Signal Hound®

VSG60
Software Manual

Signal Hound VSG60 Software Manual

Contents

1 Overview

This document outlines the operation and functionality of the Signal Hound VSG60 vector signal generator software. This document will guide you through the setup and operation of the software. You can use this document to learn about the features of the generator and how to access them in the application.

2 Preparation

2.1 SYSTEM REQUIREMENTS

Supported operating systems:

- Windows 11/10 (32/64-bit)
- Ubuntu 22.04/20.04/18.04 (64-bit)

Minimum system requirements:

- Dual core Intel i5/i7/i9 processor, 4th generation or later.
- The software will average less than 1GB of memory.
- USB 3.0 connectivity.

2.2 WINDOWS INSTALLATION

The software can be found on the CD included with your purchase or on our website www.signalhound.com. The latest version of the software can always be found on our website.

Once you have located the software, run the installer MSI file and follow the on-screen instructions. You must have administrator privileges to install the software. During installation, the VSG60 device drivers will be installed.

It is recommended to install the application folder in the default location.

2.2.1 Driver Installation for Windows

Drivers are distributed by the installer for both 32 and 64-bit systems. After installation the driver files are located at **\drivers\x86** and **\drivers\x64** in the application directory.

If the drives did not successfully install during the installation process you can manually install them.

The easiest way to install the drivers after the installer has ran is to run the Drivers32bit.exe file as administrator. The Drivers32bit.exe file is in the folder at

C:/Program Files/Signal Hound/VSG60

A console will appear to let you know if the installation was successful.

If the drivers still not install correctly, contact Signal Hound.

2.3 **LINUX INSTALLATION**

Download the Linux standalone installation directory from the Signal Hound website and follow the included instructions found in the README. All relevant files and drivers are included in the Linux install folder.

2.4 **CONNECTING YOUR SIGNAL HOUND VSG60**

With the software and drivers installed, the VSG60 can be connected to the PC.

Plug in the VSG60 using the included USB Y cable by first connecting the USB 3.0 type A connector to a USB superspeed port on your PC or laptop. Then plug in the thinner USB 2 type A connector (for extra power). Finally, plug in the micro-B connector to the VSG60 until it is fully seated and tighten the thumb screws. Do not overtighten. You should see a solid green LED on the VSG60.

Note: The VSG60 is intended for use only with the included USB cable. Longer cables may result in an intermittent connection, especially around electromagnetic interference.

The first time you connect the device to your PC, the PC may take a few seconds to recognize the device and update any drivers. Wait for this process to complete and the PC to recognize the device before launching the software.

When your device is ready, the front panel LED should emit a solid green color.

3 Getting Started

Launching the VSG60 software brings up the user interface (UI). This section describes the UI in detail and how you can use the UI to control your Signal Hound vector signal generator.

Below is a picture of the software after application startup.
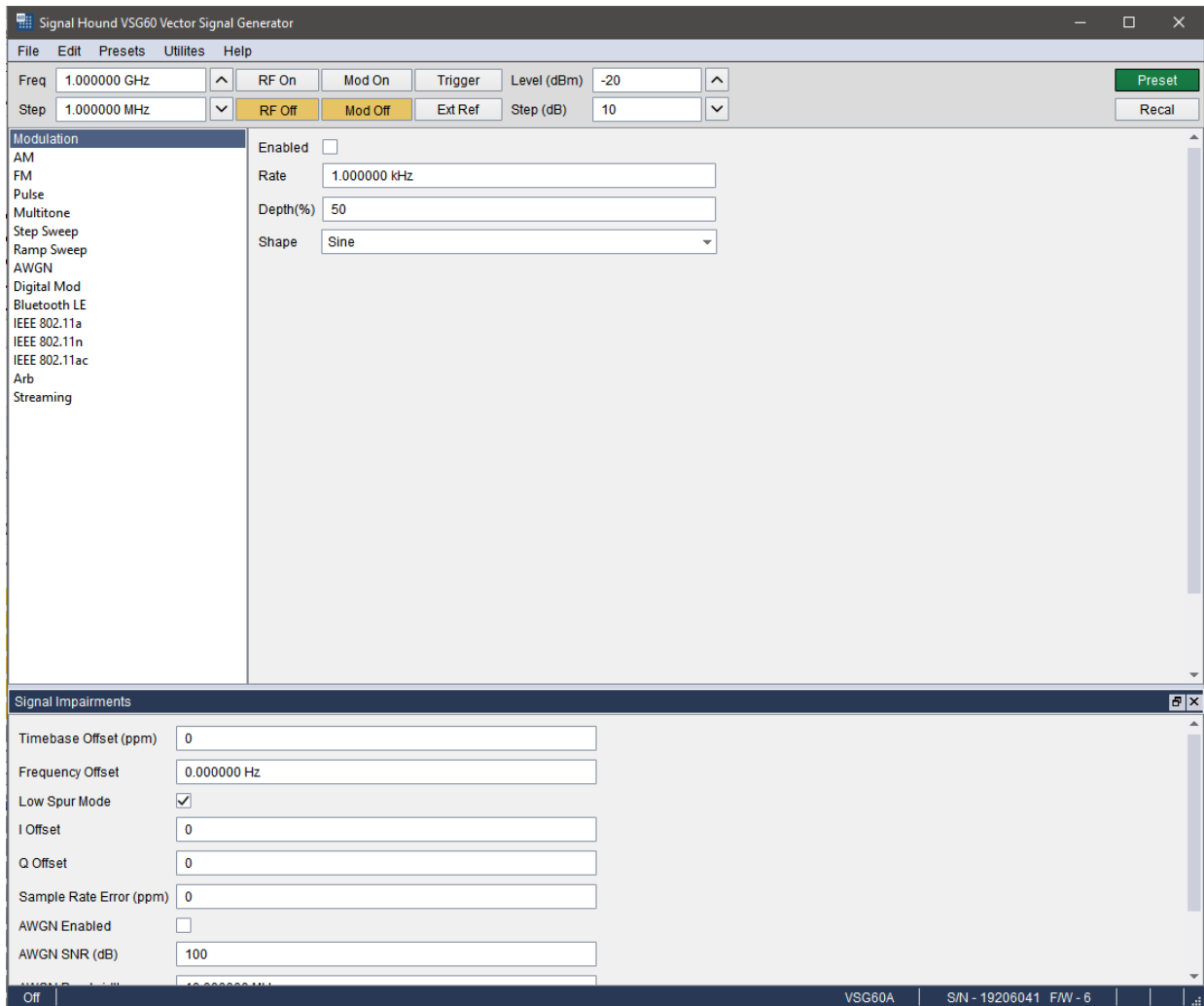
Figure 1 What you will see after program startup.

3.1 THE MENU BAR

The menu bar provides a set of drop-down menus across the top of the application.

4 File Menu

- Print – Print an image of the application. The image will appear exactly as the software appears to the user.
- Save as Image – Save an image of the application. The image will appear exactly as the software appears to the user.
- Connect– If no device is currently connected, this attempts to establish a connection to a single VSG60 device. The connect menu shows you a list of all VSG60 devices connected to the PC. Select one to connect.
- Disconnect Device – If a device is connected, disconnect it and return the software to an idle state.

- Exit – Disconnect the device and close the software.

4.1.1 **Edit Menu**

- Preferences – Edit several software configuration options.
    - o SCPI Enabled – Enable/Disable the ability to control the software via SCPI commands over TCP/IP. When disabled no socket is opened in the software.
    - o SCPI Port – Specify the SCPI port used to establish TCP/IP connection for SCPI commands.
    - o Power Saving CPU Mode – See Power Saving CPU Mode.

4.1.2 **Preset Menu**

- Load User Preset – Load a custom user preset file through the file select dialog.
- Save User Preset – Save a custom user preset file through the file select dialog.
- Quick Load – Load from 1 of 9 built in presets.
- Quick Save- Save to 1 of 9 built in presets.
- Save Power On Preset – Save the current configuration as a power on preset. The software only stores one power on preset which is loaded on software startup.
- Delete Power On Preset – Clears the power on preset. After cleared, the software will startup in the default state.

If the power on preset causes issues, such as the software to crash upon starting, making it impossible to delete the power on preset through the software, it can be manually deleted by the user. The power on preset file is located on the PC at

C:\Users\AJ\Documents\SignalHound\vsg60\PowerOnPreset.ini

on Windows PCs. Delete this file and relaunch the application.

4.1.3 **Utilities Menu**

- Show Error Log – Display the SCPI error log dialog.
- Clear Error Log – Clear the SCPI error log.
- Signal Impairments – Toggle the display of the signal impairments control panel.

4.1.4 **Help Menu**

- User Manual – Open the user manual in the system default PDF viewer.
- Product Manual – Open the VSG60 product manual in the system default PDF viewer.
- Signal Hound Website – Open www.signalhound.com in the web browser.
- Support Forums – Open www.signalhound.com/support/forums in the web browser.
- About – Display the software and API version.

4.2 **DEVICE CONTROLS**

These settings control the device output for all modulation.

- Freq – Specify the output frequency. This will also function as the center frequency for any active modulation. Some modulation types such as step sweep will ignore this frequency.
- Step – Controls the step amount applied when either the frequency arrows or arrow keys are pressed to step the output frequency.
- RF – Toggles the RF output. When off, the RF output is disabled regardless of other settings.
- Mod – Toggles the current modulation. When Mod is off and RF is on, a CW is output. When both are enabled, the currently enabled modulation type is output.
- Trigger – Trigger key. In any single trigger generation mode, pressing this button initiates a single trigger event.
- Ext Ref – Specify the timebase source as either internal or external. When Ext Ref is selected, the VSG60 expects a 10MHz reference signal to be present on the 10MHz reference BNC port.
- Level (dBm) – Specify the output amplitude in dBm.
- Step (dB) – Controls the step amount applied to the output level when either the arrows or arrow keys are pressed.
- Preset – Performs a software reset and loads the software defaults.
- Recal – Regenerates calibration constants for the current environment. The VSG60 is sensitive to large temperature drift.

4.3 MODULATION SELECTION

The modulation selection buttons expose the controls for the various modulation outputs available for the VSG60. Each button corresponds to a new set of controls to be displayed in the modulation controls area.

4.4 MODULATION CONTROLS

The modulation controls show related controls for the currently selected modulation. All controls are detailed below.

4.4.1 AM

- Rate – Specify the AM modulation frequency.
- Depth (%) – Specify the AM modulation depth as a percentage of the output amplitude.
- Shape – Specify the modulation shape of the AM waveform.

