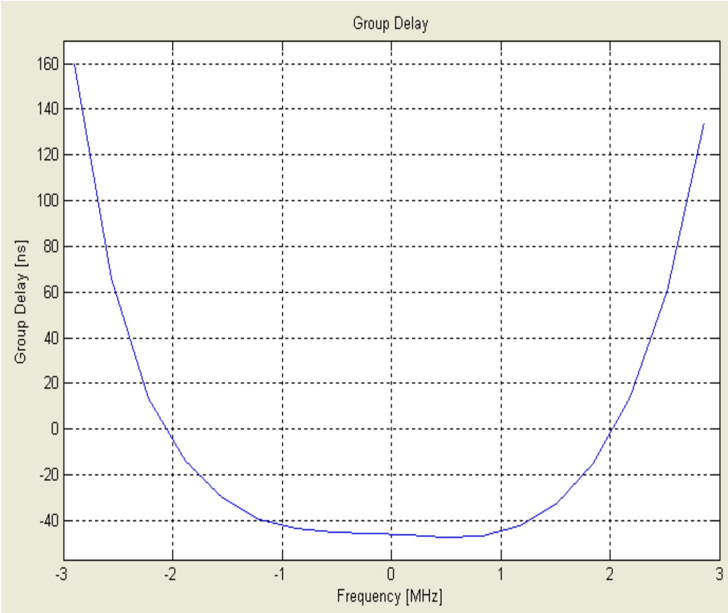

Figure 20 – Group Delay Measurement.

Crest Factor Reduction will be automatically bypassed when this measurement is being performed.

Power Spectrum Density – This is a spectral analysis using the Power Spectrum Density estimation of the IF signal. The in-band signal average power is normalized to be the 0 [dB] point.

The information bar will show the additional information:

- Shoulders attenuation @ -+ 3.25 [MHz]: shows the shoulder attenuation @ -+ 3.25 [MHz] from channel center frequency relative to the in-band average power with a 500 [kHz] equivalent resolution bandwidth.

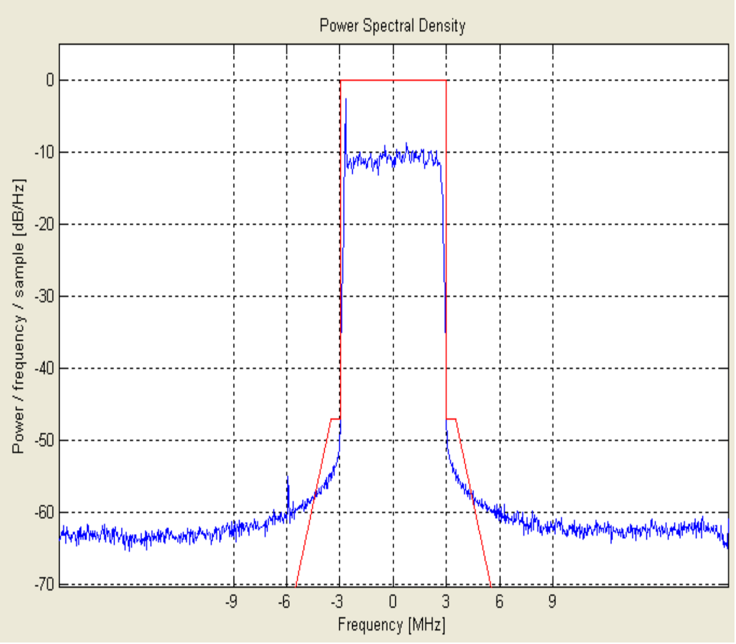

Figure 21 – Power Spectrum Density Measurement.

Symbols – This measurement represents the purely real demodulated symbols over time. Figure 22 shows the demodulated symbols after a mask filter without linear pre-corrections and then with. Straight indicates a high MER signal.

The information bar will show the additional information:

- MER: Modulation Error Rate. It is the mean squared error in [dB] considering the perfect symbol as the reference signal.

