BLE Direct Test Mode Through 2-wire UART Interface

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ABSTRACT—The Bluetooth standard defines Direct Test Mode (DTM) for RF PHY testing of Bluetooth low energy device. This standardization verify that a basic level of system performance is guaranteed for all BLE products. We will introduce the method of perform the tests through a 2-wire UART interface.

I - Introduction

The RF validation of Bluetooth device uses a protocol called Direct Test Mode. It is described in the Bluetooth Core Specification versions 4.x and 5.0, Volume 6, Part F.

The purpose is to test the radio at the physical layer for things such as transmitting power and receiver sensitivity, which is useful for regulatory EMC testing.

The Direct Test Mode (DTM) is used to control the Device Under Test (DUT) and provides a report back to the TESTER. It has two alternate methods:

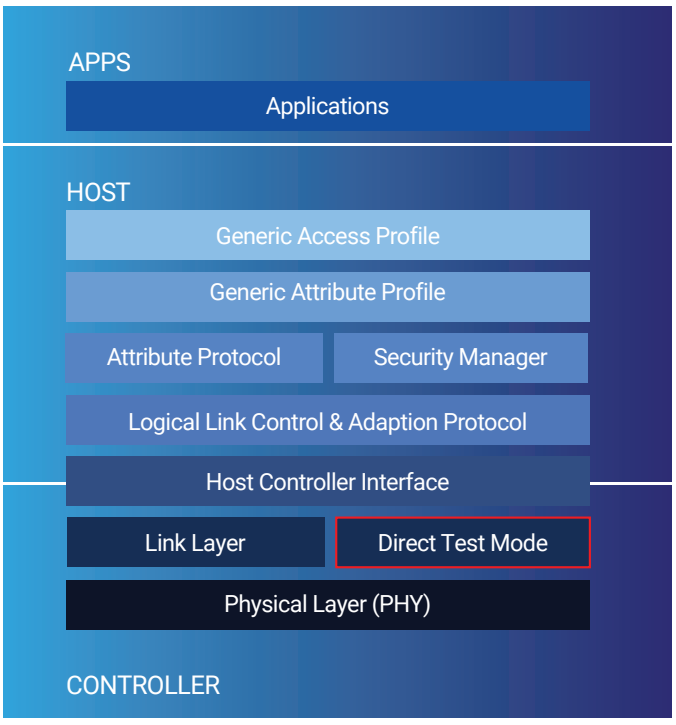
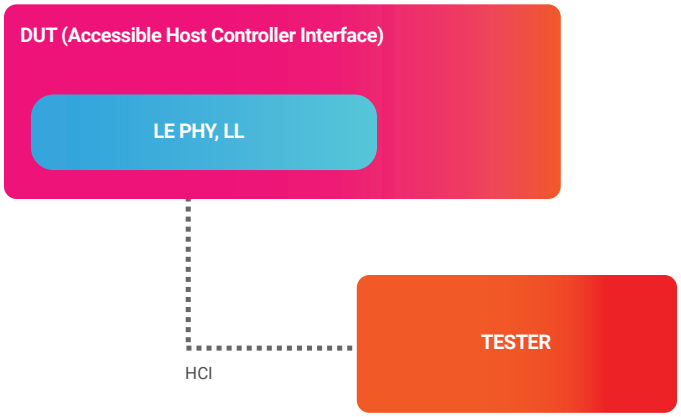
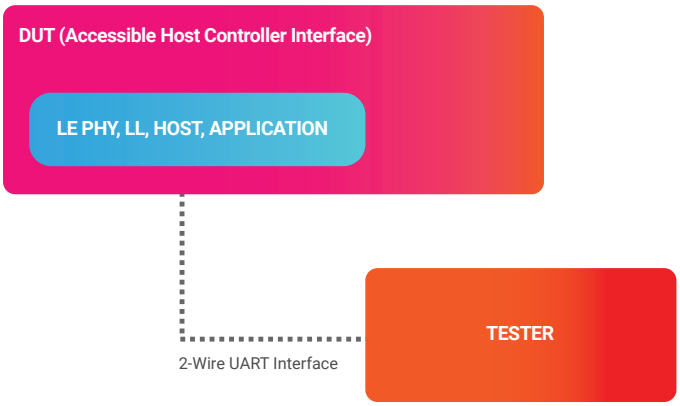


