WHITEPAPER

Practical Manufacturing Testing of Bluetooth® Wireless Devices

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Preface

The Production Testing of Bluetooth-Compliant Wireless Devices handbook provides an introduction to the production testing of Bluetooth-compliant wireless devices.

The preface includes the following topics:

- Who should use this guide
- What this guide contains
- Related documentation
- Conventions used in this manual

Who Should Use This Guide

The Production Testing of Bluetooth-Compliant Wireless Devices handbook is intended for test engineers and other technical personnel who intend to learn about testing of Bluetooth-compliant wireless devices.

What This Guide Contains

This document is divided into seven chapters and an appendix and includes the following topics:

Chapter 1: Overview of Bluetooth technology trends

Chapter 2: Introduction to Bluetooth technology and testing

Chapter 3: Advantages of LitePoint approach to testing

Chapter 4: Transmit measurements

Chapter 5: Receive measurements

Chapter 6: Information on LitePoint offerings for Bluetooth testing

Appendix A1: Bluetooth reference signals

Appendix A2: Test Purpose (TP) identifiers and API functions

Chapter 1 Bluetooth Technology Trends—An Overview

Bluetooth wireless technology exists as a standard technology in most wireless devices available on the market today and this trend is expected to continue in the future. The prevailing usage of Bluetooth technology is being driven by the ability to connect mobile phones to headsets using this technology. The catalyst for this shift was a new regulation, introduced in the U.S. in 2008, which requires motor vehicle drivers to use their mobile phones hands-free. While acceptance of this new paradigm was not a spontaneous movement, consumer behavior has since changed and consumers are ready to use Bluetooth to connect their mobile phones to devices other than hands-free headsets.

As demand increases, manufacturers of Bluetooth devices can expect a ramp-up of production volumes resulting in a decrease in the cost of the devices. The time to market becomes one of the main factors to determine the success of new products. All of these factors—high volumes, low prices, fast time-to-market—create the need for efficient and affordable solutions to test quality and compliance of Bluetooth-compliant wireless devices in the production line.

This document is intended to help manufacturers by offering an introduction to the production testing of Bluetooth-compliant wireless devices. In particular, it focuses on testing of Bluetooth V1.0, V1.2, V2.0 and V2.1, the commonly available versions in the market today.

This document provides a brief description of the Bluetooth modulation, data rates and packets and then discusses the measurement criteria used for meeting minimum requirements necessary for the distribution of the Bluetooth-compliant wireless devices in the marketplace. It also addresses the significance of each of these measurements and provides guidelines on how to set up the measurement procedure and interpret results.

Chapter 2 Introduction to Bluetooth V1, V2+EDR

Bluetooth wireless technology is a short-range communications system that operates in the unlicensed ISM band at 2.4 GHz. The Bluetooth regulatory frequency range is 2.400 to 2.4835 GHz. It is based on 79 RF channels (k = 0,…,78) with 1 MHz spacing. To comply with out-of-band regulations, a guard band, which is of 2 MHz bandwidth in the lower band edge and 3.5 MHz bandwidth in the upper band edge, is used. The system employs a frequency hop transceiver to combat interference and fading and provides many FHSS carriers. The basic hopping pattern is a pseudo-random ordering of the 79 frequencies in the ISM band.

Several versions of Bluetooth exist, of which the most common in wireless devices today are V1.0, V1.2, V2.0+EDR, and V2.1+EDR. The testing needs of versions V1.0 and V1.2 are very similar[1], and so are those of V2.0+EDR and V2.1+EDR. In the following, these four standards will be referred to as simply V1 (including V1.0, V1.2) and V2 (V2.0+EDR, V2.1+EDR). In addition to other activities, the Bluetooth Special Interest Group (SIG) drives the development of the technology by publishing Bluetooth specifications.

This chapter includes the following sections:

2.1. Bluetooth Modulation and Data Rates

2.2. Bluetooth Packets

2.3. Bluetooth Transmitter Power Classes

2.4. Bluetooth Test Modes

2.5. Manufacturing Testing—It's about Consistency, not Compliance

2.1. Bluetooth Modulation and Data Rates

Bluetooth modulation is a two-level Frequency Shift Keying, which indicates that the modulated carrier shifts between two frequencies that represent a 0 and a 1.

Both the V1 and V2 versions of Bluetooth include a Basic Rate mode. To minimize transceiver complexity, the Basic Rate operation uses a shaped, binary frequency modulation called Gaussian Frequency Shift Keying (GFSK) with a bandwidth bit period of BT=0.5; the symbol rate is 1 Megasymbol per second (Ms/s) and a gross-air bit rate is 1 Megabit per second (Mbps).

The Enhanced Data Rate (EDR) is an optional mode that was introduced in the Bluetooth version 2. EDR uses PSK modulation and has two variants: π/4-DQPSK and 8DPSK. The symbol rate for all modulation schemes is still 1 Ms/s. However, the nominal gross air data rate is 2 Mbps for EDR using π/4-DQPSK and 3 Mbps for EDR using 8DPSK[2].

A key characteristic of the EDR mode is that the modulation scheme is changed within the packet, as explained later. The supported modulation and data rates for the Bluetooth versions 1.0 to 2.1 are shown in Table 1.

Bluetooth Version	Modulation	Data Rate
Bluetooth V1.0	GFSK	1 Mbps
Bluetooth V1.2	GFSK	1 Mbps
Bluetooth V2.0	GFSK, π/4-DQPSK (EDR), 8DPSK (EDR)	1 Mbps, 2 Mbps, 3 Mbps
Bluetooth V2.1	GFSK, π/4-DQPSK (EDR), 8DPSK (EDR)	1 Mbps, 2 Mbps, 3 Mbps

Table 1. Supported modulation and data rates for the Bluetooth versions 1.0 to 2.1.

[1] with the exception of Adaptive Frequency Hopping, a major area of improvement in V1.2 with respect to V1.0
[2] the practical data rate is lower than the nominal data rate

2.2. Bluetooth Packets

The physical RF channel is sub-divided into time units known as slots. Data is transmitted between Bluetooth devices in packets, which are positioned in these slots. The general packet format of Basic Rate packets is shown in Figure 1. Each packet consists of three entities, namely the access code, the header, and the payload, which carries the header information. Table 2 provides a list of all existing basic rate packet types.

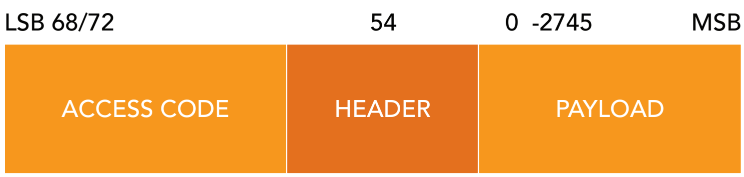


Figure 1. Basic Rate packet format. The number of bits per entity is indicated.

Packet Type	Description
NULL, POLL, FHS	System packets
DM1, DM3, DM5	Medium rate
DH1, DH3, DH5	High rate
HV1, HV3, HV5	Digitized audio
DV	Mixed data/voice
AUX1	Other uses

Table 2. Basic rate packet types.

A key characteristic of the EDR mode is that the modulation scheme is changed within the packet. The access code and packet header are transmitted with the Basic Rate of 1 Mbps GFSK modulation scheme, whereas the subsequent guard time, synchronization sequence, payload, and trailer sequence, which has two symbols, are transmitted using the EDR PSK modulation scheme with a data rate of 2 Mbps or optionally 3 Mbps.

The Bluetooth packet names can have a numerical prefix and/or a numerical suffix. A numerical prefix represents the EDR data rate for that packet and a numerical suffix represents the packet slot length. For example, the three packet names: 2DM1, 3DM3 and 2DM5 represent DM packets with data rates 2, 3 and 2Mbps and slot length of 1, 3 and 5 respectively. Figure 2 represents the general format of EDR packets.

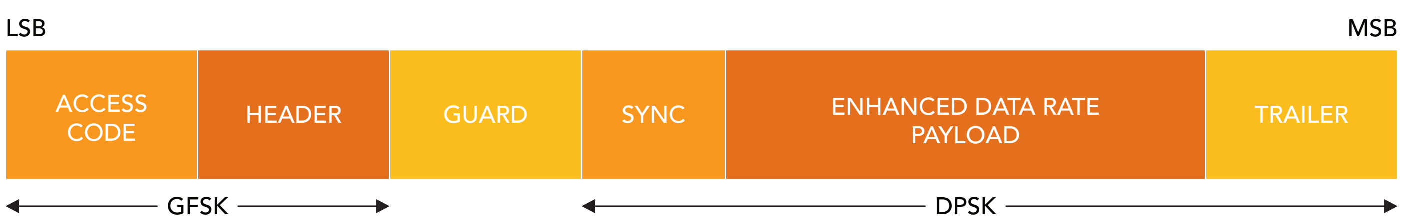


Figure 2. EDR packet format.

2.3. Bluetooth Transmitter Power Classes

Bluetooth devices are classified into three power classes, defined by their maximum and minimum output power characteristics as shown in Table 3. Bluetooth SIG mandates that power class 1 devices implement power control for limiting the transmitted power over +4 dBm. This helps optimize the output power in a physical link using Link Manager Protocol (LMP) commands. Implementing power control is optional for class 2 and class 3 modules and could be used for optimizing the power consumption and overall interference level.

