Analyzing Modulated Signals with the V93000 Signal Analyzer Tool

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Abstract
The Signal Analyzer Tool contained within the SmarTest software on the V93000 is a versatile graphical tool that can be used to post process digitized ATE (Automated Test Equipment) captured waveforms. It can also be used to pre-process waveforms that are intended to be played into the DUT (Device Under Test). The algorithms used by the Signal Analyzer Tool are identical to those used by the C++ code in the SmarTest software for RF measurements and demodulation analysis. This paper highlights some of the many features of the Signal Analyzer Tool.

Introduction
This paper provides background and examples using the Signal Analyzer Tool within the Verigy V93000 SmarTest software and shows several of its many capabilities that can be used for debug and correlation work. The benefit of the Signal Analyzer Tool is that it does not require any C++ coding, resulting in a fast implementation.

The Signal Analyzer Tool features that are highlighted have the ability to:

- Read and analyze AWG waveform files
- Resample AWG waveform files
- Read and analyze digitized ATE captures
- Downconvert ATE captured waveforms from IF to complex IQ
- Demodulate AWG waveforms or ATE captured signals
- View and Save files in Agilent Signal Studio and 89600 VSA formats

The last two bullets are oriented toward the V93000's demodulation capability. The demodulation software used by the V93000 has it's origins from the Agilent Technologies 89600 VSA (Vector Signal Analyzer) software. Many of the algorithms used are identical and when using the Signal Analyzer Tool the user may notice a lot of similar variable names to options and features found in the Agilent 89600 software.

The Signal Analyzer Tool can be started by selecting it from the 93000 pull-down menu as shown in Figure 1. Note that the underlying tool behind the Signal Analyzer Tool is also used for other SmarTest features such as BIST Assist. In order to access the Signal Analyzer Tool menu items, it may be necessary to click within the work area to initiate the Signal Analyzer Tool features when starting the tool.

Signal Analyzer Tool Functions

This discussion is limited to features of the Signal Analyzer Tool that can be accessed from the right mouse-click pull-down menu as shown in Figure 2. These are functions that are used for mixed signal and RF applications. Table 1 provides a short summary of each of the functions and their purpose. There are numerous additional features within the Signal Analyzer Tool that provide means to signal condition every type of analog waveform for mixed-signal and RF applications and even digital applications such as those using digital capture. These are not all discussed within this paper, but can be found in the V93000 Technical Documentation Center [1].

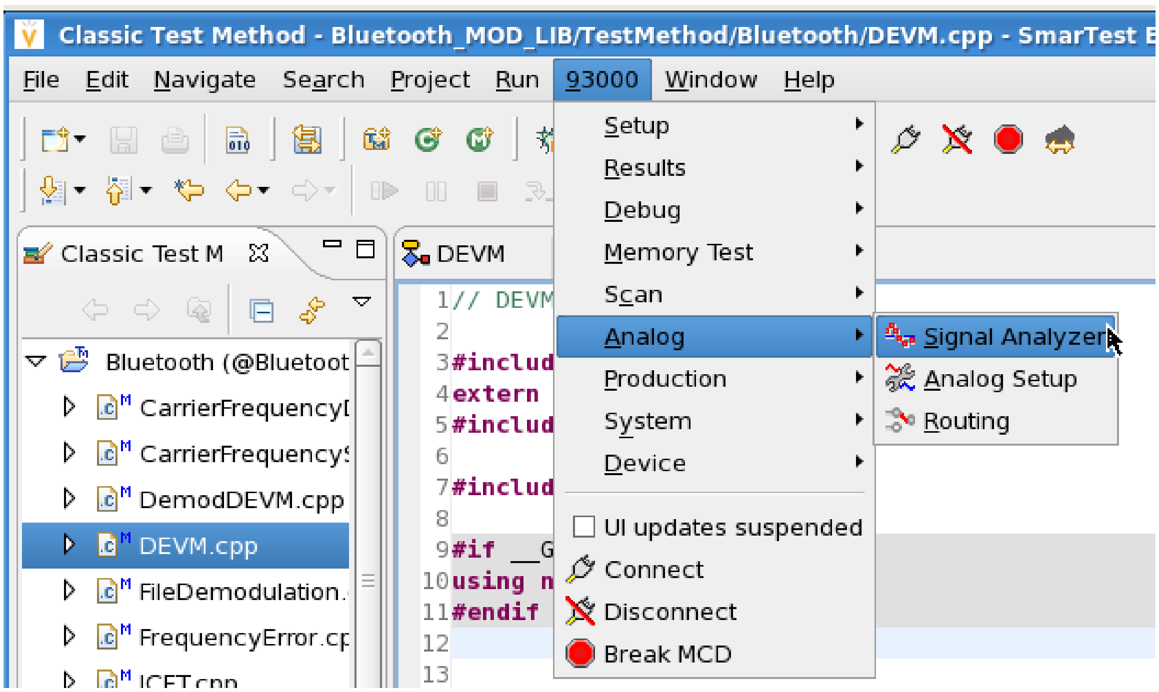

Figure 1 Starting the Signal Analyzer Tool.

