MaxEye Z-Wave (ITU-T G.9959) Measurement Suite

Version 1.0.0.1

Getting Started Guide

1. Introduction

MaxEye Technologies provides generation and analysis functions in LabVIEW for generating and analyzing the ITU-T G.9959 standard complaint signals using National Instruments Vector Signal Generators (NI VSG) and Vector Signal Analyzers (NI VSA) or Vector Signal Transceivers (NI VST). The ITU-T G.9959 Standard supports three different data rates; the current version of the toolkits supports all the following data rates.

i. R1 (9.6kbps)

ii. R2 (40 kbps)

iii. R3 (100 kbps)

The standard defines different modulation types, data rates based on the frequency band.

Data Rate	Bit Rate	Symbol Rate	Modulation Type	Coding	Frequency Offset	Seperation
R1	9.6 kbps	19.2 kbaud	FSK	Manchester	20 kHz	40kHz±20%
R2	40 kbps	40 kbaud	FSK	NRZ	0 kHz	40kHz±20%
R3	100 kbps	100 kbaud	GFSK, BT=0.6	NRZ	0 kHz	58kHz±20%

This guide explains how to use the Z-Wave Measurement Suite toolkit using the Soft Front Panel (SFP) and programming examples.

2. Installed File Location

2.1 Soft Front Panels

The Z-Wave Generation soft front panel is located in, <LabVIEW>\vi.lib\addons\MaxEye\Z-Wave\Executable\MaxEye Z-Wave Signal Generation\ MaxEye Z-Wave Signal Generation.exe

The Z-Wave Analysis soft front panel is located in, <LabVIEW>\vi.lib\addons\MaxEye\ Z-Wave \ Executable\MaxEye Z-Wave Signal Analysis\ MaxEye Z-Wave Signal Analysis.exe

You can also find a shortcut to the above location from the windows start menu.
Start->All Programs->MaxEye-> Z-Wave

2.2 Programming Examples

1. The Z-Wave signal generation example VIs are installed in, <LabVIEW>examples\MaxEye\ Z-Wave \Generation

2. The Z-Wave signal analysis example VIs are installed in, <LabVIEW>examples\MaxEye\ Z-Wave \Analysis

3. The toolkit API VIs for Z-Wave signal generation are installed in, <LabVIEW>\vi.lib\addons\MaxEye\ Z-Wave \Generation\API.

4. The toolkit API VIs for Z-Wave signal analysis are installed in, <LabVIEW>\vi.lib\addons\MaxEye\ Z-Wave \Analysis\API.

You can also find a shortcut to the above location from the windows start menu.
Start->All Programs->MaxEye-> Z-Wave

2.3 Documentation

The toolkit help file is installed in, <LabVIEW>\help\MaxEye\ Z-Wave \MaxEye Z-Wave Measurement Suite Help.chm

The toolkit documentation files are installed in, <LabVIEW>\vi.lib\addons\MaxEye\ Z-Wave \ Documentation.

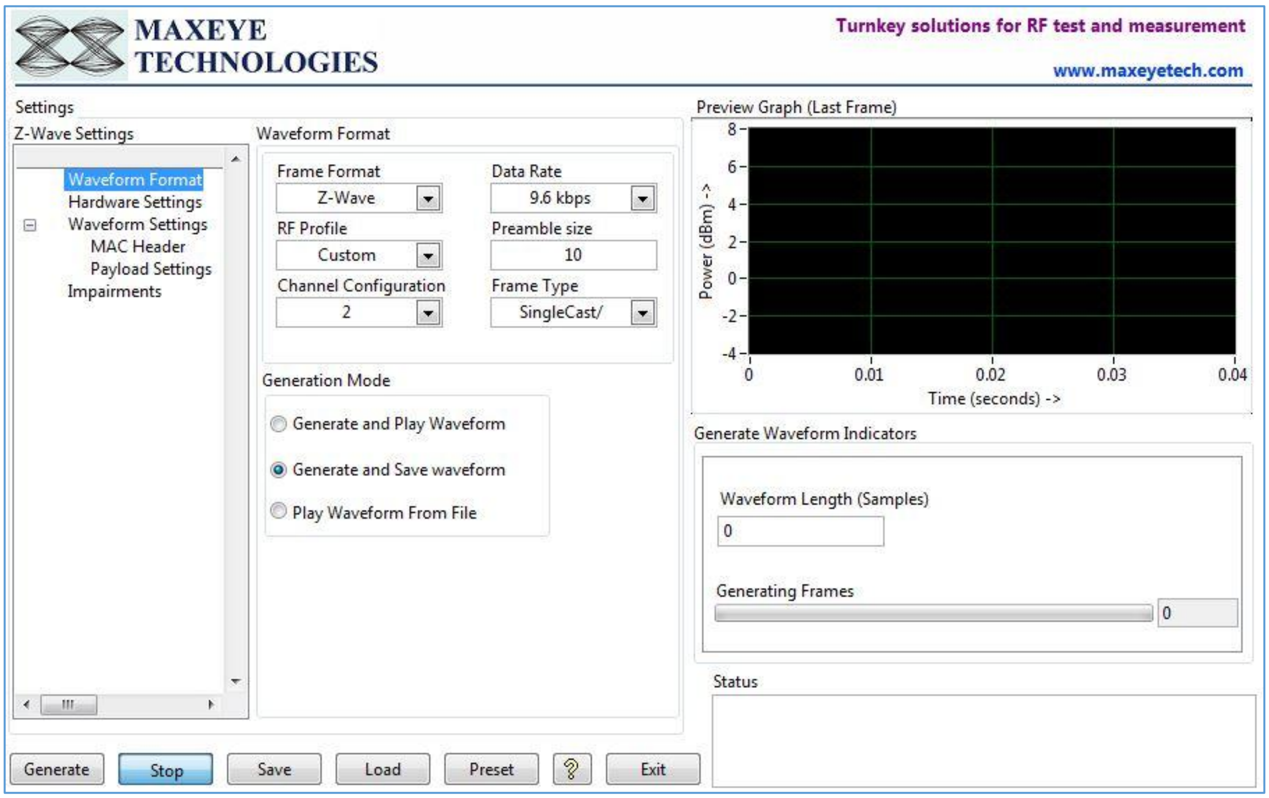
You can also find a shortcut to the above location from the windows start menu.
Start->All Programs->MaxEye-> Z-Wave

3. Soft Front Panel

The soft front panel (SFP) for generator and analyzer allow engineers to quickly generate ITU-T G.9959 complaint modulated RF signals and view, save, and perform measurements. Z-Wave Generation SFP can be used to generate Z-Wave signals of all supported frame types. Use Z-Wave Analysis SFP to perform modulated or continuous waveform or spectral measurements.

3.1 MaxEye Z-Wave Signal Generation SFP

The figure below shows the Z-Wave Signal Generation SFP.

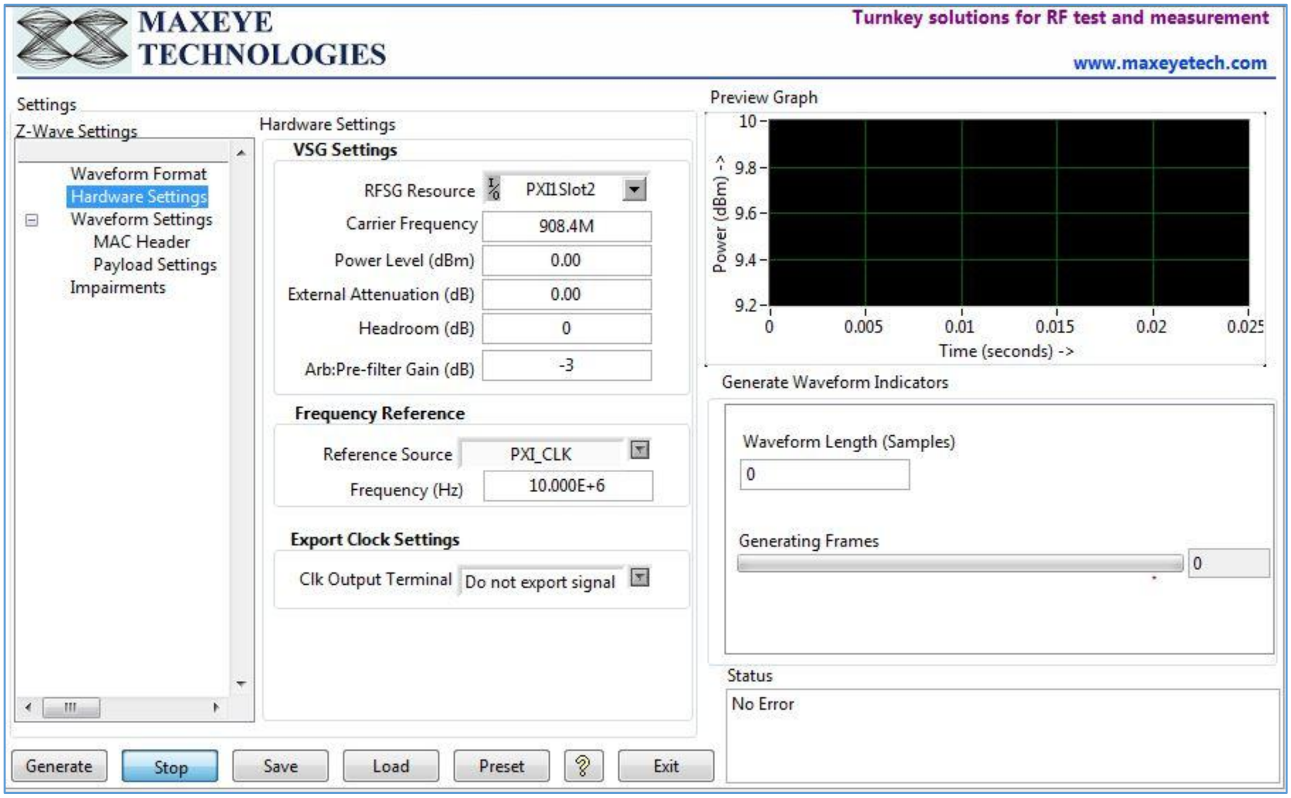


3.1.1 Generate and Save Waveform/ Generate and Play Waveform

Follow the procedure below to generate signals using SFP.

Select RF Profile depending on the type of DUT you are testing. Select Generation mode as Generate and Play Waveform or Generate and Save Waveform. Generate and Play waveform is used to generate Z-Wave RF signal using hardware. Generate and Save waveform is used to generate waveform and store in a file. For this configuration hardware is not required. The IQ baseband waveform is stored in a file. Play Waveform From File mode reads the Z-Wave waveform from the file created using the Generate and Save Waveform and then downloads the waveform to NI RFSG Memory and then plays the waveform.

1. Select the hardware settings to configure the following parameters. This settings is needed to configure only when the Generation mode is Generate and Play waveform.



RFSG Resource- Configure the resource name used in NI Measurement and Automation explorer for the NI PXIe-5673/5673E or NI PXIe 5644R/45R/46R or NI 5840 device.

Carrier Frequency (Hz)- Select Center Frequency of the Z-Wave signal in MHz. . The toolkit will use this carrier frequency only when the RF profile is chosen as Custom.

Power Level (dBm)- Average Power level of the signal in dBm.

Headroom (dB)- Configure the Headroom value higher than PAPR of the signal to be generated. Refer MaxEye Z-Wave Measurement Suite Help.chm.

External Attenuation (dB)- Specifies the external amplification or attenuation, if any, between the NI RF signal generator and the device under test. Positive values for this property represent amplification, and negative values for this property represent attenuation.

Arb: Pre-filter Gain (dB)- Specifies the AWG prefilter gain. The prefilter gain is applied to the waveform data before any other signal processing. Reduce this value to prevent overflow in the AWG interpolation filters. Other gains on the NI-RFSG device are automatically adjusted to compensate for non unity AWG prefilter gain.

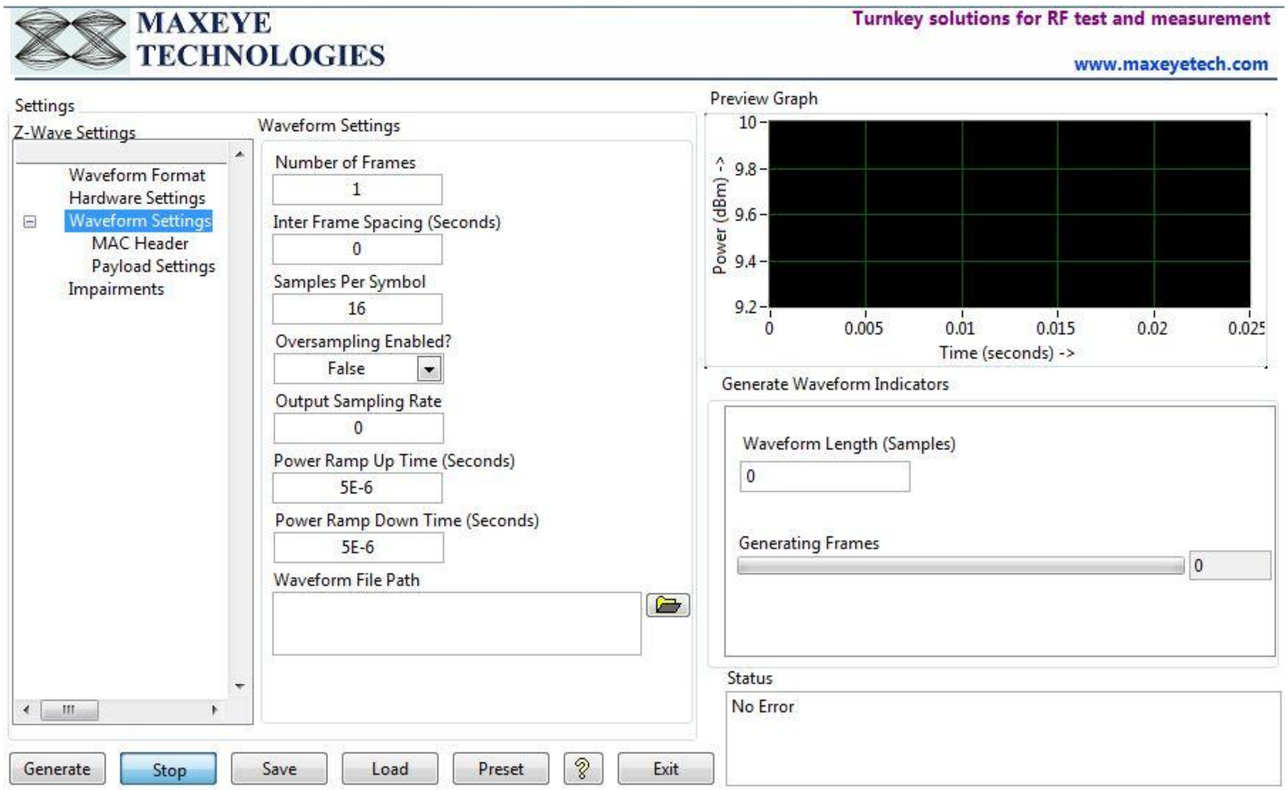
Reference Source- specifies the source of the Reference Clock signal

Frequency (Hz)- specifies the Reference Clock rate, in hertz (Hz).

Clk Output Terminal- specifies the terminal where the signal will be exported.

For more information Refer NI RFSG Signal Generators help file.

2. Select the waveform Settings.



Number of Frames- decides the length of waveform to be generated. To generate longer duration of the waveform, increase the Number of Frames value.

Inter frame Spacing (Seconds)- specifies the gap duration in seconds between the frames.

Samples Per Symbol- Specifies the number of samples per symbol. Sampling Rate of generated waveform is equal to samples per symbol multiplied by Symbol Rate.

