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APPLICATION NOTE

NI Solution for PHY Layer Testing of Zigbee and Thread

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The goal of this paper is to explain how to utilize various personalities of NI RFmx software to take physical layer (PHY) measurements required by Zigbee™ and Thread™ specifications.

This paper assumes you have a working knowledge of NI hardware and software including NI RFmx, and that you have access to IEEE 802.15.4-2020. This document is available on the IEEE website with valid credentials.

Introduction

Zigbee is a wireless communication technology based on the IEEE 802.15.4 specification. Its low cost and low power consumption makes it a great candidate for IoT and smart home applications. The Connectivity Standards Alliance (formerly known as the Zigbee Alliance) is responsible for developing and certifying Zigbee standards and is where the most up-to-date information can be found.

Similarly, Thread is another low power, short-range wireless communication technology based on IEEE 802.15.4. It is overseen by the Thread Group. Though there are significant differences between Thread and Zigbee in the network and application layers, the similarities of the PHY layers allow for some interoperability, demonstrated in official collaborations between the Connectivity Standards Alliance and the Thread Group.

This paper specifically discusses the requirements of the PHY of the OSI model (shown in Figure 1), and the tests required to comply with those requirements.

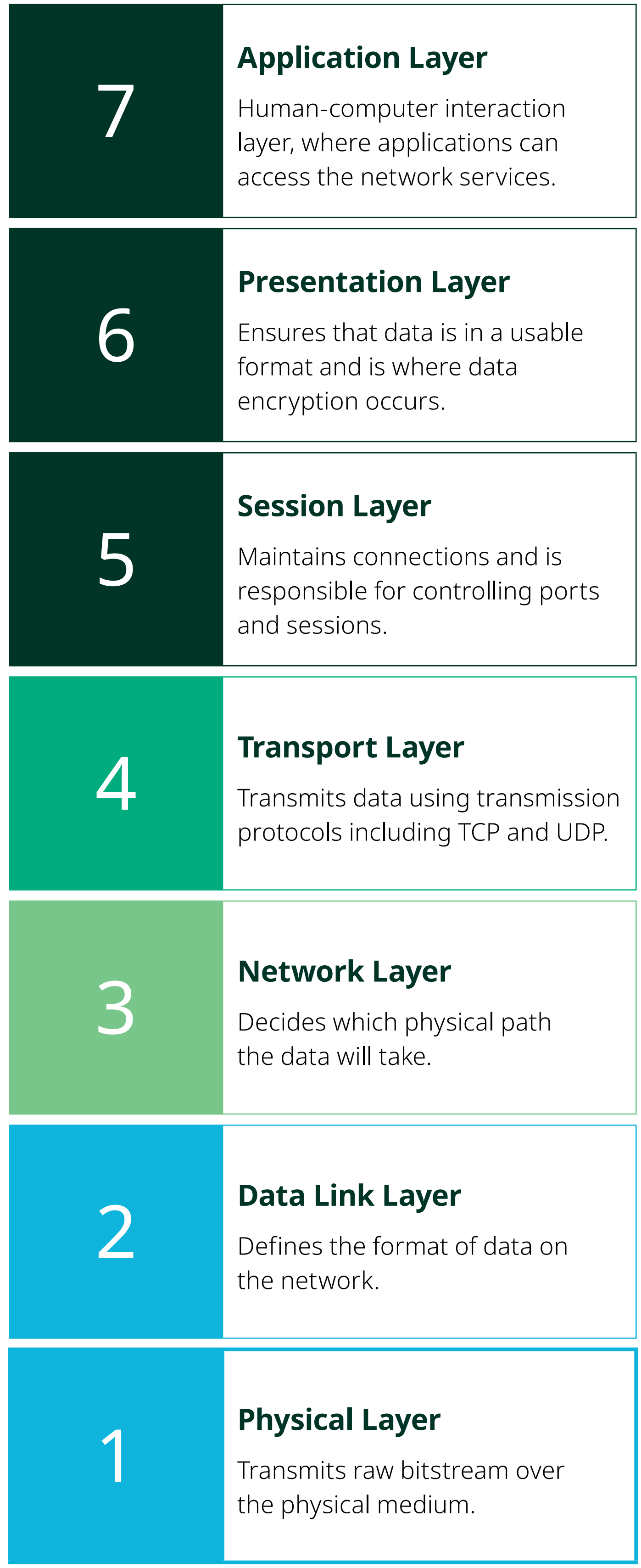

FIGURE 1
A summary of the OSI model, with the PHY highlighted.