4.4.2 FM

- Rate – Specify the FM modulation frequency.
- FM Deviation – Specify the FM modulation deviation. This is the maximum frequency difference between the FM modulated wave and carrier frequency.
- Shape – Specify the modulation shape of the FM waveform.

4.4.3 Pulse

- Trigger Mode – When set to single, a single pulse is emitted for each trigger. A minimum period is still observed equal to or greater than the configured period.

- Width – Specify the time the signal is high during one pulse cycle.
- Period – Specify the time between rising pulse edges.

4.4.4 **Multi-Tone**

- Tone Count – Specify the number of generated output tones. The result of the count times the spacing cannot exceed 40MHz.
- Freq Spacing – Specify the spacing between each output tone. The result of the tone count times the spacing cannot exceed 40MHz.
- Tone Phase – Specify how the phase of each individual tone is generated. The phase selected greatly affect the resulting dynamic range of the waveform.
- Seed – Used for seeding the random number generator used when random tone phase is selected. This makes it possible to generate repeatable random tone phases.
- Notch Width – Specify a bandwidth of a notch reject filter to be applied to the resulting output tones. Any tone that lies inside this notch is nulled.

4.4.5 **Step Sweep**

This mode steps a CW signal across a range of frequencies. Frequency and amplitude are linearly interpolated across the frequency and amplitude ranges. The frequency and amplitude switch time between each output step is 210us. (200us to change frequency and 10us to change amplitude).

- Trigger Mode – When set to single, a full sweep occurs on each trigger.
- Sweep Type – When set to *Freq*, the application level is used for each output step. When *Freq & Ampl* is selected, the *Start Level* and *Stop Level* are used to create an amplitude ramp across all output steps.
- Start Freq – Specify the start frequency of the stepped sweep signal. When start frequency exceeds stop frequency, the frequency step is negative.
- Stop Freq – Specify the stop frequency of the stepped sweep signal. This is the frequency of the final output step. When stop frequency is less than start frequency, the frequency step is negative.
- Points – Specify the number of output steps. The first step occurs at the start frequency and the final step at the stop frequency.
- Start Level – When the *Freq & Ampl* sweep type is selected, this is the level of the first step.
- Stop Level – When the *Freq & Ampl* sweep type is selected, this is the level of the last step.
- Dwell Time – Specify how long the signal dwells at each frequency. A CW is output at each output step.

4.4.6 **Ramp Sweep**

A CW is swept across a frequency span at a desired output level. The sweep is continuous and thus limited by the instantaneous bandwidth of the transmitter.

- Trigger Mode – When set to single, a full sweep occurs on each trigger. The period is still observed.
- Span – Specify the frequency span of the frequency ramp. Cannot exceed the instantaneous bandwidth of the transmitter.

- Sweep Time – Specify the time it takes the transmitter to sweep through the selected span.
- Period – Specify the time between the beginning of two sweeps. Must be greater than or equal to *Sweep Time*.

4.4.7 **AWGN**

In this mode, Gaussian noise is generated over a fixed bandwidth with a fixed channel power.

- Bandwidth – The 3dB bandwidth of the noise signal. This value cannot exceed the instantaneous bandwidth of the transmitter.
- Length – Length of the noise signal buffer. This buffer is cycled through.
- Seed – Used to seed the random number generator. Enables the generation repeatable noise vectors.

4.4.8 **Digital Mod**

- Trigger Mode – When set to single, the full waveform (all data) including off period is transmitted on each trigger event.
- Samples Off – Specify an off duration after the full waveform is transmitted.
- Symbol Rate - Specify the symbol (chip) rate of the signal. The symbol rate is limited by the device's maximum sample rate and the oversample amount. For example, the maximum symbol rate with an oversample of 2 is 50MS/s / 2 = 25 MSym/s. The minimum symbol rate is the device's minimum symbol rate with an oversample of 16 = 12.5kS/s / 16 = 781.25 Sym/s.
- Modulation Type – Specify the modulation type.
- Define Modulation – Define a custom constellation, including differential encoding and offset Q. See custom I/Q modulation editor for more information.
- Filter Type – Specify the pulse shaping filter to be applied to the oversampled waveform.
- Filter Alpha - Specify the filter roll-off factor. Does not apply to custom filters.
- Filter Length – Specify the length in symbols, of the pulse shaping filter. This only applied to non-custom filter selections.
- Define Filter – Specify the pulse shaping filter directly. This filter is applied when custom filter is selected.
- Sequence – Specify the data sequence to be used when generating the waveform. Outputs the full sequence for each trigger.
- Sequence seed – Seeds the random number generator for the PN sequences. Enabled repeatable random number generation.
- Define Sequence – Specify a data sequence to be modulated by bringing up the symbol editor. See the Symbol Editor section.
- FSK Deviation – When FSK is selected, this is the maximum deviation from 0Hz.
- IQ Scaling – Defaults to 1.0. Currently not selectable.
- Oversample – Specify the oversample amount.

4.4.9 **OFDM**

See section *OFDM Signal Generation* for additional information.

- Trigger Mode – When set to single, the full waveform including idle interval is transmitted on each trigger event. When set to continuous, the waveform including idle interval is transmitted continuously.
- Idle Interval - Specifies a duration after the waveform is output in which the transmitter output is off.
- FFT Size – FFT size used to generate each OFDM symbol. Determines the maximum number of subcarriers.
- Sample Rate – The sample rate at which the generated waveform is transmitted at.
- Guard Band Carriers – Select the number of subcarriers to be used as a guard band.
- Symbol Count – Select the number of OFDM symbols in the waveforms.
- Guard Interval (%) – Specifies the guard interval (GI) of each symbol as a percentage of the FFT Size.
- Null DC – Specify whether the 0Hz subcarrier is nulled out prior to transmission.
- Windowed – If enabled, a raised cosine (RC) window is applied to each symbol.
- Window Length (%) – Length of the RC window as a percentage of the GI.
- Symbol Editor – Press to open the symbol editor. See *OFDM Signal Generation* section for more information.
- View OFDM Mapping – Shows the OFDM waveform on a symbol vs subcarrier 2D plot.
- Save/Load OFDM Configuration – Save and load the full OFDM configuration outside the typical application presets. The configuration can be viewed and edited in other editors if desired.

4.4.10 **Bluetooth LE**

Use these controls to generate Bluetooth low energy (LE) waveform as specified by the Bluetooth v5.2 specification.

- Trigger Mode – When set to single, the full waveform including idle interval is transmitted on each trigger event.
- Idle Interval - Specifies a duration after the waveform is output in which the transmitter output is off.
- Mode – Specifies the packet format of the waveform. This also controls the sample rate of the generator.
- Channel Index – Specified as a decimal integer. Used for initializing the data whitening. Does not control frequency output. Center frequency must still be controlled manually.
- Samples Per Symbol – Specifies the oversample rate of the generator.
- FSK Modulation Index – Specifies the frequency offset of the FSK modulation. A modulation index of 0.5 (default) specifies a 250kHz frequency offset.
- Gaussian BT – Specifies the Gaussian filter bandwidth time constant. 0.5 is default.
- Filter Length (symbols) – Specifies the Gaussian filter length in symbols. The final filter length is equal to (FilterLengthInSymbols * SamplesPerSymbol) + 1.
- Access Address – Specified as hexadecimal, most significant bit first. (Transmitted LSB first).
- CRC Attached – When enabled attaches 24-bit CRC. CRC is performed over the PDU data prior to whitening.
- CRC Initialization – Initializes the CRC register when CRC is enabled, otherwise ignored.

- Data Whitening – When enabled, whitens the PDU and CRC (if attached).
- PDU Data – Selects the contents for the PDU data section in the packet. Either fill the PDU section with random bits or with a custom payload. No PDU headers are generated by the software. If a PDU header and supporting structure is required, they must be provided using the custom data entry.
- PDU Data Seed – When PN sequences are used for the PDU section, this value is used as the seed. Provided as decimal.
- Bytes – When PN sequences are used for the PDU section, this controls the number of bytes of the PN sequence to transmit. If the PN sequence is shorter than the provided bytes, the PN sequence repeats until the number of bytes is met.
- Custom Data – Specify a custom PDU payload (MSB first). MSB is transmitted first. If the custom data is not a multiple of 8 bits, 0 bits are padded at the end (LSB side).

4.4.11 **IEEE 802.11a/n/ac/ax**

Note: Transmitting 802.11ax waveforms requires the MATLAB® runtime (free download). Please see the MATLAB® runtime installation instructions.

Note: 802.11ax waveform generation is supported on 64-bit Windows operating systems only.

The VSG60 software can generate 802.11a/n/ac/ax OFDM waveforms.

802.11ax waveforms are limited to SU waveform types.

Controls for all 802.11 waveforms are described below.

- Trigger Mode – When set to single, the full waveform including idle period is transmitted on each trigger event.
- Idle Interval – Specifies a duration after the waveform is output in which the transmitter output is off.
- Bandwidth Select (ax) – Select between 20 and 40MHz bandwidths.
- Coding Select (ax) – Select coding type. BCC encoding is not available for certain waveform configurations. When those configurations are selected, this control is overridden and LDPC is selected by default.
- Rate Select (a) – Select the modulation and encoding scheme.
- MCS Select (n/ac/ax) – Selects the modulation and code rate for the given standard. Modulation and coding information is displayed in plain text for each MCS selection.
- Guard Interval (n/ac) – Select between long and short cyclic prefix length.
- Guard Interval (ax) – Selects the cyclic prefix length in combination with the LTF duration.
- Sample rate – Controls the device sample rate. Can be used to simulate alternative subcarrier spacings or simulate large sample rate offsets. This setting is coupled to subcarrier spacing.
- Subcarrier Spacing – Coupled to sample rate.
- Oversample Amount – All 802.11 waveforms are fixed to an oversample amount of 1.
- Interleave Bits (a/n/ac) – When enabled the data field symbols are interleaved.
- Scramble Bits (a/n/ac) - When enabled the data field symbols are scrambled.

- Scrambler Initialization – Initializes the data field scrambler.
- Group ID (ac) – Sets the group ID bits in the VHT SIG A1 header.
- Partial AID (ac) – Sets the SU partial AID bits in the VHT SIG A1 header.
- Window Length – When non-zero, a raised cosine window is applied to each symbol using the supplied length in samples. When the guard interval is set to short, the largest window that should be used is 8 samples.
- Data – Select the data source. When "Custom" is selected, the bits configured in the "Custom Data" field is used.
- Bytes – Specify the number of bytes in the data section. Random or custom sequences are cut short if the number of bytes selected is less than the bytes in the sequence. When the number of bytes selected is longer than the selected sequence, bits are repeated until the byte length is met.