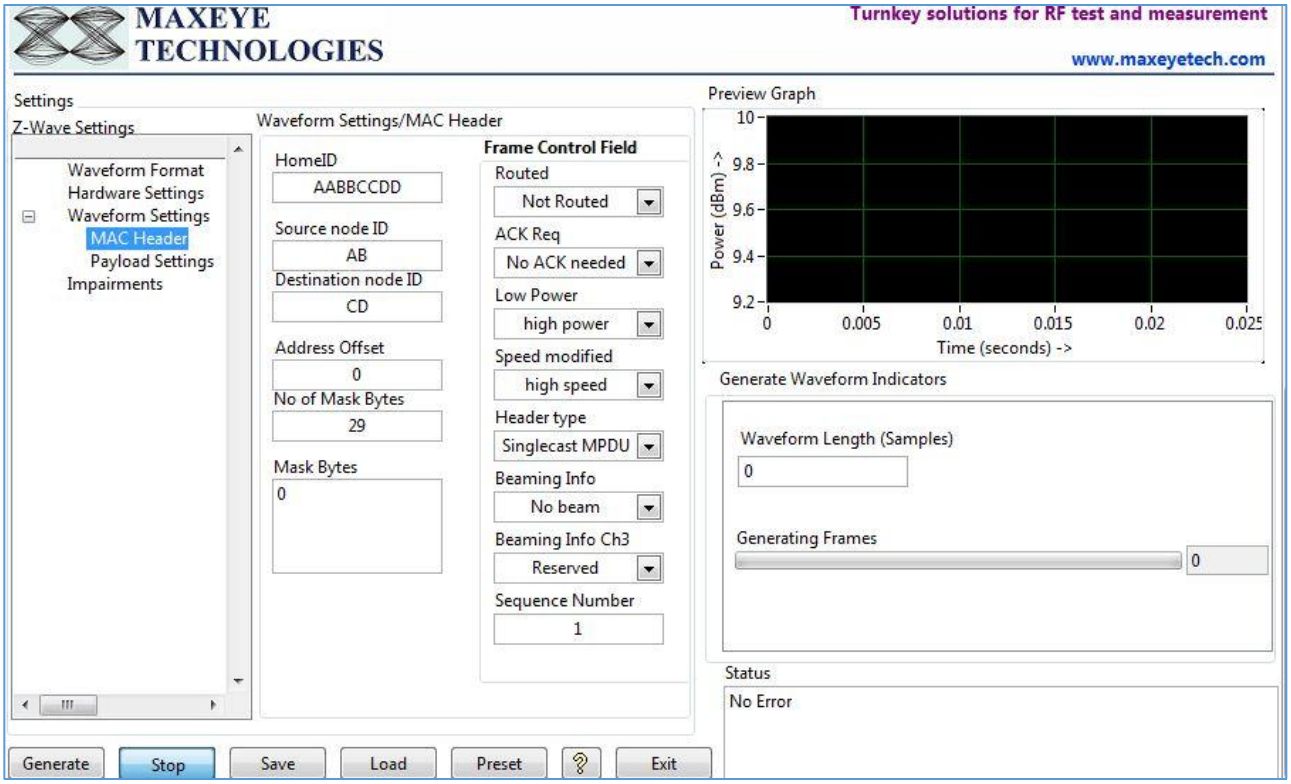
Oversampling Enabled & Output Sampling Rate- Use this configuration only when you want to resample the signal to different sampling rate. The default sampling rate is Samples per symbol multiplied by Symbol Rate. The toolkit resample's the generated signal to a sampling rate equal to the Output Sampling Rate only if the Over Sampling Enabled property is set to 1(True).

The Power Ramp Up Time- specifies the time duration during which the signal power gradually increases to the full value from zero.

The Power Down Time- specifies the time duration during which the signal power gradually reduces from the full value to close to zero.

Waveform file path- Select a path to save the waveform. Needs to be configured only when the generation mode is Generate and Save waveform.

3. Select the MAC Header settings.



The MAC Header fields can be configured as follows

HomeID - The HomeID identifier field is 4 bytes in length and specifies the unique domain identifier. All nodes in a domain shall have the same HomeID.

Source NodeID - The source NodeID is 8 bits in length and shall be a unique identifier of a node in a given domain. Together with the HomeID, the source NodeID identifies the node that originated the frame.

Destination NodeID - The destination NodeID shall specify a destination node in the same domain identified by the HomeID. The destination NodeID value 0xFF may be used for broadcasting an MPDU to all nodes within direct range.

Address Offset- The address offset field is a 3-bit field.

No of Mask Bytes- a sending node shall set the Address Offset field to zero and the number of mask bytes field shall be set to 29.

Mask Bytes- Each bit of a mask byte represents a node. Mask byte 0 represents the NodeIDs 1 to 8.

The frame control Fields can be configured as follows.

Routed- The Routed subfield is 1 bit in length and shall be set to 0 when the frame is not routed and set to 1 when the frame is routed.

Ack Req- The ACK Req subfield is 1 bit in length and set to 1 when the source node wants the destination node to acknowledge the frame, and the bit is set to 0 when no ACK is needed. A receiving node shall return an ACK MPDU in response to the ACK request.

Low Power- The Low Power subfield is 1 bit in length and is set by the source node. The bit informs a destination node that the actual transmission was using low power. A receiving node shall return an ACK MPDU in low power in response to the low power bit.

Speed Modified- The Speed modified subfield is 1 bit in length. It shall be set to 1 if an MPDU is sent at a lower speed than supported by the source and destination. The field shall not be used for routed and multicast MPDUs. The field shall be set to 0 if the MPDU is sent at the highest speed supported by the source and destination.

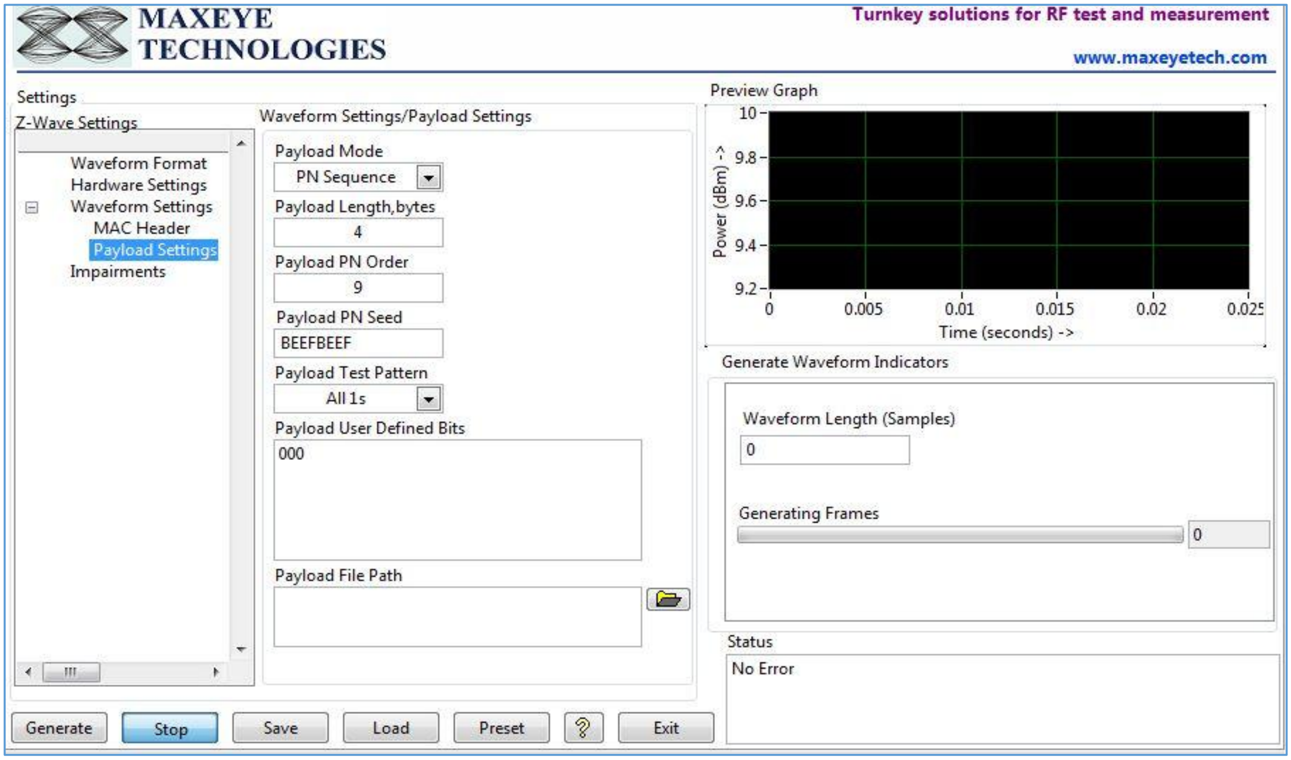
Header Type- The header type subfield defines the frame header type. A broadcast MPDU is a singlecast MPDU (header type 0x1) carrying a destination NodeID = 0xFF.

Beaming Info- The Beaming Information subfield shall advertise the capability of a sending FL node to be awakened by a beam if it is asleep. The Beaming Information subfield shall be interpreted in combination with the actual channel configuration.

Beaming Info Ch3- specifies the address of the originator of the frame. This field shall be included in the MAC frame only if the Source Addressing Mode field is nonzero.

Sequence Number- The Sequence Number is a 4-bit sub-field of the frame control field for channel configuration 1&2 and is an 8-bit field of the MPDU Header (MHR) for channel configuration 3. The MAC layer of a transmitting node shall forward the sequence number value transparently to the PHY. The MAC layer shall use the same sequence number for the initial transmission and for all retransmissions of a given MPDU. For channel configuration 1&2 the transmitted sequence number shall be in the range 0x1...0xf.The value 0xf shall be followed by the value 0x1. For Channel Configuration 3 the transmitted sequence number shall be in the range 0x00…0xff. The value 0xff shall be followed by the value 0x00.

4. Select the MAC Payload Settings. This fields are not needed to configure when the frame header type is acknowledgement.



Payload Mode- Choose the appropriate mode. PN sequence is used to generate the PN sequence. In the User defined bits, user can configure the transmitting bits. In Test Pattern, some predefined bit patterns can be used for transmitting.

Payload Length ,Bytes- Specifies the number of bytes to be transmitted

Payload PN Order- specifies the order of the PN bit sequence to be generated. The valid values is 5 to 31, inclusive. Configure this field when the Payload mode is PN sequence.

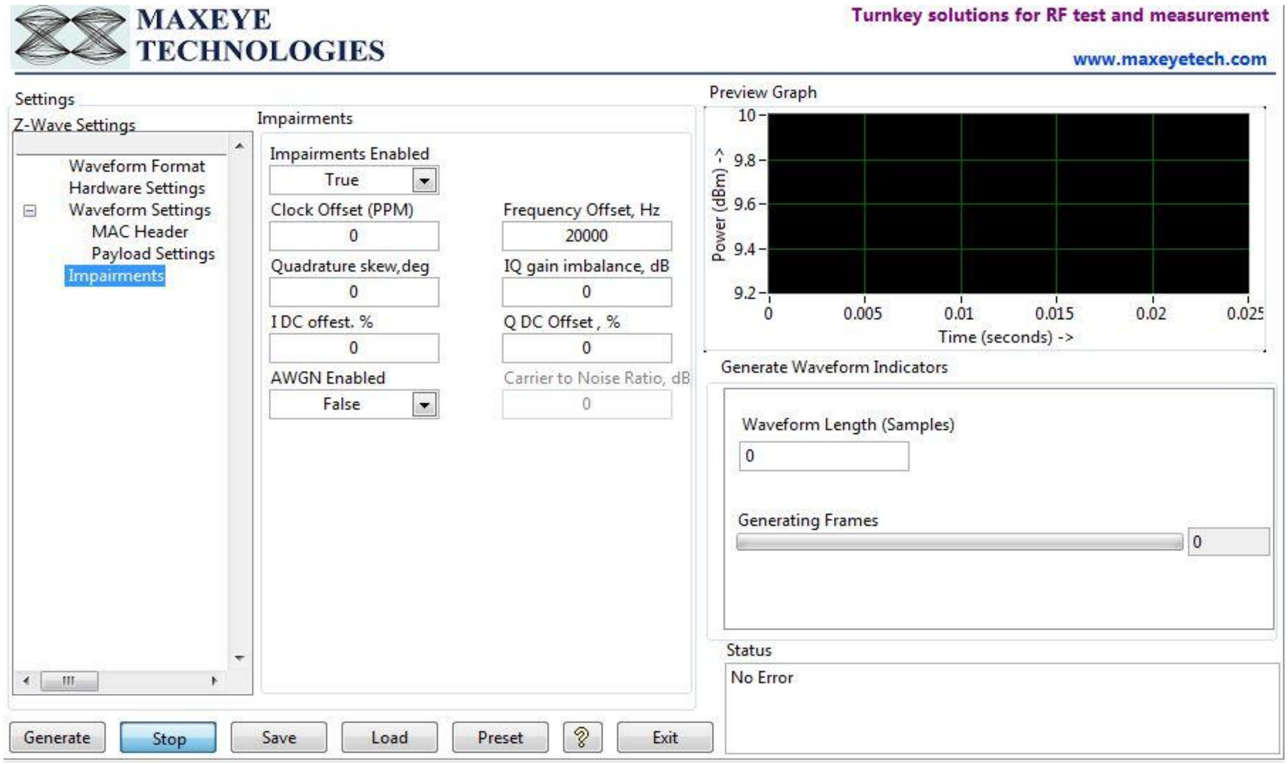
Payload PN Seed- specifies the initial state of the PN generator shift register. Configure this field when the Payload mode is PN Sequence

Payload Test Pattern- Select the required Test Pattern. Configure this field when the Payload mode is Test Pattern

Payload User Defined Bits- Configure this field when Payload mode is User Defined bits.

Payload File Path- Choose the file path when the payload mode is From File.

5. Select the Impairments.



Impairments Enabled- If this property is set to True then the toolkit adds the impairments to the generated signal as per the user configuration for the supported impairments.

Clock Offset (PPM)- The toolkit applies the clock offset to the generated waveform based on this value. The applied clock offset is relative to the clock frequency of the signal generator. The default value is 0.

Frequency Offset, Hz- The toolkit applies frequency offset to the created waveform based on the value configured in this property. The applied frequency offset is relative to the signal generator's carrier frequency. For data rate R1 the frequency offset is 20 KHz and for other data rates the frequency offset is 0.

Quadrature skew- Quadrature Skew specifies the deviation in angle from 90 degrees between the in-phase (I) and quadrature-phase (Q) signals. The default value for the Quadrature Skew is 0.

IQ gain imbalance, dB- This value specifies the ratio, in dB, of the mean amplitude of the in-phase (I) signal to the mean amplitude of the quadrature-phase (Q) signal. The default value is 0.

I DC offset, %- The toolkit adds the DC offset to the in-phase signal component (I) of the complex waveform as a percentage of the root mean square magnitude of the unaltered I signal. The default value is 0.

Q DC Offset, %- The toolkit adds the DC offset to the quadrature-phase signal component (Q) of the complex waveform as a percentage of the root mean square magnitude of the unaltered Q signal. The default value is 0.

AWGN Enabled- If this property is set to True then the toolkit adds Additive White Gaussian Noise (AWGN) to the created waveform based on the value configured in the Carrier to Noise Ratio property.

Carrier to Noise Ratio, dB- This value specifies the Carrier to Noise ratio of the generated signal. The default value is 40dB.

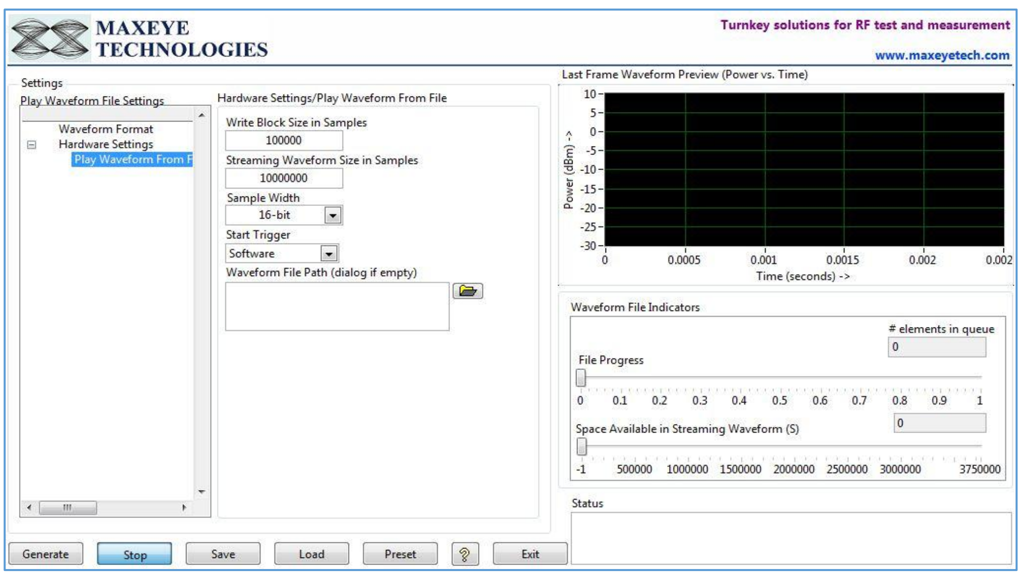
6. To generate the waveform Click on the Generate button which is on the bottom side of the SFP. To stop Generation click on the Stop button.