Power Class	Maximum Output Power	Nominal Output Power	Minimum Output Power	Operating Range
1	100 mW (20 dBm)	n.a.	1 mW (0 dBm)	100 meters
2	2.5 mW (4 dBm)	1 mW (0 dBm)	0.25 mW (-6 dBm)	10 meters
3	1 mW (0 dBm)	n.a.	n.a.	1 meter

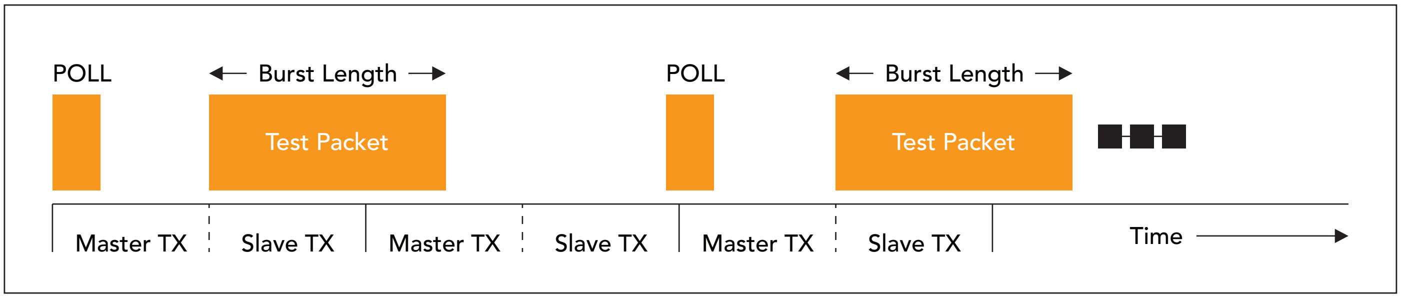
Table 3. Bluetooth transmitter power classes.

2.4. Bluetooth Test Modes

During testing, the Bluetooth device can operate in Transmitter (Tx) Test Mode or Loopback Test Mode. In Loopback test mode, the Bluetooth device receives the packets sent by the tester and transmits back the payload using the same packet type. While in Transmitter test mode, the Bluetooth device is simply asked to transmit a type of packet according to specific instructions sent by the tester. Loopback and Transmitter test modes are schematically described in Figure 3.

For testing Bluetooth, three types of payload data are used: PRBS9, 10101010, and 11110000. These different types offer specific advantages while testing for different performance parameters. For example, PRBS9, which is a pseudorandom bit sequence of period 29 –1, produces a modulated signal that simulates a real conversation.

Transmitter Test Mode



Loopback Test Mode

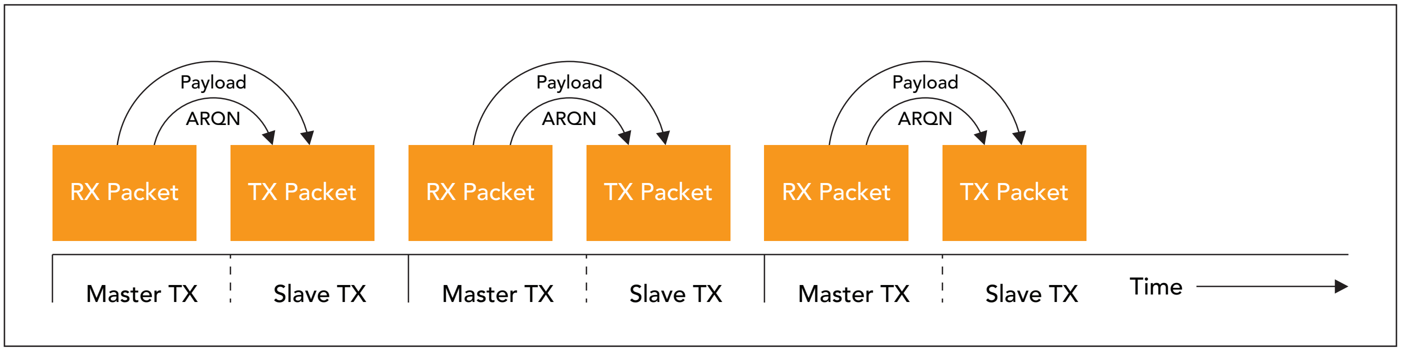


Figure 3. Representation of the two Bluetooth available test modes: transmitter (Tx) test mode and loop-back test mode. In some cases, loop-back test mode is offset by an additional packet.

2.5. Manufacturing Testing—It's About Consistency, Not Compliance

Bluetooth is a standard developed by ETSI and, consequently, a very complete and exact specification. The *Core Specification of the Bluetooth System* document includes clear definitions as to how each defined test is to be tested. As an engineer, this is clearly desirable. However, it should be clear that the specified tests are not designed for manufacturing testing. The intent of the specified tests is to ensure a given device can interoperate with other devices and meet minimum requirements. If one looks at the Bluetooth Core Specification this should be clear, as the majority of the document describes the operation of the device and only a very small portion describes the physical minimum RF performance required to actually meet the specifications.

For manufacturing testing, one usually assumes that software and chip are working correctly, and only looks for manufacturing defects. Accordingly, one tends to focus on the tests described in the specified RF test in Volume 2 (Core System Package) of the current Bluetooth *Core Specification document* (Dec. 2009) as well as Section 5 (Test Purposes) of the Bluetooth *Test Specification* document.

Even in the Core System Package volume and Test Purposes section, however, the majority of the specified RF tests are not true manufacturing tests: they are, instead, defined merely to ensure interoperability. For example, the EDR Differential Phase Encoding test (TRM/CA/12/C) verifies that the encoder performs the correct translation of transmitted bits to RF modulation. Since this is a DSP (SW) functions in the chip, it makes no sense in a manufacturing environment to test in every chip if the DSP code has somehow changed. Similarly, the C/I test (RCV/CA/09/C Basic Rate, RCV/CA/10/C EDR) in the receiver tests that the DSP receiver is able to work in the presence of an in-band interferer. This is again a test of the DSP functionality, which can be assumed not to change from DUT to DUT. In contrast, performing a typical Differential Error Vector Magnitude test (DEVM, TRM/CA/11/C) is important since it ensures that the modulator encodes the transmitted data correctly, or large DEVM error will be present.

Similarly on the receive side, the EDR - Bit Error Rate (BER) Floor test (RCV/CA/08/C) is a test that the demodulator (DSP) can decode a single Bluetooth signal with high SNR without generating errors (essentially the same test as the differential encoding test on the transmit side), hence it is of little use in a manufacturing environment. Instead, one should only ensure the BER performance (in practice, the noise figure) is sufficiently low.

An additional consideration to make is that Bluetooth is a relatively old standard, and it was derived based on the technology available at the time. In addition, the standard targeted a low cost implementation, so the lowest cost system implementation was considered to define the Specification documents. Looking at typical system solutions at the time and at the tests in the Specification documents, it becomes clear that the Bluetooth SIG expected an open-loop VCO modulation scheme. The inclusion of Basic Rate tests such as Initial Carrier Frequency Tolerance (TRM/CA/08/C), Modulation Characteristics (TRM/CA/07/C), and Frequency Drift (TRM/CA/09/C) further corroborates this conclusion, as explained below.

VCO modulation is a very inexpensive way to implement a GFSK transmitter. A schematic open-loop modulation architecture is shown in Figure 4. The architecture is based on the VCO being locked to the desired frequency using a PLL; once locking of the VCO is achieved, the loop is opened and the VCO is free running. Opening the loop may cause some charge to be injected into the loop filter causing a small frequency change; hence, the Initial Carrier Frequency Tolerance was defined in the Specification.

When the transmission is started the loop filter voltage is modulated using a baseband analog signal, often through a 2nd port, causing the VCO to change frequency (the voltage being proportional to the desired frequency change). As there will be variations from VCO to VCO, the Specification defines a minimum and maximum allowed Frequency Deviation (TRM/CA/07/C, known as Modulation Characteristics test) to ensure a correctly modulated signal given the same baseband signal.

Finally, as the loop filter is opened, the voltage on the VCO is stored in a large capacitor. As the capacitor will charge over time, a maximum Frequency Drift (TRM/CA/09/C) over time is defined in the Specification.

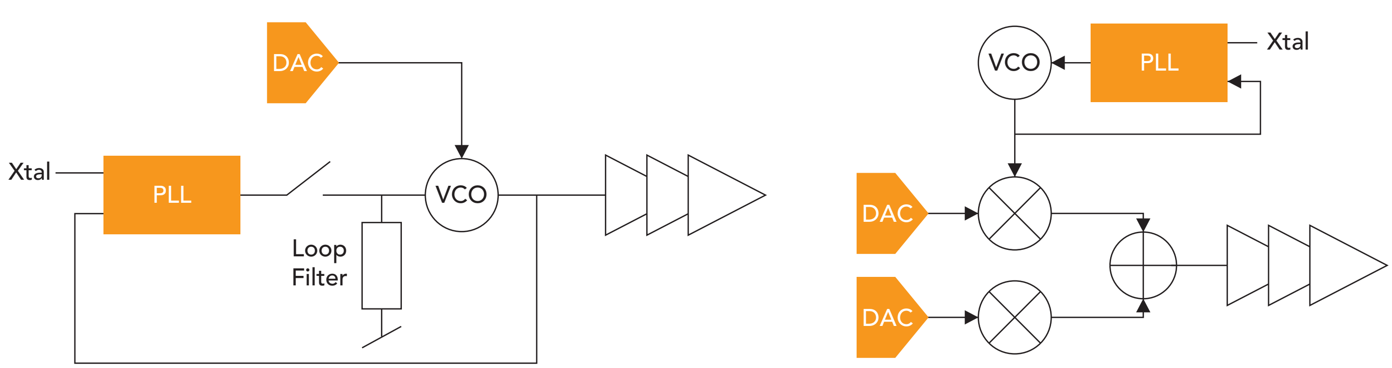
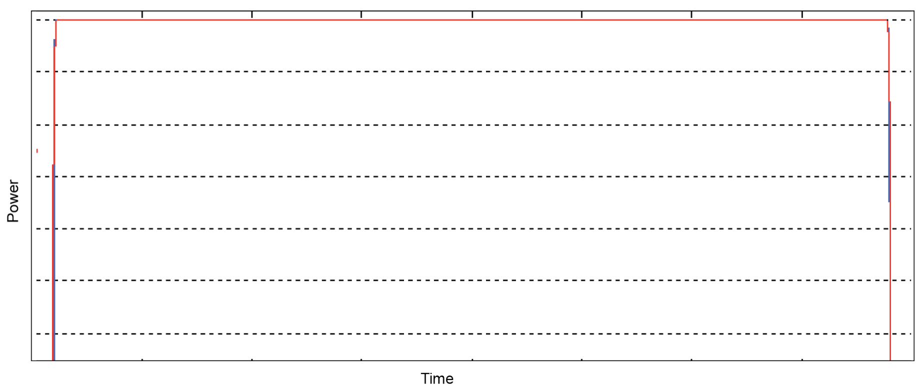


Figure 4. Typical open Loop VCO modulation transmitter vs. direct up-conversion transmit architecture.

