

Products: R&S® Signal Source Analyzer FSUP, R&S® Signal and Spectrum Analyzers FSQ, FSU, FSG, FSV

# RF Transient Analysis Software

## Examine Transients with the R&S® FSx

### Application Note

This application note describes a software application that can be utilized in conjunction with Rohde&Schwarz Signal- and Spectrum Analyzers and Signal Source Analyzers to capture and analyze transient signals. The software application takes advantage of the instrument's IQ memory buffer of up to 705 Msamples to capture and analyze IQ signals in the time domain and / or frequency domain. This is useful for measuring lock time, analyzing radar pulses, finding spurious transients, and other measurements similar in nature to these.

This application can be used with R&S® Signal Source Analyzer FSUP and R&S® Signal and Spectrum Analyzers FSQ, FSU, FSG, FSV.



# Measuring Signal Transients with the RF Transient Analysis Software

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## 1. Overview

This application note describes a software application that can be utilized in conjunction with Rohde&Schwarz Spectrum Analyzers and Signal Source Analyzers to capture and analyze transient signals. The software application takes advantage of the instrument's IQ memory buffer of up to 705 Msamples to capture and analyze IQ signals in the time domain and / or frequency domain. This is useful for measuring lock time, analyzing radar pulses, finding spurious transients, and other measurements similar in nature to these.

For example, the device under test could be a frequency oscillator and the user is interested in the lock time or frequency stability of the device.

Alternatively, transient signals such as a radar pulse can be captured to determine parameters such as the rise time, droop, and spectral content of the pulse. For example, a radar pulse with an FM chirp can be captured and demodulated yielding the frequency of the chirp vs. time.

### 1.1. Scope of this application Note

This application note will describe the installation and operation of the software application for making transient signal measurements.

### 1.2. Overview of the technique utilized by the software

This program controls an R&S spectrum analyzer, filling the internal IQ memory buffer of the spectrum analyzer with the requested number of data samples. It then processes the IQ data samples to generate different data displays. For example, one display is obtained by taking a "block" of IQ data, performing an FFT (Fast Fourier Transform) or DFT (Discrete Fourier Transform) on the block, and then searching for the maximum spectral component. The frequency of the maximum component is recorded and added to a plot of frequency vs. time, using the center time stamp of the block of IQ data. Then the next block of IQ data is processed.

Another measurement display shows the waterfall or spectrogram plot of the successive IQ data blocks, as each one is processed with an FFT.

Additional measurement windows show values such as I and Q vs. time; magnitude and phase of the IQ samples vs. time, or a vector plot of the IQ samples in the IQ plane.

The user has control over the size of the IQ data block that is processed. The user also has control over parameters such as the sample rate, IQ buffer size, FFT/DFT window type, displayed spectral span, etc. More details on operation of the software will be found in Section Three.

The software also allows the user to pause the measurement at any time, and then step through the IQ data manually, going either forward or backward in time. This allows the user to scrutinize a transient signal in order to observe more details than would otherwise be possible.

#### 1.2.1. Overview of Supported Measurements

FFT of the IQ data in a block by block process

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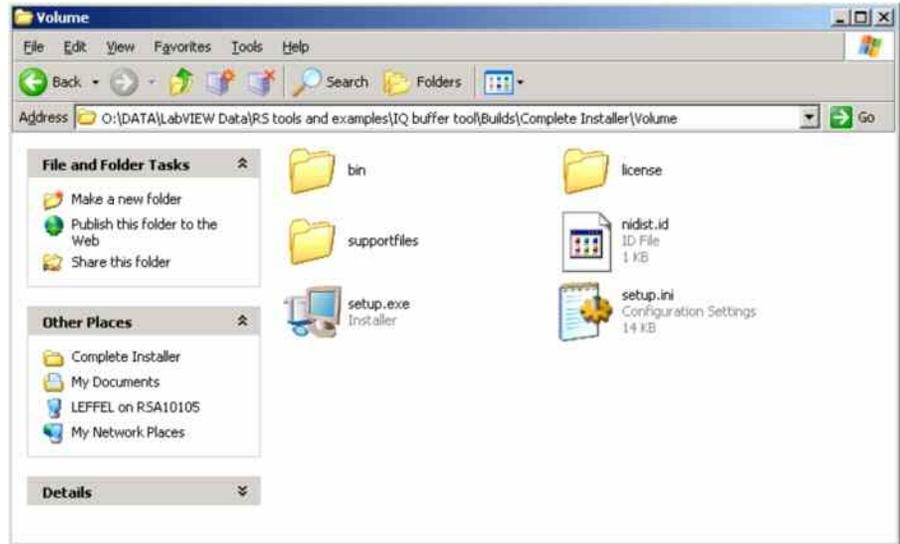
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Waterfall Diagram of subsequent FFTs  
Frequency vs. Time Plot  
Magnitude and Phase Plot  
In Phase and Quadrature Plot  
Plot of IQ data in the IQ plane

### **2. Preparation**

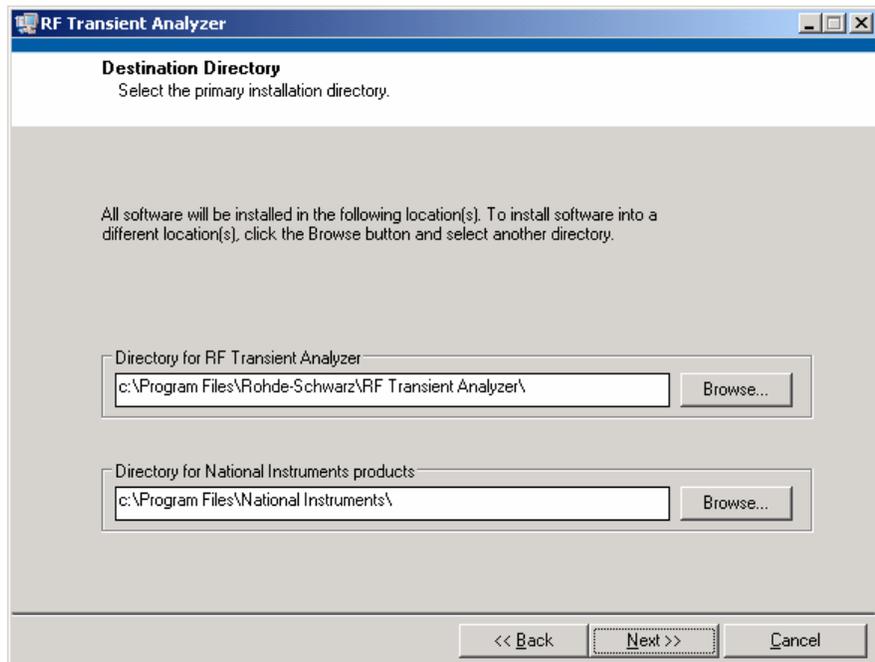
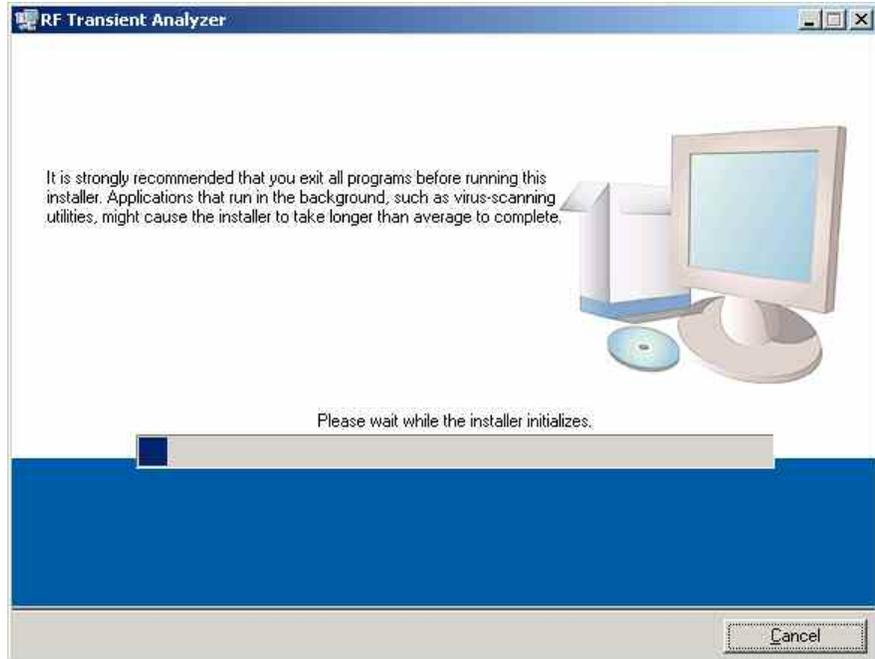
To utilize the RF Transient Analysis Software, you will need a PC with the Windows XP operating system. Additionally, the National Instruments LabVIEW Run Time Engine version 8.6 (or higher) and the National Instruments Run Time Visa are required to run the executable. Both will be installed automatically along with the RF Transient Analysis application.

When you unzip the file, you will find an installation directory that looks similar to this:

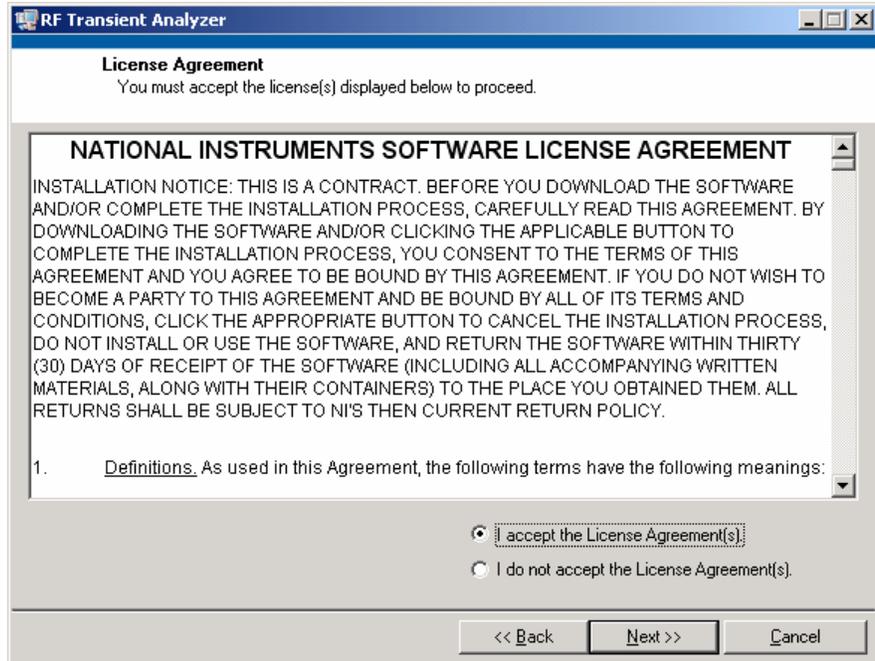


Run the installer by double clicking the "setup.exe" file. The installer will display a series of dialog boxes similar to these:

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# Measuring Signal Transients with the RF Transient Analysis Software

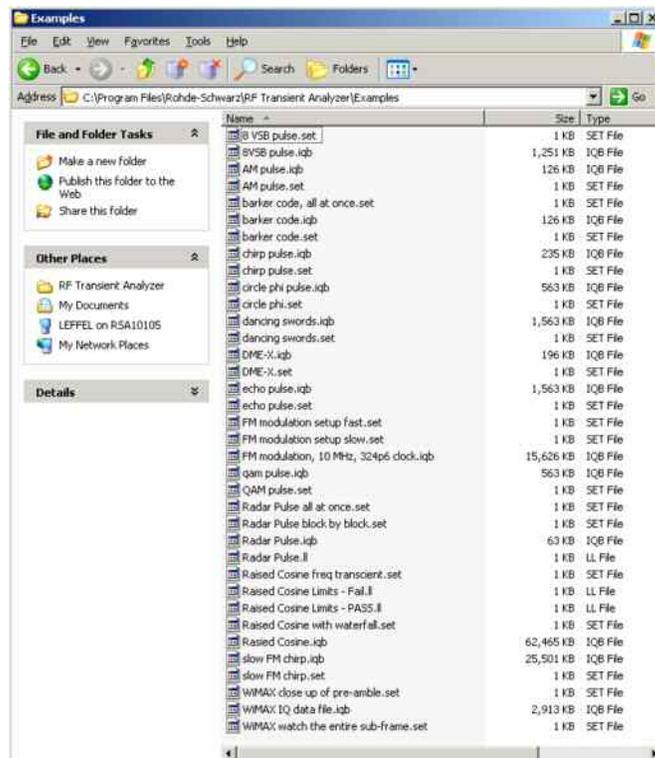


A shortcut will be added to your Program Files Directory.

C:\Documents and Settings\All Users\Start Menu\Programs\RF Transient Analyzer

A folder of example files will also be installed in the installation directory.

C:\Program Files\Rohde-Schwarz\RF Transient Analyzer\examples



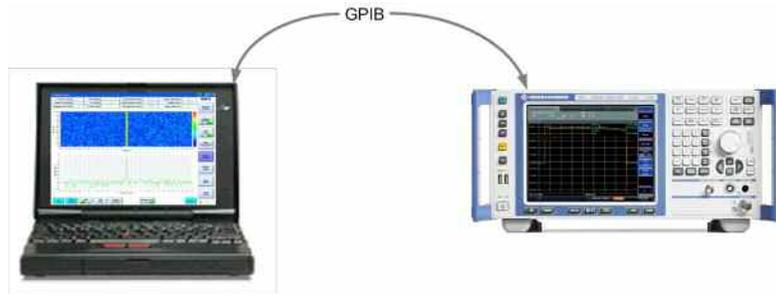
## Measuring Signal Transients with the RF Transient Analysis Software

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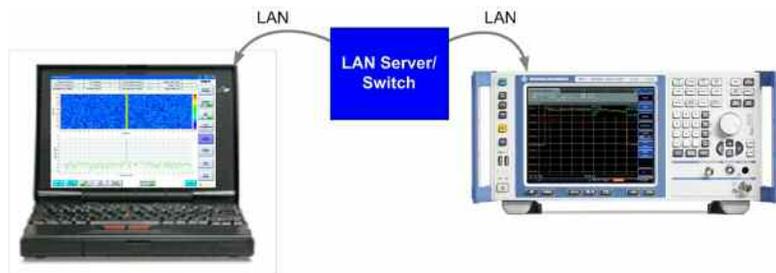
These are sample setting files, IQW files containing example IQ data and limit line files that will make it easy to evaluate the software program without a spectrum analyzer. The examples will be described in more detail in Section 4 Some Examples.