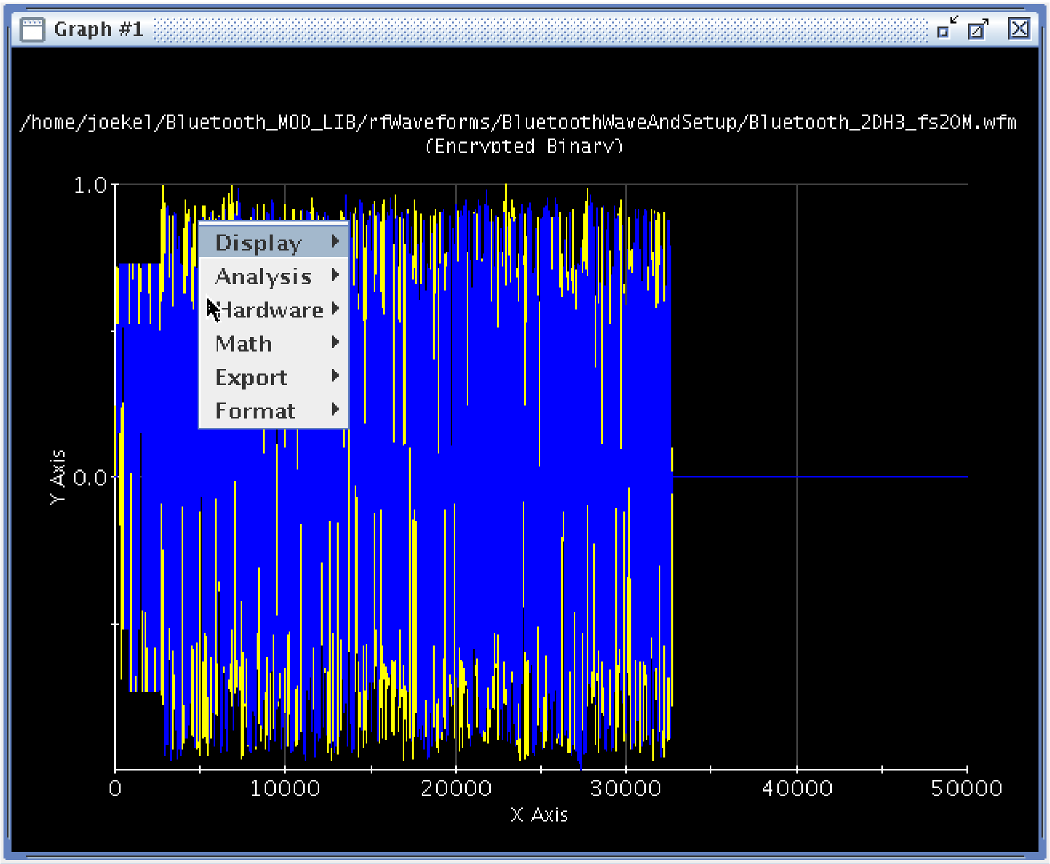

Figure 2 Features menu accessed with a right mouse-click on a waveform graph.

Feature	Function
Display	
Auto Scale	Scales trace to fit window
Clear[1]	Removes trace from window
Copy[1]	Copies trace to memory
Paste[1]	Pastes trace from memory to any open graph window
Edit Trace[1]	Opens an editor window to allow editing of trace data points
Analysis	
Signal Information	Prints statistical info about the target trace inside the graph window and in the Signal Analyzer Tool message window
Spectrum Analysis	Displays the FFT of the trace in a new window and provides SNR, THD, and SINAD values in the graph window and Signal Analyzer message window
Jitter Analysis[1]	Displays jitter analysis results in a new window and Signal Analyzer message window
Diff. Waveforms[1]	Overlays the sum/difference of two waveforms in the graph window
Show Histogram[1]	Displays a histogram of the selected trace in a new window

[1] This function will not work on Agilent Signal Studio formatted waveforms (.wfm).