7. To save the entire configuration click on the save button. You can reload this configuration by using the load button. In order to exit the SFP always use the exit button.

3.1.2 Play Waveform From File

Play Waveform From File mode reads the Z-Wave waveform from the file created using the Generate and Save Waveform and then downloads the waveform to NI RFSG Memory and then plays the waveform.

1. Select Waveform Format. Then Choose Play Waveform From File



2. Select Hardware Settings. Refer 3.1.1 for configuration.

3. Select Play Waveform From File.

Streaming Waveform Size in Samples- specifies the total number of samples used to write the waveform to NI RFSG device or output DMA Stream.

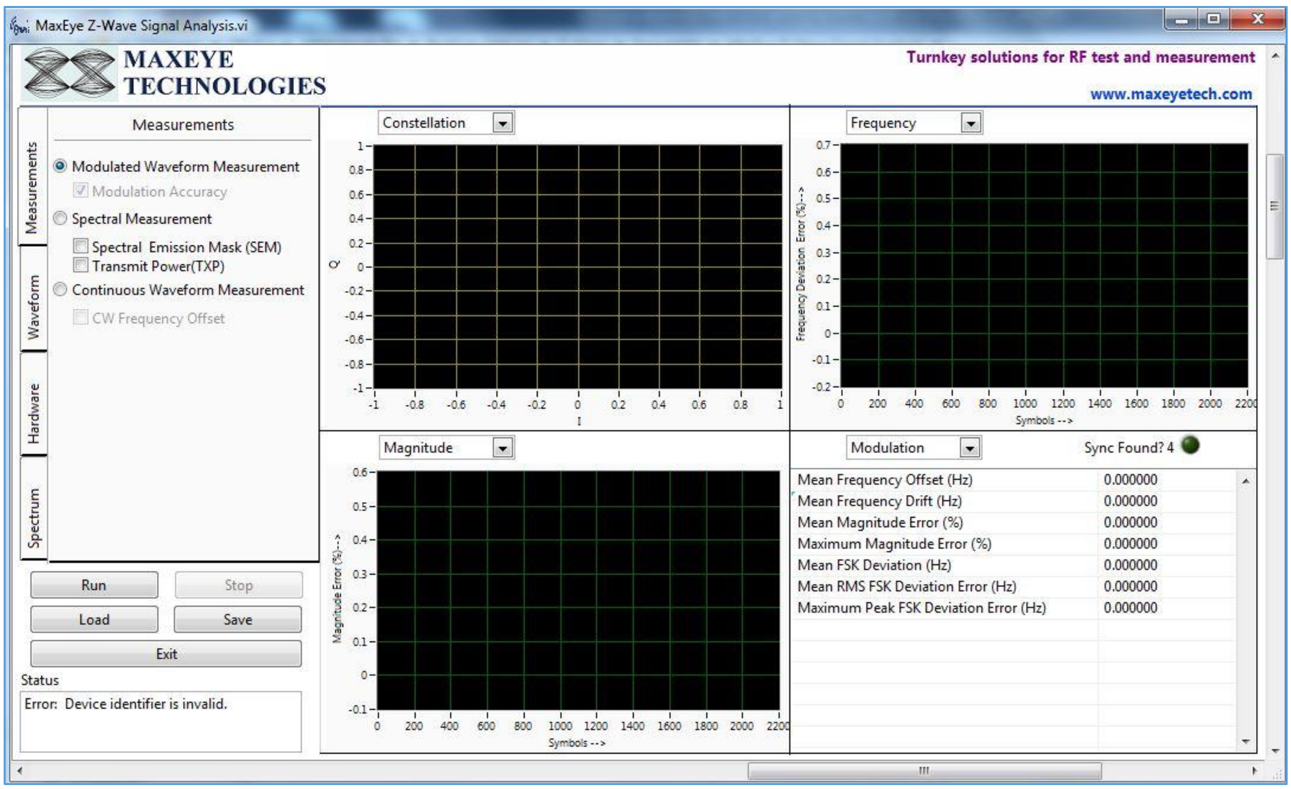
Sample Width- use the same sample width value used for storing the waveform in the file.

Start Trigger- Configures the Output Stream Start trigger type. Software option configures the device to wait until a software trigger is received, before starting generation. PFI0 option configures the device to wait until a digital edge trigger is received from PFI0, before starting generation. Input Stream Start Trigger option asserts the trigger at the same time as the Input Start trigger, which can be used to synchronize the input stream with output stream. Output Stream FIFO primed option waits until the FPGA DMA FIFO has at least as many samples as the priming threshold, before triggering.

Waveform File Path- Select the saved waveform file path.

3.2 MaxEye Z-Wave Signal Analysis SFP

The figure given below is the Z-Wave Signal Analysis SFP.



The following are the measurements available in Z-Wave Analysis SFP.

- **Modulated Waveform Measurement-** Performs demodulation measurements on the acquired I/Q complex waveform.
- **Spectral Measurements-** Spectrum measurements are implemented using time-domain acquisitions at multiple RF center frequencies, converting the acquired data to frequency domain using fast Fourier transform, and then stitching the various spectrums together to form the complete spectrum. The following spectral measurements can be performed at the same time.
  - Spectral Mask Emission- SEM measurements measure out-of-band emissions in the neighboring bands of the carrier. SEM uses the spectral mask or limit you specify to measure the margin of the emission level from the limit and reports the measurement status.

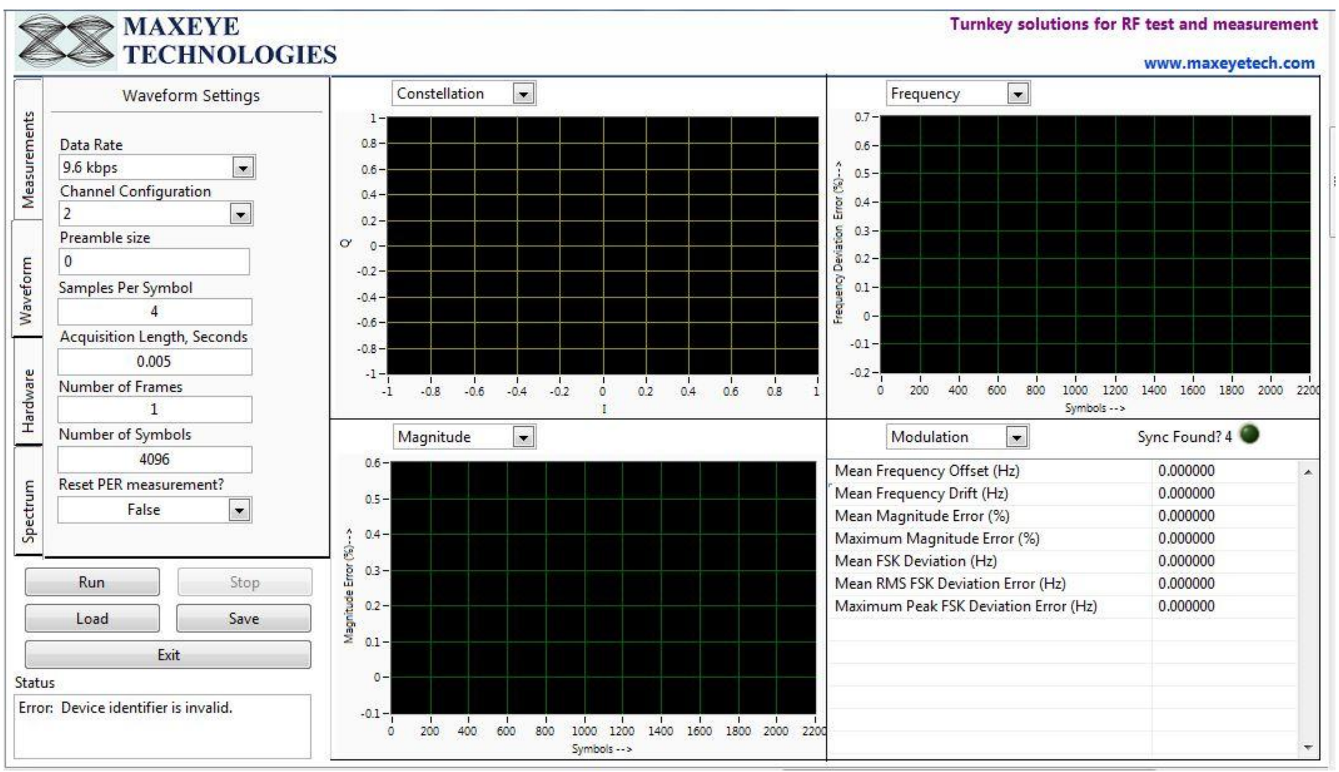
➢ Transmit Power- TXP is a zero span measurement of transmitted power using the time-domain signal as seen through a resolution bandwidth (RBW) filter for the specified measurement interval.

- **Continuous Waveform Measurement-** This measurement is performed on continuous wave signals.

3.2.1 Modulated Waveform Measurement

Follow the procedure for modulation accuracy measurements.

1. Select the Modulated Waveform measurement control from Measurement Tab.
2. Select the Waveform Tab.



Data Rate- Select the data rate as same as transmitted signal.

Channel Configuration- Select the channel configuration as same as transmitted signal.

Preamble size- Select the preamble size as same as transmitted signal.

Samples per Chip- specifies the samples per symbol used to acquire the signal for the measurement.

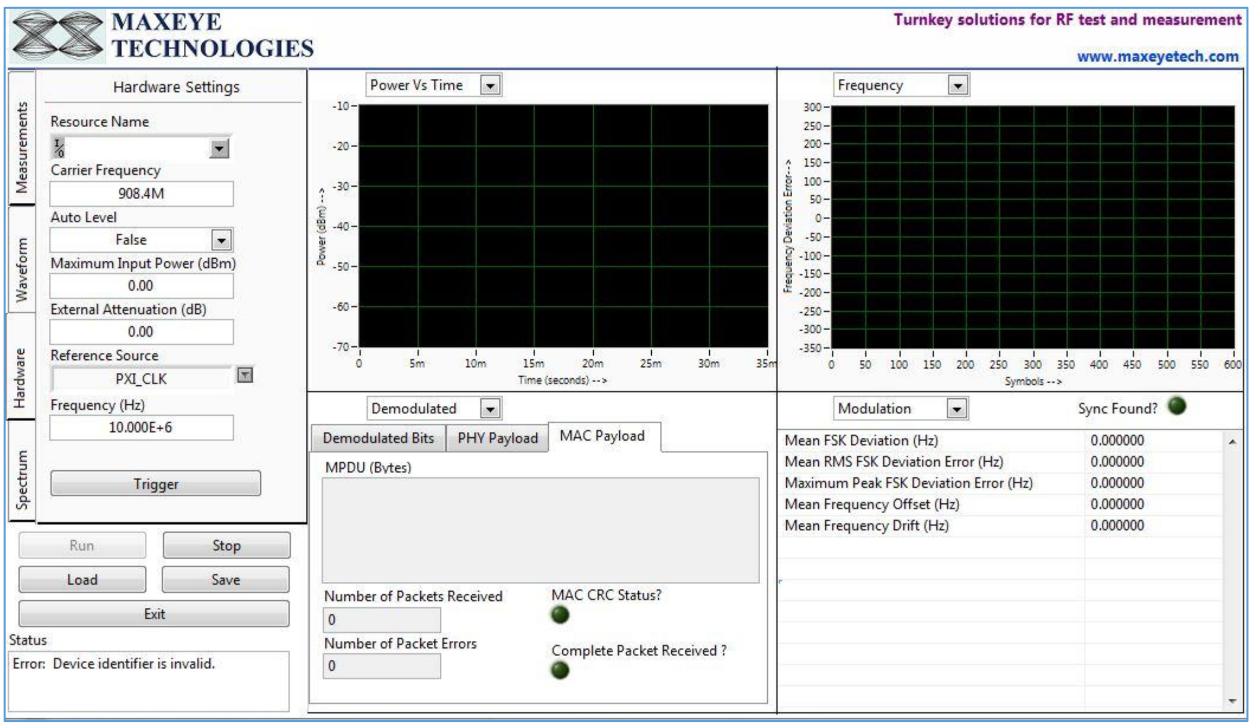
Acquisition Length, Seconds- specifies the waveform acquisition length in seconds. Number of Samples to Acquire= IQ Rate* Acquisition Length

Number of frames- Configure the number of frames to be acquired.

Number of Symbols- Configure the number of symbols to be acquired.

Reset PER measurement- If this property is set to True the toolkit internal resets the Number of Packets Received and Number of Packet Errors to 0. To perform continuous PER measurement set this to False.

3. Select the Hardware Tab



Resource Name- Configure the resource name used in NI Measurement and Automation explorer for the NI PXIe-5673/5673E device or NI PXIe 5644R/45R/46R or NI 5840 device.

Carrier Frequency- Select Center Frequency of the Z-Wave signal in MHz .

Auto Level- examines the input signal to calculate the peak power level and sets it as the value of the Reference Level property.

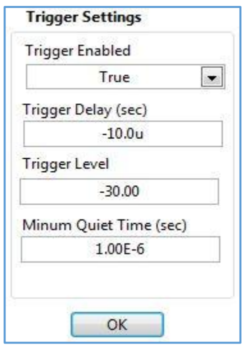
Maximum Input Power- Configures the reference level that represents the maximum expected power of an RF input signal. Configure this field only when Auto level is False.

External Attenuation- specifies the attenuation, in dB, of a switch (or cable) connected to the RF IN connector of the signal analyzer.

Reference Source- specifies the frequency reference source.

Frequency- specifies the Reference Clock rate when the Frequency Reference Source parameter is set to ClKIn or RefIn. This value is expressed in Hz. The default value is 10 MHz.

4. Click Trigger button. Configure the trigger settings as follows.



Trigger Enabled- specifies whether to enable the trigger.

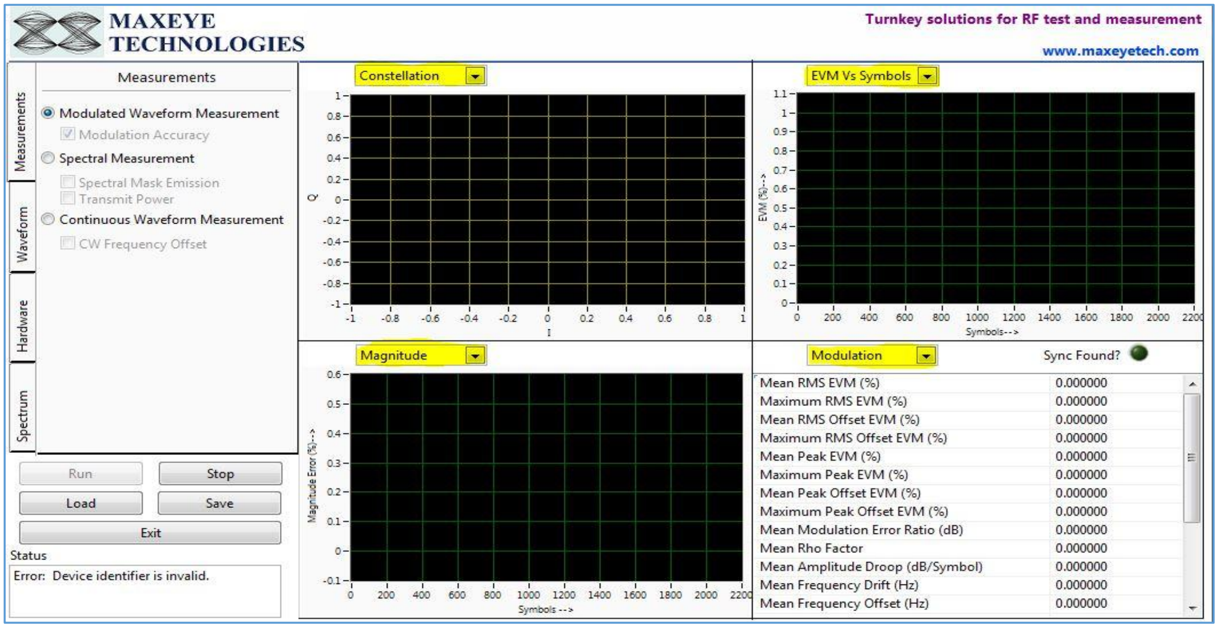
Trigger Delay- Specifies the trigger delay time, in seconds. The trigger delay time is the length of time the IF digitizer waits after it receives the trigger before it asserts the Reference Event.

