Keysight Technologies

A Low Cost Test Solution for 2.4 GHz ZigBee Transmitter and Receiver

Application Note

KEYSIGHT TECHNOLOGIES

Introduction

ZigBee is based on the IEEE802.15.4 standard and was adopted on 16 December 2004 by the ZigBee Alliance. It is used widely in the Internet of Things (IOT) industry due to its low-power use, low-cost, and wireless mesh network standard. Typical applications areas include home entertainment and control, wireless sensor networks, industrial control, medical data collection, building automation, and smart utility meter.

The bands and usage of ZigBee are as shown Table 1.

Table 1. ZigBee bands and properties

Band	Frequency (MHz)	Chip rate (kchip/s)	Modulation type	Pulse shaping filter	Usage
868	868 to 868.6	300	BPSK	RRC (root raised cosine)	European
915	902 to 928	600	BPSK	RRC	North American
2450	2400 to 2483.5	2000	O-QPSK	Half sine	Global

This application note explains a low cost measurement solution for 2.4 GHz ZigBee O-QPSK signal generation for receiver test and signal analysis for transmitter test.

2.4 GHz O-QPSK ZigBee Receiver Test Solution

During the R&D or manufacturing process, it is necessary to generate the corresponding digital modulation signals for RF receiver testing. Sensitivity is the key item to evaluate when testing the receiver's performance. You need to generate a real ZigBee signal and inject it into the receiver, and check if the receiver works properly at the minimum power level of an input ZigBee signal.

The Keysight Technologies, Inc. low-cost solution addresses this need. It uses the 33522B dual-channel waveform generator and N9310A RF signal generator to build a real-world ZigBee signal. This is an affordable alternative if an integrated vector signal generator is not available.

System setup

Configuring the receiver test solution is done by connecting the Channel 1 and Channel 2 outputs of the 33522B to the I and Q input ports of the N9310A using two BNC cables as shown in Figure 1.

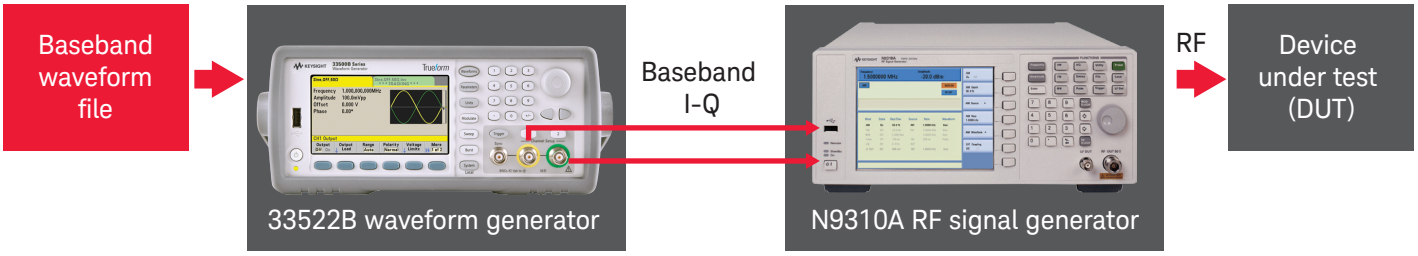

Figure 1. ZigBee signal generation with N9310A and 33522B

3 Steps to Generate a 2.4 GHz ZigBee O-QPSK Receiver Test Signal

The low-cost Keysight solution lets you generate an O-QPSK signal for your 2.4 GHz ZigBee receiver test in three simple steps.

Step 1. Generating the baseband waveform

You can use the ZigBee Baseband Signal Generation software to edit the baseband waveform, export it into a csv. file and load it on a Keysight 33522B waveform generator. After downloading you will get a zip file named as “ZigBee_Signal_Generation.zip”. Unzip it and you will get two files: “ZigBee_Signal_Generation.exe” and “PPDU.txt”. Double click “ZigBee_Signal_Generation.exe” and you will see the user interface shown in **Error!**

Figure 2. ZigBee Baseband Signal Generation Software

This software offers two ways to create the baseband waveform.