PHY Layer

Whether Zigbee or Thread, the PHY supports both sub-GHz and 2.4 GHz bands, each with its own modulation scheme. The details are summarized in Table 1.

Band	Frequency	Modulation	Regional Use	Zigbee
868 MHz	868 MHz–868.6 MHz	BPSK	Europe	Channel 0
915 MHz	902 MHz–928 MHz		US, Australia	Channels 1–10
2.4 GHz	2.4 GHz–2.4835 GHz	OQPSK	Worldwide	Channels 11–26

TABLE 1

Details of Zigbee and Thread Frequency Bands

Instrumentation Setup

The solution presented in this paper uses NI's PXI-based Vector Signal Transceiver, the **PXIe-5842**. The PXIe-5842 serves as both the waveform generator (to play out a modulated, standard-specified waveform) and the signal analyzer (to receive and take measurements). With typical DUTs like PAs, LNAs, or FEMs, the PXIe-5842 is the only RF instrumentation needed to perform the measurements described as follows. Other modules may be needed for DUT control, power, etc.

FIGURE 2

An example PXI system from NI, including the PXIe-5842 in the green box.

Measurements

Test requirements for Zigbee and Thread signals are specified in IEEE 802.15.4-2020. Refer to that specification for more details and exact requirements: section 12.3 details the OQPSK PHY RF requirements, and section 13.3 details the BPSK PHY RF requirements.

Some of the transmit test requirements are called out in Table 2, with the corresponding RFmx personality and measurement used to take them.

Requirement	RFmx Measurement
Transmit power spectral density mask	RFmxSpecAn SEM
EVM	RFmxDDemod
Transmit center frequency tolerance	RFmxSpecAn FCnt
Transmit power	RFmxSpecAn TXP

TABLE 2
Select IEEE 802.15.4 PHY Requirements and the Recommended NI RFmx Measurement to Take Them

Configuration in RFmx

RFmx is NI's measurement-based driver for RF Signal Analyzers. There are a variety of RFmx personalities, and each of those personalities allows you to take a variety of measurements. All RFmx personalities have complete APIs in LabVIEW, .NET (C# or VB), and C. All personalities and APIs support all NI RF Signal Analyzer hardware.

This section describes the recommended configurations of the various RFmx measurements needed to make certain Zigbee and Thread measurements. This is not an exhaustive list of every function needed to take these measurements, but rather the settings specifically needed for Zigbee and Thread signals.

Measuring EVM with RFmxDDemod

The RFmx shipping examples RFmxDemod DDemod (Advanced).vi in LabVIEW or the RFmxDemodDDemodAdvanced solution in C# .NET provides an excellent starting point with access to all the properties in Table 3 and more to configure this measurement, as shown in Figure 3.

RFmx Demod LabVIEW	.NET API	Recommended Setting	
		BPSK	OQPSK
RFmxDemod DDemod Configure Modulation Type	ConfigureModulationType	PSK	
RFmxDemod DDemod Configure M	ConfigureM	2	4
RFmxDemod DDemod Configure PSK Format	ConfigurePskFormat	Normal	Offset QPSK
RFmxDemod DDemod Configure Symbol Rate	ConfigureSymbolRate	300–600 kSymbol/sec	1 MSymbol/sec
RFmxDemod DDemod Configure Pulse Shaping Filter	ConfigurePulseShapingFilter	Root Raised Cosine	Half Sine
RFmxDemod DDemod Configure Number of Symbols	ConfigureNumberOfSymbols	Greater than number of symbols in the burst*	
Digital Demod:Signal Structure	ConfigureSignalStructure	Bursted	

TABLE 3

Recommended Configurations to Measure EVM with RFmx Digital Modulation for Zigbee and Thread Signals

* Utilize the Bursted Signal Structure to autodetect the falling edge of the signal's burst, given the proper configuration:

1. Configure a trigger to catch the beginning of the burst. For example, use an IQ Power Edge trigger with appropriate Level.
2. Make sure Number of Symbols is large enough to capture all symbols in the burst. The driver will find the falling edge of the burst automatically. If Number of Symbols is more than the number of symbols in the burst, only the burst will be acquired. If Number of Symbols is less than the number of symbols in the burst, the burst will be cut short by the acquisition.

