APPLICATION NOTE

A Cost-Effective Way of Testing *Bluetooth*® Modules on Smart Devices

KEYSIGHT

Introduction

The internet of things (IoT) will encompass all aspects of our everyday lives as it enables literally billions of things to be connected anytime, anywhere, with anything and anyone. Consumer use of smart devices plays an important application in IoT.

A smart device is an electronic device with ubiquitous computing capability, generally connected to other devices or networks via different wireless protocols. Several notable types of smart devices are phones, tablets, watches, smart bands, healthcare devices, and home security devices.

Interconnection of Smart Devices

Most smart devices use *Bluetooth* as the wireless protocol to interconnect with other devices or networks. As one of the major technologies for personal area network (PAN), *Bluetooth* has evolved in the past a few years from *Bluetooth* 4 (Low energy) to *Bluetooth* 5 (5.1, 5.2, and 5.3), that enable higher data rate, longer range, as well as direction finding features: AoA (angle of arrival) and AoD (angle of departure)

Table 1. Bluetooth technology evolution

	Bluetooth **1.0 (Basic rate)**	*Bluetooth* **2.1 (Enhanced data rate)**	*Bluetooth* **4 (Low-energy)**	*Bluetooth* **5 5.1, 5.2, 5.3**
Frequency range [1]	2400 to 2483.5 MHz	2400 to 2483.5 MHz	2400 to 2483.5 MHz [2]	2400 to 2483.5 MHz
Modulation	GFSK	Header: GFSK Data: π/4-DQPSK, 8DPSK	GFSK	GFSK
Frequency hopping	FHSS with 1600 hops/s (in normal operation) [3]	FHSS with 1600 hops/s (in normal operation) [3]	FHSS with 1600 hops/s (in normal operation) [3]	FHSS with 1600 hops/s (in normal operation) [3]
Duplex method	TDD	TDD	TDD	TDD
Channel spacing	1 MHz	1 MHz	2 MHz	2 MHz
Data rate	1 Mbps	2 to 3 Mbps	1 Mbps	1 to 2 Mbps

1. The *Bluetooth* specification includes a special frequency-hopping pattern to provide provisions for compliance with national limitations such as those in France. The frequency range for France is 2445.4 to 2483.5 MHz and the corresponding RF channels are
   f = 2454 + k MHz, K = 0, …, 22.
2. The *Bluetooth* low energy system uses center frequencies 2402 + k x 2 MHz (k = 0…39)
3. Hop speed may vary, depending on packet length

Standard based *Bluetooth* PHY Test Cases

The *Bluetooth* specifications are developed and licensed by the Bluetooth Special Interest Group (SIG). The *Bluetooth* Test Specification document contains the Test Suite Structure (TSS) and Test Purpose (TP) to test the *Bluetooth* RF layer including Basic Rate, Enhanced Data Rate, Low Energy, *Bluetooth* 5, 5.1 and 5.3. This specification is a basis for conformance tests of *Bluetooth* devices, giving a high probability of air interface inter-operability between different manufacturer's *Bluetooth* devices.

Table 2 provides a list of tests with their test purpose identifiers [1] and corresponding measurement applications for transmitter tests only.

Bluetooth transmitter test	Identifier	N/E/W9081EM0E Pathwave *Bluetooth* measurement application
Basic rate		
Output power	TRM/CA/01/C	Transmit analysis
Tx output spectrum – 20 dB bandwidth	TRM/CA/05/C	Output spectrum bandwidth
Tx output spectrum – adjacent CHP	TRM/CA/06/C	Adjacent channel power
Modulation characteristics	TRM/CA/07/C	Transmit analysis
Initial carrier frequency tolerance	TRM/CA/08/C	Transmit analysis
Carrier frequency drift	TRM/CA/09/C	Transmit analysis
Enhanced Data Rate (EDR)		
EDR relative transmit power	TRM/CA/10/C	Transmit analysis
EDR carrier frequency stability and modulation accuracy	TRM/CA/11/C	Transmit analysis
EDR differential phase encoding	TRM/CA/12/C	Transmit analysis
EDR in-band spurious emissions	TRM/CA/13/C	EDR in-band spurious emissions
Low Energy (LE) or Ultra Low Power (ULP)		
Output power at NOC	TRM-LE/CA/01/C	Transmit analysis
Output power at EOC	TRM-LE/CA/02/C	Transmit analysis
In-band emission at NOC	TRM-LE/CA/03/C	LE in-band emission
In-band emission at EOC	TRM-LE/CA/04/C	LE in-band emission
Modulation characteristics	TRM-LE/CA/05/C	Transmit analysis
Carrier frequency offset and drift at NOC	TRM-LE/CA/06/C	Transmit analysis
Carrier frequency offset and drift at EOC	TRM-LE/CA/07/C	Transmit analysis

