

MaxEye IEEE 802.15.4 UWB Measurement Suite

Version 1.0.0

Getting Started Guide

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1. Introduction

MaxEye Technologies provides generation and analysis functions in LabVIEW for generating and analyzing the 802.15.4 UWB standard compliant signals using National Instruments Vector Signal Generators (NI VSG) and Vector Signal Analyzers (NI VSA) or Vector Signal Transceivers (NI VST). The current version of the toolkit supports HRP UWB physical layer mode.

The standard defines BPM BPSK modulation scheme with different data rates based on the Channel number.

Channel Number	Peak PRF MHz	Bandwidth MHz	Preamble Code Length	Modulation & Coding			Data Symbol Structure						Data		
				Viterbi Rate	RS Rate	Overall FEC Rate	#Burst Positions	#Hop# Bursts	#Chips Per Burst	#Chips Per Symbol	Burst Duration (ns)	Symbol Duration (ns)	Symbol Rate (MHz)	Bit Rate Mb/s	Mean PRF (MHz)
{0:3, 5:6, 8:10, 12:14}	499.2	499.2	31	0.5	0.87	0.44	32	8	128	4096	256.41	8205.13	0.12	0.11	15.60
	499.2	499.2	31	0.5	0.87	0.44	32	8	16	512	32.05	1025.64	0.98	0.85	15.60
	499.2	499.2	31	0.5	0.87	0.44	32	8	2	64	4.01	128.21	7.80	6.81	15.60
	499.2	499.2	31	1	0.87	0.87	32	8	1	32	2.00	64.10	15.60	27.24	15.60
{0:3, 5:6, 8:10, 12:14}	499.2	499.2	31	0.5	0.87	0.44	128	32	32	4096	64.10	8205.13	0.12	0.11	3.90
	499.2	499.2	31	0.5	0.87	0.44	128	32	4	512	8.01	1025.64	0.98	0.85	3.90
	499.2	499.2	31	0.5	0.87	0.44	128	32	2	256	4.01	512.82	1.95	1.70	3.90
	499.2	499.2	31	1	0.87	0.87	128	32	1	128	2.00	256.41	3.90	6.81	3.90
{0:3, 5:6, 8:10, 12:14}	499.2	499.2	127	0.5	0.87	0.44	8	2	512	4096	1025.64	8205.13	0.12	0.11	62.40
	499.2	499.2	127	0.5	0.87	0.44	8	2	64	512	128.21	1025.64	0.98	0.85	62.40
	499.2	499.2	127	0.5	0.87	0.44	8	2	8	64	16.03	128.21	7.80	6.81	62.40
	499.2	499.2	127	0.5	0.87	0.44	8	2	2	16	4.01	32.05	31.20	27.24	62.40

This guide explains how to use the MaxEye IEEE 802.15.4 UWB Measurement Suite toolkit using programming examples.

2. Installed File Location

2.1 Programming Examples

2.1.1 802.15.4 UWB Generation and Analysis

1. The 802.15.4 UWB signal generation example VIs are installed in, <LabVIEW>examples\MaxEye\802.15.4 UWB \Generation\HRP UWB PHY
2. The 802.15.4 UWB signal analysis example VIs are installed in, <LabVIEW>examples\MaxEye\802.15.4 UWB \Analysis\HRP UWB PHY.
3. The toolkit API VIs for 802.15.4 UWB signal generation are installed in, <LabVIEW>\vi.lib\addons\MaxEye\802.15.4 UWB\Generation\HRP UWB PHY\API.

- The toolkit API VIs for 802.15.4 UWB signal analysis are installed in, <LabVIEW>\vi.lib\addons\MaxEye\802.15.4 UWB \Analysis\HRP UWB PHY\API.

You can also find a shortcut to the above location from the windows start menu.

Start->All Programs->MaxEye->802.15.4 UWB

2.2 Documentation

The toolkit help file is installed in, <LabVIEW>\help\MaxEye\802.15.4 UWB\MaxEye IEEE 802.15.4 UWB Measurement Suite Help.chm

The toolkit documentation files are installed in, <LabVIEW>\vi.lib\addons\MaxEye\802.15.4 UWB \ Documentation.

You can also find a shortcut to the above location from the windows start menu.