For more information, view the **Bursted Signal Structure Help page**.

When Fetching demodulation results, ensure the Offset versions of EVM results are used when demodulating an OQPSK waveform.

LabVIEW API

BPSK	OQPSK
RFmxDemod DDemod Fetch EVM	RFmxDemod DDemod Fetch Offset EVM
RFmxDemod DDemod Fetch Constellation Trace	RFmxDemod DDemod Fetch Offset Constellation Trace

TABLE 4

The required RFmxDDemod Fetch VIs in the LabVIEW API, which differ based on modulation scheme.

.NET API

BPSK	OQPSK
FetchEvm	FetchOffsetEvm
FetchConstellationTrace	FetchOffsetConstellationTrace

TABLE 5

The required RFmxDDemod Fetch methods in the .NET APT, which differ based on modulation scheme.

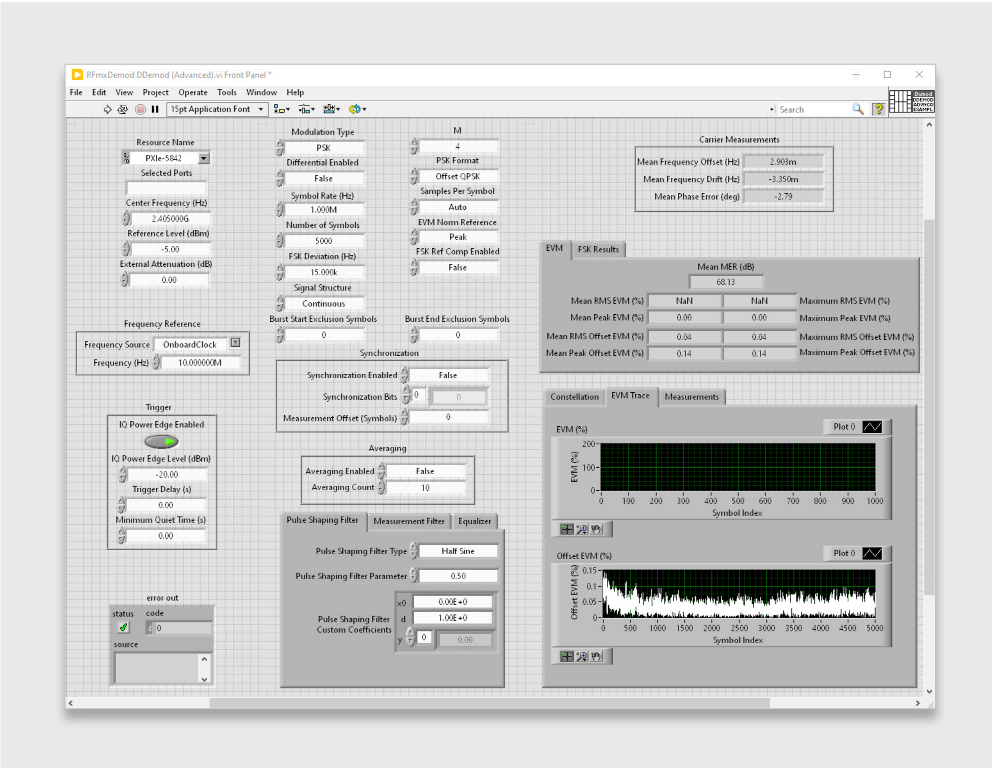

FIGURE 3

A screenshot of the RFmxDemod DDemod (Advanced).vi after running, showing the configurations used and the results returned.

Figure 3 shows the example RFmxDemod DDemod (Advanced).vi in LabVIEW after running on a PXIe-5842 in loopback, configured for an OQPSK waveform. Waveform generated was the example *zigbee_o-qpsk_1000kcps_halfsine.rfws* in RFmx Waveform Creator.

Measuring Power Spectral Density Mask with RFmxSpecAn SEM

The RFmx shipping examples RFmxSpecAn SEM (Advanced).vi in LabVIEW or the RFmxSpecAnAcp solution in C# .NET provides an excellent starting point with access to all the above properties and more to configure this measurement, as shown in Figure 4.