Fig.1. bluetooth protocol stack

1. Over HCI



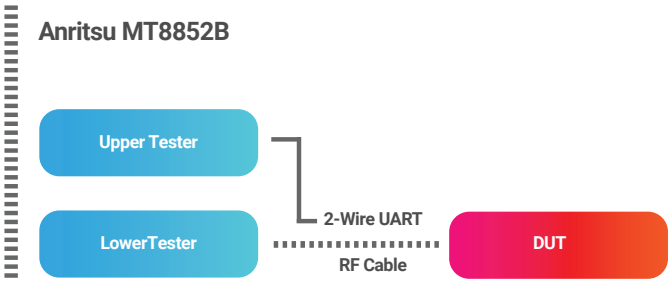
2. Through a 2-wire UART Interface



In the next section, we describe the second way to perform the tests through a 2-wire UART interface.

II- Test Sequences

The DTM protocol enables communication between the DUT (Device Under Test) and the Tester. The test equipment that we usually use in the development phase is Anritsu MT8852B, which combines the upper and lower tester functions.



The Upper Tester has direct access to the DUT through a dedicated 2-wire connection which can enter commands to start and stop the RF test. The Lower Tester is a piece of lab equipment that will measure the RF activity and performance.

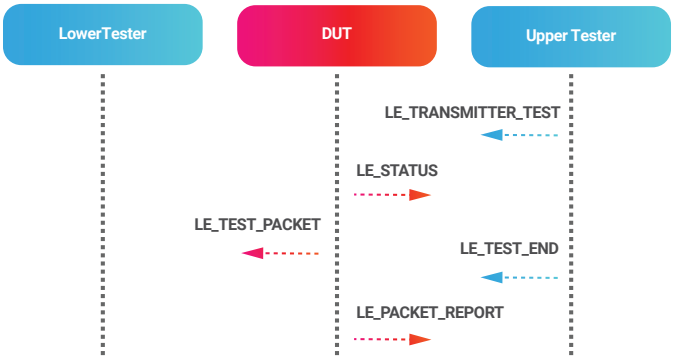


Figure 2-1: message sequence charts of transmitter test

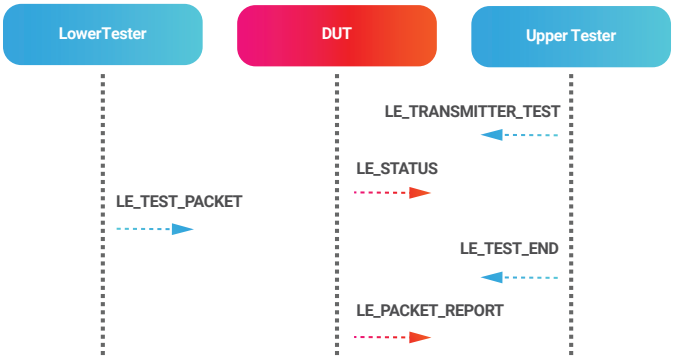


Figure 2-2: message sequence charts of receiver test

III - Commands And Events

Command and Event behavior of 2-wire UART interface.

Command (DUT TX)	Event (DUT RX)
LE_Reset	LE_Test_Status SUCCESS LE_Test_Status FAIL
LE_Transmitter_Test	LE_Test_Status SUCCESS LE_Test_Status FAIL
LE_Receiver_Test	LE_Test_Status SUCCESS LE_Test_Status FAIL
LE_Test_Eed	LE_Packet_Report LE_Test_Status FAIL

– Commands

CMD	Frequency	Length	PKT
2 bits	6 bits	6 bits	2 bits

1. CMD(command)

Value	Parameter Description
00	Reset
01	Receiver Test
10	Transmitter Test
11	Test End

2. Frequency

Value	Parameter Description
0x00 - 0x27	A Value of represents a frequency of (2N+2402)MHz Range from 240MHz to 2480MHz

3. Length

Value	Parameter Description
0x00 - 0x25	Length of payload data in each packet

4. PKT(Packet Type)

Value	Parameter Description
00	PRBS9 Packets Payload
01	11110000 Packets Payload
10	10101010 Packets Payload
11	Vendor Specific