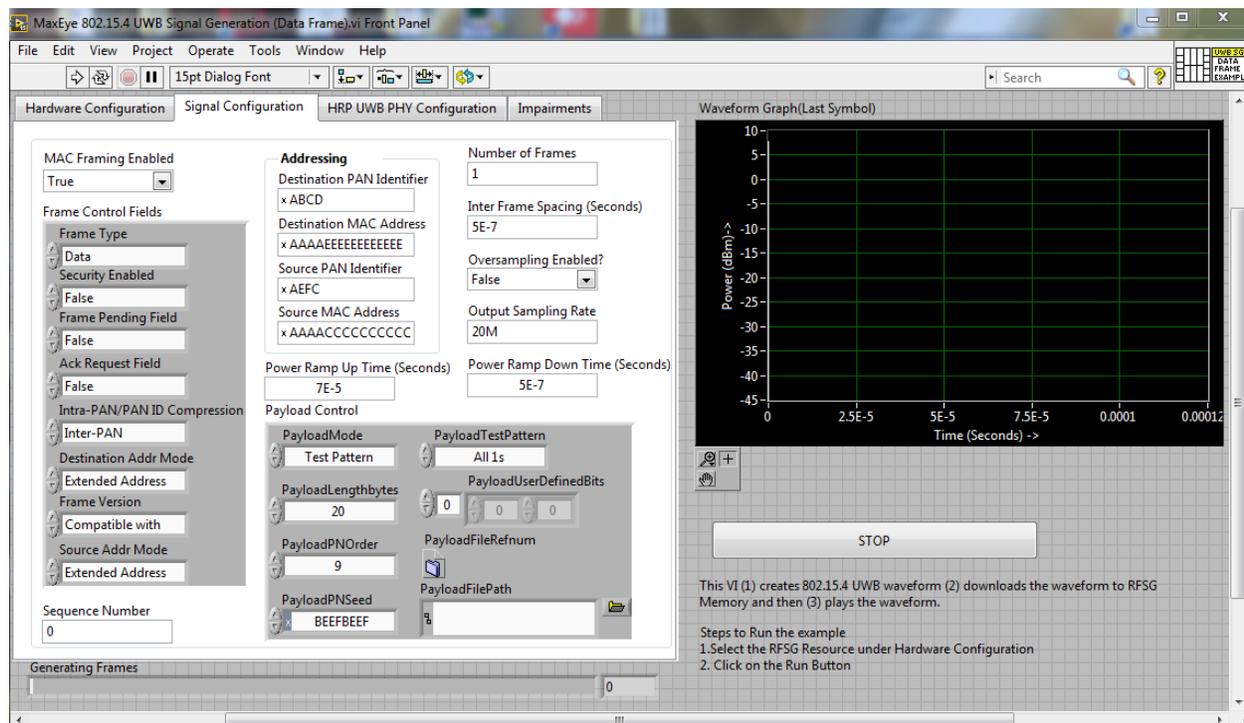
Start->All Programs->MaxEye->802.15.4 UWB

3. Programming Examples

3.1 802.15.4 UWB Signal Generation

3.1.1 MaxEye 802.15.4 UWB Signal Generation (Data Frame)

This Example is used to generate HRP UWB PHY Data Frame. The figure below shows the front panel of this example VI.



The user configurations are divided into four categories

- i. Hardware Settings
- ii. Signal Configuration
- iii. HRP UWB PHY Configuration
- iv. Impairments

Follow the below procedure to run the example.

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

Hardware Settings

RFSG Resource	AST1000
Carrier frequency(Hz)	Channel 2-3993.6MHz
Custom Carrier frequency(Hz)	4G
Power Level (dBm)	-10.00
External Attenuation (dB)	0.00
Headroom (dB)	3
Arb:Pre-filter Gain (dB)	-1

Frequency Reference

Reference Source	PXI_CLK
Frequency (Hz)	10.000M

Export Clock Settings

Clk Output Terminal	Do not export signal
---------------------	----------------------

- ♦ **RFSG Resource-** Configure the resource name used in NI Measurement and Automation explorer for the NI PXIE-5840 device.

Carrier Frequency (Hz) - Select Center Frequency of the HRP UWB signal in MHz. For HRP UWB, the carrier frequency is ranging from channel 1 (3494.4 MHz) to channel 14 (9984.0MHz) .Here the supported bandwidth is 499.2MHz

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.

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.