Demodulation	Performs demodulation on a pair of I and Q traces
Complex Spectrum Analysis	Performs FFT-based analysis on a pair of complex (I & Q) waveforms and displays the results in a new window
Resample Waveform	Resamples a waveform to a new sample rate specified by the user
Hardware	
View Waveform Memory	Opens a GUI to show AWG waveform memory/label information for an AWG pin defined in the pin configuration
Math	
Digital Down-Conversion	Performs digital downconversion (IF to IQ), providing two traces (I and Q) in a new window
Decimate	Decimates (down-samples) selected trace
Export	
Save Agilent VSA 89600[1]	Saves to a file in ASCII format readable by the Agilent 89600 VSA
Save Signal Studio	Saves in Agilent Signal Studio encrypted .wfm format
Format	
Quick Format	Allows user to modify basic graph parameters (e.g., x-axis, sampling frequency)
Detailed Format	Allows user to modify all parameters of graph and traces
Order…[1]	Reorders (e.g., bring to front) traces in a selected window

Table 1 Details of available functions available in the features pull-down menu.

Reading and Analyzing AWG Waveform Files
One of the most basic features of the V93000 Signal Analyzer Tool is the ability to read AWG waveform files. After reading them into memory all of the same calculations and algorithms that are applied during production testing can be applied to the waveforms via the Signal Analyzer Tool GUI (Graphical User Interface). These can be analyzed prior to sourcing them to the DUT. It can read ASCII waveform files (individual or combined I and Q waveform files), V93000 custom waveform format files (those containing sample rate and other waveform info), and Agilent Technologies encrypted Signal Studio format waveforms[2].

Reading and Analyzing ATE Digitized Captured Waveforms
The traditional use-model is that the PUT_DEBUG() SmarTest API (Application Programming Interface) can direct V93000 captured waveforms to the Signal Analyzer Tool for post-processing or debugging from C++ code. Once the waveforms are displayed as a graph in the tool, they can be analyzed using the means discussed in this paper. A nice feature of the PUT_DEBUG() API is that it can work with complex waveforms as well as traditional real arrays. The sample rate is retained along with the upload into the Signal Analyzer tool. This way the tool keeps track of the sampling rate and bin size behind the scenes.

Additionally, if the sample rate used during acquisition is known then waveforms from bench or even other ATE manufacturers can be read-in and analyzed with this tool. This can be beneficial for expediting the correlation process.

[2] The Agilent Technologies Signal Studio waveforms are generated in an encrypted format and the V93000 does not provide access to the unencrypted versions of the waveforms. This is purposely done to protect Agilent Technologies' intellectual property.

Saving waveforms in Agilent Signal Studio and 89600 VSA Formats
The Signal Analyzer Tool provides the ability to save a waveform in a different format than the format than what was originally brought into the tool. The two alternative formats that can be saved are both based on Agilent Technologies bench equipment. These are:

- Signal Studio Format
- 89600 VSA Format

These two choices can be accessed from the *Export* sub-menu found by right-clicking on a graph. The 89600 format is an ASCII text format that contains two columns of waveform data (I and Q) and some details about the waveform (e.g., sample rate). This makes the waveform data fully self-contained and able to be analyzed by the 89600, or SmarTest itself as the sample rate is preserved. Note that Signal Studio format (.wfm) graphs can not be saved to 89600 VSA (Vector Signal Analyzer) format. In addition to these, saving options, ASCII waveforms can be saved (or re-saved) through the main *File* pull-down in the main menu bar.

Signal Analyzer Example Use Cases
The following sections present some of the features mentioned above and demonstrate how they are executed. The examples consist of resampling An Agilent Signal Studio formatted waveform, digitally downconverting an IF waveform, demodulating a complex waveform pair (I and Q), and varying demodulation parameters.

Example: Resampling an Agilent Signal Studio Format Waveform
Problem: The user has an encrypted Agilent Signal Studio waveform that works on the bench, but needs to be optimized for the 93000 master clock.
To demonstrate how AWG waveform files can be read into the Signal Analyzer Tool, a Signal Studio (.wfm) file will be read in and resampled. Use *File > Open Graph* and select a file with the .wfm format. This is an encrypted binary file and the trace data points are not accessible by the user. However, the V93000 can read these files. They can be modified in the Signal Analyzer Tool and saved once again, but only in the encrypted Signal Studio format.

When a Signal Studio formatted file is opened, the graph window contains two traces. One represents I and the other is Q.

To resample the waveform, choose *Analysis > Resample Waveform* by right-clicking on the loaded waveform graph. A window will pop up asking to choose the trace to be resampled. For .wfm files, it is necessary to choose both traces simultaneously so that they both are resampled simultaneously and end up in a single new graph window. This is necessary so that they can be resaved because they are only able to be saved as Signal Studio format which requires two traces (I and Q). The window shown in Figure 3 then appears. In this example, the sample rate will be reduced by a factor of two from 100MHz to 50MHz.