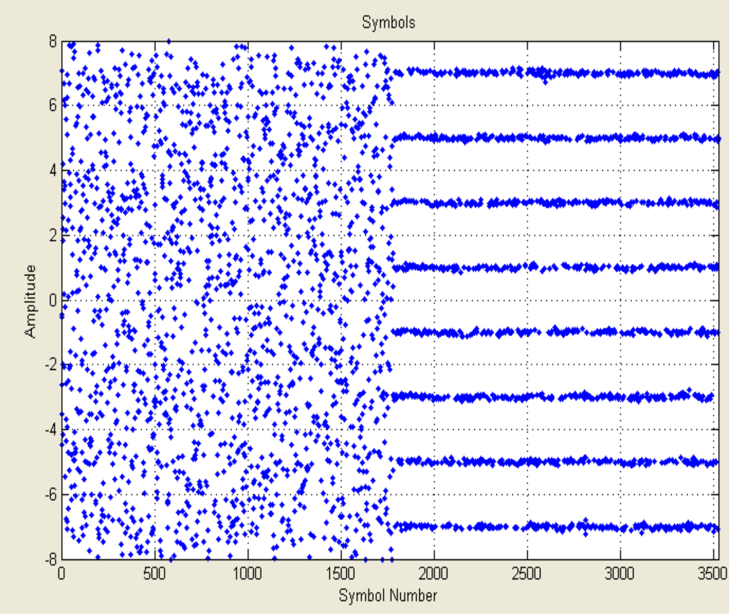

Figure 22 – Symbols Measurement.

Spectrogram – This is a three dimensional measurement representing the Power Density (Z axis) vs. Frequency (X axis) vs. Time (Y axis). The viewing angle can be rotate to any position.

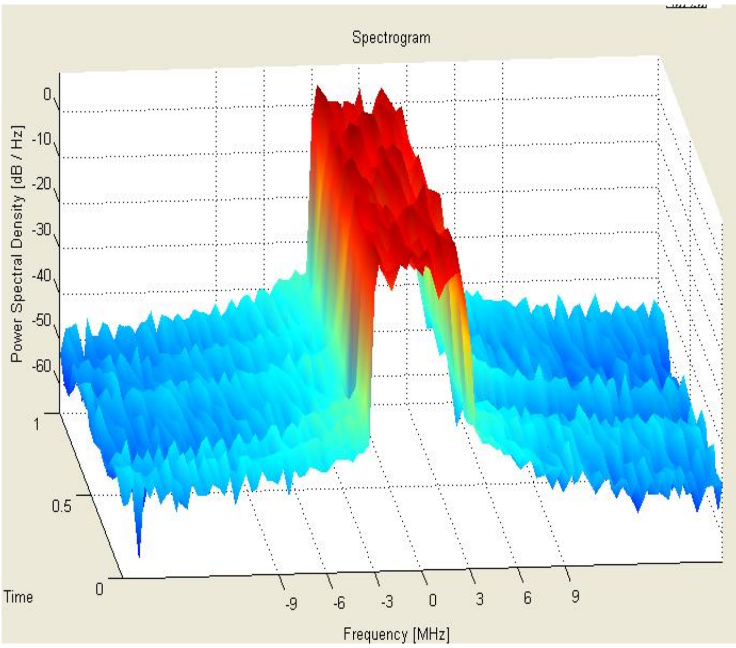

Figure 23 – Spectrogram Measurement.

Spectrogram Contour – That's the Spectrogram in the X (Frequency) – Y (Time) view, where the color gives the Power Density.