*Recommended settings in this section are provided for the 2.4 GHz, OQPSK waveform:

RFmx SpecAn	.NET API	Recommended Setting*
RFmxSpecAn SEM Configure Carrier Integration Bandwidth	ConfigureCarrierIntegrationBandwidth	2 MHz
RFmxSpecAn SEM Configure Reference Type	ConfigureReferenceType	Peak
RFmxSpecAn SEM Configure Offset Frequency	ConfigureOffsetFrequency	Start: 3.5 MHz Stop: 10 MHz
RFmxSpecAn SEM Configure Offset Frequency Definition	ConfigureOffsetFrequencyDefinition	Carrier Center to Meas BW Center
RFmxSpecAn SEM Configure Offset Absolute Limit	ConfigureOffsetAbsoluteLimit	Limit Mode: Couple Limit Start: -30 dBm
RFmxSpecAn SEM Configure Offset Relative Limit	ConfigureOffsetRelativeLimit	Limit Mode: Couple Limit Start: -20 dBc
RFmxSpecAn SEM Configure Carrier RBW Filter	ConfigureCarrierRbwFilter	RBW Auto: False RBW: 100 kHz
RFmxSpecAn SEM Configure Offset RBW Filter	ConfigureOffsetRbwFilter	RBW Auto: False RBW: 100 kHz

TABLE 6

Recommended Configurations to Measure Power Spectral Density Mask with RFmx SpecAn SEM for an O-QPSK Zigbee or Thread Signal

We also recommend using a start trigger to capture the signal burst. An IQ Power Edge trigger with an appropriate Level is one example of this.

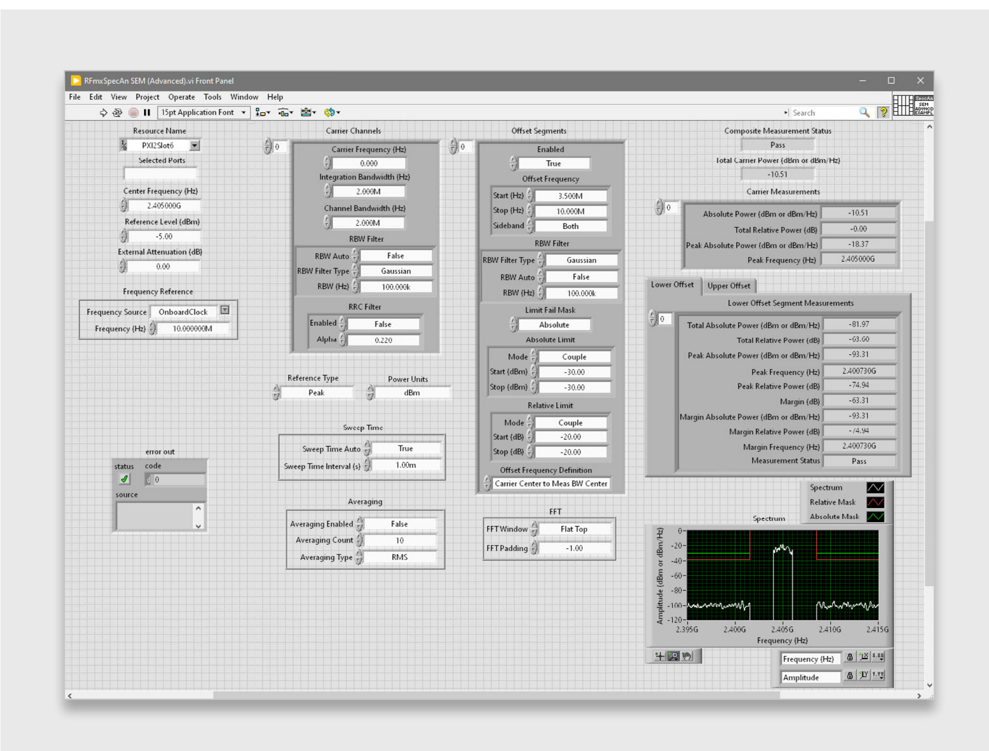

FIGURE 4

A screenshot of the RFmxSpecAn SEM (Advanced).vi after running, showing the configurations used and the results returned.