In order to use the program with an R&S spectrum analyzer, the PC that is running the software needs a remote control connection to the R&S® Spectrum Analyzer. There are the following possibilities for this connection:

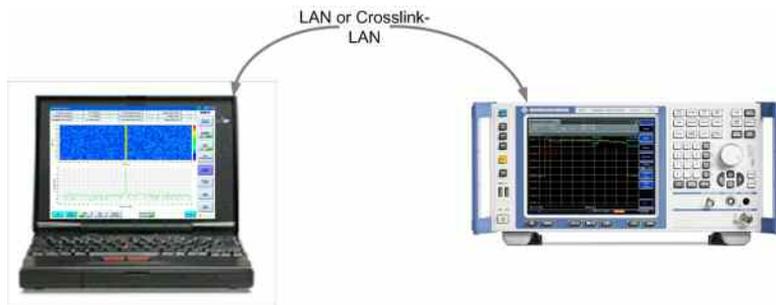
### 1. GPIB



### 2. LAN/Ethernet using Intranet or Internet



### 3. LAN/Ethernet using direct LAN or Crosslink LAN connection between PC and Network Analyzer



# Measuring Signal Transients with the RF Transient Analysis Software

## 2.1. Using GPIB to control the Spectrum Analyzer

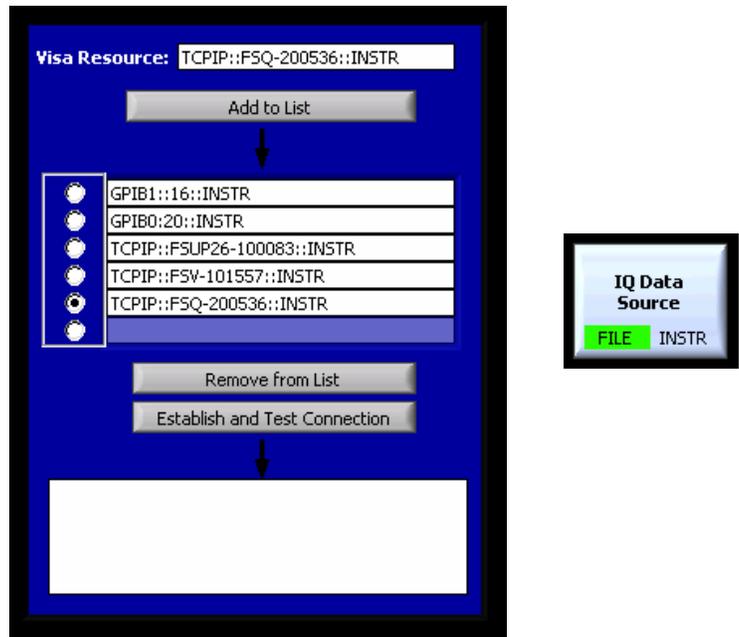
If the PC is connected to the instrument over GPIB, the user needs to enter the GPIB VISA address string for the instrument. For example, if GPIB bus 1 is utilized, and the spectrum analyzer's GPIB address is 16, then the VISA address string is the following:

GPIB1::16::instr

Alternately, if GPIB bus 0 were being utilized (most commonly used), and the instrument was at GPIB address 20 (default setting of R&S spectrum analyzers), then the address string would be:

GPIB0::20::instr

These two entries (along with some other options) are shown in the figure below. This window is accessed by pressing the "IQ Data Source" softkey to the right of the main window.



## 2.2. Using LAN to control the Spectrum Analyzer

Another method of remote control is over a LAN or Ethernet connection. In this case, we need to know either the instrument's computer name or the IP address of the instrument.

The instrument's computer name can be found by pressing SETUP, NEXT, and the open start menu buttons. Then select the control panel, and the "Systems" entry in the control panel list. In the window that opens, tab to the Computer Name page, and read the "full computer name" from this window.

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For example, you might see the string, "FSQ26-200536" as the full computer name of a 26 GHz FSQ, with serial number 200536.

Once the full computer name of the spectrum analyzer is known, enter the VISA string as:

```
TCPIP::FSQ26-200536::instr
```

with your spectrum analyzer's name between the "::" marks.

As an alternative to using the name of the spectrum analyzer, you can enter the IP address of the analyzer. To find the IP address, press SETUP, GENERAL SETUP, CONFIGURE NETWORK. In the window that opens, Select the Local Area Connection, and press enter. Using the turn wheel, move the highlighted selection up to the 'General' tab at the top of the screen, and then use the right arrow key to select the "Support" tab. In this dialog box you can read the IP address of the instrument, e.g. 192.168.0.10.

Once the IP address of the spectrum analyzer is known, enter the VISA string as:

```
TCPIP::192.168.0.10::instr
```

with your spectrum analyzer's IP address between the "::" marks.

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## 3. Operation of the Software Program

When you launch the program, you will see a screen similar to this:



### 3.1. Step One: Configure the Interface to the SA

The default IQ data source is to use a file that contains previously captured IQ data. Several IQ data files were included with the software application, and can be found in the examples folder. By default the software will prompt the user to select one of these IQ data files when the “New Run” button is pressed.

To collect new IQ data from a spectrum analyzer, the software must be linked to the spectrum analyzer. This is done by pressing the softkey labeled, “IQ Data Source.” This will open up the menu where you can enter the VISA address of the instrument.

Type in the VISA address of your spectrum analyzer, then press the add to list key. Select the address string that you want to utilize by selecting the radio button next to it. To see if the connection is working, press the establish and test connection key. If the program can communicate with the instrument, then it will update the window with the model number, serial number and version of the firmware.

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If this doesn't work, confirm that the instrument is connected to the PC. Check the firewall on your PC to make sure it isn't blocking the communication.



Successive presses of the Configure Interface softkey will toggle the option of acquiring the IQ data from a spectrum analyzer, or using previously captured IQ data that has been stored in a file.



If the File option is selected, the user will be prompted for the path to the file when the “New Run” button on the bottom of the screen is pressed.

### 3.2. Step Two: Select the General Settings Softkey

Most of the parameters of the measurement are controlled from the General Settings screen. Changes in this window can be saved and recalled with the Save Setup and Load Setup softkeys found in the lower right hand corner of the screen. Each of the parameters will be described in detail in this section.

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### 3.2.1. Frequency (GHz):

**Frequency (GHz)**   
**Display Span (MHz)**   
**Reference Level (dBm)**   
**Voltage Level for IQ plots**

This variable sets or controls the center frequency of the instrument during IQ data capture and analysis.

**If IQ data is being captured from an instrument:** This variable is used to set or control the center frequency of spectrum analyzer that is being utilized to capture IQ data. For example, if a center frequency of 1.5 GHz is entered in this variable, and then the New Run softkey is pressed, the spectrum analyzer's center frequency will be changed to 1.5 GHz.

**If IQ data is being analyzed from a file.** The center frequency notation that is present in the IQ file is used to update this variable. It has no impact on the IQ data analysis, but it is displayed here and in the header at the top of the measurement window to remind us of the setting that was used when the IQ data file was captured. For example, if a center frequency of 1.5 GHz is entered in this variable, and then a New Run softkey is pressed, the user will be prompted to select an IQ data file. If a center frequency of 2.5 GHz is

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stored in this IQ data file, then this variable will be updated to show the value of 2.5 GHz.

### **Scope:**

This variable is saved by the “Save Setup” softkey.

This variable will be over written with the “Load Setup” operation.

This variable will be over written if an IQ data file is analyzed.

### **3.2.2. Display Span (MHz)**

This variable controls the displayed X-axis range of the FFT display and the Y-axis range of the Frequency vs. Time window. But it is independent of the sampling rate or Nyquist frequency. For example, data can be collected with a sampling rate of 100 MHz. It could be displayed with a span of – 50 MHz to + 50 MHz, if desired. But if the signal of interest is concentrated in the frequency range of -7.5 MHz to + 7.5 MHz, the user may decide to only display data over a 20 MHz range. An entry of 20 MHz in the Display Span variable will effectively zoom the graph into the range of -10 MHz to + 10 MHz.

**If IQ data is being captured from an instrument:** This parameter has no impact on the instrument or the instrument settings other than to set the zoom level of the FFT plot.

**If IQ data is being analyzed from a file.** This parameter has no impact on the analysis of previously captured IQ data files, other than to set the zoom level of the FFT plot.

### **Scope:**

This variable is saved by the “Save Setup” softkey.

This variable will be over written with the “Load Setup” operation.

### **3.2.3. Reference Level (dBm)**

This variable sets or controls the reference level setting of the instrument during IQ data capture and analysis. It is also used to set the maximum Y-axis value that is displayed on the FFT plot.

**If IQ data is being captured from an instrument:** This variable is used to set or control the reference level setting of the spectrum analyzer that is being utilized to capture IQ data. For example, if a reference level of 10 dBm is entered in this variable, and then the New Run softkey is pressed, the spectrum analyzer’s reference level will be changed to 10 dBm.

**If IQ data is being analyzed from a file.** The reference level notation that is present in the IQ file is used to update this variable. It has no impact on the IQ data analysis, but it is displayed here and in the header at the top of the measurement window to remind us of the setting that was used when the IQ data file was captured. For example, if a reference level of 10 dBm is entered in this variable, and then a New Run softkey is pressed, the user will be prompted to select an IQ data file. If a reference level of -15 dBm is stored in this IQ data file, then this variable will be updated to show the value of -15 dBm.

### **Scope:**

This variable is saved by the “Save Setup” softkey.

This variable will be over written with the “Load Setup” operation.

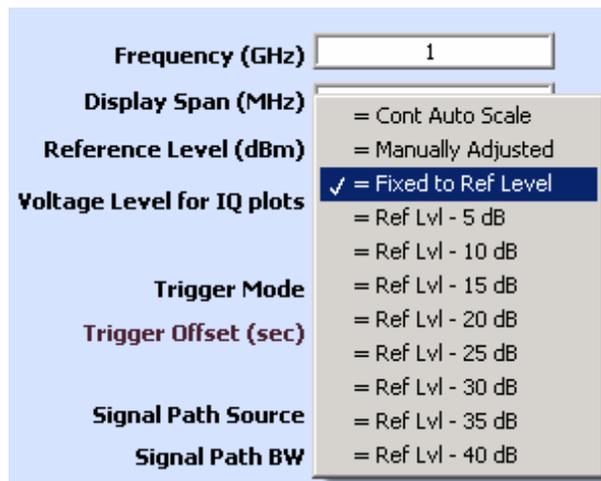
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This variable will be over written if an IQ data file is analyzed.

### 3.2.4. Voltage Level for IQ plots

This variable controls the displayed Y-axis range of the IQ plots. (Magnitude and phase, I and Q voltage vs. time, IQ voltage plane.) But it does not have an impact on the instrument settings or the IQ data. So it is a variable that is independent from the Reference Level described in section 3.2.3. For example, data can be collected with a reference level of 0 dBm. But if the signal of interest has a maximum value of -30 dBm, then the user may want to zoom in on the IQ data plots in order to see more details in the signal. This is especially true since the IQ data is plotted in linear units of volts.

This variable is controlled by a drop down menu, as shown below. The choices include the option to have the IQ voltage plots operate with a continuous auto scale, or with a manual scale that can be indecently set and does not change. Additional options are to tie the voltage scales to the Reference Level with offsets equal to 0 dB though 40 dB, in 5 dB steps, as shown below.



**If IQ data is being captured from an instrument:** This parameter has no impact on the instrument or the instrument settings, other than to set the zoom level of the IQ voltage plots.

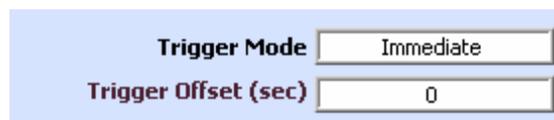
**If IQ data is being analyzed from a file.** This parameter has no impact on the analysis of previously captured IQ data files, other than to set the zoom level of the IQ voltage plots.

#### Scope:

This variable is saved by the “Save Setup” softkey.

This variable will be over written with the “Load Setup” operation.

### 3.2.5. Trigger Mode



This variable sets or controls the trigger setting of the spectrum analyzer. The choices are free run (immediate), an External Trigger, and an IF Power Trigger.

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**If IQ data is being captured from an instrument:** This variable is used to set or control the trigger setting of the spectrum analyzer that is being utilized to capture IQ data. For example, if an external trigger setting is entered in this variable, and then the New Run softkey is pressed, the spectrum analyzer will wait for an external trigger signal before it starts collecting IQ data.

**If IQ data is being analyzed from a file.** The trigger level setting notation that is present in the IQ file is used to update this variable. It has no impact on the IQ data analysis, but it is displayed here and in the header at the top of the measurement window to remind us of the setting that was used when the IQ data file was captured. For example, if a trigger mode of Immediate is entered in this variable, and then a New Run softkey is pressed, the user will be prompted to select an IQ data file. If a trigger mode value of External is stored in this IQ data file, then this variable will be updated to show the setting of External.

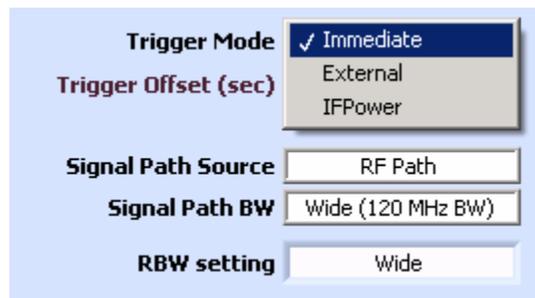
### Scope:

This variable is saved by the “Save Setup” softkey.

This variable will be over written with the “Load Setup” operation.

This variable will be over written if an IQ data file is analyzed.

### 3.2.6. Trigger Offset (sec)



This variable sets or controls the trigger offset value of the spectrum analyzer. This parameter only has an impact on the External and the IF Power trigger Modes. It has no effect in the Trigger Immediate Mode.

**If IQ data is being captured from an instrument:** This variable is used to set or control the trigger offset setting of the spectrum analyzer that is being utilized to capture IQ data. For example, if the trigger mode is set to External, and the trigger offset is set to 1 mS, and then the New Run softkey is pressed, the spectrum analyzer's will capture IQ data starting at a time of 1 mS after the trigger signal was received.