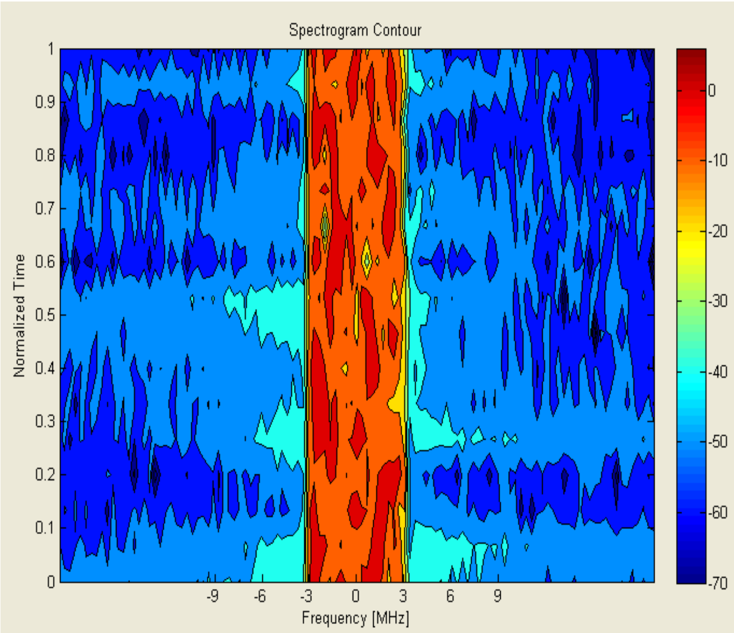

Figure 24 – Spectrogram Contour Measurement.

Time Domain – This measurement shows both input and feedback IF signals at the same time in a time domain.

The information bar will show two additional pieces of information:

- Error: Shows the Mean Squared Error between the Input and Feedback signals.

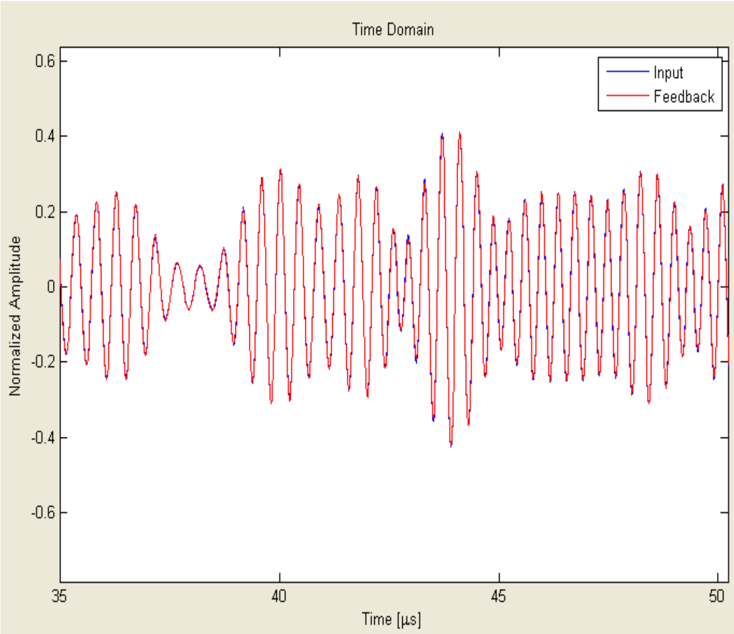

Figure 25 – Time Domain Measurement.

3.4 Calibration

Every AT7001 unit presents a internal linear distortion on feedback path. This distortion is compensated during linear pre-correction. However is not present at the mask filter. It generates an error that may be avoided using the calibration process.

1. Set the output power do 0 [dBm].
2. Make an external loop; connect the RFoutput on **After Filter Feedback Sample** in.
3. Bypass the Non-Linear and Linear Pre-Corrections.
4. Open the Signal Measurements window and Measure Frequency Response between Input and Feedback After Filter. The result is going to be the internal linear distortion to be calibrated.