Read PPDU.txt file. This is the default method:

1. Open the PPDU.txt file with the Notepad
2. Edit the “0” and “1” data in the file, then **Save** and **Exit** the Notepad. Do not rename it
3. Click **Read PPDU_txt file**
4. Click **Export I/Q Baseband Data** to **ZigBee.csv File**
5. A new ZigBee.csv file will be generated in the same folder

Input the PPDU packet data manually:

1. Click **PPDU Packet Input Manual**
2. Input the “0” and “1” data data in the corresponding field
3. Click **Export I/Q Baseband Data** to **ZigBee.csv File**
4. A new ZigBee.csv file will be generated in the same folder

What is PPDU?

PHY protocol data units (PPDU) in ZigBee physical layer is defined in Figure 3 shown below.

		Octets		
		1		Variable
Preamble	SFD	Frame length (7 bits)	Reserved (1 bit)	PSDU
SHR		PHR		PHY payload

Figure 3. ZigBee PPDU structure

3 Steps to Generate a 2.4 GHz ZigBee O-QPSK Receiver Test Signal (Continued)

Step 2. Loading the baseband waveform file in a 33522B waveform generator

1. Copy the ZigBee.csv file to a USB memory stick and insert it into the USB port of the 33522B
2. Load the .csv file into the 33522B to build the baseband signal as follows:
   - 2.1 Select **Arb** > **Arbs** ↓ > **Import Data** ↓
   - 2.2 Select **Select Data File**, then rotate the knob to highlight **External**, press the button to the lower right side of the knob. See Figure 4.

Figure 4.

   - 2.3 Rotate the knob to highlight the ZigBee.csv file, and choose **Select**
   - 2.4 Toggle the 33522B to IQ Mode and select **Next**. See Figure 5

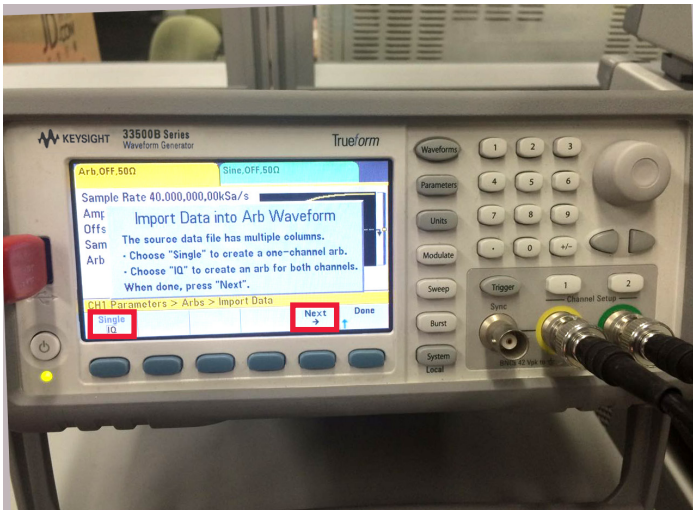

Figure 5.

   - 2.5 Toggle to **ASCII** Mode, and select **Import Data** > **Yes** to load this .csv file. See Figure 6.

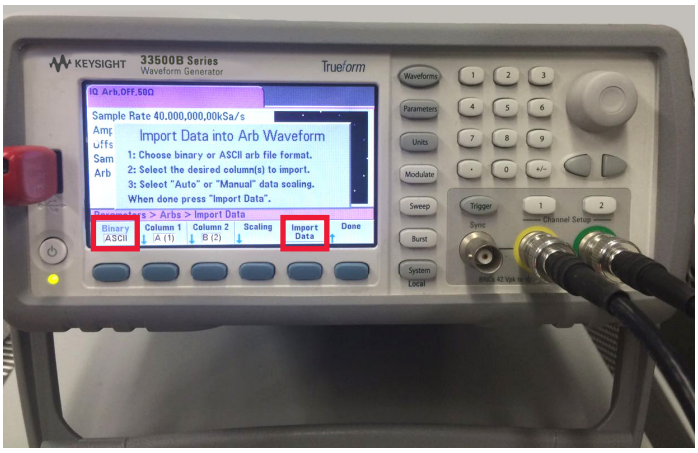

Figure 6.