**If IQ data is being analyzed from a file.** The trigger offset setting notation that is present in the IQ file is used to update this variable. It has no impact on the IQ data analysis, but it is displayed here and in the header at the top of the measurement window to remind us of the setting that was used when the IQ data file was captured. For example, if a trigger offset of 10 mS is entered in this variable, and then a New Run softkey is pressed, the user will be prompted to select an IQ data file. If a trigger offset value of 3 mS is stored in this IQ data file, then this variable will be updated to show the setting of 3 mS.

### Scope:

This variable is saved by the “Save Setup” softkey.

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This variable will be over written with the “Load Setup” operation.

This variable will be over written if an IQ data file is analyzed.

### 3.2.7. Signal Path Source



This variable controls the input of the spectrum analyzer. The choices are the RF input, the base band analog IQ inputs, and the base band digital IQ inputs. The digital IQ input option is not functional in this initial release of the RF Transient Analysis software.

**If IQ data is being captured from an instrument:** This variable is used to set the input source setting of the spectrum analyzer that is being utilized to capture IQ data. For example, if the Signal Path Source is set to Analog Base band, and the New Run softkey is pressed, the spectrum analyzer will capture IQ data that is present at the base band input BNC connectors.

**If IQ data is being analyzed from a file.** The Signal Path Source setting is only utilized with IQ data is being captured from an instrument. It has no function when IQ data is being analyzed from a file.

#### Scope:

This variable is saved by the “Save Setup” softkey.

This variable will be over written with the “Load Setup” operation.

### 3.2.8. Signal Path BW



This variable controls the IF path of spectrum analyzers that have multiple ADCs. For example, the FSQ has a 28 MHz wide IF path the first set of ADCs, and also a 120 MHz wide IF path for a second set of ADCs.

**If IQ data is being captured from an instrument:** This variable is used to select the IF path setting of the spectrum analyzer that is being utilized to capture IQ data. For example, if the Signal Path is set to wide, and the New Run softkey is pressed, the spectrum analyzer will switch to the IF path that supports 120 MHz of bandwidth, and will utilize the ADCs that support the higher sampling rate.

**If IQ data is being analyzed from a file.** The Signal Path BW setting is only utilized with IQ data is being captured from an instrument. It has no function when IQ data is being analyzed from a file.

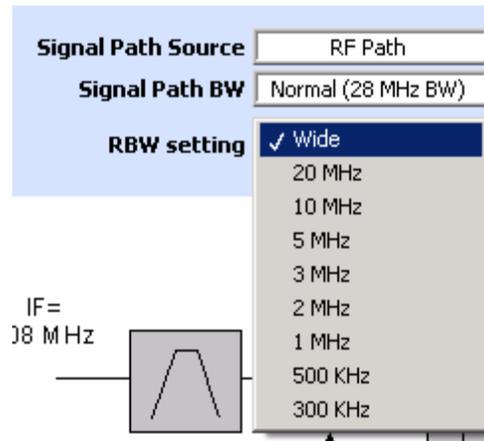
#### Scope:

This variable is saved by the “Save Setup” softkey.

This variable will be over written with the “Load Setup” operation.

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### 3.2.9. RBW setting



This variable controls the resolution bandwidth of signal path that is being sampled by the ADC. There is one exception. In the FSQ, when the “Wide” (120 MHz) Signal path is selected, the RBW setting is ignored.

**If IQ data is being captured from an instrument:** This variable is used to select the resolution bandwidth setting of the spectrum analyzer that is being utilized to capture IQ data. For example, if the RBW setting is set to 10 MHz, and the New Run softkey is pressed, the spectrum analyzer will switch to the 10 MHz RBW filter setting, and the collected IQ data will be filtered by this RBW prior to being sampled by the ADC.

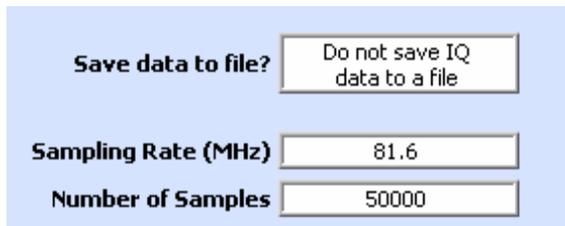
**If IQ data is being analyzed from a file.** The RBW setting is only utilized with IQ data is being captured from an instrument. It has no function when IQ data is being analyzed from a file.

#### Scope:

This variable is saved by the “Save Setup” softkey.

This variable will be over written with the “Load Setup” operation.

### 3.2.10. Save data to file?



This option allows the user to capture IQ data from an instrument, and then save that data to a file so it can be analyzed at a later date.

**If IQ data is being captured from an instrument:** This variable is used to route the IQ data from the spectrum analyzer to a file on the PC. In this release of the software, the data can only be saved to a file if the block step is set to a value of 1. For example, if the Save data to a file value is “Save IQ data from the next instrument capture to a file.”, and the New Run softkey is pressed, the software will query the user to select or create a new data file, and then all the IQ data will be saved into this file at the same time that it is being displayed in the software’s windows.

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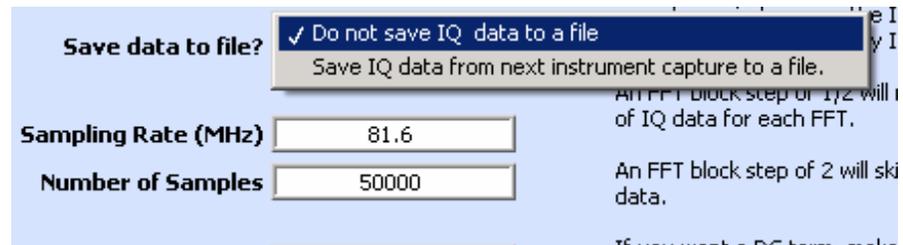
At the end of the IQ data capture, this setting is automatically reverted back to the “Do not save IQ data to a file.” value.

**If IQ data is being analyzed from a file.** The Save Data to a file setting is only utilized with IQ data is being captured from an instrument. It has no function when IQ data is being analyzed from a file.

### Scope:

This variable is reset to “Do not save IQ data to a file” after each run of the program.

### 3.2.11. Sampling Rate (MHz):



This variable sets or controls the sampling rate of the ADCs in the spectrum analyzer during IQ data capture.

**If IQ data is being captured from an instrument:** This variable is used to set or control the ADC sampling rate of the spectrum analyzer that is being utilized to capture IQ data. For example, if a sampling rate of 50 MHz is entered in this variable, and then the New Run softkey is pressed, the spectrum analyzer’s ADC sampling rate will be changed to 50 MHz.

**If IQ data is being analyzed from a file.** The sampling rate notation that is present in the IQ file is used to update this variable. It has no impact on the IQ data analysis, but it is displayed here and in the header at the top of the measurement window to remind us of the sampling rate that was used when the IQ data file was captured. For example, if a sampling rate of 81.6 MHz is entered in this variable, and then a New Run softkey is pressed, the user will be prompted to select an IQ data file. If a sampling rate of 50 MHz is stored in this IQ data file, then this variable will be updated to show the value of 50 MHz.

### Scope:

This variable is saved by the “Save Setup” softkey.

This variable will be over written with the “Load Setup” operation.

This variable will be over written if an IQ data file is analyzed.

### 3.2.12. Number of Samples

This variable sets or controls the number of samples that will be collected by the spectrum analyzer during IQ data capture.

**If IQ data is being captured from an instrument:** This variable is used to set or control the number of IQ data samples that will be collected by the spectrum analyzer that is being utilized to capture IQ data. For example, if the number of samples is set to 50000, and then the New Run softkey is pressed, the spectrum analyzer will capture 50000 IQ data pairs.

**If IQ data is being analyzed from a file.** The number of samples present in the IQ file reflected in this variable. It has no impact on the IQ data analysis, but it is displayed here and in the header at the top of the

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measurement window to remind us of the number of samples present in the file. For example, if 50000 is entered in the number of samples, and then a New Run softkey is pressed, the user will be prompted to select an IQ data file. If the selected IQ data file contains 15000 pairs of IQ data, then the number of samples will be updated to show 15000.

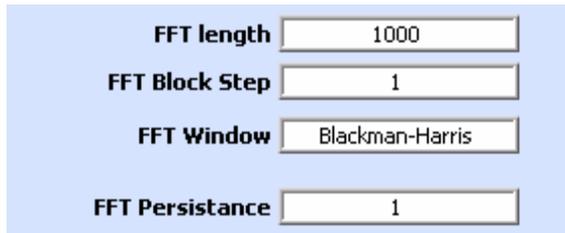
### **Scope:**

This variable is saved by the “Save Setup” softkey.

This variable will be over written with the “Load Setup” operation.

This variable will be over written if an IQ data file is analyzed.

### **3.2.13. FFT Length**



<b>FFT length</b>	<input type="text" value="1000"/>
<b>FFT Block Step</b>	<input type="text" value="1"/>
<b>FFT Window</b>	<input type="text" value="Blackman-Harris"/>
<b>FFT Persistence</b>	<input type="text" value="1"/>

This variable sets or controls the number of samples that will be transformed to the frequency domain and displayed in the FFT window.

**If IQ data is being captured from an instrument:** This is a variable needed for signal processing in the software. It does not impact the settings of the spectrum analyzer. FFT length controls the grouping of the IQ data prior to each FFT calculation.

**If IQ data is being analyzed from a file.** This is a variable needed for signal processing in the software. It is not stored in the IQ data file. FFT length controls the grouping of the IQ data as it is read out of the file, prior to each FFT calculation.

### **Scope:**

This variable is saved by the “Save Setup” softkey.

This variable will be over written with the “Load Setup” operation.

### **3.2.14. FFT Block Step**

This variable sets or controls which IQ data pairs will be transformed to the frequency domain.

**If IQ data is being captured from an instrument:** This is a variable needed for signal processing in the software. It does not impact the settings of the spectrum analyzer. FFT length controls the grouping of the IQ data prior to each FFT calculation.

**If IQ data is being analyzed from a file.** This is a variable needed for signal processing in the software. It is not stored in the IQ data file. FFT length controls the grouping of the IQ data as it is read out of the file, prior to each FFT calculation.

### **Scope:**

This variable is saved by the “Save Setup” softkey.

This variable will be over written with the “Load Setup” operation.

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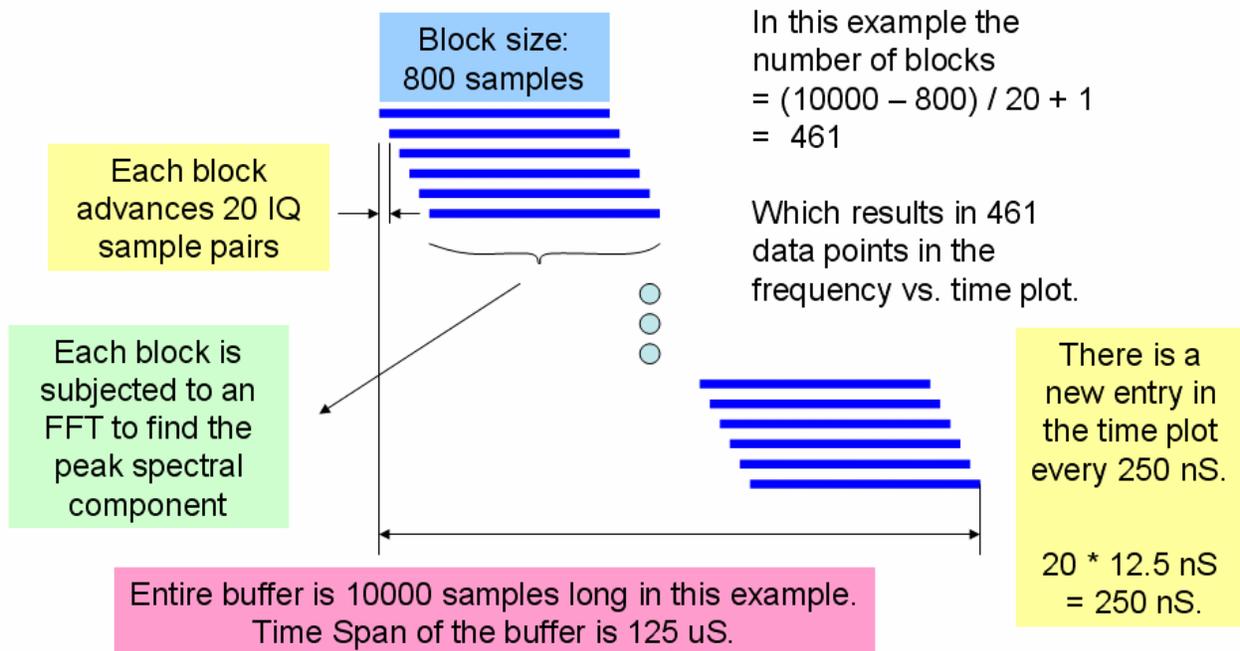
Here is an example of how the FFT Block Step functions. Consider a setup that is configured to capture 10000 IQ data pairs, and the FFT length is set to 800.

If the FFT Block Step is set to 1, then samples 1..800 would be transformed first, followed by samples 801..1600, then 1601..2400, and so on. When the IQ data runs out, the analysis terminates. No IQ data is missed in this analysis.

Another option is to process the Fourier Transforms with overlapping FFTs. This is controlled with the FFT Block Step. If the block step is set to  $\frac{1}{2}$ , or 0.5, then the Transforms will contain 50% overlapping. So samples 1..800 would be transformed first, followed by samples 401..1200, 801..1600, 1201..2000, and so on.

A third option is to skip IQ data in order to speed up the analysis. If the IQ Block step is set to a value of 3, then every third block of IQ data is analyzed, while the other blocks are ignored. So the first transform would use IQ points 1..800, but the second transform would use IQ data pairs 2401..3200, followed by 4801..5600, and so on.

A visual example for an FFT size of 800 and an FFT block step of 0.025 is shown below. With a block step of 0.025, the IQ data will only advance by 20 samples ( $0.025 * 800 = 20$ ) for each Fourier Transform.



### 3.2.15. FFT Window

This variable determines which window will be applied to the IQ data during the Fourier Transform.

**If IQ data is being captured from an instrument:** This is a variable needed for signal processing in the software. It does not impact the settings of the spectrum analyzer. FFT Window controls the window that is applied during the Fourier Transform of the IQ data.