As explained, many of the tests described in the Specification target an expected RF transmit system solution. Chip technology, however, has evolved substantially since the time the Specification was first defined and very few Bluetooth solutions today use open-loop VCO modulation. Today, a direct up-conversion scheme from baseband or very low IF is usually implemented to allow full integration on a single chip. Direct up-conversion schemes do not suffer from the typical problems that an open-loop VCO modulation exhibits. Modulation is more accurate, as it is defined by digital signals directly up-converted to RF, so one should not expect significant variation in the Frequency Deviation or Modulation Characteristics (TRM/CA/07/C) from chip to chip. Moreover, the VCO is operated in closed loop, to no Frequency Drift (TRM/CA/09/C) should be expected beyond possible frequency pushing during transmitter enabling, and the Initial Carrier Frequency Tolerance (TRM/CA/08/C) is mostly set by the frequency accuracy of the reference crystal (and possibly some frequency pushing).

Considering all of the above, it makes little sense for manufacturers of modern chip architectures to fully test for the transmitter performance specified for Basic Rate signals. One needs to verify that the transmitter works correctly, but there is no practical need to test for all the proposed tests in the Bluetooth Specification document. A simple measurement of the transmitter can determine most of the desired values and estimate the remaining values with accuracy that should be sufficient to ensure that no manufacturing problems has occurred. With the event of Bluetooth EDR, which makes extensive use of complex modulation, one should instead focus on ensuring that the chip meets this more challenging requirement, and possibly perform a single verification of the Basic Rate transmitter.



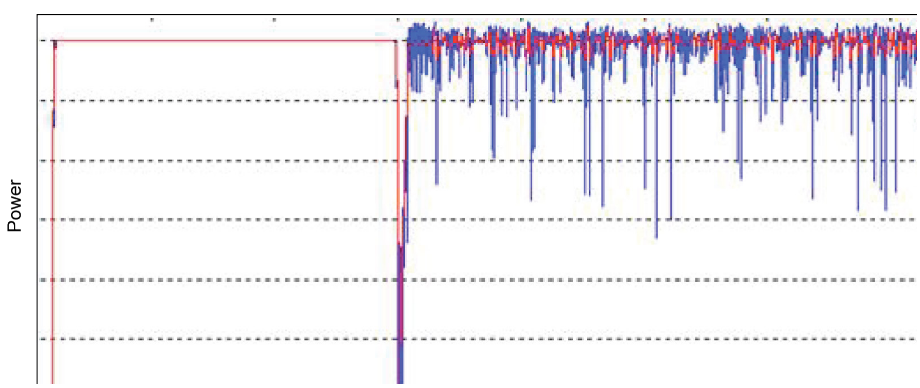


Figure 5. Comparison between BDR (top) and EDR (bottom) signals. (Complex modulation in 2nd par of EDR signal)

Finally, for a manufacturing environment the specification on the receive Sensitivity (RCV/CA/01/C, RCV/CA/02/C, RCV/CA/06/C) is worthy of discussion. Bluetooth is designed to implement a Personal area Network (PAN) and as such only needs to support a limited range. In addition, the standard was designed to offer the lowest possible cost at the time of conception. As a consequence, a very relaxed sensitivity specification is provided; today, typical receivers offer sensitivities 15-20 dB better than what is required by the Specification document. Even with a manufacturing error, a device may possibly pass a receive Sensitivity test at the level defined by the Specification. One should, therefore, consider testing the receive Sensitivity closer to the actual device performance rather than simply use the limit specified in the specification.

The improved sensitivity of typical modern receivers is partially given by improved RF performance, but more so by more advanced receivers. This further argues that one should not need to test the C/I (RCV/CA/09/C Basic Rate, RCV/CA/10/C EDR) and BER Floor (RCV/CA/08/C).

Chapter 3 Bluetooth Testing—The LitePoint Way

LitePoint recognizes that time is of essence in a production-line testing facility. Minimizing test time reduces costs and enables faster time-to-market; therefore, the goal is to obtain the minimum test time without compromising the ability to spot failures. To achieve this goal, LitePoint equipment uses non-link testing and a smart approach to Bluetooth test planning.

This chapter contains the following sections:

3.1. Using Non-link Based Bluetooth Control

3.2. Performing Effective Bluetooth Tests

3.1. Using Non-Link Based Bluetooth Control

The traditional method of testing Bluetooth devices is to use link-based mode. Here, the tester interfaces the software stack of the DUT to establish a link—as if the tester were a Bluetooth device. This approach has become popular because it tests for software failures in addition to hardware failures and it does not require any code development for the tester to communicate with the DUT. In a production line, however, one does not need to test software: failures are due to manufacturing differences, which only affect the hardware. The time to setup and teardown a connection (link) is essentially a wasted and expensive resource.

LitePoint equipment uses non-link testing, where the tester communicates with the Host Control Interface (HCI) of the DUT directly. The advantage of non-link testing is that a significant reduction in test time per DUT can be achieved, since the tester does not need to establish a link with the DUT, and to do so every time the frequency changes. The trade-offs are that the following are required:

- Special DUT driver capability;
- Development of a test program up front

Currently, most major chipsets support non-link testing3. Moreover, manufacturers of Bluetooth wireless devices can leverage LitePoint's extensive software expertise to accelerate the development of a test program. In a high-volume manufacturing environment, the significant reduction in test time per DUT typically offsets the effort required to meet the latter requirement.

A comparison between link-based and non link-based Bluetooth control is shown in Figure 6 and Figure 7.

[3] Please contact LitePoint for information on specific chipsets.

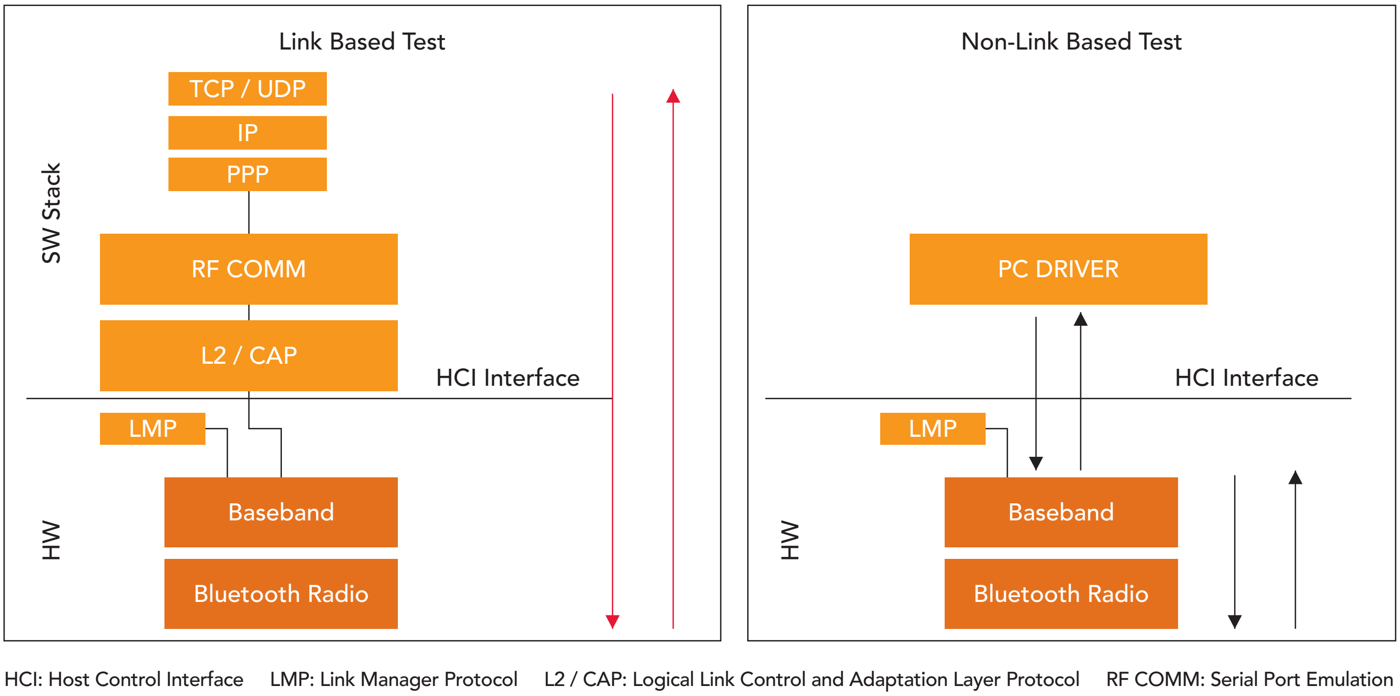


Figure 6. Difference in architecture between link-based and non-link based testing.