4.4.12 **LTE**

Note: Transmitting LTE waveforms requires the MATLAB® runtime (free download). Please see the [MATLAB® runtime installation instructions](#).

Note: LTE waveform generation is supported on 64-bit Windows operating systems only.

The VSG60 software provides downlink RMC and test model waveform generation for LTE. The downlink RMC waveforms available are R.0 through R.9 as defined in 3GPP TS 36.101 Annex A.3. The test models available are defined in 3GPP TS 36.141 section 6.3.

By default, the generated waveform is repeated continuously. Pulse or single triggered output is possible using the trigger and idle duration controls.

For downlink RMC waveforms, the following parameters are selectable

- Reference Channel – Select R.0 through R.9
- Cell ID – Physical layer cell ID.
- Duplex Mode – Select between FDD and TDD.
- Subframes – Number of subframes in generated waveform.
- Window length – Specify the OFDM window length in samples.
- Data Source – If the data source is set to custom, the bit sequence specified in the Custom Data dialog is used as the data source. When the number of bits in the specified sequence is shorter than the bits needed to generate the waveform, the sequence is repeated.

For test models, the following parameters are selectable.

- Test Model – Select test model 1.1 through 3.3.
- Bandwidth – Specify the number of resource blocks used.
- Cell ID – Physical layer cell ID.
- Duplex Mode – Select between FDD and TDD.
- Subframes – Number of subframes in generated waveform.

- Window length – Specify the OFDM window length in samples.

4.4.13 **ARB**

In this mode, a user may load an arbitrary I/Q waveform file to be output by the VSG. Waveforms can be up to 100/200 million samples depending on CPU architecture (x86/x64). Waveforms are loaded completely into system memory and impairments are applied in advance.

In ARB mode, the average power of the waveform is calculated from the I/Q samples and the device gain is adjusted to ensure the average output power of the ARB file is equal to the output level selected.

- Trigger Mode - When set to single, the full waveform (all data) including off period is transmitted on each trigger event.
- Sample Rate – Specify the device sample rate of the waveform.
- Auto Scale – When enabled, the I/Q samples are scaled such that the maximum I or Q value is equal to 1.0. For example, an ARB file containing a single I/Q sample of {1.5, 1.0} would be scaled to {1.0, 0.666}. When disabled, the manual I/Q scale is applied to the waveform.
- I/Q Scale (%) – When Auto Scale is disabled, this scaling factor is applied to every I and Q sample in the waveform. When I/Q scale is equal to 100%, this is equivalent to scaling the waveform to 1 (no scaling).
- Output Signal Average – When enabled, the signal generator output level will be adjusted to ensure the average signal power transmitted is equal to the output level selected. The average signal power is calculated after any I/Q scaling is applied. For example, if the waveform has an average power of -6dBFS (after scaling), and the output level is set to -20dBm, the output level is adjusted to -14dBm to ensure the average signal power output is -20dBm. The output level cannot be adjusted beyond +10dBm. For signals with long off durations, this should be disabled, as the average power of the signal will be significantly lowered with long off periods.
- Period – Specify the period in samples. When period is greater than samples, (period – samples) zeros are output after the waveform.
- Sample Offset – Start offset into the loaded waveform. Using the *sample offset* and *samples to use* controls, users can specify only a portion of the ARB file to transmit.
- Samples to Use – The number of samples to transmit starting from the *sample offset*. Using the *sample offset* and *samples to use* controls, users can specify only a portion of the ARB file to transmit.
- Load – Loads an ARB file to be used to generate a custom I/Q signal. See [ARB Files](#) for more information regarding the format of these files. If an ARB file is successfully loaded, the characteristics of the signal are displayed in the control area.

4.4.14 **Streaming**

In this mode, users can load an arbitrary number of binary waveform files for the software to play back in sequence. As opposed to ARB mode, in streaming mode the software reads the waveforms from the files as the VSG60 is transmitting. This allows for the playback of arbitrarily large waveform

files. The files are no longer limited to several hundred million samples, and sequences of billions of samples across several files may be transmitted.

In streaming mode, an I/Q sample magnitude of 1 will equal the output level selected. Unlike ARB mode, the device gain is not adjusted based on the waveform signal average.

- Sample Rate – Specify the device sample rate. The same sample rate must be used for the entire sequence. If different sample rates are desired for different files, it is recommended to resample the binary files prior to loading them into the software.
- I/Q Scale (%) - This scaling factor is applied to every I and Q sample in the waveform. When I/Q scale is equal to 100%, this is equivalent to scaling the waveform to 1 (no scaling).
- Load Files – Load 1 or more files of a given file type. Only files with the given type should be selected. If different file types are desired, load all files of one type first, then select load files again with a different type. Loading additional files will append the new files to the current sequence in the file list.
- Unload Files – Clears all files loaded in the software. If the device is currently streaming, it will be stopped, and no waveform will be transmitted.
- File List – Shows a list of all files loaded into the software. The order of the files from top to bottom is the order in which files are transmitted when streaming is active. User can rearrange files to change the order they are transmitted. If streaming is active when the order is changed, the sequence starts over immediately using the new order. See [ARB Files](#) for more information regarding the format of these files.

Because the files are read from disk as they are being transmitted, they should not be renamed/moved/modified while streaming mode is active.

The file list is not saved in the preset files. The file list must be reloaded each time the software is opened.

4.4.14.1 Disk Speed Requirements for Streaming

Disk sustained read speeds must be fast enough to stream the file continuously. At a 50MS/s sample rate, disk read speeds must be able to sustain 200MB/s for 16-bit complex binary files and 400MB/s for 32-bit complex binary files.

Signal Hound recommends SSD or NVME drives for optimal performance at higher sample rates.

4.5 **SIGNAL IMPAIRMENTS CONTROLS**

- Level Offset (dB) – Specify a power level offset. This offset will be added to the dBm output level of the generator when configuring the transmitter. This offset can be used to compensate for external components such as cables or attenuators. The maximum output level of the transmitter cannot be exceeded with this offset. If the level + offset exceeds the maximum output level of the transmitter, the final output level will be clamped to the maximum.

- User Flatness – When checked, user flatness corrections are applied to the output RF level. This correction will be added to the output level of the generator.
- Define User Flatness – Edit user flatness table. Offsets in the table are linearly interpolated. If the generator frequency is outside the range of the table, the offset applied will simply be outer most point in the table. The offset is a general RF leveling offset and does not apply across the IF bandwidth (baseband) of the transmitter. For baseband flatness corrections, use the channel filter.
- Timebase Offset – Specify a timebase multiplier in ppm. Available range between [-2,2].
- Frequency Offset – Fixed frequency offset. Applied to the center frequency. Modes that have separate frequency entries such as step sweep mode are not affected by this impairment.
- Invert Spectrum – When enabled, the spectrum is inverted at the devices IF for all output modes. Some output modes such as CW, AM, pulse, and others will not see any effect from this. This inversion is implemented by performing the complex conjugate on all I/Q samples sent to the device.
- Low Spur Mode – When enabled, frac-N spurs are improved through a combination of smart LO choices and digital tuning. The side effect is that the I/Q offset may no longer be at 0Hz.
- I Offset – I channel offset in counts.
- Q Offset – Q channel offset in counts.
- I/Q Phase Imbalance – Specify an I/Q phase imbalance in degrees. The phase imbalance is applied for digital modulation and ARB modes. Any non-zero phase imbalance is split between the real and imaginary channels.
- I/Q Amplitude Imbalance – Specify an I/Q amplitude imbalance in dB. The imbalance is applied for digital modulation and ARB modes. Any non-zero amplitude imbalance is split between the real and imaginary channels.
- Sample Rate Error – Specify a sample rate multiplier in ppm.
- AWGN Enabled – When enabled, gaussian noise is added to the output waveform. Only available in digital mod and ARB modes.
- AWGN SNR (dB) – Specify the desired Signal to Noise ratio (SNR) when AWGN impairments are enabled. Signal power is equal to the average output power of the signal before noise is added. Noise power is the average noise power over the selected AWGN bandwidth.
- AWGN Bandwidth – Specify the AWGN impairment noise width. Cannot exceed 80% of the device sample rate.
- Channel Filter Enabled – When enabled, a user defined channel filter is applied to the waveform. The channel filter can only be applied in digital mod and ARB modes.
- Define Channel Filter- Modify the user defined channel filter.
- Phase Noise Enabled – When enabled, a phase noise impairment is applied to the waveform. See the phase noise impairments section for more information.
- Define Phase Noise Impairments – Modify the user define phase noise impairment.

4.5.1 Phase Noise Impairments

The VSG60 can perform real-time phase noise impairments. Using the user defined phase noise curve, a real-time impairment is applied to all waveform types the VSG60 can generate, including CW outputs. The phase noise will be limited by the performance of the VSG60 itself. A gray phase

noise line is shown in the editor which represents the ideal performance of the VSG60 at 1GHz center frequency. See the product manual for typical plots at different center frequencies.

Phase noise impairments can be defined over the range of 1kHz offset to 2MHz. The impairment is symmetrical around the center frequency. It is recommended to define points spanning the full configurable range.

The phase noise impairment is a real-time impairment and adds additional processing when enabled.

4.6 STATUS BAR

The status bar displays information about the device and its current state. In the status bar you will see information about the active device such as model, serial number, and temperature. You will also see the current active modulation.

5 External Triggering

The VSG60 has a 3.3V logic trigger output that can be used to synchronize external devices to the RF output of the VSG60. The external trigger is used in several output modes, including ...

- Pulse output
- Ramp sweep
- All digital modulations
- ARB output

In these output modes, the external trigger is driven high at the beginning of the RF waveform in both single and continuous operation. The output is driven high for 10us (default).

In single operation, 1 external trigger is transmitted for each trigger event (pressing the trigger button or triggering via SCPI).