Trigger Level- Specifies the power level, in dBm, at which the device triggers. The device asserts the trigger when the signal exceeds the level specified by the value of this property, taking into consideration the specified slope.

Minum Quiet Time- Specifies a time duration, in seconds, for which the signal must be quiet before the device arms the IQ Power Edge trigger. The signal is quiet when it is below the trigger level if the trigger slope, specified by the Reference Trigger IQ Power Edge Slope property, is set to Rising Slope or when it is above the trigger level if the trigger slope is set to Falling Slope.

After configuring, click OK.

5. Choose the required graph or results from the highlighted controls.

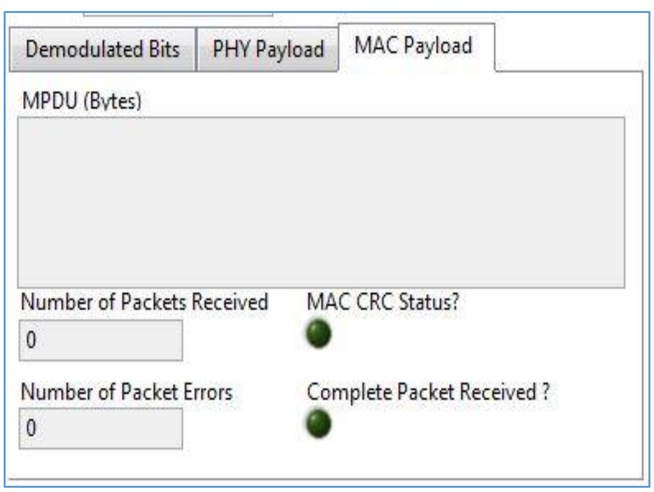


The following are measurement traces available,

- ➢ Constellation
- ➢ Frequency Deviation Error
- ➢ I Vs Time
- ➢ Q Vs Time
- ➢ Power Vs Time

The following are the results available,

- ➢ Demodulated bits



➢ MAC Frame- displays the extracted MAC frame . Choose the required MAC frame by selecting the frame number.

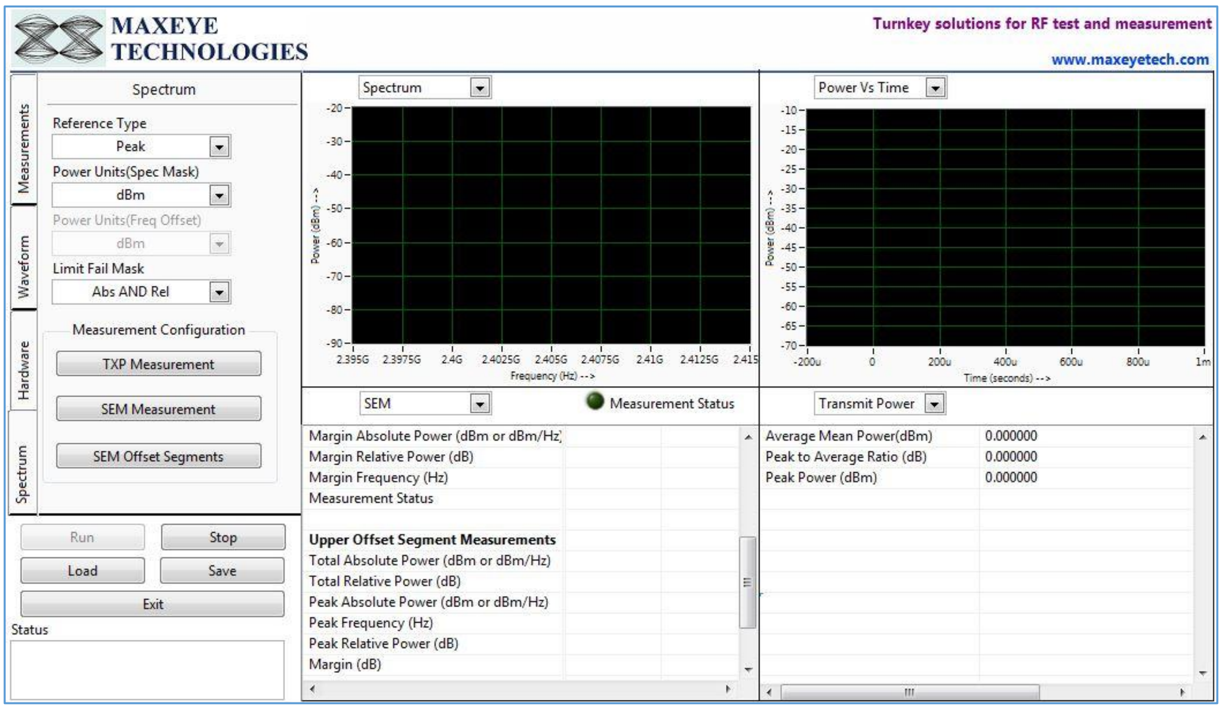
➢ Modulation Accuracy Measurement Results- This include carrier measurements, , IQ Impairments measurements, etc.

6. To pause the measurement Click on the Stop button and to continue the measurement click on the Run button. To save all the configuration, click on the save button. To load the configuration click load button. To exit the SFP click Exit button.

3.2.2 Spectral Measurement

Follow the procedure for Spectral measurements.

1. Select the Spectral measurement control from Measurement Tab. Below that Select the Spectral Mask Emission or Transmit Power or both.
2. Select the Waveform Tab and Choose the modulation Scheme
3. Select the hardware Tab and Refer 3.2.1 to configure.
4. Select Spectrum Tab

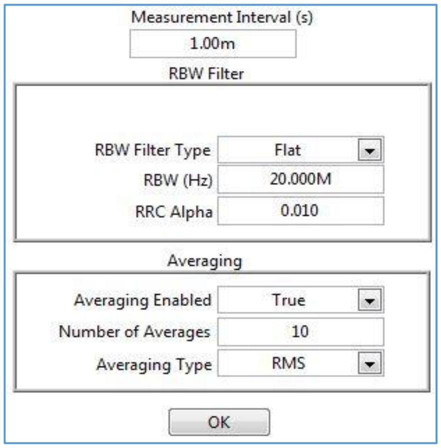


Reference Type- Configures whether the power reference is the integrated power or the peak power in the closest carrier channel. Needs to be configured only foe SEM measurement.

Power Units(Spec Mask)- Configures the units for the absolute power. Needs to be configured only foe SEM measurement.

Limit Fail Mask- Specifies the criteria to determine the measurement fail status.

5. If Transmit Power Measurement is selected, Click on TXP measurement button.



Measurement Interval- Specifies the acquisition time, in seconds, for the transmit power (TXP) measurement.

RBW Auto- specifies whether the measurement computes the resolution bandwidth (RBW) of the carrier.

RBW Filter Type- specifies the response of the digital RBW filter.

RBW- specifies the bandwidth, in Hz, of the resolution bandwidth (RBW) filter used to sweep the acquired carrier signal, when you set the RBW Auto parameter to False.

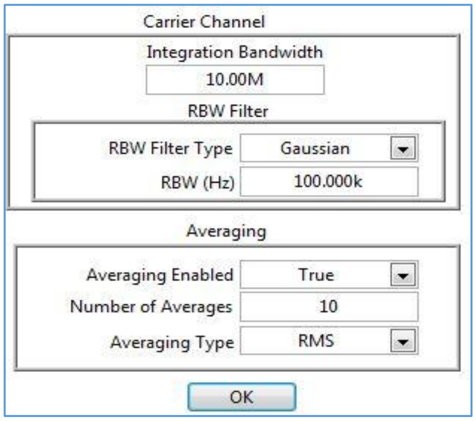
RRC Alpha- specifies the roll-off factor for the root-raised-cosine (RRC) filter.

Averaging Enabled- specifies whether to enable averaging for the measurement. The default value is False**.**

Number of Averages- specifies the number of acquisitions used for averaging when you set the Averaging Enabled parameter to True.

Averaging Type- specifies the averaging type for averaging multiple spectrum acquisitions. The averaged spectrum is used for the measurement.

6. If the measurement Spectral Mask Emission is Selected ,Click on the SEM Measurement button.



Integration Bandwidth- specifies the frequency range, in Hz, over which the measurement integrates the carrier channel power.

RBW Filter Type- specifies the response of the digital RBW filter.

RBW (Hz)- specifies the bandwidth, in Hz, of the resolution bandwidth (RBW) filter used to sweep the acquired carrier signal, when you set the RBW Auto parameter to False.

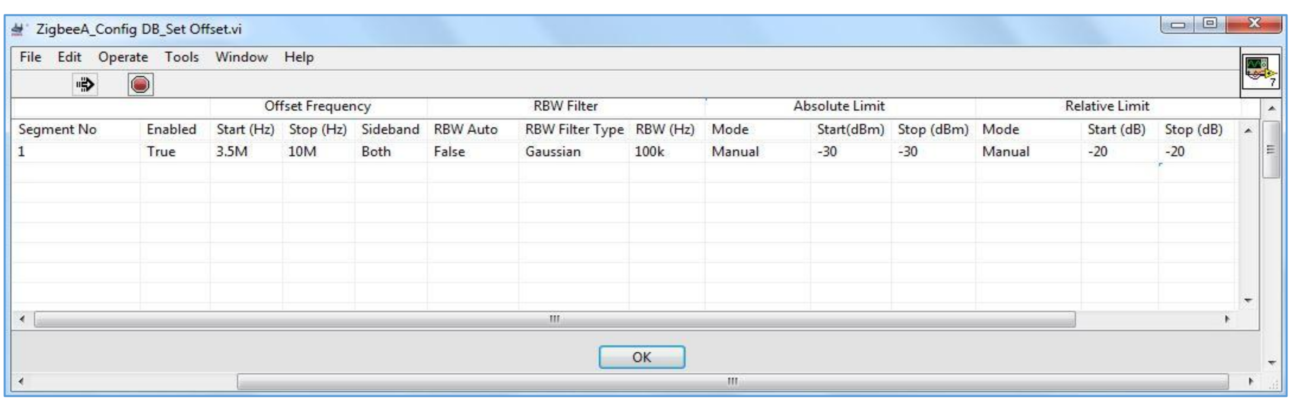
Averaging Enabled- specifies whether to enable averaging for the measurement. The default value is False**.**

Number of Averages- specifies the number of acquisitions used for averaging when you set the Averaging Enabled parameter to True.

Averaging Type- specifies the averaging type for averaging multiple spectrum acquisitions. The averaged spectrum is used for the measurement.

After configuring Click OK.

7. Click on the SEM offset Segments button and configure the SEM offset segment properties in the dialog box. Click OK button after configuring all the settings for the SEM offset segments.



Offset Frequency Enabled- specifies whether to enable the offset segment for the SEM measurement. The default value is True.

Offset Frequency Start- specifies the array of start frequencies, in Hz, of each offset segment relative to the closest configured carrier channel bandwidth center or carrier channel bandwidth edge based on the value of the SEM Offset Freq Definition property.

Offset Frequency Stop- specifies the array of stop frequencies, in Hz, of each offset segment relative to the closest configured carrier channel bandwidth center or carrier channel bandwidth edge based on the value of the SEM Offset Freq Definition property.

Offset Frequency Side band- specifies whether the offset segment is present on one side, or on both sides of the carriers. The default value is Both.

RBW Auto- specifies whether the measurement computes the RBW.

RBW (Hz)- specifies the array of bandwidths, in Hz, of the resolution bandwidth (RBW) filter used to sweep the acquired offset segment, when you set the RBW Auto parameter to False.

Absolute Limit Mode- specifies whether the absolute limit mask is a flat line or a line with a slope

Absolute Limit Start- specifies the array of absolute power limits, in dBm, corresponding to the beginning of the offset segment. The value of this parameter is also set as the stop limit for the offset segment when you set the Absolute Limit Mode parameter to Couple.

Absolute Limit Stop- specifies the array of absolute power limits, in dBm, corresponding to the end of the offset segment. This parameter is ignored when you set the Absolute Limit Mode parameter to Couple

Relative Limit Mode- specifies whether the relative limit mask is a flat line or a line with a slope.

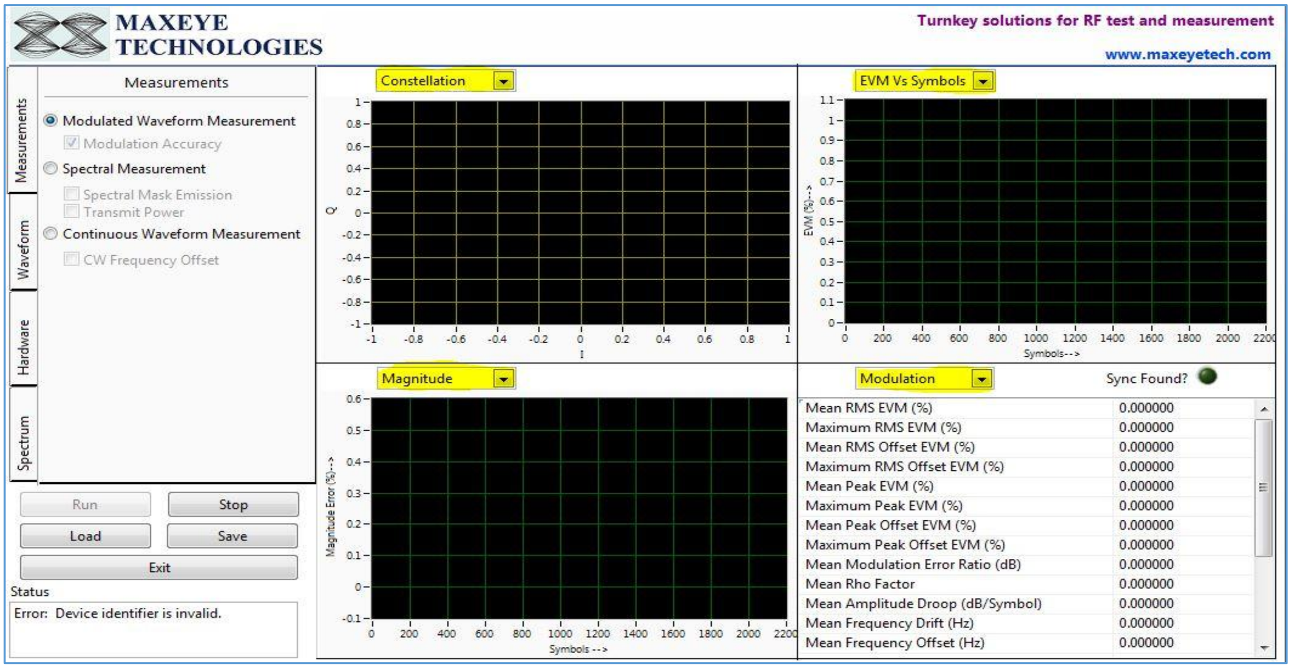
Relative Limit Start- specifies the array of relative power limits, in dB, corresponding to the beginning of the offset segment. The value of this parameter is also set as the stop limit for the offset segment when you set the Relative Limit Mode parameter to Couple

Relative Limit Stop- specifies the array of relative power limits, in dB, corresponding to the end of the offset segment. This parameter is ignored if you set the Relative Limit Mode parameter to Couple.

To add more segments , configure the values column wise. To configure Enabled, sideband, RBW Auto, RBW Filter Type, Mode Click on the appropriate box, then the selection window will display from that user can select. To configure other controls type the required values in each box. After that Click OK.

8. Choose the required graph or results from highlighted Controls shown below. In this SEM measurement the available graph is Spectrum(Power Vs Frequency) and available result is SEM measurement which includes carrier measurement , lower and upper offset segment measurements.

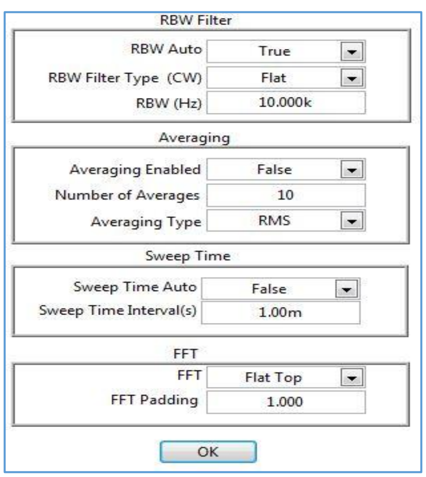
In Transmit Power measurement the available graph is Power Vs Time and available result includes Average Mean Power, Peak to Average Ratio and Peak Power.