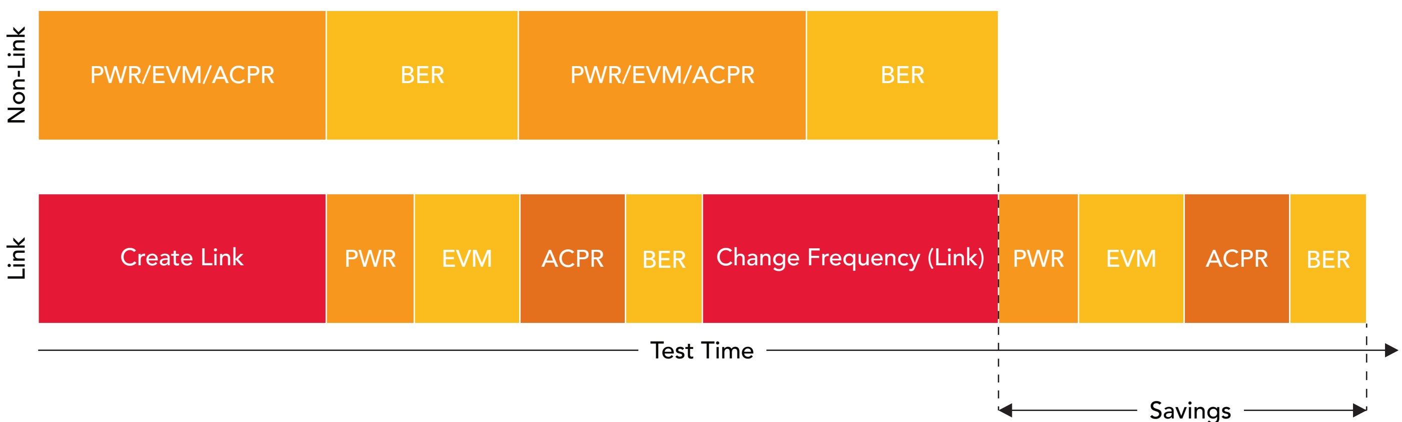


Figure 7. Difference in time between link-based and non-link based testing.

3.2. Performing Effective Bluetooth Tests

Bluetooth SIG recommends that the majority of the measurements described in this document are repeated at no fewer than the following three key frequencies of Bluetooth transmission: 2.402 MHz, 2.441 MHz, and 2.480 MHz, which are the lowest, midrange, and highest operating frequencies respectively. While this approach is certainly worthwhile during the product development phase, the main goal in production is to test for failures. Therefore, the greatest need is the ability to verify the device functionality at a single frequency. Testing multiple frequencies becomes a time-consuming and costly effort with very low probability of spotting more failures. Understandably, some parameters such as measuring transmit power and modulation is critical to the device performance and therefore need testing at all frequencies.

LitePoint knows exactly how to test only the functionality and critical performance, minimizing test time by using an effective Bluetooth test flow. Functionality is tested at fundamental data rates and at a single frequency and power; performance is tested over frequency for critical parameters.

Chapter 4 Transmit Measurements

This chapter describes the measurements performed during a Bluetooth signal transmission. The most commonly used transmit measurements as follows:

4.1. Transmit Power Measurements

4.2. Transmit Spectral Measurement

4.3. Transmit Modulation Measurements

The Bluetooth test specification allows testing with hopping always off. In addition, unless otherwise specified: (1) the DUT always transmits PRBS9 packet data at the maximum output power and the test system transmits at a power ranging between -60 dBm and -40 dBm at the DUT receiver input; (2) the test must always be performed using loopback mode and that return packets are correctly recognized by the test system must also be verified. If loopback mode is not available or if specified otherwise, the Tx mode might be used for transmit measurements.

4.1. Transmit Power Measurements

Transmit Power Measurements for Bluetooth include the following:

- Maximum Output Power
- Maximum Power Density
- Power Control
- EDR -Relative Transmit Power

Power level is a critical performance parameter in a Bluetooth communication system: it must be high enough to enable a robust link, yet not as high as to waste battery life and create interference with other devices. Therefore, it must be tested while the DUT operates at 2.402 MHz, 2.441 MHz, and 2.480 MHz operating frequencies, which are the lowest, mid, and highest operating frequencies respectively.

Maximum Output Power

What is it?

Maximum Output Power is the maximum RF transmitted power of the DUT (mW, dBm). It is usually expressed as a peak power (PPK) and average power (PAV).

Why is it important?

Bluetooth devices are classified into three power classes based on the modulation mode with the highest output power. The Bluetooth SIG specifies that the modulation mode must meet the Maximum Output Power requirements for the power class, described in Chapter 2.3 of this document; also, the Maximum Output Power used for the other modulation modes must not exceed that of the modulation mode used for classification.

This means that all DUTs must have a P_{PK} of less than 200 mW (23 dBm) and the following must be observed:

- If the DUT is a power class 1 device, the PAV value must be greater than 1 mW (0 dBm)
- If the DUT is a power class 2 device, the PAV value must be greater than 0.25 mW (-6 dBm) and less than 2.5 mW (4 dBm)
- If the DUT is a power class 3 device, the PAV value must be less than 1 mW (0 dBm)

In addition to the technology specification, regulations specific to each country of destination may limit the Maximum Output Power. For example, ETSI in Europe limits the radiated average power to less than or equal to100 mW, which is equivalent to the Maximum Output Power of a power class 1 device.

How is it measured?

The Maximum Output Power is calculated over the longest supported data rate packet in Basic Rate or EDR mode (if applicable) with full payload (1, 3 or 5 slot). The DUT must operate at maximum power setting, if power control is available. The tester records the highest power value in the trace (PPK) and calculates the average power over at least 20% to 80% of its duration (PAV).

Where is it tested?
Testing Maximum Output Power is relevant to manufacturing. With LitePoint Bluetooth solutions, the requirements on Maximum Output Power are verified during measurement of the Transmit Modulation characteristics, with no time added to the overall test procedure.

Maximum Power Density

What is it?
Maximum Power Density is the maximum RF transmitted power in a specified bandwidth of operation of the DUT.

Why is it important?
The Bluetooth SIG specifies that any modulation mode must not exceed 100 mW (20 dBm) per 100 kHz Maximum Power Density for any power class. In addition to the technology specification, regulations specific to each country of destination place an upper limit to the power density. ETSI in Europe requires that the Maximum Power Density be limited to -20 dBW (10 mW) per MHz.

How is it measured?
The measurement procedure is similar to that described for the Maximum Output Power. The power density is calculated as the peak value of the time-domain trace captured by the tester at the frequency corresponding to the peak value of power measured with a 100 kHz resolution bandwidth in the entire Bluetooth operating range.

Where is it tested?
Testing Maximum Power Density is relevant to manufacturing of only class I Bluetooth devices. Class II and III devices will always meet Maximum Power Density requirements unless undesired frequency components are present in bandwidth. If present, the latter are identified during measurement of the Transmit Modulation characteristics.

Power Control

What is it?
Power Control is used for limiting the transmitted power over +4 dBm and is a mandatory feature of any power class 1 device. Power control capability under +4 dBm is optional and could be used for optimizing the power consumption and overall interference level. With this feature, if the received signal characteristics differ too much from the preferred value of a Bluetooth device, the device may request an increase or a decrease of the other device's TX power. The power adjustment requests may be made at anytime following a successful baseband paging procedure.

Why is it important?
Bluetooth SIG specifies that Power Control is characterized by power steps, with a maximum step size of 8 dB and a minimum step size of 2 dB. In addition, the steps must form a monotonic sequence from the maximum transmit power of +20 dBm down to 4 dBm or less. Note: to implement a power control link, the DUT must also implement a RSSI.

How is it measured?
The DUT transmits DH1 packets at the maximum output power to the tester, which measures the average Maximum Output Power (PAV). Then, the DUT output power is decreased by one power step using Power Control and PAV is measured again. This sequence is repeated until the minimum output power of +4 dBm is met, and the step size compared to the specifications (2dB ≤ step size ≤ 8 dB).

Where is it tested?
Power Control validation is verified during the product development phase and is usually not relevant to manufacturing. Testing Power Control with LitePoint solutions can be achieved; however, it requires knowledge of the Bluetooth stack operation, and specifically of the gain stops that the DUT uses.

Enhanced Data Rate (EDR) – Relative Transmit Power

What is it?
EDR – Relative Transmit Power is the difference in average transmit power during frequency-modulated (GFSK) and phase-modulated (DPSK) portions of an EDR packet.

Why is it important?
Bluetooth SIG defines the requirement on the relative power of the GFSK and PSK portions of the EDR packet as follows. The average power level during the transmission of Access Code & Header period is denoted as PGFSK and the average power level during the transmission of the synchronization sequence and the payload is denoted as PDFSK. The following inequalities must be satisfied independently for every EDR packet transmitted: (PGFSK -4 dB) < PDPSK < (PGFSK +1 dB).

How is it measured?
The DUT transmits the longest supported π/4-DQPSK packet type (2-DHx or 2-EVx) with maximum length payload. Tester calculates the average power (PGFSK) over at least 80% of the GFSK portion of the packet, and the average power (PDPSK) over at least 80% of the DPSK. If 8DPSK modulation is supported by the DUT, then the measurement should be repeated also while the DUT transmits longest-supported 8DPSK packet type.

Where is it tested?
Testing EDR Relative Transmit Power is relevant to manufacturing. Here, however, LitePoint demonstrates that measuring over a smaller GFSK portion of the packet than that specified by the Bluetooth SIG is sufficient and reduces substantially the time required for an otherwise very long measurement. Moreover, in LitePoint test flow, testing EDR Relative Transmit Power is accomplished during verification of the Transmit Modulation characteristics, hence with no time added to the overall test procedure. In some chips, the Relative Power Test is not relevant, as the gain step is controlled at baseband – thus very accurate. As the result comes with no time added using LitePoint equipment, it is good practice to include it even when testing such chips.