In continuous operation, the trigger operates at a maximum rate of 2kHz. Signals shorter than 500us will be transmitted 2 or more times to ensure the trigger frequency is less than or equal to 2kHz. For example, a 400us signal will be transmitted twice for every external trigger. A 20us waveform will be transmitted 25 times for every external trigger.
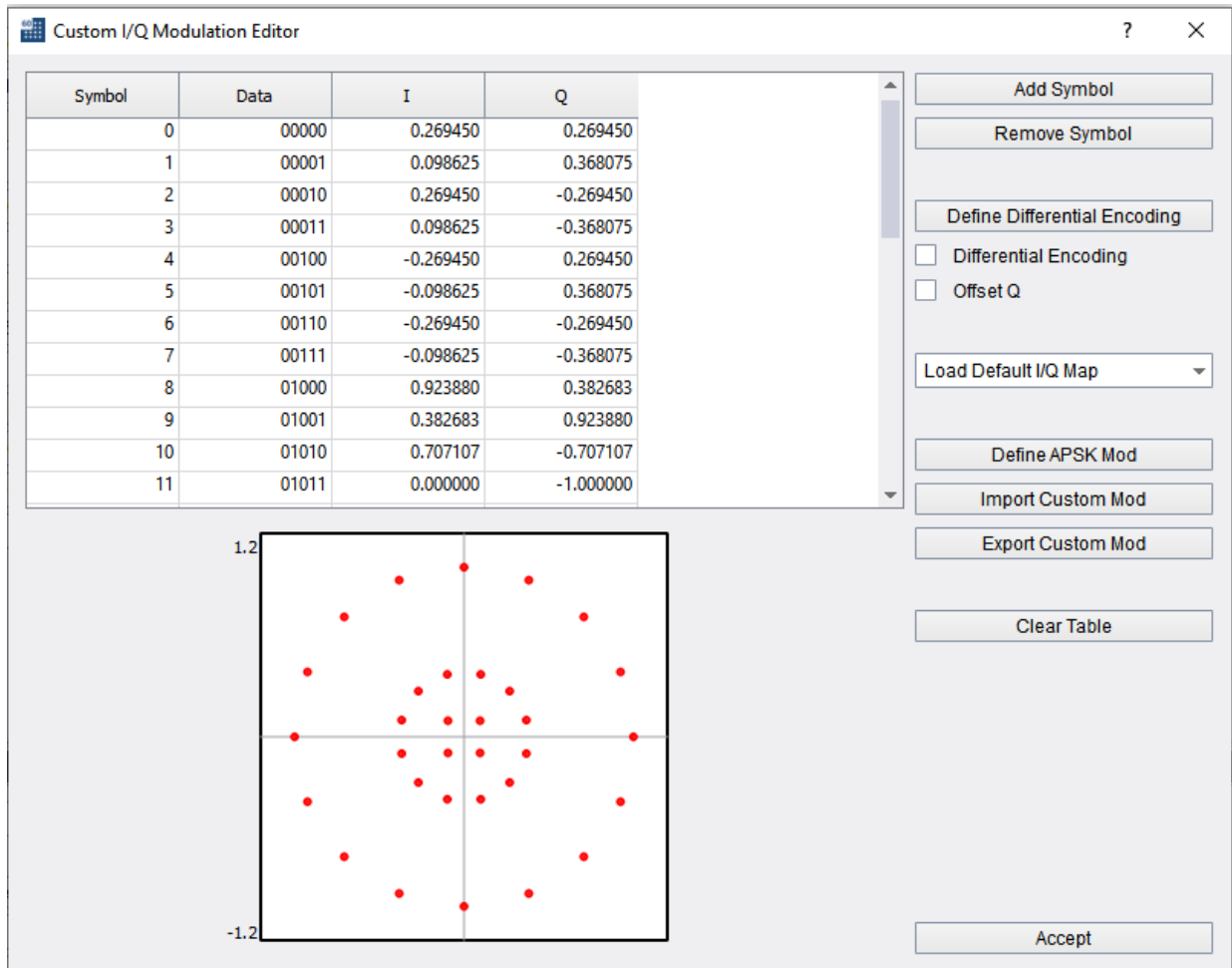
6 Custom I/Q Modulation Editor

Figure 2: APSK32 in the Custom I/Q Modulation Editor

The Custom I/Q Modulation Editor can be opened with the *Define Modulation* button on the digital demodulation control panel.

I/Q values can be entered directly in the symbol table. The constellation plot shows the currently entered I/Q values. For loading a large constellation, it is recommended to load a formatted CSV file.

- **Add Symbol –** Inserts a new symbol row at the end of the symbol table.
- **Remove Symbol –** Removes the row of the currently selected cell. If no cell is selected, the last row is removed.
- **Define Differential Encoding** – define the state transitions for differentially encoded modulations
- **Differential Encoding –** Enables/Disables differential encoding
- **Offset Q** - Enables/Disables Offset Q

- **Load Default I/Q Map –** Selects and populates the constellation table with a default selection
- **Define APSK Mod** – Opens the APSK Editor
- **Load –** Load a formatted CSV file containing a saved custom constellation.
- **Save –** Save a formatted CSV file describing the custom constellation.
- **Clear Table –** Remove all symbols.
- **Accept –** Verifies the constellation and if the constellation is valid, stores the constellation as the active custom modulation.

7 APSK Editor

The APSK editor can be opened with the *Define APSK Mod* button in the Custom I/Q Modulation Editor.

There are four parameters that are used to define each APSK ring. They can each be manually edited in the table found in the APSK editor.

- **Ring ID** – ID number where 0 is the inner most ring

- **# States** – The number of symbols represented in this ring

- **R#/R0** – The ratio of the radius of this ring to the inner most ring(R0)

- **Phase** – The phase offset of the first state in this ring

Some of the addition controls for the APSK Editor are described below.

- **Load Default I/Q Map –** Selects and populates the constellation table with a default selection

- **Add Row** – Adds another ring to the table

- **Remove Row** – Removes the last ring from the table

- **Load** – Loads a previously APSK configuration

- **Save** – Saves the current configuration to a csv

- **Accept** – Validates that the total number of states is a power of 2, stores the data, and closes the window
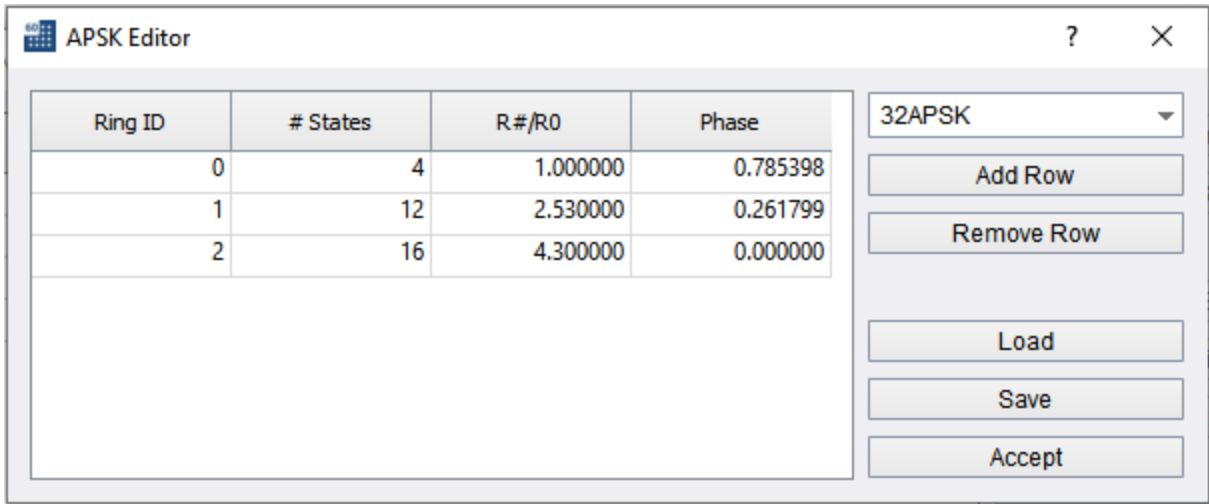
Ring ID	# States	R#/R0	Phase	32APSK
0	4	1.000000	0.785398	Add Row
1	12	2.530000	0.261799	Remove Row
2	16	4.300000	0.000000	
				Load
				Save
				Accept

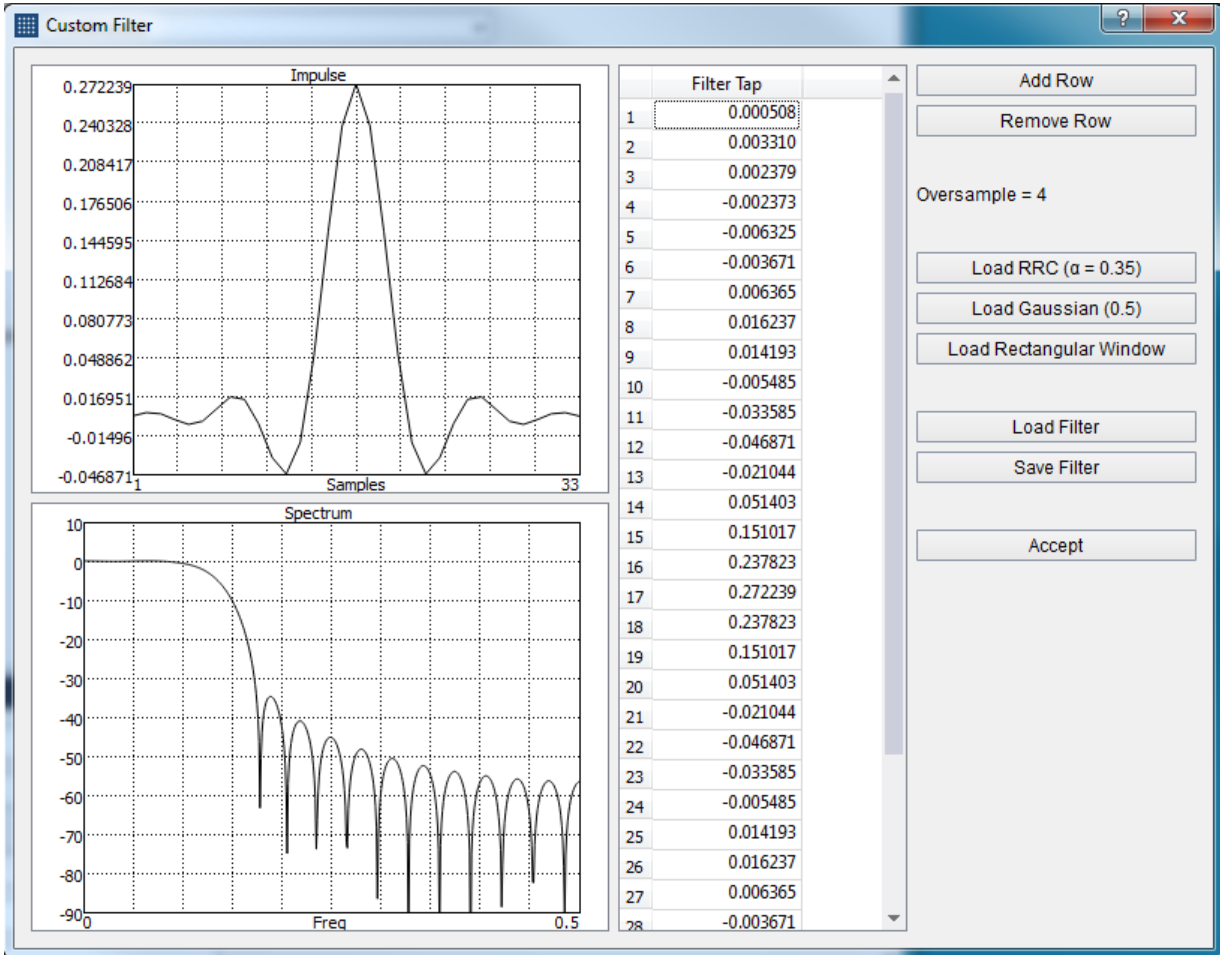*Figure 3: APSK32 in APSK Editor*

8 Custom Filter Editor

Figure 4: Custom filter editor showing the default RRC filter with alpha 0.35 and oversample 4.