9. To pause the measurement Click on to the Stop button and to continue the measurement click on to the Run button. To save all the configuration, click on to the save button. To load the configuration click on to the load button. To exit the SFP click on to the Exit button.

3.2.3 Continuous Waveform Measurement

1. Select Continuous Waveform Measurements from the Measurement Tab.
2. Select the Hardware Tab and Refer 3.2.1 to configure hardware settings.
3. Select Spectrum Tab and configure CW measurement settings by clicking CW measurement button.



RBW Auto- specifies whether the measurement computes the resolution bandwidth (RBW) of the carrier.

RBW Filter Type- specifies the response of the digital RBW filter.

RBW- specifies the bandwidth, in Hz, of the resolution bandwidth (RBW) filter used to sweep the acquired carrier signal, when you set the RBW Auto parameter to False.

Averaging Enabled- specifies whether to enable averaging for the measurement. The default value is False**.**

Number of Averages- specifies the number of acquisitions used for averaging when you set the Averaging Enabled parameter to True.

Averaging Type- specifies the averaging type for averaging multiple spectrum acquisitions. The averaged spectrum is used for the measurement.

Sweep Time Auto- specifies whether the measurement computes the sweep time.

Sweep Time Interval- specifies the sweep time, in seconds, when you set the Sweep Time Auto parameter to False. The default value is 1 ms.

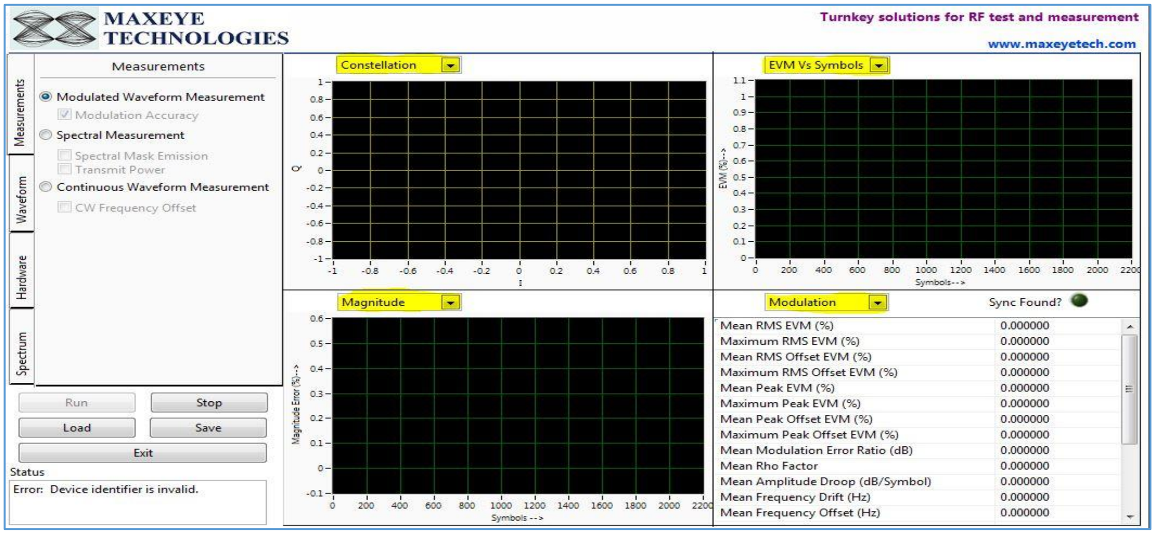
FFT- specifies the FFT window type to use to reduce spectral leakage.

FFT Padding- specifies the factor by which the time-domain waveform is zero-padded before an FFT. The FFT size is given by the following formula: FFT size = waveform size * padding. This parameter is used only when the acquisition span is less than the device instantaneous bandwidth.

After configuration all settings click OK.

4. Choose the required graph or results from highlighted Controls shown below. The following are the graphs available in this measurement.

- Power Vs Frequency
- Frequency Error Vs Time
- The results available are Average Absolute Frequency and Frequency Offset



7. To pause the measurement Click Stop button and to continue the measurement click on Run button. To save all the configuration, click the save button. To load the configuration, click load button. To exit the SFP, click Exit button.

4. Programming Examples

The Z-Wave Signal generation contains examples for performing the following

i. Creating the waveform based on the standard specific user input parameters and then downloads the waveform to NI VSG/NI VST.
ii. Creating the waveform based on the standard specific user input parameters and then writes the waveform to the file.

The Z-Wave Signal analysis contains examples for performing the following

i. Modulation Accuracy Measurement
ii. Spectral Emission Mask Measurement
iii. Transmit Power Measurement
iv. Continuous Waveform Measurement

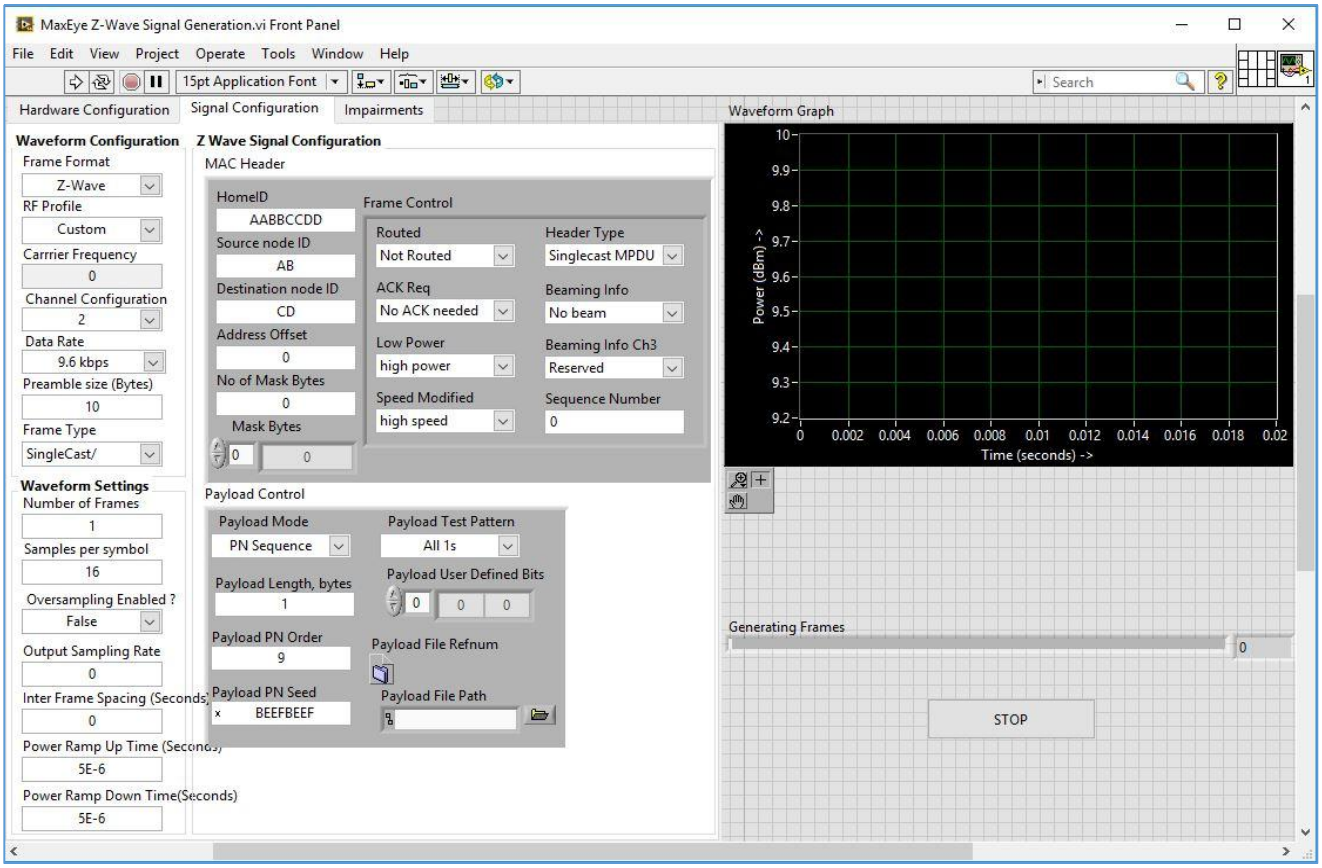
The programming examples are created using the LabVIEW API VIs. For more information about the API VI used in the example VIs refer to the MaxEye Z-Wave Measurement Suite Help.chm document, accessible at Start->All Programs->MaxEye->Z-Wave>Documentation.

4.1. Z-Wave Signal Generation

Z-Wave is an ITU-T G.9959-based specification for a suite of high-level communication protocols used to create personal area networks with small, low-power digital radios, such as for home automation, medical device data collection, and other low-power low-bandwidth needs. The toolkit has examples to demonstrate the functionality of creating Z-Wave waveform, writing the waveform to the NI RFSG memory and then playing the waveform from the memory. According to ITU-T G.9959 standard the frame type is classified into:- Acknowledgement, Singlecast, Multicast frame. So the toolkit has only one examples to generate each frame type..

4.1.1 MaxEye Z-Wave Signal Generation

This Example is used to generate Z-Wave Frame. The figure below shows the front panel of this example VI.

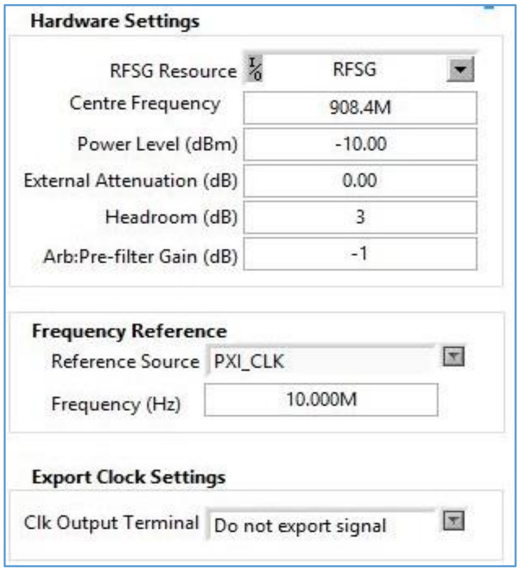


The user configurations are divided into three categories

i. Hardware Settings
ii. Z-Wave Signal Configuration
iii. Impairments

Follow the below procedure to run the example.

1. Select Hardware Configuration Tab and configure the following settings.



RFSG Resource- Configure the resource name used in NI Measurement and Automation explorer for the NI PXIe-5673/5673E or NI PXIe 5644R/45R/46R or NI 5840 device.

Carrier Frequency (Hz)- Select Center Frequency of the Z-Wave signal in MHz. Enter the desired center frequency. This frequency is configured only when the RF Profile is Custom.

Power Level (dBm)- Average Power level of the signal in dBm.

Headroom (dB)- Configure the Headroom value higher than PAPR of the signal to be generated. Refer MaxEye Z-Wave Measurement Suite Help.chm.

External Attenuation (dB)- Specifies the external amplification or attenuation, if any, between the NI RF signal generator and the device under test. Positive values for this property represent amplification, and negative values for this property represent attenuation.

Arb: Pre-filter Gain (dB)- Specifies the AWG prefilter gain. The prefilter gain is applied to the waveform data before any other signal processing. Reduce this value to prevent overflow in the AWG interpolation filters. Other gains on the NI-RFSG device are automatically adjusted to compensate for non unity AWG prefilter gain.

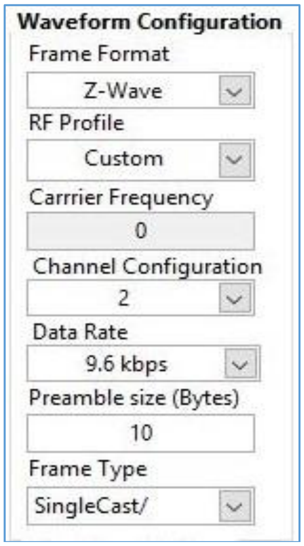
Reference Source- specifies the source of the Reference Clock signal

Frequency (Hz)- specifies the Reference Clock rate, in hertz (Hz).

Clk Output Terminal- specifies the terminal where the signal will be exported.

2. Select Signal Configuration Tab and configure the following settings.

The figure below shows the signal configuration for Z-Wave Signal Generation example.



Frame Format- To generate Z-Wave Frame select Z-Wave Frame. Inorder to generate Micro RF LinkX Frame Select Micro RF LinkX.

RF Profile- Select the approriate RF Profile. If custom is selected, the carrier frequency entered at hardware settings is chosen. Otherwise the corresponding regional frequency is automatically selected.

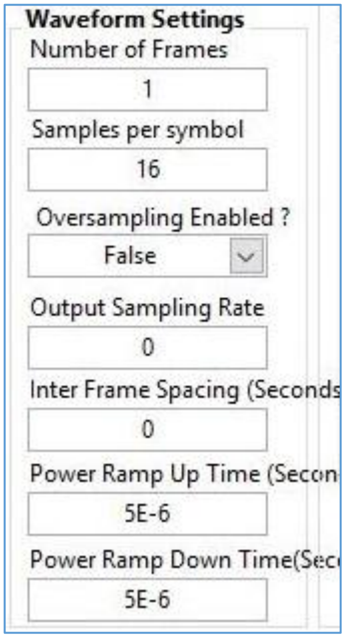
Carrier Frequency- Select the approriate RF Profile. If custom is selected, the carrier frequency entered at hardware settings is chosen. Otherwise the corresponding regional frequency is automatically selected.

Channel Configuration- Select the approriate RF Profile. If custom is selected, the carrier frequency entered at hardware settings is chosen. Otherwise the corresponding regional frequency is automatically selected.

Data Rate - Select the approriate RF Profile. If custom is selected, the carrier frequency entered at hardware settings is chosen. Otherwise the corresponding regional frequency is automatically selected.

Preamble size (Bytes) - Select the approriate RF Profile. If custom is selected, the carrier frequency entered at hardware settings is chosen. Otherwise the corresponding regional frequency is automatically selected.

Frame Type- Select the approriate RF Profile. If custom is selected, the carrier frequency entered at hardware settings is chosen. Otherwise the corresponding regional frequency is automatically selected.



Number of Frames- decides the length of waveform to be generated. To generate longer duration of the waveform, increase the Number of Frames value.

Inter frame Spacing (Seconds)- specifies the gap duration in seconds between the frames.

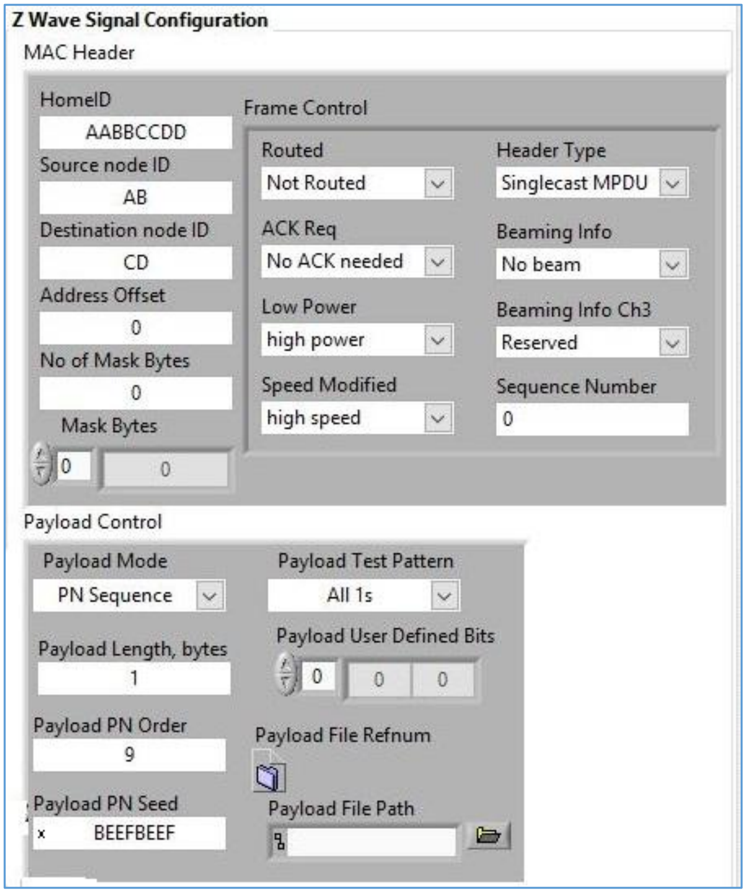
Samples Per Symbol- Specifies the number of samples per chip. Sampling Rate of generated waveform is equal to samples per chip multiplied by Sample Rate.