3. Set up the 33522B parameters as follows:
   - 3.1 Select **Sample rate** > [8] > **MSa/s**
   - 3.2 Select **Amplitude** > **1.414** > **Vpp**
   - 3.3 Select **Filter** > **Off**
   - 3.4 Press [1] of **Channel Setup** > **Output** > **On**, and press [2] of **Channel Setup** > **Output** > **On**. Now the ZigBee baseband signal output is enabled

3 Steps to Generate a 2.4 GHz ZigBee O-QPSK Receiver Test Signal (Continued)

Step 3. Generating the 2.4 GHz O-QPSK ZigBee signal with an N9310A RF signal generator

Use the following steps to configure the N9310A:

1. Select **Frequency** > [2.45] > **GHz**
2. Select **Amplitude** > [0] > **dBm**
3. Select **IQ** > **On**
4. Select **Mod On** and **RF On**

Figure 7. Set up N9310A

To verify the ZigBee O-QPSK RF signal, you can use an N9000A CXA signal analyzer and measurement application VXA (W9064A) to demodulate it. Figure 8 shows the demodulation metrics of the O-QPSK signal.

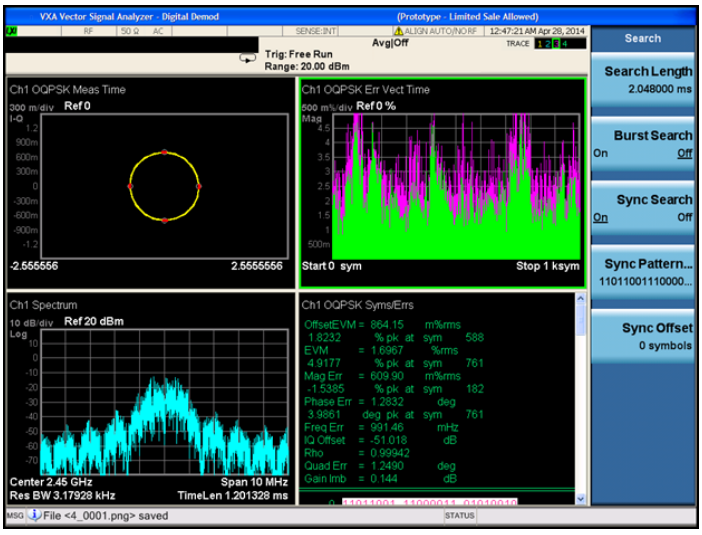

Figure 8. Demodulation metrics shown on the CXA N9000A

2.4 GHz O-QPSK ZigBee Transmitter Test Solution

According to the ZigBee transmitter characterization standards, the following items are tested with a spectrum analyzer (signal analyzer):

- Relative power spectral density
- Absolution power spectral density
- Maximum transmit power
- Center frequency tolerance
- EVM
- Offset EVM

Products used for ZigBee transmitter test solutions, shown in Figure 9, vary depending upon the end user's requirements:

- **ZigBee transmitter research and development:** N9000A CXA signal analyzer with the W9064A VXA measurement application. W9064A VXA offer in-depth vector signal analysis capability and a convenient preset for ZigBee.
- **ZigBee transmitter manufacturing and repair:** N9320B/N9322C basic spectrum analyzer (BSA). This configuration offers channel and occupied bandwidth measurements, and is best suited for production lines and repair bench dues to its high price/performance ratio.

For details about using the N9000A CXA signal analyzer and W9064A VXA measurement application, refer to the following demonstration guides:

- X-Series signal analyzers demonstration guide **http://literature.cdn.keysight.com/litweb/pdf/5989-6126EN.pdf**
- W9064A VXA measurement guide **http://literature.cdn.keysight.com/litweb/pdf/N9064-90004.pdf**