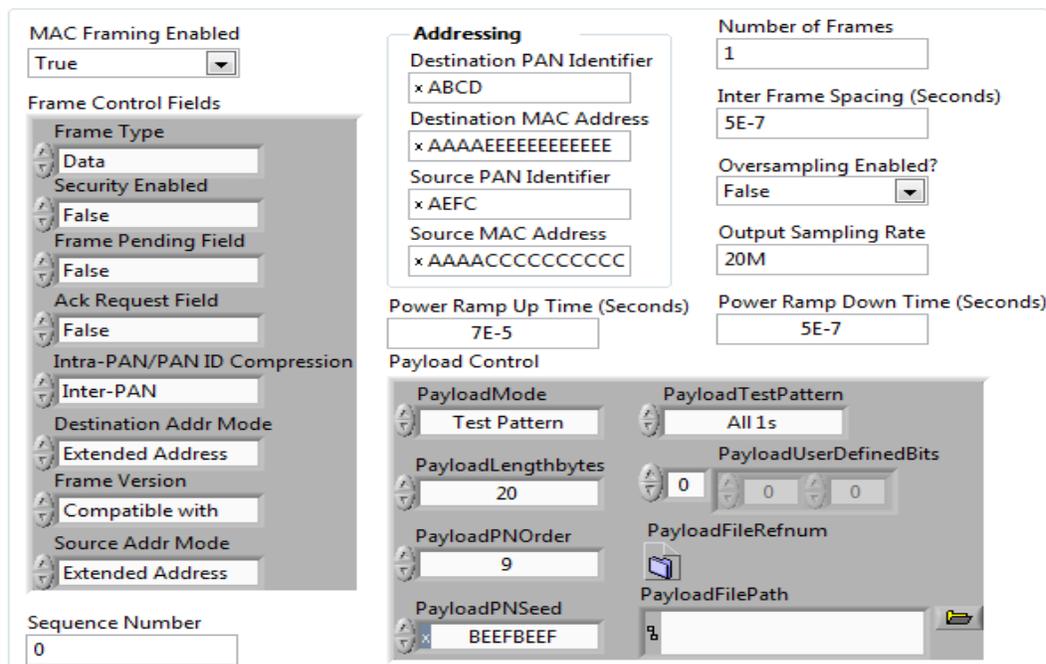
Reference Source- specifies the source of the Reference Clock signal

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 HRP UWB PHY Signal Generation Data frame example.



The screenshot shows a configuration window with the following settings:

- MAC Framing Enabled:** True
- Frame Control Fields:**
 - Frame Type: Data
 - Security Enabled: False
 - Frame Pending Field: False
 - Ack Request Field: False
 - Intra-PAN/PAN ID Compression: Inter-PAN
 - Destination Addr Mode: Extended Address
 - Frame Version: Compatible with
 - Source Addr Mode: Extended Address
- Sequence Number:** 0
- Addressing:**
 - Destination PAN Identifier: x ABCD
 - Destination MAC Address: x AAAAEEEEEEEEEEEE
 - Source PAN Identifier: x AEFC
 - Source MAC Address: x AAAACCCCCCCCCC
- Power Ramp Up Time (Seconds):** 7E-5
- Power Ramp Down Time (Seconds):** 5E-7
- Number of Frames:** 1
- Inter Frame Spacing (Seconds):** 5E-7
- Oversampling Enabled?:** False
- Output Sampling Rate:** 20M
- Payload Control:**
 - PayloadMode: Test Pattern
 - PayloadLengthbytes: 20
 - PayloadPNOrder: 9
 - PayloadPNSeed: BEEFBEEF
 - PayloadTestPattern: All 1s
 - PayloadUserDefinedBits: 0, 0, 0
 - PayloadFileRefnum: [empty]
 - PayloadFilePath: [empty]

MAC Framing Enabled- To generate MAC frame set this to true, the toolkit adds MAC layer headers and then creates payload for the physical layer. If this is set to false then the toolkit generates waveform without MAC frame parameters.

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.

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

Frame Type- Select the frame type as Data.

Security Enabled- shall be set to True if the frame is protected by the MAC sublayer and shall be set to False otherwise.

Frame Pending Field- shall be set to True if the device sending the frame has more data for the recipient. This field shall be set to False otherwise.

Ack Request Field- specifies whether an acknowledgment is required from the recipient device on receipt of a data or MAC command frame. If this field is set to True, the recipient device shall send an acknowledgment frame only if, upon reception. If this field is set to False, the recipient device shall not send an acknowledgment frame.