Oversampling Enabled & Output Sampling Rate- Use this configuration only when you want to resample the signal to different sampling rate. The default sampling rate is Samples per chip multiplied by Chip Rate. The toolkit resample's the generated signal to a sampling rate equal to the Output Sampling Rate only if the Over Sampling Enabled property is set to 1(True).

The Power Ramp Up Time- specifies the time duration during which the signal power gradually increases to the full value from zero.

The Power Down Time- specifies the time duration during which the signal power gradually reduces from the full value to close to zero.

The frame control fields can be configured as follows



HomeID - The HomeID identifier field is 4 bytes in length and specifies the unique domain identifier. All nodes in a domain shall have the same HomeID.

Source NodeID - The source NodeID is 8 bits in length and shall be a unique identifier of a node in a given domain. Together with the HomeID, the source NodeID identifies the node that originated the frame.

Destination NodeID - The destination NodeID shall specify a destination node in the same domain identified by the HomeID. The destination NodeID value 0xFF may be used for broadcasting an MPDU to all nodes within direct range.

Address Offset- The address offset field is a 3-bit field.

No of Mask Bytes- a sending node shall set the Address Offset field to zero and the number of mask bytes field shall be set to 29.

Mask Bytes- Each bit of a mask byte represents a node. Mask byte 0 represents the NodeIDs 1 to 8.

Routed- The Routed subfield is 1 bit in length and shall be set to 0 when the frame is not routed and set to 1 when the frame is routed.

Ack Req- The ACK Req subfield is 1 bit in length and set to 1 when the source node wants the destination node to acknowledge the frame, and the bit is set to 0 when no ACK is needed. A receiving node shall return an ACK MPDU in response to the ACK request.

Low Power- The Low Power subfield is 1 bit in length and is set by the source node. The bit informs a destination node that the actual transmission was using low power. A receiving node shall return an ACK MPDU in low power in response to the low power bit.

Speed Modified- The Speed modified subfield is 1 bit in length. It shall be set to 1 if an MPDU is sent at a lower speed than supported by the source and destination. The field shall not be used for routed and multicast MPDUs. The field shall be set to 0 if the MPDU is sent at the highest speed supported by the source and destination.

Header Type- The header type subfield defines the frame header type. A broadcast MPDU is a singlecast MPDU (header type 0x1) carrying a destination NodeID = 0xFF.

Beaming Info- The Beaming Information subfield shall advertise the capability of a sending FL node to be awakened by a beam if it is asleep. The Beaming Information subfield shall be interpreted in combination with the actual channel configuration.

Beaming Info Ch3- specifies the address of the originator of the frame. This field shall be included in the MAC frame only if the Source Addressing Mode field is nonzero.

Sequence Number- The Sequence Number is a 4-bit sub-field of the frame control field for channel configuration 1&2 and is an 8-bit field of the MPDU Header (MHR) for channel configuration 3. The MAC layer of a transmitting node shall forward the sequence number value transparently to the PHY. The MAC layer shall use the same sequence number for the initial transmission and for all retransmissions of a given MPDU. For channel configuration 1&2 the transmitted sequence number shall be in the range 0x1...0xf.The value 0xf shall be followed by the value 0x1. For Channel Configuration 3 the transmitted sequence number shall be in the range 0x00…0xff. The value 0xff shall be followed by the value 0x00.

MaxEye Z-Wave Measurement Suite Toolkit allows you to configure various payload settings. The possible payload options are

i. **PN Sequence-** In this mode configure Sync Insertion Enabled, Payload PN order and PN Seed properties and the toolkit ignores other properties in the Z-Wave Payload Control. The toolkit generates pseudo random sequence based on the PN order and seed value, the generated bit sequence is used as a payload for generating the signal. Use this mode for testing the receiver performance for random payload values.

ii. **User defined bits-** In this mode configure Sync Insertion Enabled and Payload User Defined Bits property and the toolkit ignores other properties in the Z-Wave Payload Control.

iii. **Test Pattern-** In this mode configure Sync Insertion Enabled and Payload Test Pattern property and the toolkit ignores other properties in the Z-Wave Payload Control. The possible values for the Test Pattern are All 1s, All 0s, 10101010 and 01010101.
This mode is used for generating signal with known test patterns.

iv. **Test File-** In this mode configure the Sync Insertion Enabled and Payload File Path property and the toolkit ignores other properties in the Z-Wave Payload Control. This mode is used for generating signal with the data from the file.

The payload settings can be configured as follows.

Payload Mode : Choose the appropriate mode. PN sequence is used to generate the PN sequence. In the User defined bits, user can configure the transmitting bits. In Test Pattern, some predefined bit patterns can be used for transmitting.

Payload Length ,Bytes- Specifies the number of bytes to be transmitted

Payload PN Order- specifies the order of the PN bit sequence to be generated. The valid values is 5 to 31, inclusive. Configure this field when the Payload mode is PN sequence.

Payload PN Seed- specifies the initial state of the PN generator shift register. Configure this field when the Payload mode is PN Sequence

Payload Test Pattern- Select the required Test Pattern. Configure this field when the Payload mode is Test Pattern

Payload User Defined Bits- Configure this field when Payload mode is User Defined bits.

Payload File Path- Choose the file path when the payload mode is From File.

The impairments can be configured as follows.

Impairments Enabled- If this property is set to True then the toolkit adds the impairments to the generated signal as per the user configuration for the supported impairments.

Clock Offset (PPM)- The toolkit applies the clock offset to the generated waveform based on this value. The applied clock offset is relative to the clock frequency of the signal generator.

Frequency Offset, Hz- The toolkit applies frequency offset to the created waveform based on the value configured in this property. The applied frequency offset is relative to the signal generator's carrier frequency.

Quadrature skew- Quadrature Skew specifies the deviation in angle from 90 degrees between the in-phase (I) and quadrature-phase (Q) signals.

IQ gain imbalance, dB- This value specifies the ratio, in dB, of the mean amplitude of the in-phase (I) signal to the mean amplitude of the quadrature-phase (Q) signal..

I DC offset, %- The toolkit adds the DC offset to the in-phase signal component (I) of the complex waveform as a percentage of the root mean square magnitude of the unaltered I signal.

Q DC Offset, %- The toolkit adds the DC offset to the quadrature-phase signal component (Q) of the complex waveform as a percentage of the root mean square magnitude of the unaltered Q signal.

AWGN Enabled- If this property is set to True then the toolkit adds Additive White Gaussian Noise (AWGN) to the created waveform based on the value configured in the Carrier to Noise Ratio property.

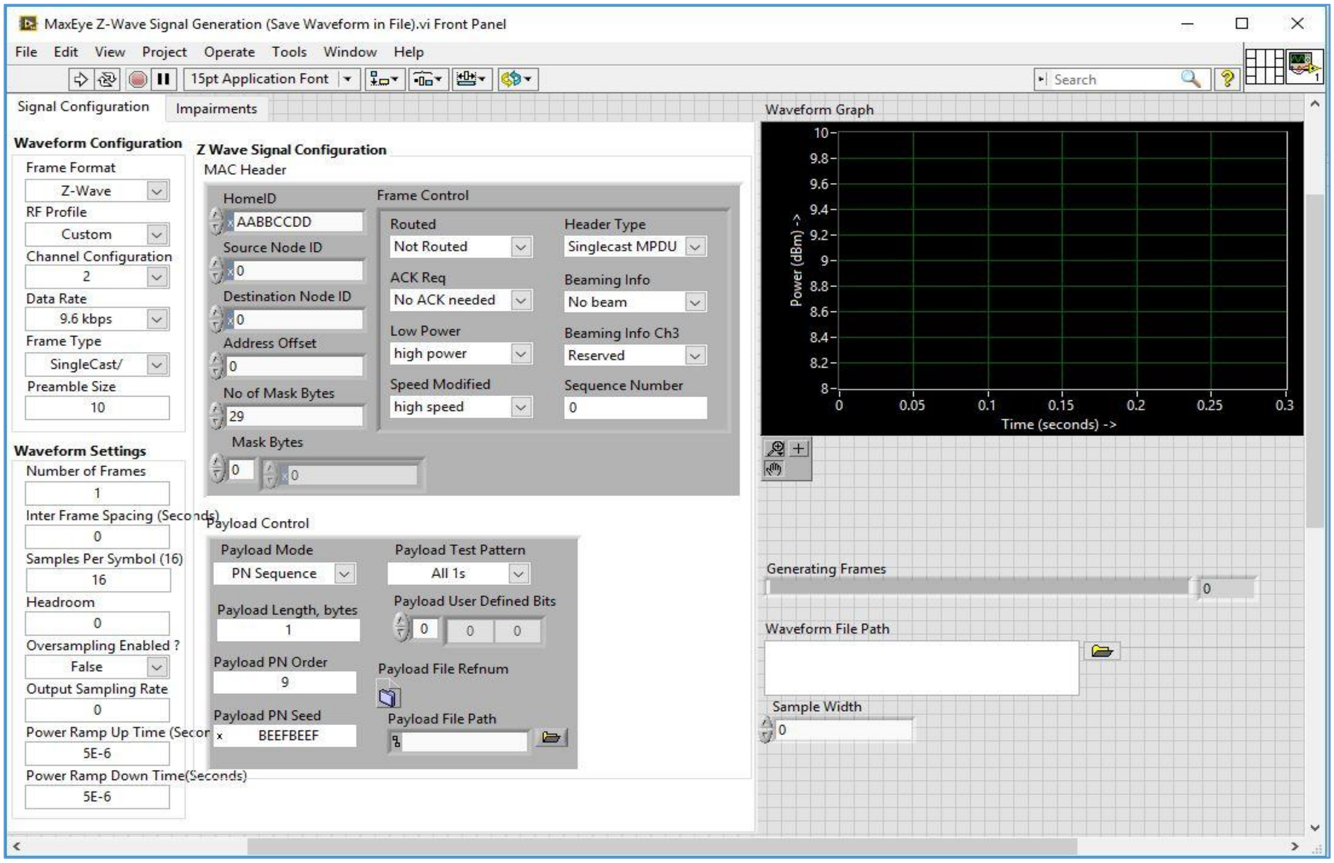
Carrier to Noise Ratio, dB- This value specifies the Carrier to Noise ratio of the generated signal.

4.1.2 MaxEye Z-Wave Signal Generation (Save Waveform in file)

This Example is used to generate multiple Z-Wave Data transmission frames and the generated waveform is stored in a file for play back. Use this example

- To generate and store the custom waveforms based on your test requirement.
- To avoid generating the waveform at the beginning of your test every time. This reduces your test starting time as some of the signal configuration will take longer to generate the waveform.
- For generating the longer duration waveform as the RFSG memory size is limited.
- For testing your receiver for continuous signal reception.
- For receiver sensitivity measurement (BER) for longer duration.

The figure below shows the front panel.



The toolkit configurations are same as specified in section 4.1.1.1. This example is used to store data frame waveform.

This example requires the following additional input parameters.

1. **Waveform File Path-** The toolkit writes the generated waveform in a file specified by this file path control.
   If the Output Waveform File Path for the combined waveform containing multiple carriers is not specified then a file dialog box opens prompting the user to enter the file name.
2. **Oversampling Enabled-** set this property value to TRUE if re sampling is required.
3. **Output Sampling Rate (Hz)-** Configure this control to a suitable value if Oversampling Enabled property is set to TRUE.
4. **Output Sample Width-** The default sample width of the output waveform is 8-bits. The available options are 8-bits and 16-bits. We recommend 16-bits sample width for better signal quality of the generated waveform.

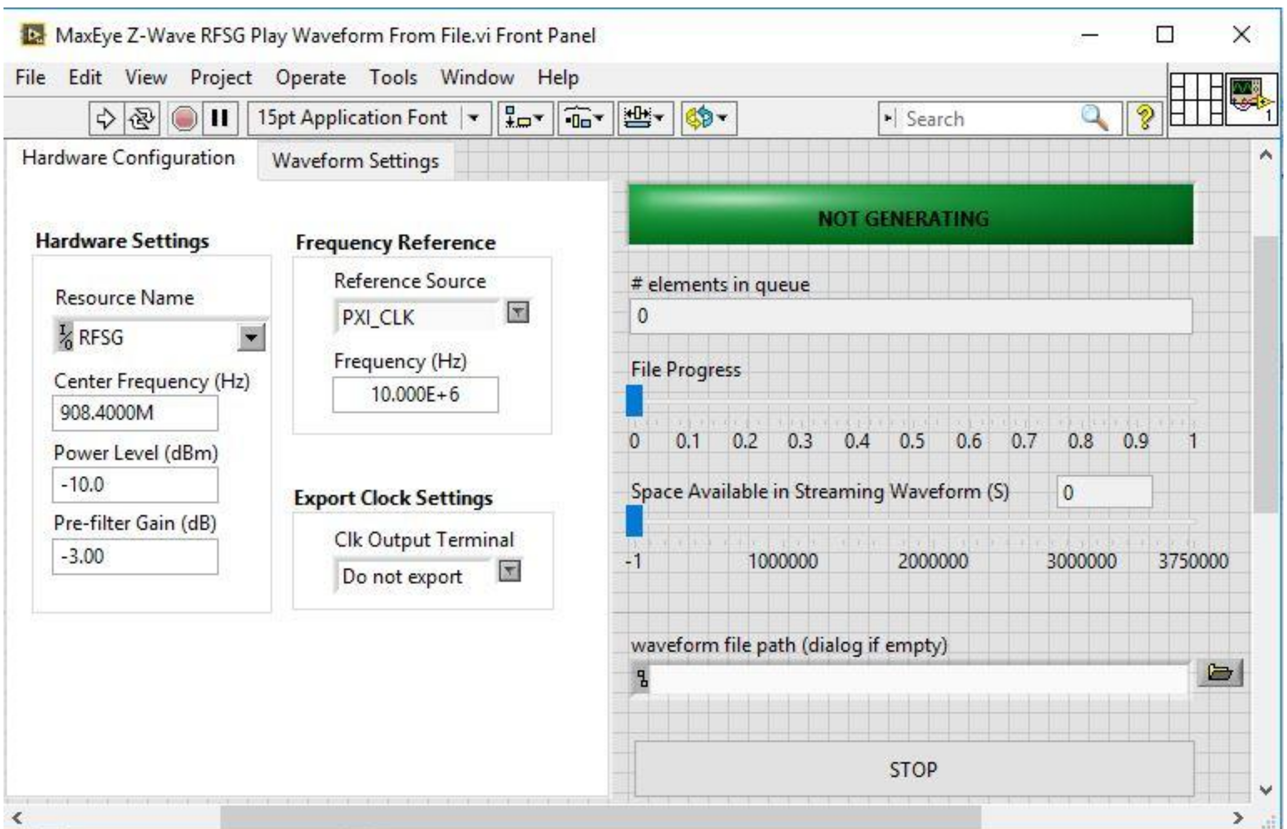
4.1.3 MaxEye Z-Wave RFSG Play Waveform From File

This example reads the Z-Wave waveform from the file created using the previous example in section 4.1.1.5 and then downloads the waveform in real-time to NI RFSG Memory and then plays the waveform. This example is created using the NI RFSG streaming example available in the NI website.

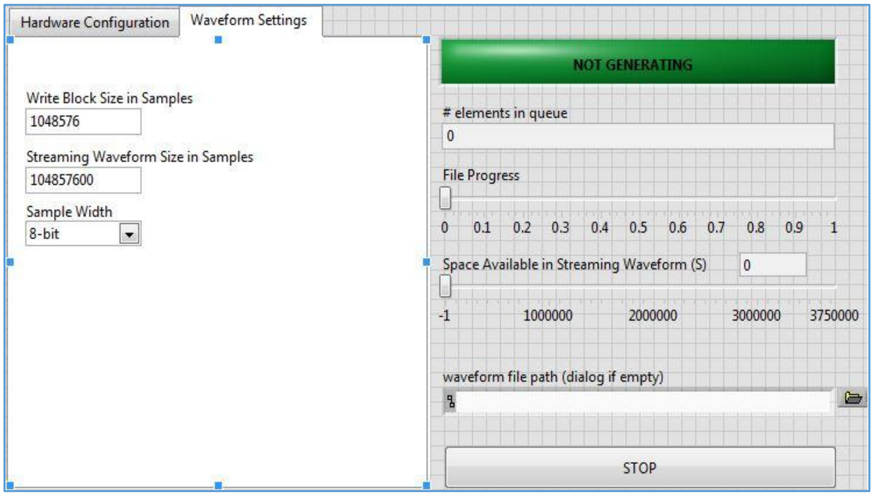
This example uses NI RFSG in streaming mode for playing the waveform in real-time. The performance of this example is related to the performance of your CPU and available RAM memory.