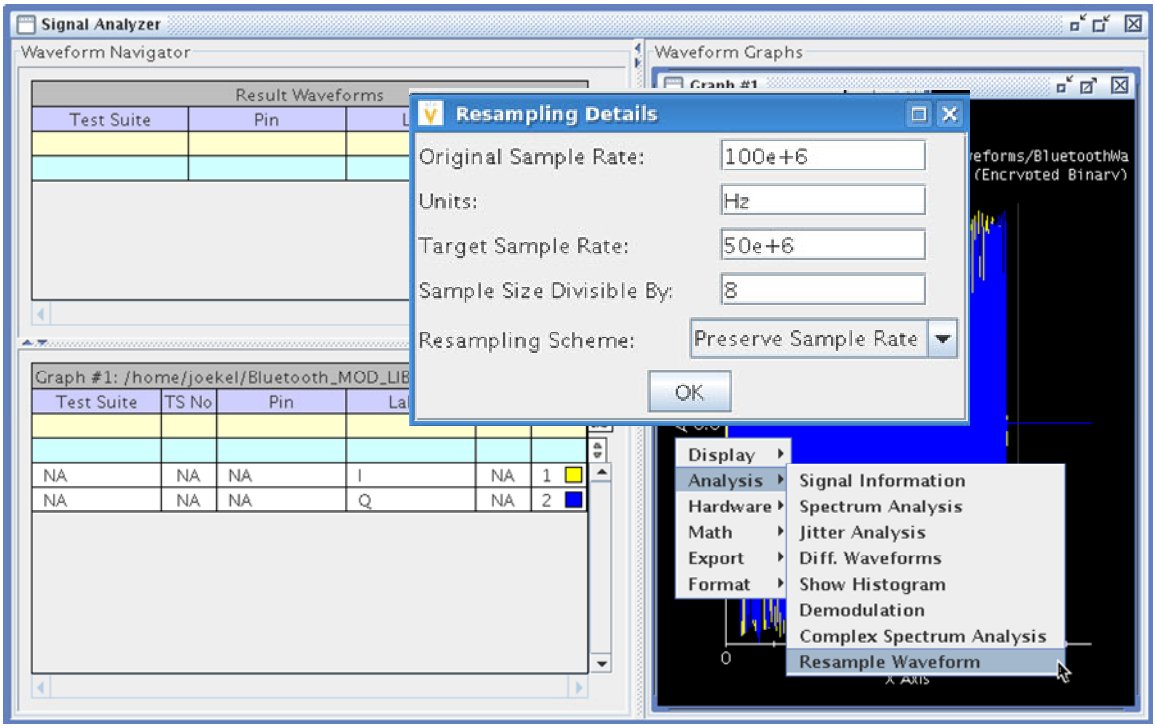

Figure 3 Detail of the resampling parameter window.

Afterwards, to save the resampled waveforms with a new name, right click on the new graph and select *Export > Save Signal Studio*.

Example: Digital Downconversion

Problem: The user has a single IF capture array and needs to work with its modulated I/Q components.

At times, a user may have an IF waveform that needs to be digitally downconverted. This may be because they wish to perform complex waveform analysis such as demodulation or complex FFTs on the signal. The origin of the IF waveform may be from ATE, bench equipment, or elsewhere. For example, on the V93000, for RF measurements that have greater than about 22MHz measurement bandwidth, the captured waveform is an IF waveform, i.e., only having a real component.

In this example, an IF waveform captured during an RF measurement is digitally downconverted to I and Q waveforms so that they are in a complex format and able to be demodulated.

After the waveform is either loaded in from a file or brought into the Signal Analyzer through the SmarTest PUT_DEBUG() API, right click on IF waveform graph to do digital downconversion, selecting *Math > Digital Down-Conversion*. A window will appear asking the user to select the IF trace. If only one waveform is loaded in the graph window (which is usually the case for IF waveforms) this will automatically be selected. If more than one, then make sure your desired IF waveform is selected.

A second window appears (Figure 4). This window requires the user to specify the downconversion parameters, Sample Rate and IF Frequency. After pressing OK, the downconversion is performed and a new graph window appears with two traces, the

I and Q waveforms downconverted from IF. There is an additional FIR (Finite Impulse Response) filtering parameter that can be used if the user chooses.