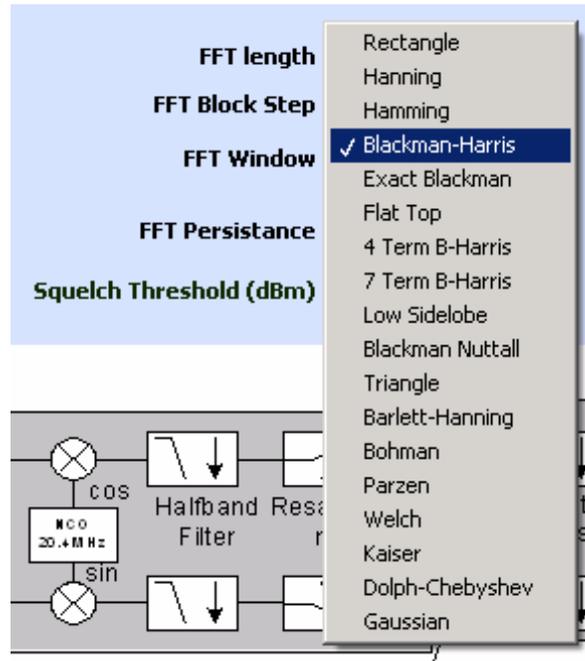
## Measuring Signal Transients with the RF Transient Analysis Software

**If IQ data is being analyzed from a file.** This is a variable needed for signal processing in the software. It is not stored in the IQ data file. FFT Window controls the window that is applied during the Fourier Transform of the IQ data.

### Scope:

This variable is saved by the “Save Setup” softkey.

This variable will be over written with the “Load Setup” operation.



### 3.2.16. FFT Persistence

This variable determines how many “history” traces from past FFTs will be displayed on the FFT plot. Persistence allows the user to see how a signal transitioned from a past value to a current value.

**If IQ data is being captured from an instrument:** This is a variable needed for signal processing in the software. It does not impact the settings of the spectrum analyzer. FFT Persistence controls how many “history” traces from past FFTs will be displayed on the FFT plot.

**If IQ data is being analyzed from a file.** This is a variable needed for signal processing in the software. It is not stored in the IQ data file. FFT Persistence controls how many “history” traces from past FFTs will be displayed on the FFT plot.

### Scope:

This variable is saved by the “Save Setup” softkey.

This variable will be over written with the “Load Setup” operation.

### 3.2.17. Squelch Threshold (dBm)

This variable determines when data will be transferred from the FFT plot to the Frequency vs. Time plot. If the highest spectral component in the FFT exceeds the Squelch Threshold, then it is transferred to the Frequency vs. Time plot. Otherwise, no data is transferred.

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**If IQ data is being captured from an instrument:** This is a variable needed for signal processing in the software. It does not impact the settings of the spectrum analyzer. The Squelch Threshold controls when data is transferred from the FFT plot to the Frequency vs. Time plot.

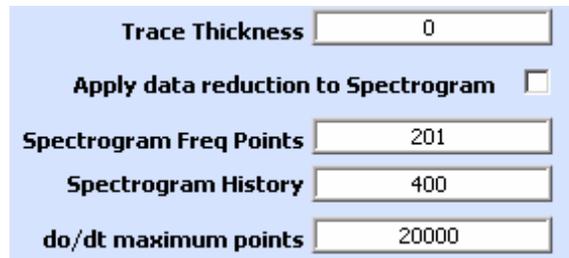
**If IQ data is being analyzed from a file.** This is a variable needed for signal processing in the software. It is not stored in the IQ data file. The Squelch Threshold controls when data is transferred from the FFT plot to the Frequency vs. Time plot.

### Scope:

This variable is saved by the “Save Setup” softkey.

This variable will be over written with the “Load Setup” operation.

### 3.2.18. Trace Thickness



Trace Thickness	0
Apply data reduction to Spectrogram	<input type="checkbox"/>
Spectrogram Freq Points	201
Spectrogram History	400
do/dt maximum points	20000

This variable sets the width or thickness of the traces that are plotted in the various windows. A thickness value of 0 is a hair line, or as narrow as possible. A thickness value of 5 is the widest, and makes it easier to see the trace if the data is being captured in a presentation, for example.

**If IQ data is being captured from an instrument:** This is a variable needed for signal processing in the software. It does not impact the settings of the spectrum analyzer. The Trace Thickness setting impacts the display of the traces in the various windows.

**If IQ data is being analyzed from a file.** This is a variable needed for signal processing in the software. It is not stored in the IQ data file. The Trace Thickness setting impacts the display of the traces in the various windows.

### Scope:

This variable is saved by the “Save Setup” softkey.

This variable will be over written with the “Load Setup” operation.

### 3.2.19. Apply Data Reduction to Spectrogram

This is a new feature that is not yet fully operation. When this checkbox is selected, the IQ data displayed in the spectrogram will be compressed so that the entire set of IQ data is visible on the screen. This will result in loss of detail. If the checkbox is NOT selected, then the data will not be compressed, and the full detail of the signal is displayed as it is processed. However, at some point the data will scroll off the top of the screen, and then it is no longer available for observation.

**If IQ data is being captured from an instrument:** This is a variable needed for signal processing in the software. It does not impact the settings

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of the spectrum analyzer. The Data Reduction option impacts how the data is stored and displayed.

**If IQ data is being analyzed from a file.** This is a variable needed for signal processing in the software. It is not stored in the IQ data file. The Data Reduction option impacts how the data is stored and displayed.

### **Scope:**

This variable is saved by the “Save Setup” softkey.

This variable will be over written with the “Load Setup” operation.

### **3.2.20. Spectrogram Frequency Points**

This setting determines the resolution of the Spectrogram on the X-Axis. It is the number of frequency bins or pixels that are displayed on the plot. If there are more data points than frequency bins, then adjacent data points are combined into a bin so that the data will fit into the allocated space.

**If IQ data is being captured from an instrument:** This is a variable needed for signal processing in the software. It does not impact the settings of the spectrum analyzer. The Spectrogram Frequency Points setting controls the frequency resolution of the spectrogram plot.

**If IQ data is being analyzed from a file.** This is a variable needed for signal processing in the software. It is not stored in the IQ data file. The Spectrogram Frequency Points setting controls the frequency resolution of the spectrogram plot.

### **Scope:**

This variable is saved by the “Save Setup” softkey.

This variable will be over written with the “Load Setup” operation.

### **3.2.21. Spectrogram History**

This setting determines the number of spectrogram traces that are saved and displayed in the spectrogram plot. Once this number of traces has been captured and displayed, then each new trace will result in the removal of the oldest trace from the plot. The old traces will shift upward and off the screen as the new traces are added to the bottom of the Spectrogram plot.

**If IQ data is being captured from an instrument:** This is a variable needed for signal processing in the software. It does not impact the settings of the spectrum analyzer. The Spectrogram History setting controls how far back in time the spectrogram plot can display data.

**If IQ data is being analyzed from a file.** This is a variable needed for signal processing in the software. It is not stored in the IQ data file. The Spectrogram History setting controls how far back in time the spectrogram plot can display data.

### **Scope:**

This variable is saved by the “Save Setup” softkey.

This variable will be over written with the “Load Setup” operation.

### **3.2.22. do/dt maximum points**

This parameter controls a new feature that is not fully implemented in this version of the software. When selecting the measurement option of frequency vs. time, there are two ways to calculate the frequency data. One

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is to use the maximum spectral component from each FFT, resulting in one frequency data point per Fourier Transform. The second is to calculate the frequency based on the derivative of the phase values in the IQ data. This can result in a new frequency point for nearly every IQ data pair. This parameter controls the level of data reduction that is applied to this second method of calculating frequency vs. time.

**If IQ data is being captured from an instrument:** This is a variable needed for signal processing in the software. It does not impact the settings of the spectrum analyzer. The do/dt maximum points controls how many of the frequency vs. time data points are plotted on the graph.

**If IQ data is being analyzed from a file.** This is a variable needed for signal processing in the software. It is not stored in the IQ data file. The do/dt maximum points controls how many of the frequency vs. time data points are plotted on the graph.

### Scope:

This variable is saved by the “Save Setup” softkey.

This variable will be over written with the “Load Setup” operation.

### 3.3. Step Three: Configure the Limit Lines

Limit Lines are available for the frequency vs. time plot. They are useful, for example, for making transient lock time measurements or to check for the linearity of a radar chirp pulse. If a limit line is selected, there will be an indication of pass or failure on the frequency vs. time plot.

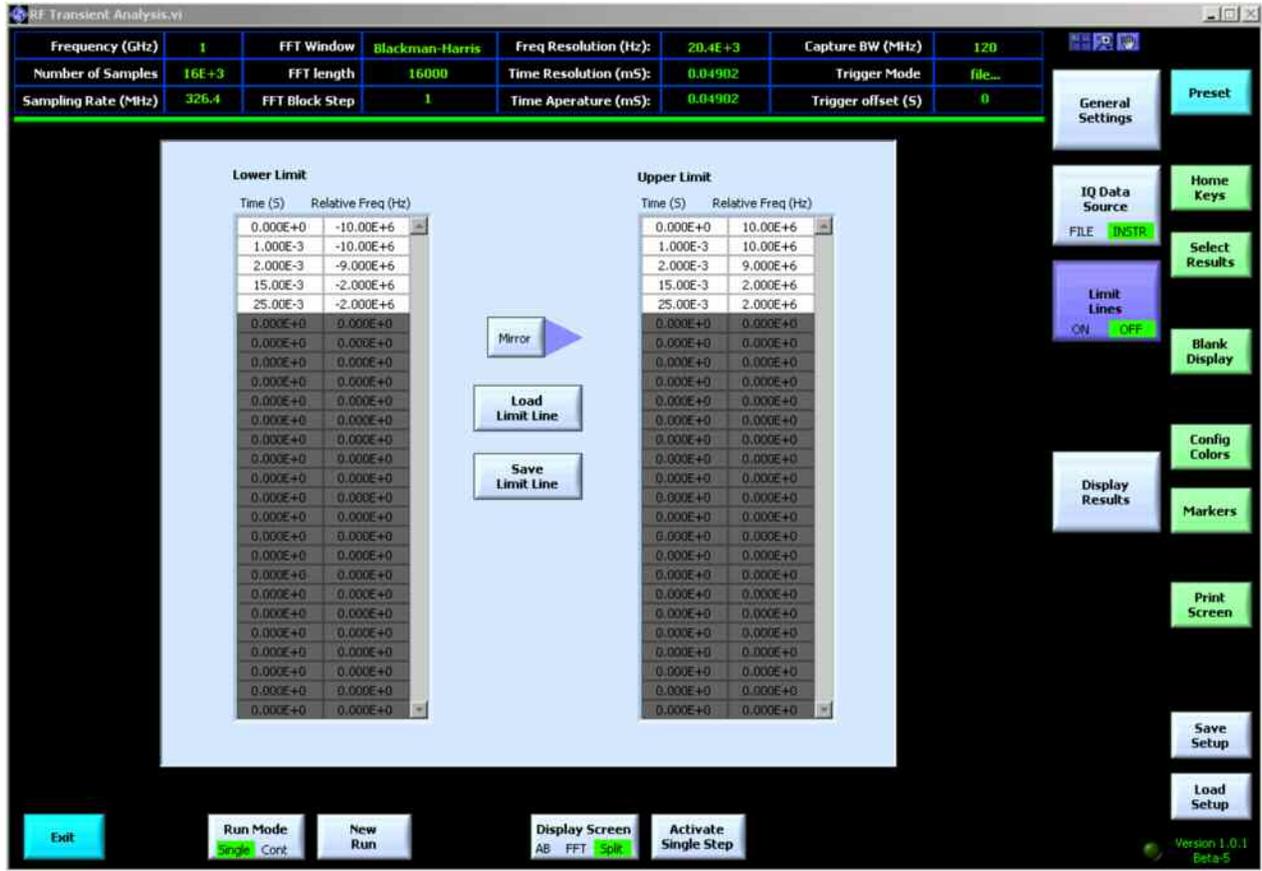


The limit line values are entered in a table. There is one table for the lower limit, and a second table for the upper limit. If the intended limit lines are symmetrical about the center frequency of the measurement, then enter the lower limit line first, and press the “Mirror” button. A symmetrical limit line will be entered into the Upper Limit table.

The Limit Lines softkey has an indication of the state of the limit lines, either enabled or not. After the limit line softkey is pressed the first time, then each subsequent press of the softkey will toggle the enabled state from ON to OFF and back again.

The limit lines can be saved to a file, or read from a file. The files are text based, so it is easy enough to open a file up and determine the appropriate format if a limit line file is to be created in an external program.

