GR55xx DTM Test Application Note

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Preface

Purpose

This document introduces the test framework, test methods, and HCI control frame format of Direct Test Mode (DTM) in Bluetooth Low Energy (Bluetooth LE) applications. It describes how to use a Bluetooth tester to test the radio frequency (RF) performances of GR55xx SoCs and demonstrates a GR55xx DTM example, helping users quickly get started with secondary development.

Audience

This document is intended for:

- GR55xx user
- GR55xx developer
- GR55xx tester
- Hobbyist developer
- Technical writer

Release Notes

This document is the sixth release of *GR55xx DTM Test Application Note*, corresponding to GR55xx SoC series.

Revision History

Version	Date	Description
1.0	2019-12-08	Initial release
1.3	2020-03-16	Updated the release time in the footers.
1.5	2020-05-30	Modified "Deliver HCI Commands".
1.6	2020-06-30	Updated the document version based on SDK changes.
1.7	2020-09-20	• Added two private commands: the LE Generate Signal Carrier Wave Command (to generate single carrier waves), and the LE Modify TX Power Command (to set the TX power for DTM TX tests), and updated relevant content. • Modified "Deliver HCI Commands" to "DTM Tests (Manual Operation)". • Added "Test Considerations".
1.8	2021-06-26	• Updated GR551x to GR55xx. • Optimized descriptions in "Initial Operation".

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1 Introduction

The Direct Test Mode (DTM) is a standard mechanism defined by Bluetooth Special Interest Group (Bluetooth SIG) to test the radio frequency (RF) performance of Bluetooth devices for all Bluetooth channels. In general, DTM is used in application validation and product line tests, enabling RF engineers to effortlessly verify and optimize Bluetooth RF performances. Tested RF factors include:

- Transmission power and receiver sensitivity
- Frequency offset and drift
- Modulation characteristics
- Packet error rate

The DTM test on GR55xx SoCs is based on UART physical interfaces and a Bluetooth tester. The Bluetooth tester controls GR55xx RF physical layer (PHY) by using Host Controller Interface commands (HCI CMD) to implement test procedures.

Before getting started, you can refer to the following documents.

Table 1-1 Reference documents

Name	Description
Developer guide of the specific GR55xx SoC	Introduces the software/hardware and quick start guide of the specific GR55xx SoC in use.
Keil User Guide	Offers detailed Keil operational instructions. Available at www.keil.com/support/man/docs/uv4/.
RF PHY Bluetooth Test Suite TS	Introduces RF PHY test specifications. For Core-Test Requirements, see http://bluetooth.com/specifications/qualification-test-requirements/.

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2 DTM Test Framework and Procedures

This chapter introduces the test framework and fundamental test procedures of DTM.

2.1 DTM Test Framework

A DTM test involves three types of test devices:

- Device Under Test (DUT)
- Upper Tester (UT)
- Lower Tester (LT)

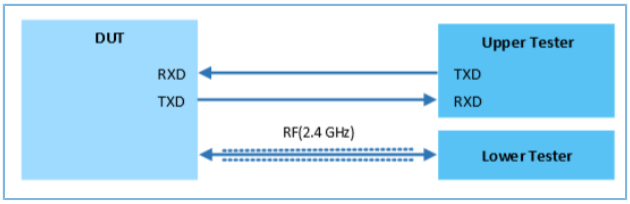

Figure 2-1 DTM test framework

DUT can work as a Transmitter Device (TXD) that transmits (TX) Bluetooth LE packets or a Receiver Device (RXD) that receives (RX) Bluetooth LE packets.

- TX test

  As a TXD, the DUT transmits test group sequences at a specified frequency to the LT that analyzes the transmission power, frequency offset, and modulation characteristics based on the received signals.

- RX test

  As an RXD, the DUT receives test group sequences transmitted by the LT at a specified frequency that is the same with that in LT transmission. After receiving, Bit Error Rate (BER) and other indicators received by the DUT are used to measure the RXD performance.

  UT communicates with DUT through UART, and LT communicates with DUT through Bluetooth LE links. The UART parameters of DUT are as follows:

Table 2-1 UART parameter setting in UT-DUT communications

Baud Rate (Recommended)	Bit Size	Checksum Bit	Stop Bit	Flow Control
1200, 2400, 9600, 14400, 19200, 38400, 57600, 115200, 230400, 460800, and 921600	8 bits	N/A	1 bit	Not supported

2.2 DTM Test Procedures

During DTM tests, the UT transmits an HCI test command through a UART interface to the DUT that returns the test Status Event or Packet Report Event to the UT. Before receiving a reply from the DUT, the UT does not deliver another test command. If the UT does not receive any reply from the DUT within a regulated time period, the UT delivers a reset command to the DUT.

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The mapping between RF test commands/events and HCI commands/events is shown in Table 2-2.

Table 2-2 Mapping between RF test commands/events and HCI commands/events

RF Test Command/Event	HCI Command/Event
LE_TRANSMITTER_TEST	LE Transmitter Test Command or LE Enhanced Transmitter Test Command
LE_RECEIVER_TEST	LE Receiver Test Command or LE Enhanced Receiver Test Command
LE_TEST_END	LE Test End Command
LE_STATUS	Command Complete Event
LE_PACKET_REPORT	Command Complete Event

Figure 2-2 illustrates the TX, RX, and End procedures of a DTM test using the LE Transmitter Test Command, LE Receiver Test Command, and LE Test End Command as examples.