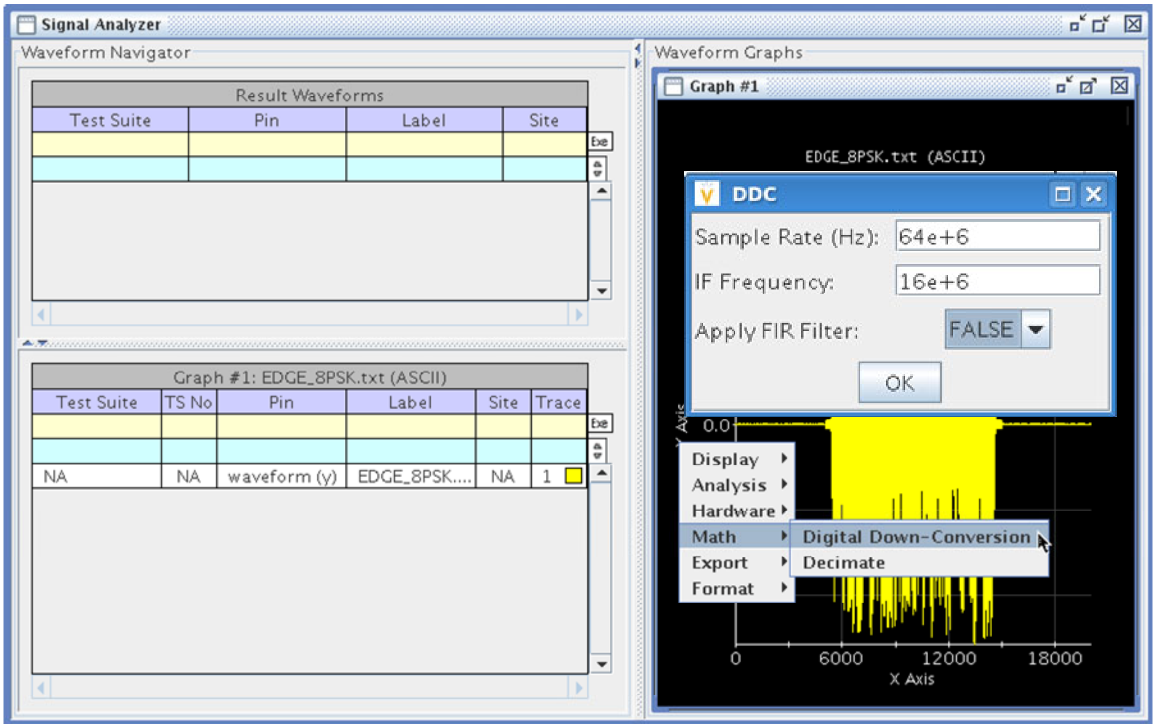

Figure 4 Detail of the digital downconversion parameter window overlaid upon right-click pull-down menu.

Example: Demodulation with FLEX-Based Demodulation Algorithms

Problem: An unknown waveform needs to be checked for EVM (Error Vector magnitude) using a common demodulation algorithm, and the AE needs a quick answer about whether the waveform is good or not.

In this example an EDGE-modulated waveform is demodulated. The waveform is actually a pair of waveforms that are the I and Q captures in complex format. To start the demodulation, right-click in the graph that contains the I and Q traces. Choose *Analysis* > *Demodulation*. A demodulation parameter window will appear. For this example, EDGE_FLEX is chosen. After choosing the traces (almost always these will be default values with Trace 1 containing I and Trace 2 containing Q) the demodulation control window will appear. The most important entry in this window is the ACTION field. This controls everything within the demodulation function of the Signal Analyzer Tool. Execute the demodulation with the default settings for EDGE_FLEX and notice the poor EVM of 102%. These parameter windows and default-based results are shown in Figure 5.