Use the custom filter editor to define your own pulse shaping filter. Easily load default filters for quick modification, or your own custom filters through CSV save/load buttons. Visualize the time and amplitude response of the filter as you edit.

Pulse shaping filter are defined as real, time domain impulses. The filter is applied to the up sampled I/Q data as a complex filter (with the imaginary filter channel equal to zero).

9 Channel Filter Editor

Use the channel filter editor to define your own channel response. Easily load default filters for quick modification, or your own custom filters through CSV save/load buttons. Visualize the time and amplitude response of the filter as you edit.

Channel filters are defined as complex time domain impulses. The filter is applied to the waveform as a complex filter.

9.1 GENERATING MULTI-PATH CHANNEL RESPONSES

Using the "Generate Multipath" button found in the channel filter editor, the software can quickly generate randomized multipath channel scenarios based on basic supplied parameters.

To generate a multipath channel you must enter the following parameters

- Sample rate – This is the sample rate of the transmitted waveform.
- Delay Spread – The difference in time between the time of arrival of the earliest component of signal and the latest. Typical values are in the hundreds of nanoseconds for indoor scenarios and a few microseconds for outdoor urban environments.
- Filter length – The size of the filter. Should be large enough to accommodate the delay spread.
- Auto seed – When enabled, a random seed is used.
- Manual seed value – Use a manual seed to have reproducible channel filters.

10 OFDM Signal Generation

The OFDM signal generation capabilities of the VSG60 allows customers to easily define simple OFDM structures for approximating industry standards or developing and testing custom OFDM formats.

OFDM waveforms in the VSG60 software take the form of a sequence of OFDM symbols where the symbol structure is defined below.
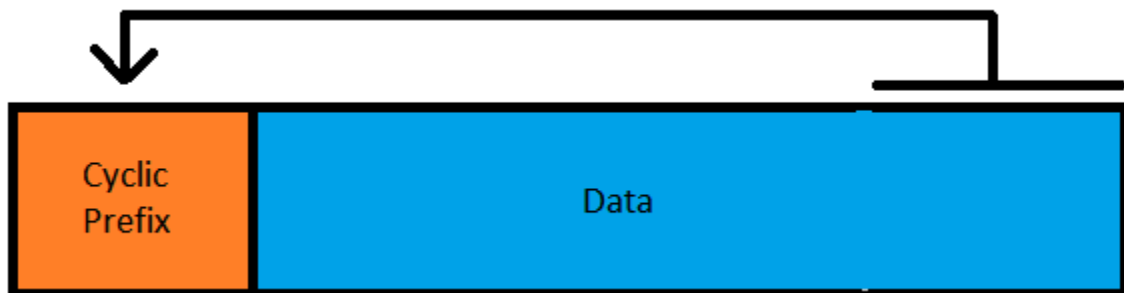

Figure 5: OFDM Symbol

The data section of the OFDM symbol is *FFT Size* number of complex samples long, and the Cyclic Prefix (CP) length is determined by the Guard Interval (GI). The overall waveform length is,

$$Waveform\ Length\ =\ Symbol\ Count\ *\ Symbol\ Length$$

Each symbol is built with the following steps,

1. Initializing all subcarriers to zero.
2. Populating all subcarriers (frequency domain) for that symbol using user provided data in the symbol editor.
3. Nulling out any subcarriers specified in the null DC and guard band subcarriers settings.
4. Performing an inverse FFT.
5. Appending the CP to the front of the symbol.

The symbol editor allows customers to define several resources. Each resource is assigned a symbol range and subcarrier index range. The customer then defines data to populate those subcarriers. Data can be specified directly as I/Q data or generated using a bit stream and constellation mapper.

Subcarriers are populated in the order of the resources defined. If two resources contain overlapping subcarriers, the resource lower/later in the list will overwrite subcarriers populated earlier. The symbol editor allows for reordering of resources.

It is for this reason it might be desirable to define certain resources such as pilots after a payload resource. The payload resource might span the usable subcarriers for several symbols, and the appropriate subcarriers can then be overwritten for the pilots. If pilots are ordered before the payload resource, care must be taken to ensure the payload subcarriers do not overwrite the pilots.

10.1 **OFDM SYMBOL EDITOR**

Note: Several fields in the symbol editor use a custom range editor to specify ranges of values. To see example inputs to the range editor, right click on the range editor and select Help.

The symbol editor is used to populate the available OFDM subcarriers. Resources are added to the symbol editor using add/remove/copy buttons. Resources can be reordered in the list by dragging them with the mouse. Clicking on a resource shows a list of settings for that resource on the right-hand side of the dialog.
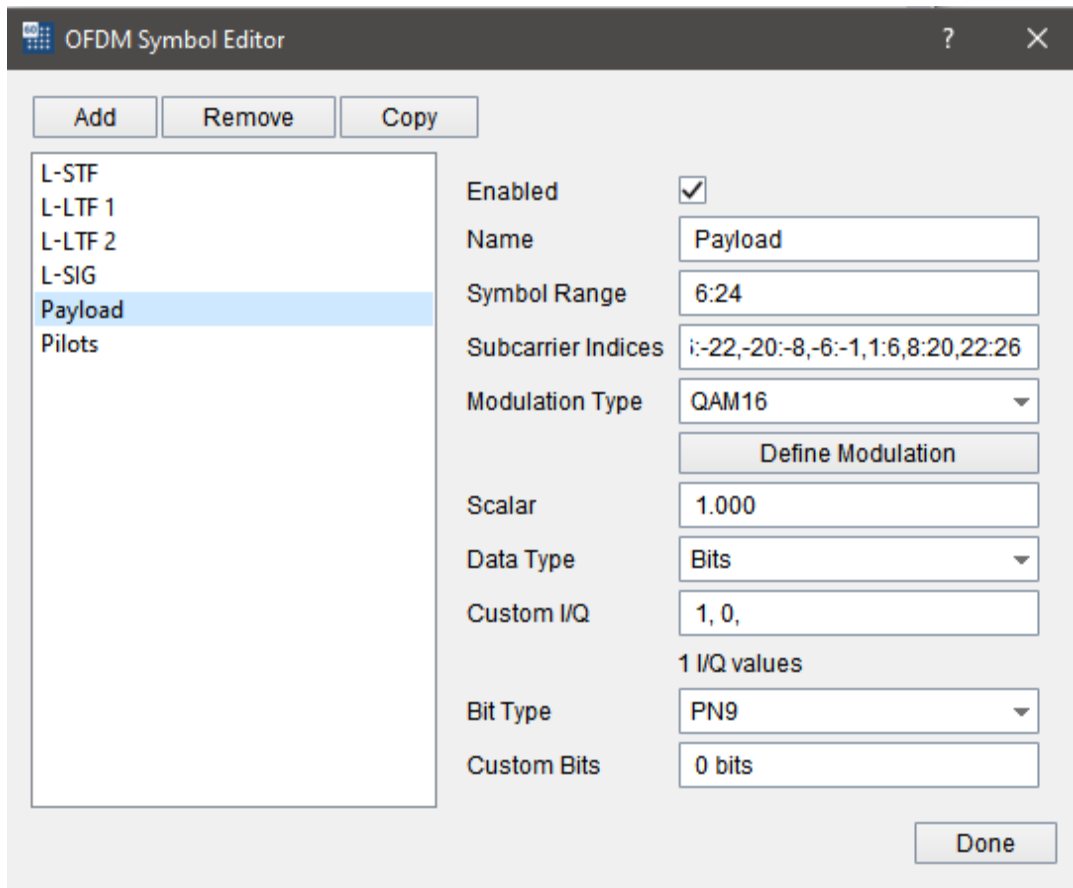
Figure 6: OFDM Symbol Editor

- Enabled – If disabled, this resource is not used to populate the waveform subcarriers.
- Name – Updates the name shown in the resource list.
- Symbol Range – Specify the range of symbols associated to this resource.
- Subcarrier Indices – Specify the symbol indices associated to this resource. The indices are the same for every symbol in this resource. If a different set of subcarriers is needed for a subset of symbols, a new resource should be used.
- Modulation type – Which constellation map should be used when the "Bits" data type is used.
- Define Modulation – Define a custom modulation to be used when "Custom" modulation is selected.
- Scalar – This scalar is applied to all subcarriers associated with this resource.
- Data Type – Specifies how to generate the custom I/Q data for the subcarriers. *Bits* uses the bit stream and constellation mapper to generate complex data, *I/Q Values* uses I/Q values specified in the Custom I/Q field.
- Custom I/Q – Specify a custom I/Q sequence. I/Q values are specified as comma separate values of the form, { I1, Q1, I2, Q2, …, In, Qn }. In this example, N I/Q values are specified as 2*N comma separated floating point values.
- Bit Type – Specifies the bit source for the *Bits* generated complex values.
- Custom Bits – If custom bit source is selected, this user entered source of bits is used.
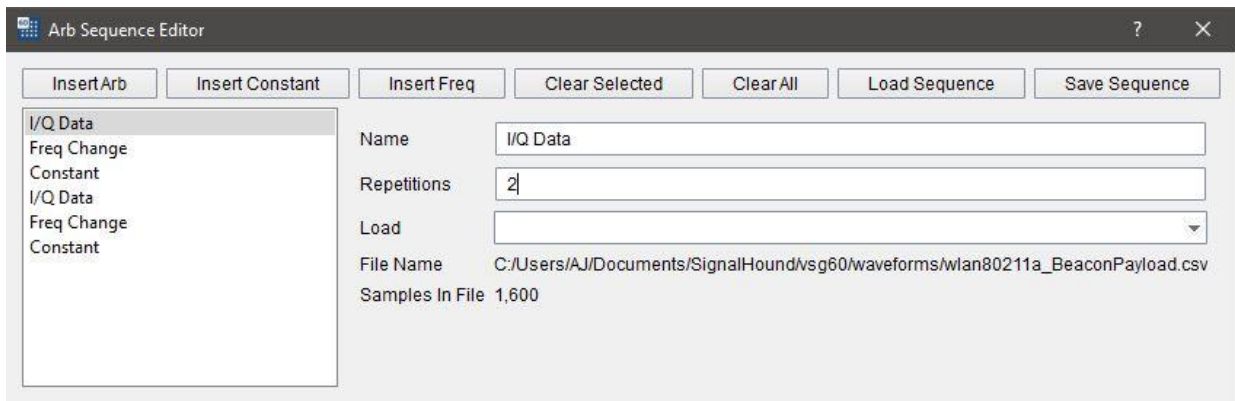
11 ARB Sequence Editor

Figure 7: ARB Sequence Editor

ARB sequence files allow customers to define complex frequency hopping signal waveforms.

