Bluetooth Core Production Test Using HCI Tester

1. Introduction

Using the HCI Tester tool for PC it is possible to run receive (RX) BER test on the Bluetooth (BT) core of the CC256x, BL6450L, WL127x and WL128x devices. The RX BER rate test can be performed between two TI BT devices, or between a production line test (PLT) instrument such as a LitePoint IQ2010, Rohde & Schwarz CBT or Agilent N4010A.

2. Bluetooth Receive Bit-Error-Rate Test Procedure

The BT RX BER test requires the transmitting entity to have the same settings as the CC256x/BL6450L/WL127x/WL128x device. The RX device settings and commands to be used are explained in section 2.1, while section 2.2 will explain the settings and commands to be used on the TX side if a TI BT device is being used as the transmitter instrument.

2.1 BT RX Device Settings and Commands

The BT device is connected to the HCI Tester and loaded with the appropriate service pack. After the service pack has been loaded, the following three commands must be used in HCI Tester:

```
Send_HCI_VS_DRPb_BER_Meter_Start 0xFD8B, 0, 0, 0x341278563412, 1, 0x5, 339, 1, 0x1FF, 0x1
Wait_HCI_Command_Complete_VS_DRPb_BER_Meter_Start_Event 5000, any, HCI_VS_DRPb_BER_Meter_Start, 0x00

Sleep 2000

Send_HCI_VS_DRP_Read_BER_Meter_Result 0xFD13
Wait_HCI_Command_Complete_VS_DRP_Read_BER_Meter_Result_Event 5000, any,
HCI_VS_DRP_Read_BER_Meter_Result, 0x00, 0x00, 0x00, 0x00, 0x00
```

The first command line's (`Send_HCI_VS_DRPb_BER_Meter_Start`) parameters are summarized below:

The ***first parameter*** is the ***frequency channel***. The frequency channel is as follows:

$f = 2402 + (2 \cdot i)\ (\text{MHz})$ with i=0...39 for frequencies from 2402 to 2480 in 2 MHz channel steps.

And

$f = 2403 + 2(i - 40)\ (\text{MHz})$ with i=40...78 for frequencies from 2403 to 2479 in 2 MHz channel steps.

The ***second parameter*** is ***Reserved*** and needs to be 0.

The ***third parameter*** is the ***BD address*** of the transmitting unit. The BD_ADDR parameter must be in little-endian format compared to the transmitting unit's BD_ADDR. For example, if TX BD_ADDR is written as 12345678ABCD, then RX BD_ADDR should be CDAB78563412.

The ***fourth parameter*** is the ***logical transport*** address (LT address) and should be set to 1.

The ***fifth parameter*** is the ***packet type*** in use, and it must match the transmitting unit's packet type (i.e. DH1, DH3, DH5, DM1, DM3,…)

The ***sixth parameter*** is the ***packet length***, and must also match the transmitting unit's packet length. The packet length allowed by the different packet types is:

Packet Type	Data Length
DM1	0 – 17
DH1	0 – 27
DM3	0 – 121
DH3	0 – 183
DM5	0 – 224
DH5	0 – 339

The ***seventh parameter*** is the ***number of packets*** the BER is to be tested over.

The ***eighth parameter*** is the ***PRBS Initialize*** **number** and this Pseudo Random Bit Sequence seed number should be set to the default, 0x1FF.

The ***ninth parameter*** is the ***POLL period***, and if set to 1, the measurements will be taken every BT frame, and the test will be performed quicker as the BER calculation will not skip every n'th frames. If the POLL period is set to 5 as an example, then the BER measurements will measure the TX portion of the BT frame every five frames, hence making the measurement five times as long.

The first command's parameters are summarized in Figure 1.

HCI_VS_DRPb_BER_Meter_Start	
Type	sc
Opcode	0xFD8B
Frequency Channel	0
Reserved	0
BD Address	0x341278563412
LT Address	1
ACL Packet Type	(0x1) DH1
packet length	27
Number of packets	1
PRBS Initilaize	0x1FF
POLL Period	0x1

Figure 1. `HCI_VS_DRPb_BER_Meter_Start` parameters

The third command (`Sleep`) line is the delay needed in the HCI Tester for the BER test to finish. The delay is given in ms. As shown below, the delay is 2,000 ms, or 2 seconds.

```
Sleep 2000
```

The fourth command line (`Send_HCI_VS_DRP_Read_BER_Meter_Result`) will display the results for the BER test. The last two lines shows the result, and in the example shown below a total of 5,400 bits were counted with 0 error bits found. Hence, the BER is 0% for this case.

```
18:15:46.101 --
18:15:46.101 Packet "HCI_Command_Complete_VS_DRP_Read_BER_Meter_Result_Event", Opcode 0xfd13
18:15:46.101 Parameters:
18:15:46.101 | Number HCI commands                           : 0x01
18:15:46.101 | Command Opcode                                : 0xfd13
18:15:46.101 | Status                                        : 0x00 (Success)
18:15:46.101 | Finished at least 1 test                      : 0x01
18:15:46.101 | Number of packet received in current measurment : 0x0005
18:15:46.101 | Total bits counted                            : 0x00001518
18:15:46.101 | Number of bits error found                    : 0x00000000
```

