

## DIRECT TEST MODE

*This part of the specification describes the Direct Test Mode for RF PHY testing of Bluetooth low energy devices.*



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# 1 INTRODUCTION

Direct Test Mode is used to control the Device Under Test (DUT) and provides a report back to the Tester.

Direct Test Mode shall be set up using one of two alternate methods:

- over HCI (as defined in [Section 2](#)) or
- through a 2-wire UART interface (as defined in [Section 3](#))

Each DUT shall implement one of the two Direct Test Mode methods in order to test the Low Energy PHY layer. [Figure 1.1](#) illustrates the alternatives for Direct Test Mode setup.

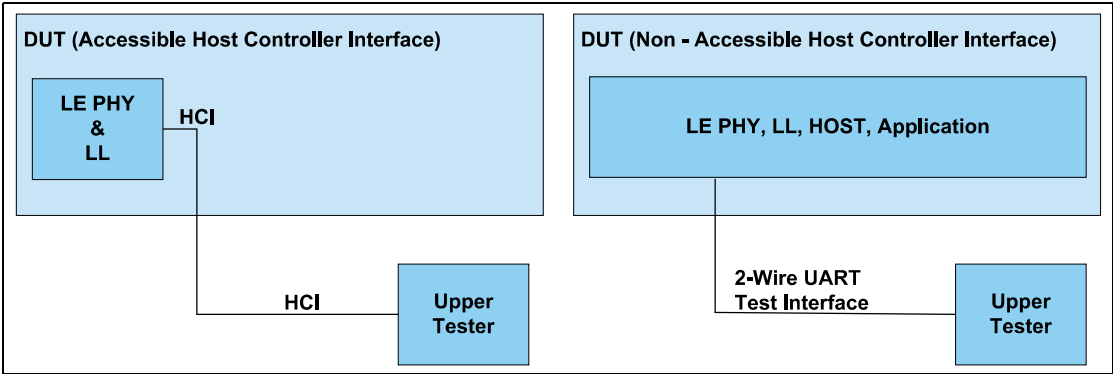


Figure 1.1: Setup alternatives for LE Direct Test Mode: Designs with accessible HCI (left) and designs without accessible HCI (right)

[Figure 1.2](#) illustrates the Bluetooth LE Direct Test Mode setup principle using a 2-wire UART interface.

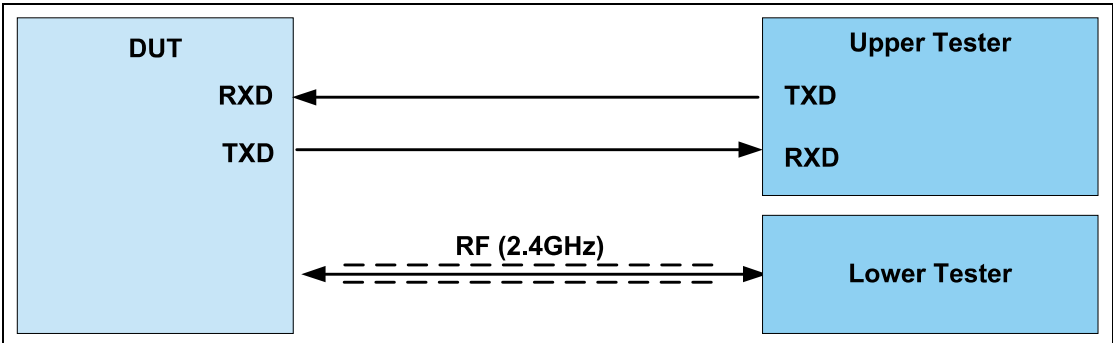


Figure 1.2: RF PHY test setup for Direct Test Mode (UART control)



## 2 LOW ENERGY TEST SCENARIOS

### 2.1 TEST SEQUENCES

These sequences are used as routines and used to control an LE DUT with an accessible HCI or a 2-wire UART interface for RF testing.

The following mapping shall be performed from the RF testing commands to HCI commands and events or 2-wire UART commands and events:

| RF Test Command / Event | HCI Command / Event  | 2-wire UART Command / Event |
|-------------------------|--|-----------------------------|
| LE_TRANSMITTER_TEST     | LE Transmitter Test command or<br>LE Enhanced Transmitter Test command | LE Transmitter Test         |
| LE_RECEIVER_TEST        | LE Receiver Test command or<br>LE Enhanced Receiver Test command       | LE Receiver Test            |
| LE_TEST_END             | LE Test End command  | LE Test End                 |
| LE_STATUS               | Command Complete event   | LE Test Status              |
| LE_PACKET_REPORT        | Command Complete event   | LE Packet Report            |

Table 2.1: Mapping table of HCI / 2-wire Commands/Events

The HCI commands and events used in Direct Test Mode are defined in [\[Vol 2\] Part E, Section 7.8](#).