The figure below shows the front panel of the Example VI. For more information about NI RFSG streaming refer to the web link below.

http://zone.ni.com/reference/en-XX/help/371025K-01/rfsg/streaming/



This example requires the following additional input parameters.

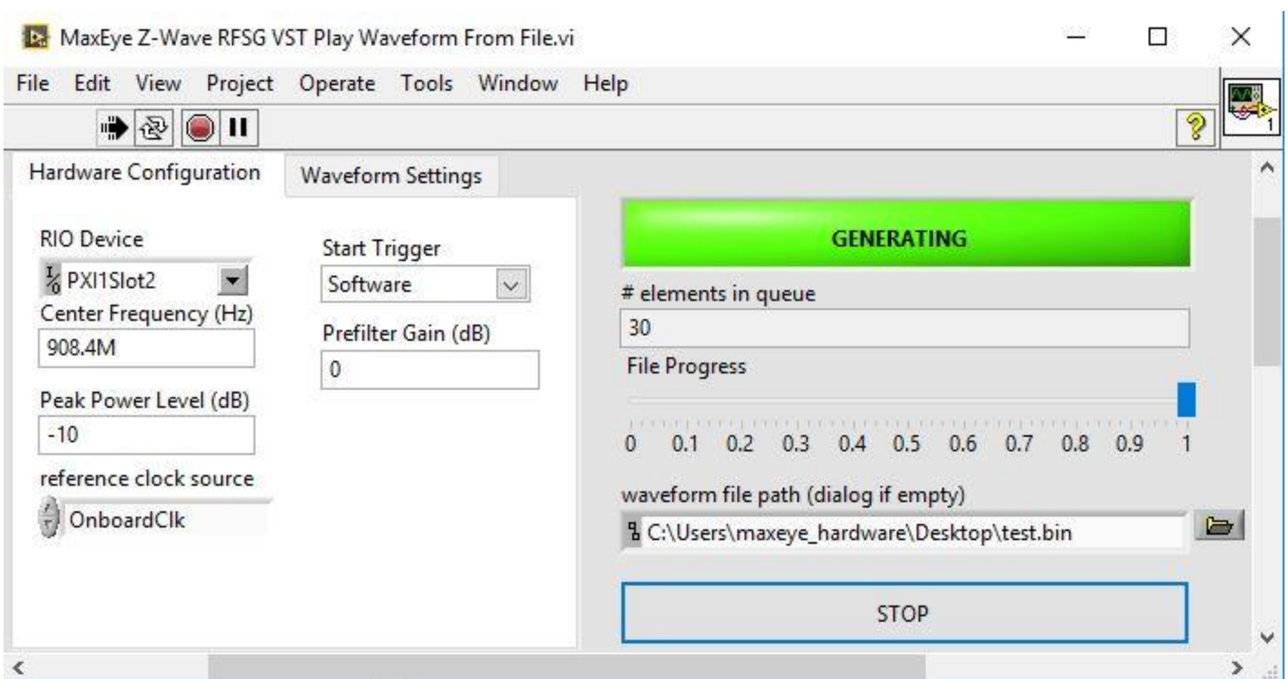


Streaming Waveform Size in Samples- specifies the total number of samples used to write the waveform to NI RFSG device or output DMA Stream.

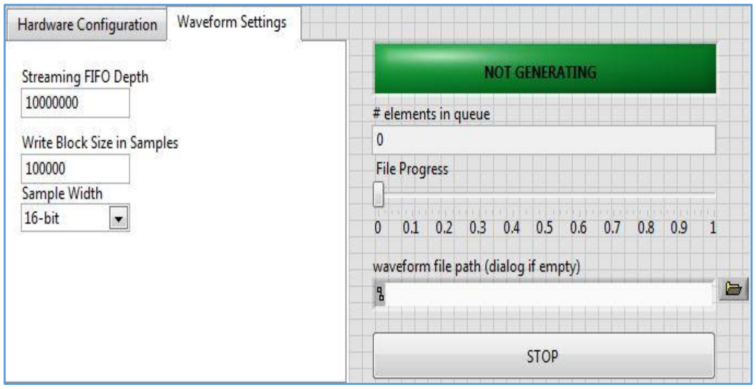
Sample Width- use the same sample width value used for storing the waveform in the file.

4.1.4 MaxEye Z-Wave RFSG VST Play Waveform From File

This example reads the Z-Wave waveform from the file created using the previous example in section 4.1.1.5 using VST. This example deploy the bit file dynamically to the respective target(FPGA) and configures a stream from the Host to the FPGA target and writes waveform data to the streaming DMA FIFO.



This example requires the following additional input parameters.



Streaming Waveform Size in Samples- specifies the total number of samples used to write the waveform to output DMA Stream.

Sample Width- use the same sample width value used for storing the waveform in the file.

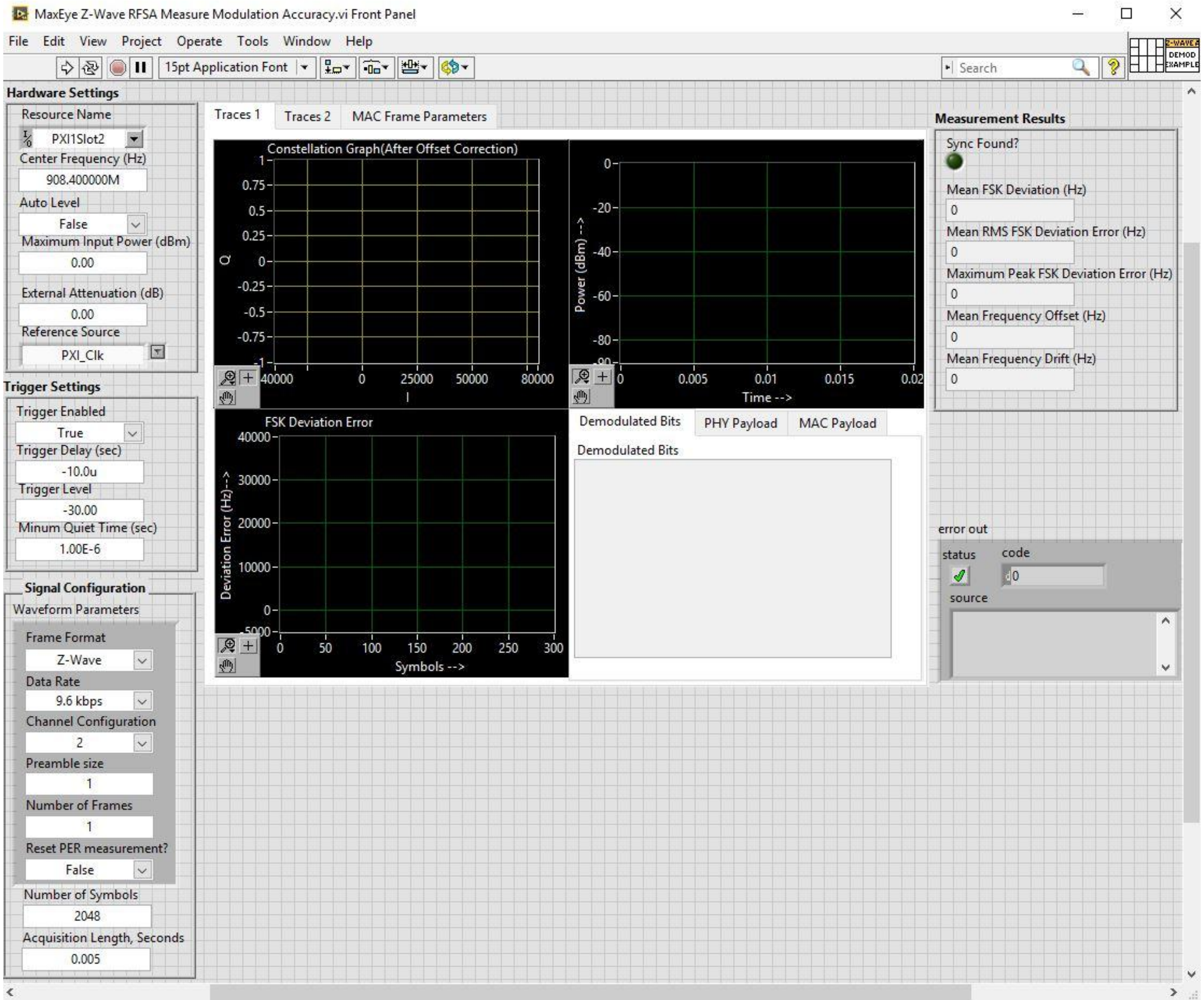
4.2 Z-Wave Signal Analysis

4.2.1 MaxEye Z-Wave RFSA Measure Modulation Accuracy

This example VI is to find out various carrier measurements, EVM measurements, magnitude and phase error measurements, impairments measurement, etc. The user Configurations are divided into three

i. Hardware Settings
ii. Trigger Settings
iii. Signal Configuration

1. Hardware Settings can be configured as follows.



Resource Name- Configure the resource name used in NI Measurement and Automation explorer for the NI PXIe-5673/5673E device or NI PXIe 5644R/45R/46R or NI 5840 device..

Auto Level- examines the input signal to calculate the peak power level and sets it as the value of the Reference Level property.

Maximum Input Power- Configures the reference level that represents the maximum expected power of an RF input signal. Configure this field only when Auto level is False.

External Attenuation- specifies the attenuation, in dB, of a switch (or cable) connected to the RF IN connector of the signal analyzer.

Reference Source- specifies the frequency reference source.

Frequency- specifies the Reference Clock rate when the Frequency Reference Source parameter is set to ClKIn or RefIn. This value is expressed in Hz.

2. Trigger Settings can be configured as follows.

Trigger Enabled- specifies whether to enable the trigger.

Trigger Delay- Specifies the trigger delay time, in seconds. The trigger delay time is the length of time the IF digitizer waits after it receives the trigger before it asserts the Reference Event.

Trigger Level- Specifies the power level, in dBm, at which the device triggers. The device asserts the trigger when the signal exceeds the level specified by the value of this property, taking into consideration the specified slope.

Minum Quiet Time- Specifies a time duration, in seconds, for which the signal must be quiet before the device arms the IQ Power Edge trigger. The signal is quiet when it is below the trigger level if the trigger slope, specified by the Reference Trigger IQ Power Edge Slope property, is set to Rising Slope or when it is above the trigger level if the trigger slope is set to Falling Slope.

3. Signal Configuration can be configured as follows.

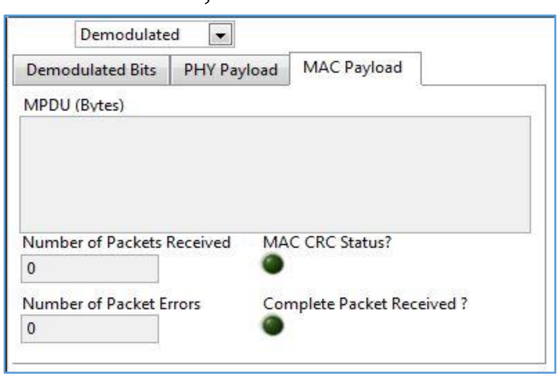
Acquisition Length, Seconds- Needs to be configured for OQPSK modulation. Number of Samples to Acquire= IQ Rate* Acquisition Length

Number of frames- Configure the number of frames to be acquired.

Number of Symbols- Configure the number of symbols to be acquired.

Reset PER measurement- If this property is set to True the toolkit internal resets the Number of Packets Received and Number of Packet Errors to 0. To measure PER measurement continuously set this property to True only in the first iteration.

4. In Measurement Traces, Traces1 Include Constellation Graph, Power Vs Time, Frequency Deviation Error, Demodulated Bits.



To see the transmitted payload , select the MAC Payload which is in hexadecimal format.

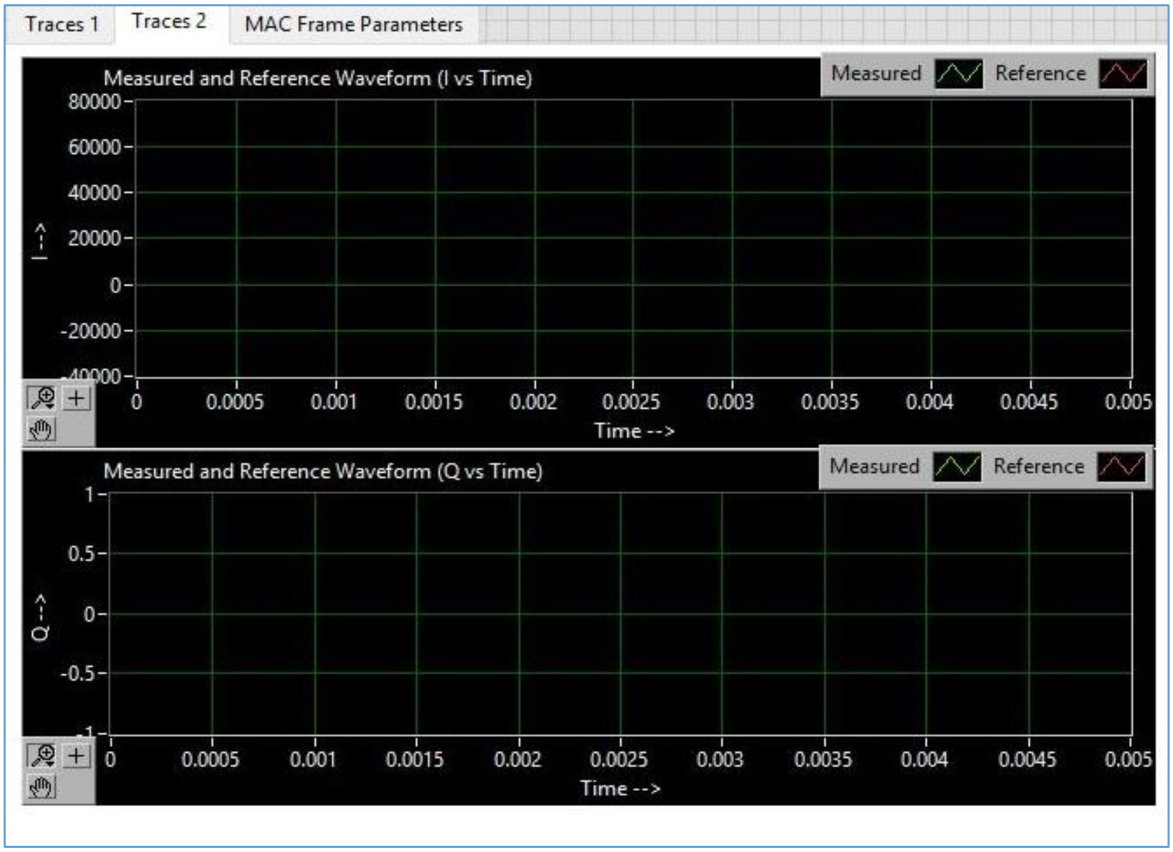
Number of Packets Received- This shows the total number of Packets received

MAC CRC Status- this will turn ON when CRC check failed.