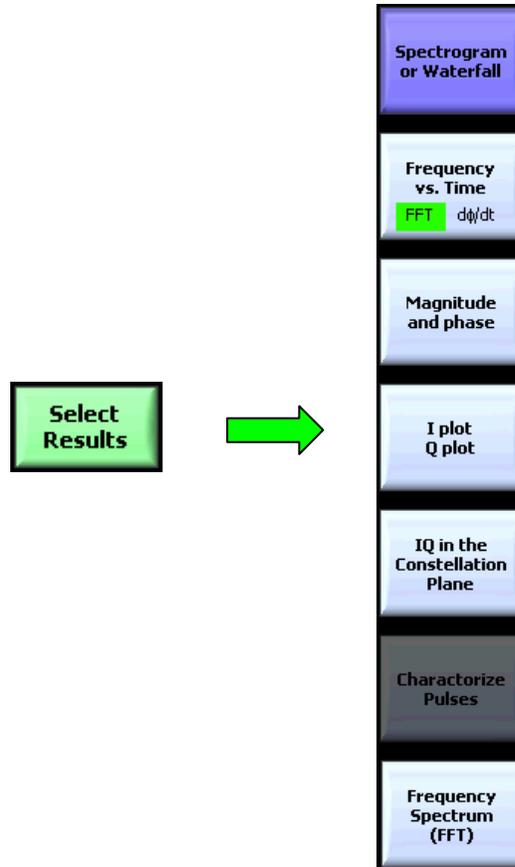
# Measuring Signal Transients with the RF Transient Analysis Software



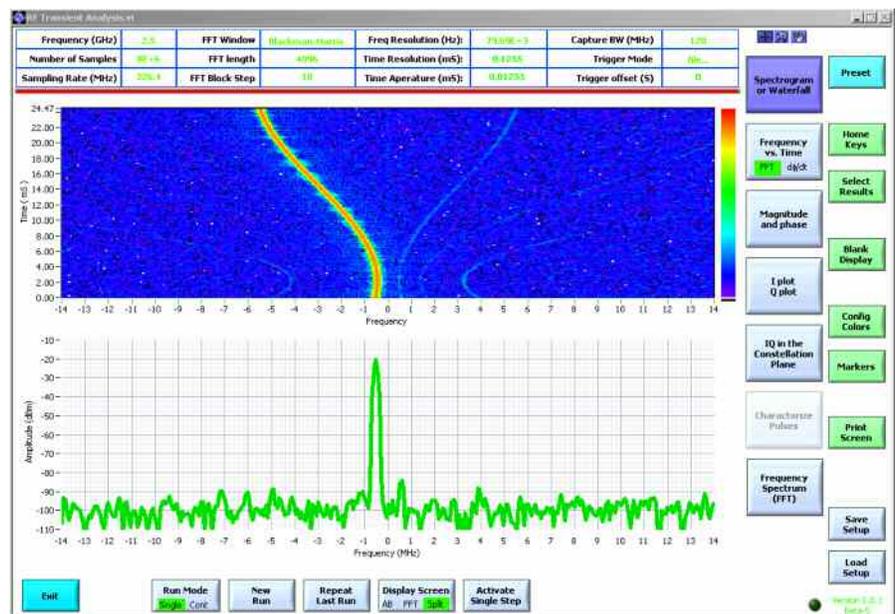
## 3.4. Step Four: Select Measurement Result

The captured IQ data can be displayed in a variety of ways. Press the Select Results Softkey to get a list of displays.

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A spectrogram uses the FFT trace associated with each block of IQ data to create a color plot with frequency on the X-axis, time on the Y-axis (older data to the top) and amplitude on the Z-axis (represented with a color ramp). An example using the same IQ data is shown below.

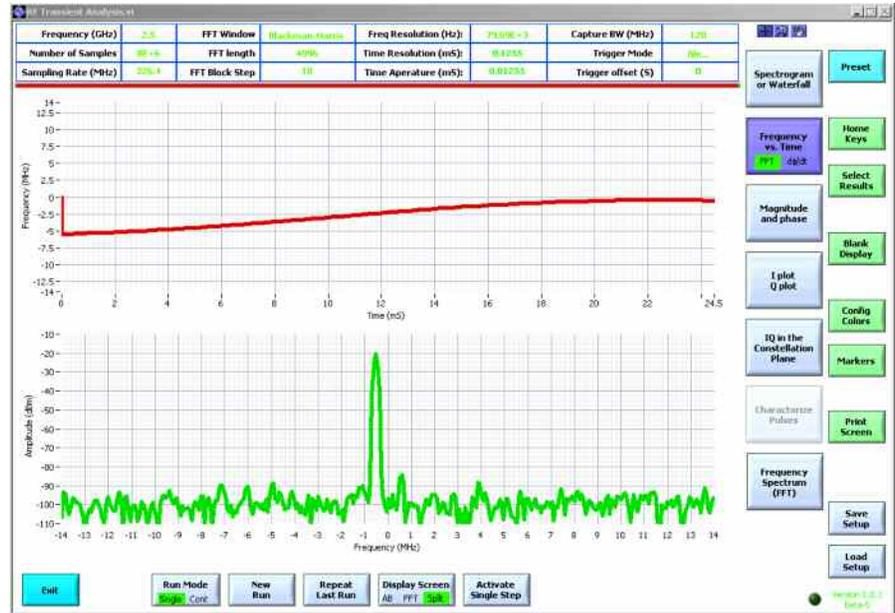


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Frequency vs. Time is a plot of the dominant spectral component in each block of IQ data, plot against time on the X axis.

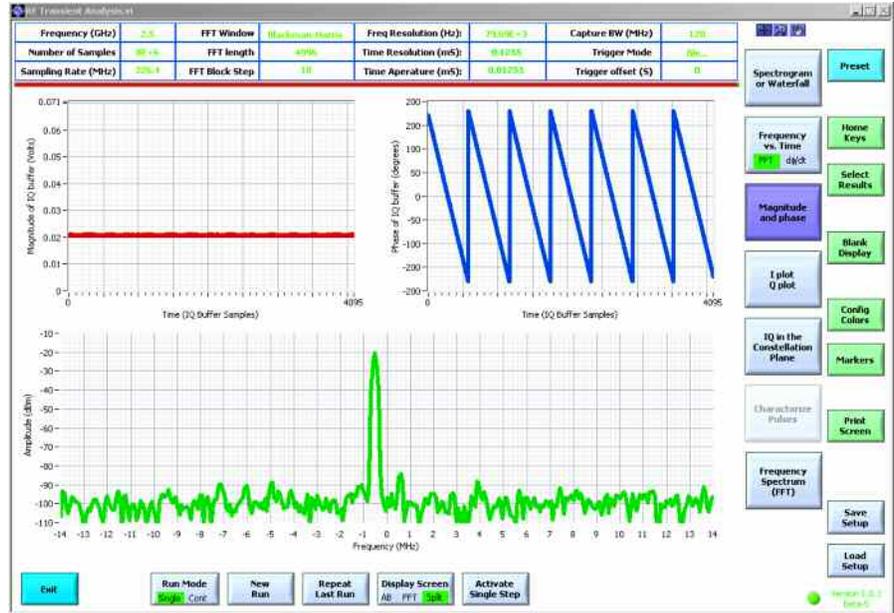
Each block of IQ data is processed with an FFT. Then the maximum point is searched for in the FFT. The frequency associated with this point is plotted on the Y-axis, and the center time stamp of the block of IQ data is plotted on the X-axis.

An example is shown below: In this screen shot, the upper window is the frequency transient vs. time, and the lower window is the most recent FFT which was performed on the last block of IQ data.

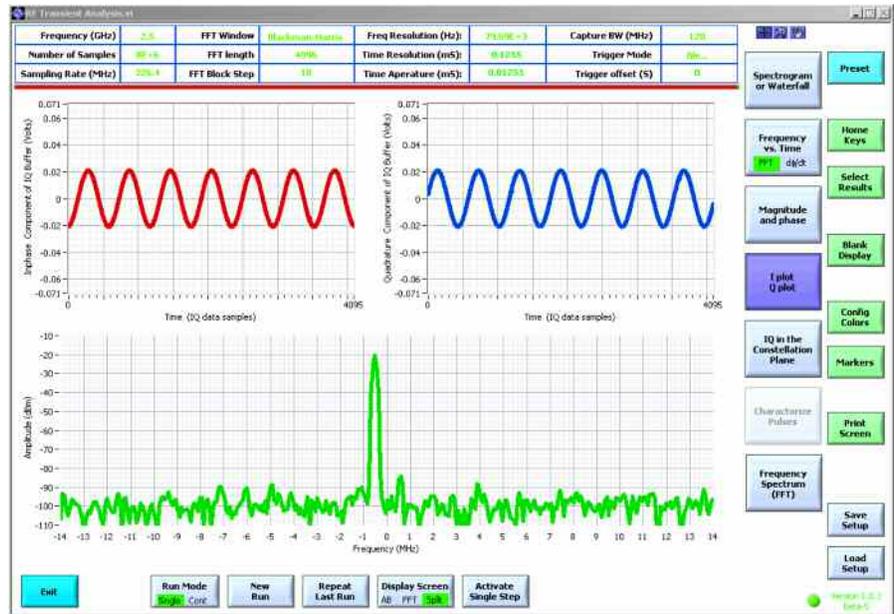


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Another view of this same IQ data can be presented as the magnitude and phase of the I and Q values in each block. This presents a time varying display, similar to what would be seen on an oscilloscope. A representative screen shot is shown below:

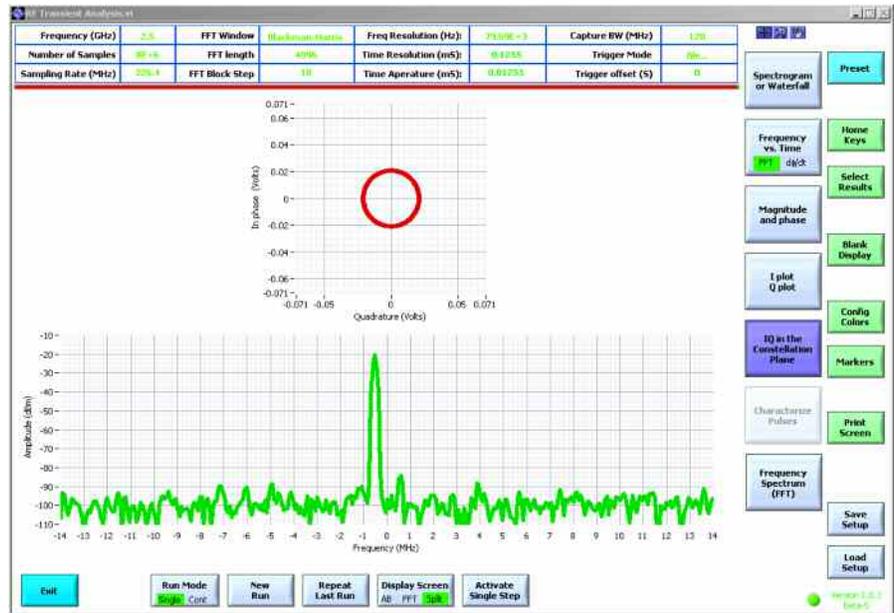


Alternatively, the I and Q values can be displayed directly. A representative screen shot is shown below:



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A final plot shows the I and Q values in an IQ plane:



## 3.5. Step Five: Start the Analysis

Once the intended measurement is configured, press the New Run softkey to start the measurement. The results screen will be displayed automatically. If the Data Source is set to file, a dialog box will open asking which file should be analyzed. Otherwise the software will attempt to acquire the data from the configured spectrum analyzer.

Once the software is running, an abort key will show up so that the measurement can be aborted.

Different measurement plots can be selected even while the data is being processed. All of the measurement windows are updated even when they are not displayed.

## 3.6. Step Six: Customize the way the data is displayed

There are a number of options for changing the way the data is displayed on the screen. Each will be reviewed in this section.

### 3.6.1. Colors

There is a softkey on the right hand side of the display named “config colors”. Selecting this softkey brings up a new menu where the colors of a few items can be modified.

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The first button changes the background color scheme between a dark setup and a light setup. A dark setup may be ideal for viewing the data on a computer screen, while a light setup is a better choice for printing the results or for placing a screenshot in a document.

After selecting a dark or light color scheme, the background color can be adjusted further by left clicking in the color box that is contained in the Background Color softkey. If changing from a very dark background to a very light background, it may be helpful to first select a light background color scheme so that the text, gridlines and other displayed artifacts compliment the background.

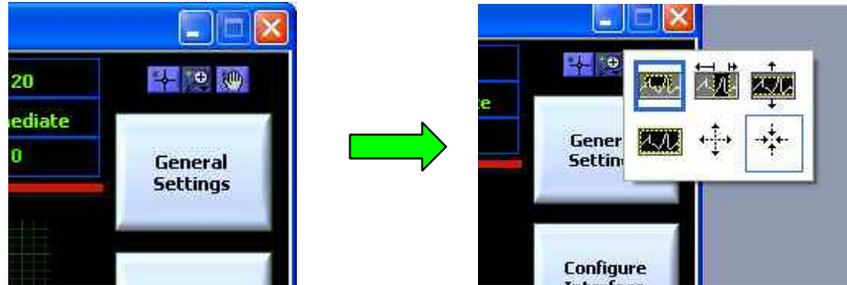
### 3.6.2. Trace Widths

By default, the traces are normally displayed as narrow lines. To make them more visible, perhaps in a printout or when documenting the results, it may be desirable to have thicker traces. The trace width can be modified by selecting the Home Keys -> General Settings softkeys, and then entering a number in the Trace Thickness variable. The valid range is 0 to 5, with 0 being the narrowest, and 5 being the thickest.

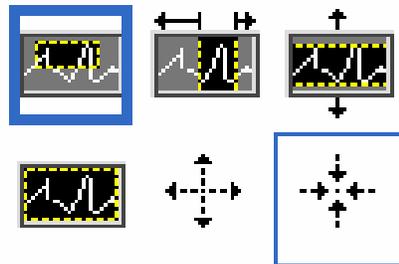
### 3.6.3. Panning, Zooming and controlling scales

In the upper right hand corner of the window are some tools for zooming in or panning the displayed data

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Select a tool by left clicking on the magnifying glass in the center of the selection pallet, and then you will be able to manipulate the displayed charts.



The first tool, in the upper left hand corner of the selection box, allows you to click and drag an area on a plot to zoom into that area. The tool to the right also zooms in on an area of the plot, but only zooms in on the X-axis. The last tool on the top row zooms in on an area of the plot, but only zooms in on the Y-axis.

The leftmost selection in the bottom row is currently not functional. The middle selection in the bottom row will zoom in on a point that is clicked on in a plot. The rightmost selection in the bottom row will zoom out on a point that is clicked on in a plot.

You can also change the scales of the charts by double clicking on the maximum and minimum values of either the X-axis or the Y-axis. This allows fine control over the level of zooming in either direction.

Panning is selecting by choosing the Hand Tool from the selection pallet. It is the rightmost selection in the pallet directly above the General Settings Softkey. Once the hand has been selecting, you can click and drag on a plot to change the area that is displayed.

### 3.6.4. New Run vs. Repeat Last Run; and Continuous Run

The New Run softkey will reset all the plots to the default zoom levels. This allows the user to observe the entire signal at the completion of the test.

The Repeat Last Run softkey retains the current zoom levels of the plots. If a zoomed in section of a plot contains the signal of interest, and this area is to remain zoomed in for subsequent tests, then use the Repeat Last Run softkey to collect the next set of data.

Additionally, if a data file is being analyzed instead of new data from the a spectrum analyzer, then the Repeat Last Run softkey will automatically use the same data file for subsequent runs.

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There is also a mode softkey that allows the user to place the software into a continuous run mode. This is equivalent to pressing the Repeat Last Run softkey at the conclusion of each run.