2.2 MESSAGE SEQUENCE CHARTS

Transmitter Test

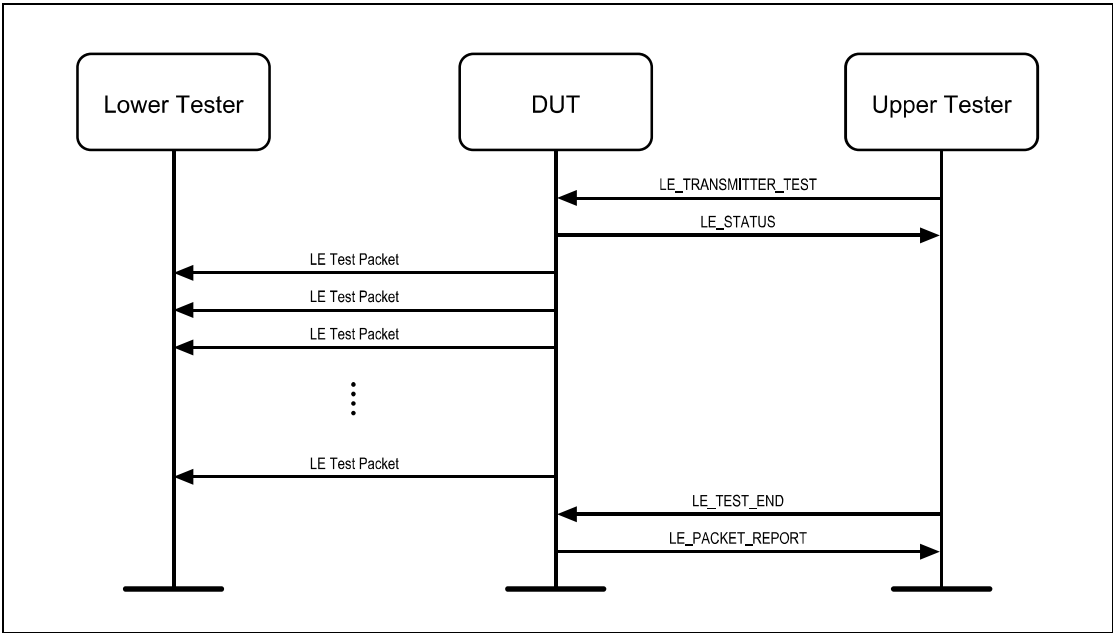


Figure 2.1: Transmitter Test MSC

Receiver Test

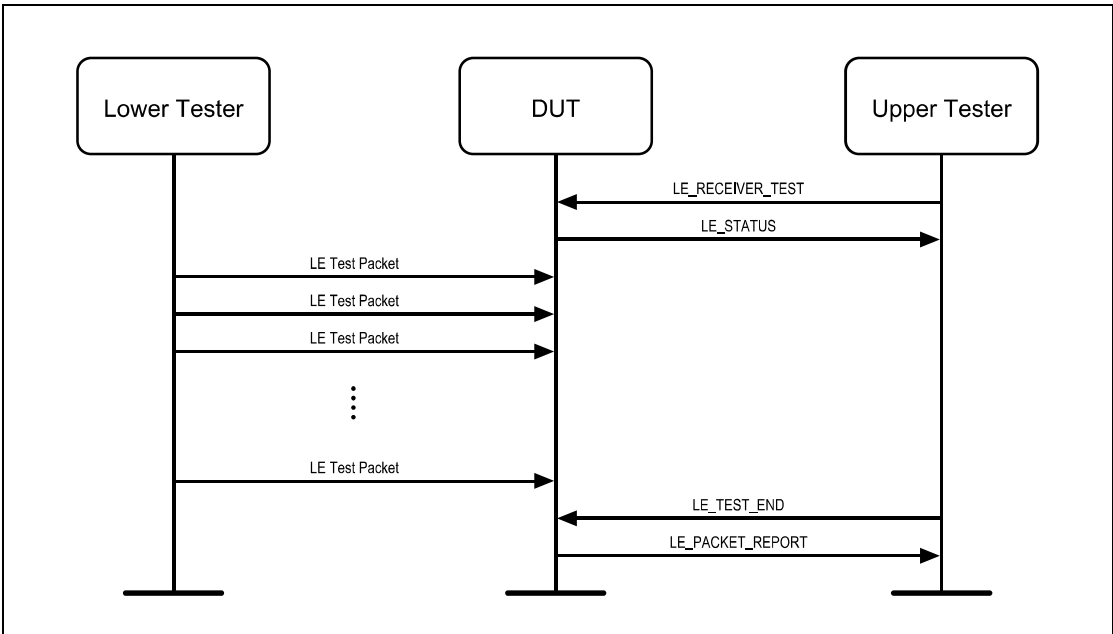


Figure 2.2: Receiver Test MSC



## 3 UART TEST INTERFACE

### 3.1 UART INTERFACE CHARACTERISTICS

The UART interface characteristics shall be set to use the following parameters:

- Baud rate: One of the following shall be supported by the DUT:  
1200, 2400, 9600, 14400, 19200, 38400, 57600, 115200
- Number of data bits: 8
- No parity
- 1 stop bit
- No flow control (RTS or CTS)

### 3.2 UART FUNCTIONAL DESCRIPTION

The Upper Tester shall always initiate any a test scenario using the UART interface. The DUT shall respond to the commands from the Upper Tester.