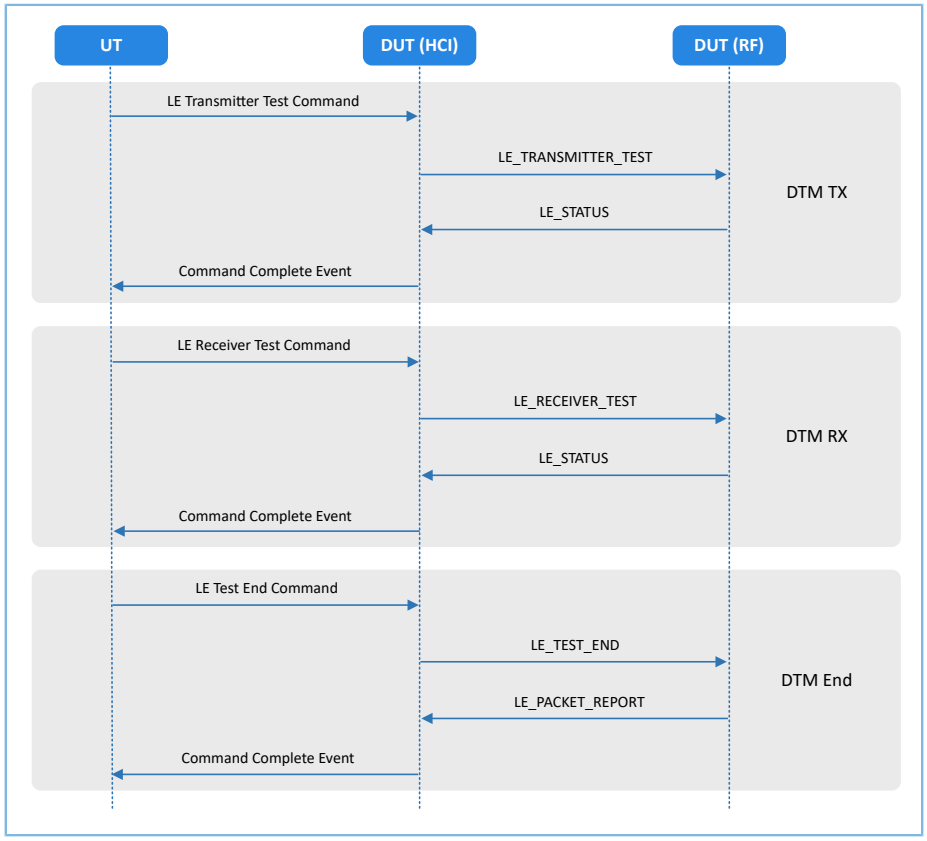

Figure 2-2 DTM test procedure example

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3 Initial Operation

This chapter introduces how to quickly verify a DTM example in GR55xx SDK.

Note:

SDK_Folder is the root directory of the GR55xx SDK in use.

3.1 Supported Development Platform

You can use and modify the DTM example on the following platform.

Table 3-1 Supported development platform

Hardware Platform	Development Board Model
GR551x development kit	GR5515-SK-BASIC

3.2 Firmware Download

The source code of the DTM example is in SDK_`Folder\projects\ble\dtm\direct_test_mode`.

You can download *direct_test_mode_fw.bin* to the GR55xx SK Board through GProgrammer. For details, see *GProgrammer User Manual*.

Note:

- The *direct_test_mode_fw.bin* is in SDK_`Folder\projects\ble\dtm\direct_test_mode\build\`.
- You can find GProgrammer in SDK_`Folder\tools\GProgrammer`.

3.3 Test and Verification

The hardware and software required for test and verification are listed as follows:

Table 3-2 Hardware and software resources

Name	Description
GRUart (Windows)	A serial port debugging tool. Available in SDK_`Folder\tools\GRUart`.
TLF3000 RF-PHY Tester and driver	Downloaded at: http://www.fte.com/products/tlf3000.aspx.
R&S®CMW500 tester and driver	Downloaded at: https://www.rohde-schwarz.com.
Bluetooth tester	R&S CBT, MT8852B, CMW500, TLF3000, or others.

The DTM test on GR55xx SoCs adopts a two-wire UART to transmit HCI frame formats to control the RF PHY. Therefore, any testers supporting HCI format can be used in DTM tests and verification on GR55xx SoCs. This section introduces the DTM test and verification procedures by using TLF3000 and R&S®CMW500.

3.3.1 DTM Testing with TLF3000

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Set up a DTM test environment with TLF3000.

1. Install TLF3000 RF-PHY Tester software and drivers on a PC.
2. Connect the TLF3000 hardware to the PC and the GR55xx Board to the PC with Micro USB cables respectively. Connect the RF pin on the DUT to the TX/RX port on the TLF3000 hardware through a cable. The details are shown in the figure below.

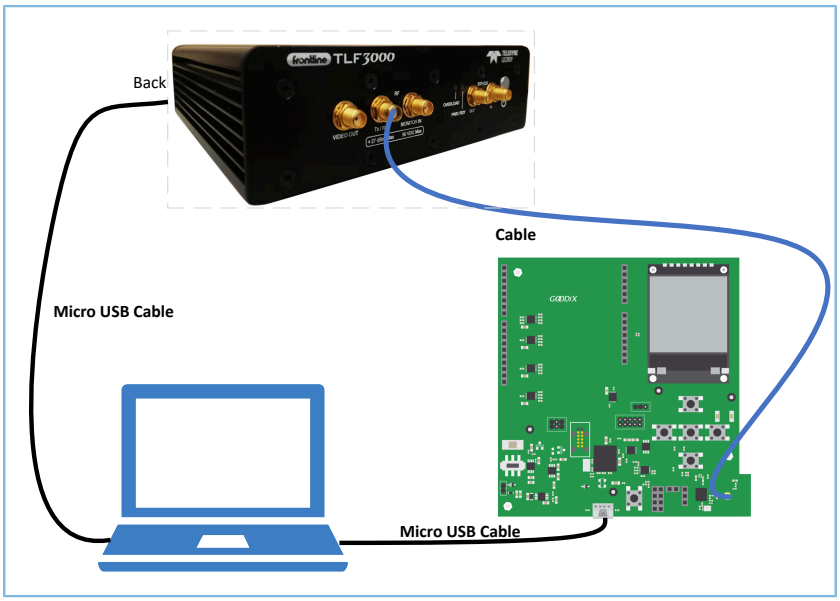

Figure 3-1 Hardware connection in a TLF3000 test environment

DTM test procedures with TLF3000:

1. Power the TLF3000 hardware on, start the TLF3000 software, and select the TLF3000 model used in the DTM test. Click **RUN APP** to enter the TLF3000 software GUI.

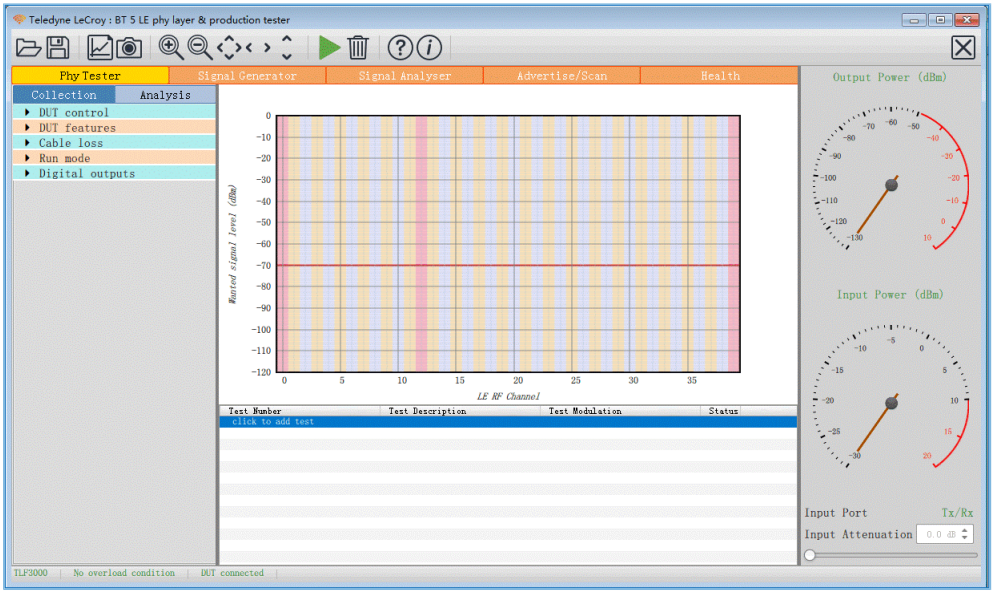

Figure 3-2 Hardware connection in a TLF3000 test environment

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2. Configure **DUT control** parameters. Select a serial port from the **Comport** list. Select **H4** from **Interface** and **115200** from **Baud rate**. Select **None** from the **HW flow**, **SW flow**, and **Parity bits** lists. Select **One** from the **Stop bits** list.