4.2. Transmit Spectral Measurements

The following are the Bluetooth Transmit Spectral Measurements and are described in this section:

- 20 dB Bandwidth
- Frequency Range
- Adjacent Channel Power
- In-Band Spurious Emission
- Out-of-Band Spurious Emission

With these tests, the power levels are analyzed in the frequency domain to ensure minimum interference with other communication technologies as well as compliance to regulations, where applicable.

20 dB Bandwidth

What is it?
20 dB Bandwidth is defined as the frequency range outside which the DUT signal power drops at least 20 dB below the peak signal power.

Why is it important?
The Bluetooth SIG requires the 20 dB Bandwidth to be equal or less than 1.0 MHz, in order to minimize interference.

How is it measured?
The DUT transmits the longest supported packet with full payload. The tester finds the highest power value in the transmit channel, which is the peak of the emission; then, it measures the lowest frequency below and, the highest frequency above the operating frequency at which the transmit power drops 20 dB below the level measured. The difference between the lowest and highest frequencies measured is the 20 dB Bandwidth.

Where is it tested?
Testing 20 dB Bandwidth is relevant to manufacturing.

Frequency Range

What is it?
Frequency Range is defined by the range in which the power density of the DUT is above a specified level.

Why is it important?
Bluetooth SIG specifies that the Frequency Range is defined by a power density of –80 dBm/Hz or higher4 and must be within the allowed frequency band: 2.4 GHz – 2.4835 GHz.

How is it measured?
The test procedure is very similar to that described for the 20 dB Bandwidth. To measure the Frequency Range, the DUT first transmits the longest supported packet with full payload at the lowest operating frequency. The tester finds the lowest frequency below the operating frequency at which point the spectral power density drops below –80 dBm/Hz. The measurement is then repeated while the DUT transmits on the highest operating frequency. The tester finds the highest frequency above the operating frequency at which point the spectral power density drops below –80 dBm/Hz. The measured lowest and highest frequencies define the Frequency Range.

Where is it tested?
Testing Frequency Range is relevant to manufacturing. LitePoint recommends verifying the Power Density at only the lowest and highest frequencies unless high power variations are identified during the product development stage.

Adjacent Channel Power

What is it?
Adjacent Channel Power is the sum of the measured power in a 1 MHz channel within the Bluetooth Frequency range while the DUT transmits a signal in an adjacent channel. The adjacent channel number can be secondary, where the difference in the channel number is two, or greater, where the difference in the channel number is three or more.

Why is it important?
Bluetooth SIG requires that the Adjacent Channel Power does not exceed -20 dBm for the second adjacent channels and -40 dBm for the third and subsequent adjacent channels, in order to minimize interference with other Bluetooth devices. Refer to Table 4 for information on the adjacent channel power specifications.

How is it measured?
For both Basic Rate and EDR mode[5], the Adjacent Channel Power is measured on the channel number N while the DUT transmits packets on the channel M. In a first step, M=3, i.e. the DUT transmits in the channel 2 MHz away from the lowest operating frequency, and the power of the trace is measured in any 1 MHz channel N with $N \neq M$. The typical test set measures N such that $|M-N| \leq 3$, though it is recommended to measure Adjacent Channel Power in any 1 MHz channel N such that $|M-N| \leq 5$. Then the test sequence is repeated while the DUT transmit frequency is in the channel at the middle of the operating range and two channels below the highest operating frequency.

[4] The spectral power density is at -30 dBm if measured in a 100 kHz bandwidth.
[5] The test is the same for Basic Rate and EDR but the DUT always transmits the longest supported packet type

Where is it tested?
Testing Adjacent Channel Power is relevant to manufacturing, especially for class 1 power devices since the specifications provides by the Bluetooth SIG are absolute, that is, independent from the transmit signal power. (A 20 dB relative requirement overrules the absolute adjacent channel power requirement stated in Table 4 only if the output power is less than 0dBm).

Δ Channel Number	Frequency Offset	Transmit Power
$\|M-N\|=2$	= 2 MHz	-20 dBm
$\|M-N\| \geq 3$	≥ 3 MHz	-40 dBm

Table 4. Adjacent Channel Power specifications.

In-Band Spurious Emission

What is it?
In-Band Spurious Emission is the sum of the power in a 500 kHz bandwidth of a channel while the DUT transmits a signal in the adjacent channel.

Why is it important?
For Basic Rate, Bluetooth SIG specifies the In-Band Spurious Emission to be at least 20 dB below the maximum power measurement for up to 500 kHz from the carrier.

For EDR, the In-Band Spurious Emission must be at least 26 dB below the maximum power measurement for up to 500 kHz from the carrier. In combination with the requirements of Adjacent Channel Power, the requirements of In-Band Spurious Emission define the so-called transmitter Spectral Mask of the EDR Bluetooth signal shown in Figure 8.

How is it measured?
This test is similar to Adjacent Channel Power measurement test except that the measurement is gated to cover only the DPSK portion of the packet. As indicated in section 3.3.3, In-band Spurious Emissions is measured with the DUT transmitting on one channel and receiving on a second channel. Note that the channel may change between reception and transmission, but always returns to the same transmit channel. The power is measured between 1 MHz and 1.5 MHz from the carrier.

Where is it tested?
Measuring In-Band Spurious Emission is relevant to manufacturing. With LitePoint test solutions, verification of the SIG requirements is obtained during measurement of the Adjacent Channel Power, hence with no time added to the overall test procedure.

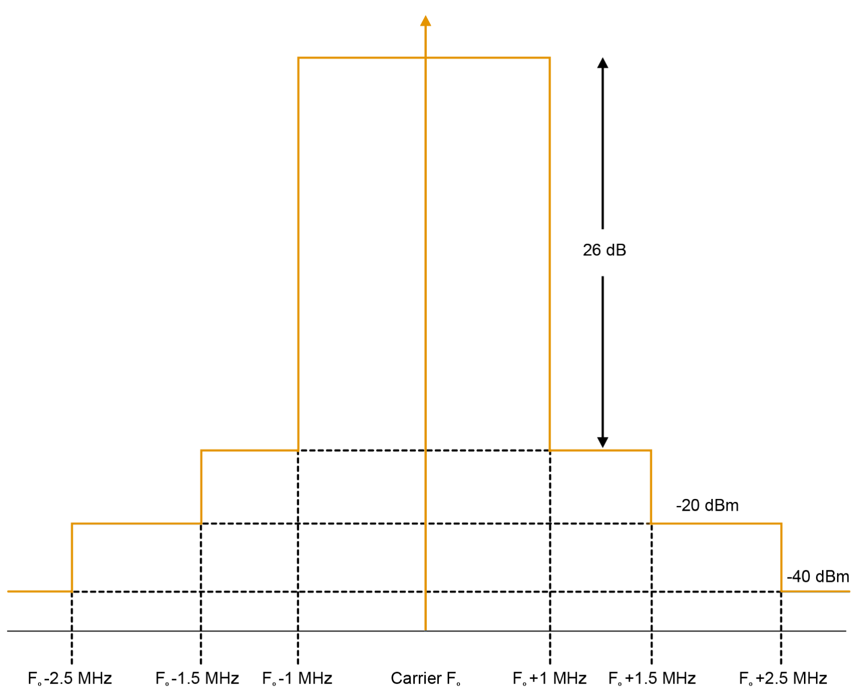


Figure 8. Transmitter spectral mask for EDR mode Bluetooth signal.

Out-of-Band Spurious Emission

What is it?
Out of band spurious emissions are unwanted emissions immediately outside the channel bandwidth resulting from the modulation process and non-linearity in the transmitter. It is the sum of the power in a 1 MHz bandwidth outside of the Bluetooth Frequency Range while the DUT transmits a signal in a channel within its normal operating range.

Why is it important?
Bluetooth SIG does not specify emissions that are outside of the ISM band: the equipment manufacturer is responsible for compliance in the intended country of use for emissions outside of the ISM band. The measurement is especially important at and near the edges of the Bluetooth Frequency Range.

How is it measured?
The measurement is very similar to that of Adjacent Channel Power; only the power of the trace is measured in 1 MHz bandwidth outside the Bluetooth Frequency Range.

Where is it tested?
Meeting Out-of-Band Spurious Emission requirements is a design problem and emission requirements should be verified during the product development phase. Testing unwanted emissions immediately outside the channel bandwidth is usually not relevant to manufacturing.

4.3. Transmit Modulation Measurements

The following are the Transmit Modulation Measurements and are described in this section:

- Modulation Characteristics (Frequency Deviation)
- Initial Carrier Frequency Error
- Carrier Frequency Drift
- EDR -Carrier Frequency Stability
- EDR -Differential Phase Encoding
- EDR -Differential Error magnitude (Modulation Accuracy)

These tests ensure that the transmit signal meet the minimum level of quality so that the frequency of each bit of information can be correctly interpreted by a receiver. Typically, poor modulation performance can indicate that the modulation circuitry and/or local oscillator circuitry is affected by noise and frequency pulling by the power supply or instability.

Modulation Characteristics (Frequency Deviation)

What is it?
In a Bluetooth message, a positive frequency deviation represents a binary one and a negative frequency deviation a binary zero. The frequency deviations are known as the Modulation Characteristics of a Bluetooth system.

Why is it important?
Bluetooth SIG specifies the values of the frequency deviations for two sequences: the 11110000 bit pattern and 01010101 bit pattern. The frequency deviation corresponding to a 01010101 bit pattern (df2max, ideally the minimum Bluetooth frequency deviation) should be of absolute value no smaller than 115 kHz. For each bit pattern, the maximum frequency variation (df1max, df2max) must be greater than 115 kHz and the average frequency variation (df1avg, df2avg) must be within 140 kHz and 175 kHz. Finally, the ratio df2avg/df1avg should be at least 0.8.