PAN ID Compression- specifies whether the MAC frame is to be sent containing only one of the PAN identifier fields when both source and destination addresses are present. If this field is set to Intra-PAN and both the source and destination addresses are present, the frame shall contain only the Destination PAN Identifier field, and the Source PAN Identifier field shall be assumed equal to that of the destination. If this field is set to inter-PAN, then the PAN Identifier field shall be present if and only if the corresponding address is present.

Destination Address Mode- Select the required destination address mode.

Frame Version- specifies the version number corresponding to the frame.

Source Address Mode- Select the required source addressing mode.

Sequence Number- The Sequence Number field specifies the sequence identifier for the frame.

The addressing fields can be configured as follows.

Destination PAN Identifier- specifies the unique PAN identifier of the intended recipient of the frame. This field shall be included in the MAC frame only if the Destination Addressing Mode field is nonzero.

Destination MAC Address- specifies the address of the intended recipient of the frame. Based on the Destination Address mode this field may be 16 bit or 64 bit. This field shall be included in the MAC frame only if the Destination Addressing Mode field is nonzero

Source PAN Identifier- specifies the unique PAN identifier of the originator of the frame. This field shall be included in the MAC frame only if the Source Addressing Mode field is nonzero and the PAN ID Compression field is equal to zero.

Source MAC Address- 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.

MaxEye IEEE 802.15.4 UWB Measurement Suite Toolkit allows you to configure various payload settings. The possible payload options are

- i. **PN Sequence-** In this mode configures Sync Insertion Enabled, Payload PN order and PN Seed properties and the toolkit ignores other properties in the 802.15.4 UWB 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 802.15.4 UWB 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 802.15.4 UWB 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 802.15.4 UWB 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 are 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.

3. Select HRP UWB PHY Configuration Tab and configure the following settings.

Data Parameter Settings:

- **Mean PRF, (MHz)** - Select the Mean PRF according to IEEE 802.15.4 UWB standard. There are three possible Mean PRFs (15.60 MHz, 3.90 MHz and 62.40MHz). The mean PRF is defined as the total number of pulses emitted during a symbol period divided by the length of the symbol duration.
- **Data Rate Mb/s-** Select the Data Rate according to IEEE 802.15.4 UWB standard. There are five possible data rates (0.11, 0.85, 6.71, 27.24, 1.70 Mb/s) available in the standard. Depending on the data rate to be used in the transmission of the PSDU, the number of chips in a burst varies, e.g., for low data rates, the burst consists of more chip periods than for high data rates.
- **Ranging packets-** shall be set to one if the current frame is an RFRAME; otherwise, it shall be set to zero.

Preamble Parameters:

- **Preamble code index-** Select the code index as per the standard. There are total 24 codes. The first 8 codes (index 1–8) are length of 31, while the remaining 16 (index 9–24) are length of 127.
- **Preamble duration-** Select the duration type among short, default, medium and long.
- **No of symbols in SFD-** Select the no of symbols in SFD between 8 or 64.

4. 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.