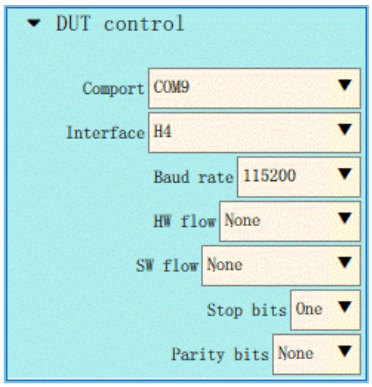

Figure 3-3 DUT control configuration

3. Open the **DUT features** pane, and click **Query DUT** to obtain the DUT-related features.

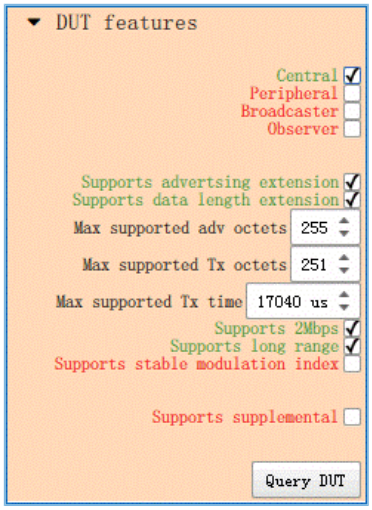

Figure 3-4 Obtaining DUT features

4. Select a running mode in the **Run mode** pane.

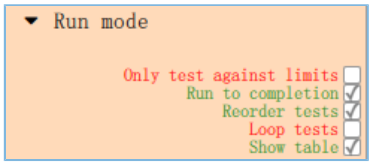

Figure 3-5 Configuring Run mode

5. Click **click to add test**, and the **Phy Level Test** window opens. Select test cases in the **TP/TRM-LE/CA/BV-12** tab. Configure the **Channels**, **Packet Lengths**, and **Number of packets** for the selected test cases. After configuration, click **Apply** to complete test adding.

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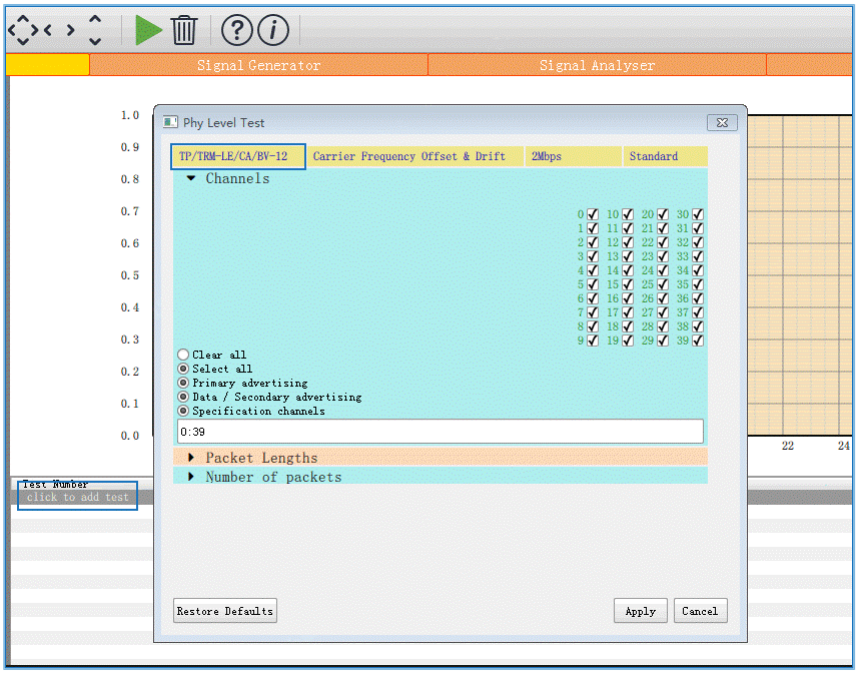

Figure 3-6 Selecting test cases

6. Click ▶ to start the DTM test. When the test completes, a window containing logs in HTML format automatically opens. Click 🖫 to store the logs in a HTML file, or click 📷 to save the log screenshot.

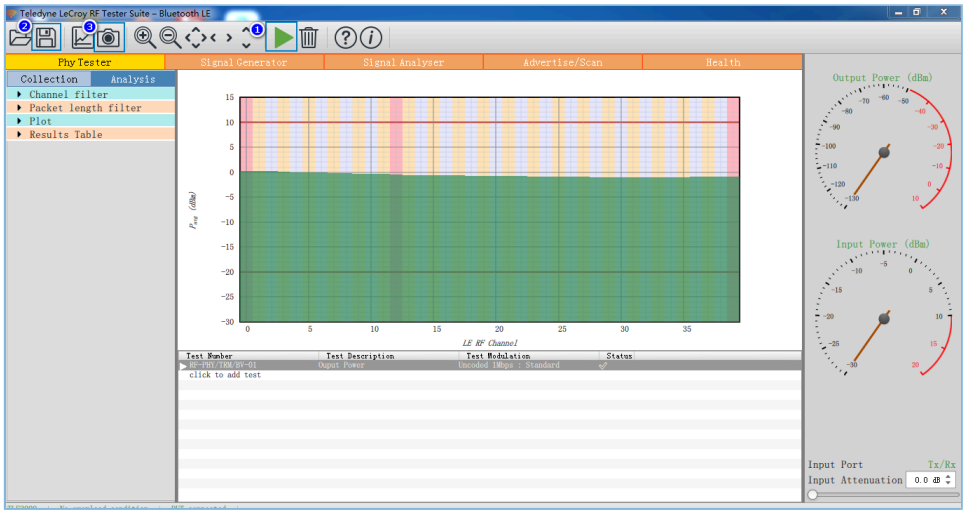

Figure 3-7 Running test cases

3.3.2 DTM Testing with R&S® CMW500

Set up a DTM test environment with R&S® CMW500.

1. Install R&S® CMW500 automation software tool (R&S® CMWrun Sequencer Software Tool) and drivers on a PC.

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2. Connect the R&S®CMW500 USB port to the UART port on the GR55xx Board with a Micro USB cable. Connect the RF COM port on the R&S®CMW500 to the RF port on the SK Board with a cable. The connection diagram is displayed in the Figure 3-8.