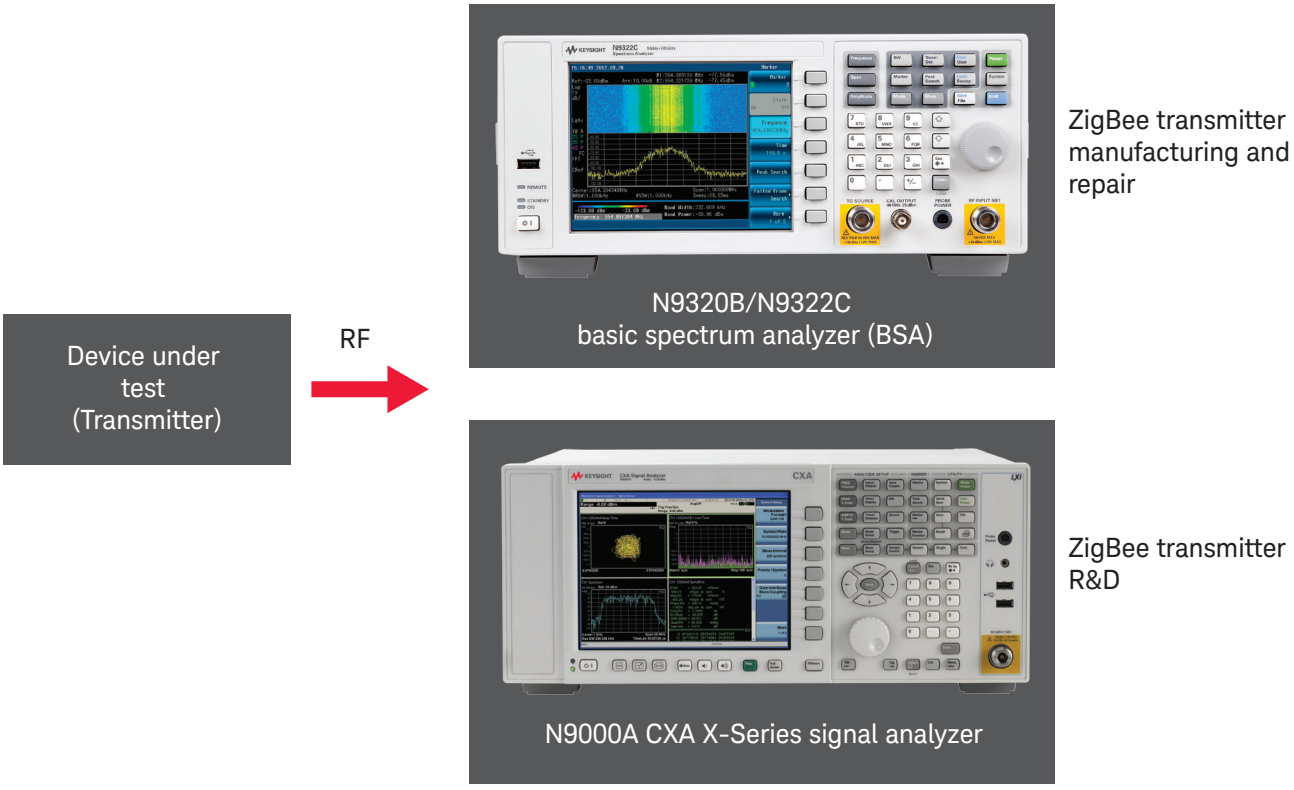

Figure 9 ZigBee transmitter test solutions

Conclusion

The combination of the 33522B waveform generator, N9310A RF signal generator, N9320B/22C spectrum analyzer, and N9000A CXA signal analyzer offer flexible, reliable, and low-cost solutions to test ZigBee receiver and transmitter.

Reference Test System Setup

Table 2. Equipment models and options for low cost 2.4 GHz ZigBee O-QPSK signal generation.

Model/Option	Description
Keysight 33522B	**30 MHz, dual channel waveform generator**
33522B-MEM	16 M memory
33522B-IQP	I/Q baseband signal player
33522B-OCX	High-stability OCXO timebase
Keysight N9310A	**RF signal generator, 9 kHz to 3 GHz**
N9310A-001	I/Q modulator, 20 MHz
Keysight N9000A CXA	**CXA signal analyzer, 9 kHz to 3/7/13/26 GHz**
W9064A-1FP and -2FP	VXA vector signal analysis measurement application
Keysight N9320B/N9322C	**BSA spectrum analyzer, 9 kHz to 3/7 GHz**

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