How is it measured?
In the first part of the test, the DUT transmits the longest supported packet with full payload (1, 3 or 5 slot) with 11110000 bit pattern. For each 8-bit sequence received in the payload, the tester calculates the average frequency over the frequency values of the 8 bits, oversampling each at least four times and averaging these four samples to determine the correct deviation value of each bit. The maximum (df1max) and average (df1avg) of these deviation values is then calculated. In the second part of the test, the measurement is repeated while the DUT transmits a 01010101 bit pattern to obtain another set of maximum (df2max) and average (df2avg) deviation values. These four deviation values (average and maximum, for both 11110000 and 01010101 bit pattern) are compared with the specifications. Bluetooth SIG recommends that the measurement be repeated for at least 10 packets and that the performance be verified each time.

Where is it tested?
Testing Modulation Characteristics is relevant to manufacturing, and it is usually performed at a single frequency to validate the transmit signal; yet, following Bluetooth SIG recommendations can be impractical and time-consuming. LitePoint has developed a methodology for estimating the Modulation Characteristics that supports the specifications yet does not require testing at different modulations, enabling significant reduction in test times.

Initial Carrier Frequency Error

What is it?
The Initial Carrier Frequency Error is a measure of the carrier frequency accuracy before any packet information is transmitted. It is often indicated as "ωi."

Why is it important?
In modern designs, the Initial Carrier Frequency Error measures the accuracy of the crystal and has an impact on the constellation. Bluetooth SIG specifies that the Initial Carrier Frequency Error be within ±75 kHz from the carrier frequency. Because the same carrier frequencies are used for Basic Rate and EDR transmissions, the specifications are the same for the two modes.

How is it measured?
Bluetooth SIGN specifies that the DUT should transmit DH1 packets to the tester at the lowest operating frequency. The tester calculates the actual carrier frequency of the signal by integration over the preamble bits. The Initial Carrier Frequency Error is the difference between the measured frequency and nominal operating frequency.

Where is it tested?
Testing the Initial Carrier Frequency Error is relevant to manufacturing; however, LitePoint recommends testing at the highest operating frequency. Given the current Bluetooth device design, the error is always the highest at this frequency.

Carrier Frequency Drift

What is it?
The Carrier Frequency Drift is the transmitter center frequency drift within a packet.

Why is it important?
Bluetooth SIG sets a maximum limit to the Carrier Frequency Drift in a packet, which varies according to the number of slots in a packet. Table 5 summarizes these upper limits. In addition, a maximum drift rate of 400 Hz/μs (20 kHz/50μs) is allowed.

How is it measured?
The longest supported packet types for all supported number of slots, which could be 1,3, or 5, must be tested with the 10101010 bit sequence. The tester calculates the carrier frequency of the signal by integration over the preamble bits. Then, it integrates the frequency deviations of every 10-bit block.

Where is it tested?
Testing the Carrier Frequency Drift is usually relevant to manufacturing, albeit the verification of the transmit modulation characteristics other that the Carrier Frequency Drift usually ensures that the device meet the Bluetooth SIG requirement. Given the current device designs, testing at the maximum number of slots may be sufficient, provided that the modulation is working.

Duration of Packet	Frequency Drift
One Slot	± 25 kHz
Three Slots	± 40 kHz
Five Slots	± 40 kHz

Table 5. Maximum allowable Carrier Frequency Drift.

EDR - Carrier Frequency Stability

What is it?

Carrier Frequency Stability measures the combined error and drift of the transmitter carrier frequency of each EDR portion of the packet after the correction is made for the Initial Carrier Frequency Error. It is often indicated as "ω0."

Why is it important?

Bluetooth SIG specifies that the maximum ω0 shall be ±10 kHz.

Note: In addition, the sum of Initial Carrier Frequency Error and Carrier Frequency Stability must be within ±75 kHz. Figure 9 illustrates Bluetooth EDR Carrier Frequency Stability limits as a function of the symbol position.

How is it measured?

The measurement is similar to that of the Initial Carrier Frequency Error. It occurs over the GFSK and DPSK portions of the EDR waveform that, corrected for ω1, is partitioned into blocks of 50 symbols in length. The carrier frequency is obtained by integration over each block. The measurement continues over 200 non-overlapping blocks. The remaining frequency error in each block is reported as ω0 and the specifications by SIG Bluetooth are applied to the worst-case block frequency error ω0.

Where is it tested?

Testing the EDR -Carrier Frequency Stability is usually relevant to manufacturing as it tests for frequency pulling/pushing effects. Similarly to the Carrier Frequency Drift, verification of the Transmit Modulation characteristics other that the Carrier Frequency Stability usually ensures that the device meet the Bluetooth SIG requirement. However, EDR may be more relevant to test since it has tighter requirements.

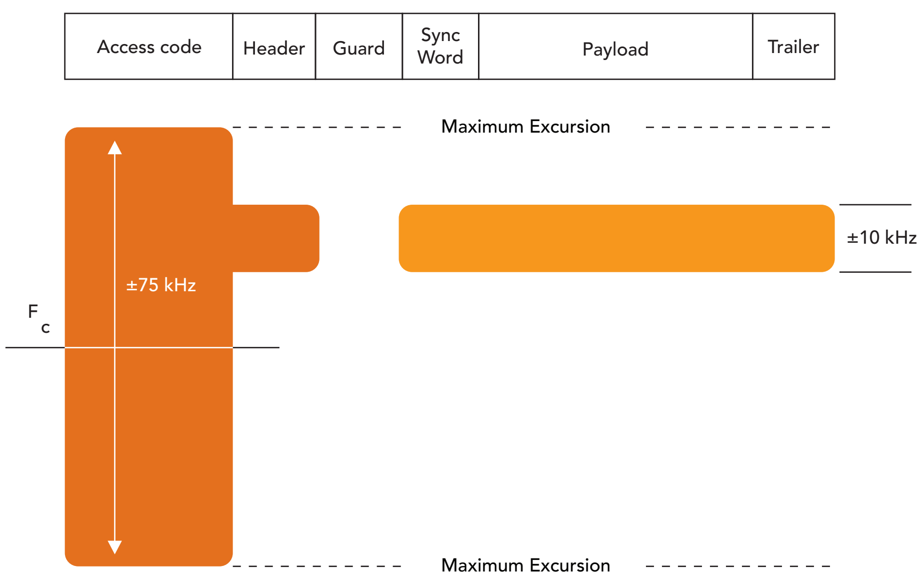


Figure 9. EDR Carrier Frequency Stability limits as a function of the symbol position.

EDR - Differential Phase Encoding

What is it?

In EDR mode, a differential PSK modulator is used that maps the binary data stream into a set of specified phase angles in the complex plane. The Differential Phase Encoding parameter describes the performance of the PSK modulator.

Why is it important?

This test verifies that the modulator correctly encodes the differential phase data. Bluetooth SIG mandates that the relationship between the binary input (b_k) and the phase (φ_k) shall be as defined in Table 6 for the 2 Mbps transmission (π/4-DQPSK) and in Table 7 for the 3 Mbps transmission (8DPSK).

How is it measured?
The DUT transmits 2-DH1 or 2-EV3 packets to the tester with π/4-DQPSK modulation and maximum length payload. The tester demodulates 100 packets and compares each payload with the expected data. If 8DPSK modulation is supported by the DUT, then steps that use 3-DH1 or 3-EV3 packets with maximum length payload must be repeated. The expected outcome of this test is that 99% of the packets will have no detected errors.

Where is it tested?
EDR – Differential Phase Encoding verification may be important during the product development phase, to verify performance of the PSK modulator at least once. Testing this parameter is usually not relevant to manufacturing (measuring the Differential Error Vector Magnitude ensures that the modulator works correctly).

b(2k-1)	b(2k)	φ(k)
0	0	π/4
0	1	3π/4
1	1	-3π/4
1	0	-π/4

Table 6. π/4-DQPSK mapping.

b(3k-2)	b(3k-1)	b(3k)	φ(k)
0	0	0	0
0	0	1	π/4
0	1	1	π/2
0	1	0	3π/4
1	1	0	π
1	1	1	-3π/4
1	0	1	-π/2
1	0	0	-π/4

Table 7. 8DPSK mapping.

EDR - Differential Error Vector Magnitude (Modulation Accuracy)

What is it?
The Differential Error Vector is the difference between the vectors representing consecutive[6] symbols of the transmitted signal after passing the signal through a specified measurement filter, sampling it at the symbol rate with an optimum sampling phase, and compensating it for carrier frequency error and for the ideal carrier phase changes. The Differential Error Vector Magnitude (DEVM) is the magnitude of the normalized Differential Error Vector. The transmitter Modulation Accuracy is described by a set of three DEVM values: Peak DEVM, RMS DEVM, and 99% DEVM, which is the value of DEMV at which 99% of the symbols have DEMV value lower than 0.3 for pi/4-DPSK and 0.2 for 8DPSK.

[6] Spaced one symbol apart in time

Why is it important?

The objective of the DEVM is to estimate the modulation errors that would be perceived by a differential receiver. In this sense, it is similar to the Error Vector Magnitude (EVM) parameters in 802.11 communications. Bluetooth SIG specifies that the Peak DEVM shall not exceed 0.35 for all π/4-DQPSK symbols and 0.25 for all 8DPSK symbols. The RMS DEVM shall not exceed 0.20 for all π/4-DQPSK blocks and 0.13 for all 8DPSK blocks. Finally 99% DEVM shall not exceed 0.30 for all π/4-DQPSK blocks and 0.20 for all 8DPSK blocks. These maximum values of DEVM are also described in Table 8.