The Upper Tester sends test commands to the DUT. The DUT shall respond with a test status event or packet report event.

The Upper Tester shall not transmit further commands before it receives a response from the DUT. If the Upper Tester does not receive a response from the DUT within the time  $t_{\text{TIMEOUT}}$ , the Upper Tester shall transmit a reset command (i.e., a test setup command with the control argument set to 0x00) to the DUT and display an appropriate error message. For the reset command,  $t_{\text{RESPONSE}}$  and  $t_{\text{TIMEOUT}}$  do not apply.

On reception of a reset command, the DUT shall reset all parameters to their default state.

#### Definitions

- All Commands and Events consist of 16 bits (2 bytes).
- The most significant bit is bit number 15.
- The least significant bit is bit number 0.
- The most significant byte is from bit 15 to 8.
- The least significant byte is from bit 7 to 0.
- Commands and Events are sent most significant byte (MSB) first, followed by the least significant byte (LSB).



3.3 COMMANDS AND EVENTS

3.3.1 Command and Event Behavior

Table 3.1 outlines the set of commands which can be received by the DUT and the corresponding response events that can be transmitted by the DUT.

| Command (DUT RXD)   | Event (DUT TXD)                               |
|---------------------|---|
| LE_Test_Setup       | LE_Test_Status SUCCESS<br>LE_Test_Status FAIL |
| LE_Receiver_Test    | LE_Test_Status SUCCESS<br>LE_Test_Status FAIL |
| LE_Transmitter_Test | LE_Test_Status SUCCESS<br>LE_Test_Status FAIL |
| LE_Test_End         | LE_Packet_Report<br>LE_Test_Status FAIL       |

Table 3.1: 2-Wire command and event behavior

3.3.2 Commands

Command packet formats are shown in Figure 3.1 and Figure 3.2.

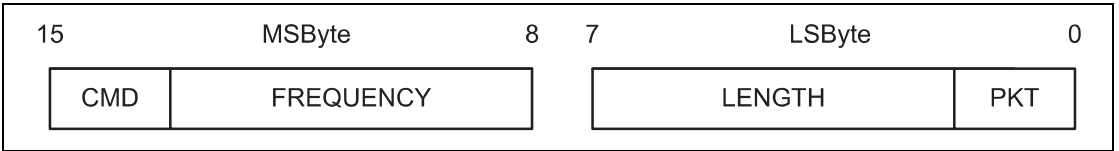


Figure 3.1: Command message format for Transmitter Test and Receiver Test commands

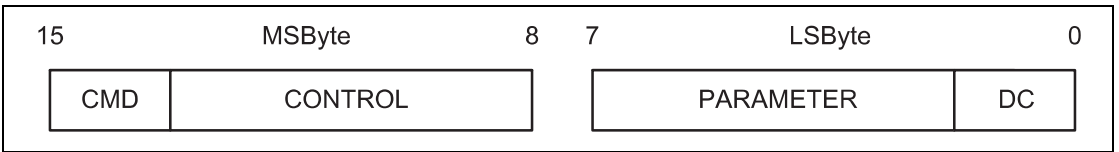


Figure 3.2: Command message format for Test Setup and Test End commands

*Direct Test Mode**CMD (command):**Size: 2 Bits*

| Value $b_1b_0$ | Parameter Description |
|----------------|-----------------------|
| 00             | Test Setup            |
| 01             | Receiver Test         |
| 10             | Transmitter Test      |
| 11             | Test End              |

*Test Setup Command:**Size: 12 Bits*

| Control (6 bits) | Parameter (6 bits) | Description  |
|------------------|--------------------|--|
| 0x00             | 0x00               | RESET; the upper 2 bits of the data length for any Transmitter or Receiver commands following are set to 00, the PHY is set to LE 1M, and the receiver assumes the transmitter has a standard modulation index |
|                  | 0x01 – 0x3F        | Reserved for future use  |
| 0x01             | 0x00 – 0x03        | Set the upper 2 bits of the data length for any Transmitter or Receiver commands following (to enable a length greater than 0x3F to be used)   |
|                  | 0x04 – 0x3F        | Reserved for future use  |
| 0x02             | 0x00               | Reserved for future use  |
|                  | 0x01               | PHY set to LE 1M   |
|                  | 0x02               | PHY set to LE 2M   |
|                  | 0x03               | PHY set to LE Coded; transmitter is to use S=8 data coding   |
|                  | 0x04               | PHY set to LE Coded; transmitter is to use S=2 data coding   |
|                  | 0x05 – 0x3F        | Reserved for future use  |
| 0x03             | 0x00               | Receiver assumes transmitter has a standard modulation index   |
|                  | 0x01               | Receiver assumes transmitter has a stable modulation index   |
|                  | 0x02 - 0x3F        | Reserved for future use  |
| 0x04             | 0x00\              | Read the test case supported features.<br>The Test Status event will return the state of the test case supported features as detailed in the Test Status event ( <a href="#">Section 3.4.1</a> ).              |
|                  | Any other value    | Reserved for future use  |