Sequence files have the file suffix (.seq) and are proprietary binary files.

Sequence files are not filtered by the custom channel filter.

The ARB sequence editor is found under the Utilities menu. The sequence editor allows the customer to build sequence files using a convenient GUI. ARB sequence files are user defined ARB files that are constructed of three components,

1) Other ARB files
   a. The files cannot be another sequence file.
   b. The file can be repeated a specific number of times.
   c. Once ARB files are loaded and saved in a sequence, the original ARB files are no longer needed. All I/Q samples in that ARB file are stored in the sequence.
2) Constant values
   a. Customers enter a specific I/Q value to be repeated for a specific number of samples.
3) Frequency switches
   a. Customers specify a new frequency for the VSG60 to jump to. The frequency change takes 200us to complete.
   b. A sequence does not have to contain any frequency switches. If a sequence contains a frequency switch, there must be at least 2 of them.

Users can add any number of these 3 components to a sequence file and reorder the components in any order.

The maximum number of samples in a fully constructed sequence cannot contain more than the ARB file size limit.

Once all editing is completed, save the waveform. The waveform can now be loaded and transmitted using the ARB controls.

11.1 **EXAMPLE: CREATING A FREQUENCY HOPPING SEQUENCE FILE**

This section illustrates creating a simple frequency hopping sequence using the ARB sequence editor. This example uses an ARB file found in the example ARB files for the VSG60, which can be downloaded using the following link https://signalhound.com/support/product-downloads/vsg60a-downloads/ Customers may substitute their own ARB file if desired. The sequence file that is generated from this example also is present in the ARB file download.

First, open the ARB sequence editor from the Utilities menu. You should see an empty sequence editor.
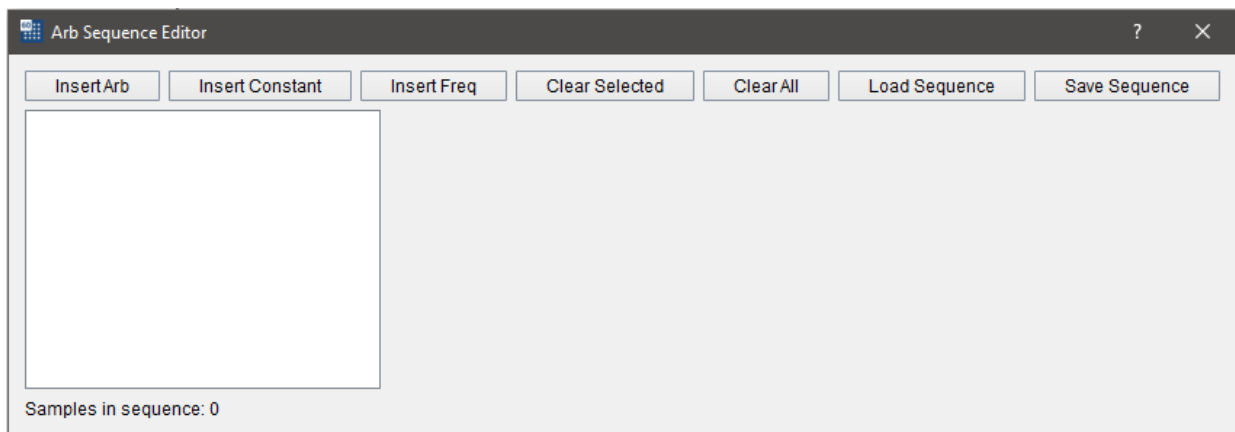

Figure 8: Empty Arb Sequence Editor

Insert the following components and configure each component as follows.

1. Insert Freq Change
    o Set frequency to 990MHz.
2. Insert ARB
    o Load the WLAN80211a.csv waveform and set repetitions to 2.
3. Insert Constant
    o Set I and Q values to zero and set sample count to 1000.
4. Insert Freq
    o Set frequency to 1010MHz.
5. Insert ARB
    o Load the WLAN80211a.csv waveform and set repetitions to 1.
6. Insert Constant
    o Set I to 1 and Q to 0 and set sample count to 2000.

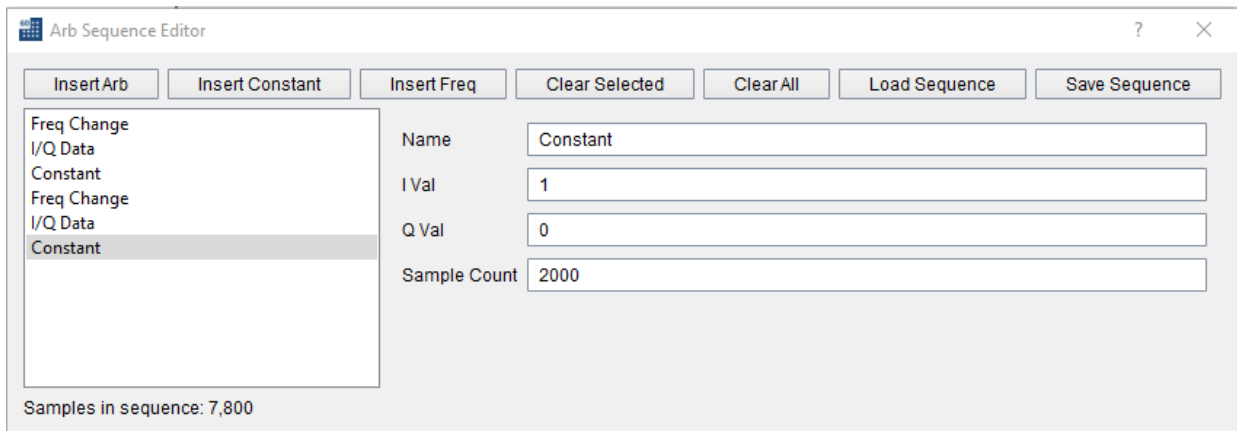You should now see the following in the editor.

Figure 9: Sequence editor after inserting 6 components.

Now save the sequence file as "user_seq_example.seq" and close the sequence editor. Navigate to the ARB output mode and load a custom sequence file and select our sequence example file. Configure the sample rate to 40MHz. Disable output signal average. When finished the VSG60 UI will look like this.
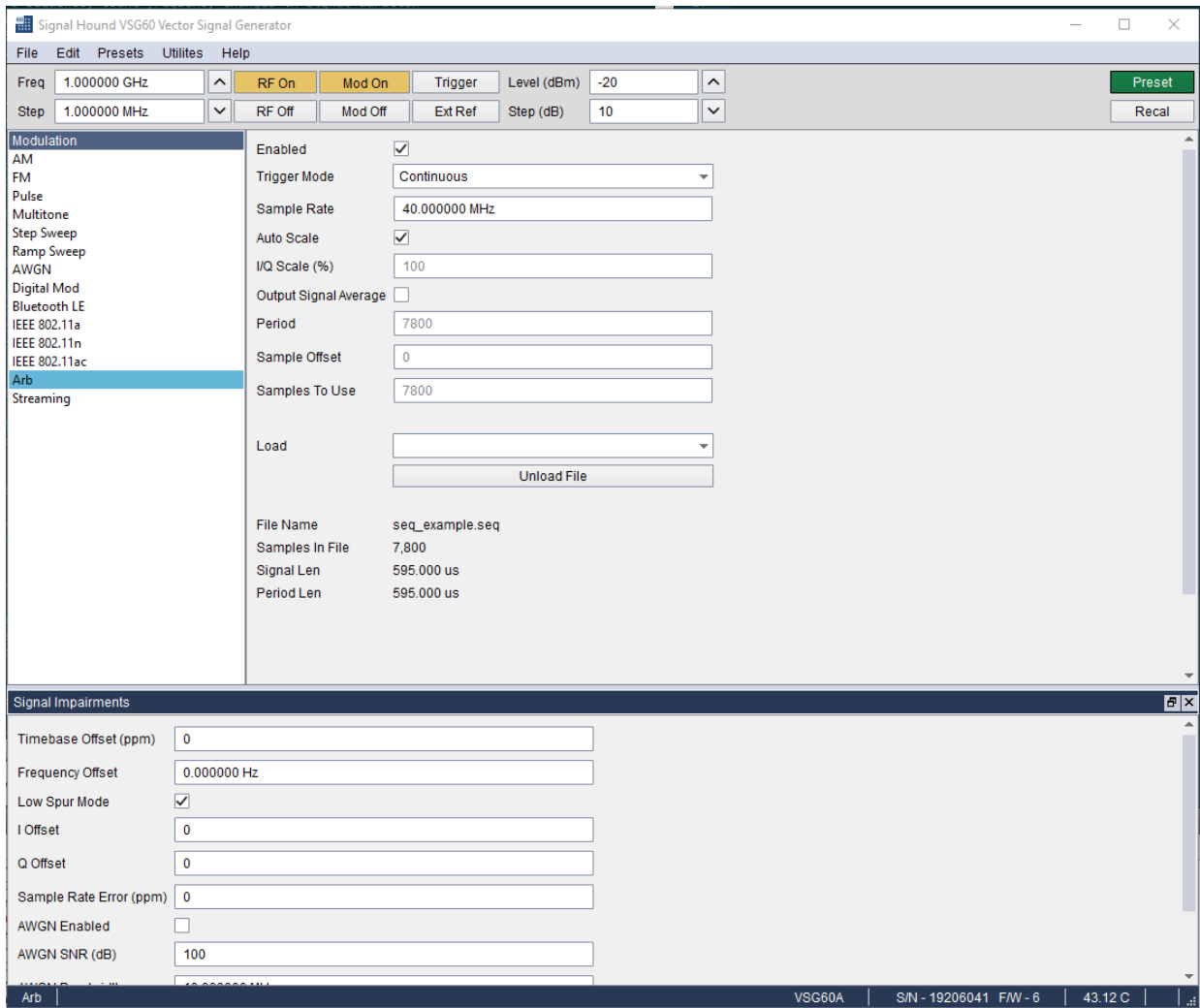
Figure 10: VSG60 UI with custom sequence loaded.