### 3.6.5. Full Screen vs. Split Screen

Any of the displays can be displayed in “full screen” mode. The FFT window is always displayed on the bottom when in “split screen” mode, and the top screen is used for all the other measurements. Toggle between these modes with the Display softkey:



### 3.6.6. Pausing the Analysis and Single Stepping

During the processing of the IQ data, the updates can be “Paused” by selecting the “Activate Single Step” button at the bottom of the screen. Once the measurement has been paused, the user can step forward and backward through the IQ data in integer increments of an IQ block. Set the desired step size in the “blocks to step” entry, and then press the forward and backward buttons as desired.

If you want the automatic processing to continue, press the “Single Step IQ Blocks” button a second time to release it. Alternatively, press the “Abort Run” button to stop analysis on this IQ buffer of data.



### 3.6.7. Using Markers

Four Markers and Four delta markers are available for making measurements. In this release of the software, the markers can only be used on the FFT spectrum trace, or on the Frequency vs. time trace.

The markers can either be snapped to the displayed trace, or they can be free floating so that you can place them anywhere.

When the markers are first turned on, they default to the far left side of the screen, on the first data point. To move them around, select the cursor tool from the pallet. It is the one on the left, which looks like a cross hair



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Using that tool, click on a marker and drag it to the desired location. The Marker's name can also be moved relative to the marker's placement. Click on the maker name with the same tool, and move it to the desired location.



### 3.6.8. Optimizing Measurement Speed

Analysis of a large set of IQ data can take a long time. It is especially important to use a computer with a large amount of memory, preferably 2 Giga Bytes of Ram or more. The RF Transient Analysis software also takes advantage of multi-threading, so dual or quad core processors will also improve performance significantly.

Beyond using the highest performance computing resources, the speed of the software can also be improved by turning off the screen updates. This is accomplished by pressing the “Blank Display” softkey. The results are still accumulated and stored, but the window will not be updated until the entire IQ buffer has been processed.

### 3.7. Step Seven: Save the Setup to a File

Once the desired measurements and settings are configured, they can be saved to a file for easy recall in the future. Press the Save Setup softkey to create this file.

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Likewise, settings from a previous session can be recalled with the Recall Setup softkey.

### **4. Some Examples**

These examples will use the \*.iqw files, settings files, and limit lines that were delivered with the software. They are installed in the same folder as the executable, in a folder named examples.

#### **4.1. Barker Code**

This example uses a pre-captured IQ data file of a Barker Code Transmission. These step by step instructions will allow you to analyze this signal and arrive at the screen shot shown below:

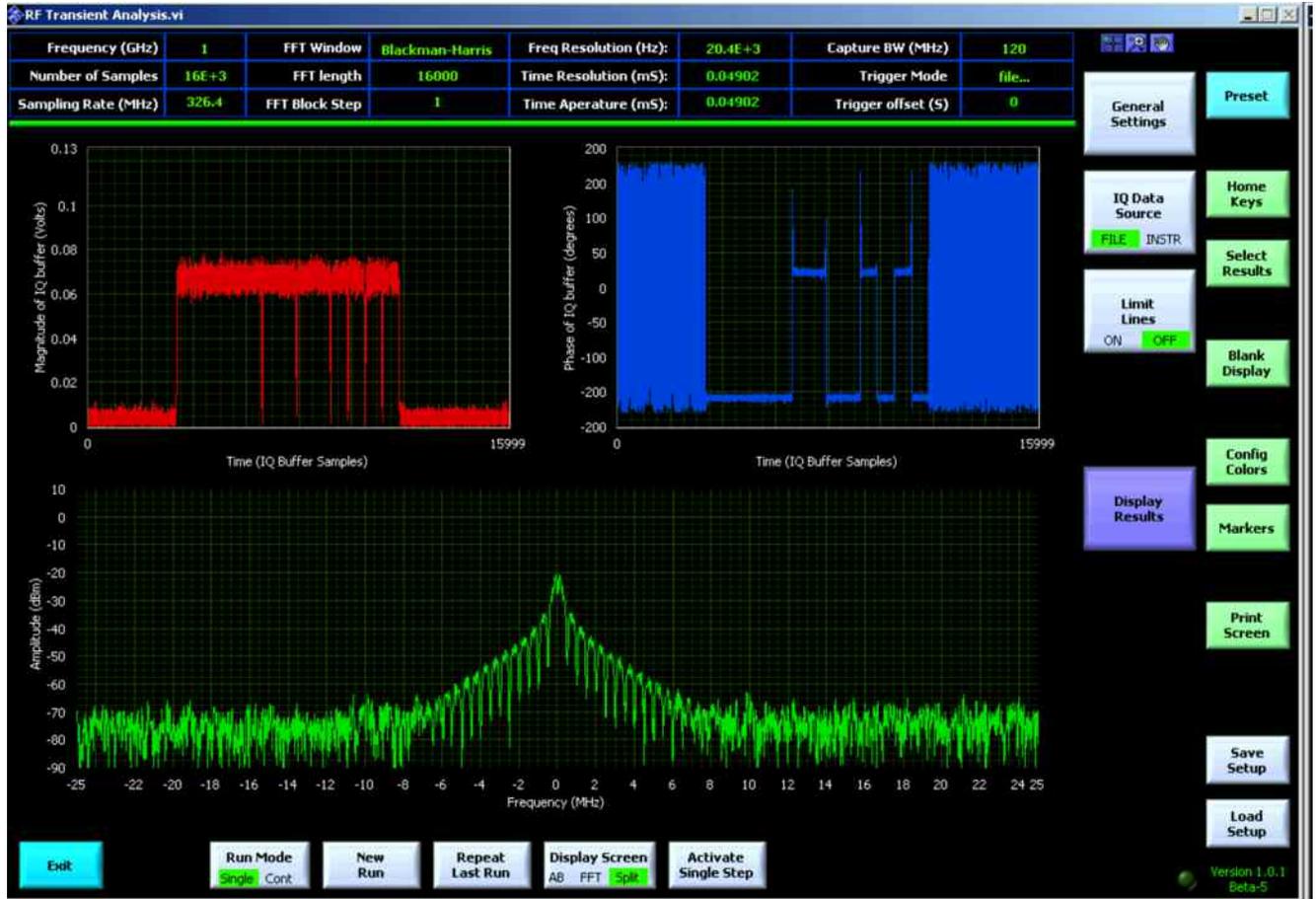
1. Start by launching the RF Transient Analysis Software
2. Press the “Preset” button in the upper right hand corner.
3. Press the “Load Setup” softkey.
4. Select the file named, “Barker code, all at once.set”
5. Press the “New run” softkey
6. Select the file named, “Barker code.iqb”

There will be three plots on the screen. The upper left hand plot, shown here in red, is the magnitude of the IQ data vs. time. The upper right hand plot, with a blue trace, is the phase of the IQ data vs. time. The bottom plot, in green, is the FFT of this same IQ data.

The Barker code itself, which is present in the signal as a phase modulation that alternates between two states, can be seen in the upper right hand plot. Visually, it can be read as:

Low, Low, Low, Low, High, High, Low, Low, High, Low, High, Low

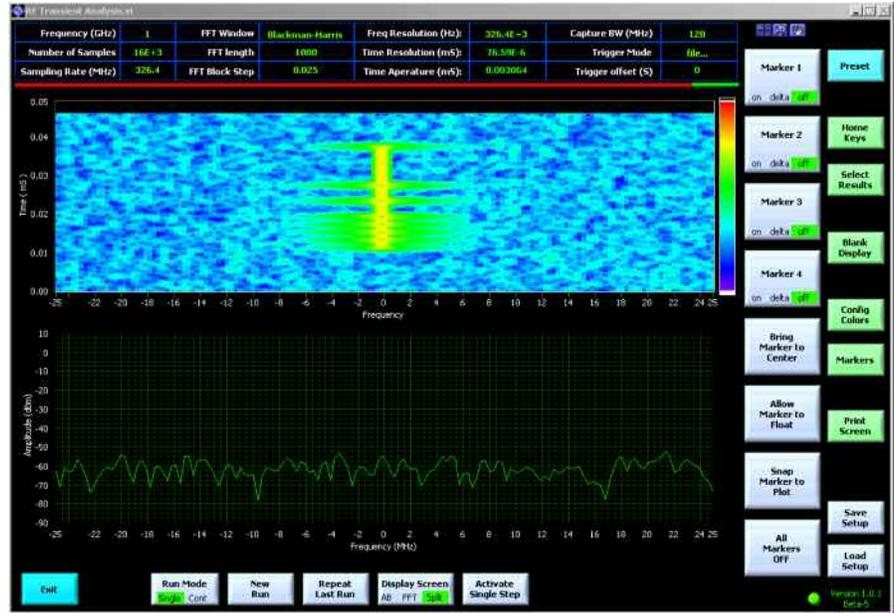
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The same data can be analyzed in more detail by breaking the analysis of the IQ data up into blocks. To do this use the following steps:

1. Start by launching the RF Transient Analysis Software
2. Press the “Preset” button in the upper right hand corner.
3. Press the “Load Setup” softkey.
4. Select the file named, “Barker code.set”
5. Press the “New run” softkey
6. Select the file named, “Barker code.iqb”

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### 4.2. Chirp Pulse

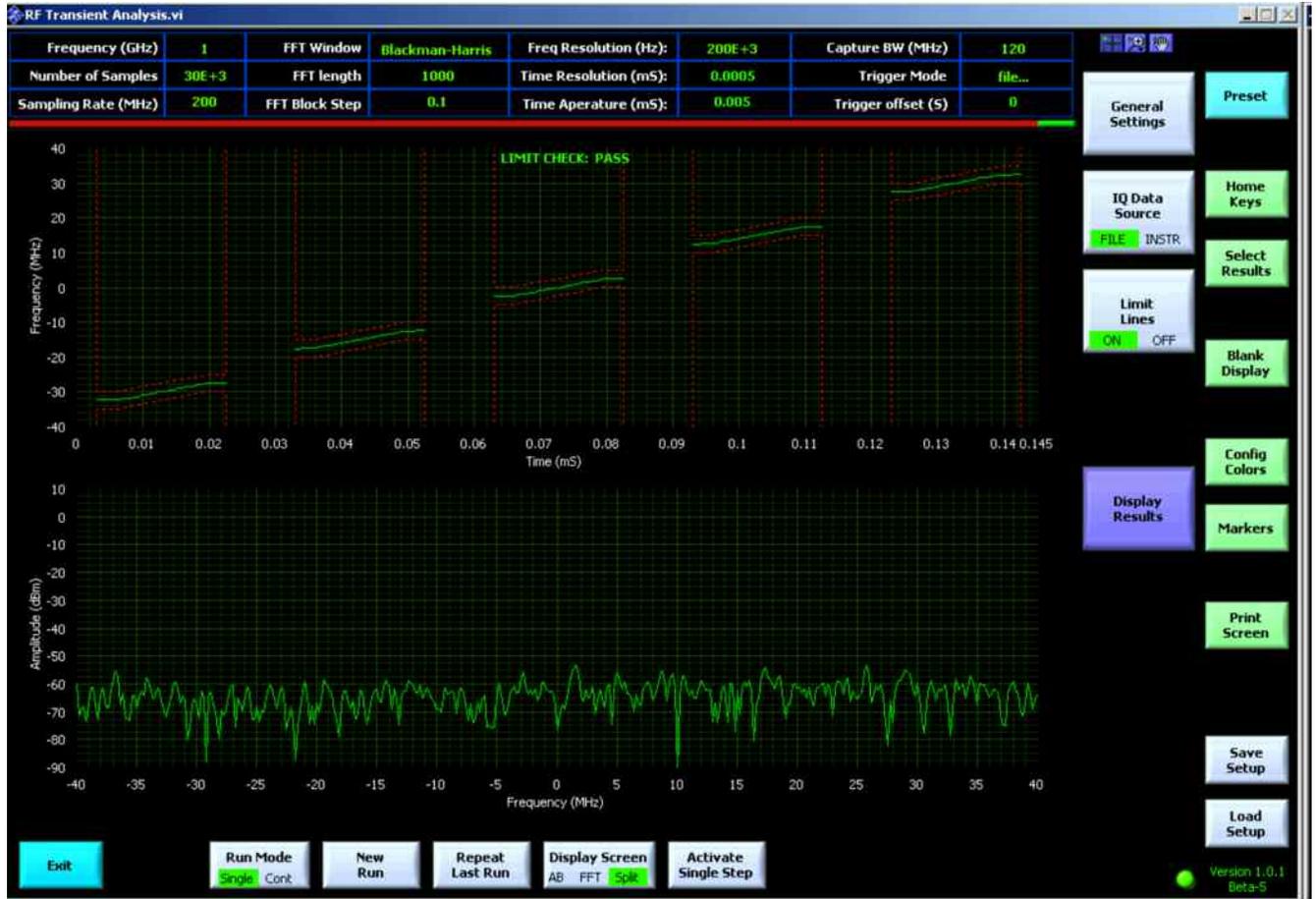
This example uses a pre-captured IQ data file of a frequency hopping, chirp modulated pulse transmission. These step by step instructions will allow you to analyze this signal and arrive at the screen shot shown below:

1. Start by launching the RF Transient Analysis Software
2. Press the “Preset” button in the upper right hand corner.
3. Press the “Load Setup” softkey.
4. Select the file named, “Chirp pulse, freq vs. time.set”
5. Press the “Limit Lines” softkey
6. Press the “Load Limit Line” softkey
7. Select the file named, “chirp pulse.ll”
8. Press the “New run” softkey
9. Select the file named, “chirp pulse.iqb”

There will be two plots on the screen. The upper plot, shown here with a green trace, is the frequency of the FM chirp vs. time. It is squelched or suppressed when the chirp is not present. The bottom plot, in green, is the most recent FFT of this same IQ data. In this particular screen shot, the pulse was off during the most recent FFT.

Also visible in the top plot are lower and upper limit lines, shown with dashed red lines. This is also an indication that the collected data passed the limit check.