How is it measured?

The DEVM is measured over the synchronization sequence and payload portions of the packet, but not the trailer symbols. For each modulation method, DEVM measurement is made over a total of 200 non-overlapping blocks, where each block contains 50 symbols. The transmitted packets are the longest supported packet type for each modulation method. Usually, both the Peak DEVM, which is the maximum DEVM across symbols, and RMS DEVM, which is the root mean square of the DEVM computed over 50 symbols, are calculated to ensure that the requirements are met. The carrier frequency drift of the sample sequence is compensated for prior to calculating both values of DEVM.

Where is it tested?

Testing DEVM is the single most important step in manufacturing. It is important to know that DEVM is very sensitive to power; therefore, measuring correlation across devices can be challenging especially if the DUT is given enough time to heat and drift during testing. LitePoint's fast test times minimize the possibility that the DUTs heat and drift, making the goal of measuring correlation across devices easier.

Modulation Accuracy	π/4-DQPSK	8DPSK
Peak DEVM	0.35	0.25
RMS DEVM	0.20	0.13
99% DEVM	0.30	0.20

Table 8. Modulation Accurac

Chapter 5 Receive Measurements

If not stated differently in the corresponding test description, the DUT always transmits PRBS9 packet data at the maximum output power and the tester transmits with a power between -60 dBm and -40 dBm at the DUT receiver input. Whenever possible, the test must be performed using loopback mode and the user must ensure that the tester correctly identifies all return packets. If loopback mode is not available or unless otherwise specified, the TX mode might be used if this mode is supported by both the test system and DUT.

Receive Measurements include the following:

- Sensitivity
- C/I Performance
- Intermodulation
- Max Usable Level
- EDR -Bit Error Rate (BER) Floor Performance

These tests measure the performance of the Bluetooth receiver under ideal and realistic conditions. In all cases, the criterion used to evaluate these performance parameters is the Bit Error Rate (BER), which is determined by a comparison between the transmitted and the recovered payload data. The tester calculates BER as a ratio of the recovered erroneous bits vs. the total number of recovered bits.

Sensitivity

What is it?

The actual Sensitivity of the receiver is defined as the input level for which a certain maximum value of Bit Error Rate (BER) is met.

Why is it important?

Sensitivity is a measure of the minimum signal level needed by the receiver to operate reliably in a real conversation setting. It correlates with, and hence it is a measure of, the noise figure of the device. For the Basic Rate mode, the maximum value of BER at which Sensitivity is defined is 0.1% (after 1,600,000 returned payload bits); for EDR mode, the maximum value of BER is 0.01% (after 16,000,000 returned payload bits). The test can be interrupted earlier if the device performs well above BER specifications at the sensitivity level. The Bluetooth SIG specifies that the measured sensitivity must be –70 dBm or better in both modes.

How is it performed?

Sensitivity of Basic Rate mode devices is measured with single slot packets or multi-slot packets.

Sensitivity with Single Slot Packets is tested by continuously sending a one-slot-packet, non-ideal signal, which is a signal with various impairments at a sensitivity level of -70 dBm, to the DUT. The DUT receives and loops back; using the return packets, the tester calculates the BER of the recovered signal. The impaired DH1 packets are called Dirty Single Slot Packets and their impairments are described in Table 9: the tester transmits the first 20 ms using the first parameter set, the second 20 ms using the second set, and so forth[7]. Additionally, a synchronized sine wave frequency modulation with a deviation of ± 25 kHz and a modulation frequency of 1.6 kHz is modulated on the signal to realize a carrier-frequency drift. Packets are repeated until 1,600,000 have been returned.

[7] After the tenth set, the tester starts again from the beginning

Sensitivity with Multi-Slot Packets is measured with a similar approach, but the tester sends the longest supported packets (DH3 or DH5, if the latter is supported). The impairments are the same described in Table 9, however the additional sine wave frequency modulation that realizes the carrier frequency drift has a deviation of ± 40 kHz and a modulation frequency of 500 Hz for 3 slot packets and 300 Hz for 5 slot packets. Packets are repeated until 16,000,000 have been returned.

For EDR mode devices, the measurement is similar, but the tester continuously sends π/4-DQPSK packets with the longest supported packet type. The measurement is repeated with 8DPSK packets, if supported by the DUT. The packets impairments are described in Table 10; the frequency modulation has a deviation of ±10 kHz and a synchronized sine wave modulation period of 100 μs.

Where is it tested?
Testing Sensitivity is relevant to manufacturing; however, testing with standard packets is sufficient. The verification of the Sensitivity performance using Dirty Packets is important only during the product development phase.

Set of Parameters	Carrier Frequency Offset [kHz]	Modulation Index	Symbol Timing Error [ppm]
1	75	0.28	-20
2	14	0.30	-20
3	-2	0.29	+20
4	1	0.32	+20
5	39	0.33	+20
6	0	0.34	-20
7	-42	0.29	-20
8	74	0.31	-20
9	-19	0.28	-20
10	-75	0.35	+20

Table 9. Dirty transmitter single slot packets.

Set of Parameters	Carrier Frequency Offset [kHz]	Symbol Timing Error [ppm]
1	0	0
2	+65	+20
3	-65	-20

Table 10. Dirty transmitter for EDR packets.

C/I Performance

What is it?
The minimum C/I Performance is described by a set of power levels of both the signal and interference at which a maximum BER value must be demonstrated.

Why is it important?
C/I Performance measures the ability of the receiver to interpret a signal in a specified channel while an interferer is present in a co-channel or adjacent channel. By doing so, C/I Performance tests the functionality of the device DSP. The requirements specified by the Bluetooth SIG apply if the frequency of the interferer is inside of the band 2400-2483.5 MHz only. For outside of the band 2400-2483.5 MHz, the out-of-band blocking specification applies. For both Basic Rate mode and EDR, a maximum value of BER equal to 0.1% must be demonstrated for all the signal-to-interference ratios listed in Table 11.

How is it performed?
For Basic Rate mode, the interference performance is measured with the wanted signal 10 dB over the reference sensitivity level on the co-channel and on the adjacent 1 MHz and 2 MHz channels; also, it is measures with the wanted signal 3 dB over the reference sensitivity level on all other RF channels. The interfering signal shall be Bluetooth-modulated. The tester transmits at the same time the wanted signal (DH1 packets with PRBS 9) and the Bluetooth modulated interfering signal are being transmitted. The returned packets are received and the BER is measured. The measurement should be repeated for all frequencies that are regular Bluetooth transmit frequencies.

For EDR mode, the measurement procedure is the same but the interfering signal is similarly modulated as the wanted signal for co-channel interference, and equivalent to a nominal Bluetooth Basic Rate GFSK transmitter for other channels.

Where is it tested?
DSP functionality should be guaranteed by design; hence, testing C/I Performance is important during the product development phase and is not relevant to manufacturing.

Frequency of Interference	Ratio of Carrier vs. Interference Signal Level		
	C/I Performance, Basic Rate	C/I Performance, EDR π/4-DQPSK	C/I Performance, EDR 8DPSK
Co-Channel Interference	11 dB	13 dB	21 dB
Adjacent (1 Mhz) Interference	0 dB	0 dB	5 dB
Adjacent (2 Mhz) Interference	-30 dB	-30 dB	-25 dB
Adjacent (3 Mhz) Interference	-40 dB	-40 dB	-33 dB
Image Frequency Interference	-9 dB	-7 dB	0 dB
Adjacent (1 Mhz) Interference to In-Band Image Frequency	-20 dB	-20 dB	-13 dB

Table 11. C/I performance for basic rate and EDR modes.

Intermodulation

What is it?
Intermodulation is a performance parameter for the receiver when multiple frequencies are present at its input. It is described as a degradation of the receiver's BER performance in the presence of three frequencies: a desired signal and two undesired signals.

Why is it important?
Bluetooth SIG specifies that, for Basic Rate and EDR modes, the reference sensitivity performance (BER = 0.1% and 0.01%, respectively) must be met under specified conditions describing the frequency and power of the desired and undesired signals.

How is it performed?
The tester continuously transmits:

- The wanted nominal signal at frequency f0 with a power level 6 dB over the reference sensitivity level.
- A static sine wave signal at a frequency f1 with a power level of –39 dBm.
- A Bluetooth modulated signal at a frequency f2 with a power level of -39 dBm and payload PRBS15.

Bluetooth SIG specifies that f0=2f1-f2 and | f2-f1 =n*1 MHz, where n can be 3, 4, or 5. Similarly to the Sensitivity measurement, the tester calculates the BER of the recovered signal (at frequency f0) and compares to the specifications.

Where is it tested?
While testing Intermodulation may be relevant to manufacturing, it is a time consuming measurement rarely performed during manufacturing. Ensuring Intermodulation performance in the product development phase is usually sufficient. With LitePoint solutions, testing Intermodulation could be achieved using specialized waveforms.

Max Usable Level

What is it?
Max Usable Level is the maximum usable input level at which the receiver operates. Similar to Intermodulation, this is the degradation of the receiver's BER performance; here, the input signal is at a specified high power level.

Why is it important?
Bluetooth SIG specifies that the BER must be less than or equal to 0.1% at a Max Usable Level of -20 dBm or greater.

How is it performed?
The DUT receives and loops back a reference Bluetooth signal (DH1 packets) sent continuously by the tester at –20 dBm power. The tester measures the BER of the recovered signals.

Where is it tested?
Testing the Max Usable Level is generally not relevant to manufacturing, since it is a time consuming measurement whose results cannot rule out the presence of device malfunctioning. If desired, LitePoint solutions do support testing of the Max Usable Level.