*Direct Test Mode*

| Control (6 bits) | Parameter (6 bits) | Description  |
|------------------|--------------------|--|
| 0x05             | 0x00               | Read supportedMaxTxOctets (see [Vol 6] Part B, Section 4.5.10) |
|                  | 0x01               | Read supportedMaxTxTime (see [Vol 6] Part B, Section 4.5.10)   |
|                  | 0x02               | Read supportedMaxRxOctets (see [Vol 6] Part B, Section 4.5.10) |
|                  | 0x03               | Read supportedMaxRxTime (see [Vol 6] Part B, Section 4.5.10)   |
|                  | Any other value    | Reserved for future use  |

*Test End Command:**Size: 12 Bits*

| Control (6 bits) | Parameter (6 bits) | Description             |
|------------------|--------------------|-------------------------|
| 0x00             | 0x00               | Test End Command        |
| 0x00             | 0x01 – 0x3F        | Reserved for future use |
| 0x01 – 0x3F      | 0x00 – 0x3F        | Reserved for future use |

**Transmit and receive commands:***Frequency:**Size: 6 Bits*

| Value       | Parameter Description   |
|-------------|---|
| 0x00 – 0x27 | The frequency to be used; a value of N represents a frequency of (2N+2402) MHz (the available range is therefore even MHz values from 2402 to 2480 inclusive) |
| 0x28 – 0x3F | Reserved for future use   |

*Length:**Size: 6 Bits*

| Value       | Parameter Description  |
|-------------|--|
| 0x00 - 0x3F | The lower 6 bits of the packet length in bytes of payload data in each packet (the top two bits are set by the Test Setup command) |

*PKT (Packet Type):**Size: 2 Bits*

| Value $b_1b_0$ | Parameter Description  |
|----------------|--|
| 00             | PRBS9 Packet Payload   |
| 01             | 11110000 Packet Payload  |
| 10             | 10101010 Packet Payload  |
| 11             | On the LE Uncoded PHYs: Vendor Specific<br>On the LE Coded PHY: 11111111 |



3.4 EVENTS

There are two types of events sent by the DUT:

- 1. LE\_Test\_Status\_Event
- 2. LE\_Packet\_Report\_Event

The event packet format is shown in [Figure 3.3](#). This packet format is used for both Test Status Events and Packet Report Events.

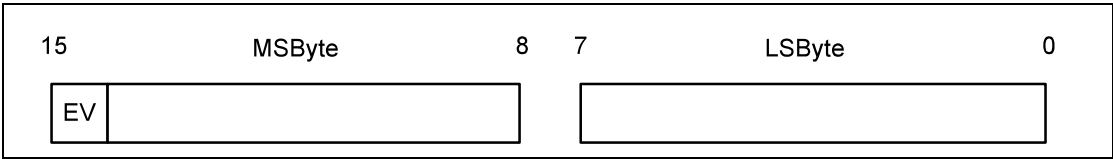


Figure 3.3: Event packet format

EV (Event): Size: 1 Bit

| Value | Parameter Description  |
|-------|------------------------|
| 0     | LE_Test_Status_Event   |
| 1     | LE_Packet_Report_Event |



3.4.1 LE\_Test\_Status\_Event

The LE\_Test\_Status\_Event packet format is as shown in Figure 3.4.

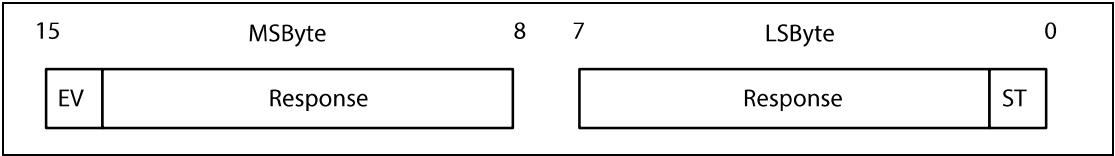


Figure 3.4: LE Test Status event

ST (status): Size: 1 Bit

| Value | Parameter Description |
|-------|-----------------------|
| 0     | Success               |
| 1     | Error                 |

Response<sup>1</sup> Size: 14 Bits

| Test Setup command control parameter | Value bits 1 to 14 <sup>2</sup> |  |
|--------------------------------------|---------------------------------|--|
| 0x04                                 | Bit 1                           | LE Data Packet Length Extension feature supported  |
|                                      | Bit 2                           | LE 2M PHY supported  |
|                                      | Bit 3                           | Transmitter has a Stable Modulation Index  |
|                                      | Bits 4 to 14                    | Reserved for future use  |
| 0x05                                 | Bits 1 to 14                    | Maximum transmit or receive time divided by 2 or maximum number of payload octets (depending on the parameter in the original query) that the local Controller supports for transmission of a single Link Layer Data Channel PDU.<br>Range 0x00A4-0x2148 for times or 0x001B-0x00FF for number of octets (all other values reserved for future use). |
| All other values                     |                                 | Reserved for future use  |

<sup>1</sup> If the event has a status of "Error" or was generated in response to a command other than Test Setup, then this field is Reserved for future use.