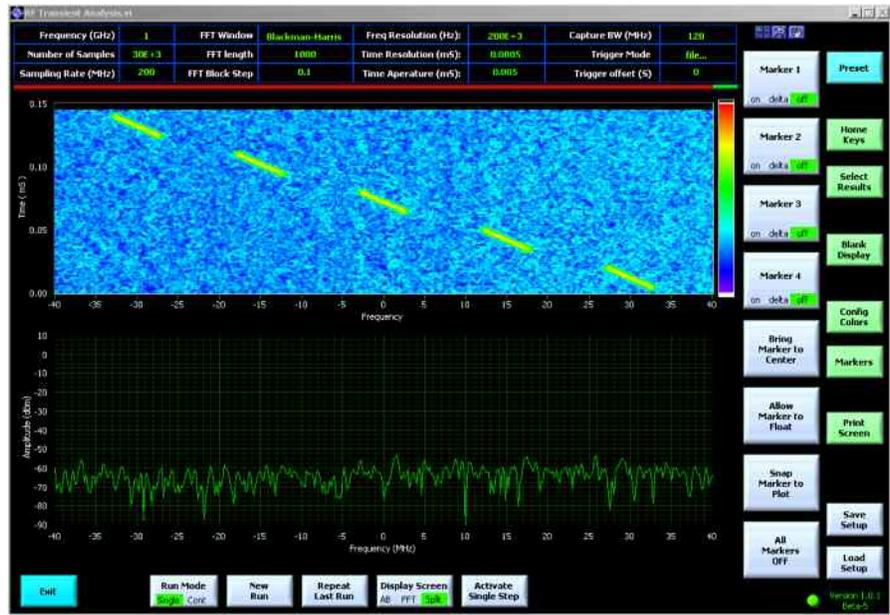
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Another way to view this data is in a spectrogram display. To see this, use the following sequence.

1. Start by launching the RF Transient Analysis Software
2. Press the "Preset" button in the upper right hand corner.
3. Press the "Load Setup" softkey.
4. Select the file named, "Chirp pulse.set"
5. Press the "New run" softkey
6. Select the file named, "chirp pulse.iqb"

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### 4.3. Circle Phi Pulse

This example uses a pre-captured IQ data file of a frequency hopping, circle phi modulated pulse transmission. These step by step instructions will allow you to analyze this signal and arrive at the screen shot shown below:

1. Start by launching the RF Transient Analysis Software
2. Press the “Preset” button in the upper right hand corner.
3. Press the “Load Setup” softkey.
4. Select the file named, “circle phi, freq vs. time.set”
5. Press the “Limit Lines” softkey
6. Press the “Load Limit Line” softkey
7. Select the file named, “circle phi.ll”
8. Press the “New run” softkey
9. Select the file named, “circle phi pulse.iqb”

There will be two plots on the screen. The upper plot, shown here with a green trace, is the frequency of the modulated chirp vs. time. It is squelched or suppressed when the chirp is not present. The bottom plot, in green, is the most recent FFT of this same IQ data. In this particular screen shot, the pulse was off during the most recent FFT.

Also visible in the top plot are lower and upper limit lines, shown with dashed red lines. This is also an indication that the collected data passed the limit check.

## Measuring Signal Transients with the RF Transient Analysis Software



Another way to view this data is in an IQ plane display. To see this, use the following sequence.

1. Start by launching the RF Transient Analysis Software
2. Press the “Preset” button in the upper right hand corner.
3. Press the “Load Setup” softkey.
4. Select the file named, “circle phi.set”
5. Press the “New run” softkey
6. Select the file named, “circle phi pulse.iqb”

In this screenshot, the pause button was pressed during the analysis to capture the results at a particular point in time.

## Measuring Signal Transients with the RF Transient Analysis Software



### 4.4. Frequency Hopping

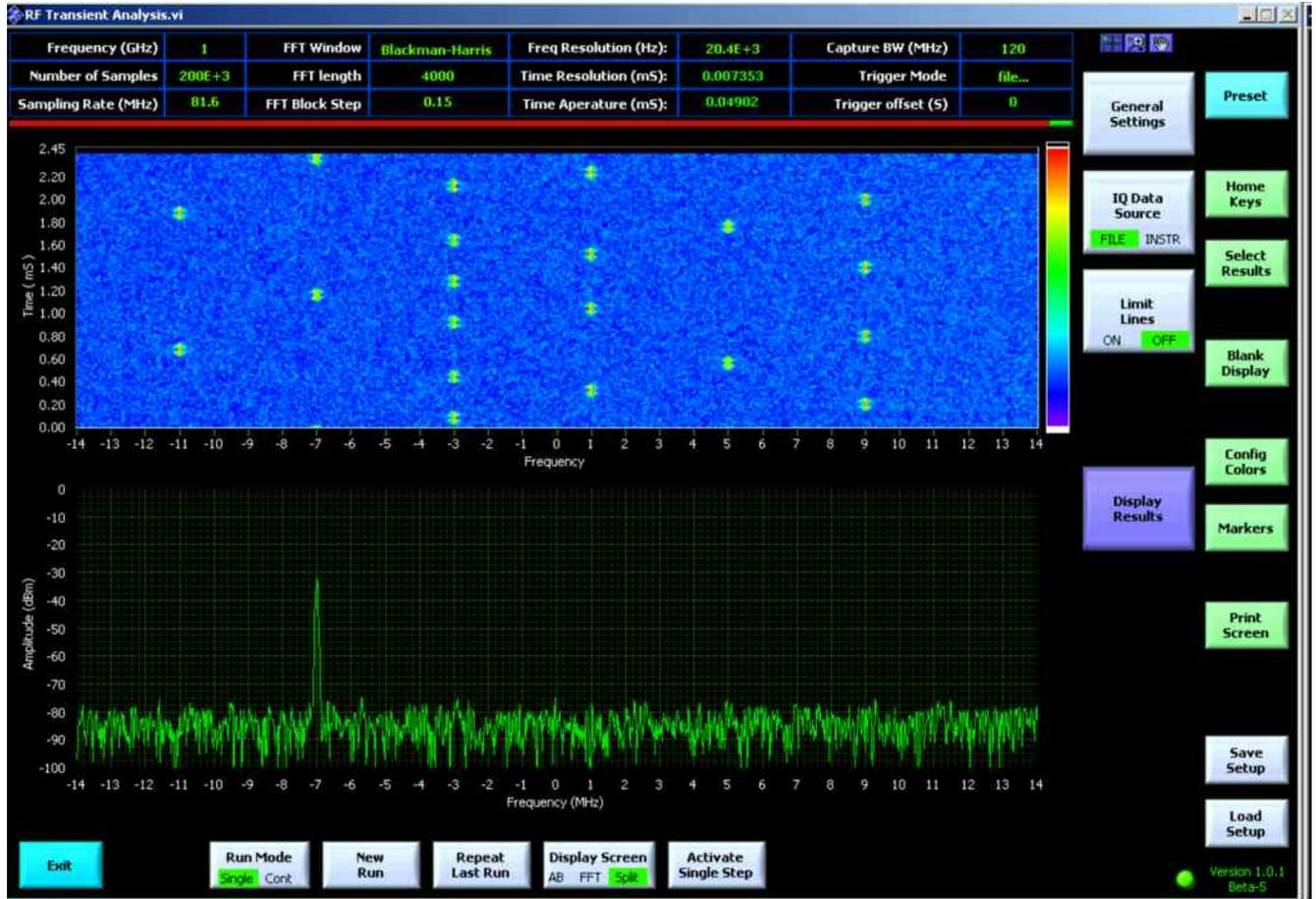
This example uses a pre-captured IQ data file of a frequency hopping CW carrier. These step by step instructions will allow you to analyze this signal and arrive at the screen shot shown below:

1. Start by launching the RF Transient Analysis Software
2. Press the “Preset” button in the upper right hand corner.
3. Press the “Load Setup” softkey.
4. Select the file named, “frequency hopping.set”
5. Press the “New run” softkey
6. Select the file named, “frequency hopping.iqb”

There will be two plots on the screen. The upper plot, shown here with a green trace, is the frequency of the modulated chirp vs. time. It is squelched or suppressed when the chirp is not present. The bottom plot, in green, is the most recent FFT of this same IQ data. In this particular screen shot, the pulse was off during the most recent FFT.

Also visible in the top plot are lower and upper limit lines, shown with dashed red lines. This is also an indication that the collected data passed the limit check.

## Measuring Signal Transients with the RF Transient Analysis Software



Another way to view this data is in the frequency vs. time display. Get to this plot by pressing the following keys

7. Press the “Select Measurement” softkey
8. Press the “Freq vs. Time” softkey
9. Press the “Repeat Last Run” softkey.

## Measuring Signal Transients with the RF Transient Analysis Software



### 4.5. QAM Pulse

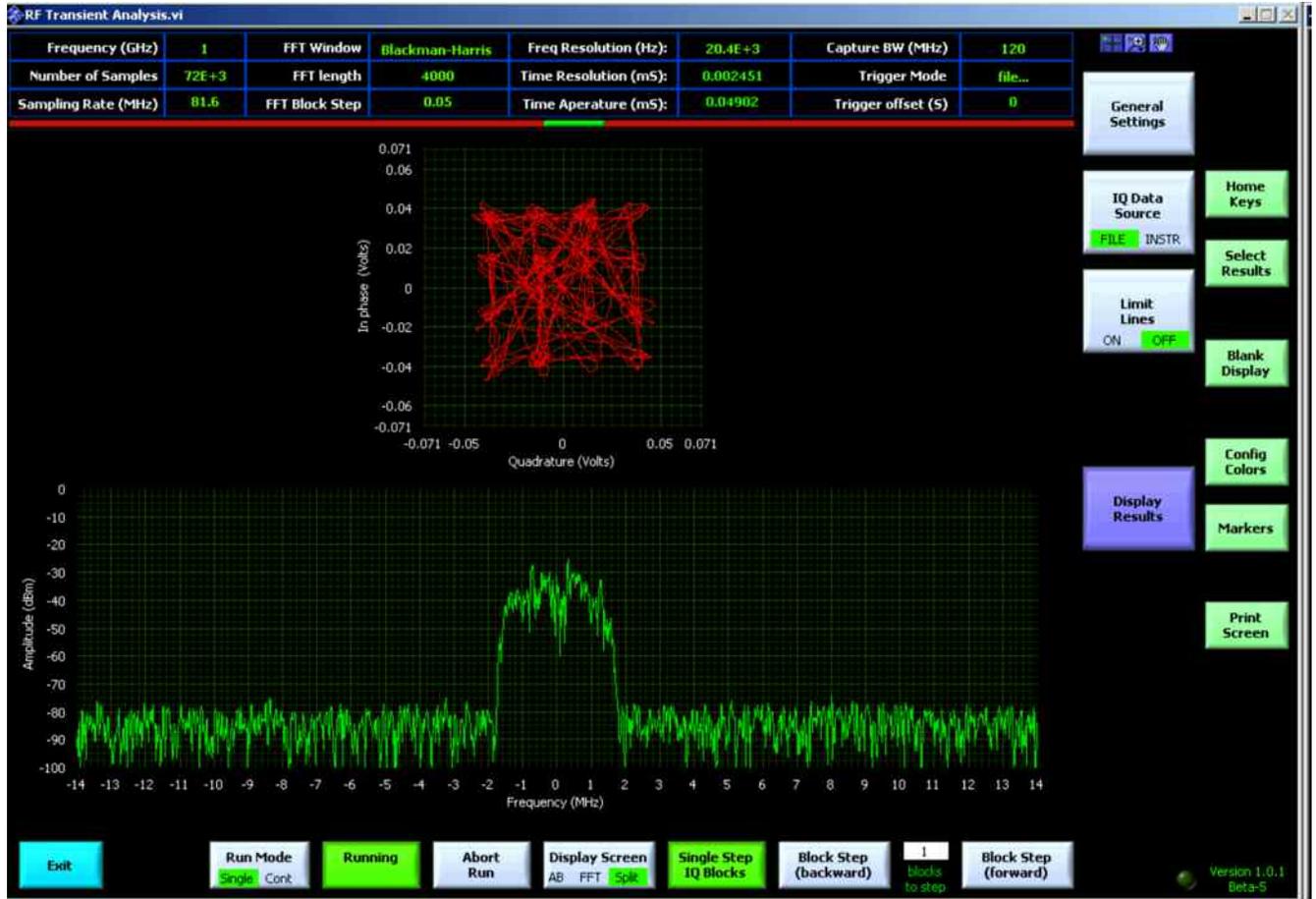
This example uses a pre-captured IQ data file of a pulsed signal with 16 QAM modulation on the carrier. These step by step instructions will allow you to analyze this signal and arrive at the screen shot shown below:

1. Start by launching the RF Transient Analysis Software
2. Press the “Preset” button in the upper right hand corner.
3. Press the “Load Setup” softkey.
4. Select the file named, “QAM Pulse.set”
5. Press the “New run” softkey
6. Select the file named, “QAM Pulse.iqb”

There will be two plots on the screen. The upper plot, shown here with a red trace, is a view of the modulated signal in the IQ plane. The 16 QAM constellation is clearly visible. The lower plot is the most recent FFT of the IQ data.

Also visible in the top plot are lower and upper limit lines, shown with dashed red lines. This is also an indication that the collected data passed the limit check.

## Measuring Signal Transients with the RF Transient Analysis Software



### 4.6. Radar Pulse

This example uses a pre-captured IQ data file of an FM chirped Radar Pulse. These step by step instructions will allow you to analyze this signal and arrive at the screen shot shown below:

1. Start by launching the RF Transient Analysis Software
2. Press the “Preset” button in the upper right hand corner.
3. Press the “Load Setup” softkey.
4. Select the file named, “radar pulse, all at once.set”
5. Press the “New run” softkey
6. Select the file named, “radar pulse.iqb”

There will be three plots on the screen. The upper left plot, shown here with a red trace, is the I (of the IQ data) vs. time. The upper right plot, in blue, is the Q value vs. time. And the bottom plot is the FFT of the entire IQ data file.