With the sequence loaded and RF/Mod enabled, the following sequence is transmitted.

- The generator will switch to 990MHz center frequency, in 200us.
- The generator will output the ARB file twice, a total of 3200 samples over 80us.
- The generator will output no signal for 1000 samples, or 25us.
- The generator will switch to 1010MHz center frequency over 200us.
- The generator will output the ARB file once, a total of 1600 samples over 40us.
- The generator will output a CW signal for 2000 samples, or 50us.

Using the SM200 spectrum analyzer we can see this sequence in the picture below. The upper left plot shows the leading frequency change. The waterfall plot is read top-down. The output at 990 on the left side of the waterfall is transmitted first, followed by the output at 1010 on the right later.
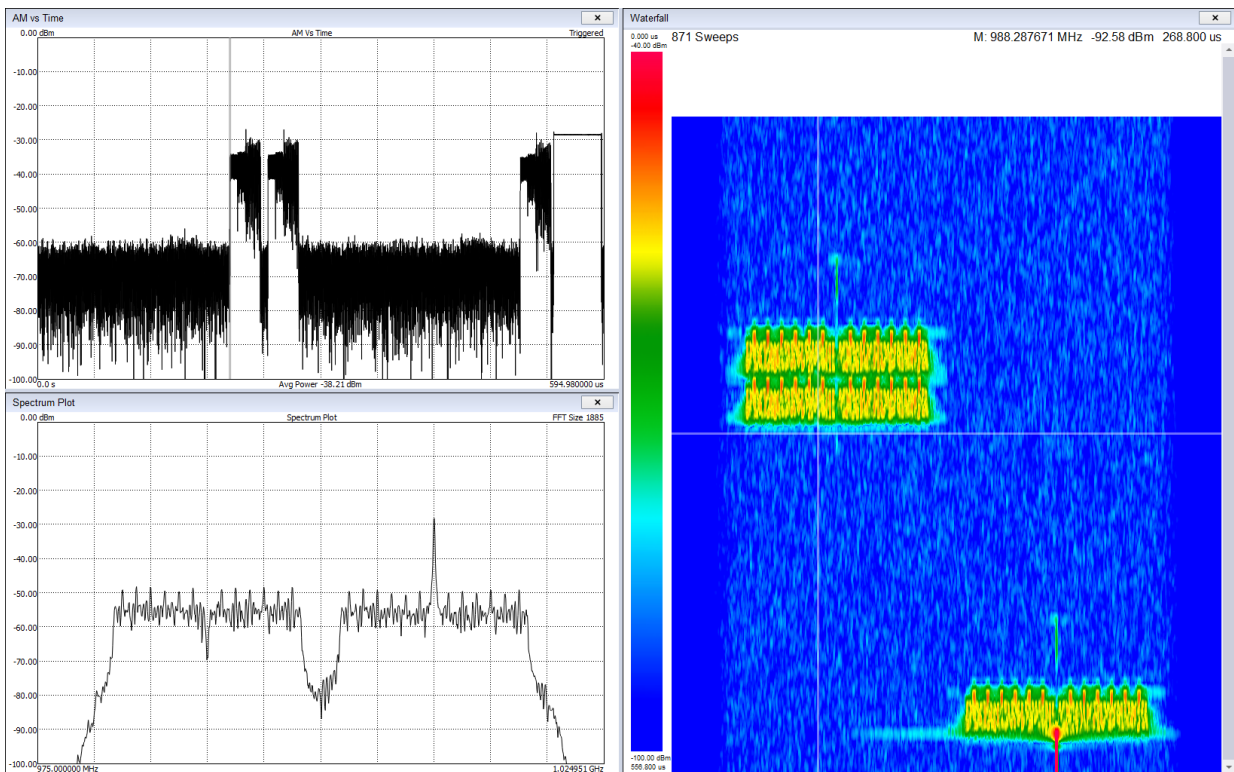

Figure 11: Custom sequence shown on spectrum analyzer.

12 MSK/GMSK Generation

MSK signals can be generated with the VSG60 software using the proper combination of settings.

MSK is commonly generated in 1 of 2 ways using the Digital Mod output mode.

1. Modulation type of 2FSK with a modulation index of 0.5*.

2. Modulation type of OQPSK with a half-sine filter. The combination of half-sine filter and offset symbols guarantees constant amplitude output.

GMSK is commonly generated using a modulation type of 2FSK with a modulation index of 0.5* and a Gaussian shaping window with 0.5 filter coefficient.

*The modulation index of 0.5 represents the peak frequency deviation over the highest possible frequency component. For a given symbol rate N, the highest possible frequency component is N/2, so a modulation index of 0.5 is half of that, giving you a frequency deviation of N/4.

13 Symbol Editor
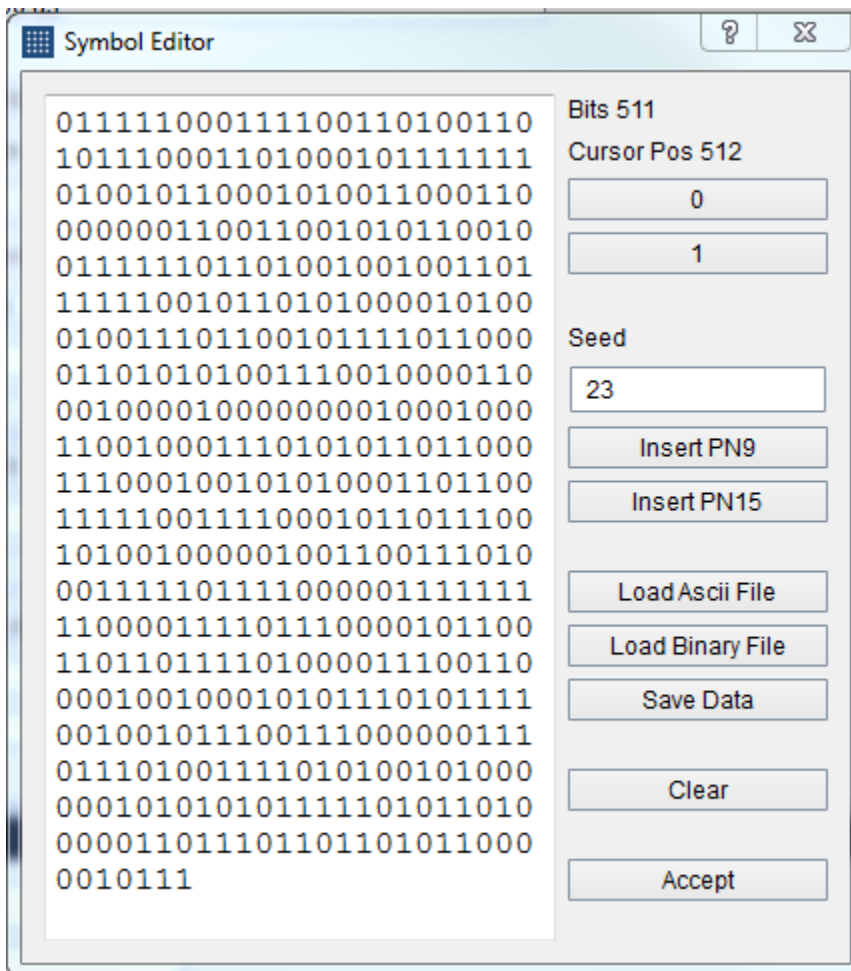
The symbol editor is a dialog window used to create custom data sequences in the software for the various digital modulations. The symbol editor makes it fast and easy to enter custom binary sequences. The symbol editor allows you to save sequences and load them for later use.

The symbol editor consists of the current binary output on the left and several action buttons on the right. Above the binary output, you can see the current size of the binary sequence measured in bits and the current bit position of the cursor. Using the buttons on the right of the output sequence, you can add additional bits into the sequence at the cursor location. You can also insert pseudo-noise sequences with the *Insert PN9* and *Insert PN15* buttons. You can manually set the seed for the pseudo random sequences for repeatability tests.

Using the *Load File* and *Save Data* buttons you can export and import text files containing binary sequences. Files are saved in an ascii binary ('0' or '1') format. Ascii files can be loaded as either ascii binary or hex.

13.1 **LOADING AN ASCII FILE**

When ascii files are loaded they are interpreted as either ascii binary or hex. If all characters read are '0' and '1', the file is interpreted as ascii binary. If any character is '2' through 'F', the whole file is interpreted as ascii hex. If any character falls outside the hex ascii range, the file will not be loaded.

13.2 **INTERPRETING THE BINARY SEQUENCE**

The binary sequence will be interpreted differently depending on modulation type selected. The sequence will be split according to how many bits per symbol are required for the selected modulation. The sequence is zero-padded at the end of the sequence if needed to create a sequence of an integer number of symbols.

14 ARB Files

The software allows you to load custom I/Q ARB files which fully define the device output. The files follow a standard format which is described below.

14.1 **CSV FILES**

These files should have a .txt or .csv extension. They should be in plain text. Each line should contain a pair of complex values (I/Q) separated by a comma. Each line should end in a newline. The file is read until a line no longer follows this format.

I(0), Q(0),
I(1), Q(1),
…
I(n), Q(n)

14.2 **BINARY FILES**

The software can load binary files with extension .bin .dat and .iq. These files should be interleaved complex values, either 16-bit integer or 32-bit floating point scaled to 1.0 magnitude.

14.3 **MIDAS BLUE**

The file extension for these files should be .tmp or .prm. Only files that have these characteristics can be loaded properly,

- Little endian headers and data
- Cannot be detached
- Must be 1D complex data (type code 1000)
- Must have data_format of 'F', 'D', or 'I'

Sample rate is retrieved from VariableHeader.x_delta.

14.4 **WAV FILES**

The VSG60 software can read WAV files with the following format.