2.2 BT TX HCI Device Settings and Commands

If a TI BT device is used as a BT transmitter for the RX BER test, the following commands needs to be written to the device (CC256x/BL6450L/WL127x/WL128x):

```
Send_HCI_VS_Write_BD_ADDR 0xFC06, "123456781234"
Wait_HCI_Command_Complete_VS_Write_BD_ADDR_Event 5000, any, HCI_VS_Write_BD_ADDR, 0x00

Send_HCI_VS_DRPb_Tester_Packet_TX_RX 0xFD85, 3, 0, 0xFF, 0x6, 0x5, 0, 27, 9, 1, 0x01FF
Wait_HCI_Command_Complete_VS_DRPb_Tester_Packet_TX_RX_Event 5000, any, HCI_VS_DRPb_Tester_Packet_TX_RX, 
0x00
```

The first command line sets the Bluetooth address (BD address) of the transmitter. This address must match the address that the receiver is seeking for (i.e. what the first command line in section 2.1 is set to).

The second command line contains the parameters that set the transmitter to the desired. This command has ten parameters.

The ***first parameter*** is ***frequency mode***. The selection is either single frequency (transmitting packets on a single frequency), or frequency hop (the regular Bluetooth frequency hopping scheme).

The ***second parameter*** is the ***TX single frequency index***. This selection is used if the first parameter (frequency mode) is set to *single frequency*. The transmit frequency channel is set as follows:

$f = 2402 + (2 \cdot i)\ (\mathrm{MHz})$ with i=0,1,2,...39 for frequencies from 2402 to 2480 in 2 MHz channel steps.

And

$f = 2403 + 2(i - 40)\ (\mathrm{MHz})$ with i=40,41,42,...78 for frequencies from 2403 to 2479 in 2 MHz channel steps.

The ***third parameter*** is the ***RX single frequency index***. This selection sets the receiver frequency. The receive frequency channel is set as follows:

$f = 2402 + (2 \cdot i)\ (\mathrm{MHz})$ with i=0,1,2,...39 for frequencies from 2402 to 2480 in 2 MHz channel steps.

And

$f = 2403 + 2(i - 40)\ (\mathrm{MHz})$ with i=40,41,42,...78 for frequencies from 2403 to 2479 in 2 MHz channel steps. If the parameter is set to 0xFF, the receive functionality is disabled.

The ***fourth parameter*** is the ***ACL TX packet type***. This selection sets the type of packet(s) to be transmitted. The choices are:

SDR: DM1, DH1, DM3, DH3, DM5, DH5
EDR 2 Mbps: 2-DH1, 2-DH3, 2-DH5
EDR 3 Mbps: 3-DH1, 3-DH3, 3-DH5.

The ***fifth parameter*** is the ***ACL TX packet data pattern***. This parameter determines the bit content of the packet to be transmitted. The choices are all 0's, all 1's, Z0Z0, F0F0 (i.e. 1111000011110…), ordered, or PRBS9.

The ***sixth parameter*** is the ***use extended features***. This parameter can either be enabled or disabled.

The ***seventh parameter*** is the ***ACL packet data length***. The packet length allowed by the different packet types is:

Packet Type	Data Length
DM1	0 – 17
DH1	0 – 27
DM3	0 – 121
DH3	0 – 183
DM5	0 – 224
DH5	0 – 339

The ***eighth parameter*** is the ***power level index.*** This parameter corresponds to the `HCI_VS_DRPb_Set_Power_Vector` command in the service pack loaded into the device. Power level index 0 is the lowest output power, power level 1 is the BLE output (for SDR mode, not EDR2 and EDR3), and power level 15 is the highest RF output power.

The ***ninth parameter*** is the ***disable whitening*** feature. This parameter input can enable or disable the whitening feature of the packets. Data whitening is a scrambling process applied to both the header and data. It is applied to minimize any DC bias in the packet.

The ***tenth parameter*** is the ***PRBS9 init value***. This parameter seeds the pseudo random bit sequence generator seed.

The second command line's parameters are summarized in Figure 2.

HCI_VS_DRPb_Tester_Packet_TX_RX	
Type	sc
Opcode	0xFD85
Frequency Mode	(0x03) Single freq
TX Single Frequency Index	0
RX Single Frequency Index	0xFF
ACL TX Packet Type	(0x6) 2-DH1
ACL TX Packet Data Pattern	(0x5) PRBS9 Random
Use Extended features	(0) Disable
ACL Packet Data Length	27
Power level index	(9) Power Level 9
Disable whitening	(0x01) Disable
PRBS9 Init Value	0x01FF

Figure 2. `HCI_VS_DRPb_Tester_Packet` parameters

2.3 Sequence for using TI devices for both RX and TX for the RX BER test

The sequence for running a receive BER test with having a TI HDK for both the transmitter and receiver units would be to load the respective service packs for the two HDKs (or one HDK and one DUT) using HCI Tester tool for PC. One HCI Tester Tool program would be connected to each of the two HDKs, having a total of two HCI Tester programs running on the PC.