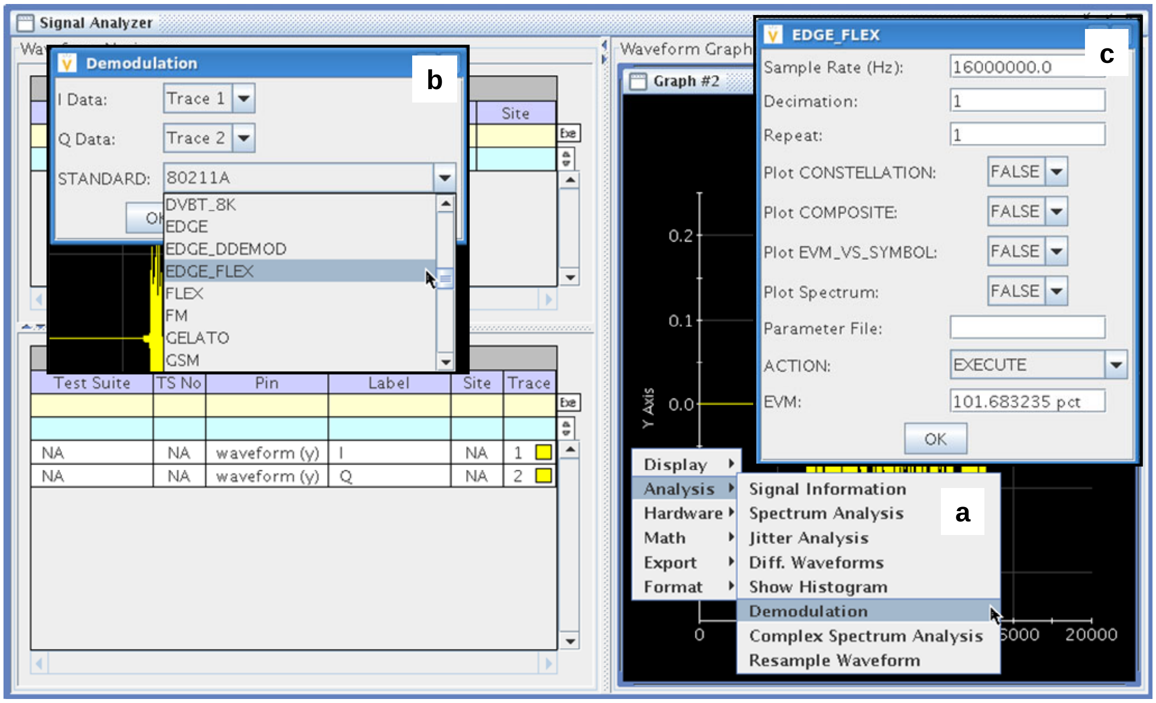

Figure 5 Detail of the demodulation parameter window (b) and demodulation control window (c) overlaid upon right-click pull-down menu (a).

Select "CHANGE INPUTS" to make some adjustments to the input parameters. The new window which shows all available input demodulation parameters will appear. Change default ifFilteringFlag from FALSE to TRUE. Select "OK" then execute again and notice improved EVM (1.25%). The ifFilteringFlag was changed to TRUE which allowed an IF filter to be applied because this had not been done during the downconversion from IF to complex IQ. Had this been done, then this switch would not have been necessary. The steps and results can be viewed in Figure 6.

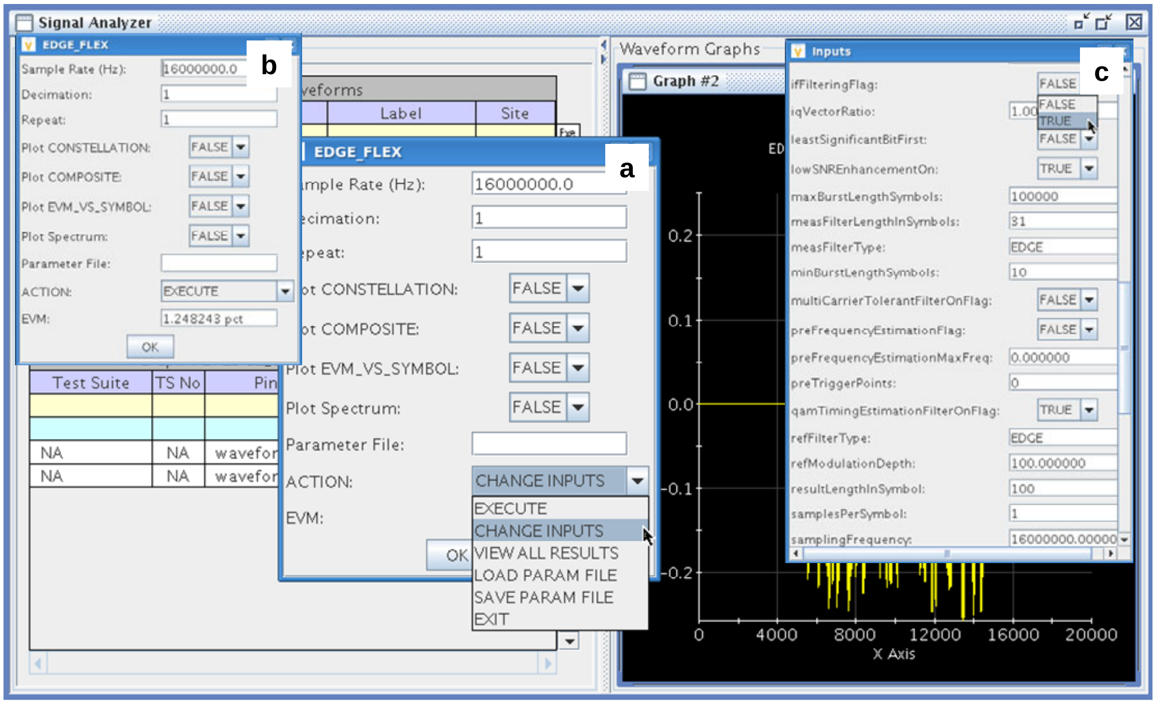

Figure 6 Detail of the demodulation parameter window before (a) and after (b) making adjustments to demodulation inputs (c).