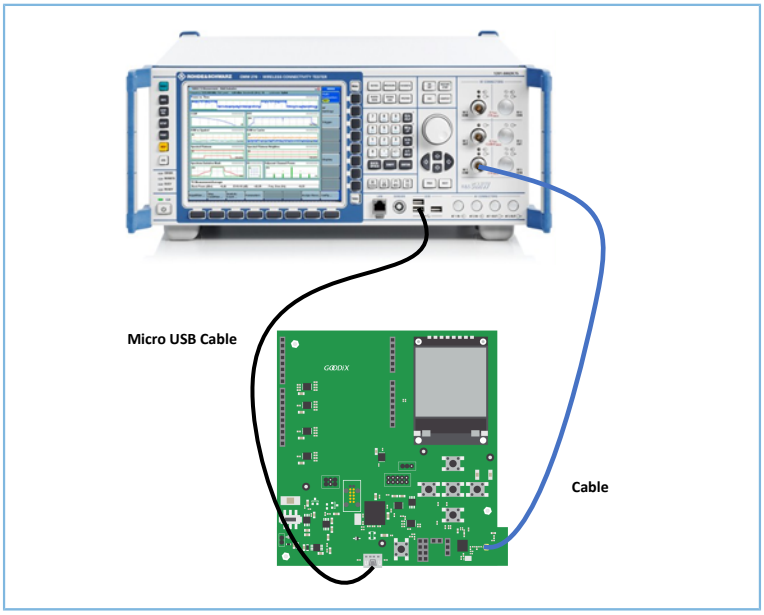

Figure 3-8 Hardware connection in an R&S®CMW500 test environment

DTM test procedures with R&S®CMW500:

1. Configuring the Bluetooth signaling test mode on the R&S®CMW500. In this mode, the R&S®CMW500 automatically delivers HCI commands to interact with the GR55xx Board, enabling automated DTM tests.

   (1). On the R&S®CMW500, press **MEASURE** to open the **Measurement Controller** window, and select **Measurements** in **Bluetooth**.

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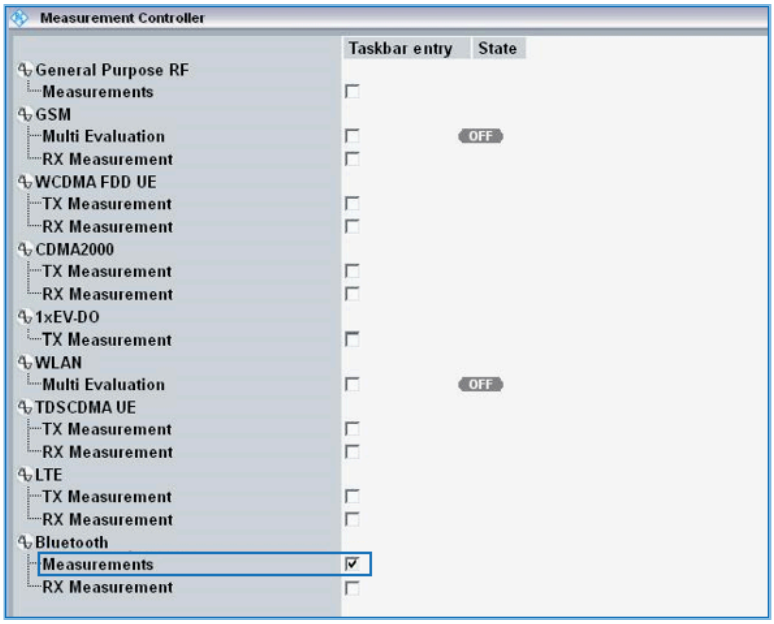

Figure 3-9 Configuring Bluetooth measurements for R&S®CMW500

(2). On the R&S®CMW500, press **SIGNALGEN** to open the **Generator/Signaling Controller** window, and select **Signaling** in **Bluetooth**.

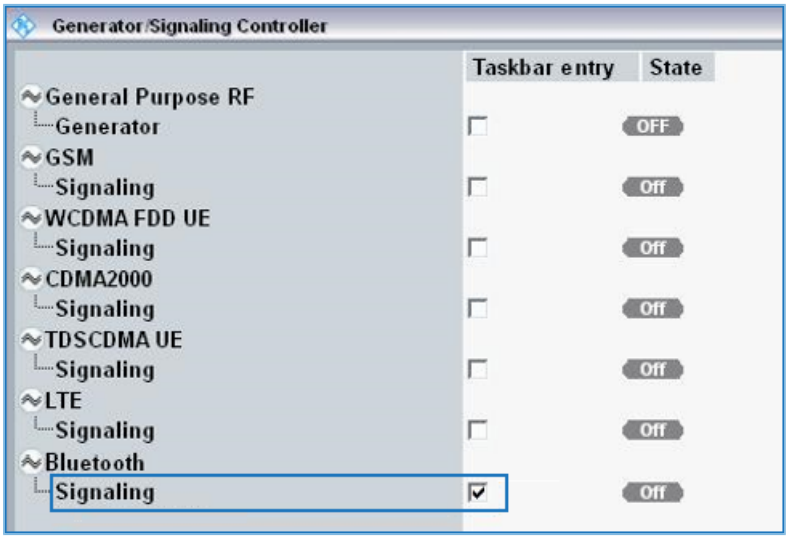

Figure 3-10 Configuring Bluetooth signaling mode for R&S®CMW500

2. Connecting to UART

(1). Confirm that the R&S®CMW500 serial drivers have been properly installed on the PC. Make sure that the R&S®CMW500 tester has been correctly connected to the UART port of the GR55xx Board.

(2). The R&S®CMW500 tester automatically identifies the COM port used by the UART, and developers only need to configure the baud rate, odd-even parity, and other parameters related to the DTM test firmware.

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After setting these parameters, click **Connection Check** to connect the R&S® CMW500 tester to the UART. You can implement the DTM test after successful connection to UART.

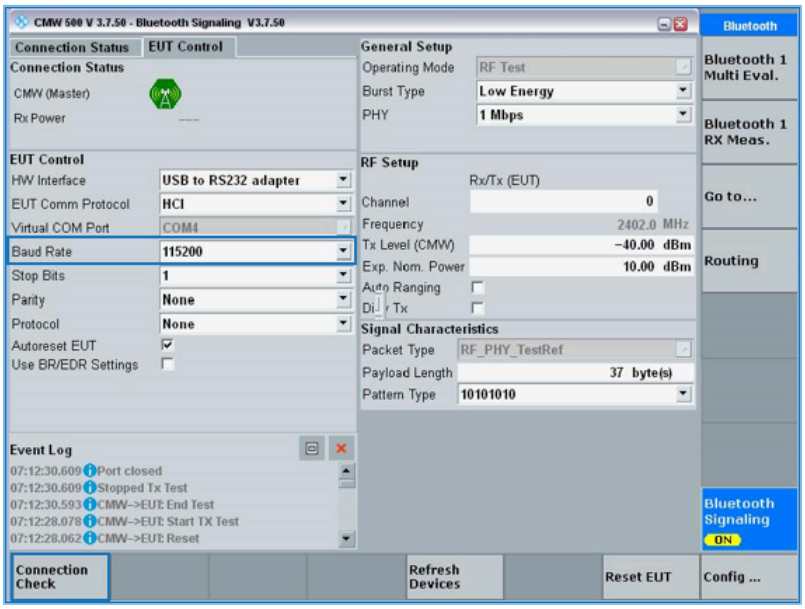

Figure 3-11 Connecting to UART

3. Running DTM automation test

Start R&S® CMWrun, and select **CMW RUN**. Load the Bluetooth LE test program, BLE_PHY_5_0_0, and click Run to run the DTM test.