Note: Vendor specific will be detailed in section

Events

- LE_Test_Status_Event

EV	DC	ST
1 bits	14 bits	1 bits

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1. EV (event)

Value	Parameter Description
0	LE_Test_Status_Event

2. ST (status)

Value	Parameter Description
0	Success
1	Error

3. DC (don't care)

- LE_Packet_Report_Event

EV	PACKET COUNT
1 bits	15 bits

1. EV(event)

Value	Parameter Description
1	LE_Packet_Report_Event

2. ST(status)

Value	Parameter Description
0 - 32767	Number of packets received

IV - Vendor Specific

The standard 2-wire UART interface Command reserves binary value “11” at PKT field for Vendor Specific packet payload.

CMD	Frequency	Length	PKT
10	111100	000010	11

For instance, Nordic nRF52832 have four vendor options as below:

Vendor Command	Parameter Description
00	CARRIER_TEST
01	CARRIER_TEST_STUDIO
10	SET_TX_POWER
11	SELECT_TIMER

CARRIER_TEST

If column 3 (the length) of the packet is set to 0, an unmodulated carrier 2.

ST (the status) is turned on at the channel indicated by column 2 (the frequency).

CARRIER_TEST_STUDIO

If column 3 (the length) of the packet is set to 1, an unmodulated carrier is turned on at the channel indicated by nRFgo studio, which is an application for configuring Nordic chips and which also supports a range of radio testing.

SET_TX_POWER

If column 3 (the length) of the packet is set to 2, column 2 (the frequency) sets the TX power in dBm..

Valid settings on Nordic nRF52832 are -40, -20, -16, -12, -8, -4, 0, +3, +4dB. They can only be modified while no transmitter or receiver test is running.

Only the 6 least significant bits of Tx power value will be fit in. Take -4dBm as an example: The representation of 8-bit binary in decimal -4 is 11111100. Determine that the 6 least significant bits are 111100, then fit them into the frequency field of the packet payload.

CMD	Frequency	Length	PKT
10	111100	000010	11

The command of setting Tx power to -4dBm in hexadecimal form will be 0xBC0B.

SELECT_TIMER

If column 3 (length) is set to 3, column 2 (frequency) selects the timer for transmitter test timing. The valid values of the timer are 0, 1, 2.

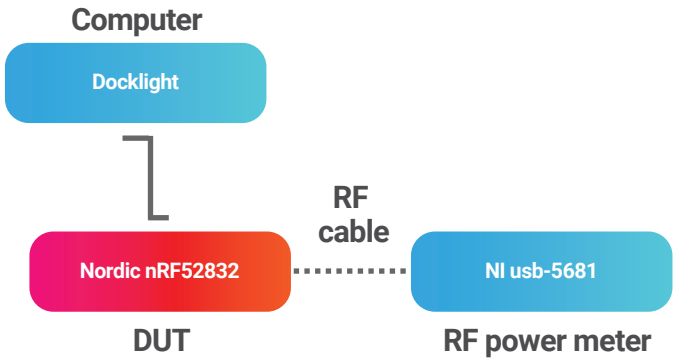
Summarize the Vendor Specific packet payload into one format.

CMD (2 bits)	Frequency (6 bits)	Length (6 bits)	PKT (2 bits)
10	Channel	000000	11
	Channel (Indicate by nRFgo)	000001	
	TX Power	000010	
	Timer	000011	

V - Debugging

All commands and events are binary messages, we need a simulator for monitoring the communication between two devices. Docklight is an application that can be simulated as a RS232/UART device and can manually create send/receive sequences from the communication data.

Using Nordic nRF52832 as a DUT, set Docklight to send the SET_TX_POWER of vendor commands, and check if the transmit power is correct through the RF power meter.