Figure 7 shows some of the extensive list of available results from the demodulation algorithm used within the Signal Analyzer Tool. These results are identical to those available with the code-based demodulation algorithm since the algorithms are shared. A few of the important EDGE-based parameters of interest are rms EVM (symbolRmsEVM) and peak EVM (symbolPeakEVM). Notice that low-level details such as the symbol number exhibiting the peak EVM are also available.

In the demodulation parameter window the default displayed graph settings can be changed from FALSE to TRUE to exhibit useful graphs. For example, switch Plot Constellation from FALSE to TRUE to view the constellation. Press OK and a new Signal Analyzer window will appear with the EDGE constellation as shown in Figure 8.

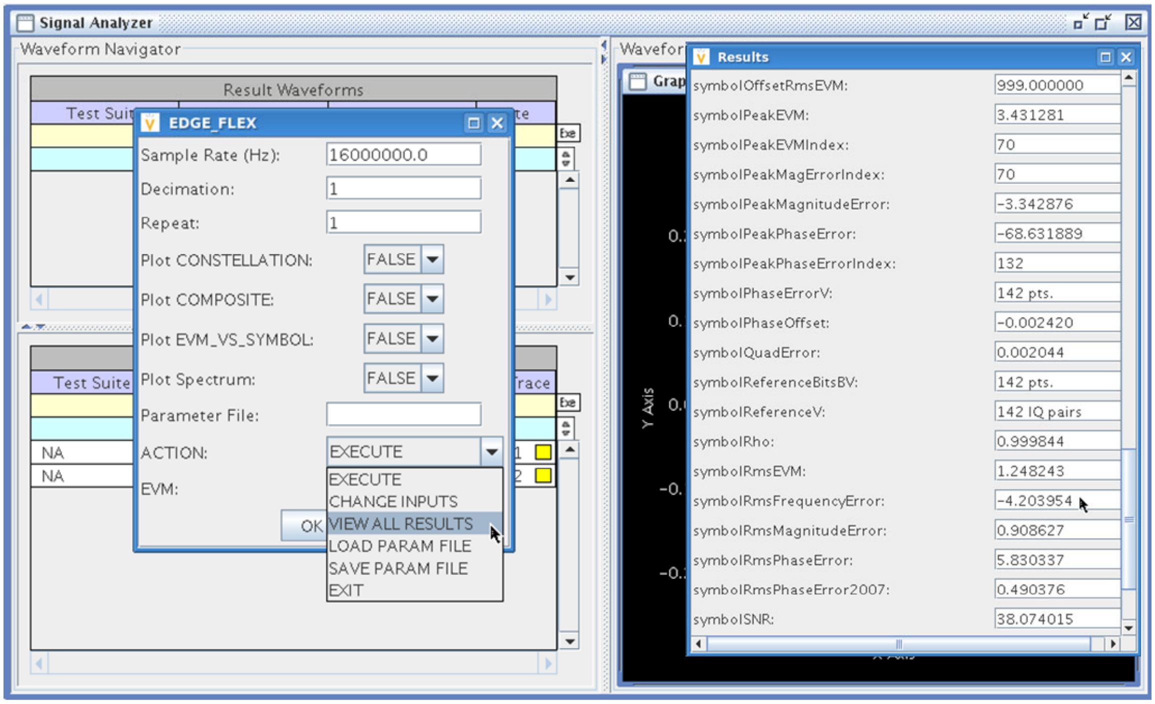

Figure 7 Detail of all available results in the demodulation analysis.