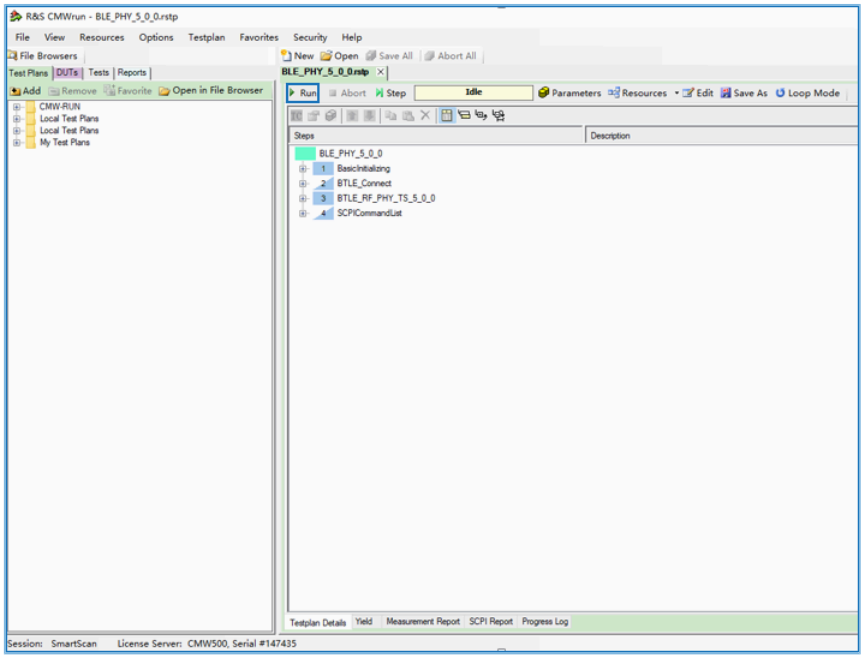

Figure 3-12 R&S®CMW500 DTM test interface

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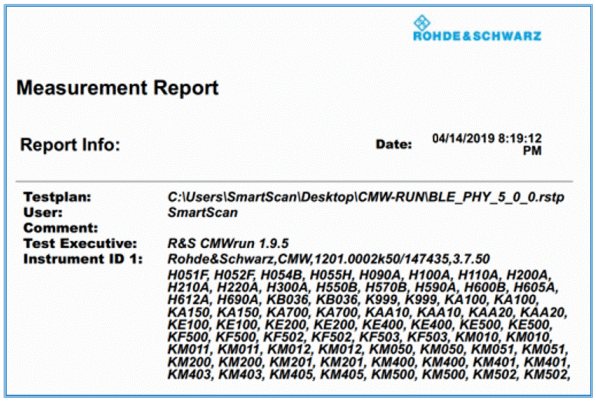
4. Generating a test report.

   After the test completes, the R&S®CMW500 software tool automatically generates a test report, as shown in Figure 3-13.


ROHDE&SCHWARZ

Measurement Report

Report Info: **Date:** 04/14/2019 8:19:12 PM

Testplan:	*C:\Users\SmartScan\Desktop\CMW-RUN\BLE_PHY_5_0_0.rstp*
User:	*SmartScan*
Comment:	
Test Executive:	*R&S CMWrun 1.9.5*
Instrument ID 1:	*Rohde&Schwarz,CMW,1201.0002k50/147435,3.7.50*
	H051F, H052F, H054B, H055H, H090A, H100A, H110A, H200A, H210A, H220A, H300A, H550B, H570B, H590A, H600B, H605A, H612A, H690A, KB036, KB036, K999, K999, KA100, KA100, KA150, KA150, KA700, KA700, KAA10, KAA10, KAA20, KAA20, KE100, KE100, KE200, KE200, KE400, KE400, KE500, KE500, KF500, KF500, KF502, KF502, KF503, KF503, KM010, KM010, KM011, KM011, KM012, KM012, KM050, KM050, KM051, KM051, KM200, KM200, KM201, KM201, KM400, KM400, KM401, KM401, KM403, KM403, KM405, KM405, KM500, KM500, KM502, KM502,

Figure 3-13 CMW500 DTM test report

Note:

The R&S®CMW500 automation software tool (R&S®CMWrun) should be purchased by users.

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4 Application Details

Settings for serial ports vary, depending on the DUT. Users can modify the configurations on the serial ports of the direct_test_mode project to meet the DTM test requirements from the DUT. By default, a GR55xx SK Board is used as the DUT for direct_test_mode.

4.1 Project Directory

The direct_test_mode project is in SDK_Folder\projects\ble\dtm\direct_test_mode, and the project file is located in the Keil_5 folder.

Double-click the project file, *direct_test_mode.uvprojx*, to view the direct_test_mode project directory structure of the DTM application in Keil. For related files, see Table 4-1.

Table 4-1 Description of direct_test_mode files

Group	File	Description
gr_libraries	hci_uart.c	This file adapts to the UART drivers of Bluetooth LE Stack DTM test.
user_app	main.c	This file contains the main() function, enabling registration of HCI UART interfaces.

4.2 Configure UART Ports

GR55xx provides two UART ports: UART0 and UART1. UART0 is used by the GR55xx Board, and GPIO10/GPIO11 are used for TX/RX of UART. GPIO2/GPIO5 are used for signal flow control, with baud rate at 115200. Taking GR551x SDK for an example, configurations shall be made based on IO mapping of the board, which are described below:

Path: user_app\GR5515_SK.h under direct_test_mode project directory

Name: HCI UART IO CONFIG

```
/*******HCI UART IO CONFIG**********************/
#define HCI_UART_ID                      APP_UART_ID_0
#define HCI_UART_FLOW_ON                 0
#define HCI_UART_BAUDRATE                115200
#define HCI_UART_TRN_PORT                APP_IO_TYPE_NORMAL
#define HCI_UART_FLOW_PORT               APP_IO_TYPE_NORMAL
#define HCI_UART_TX_PIN                  APP_IO_PIN_10
#define HCI_UART_RX_PIN                  APP_IO_PIN_11
#define HCI_UART_CTS_PIN                 APP_IO_PIN_2
#define HCI_UART_RTS_PIN                 APP_IO_PIN_5
#define HCI_UART_TX_PINMUX               APP_IO_MUX_2
#define HCI_UART_RX_PINMUX               APP_IO_MUX_2
#define HCI_UART_CTS_PINMUX              APP_IO_MUX_0
#define HCI_UART_RTS_PINMUX              APP_IO_MUX_0
#define HCI_UART_TRIGGER_PIN             AON_GPIO_PIN_1
```

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Note:

Configurations on the serial ports shall be modified according to the hardware layout of the DUT.