Set commands of sending sequence on Docklight:

1. DTM_tx set as LE_Transmitter_Test command (0x8000)

Transmitter Test	2402 MHz	Payload=0	PRBS9 Packet Payload
10	000000	000000	00

2. DTM_end set as LE_Test_End command (0xC000)

Test End	Zero	Zero	Zero
11	000000	000000	00

3. DTM_reset set as LE_Reset command (0x0000)

Reset	Zero	Zero	Zero
00	000000	000000	00

4. vender_value set as SET_TX_POWER of vendor commands

Valid TX Power	Value	Command
0 dBm	0x00	0x800B
+3 dBm	0x03	0x830B
+4 dBm	0x04	0x840B
-40 dBm	0xD8	0x880B
-20 dBm	0xEC	0xAC0B
-16 dBm	0xF0	0xB00B
-12 dBm	0xF4	0xB40B
-8 dBm	0xF8	0xB80B
-4 dBm	0xFC	0xBC0B

Click the button for vendor_value to set the Tx power, then click the DTM_tx button to start sending the sequence. DUT will response [RX]0x0000 every time an event is successful.

Communication

ASCII / HEX / DECIMAL / BINARY				
2017/11/27	16:16:27.921	[RX]	-	00 00
2017/11/27	16:16:30.109	[TX]	-	00 00
2017/11/27	16:16:30.111	[RX]	-	00 00
2017/11/27	16:16:34.708	[TX]	-	88 00
2017/11/27	16:16:34.711	[RX]	-	00 00
2017/11/27	16:16:35.742	[TX]	-	80 00
2017/11/27	16:16:35.743	[RX]	-	00 00
2017/11/27	16:16:41.606	[TX]	-	00 00
2017/11/27	16:16:41.608	[RX]	-	00 00
2017/11/27	16:16:44.268	[TX]	-	AC 0B
2017/11/27	16:16:44.270	[RX]	-	00 00
2017/11/27	16:16:45.322	[TX]	-	80 00
2017/11/27	16:16:45.324	[RX]	-	00 00
2017/11/27	16:16:48.342	[TX]	-	00 00
2017/11/27	16:16:48.344	[RX]	-	00 00
2017/11/27	16:16:50.281	[TX]	-	B0 0B
2017/11/27	16:16:50.282	[RX]	-	00 00
2017/11/27	16:16:51.277	[TX]	-	80 00
2017/11/27	16:16:51.279	[RX]	-	00 00
2017/11/27	16:16:53.116	[TX]	-	00 00
2017/11/27	16:16:53.118	[RX]	-	00 00

Send Sequences

SEND / NAME / SEQUENCE		
--->	DTM_tx	80 00
--->	DTM_end	CD 00
--->	DTM_end	C0 00
--->	vendor_D	80 0B
--->	vendor_+3	83 0B
--->	vendor_+4	84 0B
--->	vendor_-40	88 0B
--->	vendor_-20	AC 0B
--->	vendor_-16	B0 0B
--->	vendor_-12	B4 0B
--->	vendor_-08	BB 0B
--->	vendor_-04	BC 0B
--->	DTM_x	40 00

Figure 5-1: screenshot of Docklight simulating as a Tester

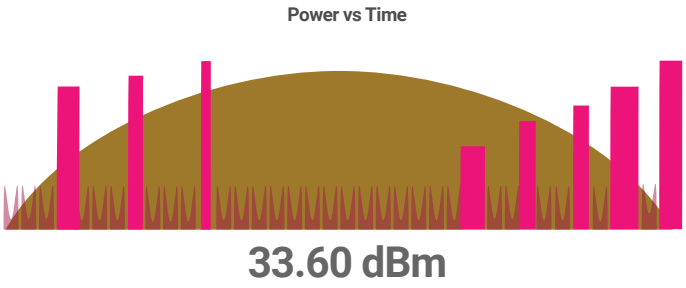


Figure 5-2: screenshot of power meter NI USB-5681 Soft Front Panel

V - Debugging

1. Bluetooth Specification

Version 4.0 Volume 6 Part F, Bluetooth Special Interest Group.

2. Nordic Semiconductor Infocenter

[Online].https://infocenter.nordicsemi.com/index.jsp?topic=%2Fcom.nordic.infocenter.sdk5.v12.3.0%2Fble_sdk_app_dtm_serial.html

3. Nordic Semiconductor nRF5 SDK v12.3.0

Directory:nRF5_SDK_12.3.0_d7731ad/examples/dtm/direct_test_mode