<sup>2</sup> This field is described as having bits 1 to 14 rather than 0 to 13 to avoid confusion.



### 3.4.2 LE\_Packet\_Report\_Event

The LE\_Packet\_Report\_Event packet format is shown in [Figure 3.5](#). The *Packet Count* parameter indicates the number of received LE Test Packets. The *Packet Count* in the Packet Report ending a transmitter test shall be 0.

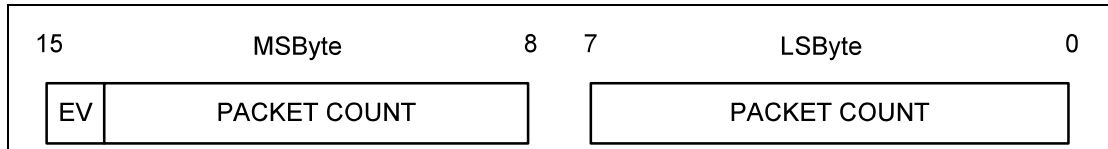


Figure 3.5: LE Packet Report event

**PACKET COUNT:**

*Size: 15 Bits*

| Value | Parameter Description                                      |
|-------|--|
| N     | N is the number of packets received<br>Range = 0 to 32767. |

Note: The DUT is not responsible for any overflow conditions of the packet counter. That responsibility belongs with the RF PHY Tester or other auxiliary equipment.

## 3.5 TIMING – COMMAND AND EVENT

The timing requirements are as shown in [Table 3.2](#).

| Symbol                  | Parameter  | Min. | Max. | Unit |
|-------------------------|--|------|------|------|
| b <sub>ERR</sub>        | Baud rate accuracy   |      | ±5   | %    |
| t <sub>MIN</sub>        | The time between the first and second byte of the command (end of stop bit to start of start bit)  | 0    | 5    | ms   |
| t <sub>RESPONSE</sub>   | The time from a DUT receiving a command (end of stop bit) until the DUT responds (start of start bit)  | 0    | 50   | ms   |
| t <sub>TURNAROUND</sub> | The time from when the tester receives a response (end of stop bit) until the tester sends another command (start of start bit)                    | 5    | -    | ms   |
| t <sub>TIMEOUT</sub>    | The time from when a tester sends a command (end of stop bit) until the tester times out (not having received end of the stop bit in the response) | 51   | 100  | ms   |

Table 3.2: Parameter requirements table for 2-wire UART interface

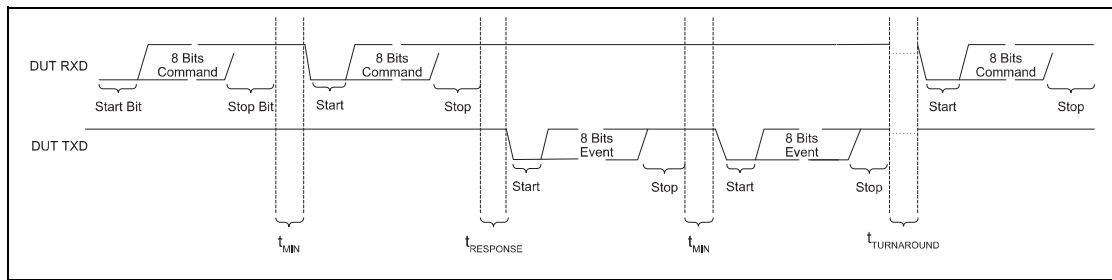


Figure 3.6: Command and event timing on 2-wire UART interface

The commands and events shall be transmitted with two 8-bit bytes with a maximum time between the 2 transmissions. A timeout is required for no response or an invalid response from the DUT.