Figure 4 shows the example RFmxSpecAn SEM (Advanced).vi in LabVIEW after running on a PXIe-5842 in loopback, configured for an OQPSK waveform. Waveform generated was the example *zigbee_o-qpsk_1000kcps_halfsine.rfws* in RFmx Waveform Creator.

RFmx Waveform Creator: Generation

NI has two Zigbee waveform examples available in the RFmx Waveform Creator. There is one example for OQPSK and one for BPSK. These are already configured in accordance with the standard, though all parameters in these configurations can be modified for your requirements if necessary.

To access these examples, go to Modulation > Generic > PSK, as shown in Figure 5. In the pop-up window that appears, select the option for Example Settings; locate the following examples in the dropdown:

zigbee_bpsk_300kcps_gaussian-0.4.rfws

zigbee_o-qpsk_1000kcps_halfsine.rfws

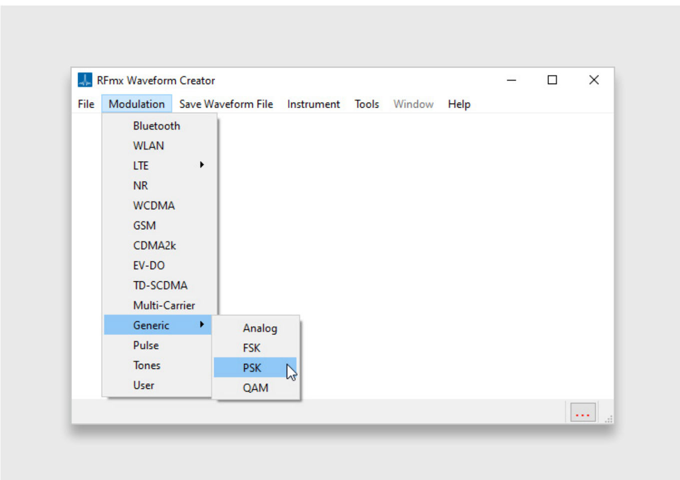

FIGURE 5
The RFmx Waveform Creator User Interface with Navigation to PSK Waveforms Shown

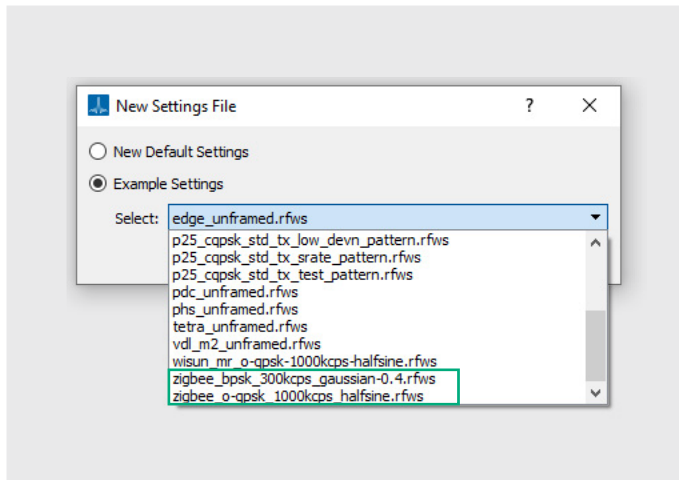

FIGURE 6
The New Setting File Pop-Up Window in RFmx Waveform Creator, Showing the Two Zigbee Example Waveforms

These waveforms can be generated directly from RFmx Waveform Creator or they can be saved as .tdms waveform files to be played out via other applications like InstrumentStudio™ software.

Recommended NI Bundle

Hardware

866573-01B Wi-Fi and Bluetooth®, 30 MHz to 8 GHz, 1 GHz BW, 9 slot chassis, controller

This solution relies on the PXIe-5842, which is included in this bundle. Additional options are available. Contact your NI representative for more information or to order.

FIGURE 7
The PXIe-5842 Vector Signal Transceiver, included in this bundle.

Software

The software required for the previously mentioned measurements are all components of RFmx.

An RFmx Digital Modulation license is required for the previously mentioned EVM measurements. RFmx SpecAn is required for the spectral measurements previously mentioned, though this software does not require the purchase of a license.

Related Links

RFmx Demod User Manual (LabVIEW API documentation)

RFmx Demod .NET Help Documentation

RFmx SpecAn User Manual (LabVIEW API documentation)

RFmx SpecAn .NET

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