- Must be a 2-channel file
- I-values are stored in channel 1, Q-values are stored in channel 2
- Must have either WAVE_FORMAT_PCM or WAVE_FORMAT_IEEE_FLOAT audio types.
- Supports 16-bit shorts and 32-bit floats only.

14.5 **ARB SEQUENCE FILES**

ARB sequence files allow customers to define complex frequency hopping signal waveforms.

ARB sequence files are generated using the sequence editor in the Utilities menu. See ARB Sequence Editor for more information.

15 Command Line Options

The following command line options are available when launching the VSG60 software.

--hidden, Hides the user interface, including on the taskbar. To be used in conjunction with SCPI to allow for 'headless' operation. The application can be closed via the SCPI commands or manually in the task manager.

The following dialogs will not be shown in hidden mode:

- Connecting device

- Multiple devices found

- No device found

- Unable to open device

- Device connection lost

Note: The SCPI lockout dialog is still visible when the application is hidden. This dialog can also be hidden using the preferences menu -> Enable SCPI Lockout Dialog.

--scpi-port=n, Set the SCPI port after launching the VSG60 software. n should be an integer not exceeding 65535. This has the same effect as modifying the SCPI port through the preferences menu. This command line assists customers who want to interface multiple instances of the VSG60 software with different SCPI ports.

16 Power Saving CPU Mode

Newer CPU models implement efficient power saving techniques that can interfere with and reduce USB bandwidth. If you are using one of these CPU models, you can experience issues with the VSG60 which might appear as data loss (signal dropouts) when inspecting the out of the VSG60. We are offering 2 potential solutions to this problem.

1) Enable the power saving CPU mode. This has the effect of adding an artificial CPU load to the application to keep the CPU from entering low power states that might affect the USB throughput. You will see an increase in CPU usage with this method.

2) Disable "C-States" in the BIOS of the PC. This prevents the OS from being able to put the CPU in these lower power states which affect USB performance. This will increase power consumption of the PC which will affect battery life but will see lower CPU usage (since power saving CPU mode can be disabled).

Power saving CPU mode is enabled by default and can be disabled in the preferences menu.

If customers are affected negatively by the increase in CPU usage, we recommend disabling this mode to determine if their PC is subject to this issue at all.

PCs most affected are laptops and ultraportable devices running Windows.

17 MATLAB® Runtime Installation Instructions

To transmit either LTE or 802.11ax waveforms with the VSG60, the MATLAB® runtime and Visual Studio 2019 C++ redistributable libraries must be installed on the PC. The next two sections detail how to install these freely available libraries.

17.1 INSTALLING THE MATLAB RUNTIME

The MATLAB® runtime is available for download from the following website.

https://www.mathworks.com/products/compiler/matlab-runtime.html

Download the 64-bit Windows installer for R2021b (9.11). Extract the downloaded folder and run the setup.exe file. Install the MATLAB® Runtime to the default installation folder.

During installation, the installer will add the MATLAB® runtime folder to the system path. If this fails, you will receive this warning during installation.

"The MATLAB Runtime could not be successfully added to your system path. You must add the following folder manually: C:\Program Files\MATLAB\MATLAB Runtime\v911\runtime\win64"

This will often fail due to the system PATH environment variable exceeding its maximum length. In this event, you must add the runtime folder to the system path manually. This can be performed using the registry editor or through the environment variable editor on Windows. Editing the system path via the registry editor will allow you to exceed the length limit of 2047 characters. Editing the path via either method will require you to restart the PC before the VSG60 software will properly detect the MATLAB® runtime libraries.

17.2 INSTALLING THE VS2019 C++ REDISTRIBUTABLE LIBRARIES

The Visual Studio 2019 C++ redistributable libraries are available at the following link. Download and install the 64-bit (non-ARM) libraries.

https://docs.microsoft.com/en-US/cpp/windows/latest-supported-vc-redist?view=msvc-170

17.3 LOAD TIMES

The VSG60 software initializes the MATLAB® runtime when the LTE or 802.11ax transmit controls are accessed. This load time can take typically anywhere from 3-15 seconds. This load time cost will be incurred once per instance of the VSG60 application. The presence of anti-virus software can greatly affect these load times. Consider disabling any real-time anti-virus monitoring software to reduce these load times.

18 Troubleshooting

18.1 THE DEVICE DOES NOT CONNECT TO THE SOFTWARE

- Confirm the USB 3.0 cable is connecting the VSG60 to the PC and is solidly connected at both ends.

- The USB cable must be connected to USB 3.0 ports on the PC. USB 3.0 ports are usually blue or are labeled with an "SS" marking near the port. If you are unsure if your PC has USB 3.0 ports, refer to your PC manual or contact Signal Hound.

- Once the USB cable is connected, ensure the LED on the VSG60 is solid green.

- If using a USB 3.0 hub, try removing the hub and connecting the device directly to the PC.

- Manually reinstall the USB 3.0 driver. Navigate to the driver directory at *C:\Program Files\Signal Hound\VSG60\drivers\x64.* Find the cyusb3.inf file, right click this file and select "Install". Once installed successfully, power cycle the VSG60 and attempt to reconnect the device.

- Try a different USB 3.0 cable. You can use any single ended USB 3.0 cable for this test. You can often find compatible cables on USB 3.0 hard drives. If you do not have a spare, you can request one from Signal Hound.

- Verify the PC meets the system requirements (listed near the top of this document). In particular, the CPU requirement.

- Try a different PC.

If the VSG60 works on a different PC, contact Signal Hound with information about the non-working PC for additional troubleshooting help. If the VSG60 does not connect on multiple PCs, contact Signal Hound.

18.2 THE DEVICE DOES NOT TRANSMIT A STABLE SIGNAL

If the output of the VSG60 does not seem continuous or stable, try the troubleshooting steps below.

This issue will appear as a pulsed output on a continuous signal like a CW or a continuously modulated signal like AM/FM. This behavior can be observed in the time domain or frequency domain with a spectrum analyzer. This indicates the PC is unable to meet the CPU or USB streaming requirements to sustain the data rates required for the given configuration.

- Verify the PC meets the system requirements (listed near the top of this document). In particular, the CPU requirement.

- Our software is optimized for Intel processors. If using an AMD processor, this could be the reason. Please contact Signal Hound with information about your PC in this event.

- Enable the high-performance power plan. (See picture below) If high-performance is not available, "show additional plans" can be expanded to reveal more plans. Some low power laptops might not have a high-performance plan.
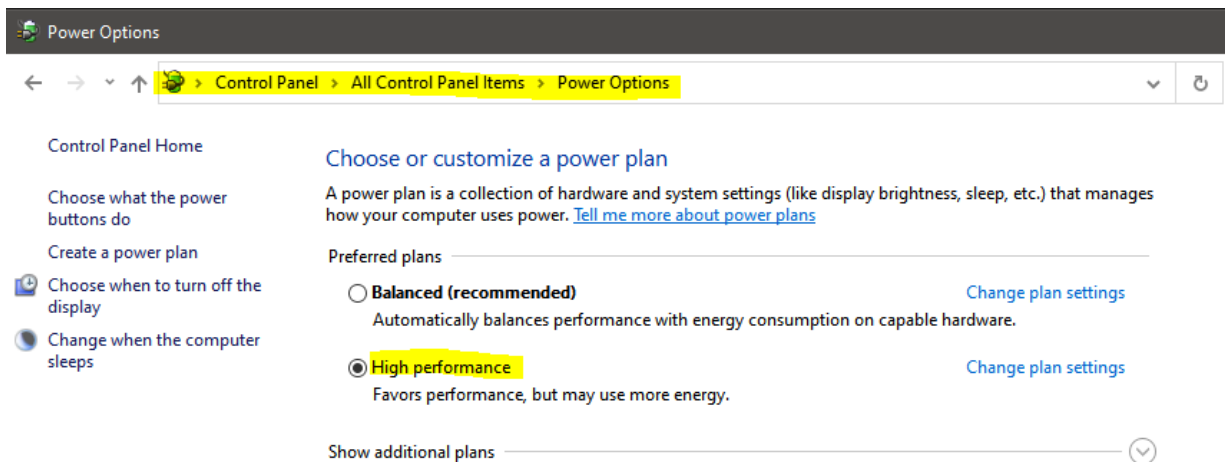
- If using a USB 3.0 hub, try removing the hub and connecting the device directly to the PC.

- Try connecting the USB 3.0 cable to different USB 3.0 ports on the PC. If using a desktop, avoid front panel USB 3.0 ports. Instead connect to ports on the rear of the PC.

- If any other USB devices are connected or are being actively used (such as a Signal Hound spectrum analyzer) disconnect that device and run the VSG60 by itself.

- If any other high CPU usage software is being run simultaneously, close that software and run the VSG60 by itself.

- If any anti-virus or corporate security software is installed on the PC, temporarily disable it before running the VSG60.

- Try running the VSG60 with and without the "Power Saving CPU Mode" checkbox enabled in the Preferences menu in the VSG60 software.

- Try using a different USB 3.0 cable. You can use any single ended USB 3.0 cable for this test. You can often find compatible cables on USB 3.0 hard drives. If you do not have a spare, you can request one from Signal Hound.

- Disable C-states in the BIOS. Newer Intel processors have low power sleep states that can interfere with USB transfers causing enough latency to interrupt the VSG60 output. Disabling C-states in the BIOS will eliminate this at the expense of higher power usage on the machine. Even if this is not a tradeoff you are willing to make, it is helpful to determine if this is the source of the issue. If it is and you cannot afford disabling this permanently, this PC may not be usable with the VSG60.

18.3 USING MULTIPLE USB 3.0 DEVICES ON LINUX

There are system limitations when attempting to use multiple Signal Hound USB 3.0 devices* simultaneously on Linux operating systems. The default amount of memory allocated for USB transfers on Linux is 16MB. A single Signal Hound USB 3.0 device will stay within this allocation size, but two devices will exceed this limitation and can cause connection issues or will cause the software to crash.

The USB memory allocation size can be changed by writing to the file

/sys/module/usbcore/parameters/usbfs_memory_mb

A good value would be N * 16 where N is the number of devices you plan on interfacing simultaneously. One way to write to this file is with the command

sudo sh -c 'echo 32 > /sys/module/usbcore/parameters/usbfs_memory_mb'

where 32 can be replaced with any value you wish. You may need to restart the system for this change to take effect.

*Includes both Signal Hound USB 3.0 spectrum analyzers and signal generators.

19 Calibration and Adjustment

For more information regarding calibration and adjustment see the VSG60 product manual on our website or shipped with our software or contact Signal Hound.

20 Warranty and Disclaimer

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