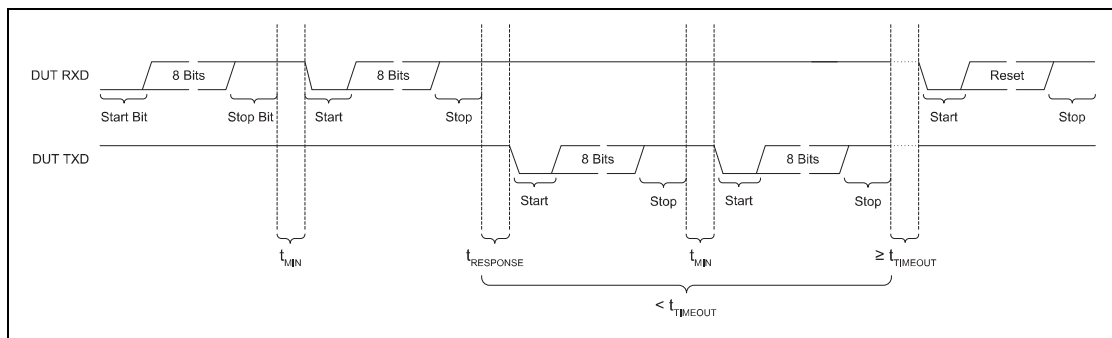


Figure 3.7: Command and event timing on 2-wire UART interface showing timeout

## 4 LE TEST PACKET DEFINITION

### 4.1 LE TEST PACKETS FORMAT

The LE Test packet format for the LE Uncoded PHYs shall be as shown in [Figure 4.1](#). The LE Test packet format for the LE Coded PHY shall be as shown in [Figure 4.2](#). LE test packets are required for LE RF PHY conformance testing using Direct Test Mode.

Depending on the test, the packet payload content may vary.

For the LE Uncoded PHYs, the LE test packet consists of the following fields; preamble (8 bits with the LE 1M PHY or 16 bits with the LE 2M PHY), synchronization word (32 bits), PDU header (8 bits), PDU length (8 bits), payload (0-2040 bits) and CRC (24 bits).

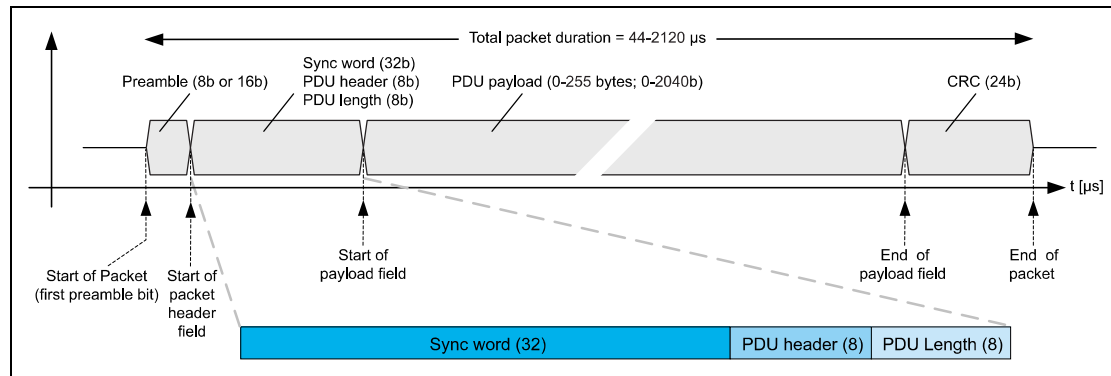


Figure 4.1: LE Test packet format for the LE Uncoded PHYs

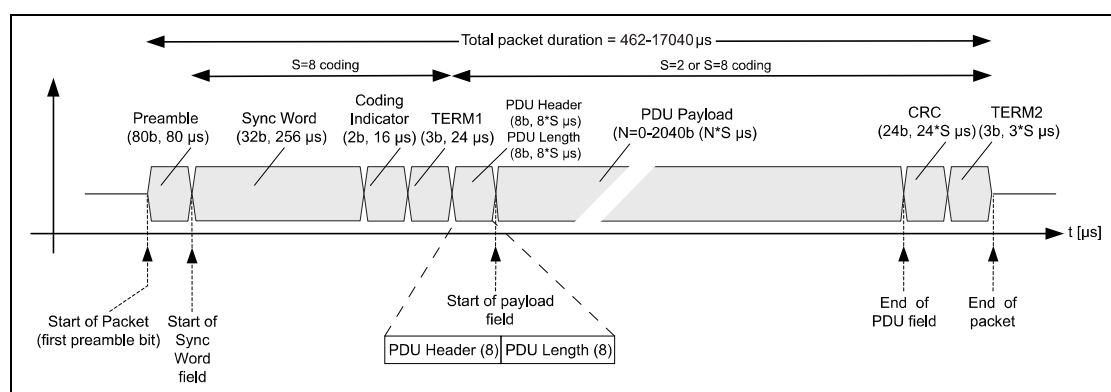


Figure 4.2: LE Test packet format for the LE Coded PHY

#### 4.1.1 Whitening

LE test packets shall not use whitening.



#### **4.1.2 Preamble and Synchronization Word**

LE test packets shall have '10010100100000100110111010001110' (in transmission order) as the synchronization word. The preamble for all LE test packets is thus '10101010' (in transmission order) when the device under test is configured for the LE 1M PHY, '1010101010101010' (in transmission order) if the device under test is configured for the LE 2M PHY, and the preamble described in [\[Vol 6\] Part B, Section 2.1.1](#) if the device under test is configured for the LE Coded PHY.

#### **4.1.3 CRC**

The CRC shift register shall be preset with 0x555555 for every LE test packet.