If you want to use UART1 as the HCI communications interface, define the HCI_UART_ID macro as APP_UART_ID_1 in *GR5515_SK.h*. Modify the UART pin macro in the *GR5515_SK.h* based on the UART I/O mapping on the DUT. For more information about I/O multiplexing on GR55xx SoCs, refer to specific GR55xx Datasheet in use.

4.3 Transplant DTM Function

This section elaborates on how to transplant the DTM function to a Bluetooth LE application project.

To do that, follow the steps below:

1. Add the *hci_uart.c* file to the application project, and refer to *hci_uart.c* in the *main.c* file.
2. Call the ble_stack_init() function to initialize the Bluetooth Protocol Stack.
3. During initialization, call the ble_hci_uart_init() function to initialize the UART port and communications protocol stack required in a DTM test.

Path: `user_app\main.c` under direct_test_mode.uvprojx

Name: main();

```
#include "hci_uart.h"

static uint8_t s_hci_buffer[256] = {0};

int main (void)
{
    ble_stack_init(&app_ble_callback, &heaps_table);/*< init ble stack*/

    ble_hci_uart_init(s_hci_buffer, sizeof(s_hci_buffer));

    //loop
    while(1)
    {

    }
}
```

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5 DTM Tests (Manual Operation)

In general, DTM tests are performed by dedicated instruments automatically. The instrument and the DUT communicate through HCI commands. Alternatively, users can also simulate DTM test instrument to perform tests by sending HCI commands manually.

This section introduces how to use GRUart, a serial port debugging tool, to deliver HCI commands and to control the DUT to enter the TX or RX mode, as well as some more functions. Operations of UT are customized according to the Core-Test Requirements, and are not described in this document.

Note:

DTM tests shall be performed in shielding boxes.

5.1 Introduction to HCI

The UT controls the DUT to perform DTM tests by delivering HCI commands. The HCI commands are used to configure the DUT status or send requests to the DUT to complete related operations. The HCI Event Packets returned to the UT from the DUT are used to respond to relevant information. Each HCI command corresponds to an HCI event.

5.1.1 HCI Command Format

The data structure of an HCI command is shown in Figure 5-1.

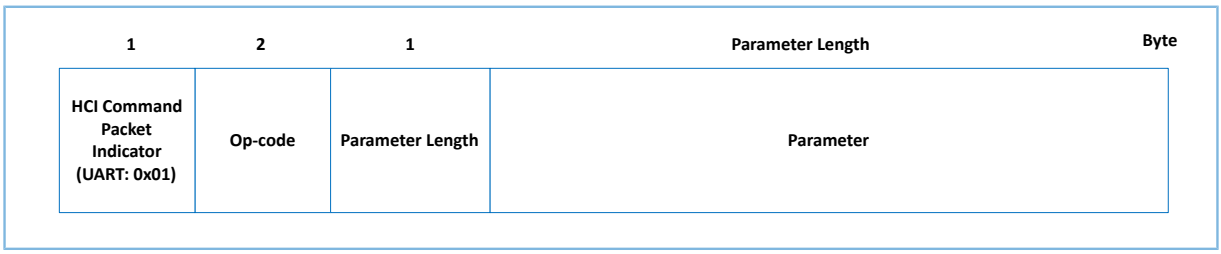

Figure 5-1 Format of an HCI Command Packet

- HCI Command Packet indicator: Indicates the HCI type. The indicator byte for the UART interface is 0x01 .
- Op-code: a 2-byte code that identifies the command type.
- Parameter Length: the total length of all parameters. Length: 1 byte.
- Parameter: parameter description. The parameter quantity and length vary depending on the command.

5.1.2 HCI Event Format

The data structure of an HCI event is shown in Figure 5-2.

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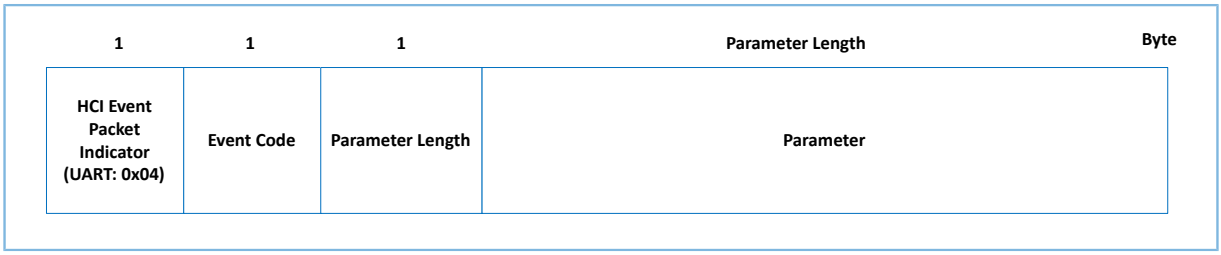

Figure 5-2 Format of an HCI Event Packet

- HCI Event Packet indicator: Indicates the HCI type. The indicator byte for the UART interface is 0x04.
- Event Code: a 1-byte code that identifies the command type.
- Parameter Length: the total length of all parameters. Length: 1 byte.
- Parameter: event parameter. The parameter quantity and length vary depending on the command.

5.2 Deliver HCI Commands

Before delivering an HCI test command, complete the following steps:

- Power the GR55xx SoC on (with DTM test firmware installed) to wait for HCI commands.
- Start GRUart, and select baud rate, data bit, stop bit, and parity parameters based on the UART configurations in the DTM test firmware. Enable the UART.

Use GRUart to deliver an HCI command. DTM-test-related HCI commands include:

- LE Reset Command
- LE Transmitter Test Command
- LL Enhanced Transmitter Test Command
- LE Receiver Test Command
- LE Enhanced Receiver Test Command
- LE Test End Command

The sections below introduce three common HCI commands related to DTM tests: LE Transmitter Test Command, LE Receiver Test Command, and LE Test End Command.

5.3 DTM TX Test (Manual Operation)

5.3.1 Initiate a DTM TX Test

The LE Transmitter Test Command is used to enable the DTM TX test. The GR55xx SoC generates a specific type of test packets on a specified channel at a fixed interval.

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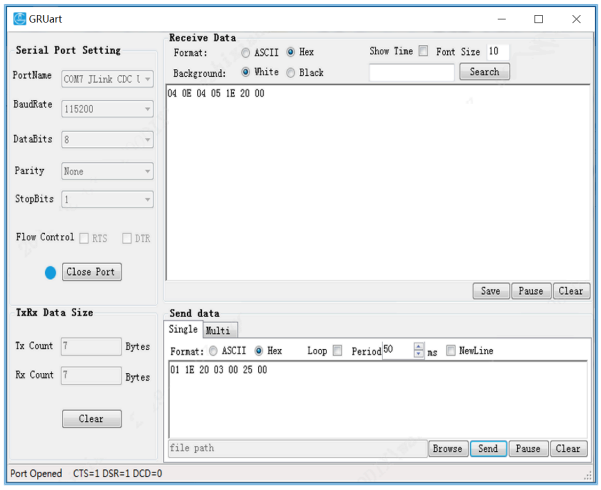

Figure 5-3 Transmitting command and response

As shown in Figure 5-3, the GRUart sends an HCI command in hexadecimal format, 01 1E 20 03 00 25 00, to the tested GR55xx SoC. The command indicates that the RF physical layer (PHY) sends a 37-byte pseudorandom binary sequence 9 (PRBS9) test sequence packet on a channel at a frequency of 2402 kHz. After the GR55xx SoC executes the command, the GRUart receives an HCI event in hexadecimal format, 04 0E 04 05 1E 20 00.