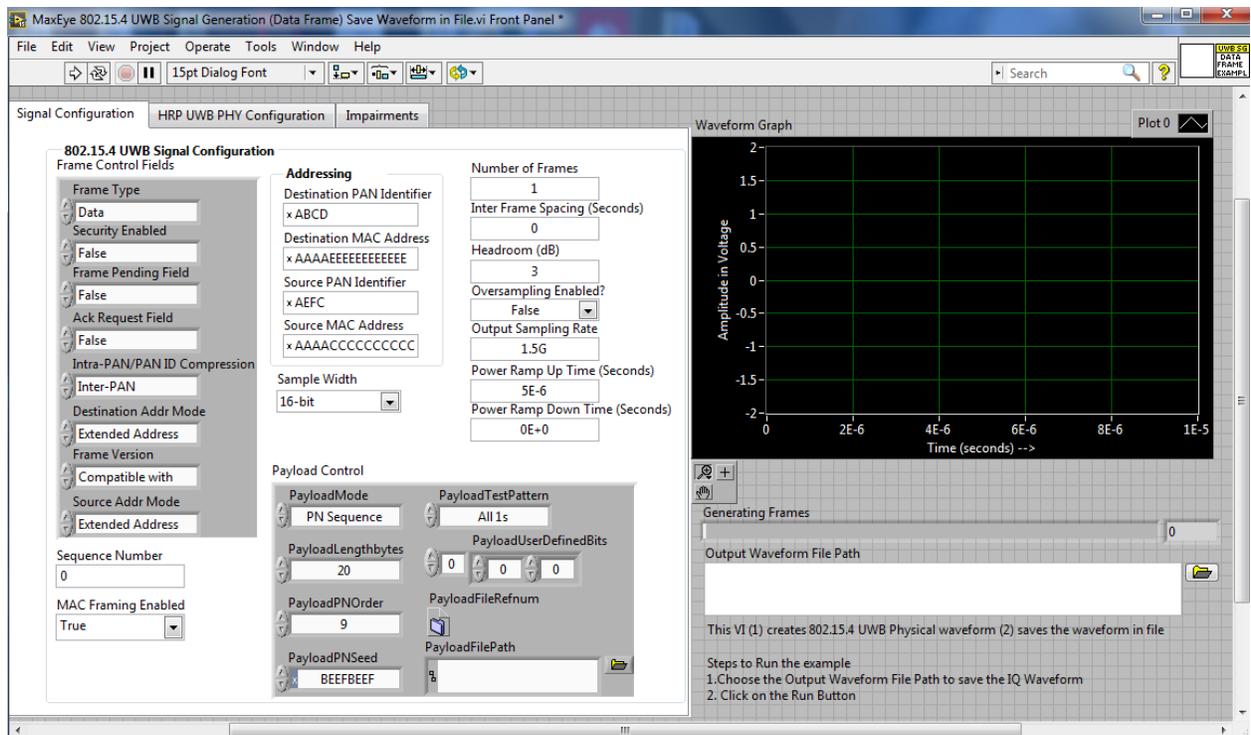
Carrier to Noise Ratio, dB- This value specifies the Carrier to Noise ratio of the generated signal.

3.1.2 MaxEye 802.15.4 UWB Signal Generation (Data) Save Waveform in file

This Example is used to generate multiple UWB 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 test starting time as some of the signal configuration will take longer to generate 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 3.1.1. 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.