4.1.4 LE Test Packet PDU

The LE test packet PDU consists of an 8-bit header, an 8-bit length field and a variable size payload. Its structure is as shown in [Figure 4.3](#).

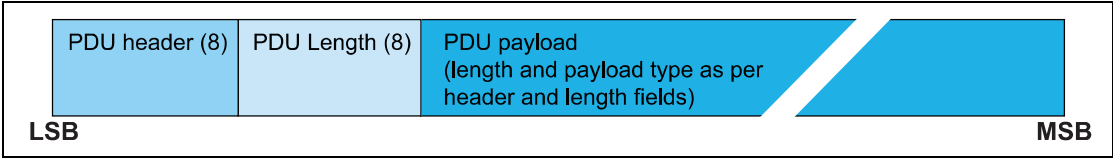


Figure 4.3: LE Test packet PDU structure

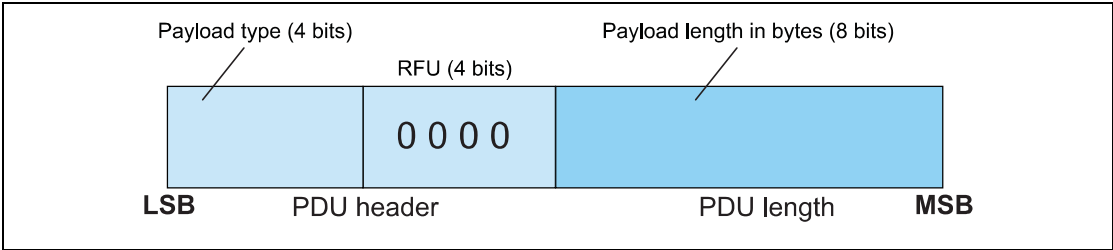


Figure 4.4: LE Test packet header and length field structure

The first four bits of the PDU header field indicate the payload content type as defined in [Table 4.1](#). The length field expresses the payload field length in bytes.

Note: On the LE Coded PHY, this section defines the PDU contents before coding.

| Payload type<br>b <sub>3</sub> b <sub>2</sub> b <sub>1</sub> b <sub>0</sub> | Payload description   |
|---|---|
| 0000b   | PRBS9 sequence ‘1111111100000111101...’ (in transmission order) as described in <a href="#">Section 4.1.5</a> |
| 0001b   | Repeated ‘11110000’ (in transmission order) sequence as described in <a href="#">Section 4.1.5</a>            |
| 0010b   | Repeated ‘10101010’ (in transmission order) sequence as described in <a href="#">Section 4.1.5</a>            |
| 0011b   | PRBS15 sequence as described in <a href="#">Section 4.1.5</a>   |
| 0100b   | Repeated ‘11111111’ (in transmission order) sequence  |
| 0101b   | Repeated ‘00000000’ (in transmission order) sequence  |
| 0110b   | Repeated ‘00001111’ (in transmission order) sequence  |
| 0111b   | Repeated ‘01010101’ (in transmission order) sequence  |

Table 4.1: LE test packet PDU header’s Type field encoding



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*Example:* For LE test packets with 0x0F payload contents ('11110000' in transmission order) and with an LE test packet payload length of 37 bytes (296 bits), the LE test packet header and length type field will be '1000000010100100' in transmission order.



#### 4.1.5 LE Test Packet Payload Description

The LE test packet payload content alternatives required for the Bluetooth low energy RF PHY conformance tests are:

##### PRBS9:

A 9-bit pseudorandom binary sequence used for wanted signal payload content. The PRBS9 sequence repeats itself after the  $(2^9 - 1 = 511)$  bit. The PRBS9 sequence may be generated in a nine stage shift register whose 5<sup>th</sup> and 9<sup>th</sup> stage outputs are added in a modulo-two addition stage (see Figure 4.5) and the result is fed back to the input of the first stage. The sequence begins with the first ONE of 9 consecutive ONES (i.e. the shift register is initialized with nine ONES).

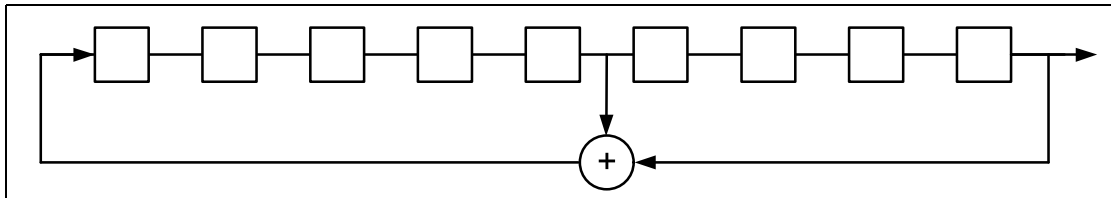


Figure 4.5: Linear feedback shift register for generation of the PRBS9 sequence

The same pseudorandom sequence of bits shall be used for each transmission (i.e. the packet is repeated).