EDR – Bit Error Rate (BER) Floor Performance

What is it?
Floor Performance is a measurement of the BER while the EDR mode DUT receives a signal at a specified low power level.

Why is it important?
BER Floor Performance tests the device DSP functionality and ensures the ability to reach 0% BER. Bluetooth SIG specifies the low power level at which minimum BER must be demonstrated to be -60 dBm. This value was chosen assuming an 80 dB path loss in the transmission of a power class 1 Bluetooth device, which corresponds to a traveling distance of about 100 m. Hence, this measurement provides an indication of the performance of the receiver in practical situations where two Bluetooth devices communicating while spaced far apart (or, while located in less-than-ideal conditions, e.g. out of sight). Bluetooth SIG specifies that the EDR receiver shall achieve a BER less than 0.001% at 10 dB above the reference sensitivity level, which is defined as –70 dBm, after 160,000,000 bits, or less than 0.0007% after 8,000,000 bits.

How is it performed?
The tester continuously sends π/4-DQPSK packets, such that the input power to the DUT receiver is -60 dBm (measured over the DPSK modulated portion of the packets). The packets returned by the DUT are received and the BER is measured. After 8,000,000 bits have been received, the BER is compared with the threshold defined by the specifications. If supported by the DUT, then the measurement should be repeated while the tester continuously sends 8DPSK packets.

Where is it tested?
Testing BER Floor Performance is extremely time consuming and not relevant to manufacturing. As C/I Performance, this parameter tests the DSP functionality, which should be verified during the product development phase.

Chapter 6 LitePoint Offerings for Bluetooth Testing

LitePoint products include a combination of hardware/software platforms, graphical user interfaces (GUI), and chipset-specific calibration and test application programs. In manufacturing, the hardware platform and chipset-specific calibration and test programs are optimized to find any manufacturing defects. Combined with support expertise, these products are key elements of LitePoint's test system solutions.

Figure 10 shows an IQxel-M tester in a typical module test setup. LitePoint offerings for Bluetooth Testing includes the IQxel family of testers. The built-in test application programs for manufacturing are developed in LitePoint's IQfact+ software environment.

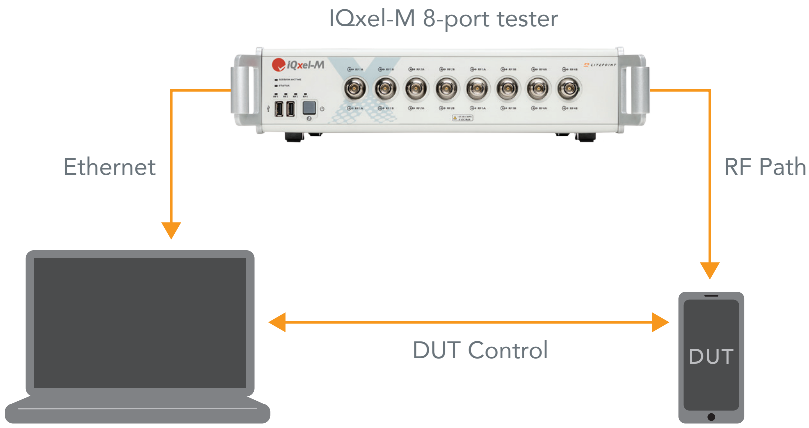


Figure 10. Typical module test setup based on an IQxel-M tester.

IQxel Family of Testers

IQxel

The LitePoint IQxel is the first One Box Tester (OBT) for 802.11ac devices. Its rugged design makes it simple to deploy in high-volume device manufacturing applications. IQxel delivers the quickest and easiest factory test capabilities because of its simple but robust architecture that uses a compact 2U high chassis. It requires no external PC for processing of captured measurements, and utilizes standard gigabit Ethernet communication and SCPI-compliant control commands.

IQxel-M

The LitePoint IQxel-M test system is a major advancement in the speed and efficiency for performing parallel tests on up to four wireless devices. It is the ideal solution for high-volume production environments enabling testing of numerous connectivity standards including 802.11, Bluetooth, ZigBee, Z-Wave, WiSUN, LTE-U and DECT as well as all navigation and broadcast standards, while delivering with superior reliability and test speed.

IQxel-MW

The LitePoint IQxel-MW is the world's first test solution for 802.11ax Wi-Fi technology. Ideal for both R&D and high-volume production, IQxel-MW delivers high performance verification for the most popular wireless connectivity standards including 802.11, Bluetooth, DECT and ZigBee. Additionally, IQxel-MW offers high efficiency parallel testing for up to 16 devices. The IQxel-MW series is available in three configurations, 2 ports, 8 ports and 16 ports, which support up to 2x2 and 4x4 true MIMO testing. This can be extended to true 8x8 MIMO testing by stacking multiple testers.

IQfact+ Software Solutions

IQfact+ Manufacturing Test Software is optimized for the most popular chipsets. The test programs are a result of LitePoint's partnership with the leading chipset manufacturers, and offer a quick, easy, and cost-effective way to develop and test chipsetspecific solutions. IQfact+ test programs run on LitePoint manufacturing test platforms to provide high-volume production testing. The software contains a flexible operator interface, a test suite with calibration and verification procedures, all tailored for the manufacturing requirements of specific chipset-based wireless products.

Appendix A1 Bluetooth Reference Signals Definition

The reference sensitivity level is defined as –70 dBm.

Basic Rate

A Bluetooth modulated interfering signal shall be defined as:

- Modulation = GFSK
- Modulation index = 0.32±1%
- BT= 0.5±1%
- Bit Rate = 1 Mbps ±1 ppm
- Modulating Data for wanted signal = PRBS9
- Modulating Data for interfering signal = PRBS 15
- Frequency accuracy better than ±1 ppm

Enhanced Data Rate

A 2 Mbps Bluetooth signal used as "wanted" or "interfering signal" is defined as:

- Modulation = π/4-DQPSK
- Symbol Rate = 1 Msym/s ± 1 ppm
- Frequency accuracy better than ±1 ppm
- Modulating Data for wanted signal = PRBS9
- Modulating Data for interfering signal = PRBS15
- RMS Differential Error Vector Magnitude < 5%
- Average power over the GFSK and DPSK portions of the packet shall be equal to within +/-1 dB

A 3 Mbps Bluetooth signal used as "wanted" or "interfering signal" is defined as:

- Modulation = 8DPSK
- Symbol Rate = 1 Msym/s ± 1 ppm
- Frequency accuracy better than ±1 ppm
- Modulating Data for wanted signal = PRBS9
- Modulating Data for interfering signal = PRBS15
- RMS Differential Error Vector Magnitude < 5%
- Average power over the GFSK and DPSK portions of the packet shall be equal to within +/-1 dB
- The modulated interfering signal shall be continuous modulated

Appendix A2 TP Identifiers and API Functions

Included in this section is, for each test described in this document, the corresponding Test Purpose (TP) identifiers described in the Bluetooth Test Specification (RF.TS/2.1.E.0, 2006). References to additional documentation, when appropriate, are provided. Finally, a list of the most relevant API functions for each test is also presented.

Test	TP Identifier Bluetooth Test Spec	Additional References	API Function
Maximum Output Power	TRM/CA/01/C	ETS 300 328 (subclause 5.2.1)	P_pk_each_burst P_av_each_burst
Maximum Power Density	TRM/CA/02/C	ETS 300 328 (subclause 5.2.2)	(comment A2.1) iqapiAnalysisFFT() x(frequency)y(power in dBm)
Power Control	TRM/CA/03/C		P_av_no_gap_all_dBm
EDR - Relative Transmit Power	TRM/CA/10/C		EdrPowDiffdB
20 dB Bandwidth	TRM/CA/05/C		bandwidth20dB
Frequency Range	TRM/CA/04/C		iqapiAnalysisFFT() x(frequency) y(power in dBm)
Adjacent Channel Power	TRM/CA/06/C		maxPowerAcpDbm
In-Band Spurious Emission	TRM/CA/06/C TRM/CA/13/C		maxPowerAcpDbm maxPowerEdrDbm sequenceDefinition
Out-of-Band Spurious Emission		ETS 300 328 (subclause 5.2.4)	
Modulation Characteristics	TRM/CA/07/C		deltaF1Average deltaF2Max deltaF2Average deltaF2MaxAccess deltaF2AvAccess freq_deviation freqDeviationPointer freq_deviationpktopk
Initial Carrier Frequency Error	TRM/CA/08/C		freq_est freq_estHeader
Carrier Frequency Drift	TRM/CA/09/C		freq_drift maxfreqDriftRate
EDR - Carrier Frequency Stability	TRM/CA/11/C EdrOmegaI EdrExtremeOmega0 EdrFreqExtremeEdronly EdrExtremeOmegaI0		
EDR - Differential Phase Encoding	TRM/CA/12/C		(comment A2.2)

EDR - Differential Error Vector Magnitude	TRM/CA/11/C		EdrEVMAv EdrEVMpk EdrEVMvalid EdrEVMvsTime
Test	**TP Identifier Bluetooth Test Spec**	**Additional References**	**API Function**
Sensitivity	RCV/CA/01/C RCV/CA/02/C RCV/CA/07/C		Reported by DUT
C/I Performance	RCV/CA/09/C RCV/CA/10/C		
Intermodulation	RCV/CA/05/C		
Max Usable Level	RCV/CA/06/C RCV/CA/10/C		
EDR - Bit Error Rate Floor Performance	RCV/CA/08/C		Reported by DUT

Comment A2.1: The bandwidth must be known as defined in the Specifications. Comment A2.2: This is essentially a DEVM measurement.

Note: The information provided in Appendix A2 is not intended to be an exhaustive list of all LitePoint API functions. It is intended only to provide the API functions most relevant to each test.

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