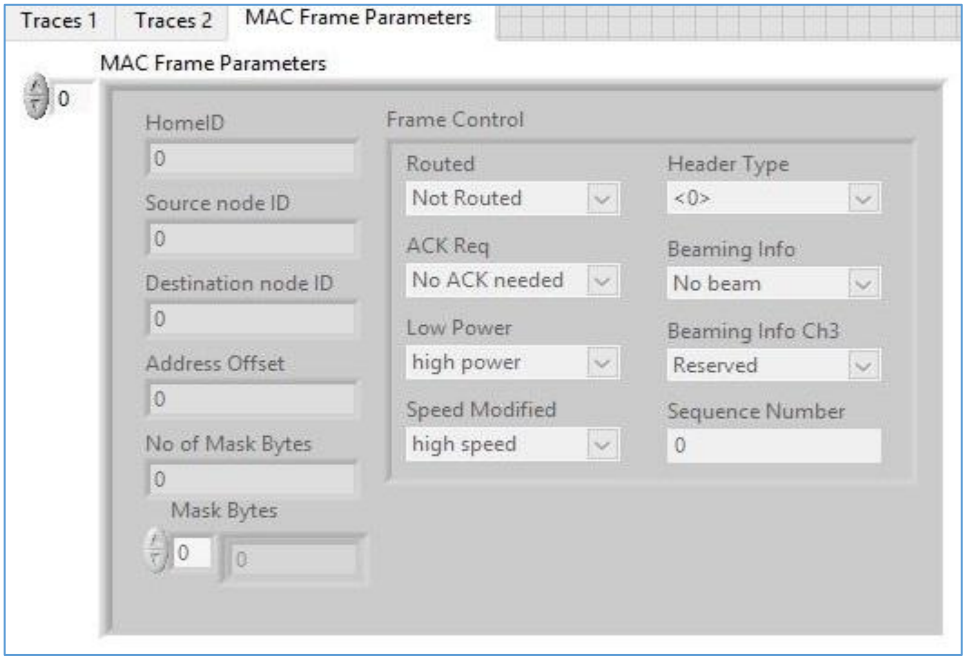
Number of Packet Errors- It will display the total number of error packets

Complete Packet Received- his will turn on if packet reception is completed.

5. Traces 2 include I Vs Time, Q Vs Time and Eye Diagram



6. MAC Frame Parameters include the MAC frame. This extract the transmitted MAC frame and displays the MAC frame Parameters to the user. Array index refers to the frame number.



Measurement Results displays various carrier measurements, EVM measurements, magnitude and phase error measurements, impairments measurement, etc.

4.2.2 MaxEye Z-Wave RFSA Measure Spectral Emission Mask

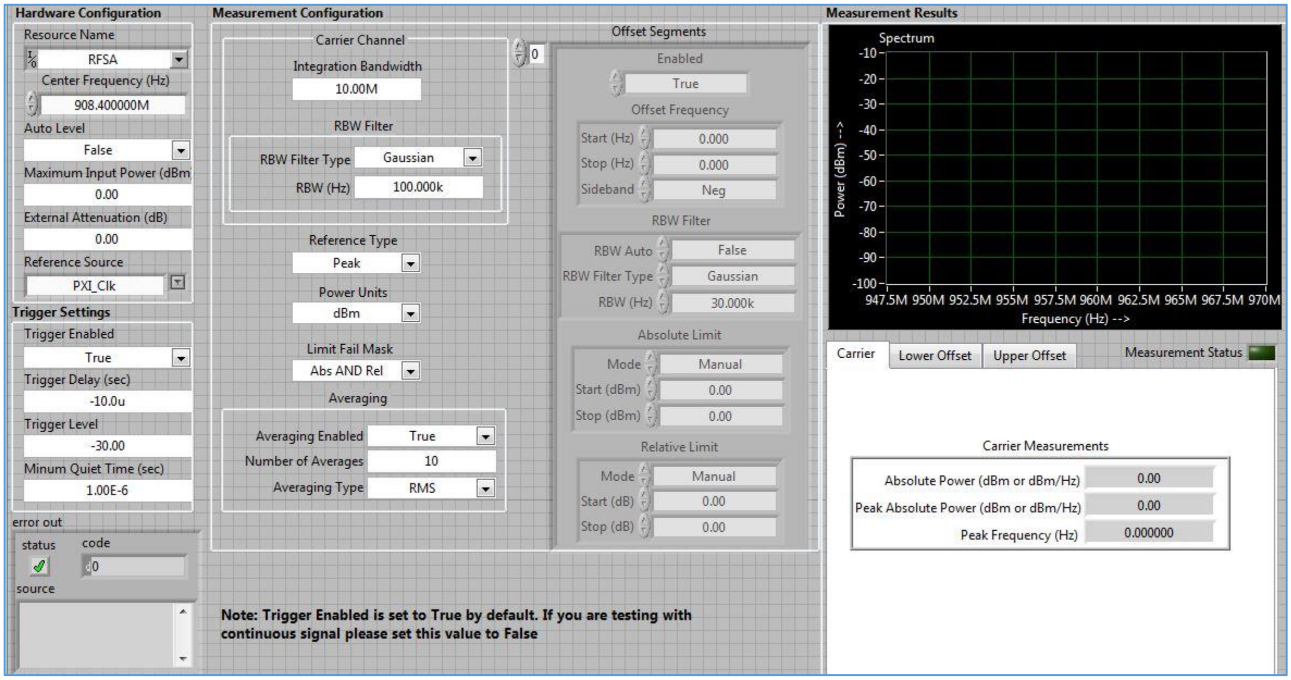
In this example SEM measurement which includes carrier measurement , lower and upper offset segment measurements are calculated.

The user configuration can be divide into three parts

i. Hardware settings
ii. Trigger Settings
iii. Measurement Configuration

1. Refer 4.2.1.1 for Hardware Settings and Trigger Settings.

2. Measurement Configuration can be configured as follows.



Integration Bandwidth- specifies the frequency range, in Hz, over which the measurement integrates the carrier channel power

RBW Filter Type- specifies the response of the digital RBW filter.

RBW (Hz)- specifies the bandwidth, in Hz, of the resolution bandwidth (RBW) filter used to sweep the acquired carrier signal, when you set the RBW Auto parameter to False.

Reference Type- Configures whether the power reference is the integrated power or the peak power in the closest carrier channel. Needs to be configured only foe SEM measurement.

Power Units(Spec Mask)- Configures the units for the absolute power. Needs to be configured only foe SEM measurement.

Limit Fail Mask- Specifies the criteria to determine the measurement fail status.

Averaging Enabled- specifies whether to enable averaging for the measurement. The default value is False**.**

Number of Averages- specifies the number of acquisitions used for averaging when you set the Averaging Enabled parameter to True.

Averaging Type- specifies the averaging type for averaging multiple spectrum acquisitions. The averaged spectrum is used for the measurement

3. Offsets Segments can be configured as follows.

Offset Frequency Enabled- specifies whether to enable the offset segment for the SEM measurement. The default value is True.

Offset Frequency Start- specifies the array of start frequencies, in Hz, of each offset segment relative to the closest configured carrier channel bandwidth center or carrier channel bandwidth edge based on the value of the SEM Offset Freq Definition property.

Offset Frequency Stop- specifies the array of stop frequencies, in Hz, of each offset segment relative to the closest configured carrier channel bandwidth center or carrier channel bandwidth edge based on the value of the SEM Offset Freq Definition property.

Offset Frequency Side band- specifies whether the offset segment is present on one side, or on both sides of the carriers. The default value is Both.

RBW Auto - specifies whether the measurement computes the RBW.

RBW (Hz)- specifies the array of bandwidths, in Hz, of the resolution bandwidth (RBW) filter used to sweep the acquired offset segment, when you set the RBW Auto parameter to False.

Absolute Limit Mode- specifies whether the absolute limit mask is a flat line or a line with a slope

Absolute Limit Start- specifies the array of absolute power limits, in dBm, corresponding to the beginning of the offset segment. The value of this parameter is also set as the stop limit for the offset segment when you set the Absolute Limit Mode parameter to Couple.

Absolute Limit Stop- specifies the array of absolute power limits, in dBm, corresponding to the end of the offset segment. This parameter is ignored when you set the Absolute Limit Mode parameter to Couple

Relative Limit Mode- specifies whether the relative limit mask is a flat line or a line with a slope.

Relative Limit Start- specifies the array of relative power limits, in dB, corresponding to the beginning of the offset segment. The value of this parameter is also set as the stop limit for the offset segment when you set the Relative Limit Mode parameter to Couple.

Relative Limit Stop- specifies the array of relative power limits, in dB, corresponding to the end of the offset segment. This parameter is ignored if you set the Relative Limit Mode parameter to Couple.

4. The measurement results include Carrier Measurements, Lower and Upper Offset Segment Measurements. The available graph is Power Vs frequency.

4.2.3 MaxEye Z-Wave RFSA Measure Transmit Power

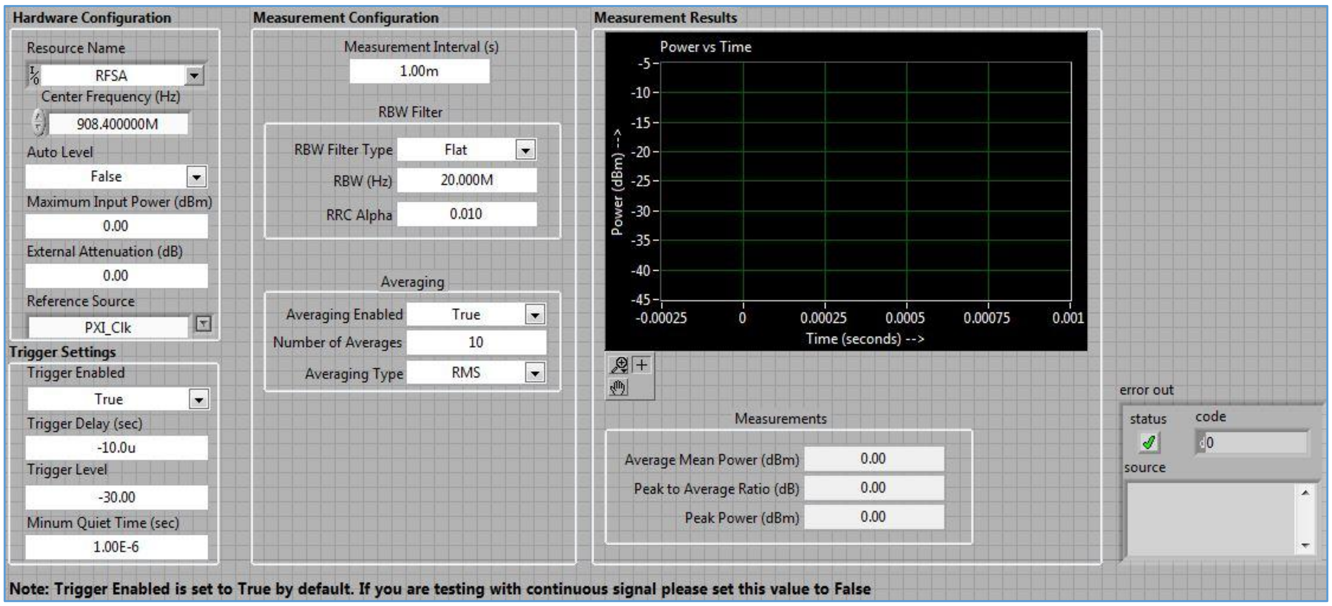
Transmit Power is a zero span measurement of transmitted power using the time-domain signal as seen through a resolution bandwidth (RBW) filter for the specified measurement interval.

This example is used to find out Average Mean Power, Peak to Average Ratio and Peak Power of the transmitted signal. The user configurations are divided into three.

i. Hardware Settings
ii. Trigger Settings
iii. Measurement Configuration

1. Refer 4.2.1.1 for Hardware Settings and Trigger Settings.

2. Measurement Configuration can be configured as follows.



Measurement Interval- Specifies the acquisition time, in seconds, for the transmit power (TXP) measurement. Needs to be configured only for Transmit Power Measurements

RBW Filter Type- specifies the response of the digital RBW filter.

RBW- specifies the bandwidth, in Hz, of the resolution bandwidth (RBW) filter used to sweep the acquired carrier signal, when you set the RBW Auto parameter to False.

RRC Alpha- specifies the roll-off factor for the root-raised-cosine (RRC) filter.

Averaging Enabled- specifies whether to enable averaging for the measurement. The default value is False**.**

Number of Averages- specifies the number of acquisitions used for averaging when you set the Averaging Enabled parameter to True.

Averaging Type- specifies the averaging type for averaging multiple spectrum acquisitions. The averaged spectrum is used for the measurement.

3. The measurement Results consists of Average Mean Power, Peak to Average Ratio, Peak Power. The available graph is Power Vs Time.

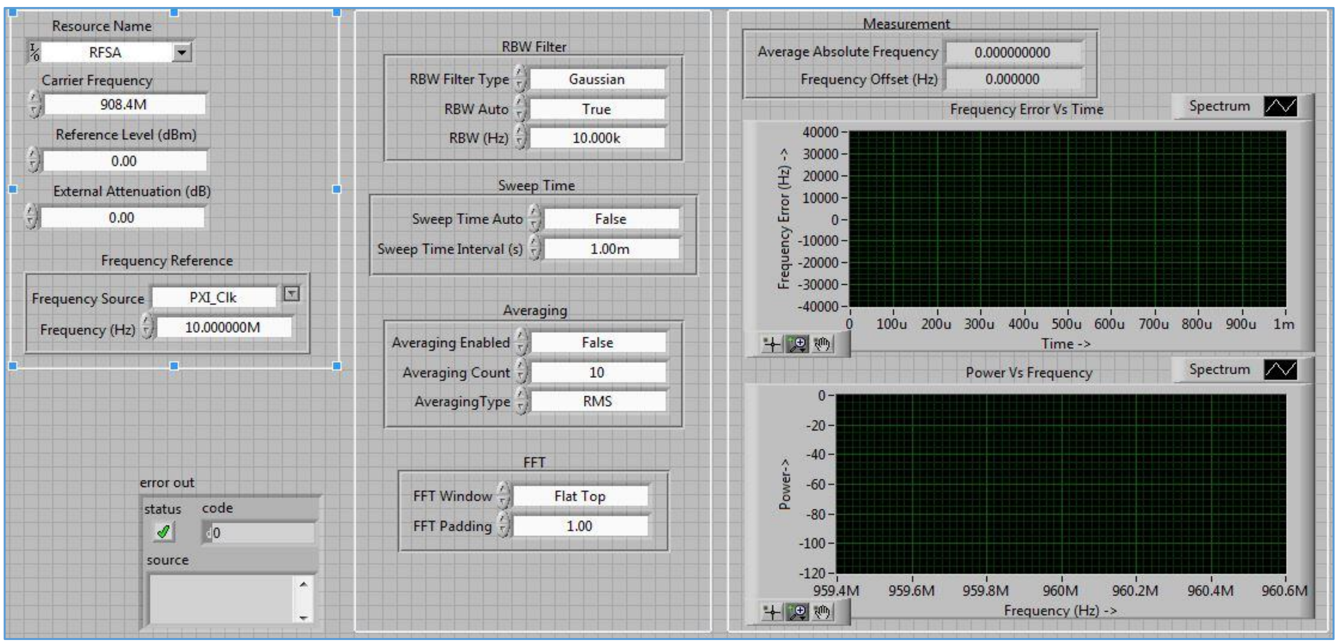
4.2.4 MaxEye Z-Wave RFSA Measure CW Frequency Offset

This example is used to find out absolute frequency and frequency offset of transmitted continuous wave signal. The user configurations are divided into two.

i. Hardware Settings
ii. Measurement Configuration

1. Refer 4.2.1.1 for Hardware Settings.

2. Measurement Configuration can be configured as follows.



RBW Filter Type- specifies the response of the digital RBW filter.

RBW Auto- specifies whether the measurement computes the resolution bandwidth (RBW) of the carrier.

RBW (Hz)- specifies the bandwidth, in Hz, of the resolution bandwidth (RBW) filter used to sweep the acquired carrier signal, when you set the RBW Auto parameter to False.

Sweep Time Auto- specifies whether the measurement computes the sweep time.

Sweep Time Interval- specifies the sweep time, in seconds, when you set the Sweep Time Auto parameter to False. The default value is 1 ms.

Averaging Enabled- specifies whether to enable averaging for the measurement. The default value is False**.**
Averaging Count- specifies the number of acquisitions used for averaging when you set the Averaging Enabled parameter to True.

Averaging Type- specifies the averaging type for averaging multiple spectrum acquisitions. The averaged spectrum is used for the measurement.

FFT window- specifies the FFT window type to use to reduce spectral leakage.

FFT Padding- specifies the factor by which the time-domain waveform is zero-padded before an FFT. The FFT size is given by the following formula: FFT size = waveform size * padding. This parameter is used only when the acquisition span is less than the device instantaneous bandwidth.

3. The measurement Results consists of Average Absolute frequency and frequency offset. The available graphs are Frequency Error Vs Time and Power Vs Frequency.