For command details, see “Section 7.2 LE Transmitter Test Command”.

5.3.2 End a DTM TX Test

The LE Test End Command is used to end an ongoing DTM test. To start a new DTM test, the ongoing DTM test shall be terminated.

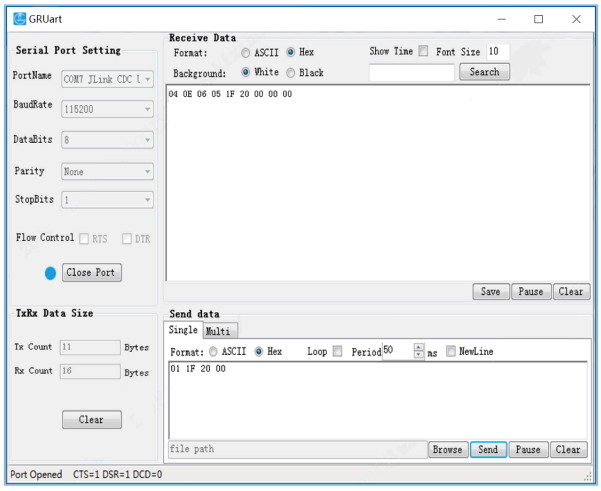

Figure 5-4 To end an ongoing test

As shown in Figure 5-4, GRUart sends the hexadecimal HCI command “01 1F 20 00” to the GR55xx SoC to terminate the ongoing DTM test. When the GR55xx SoC starts to act accordingly, GRUart will receive the reply, which is a hexadecimal HCI event “04 0E 06 05 1F 20 00 00 00”.

For command details, see “Section 7.7 LE Generate Signal Carrier Wave Command”.

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5.4 DTM RX Test (Manual Operation)

5.4.1 Initiate a DTM RX Test

The LE Receiver Test Command is used to enable the DTM RX test. The GR55xx SoC sniffs data packets at a fixed frequency and records the number of received data packets.

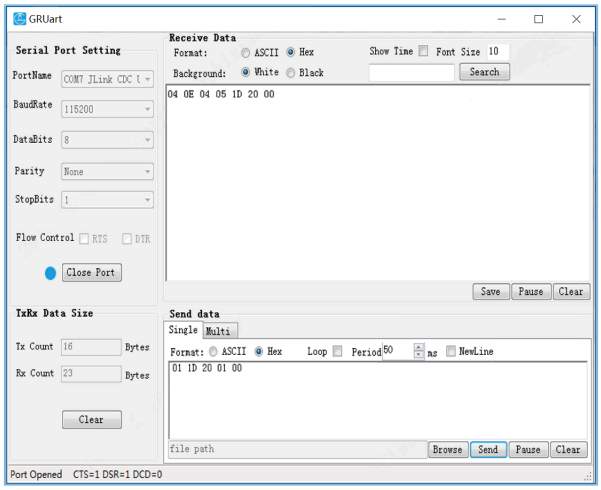

Figure 5-5 Receiving command and response

As shown in Figure 5-5, the GRUart sends an HCI command in hexadecimal format, **01 1D 20 01 00**, to the tested GR55xx SoC. The command indicates that the RF PHY sniffs data packets on a channel at a frequency of 2402 kHz. After the GR55xx SoC executes the command, the GRUart receives an HCI event in hexadecimal format, **04 0E 04 05 1D 20 00**.

For command details, see "Section 7.4 LE Receiver Test Command".

5.4.2 End a DTM RX Test

The LE Test End Command stops all ongoing tests. In TX test mode, the Parameter value of the number of the received packets is zero in the returned HCI event. In RX test mode, the number of the received packets is the number of packets that have been actually received.

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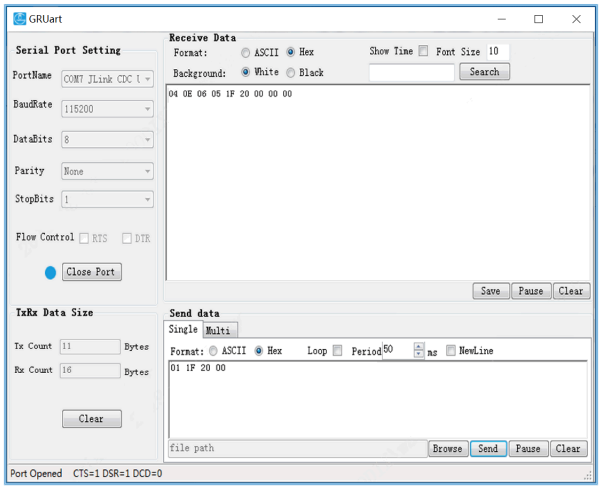

Figure 5-6 End command

As shown in Figure 5-6, the GRUart sends an HCI command in hexadecimal format, 01 1F 20 00, to the tested GR55xx SoC. The command indicates that the DTM test ends. After the GR55xx SoC executes the command, the GRUart receives an HCI event in hexadecimal format, 04 0E 06 05 1F 20 00 00 00.

For command details, see “Section 7.6 LE Test End Command”.

5.5 Private Commands

5.5.1 Command to Generate Single Carrier Waves

Use the LE Generate Signal Carrier Wave Command to generate single carrier waves, to start a single-carrier test. The GR55xx SoC can generate single-carrier packets on the designated channel.