##### PRBS15:

A 15-bit pseudorandom binary sequence that is used for the interfering signal and can optionally be used for wanted signal payload content. The PRBS15 sequence repeats itself after the  $(2^{15} - 1 = 32767)$  bit. The PRBS15 sequence may be generated in a fifteen stage shift register whose 14<sup>th</sup> and 15<sup>th</sup> stage outputs are added in a modulo-two addition stage (See Figure 4.6) and the result is fed back to the input of the first stage. The sequence begins with the first ONE of 15 consecutive ONES (i.e., the shift register is initialized with fifteen ONES).

This PRBS15 definition is consistent with ITU T-REC-01 150-199605-I.  
SERIES O: SPECIFICATIONS OF MEASURING EQUIPMENT - Equipment for the measurement of digital and analogue/digital parameters.

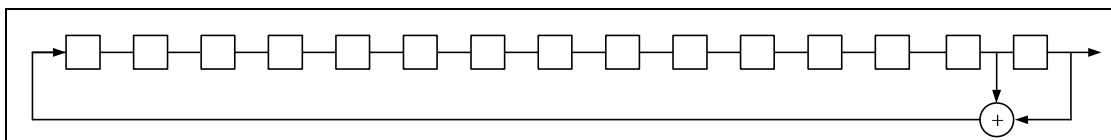


Figure 4.6: Linear feedback shift register for generation of the PRBS15 sequence

The same pseudorandom sequence of bits shall be used for each transmission (i.e. the packet is repeated).

**10101010:**

Repeated sequence of alternating 1's and 0's, starting at the first payload bit and ending at the start of the first bit in the CRC field. This pattern is used to verify the frequency deviation and the Gaussian filtering properties of the transmitter modulator.

**11110000:**

Repeated sequence of alternating 0's and 1's in groups of four (i.e. 1111000011110000...), starting at the first payload bit and ending at the start of the first bit in the CRC field. This pattern is used to verify the frequency deviation and the Gaussian filtering properties of the transmitter modulator.



#### 4.1.6 LE Test Packet Interval

While in LE direct TX mode, LE test packets shall be transmitted from the EUT with a packet interval  $I(L)$  as defined below; see the top half of Figure 4.7 for reference.

While in LE direct RX mode, the nominal packet interval of the LE test packets transmitted from the tester is  $I(L)$ , but the tester packet interval may be extended to a maximum of  $T(L)$  upon change of the dirty transmitter parameter settings and during verification of the EUT PER reporting functionality. See the bottom half of Figure 4.7 for reference.

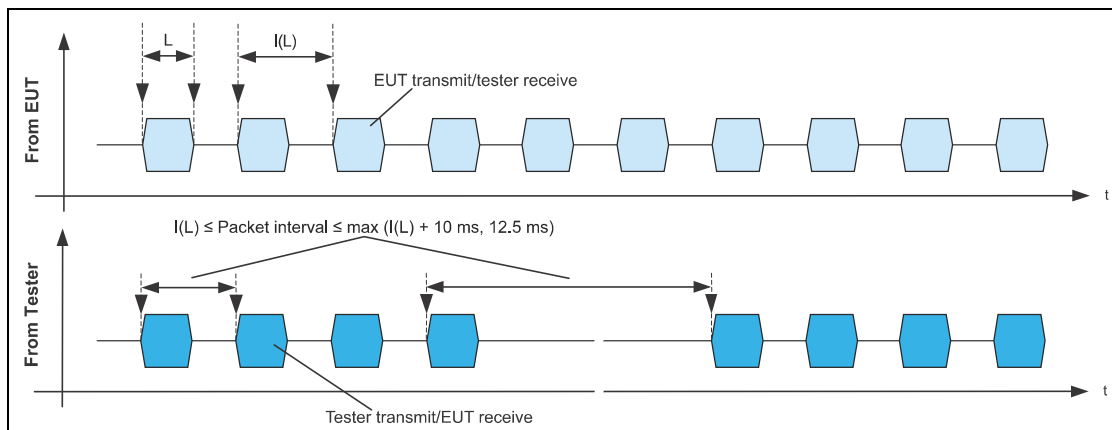


Figure 4.7: LE Test packet interval in LE Direct Test Mode

For an LE Test Packet length of  $L \mu\text{s}$ ,  $I(L) = \text{ceil}((L + 249) / 625) * 625 \mu\text{s}$ , where  $\text{ceil}(x)$  is the smallest integer greater than or equal to  $x$ , and  $T(L) = \max(I(L) + 10 \text{ ms}, 12.5 \text{ ms})$ .

# Core System Package [Wireless Coexistence volume]

Specification of the **Bluetooth®** System

---

Specification Volume 7



**Covered Core Package Version:** 5.0  
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Bluetooth SIG Proprietary



## Revision History

The Revision History is shown in the [\[Vol 0\] Part C](#), Appendix.

## Contributors

The persons who contributed to this specification are listed in the [\[Vol 0\] Part C](#), Appendix.

## Web Site

This specification can also be found on the official Bluetooth web site:  
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