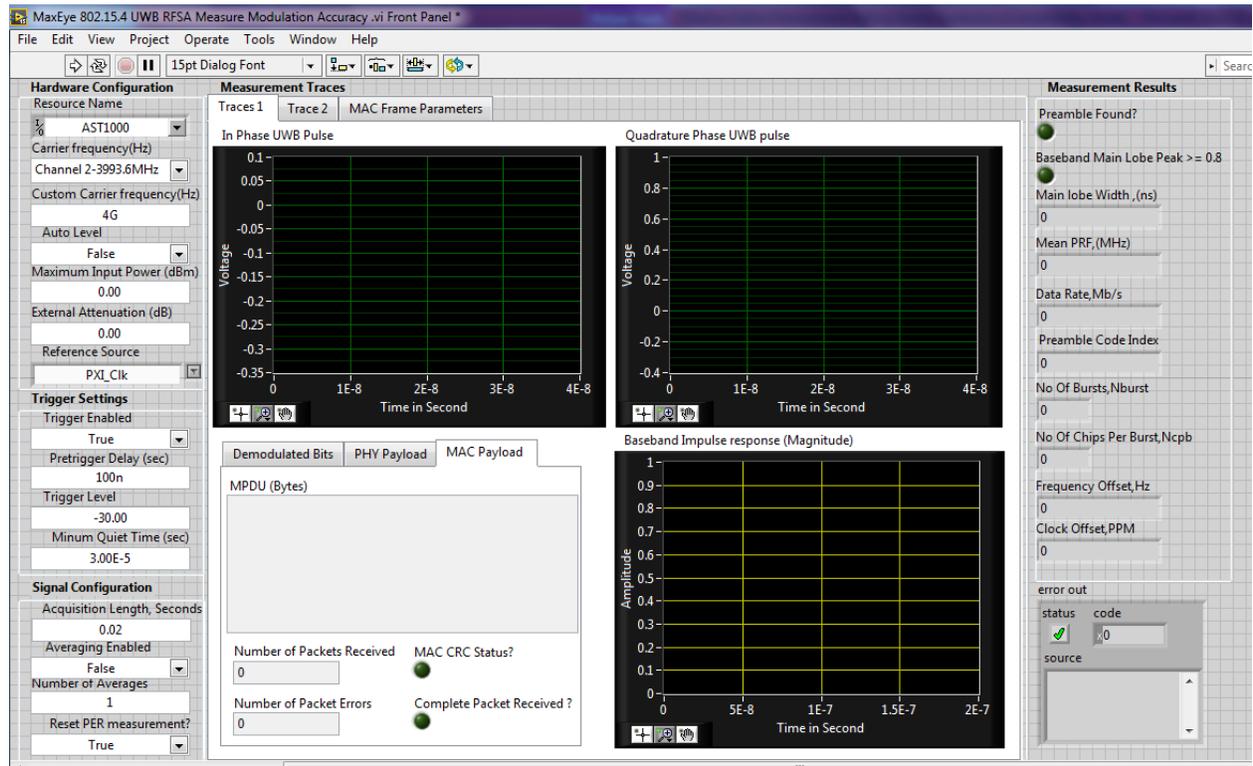
4. 802.15.4 UWB Signal Analysis

4.1 MaxEye 802.15.4 UWB RFSA Measure Modulation Accuracy

This example VI is to find out Clock offset estimation, frequency offset estimation, Baseband impulse response measurements, 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- 5840 device..

Carrier Frequency- Select Carrier Frequency of the 802.15.4 UWB signal in MHz. For UWB, the carrier frequency is ranging from Channel 1 (3494.4 MHz) to channel 14(9984.0 MHz), supporting 499.2 MHz bandwidth only. Choose the Channel Number as same as transmitted signals channel number. Custom frequency is optional .It can be set only for testing purpose.

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 UWB data acquisition. Number of Samples to Acquire= IQ Rate* Acquisition Length

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 I vs. time and Q vs. time UWB pulse signal, Baseband impulse response magnitude vs. time, Demodulated Bits, PHY payload, MAC payload.

Demodulated Bits	PHY Payload	MAC Payload
MPDU (Bytes)		
Number of Packets Received	MAC CRC Status?	
0	<input checked="" type="checkbox"/>	
Number of Packet Errors	Complete Packet Received ?	
0	<input checked="" type="checkbox"/>	

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

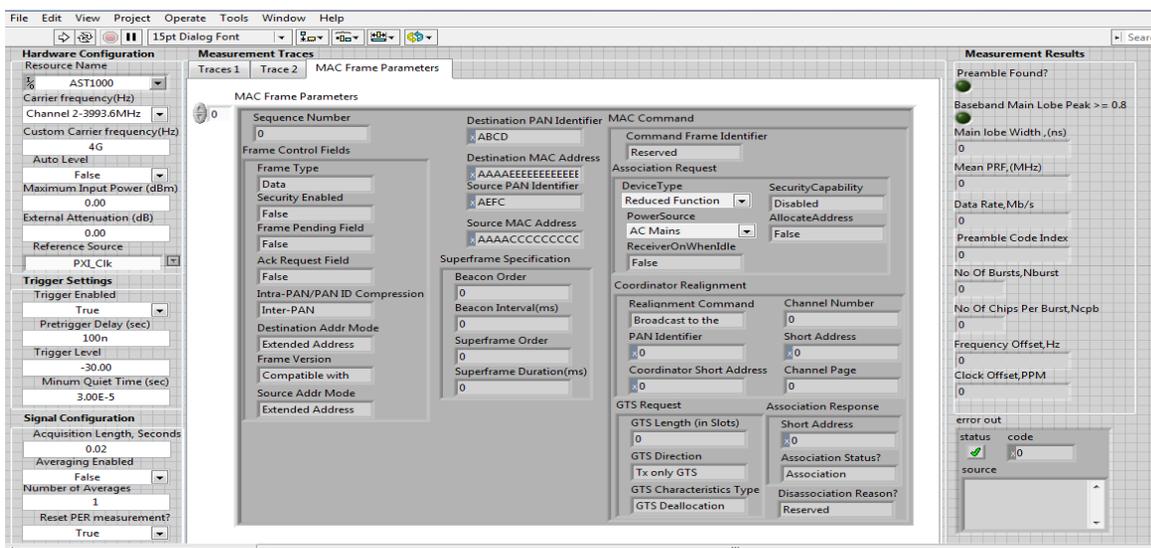
MAC CRC Status- this will turn ON when CRC check failed.

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

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

5. Traces 2 include baseband impulse response I vs. time, baseband impulse response Q vs. time.

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 Main lobe width of baseband impulse response, peak value of impulse response, clock offset, frequency offset, received Mean PRF ,data rate ,code index etc.