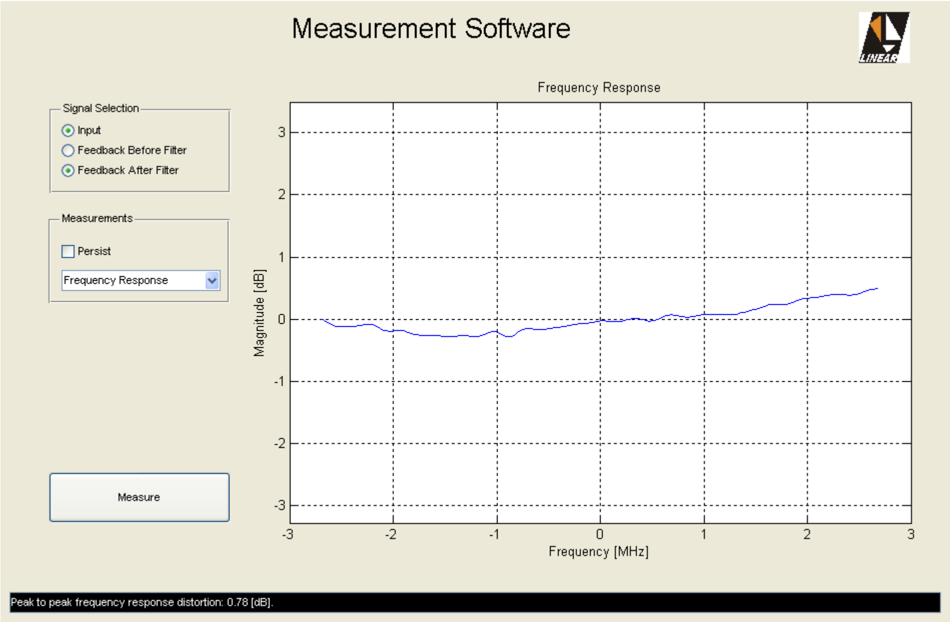

Figure 26 – Internal feedback linear distortion.

5. At the main screen click on **Advanced** and the on **Calibration**. The Calibration window will open.
6. Press **Run** the calculate the distortion. The inverse response will appear compared to the last Frequency Response measurement. Next Figure shows the results.

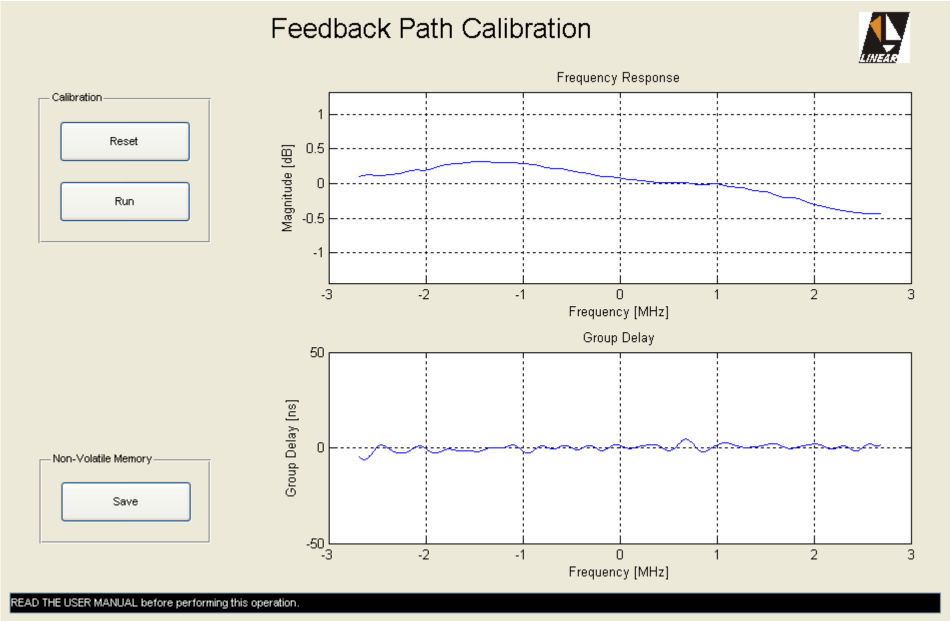

Figure 27 – Calibration window.

7. Press **Save** on the Non-Volatile Memory Panel. Close the Calibration window.
8. Back to the measurement window measure the frequency response again. Now with the compensation taking place a flat response will appear.

The calibration will take effect on Linear-Precorrection and on measurements like Frequency Response, Group Delay, MER, Constellation, etc.