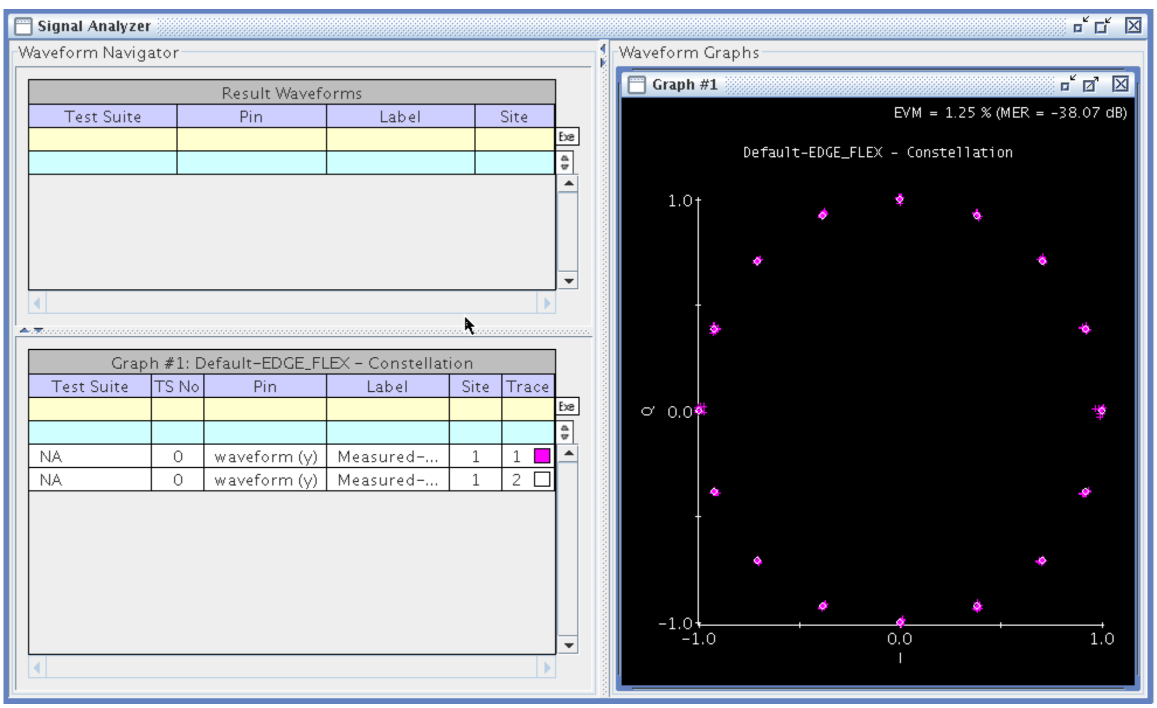

Figure 8. Displaying an IQ constellation plot.

Example: Varying Demodulation Parameters

To demonstrate the power and a suggested use case of the Signal Analyzer Tool, the filter shape parameter, alpha, will be varied for the filter that is used during demodulation. In this scenario, the EDGE_FLEX demodulation format will be chosen. The default setting for the filter shaping constant, alpha, for this format is 0.3. Varying the filter alpha has a notable impact on the phase error and EVM. Figure 9 shows the trends of the impact of this filter constant on rms phase error and rms EVM.

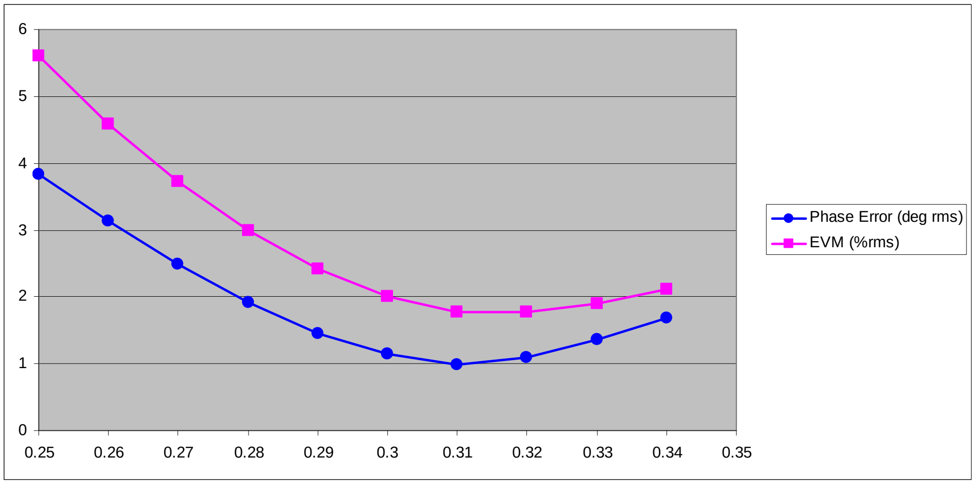

Figure 9 Results showing rms EVM and rms phase error as a function of reference and measurement filter constant alpha.

Summary

The SmarTest Signal Analyzer Tool on the V93000 provides a graphical means to evaluate signal integrity and perform calculations such as spectral analysis and demodulation. It can be used to quickly determine if the signals aquired are good ones or if sampling and filtering parameters need to be changed in the instrument before writing the production code. Understanding its capabilities will greatly enhance time to market and the ability to test different user scenarios without having to write a single line of code. The Signal Analyzer Tool is aimed at providing an easy way to perform evaluations before diving into the test program C++ code.

References

[1] Verigy, “V93000 Technical Documentation Center,” Verigy V93000 SmarTest 6.5.3 Help Documentation (2010).