Set the transmit parameters (outlined in chapter 2.2) and send them using the HCI Tester tool connected to the transmit unit.

Set the receive parameters to match the transmit parameter exactly, and using the second HCI Tester tool connected to the receive HDK (or the DUT) to the unit to be tested for BER.

Remember to allow enough delay between the two commands outlined in chapter 2.1 for the BER test to finish. Otherwise erroneous results will occur as the `HCI_VS_DRPb_BER_Meter_Start` is not given enough time to complete the number of packets specified.

3. HCI commands for Bluetooth TX FCC testing

The TI Bluetooth radios (CC256x/BL6450L/WL127x/WL128x) can be put into a special mode for FCC testing. This chapter provides the HCI commands to put the Bluetooth radio in this mode. The commands are the same for any of the CC256x/BL6450L/WL127x/WL128x Bluetooth radio.

3.1 Constant transmission at a single frequency channel

To put the device in constant transmission at a constant frequency the following commands need to be sent:

```
Send_HCI_VS_DRPb_Tester_Con_TX 0xFD84, 0x1, 0x0, 78, 15, 0x00000000, 0x00000000
Wait_HCI_Command_Complete_VS_DRPb_Tester_Con_TX_Event 5000, any, HCI_VS_DRPb_Tester_Con_TX, 0x00

#PM generator on
Send_HCI_VS_Write_Hardware_Register 0xFF01, 0x0019180c, 0x0101
Wait_HCI_Command_Complete_VS_Write_Hardware_Register_Event 5000, any, HCI_VS_Write_Hardware_Register,
0x00

# Disables Continuous Calibration
Send_HCI_VS_DRPb_Enable_RF_Calibration 0xFD80, 0xFF, 0xFFFFFFFF, 0x01
Wait_HCI_Command_Complete_VS_DRPb_Enable_RF_Calibration_Event 5000, any,
HCI_VS_DRPb_Enable_RF_Calibration, 0x00
```

The three command lines above will setup the device for continuous transmission for the specified BT frequency channel, data rate and power level.

The first command line (`Send_HCI_VS_DRPb_Tester_Con_TX`) sets up the frequency, data rate and power level. The selectable parameters are explained below:

The ***first parameter*** is ***modulation scheme***. The selections are:

CW	Second parameter, *test pattern*, needs to be either "*All 1*" or "*All 0*"
GFSK	Standard data rate
2-EDR	EDR, 2 Mbps
3-EDR	EDR, 3 Mbps
BLE	Low Energy

The ***second parameter*** is the ***test pattern***. This sets the data transmitted:

PN9	This choice provides a psuedo-random bit sequence containing 511 bits (2^9–1)
PN15	This choice provides a psuedo-random bit sequence containing 32767 bits (2^15–1)
Z0Z0	This choice sends a 1010,1010,1010 bit pattern (A0A0A0A0..) as data load
All 1	This choice sends all 1's as data load
All 0	This choice sends all 1's as data load
F0F0	This choice sends 1111,0000,1111,0000… as data load
FF00	This choice sends 1111,1111,0000,0000,1111…. As data load
User defined	This choice lets the user send a custom bit pattern as data load

The ***third parameter*** is the ***frequency index***. This parameter sets the frequency to be used for the transmission. The frequency is calculated as:

$f = 2402 + (2 \cdot i)$ (MHz) with i=0,1,2,...39 for frequencies from 2402 to 2480 in 2 MHz channel steps.

And

$f = 2403 + 2(i - 40)$ (MHz) with i=40,41,42,...78 for frequencies from 2403 to 2479 in 2 MHz channel steps.

The ***fourth parameter*** is the ***power level index.*** This parameter corresponds to the `HCI_VS_DRPb_Set_Power_Vector` command in the service pack loaded into the device. Power level index 0 is the lowest output power, power level 1 is the BLE output (for BLE mode, not GFSK, EDR2 or EDR3), and power level 15 is the highest RF output power.

The ***fifth parameter*** is the ***generator init value.*** This parameter sets the initial generator startup value.
The ***sixth parameter*** is the ***EDR generator mask value.*** This parameter sets the generator mask value.

3.2 Constant transmission in frequency hopping mode

To put the device in constant transmission and frequency hop mode the following commands need to be sent:

```
Send_HCI_VS_DRPb_Tester_Packet_TX_RX 0xFD85, 0x01, 0, 0xFF, 0, 2, 0, 27, 15, 1, 0x01FF
Wait_HCI_Command_Complete_VS_DRPb_Tester_Packet_TX_RX_Event 5000, any, HCI_VS_DRPb_Tester_Packet_TX_RX, 0x00
```

The command line above will setup the device for continuous transmission with frequency hopping for the data rate and power level.

The command line (`Send_HCI_VS_DRPb_Tester_Packet_TX_RX`) sets up the frequency, data rate and power level. The selectable parameters are explained in section 2.2 in this application note.