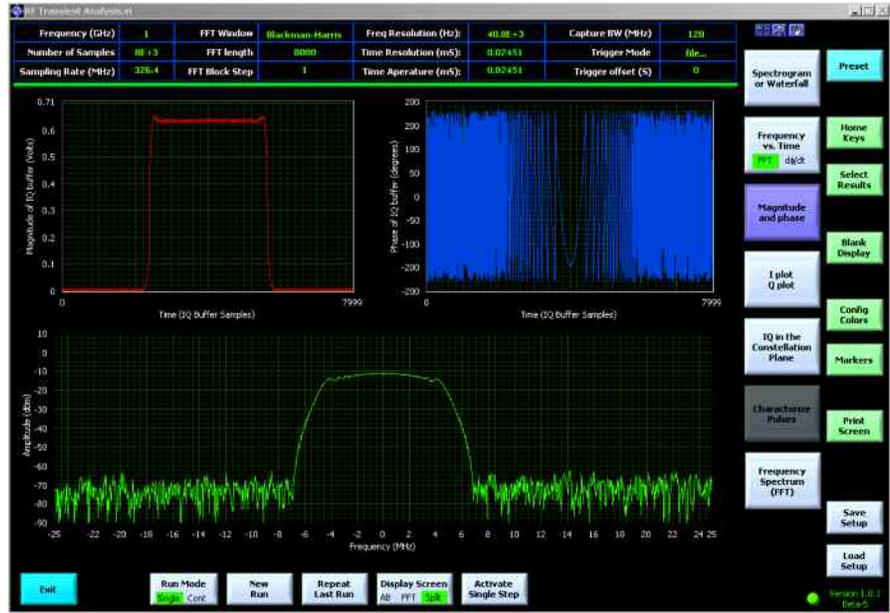
## Measuring Signal Transients with the RF Transient Analysis Software



Another way to view this data is to display the magnitude and phase of the IQ data.. Get to this plot by pressing the following keys

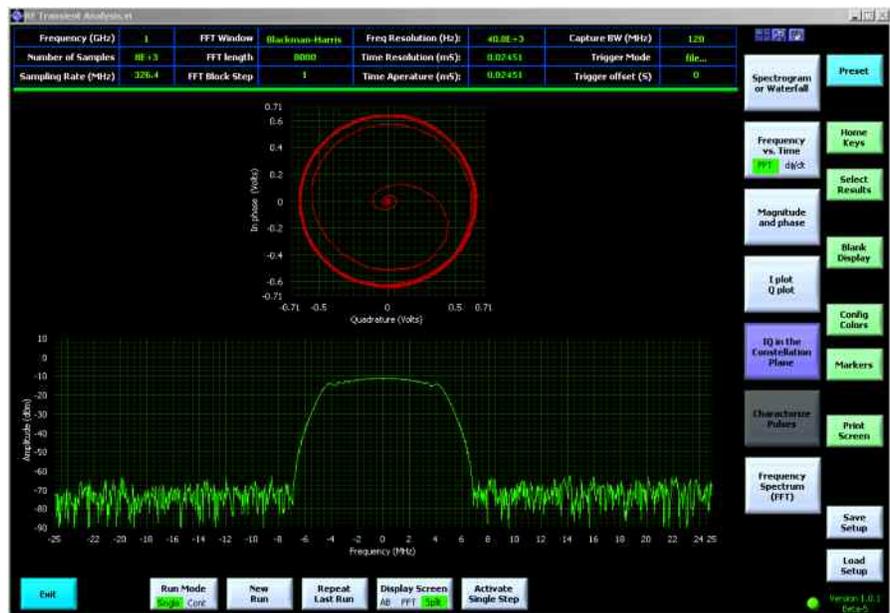
7. Press the “Select Measurement” softkey
8. Press the “Magnitude and Phase” softkey

# Measuring Signal Transients with the RF Transient Analysis Software



A third option is to observe the data in the IQ plane:

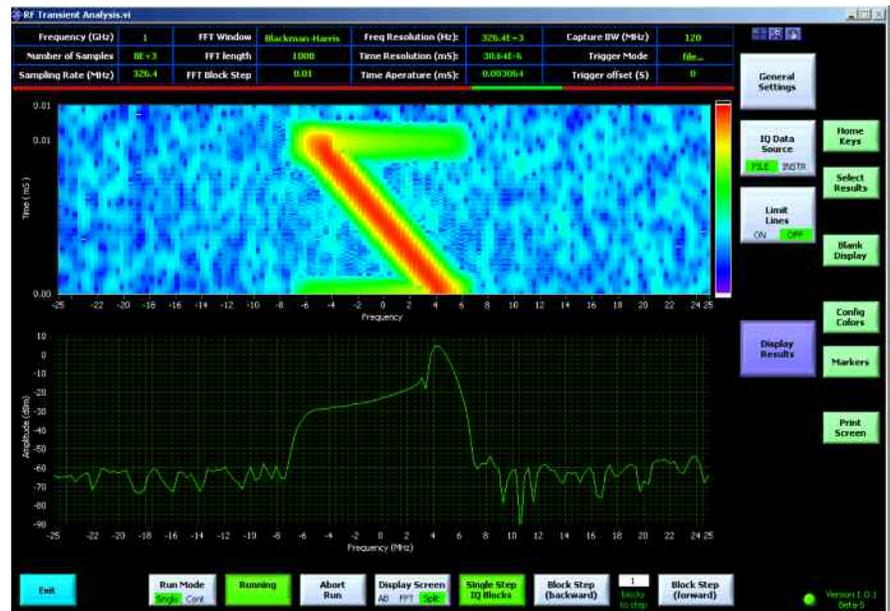
9. Press the “Select Measurement” softkey
10. Press the “IQ in the constellation plane” softkey



## Measuring Signal Transients with the RF Transient Analysis Software

The same data can be analyzed in more detail by breaking the analysis of the IQ data up into blocks. For example, a spectrogram plot shows the details of the radar pulse. To get this display use the following steps:

11. Press the “Load Setup” softkey.
12. Select the file named, “radar pulse, block by block.set”
13. Press the “New run” softkey
14. Select the file named, “radar pulse.iqb”



Another way to view this data is in a frequency vs. time plot. This is a plot that allows the application of limit lines. Get this plot with the following sequence:

15. Press the “Select Measurement” softkey.
16. Press the “Frequency vs. Time” softkey
17. Press the “Home Keys” softkey
18. Press the “Limit Lines” softkey
19. Press the “Load Limit Lines” key
20. Select the file named, “radar pulse.11”
21. Press the “Repeat Last run” softkey

The resulting plot shows the linearity of the FM chirp, and also provides an indication of pass or fail based on the selected limit line.

## Measuring Signal Transients with the RF Transient Analysis Software



### 4.7. WiMAX waveform

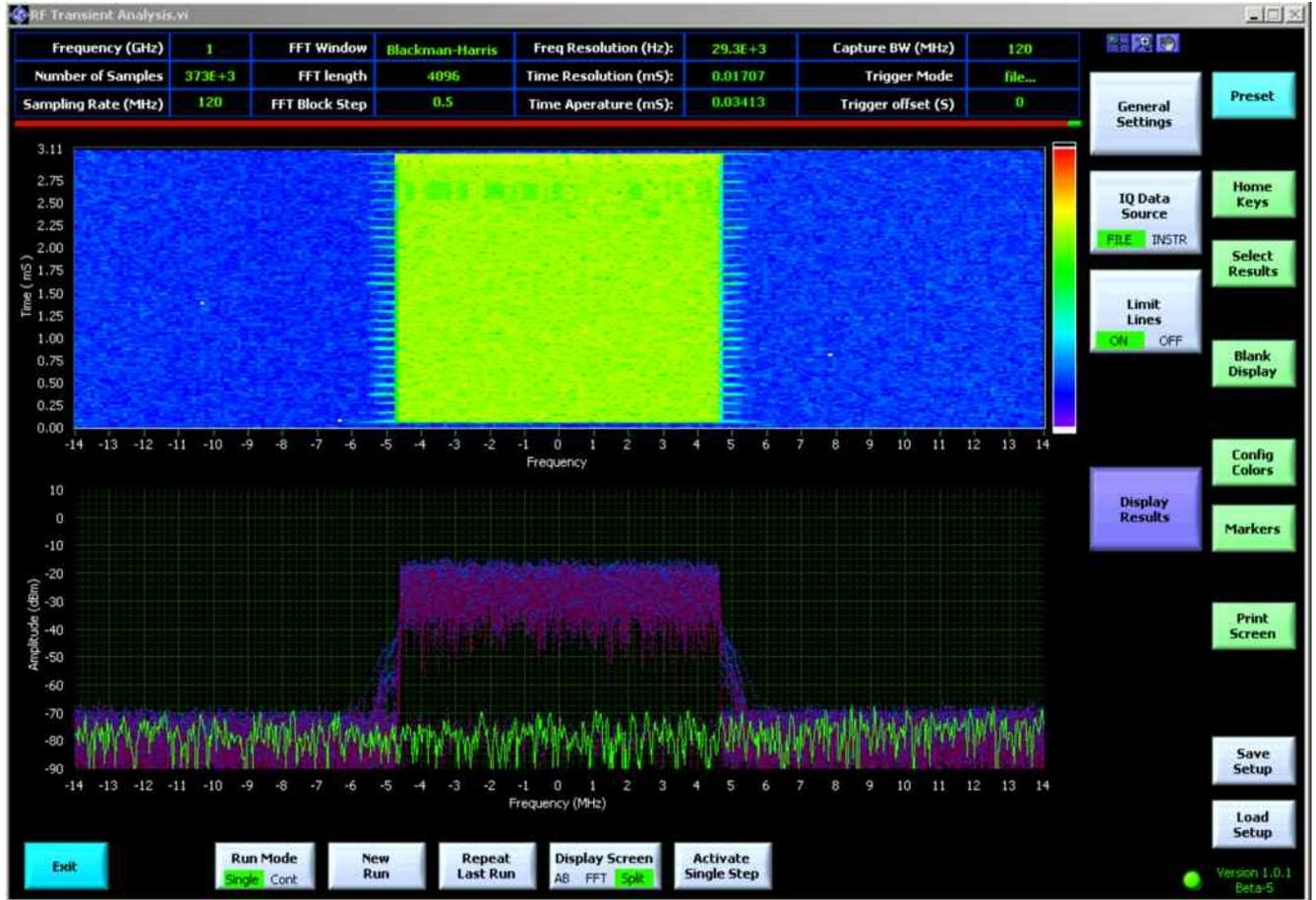
This example uses a pre-captured IQ data file of WiMAX transmission. These step by step instructions will allow you to analyze this signal and arrive at the screen shot shown below:

1. Start by launching the RF Transient Analysis Software
2. Press the “Preset” button in the upper right hand corner.
3. Press the “Load Setup” softkey.
4. Select the file named, “WiMAX, watch the entire subframe.set”
5. Press the “New run” softkey
6. Select the file named, “WiMAX IQ data file.iqb”

There will be two plots on the screen. The upper plot is a spectrogram of the WiMAX transmission frame. The spectral regrowth between symbol transmissions makes a nice delineator on the plot, allow for easy observation of the number of transmitted symbols. The bottom plot is the FFT of the most recent IQ samples.

This particular plot also shows the FFT persistence option. Older FFT traces are saved on the screen and displayed with an alternate color scheme. During analysis, this option allows the user to see past transients that occurred in the signal.

## Measuring Signal Transients with the RF Transient Analysis Software

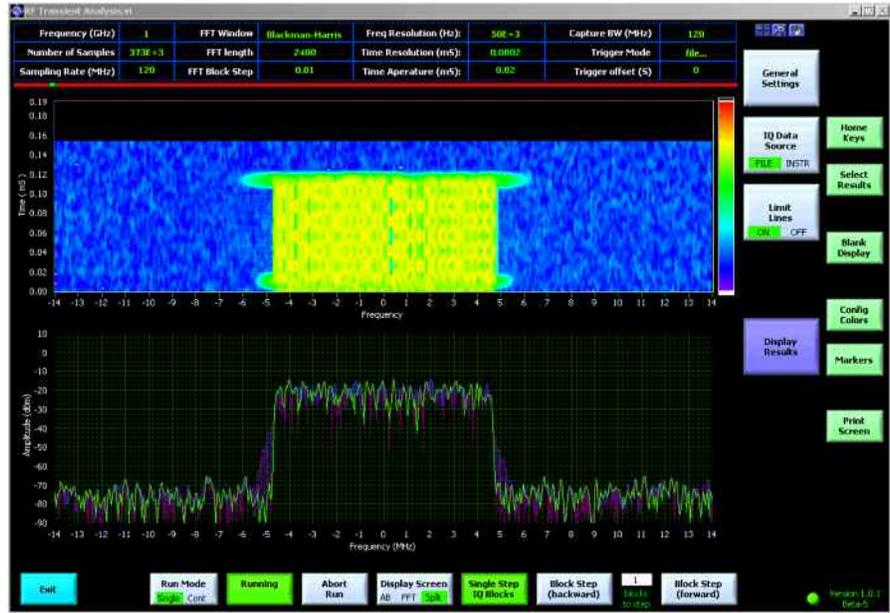


This same data can be observed in greater detail by changing some of the settings. Use the following steps:

7. Press the “Load Setup” softkey
8. Select the file, “WiMAX, close up of the preamble.set”
9. Press the “New run” softkey
10. Select the file named, “WiMAX IQ data file.iqb”

In the resulting plot, the WiMAX signal can be observed in greater detail.

# Measuring Signal Transients with the RF Transient Analysis Software



## 5. Requirements

### 5.1. PC Hardware Requirements

	Minimum	Recommended
<b>CPU</b>	Pentium 600 MHz	Dual Core 2.4 GHz or higher
<b>RAM</b>	1024 Mbyte	2048 MByte
<b>Hard Disc</b>	50 MByte free space	100 MByte free space
<b>Monitor</b>	SVGA monitor (800x600)	XVGA color monitor, resolution 1024x600 or better
<b>IEEE Bus or LAN/Ethernet</b>	required	

### 5.2. PC Software Requirements

	Minimum	Recommended
<b>OS</b>	Windows XP	Windows XP
<b>IEEE Bus Driver</b>	Version 1.70 (or above)	Version 1.70 (or above)
<b>VISA</b>	VISA 4.0	VISA 4.4.1

## 6. Literature and References

## 7. Additional Information

This application note and the associated program are updated from time to time. Please visit the website [www.rohde-schwarz.com/appnote](http://www.rohde-schwarz.com/appnote) in order to download new versions. Please send any comments or suggestions about this application note to [TM-Applications@rsd.rohde-schwarz.com](mailto:TM-Applications@rsd.rohde-schwarz.com).

## 8. Ordering information

Please note, that complete solutions for signal generation and signal analysis for various applications are available from Rohde & Schwarz.

For additional information about equipment, see the Rohde & Schwarz website [www.rohde-schwarz.com](http://www.rohde-schwarz.com).



ROHDE & SCHWARZ GmbH & Co. KG · Mühlhofstraße 15 · D-81671 München · Postfach 80 14 69 · D-81614 München ·  
Tel (089) 4129 -0 · Fax (089) 4129 - 13777 · Internet: <http://www.rohde-schwarz.com>

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