1. Identifier format is: (Test)/CA/NN/C, in which
   - TRM = Transmitter test
   - CA = Capability test (defines the type of testing)
   - NN = Test purpose number
   - C = Conformance test performed on dedicated Bluetooth test system

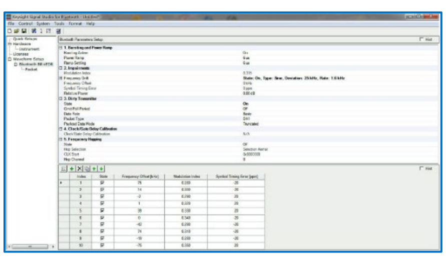
Testing *Bluetooth* devices

Most manufacturers develop smart devices with *Bluetooth*-certified chipsets and modules. Although the chipset vendors and module vendors provide reference designs that guarantee the RF performance, smart device manufacturers usually cannot leverage 100 percent of the reference design due to various requirements of the smart devices. For example, the small footprint of a device may require a different antenna design, or the design of a printed circuit board may cause the *Bluetooth* circuit to get crosstalk from the device's other digital and RF circuits. Therefore, smart device manufacturers need to test the *Bluetooth* RF performance in both R&D and manufacturing phases, in order to make sure their products meet the *Bluetooth* RF specifications.

For general purpose RF designers or system engineers, the solution for RF layer test procedure and specifications (TSS/TP 4) is the X-series signal analyzer, and N//E/W9081EM0E Pathwave *Bluetooth* measurement application for RF transmitter test. For receiver test, the solution is with a N5166B CXG vector signal generator and N7606EMBC Pathwave signal generation software for *Bluetooth*.

W9081EM0E *Bluetooth* signal analysis application runs inside the N9000B CXA signal

Figure 1. General purpose transmitter test solution for *Bluetooth* devices



N7606EMBC signal studio for *Bluetooth* creates and downloads waveform files into the

N7606EMBC Signal Studio for *Bluetooth*

Figure 2. General purpose receiver test solution for *Bluetooth* devices

A cost-effective Bluetooth Test solution

Many of the smart device manufacturers are small to medium size, and some are even start-ups. Since *Bluetooth* is a mature technology, these types of manufacturers often search for low-cost RF solutions.

One cost-effective *Bluetooth* test solution uses the Keysight Technologies N9321C basic spectrum analyzer (BSA).

To use this test solution, the device-under-test (DUT) is set to test mode to disable frequency hopping. Keysight recommends measuring the three advertising channels, shown in Table 3 below.

RF center frequency	Channel type	Data channel index	Advertising channel index
2402 MHz	Advertising channel		37
2404 MHz	Data channel	0	
2406 MHz	Data channel	1	
-	Data channel	-	
2424 MHz	Data channel	10	
2426 MHz	Advertising channel		38
2428 MHz	Data channel	11	
2430 MHz	Data channel	12	
-	Data channel	-	
2478 MHz	Data channel	36	
2480 MHz	Advertising channel		39
2402 MHz	Advertising channel		37

When the DUT transmits in the advertising channels in table 3, the N9321C BSA spectrum analyzer measures the frequency and power of the transmitted signals. The following screenshots show some measurement results on a smart band:

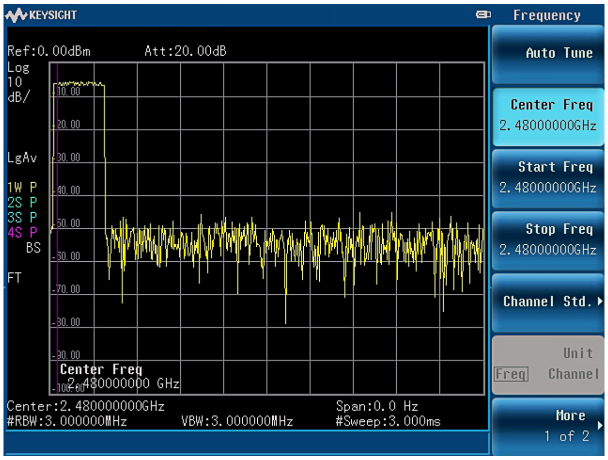


Figure 3. *Bluetooth* pulse

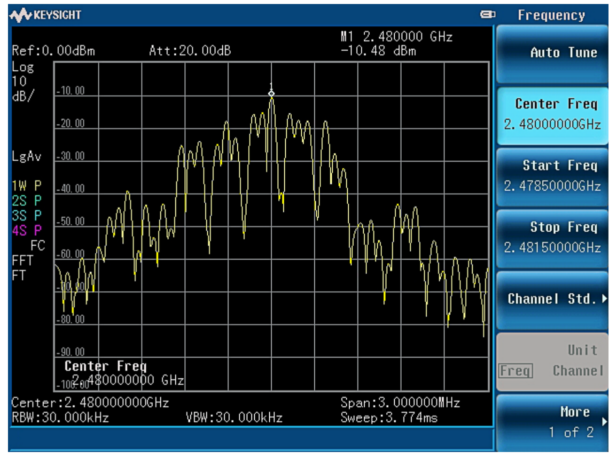


Figure 3. Peak search

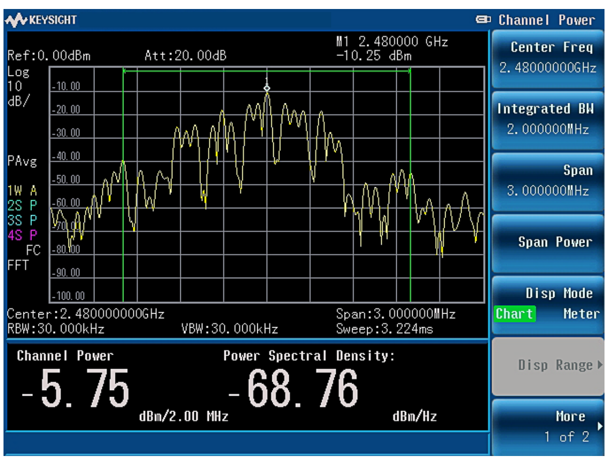


Figure 3. Channel power

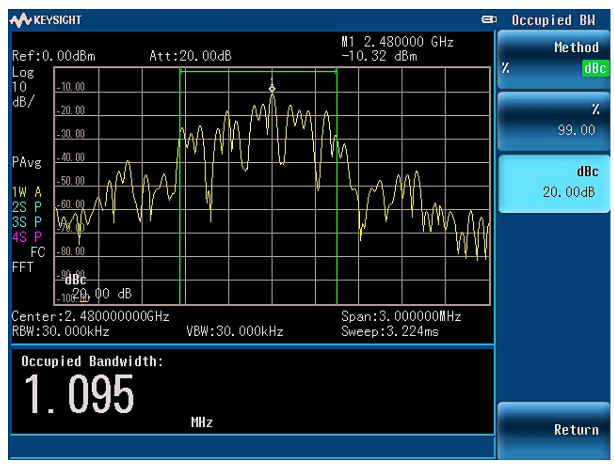


Figure 3. –20 dB bandwidth

Conclusion

There are pros and cons for this cost-effective test solution. When selecting a test solution, these attributes should be assessed along with the alternative test techniques. The small to medium size companies may find the N9321C-based cost-effective solution appealing for the following reasons:

- *Bluetooth* is a mature technology so complete *Bluetooth* RF test may not be necessary, especially for production test.
- The N9321C basic spectrum analyzers costs only a fraction of a *Bluetooth* test set.
- In test mode, *Bluetooth* devices do not hop over frequencies, so it is easier to make stable power measurement.
- This solution measures only three advertising channels to save test time.

The major limitations of this cost-effective solution are:

- It cannot measure modulation characteristics.
- The N9321C do not provide an automatic *Bluetooth* test application. An external computer and custom-developed software are required for an automated test solution. However, since the N9321C support USB, LAN, and GPIB ports, as well as SCPI programming, it is possible for customers to develop their own test software.

For customers who needs deeper dive into *Bluetooth* signal analysis, the N9000B CXA signal analyzer with W9081EM0E *Bluetooth* measurement application is a preferred solution.