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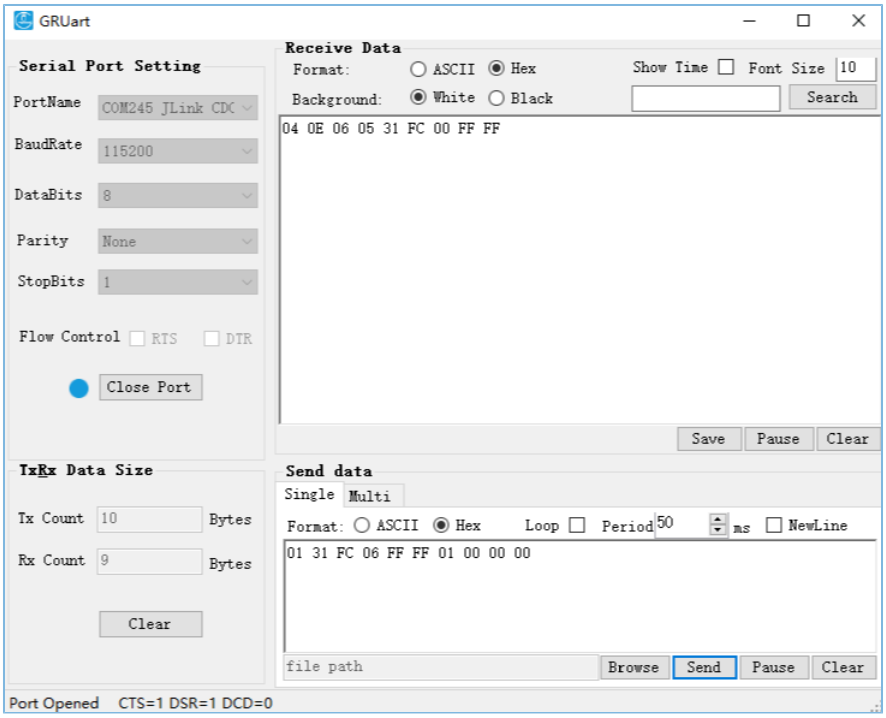

Figure 5-7 Sending command to generate single carrier waves

As shown in Figure 5-7 above, GRUart sends the hexadecimal HCI command “01 31 FC 06 FF FF 01 00 00 00” to GR55xx, which means the RF PHY sends a single-carrier test sequence packet to the channel (frequency: 2402 kHz). After the GR55xx SoC finishes this task, GRUart will receive the hexadecimal HCI event “04 0E 06 05 31 FC 00 FF FF” replied from GR55xx.

For command details, see “Section 7.7 LE Generate Signal Carrier Wave Command”.

Note:

If there is a task in progress before you use the LE Generate Signal Carrier Wave Command, end the ongoing task first by using the LE Test End Command.

5.5.2 Command to Modify TX Power for DTM TX Test

The LE Modify TX Power Command is used to modify the TX power for a DTM TX test (initiated by the LE Transmitter Test Command). By default, the TX power in a DTM TX test is 7 dBm.

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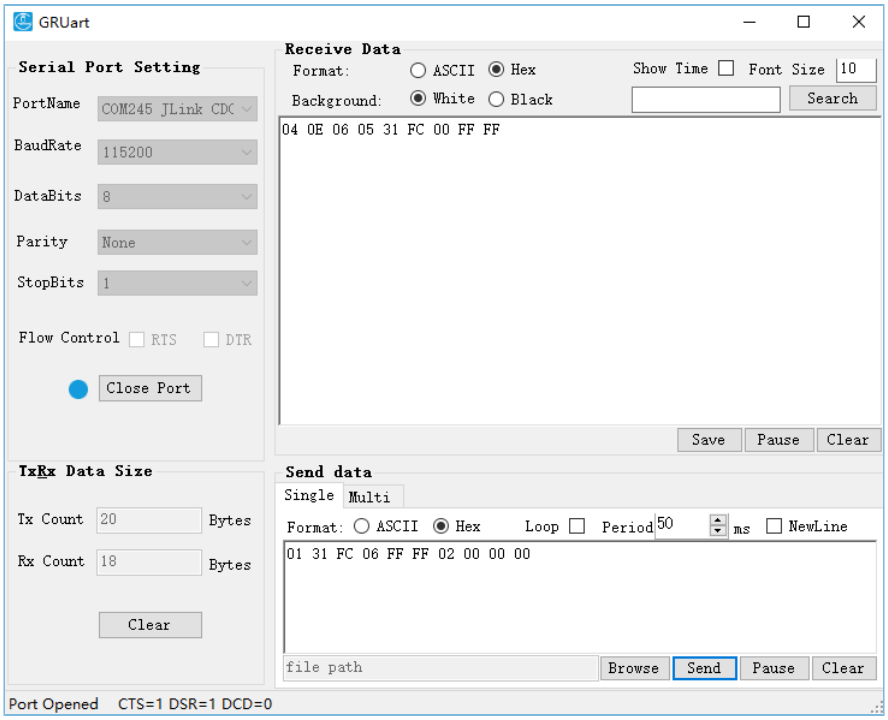

Figure 5-8 Sending the command to modify TX power

As shown in Figure 5-8 above, GRUart sends the hexadecimal HCI command “01 31 FC 06 FF FF 02 00 00 00” to the GR55xx SoC to set the TX power to 0 dBm. After the GR55xx SoC completes this task, GRUart will receive the hexadecimal HCI event “04 0E 06 05 31 FC 00 FF FF” replied from GR55xx.

For command details, see “Section 7.8 LE Modify TX Power Command”.

Note:

- The LE Modify TX Power Command can also be used in DTM TX tests initiated by the LE Enhanced Transmitter Test Command.
- TX power must be configured prior to a DTM TX test.
- If there is a task in progress before you use the LE Modify TX Power Command, end the ongoing task first by using the LE Test End Command.

5.6 Test Considerations

1. See *RF-PHY.TS.pdf* for test standards.
2. Results of a TX power test shall be taken into account in cable loss.
3. In a DTM TX test, the LE Transmitter Test Command and the LE Enhanced Transmitter Test Command are interchangeable.
4. In a DTM RX test, the LE Receiver Test Command and the LE Enhanced Receiver Test Command are interchangeable.

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6 FAQ

This chapter describes possible problems, reasons, and solutions during the DTM test.

6.1 Why do I Fail to Deliver Commands and Encounter Invalid Commands?

- Description

  Developers fail to deliver commands when using the GRUart serial port debugging tool or testers. Or the delivered commands are invalid.

- Analysis

  An error occurs in configurations of the GRUart serial port debugging tool, testers, or the serial cable.

- Solution

  Check whether the UART port on the DUT matches to the UART pin in the DTM firmware. Fore details, see “Section 4.2 Configure UART Ports”.

  If the UART pin is correctly used, check the configurations (baud rate, stop bit, and data bit) on GRUart and testers. Check the RX and TX pins are correctly connected to each other.

6.2 Why do I Fail to Execute Commands That Have Been Delivered?

- Description

  Execution of control commands delivered by serial port tools fails.

- Analysis

  The failure is caused by incorrectly input commands.

- Solution

  When using serial port debugging tools to deliver commands, pay attention to the following:

  - All commands should be delivered in hexadecimal format.
  - The commands shall conform to the HCI-related regulations.
  - Do not deliver line breaks using Enter on keyboard when delivering commands.
  - Commands of the same type cannot be executed at the same time. End the ongoing command (if any) before running a command.

6.3 Why do I Fail to Generate Single Carrier Waves?

- Description

  After GRUart sends the LE Generate Signal Carrier Wave Command, it receives reply from the GR55xx SoC, but the spectrum analyzer has not detected the correct packet.

- Analysis

  There are other ongoing tasks.

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- Solution

  1. Send the LE Test End Command to end the ongoing task.
  2. Send the LE Generate Signal Carrier Wave Command to generate single carrier waves.

6.4 Why do I Fail to Modify TX Power?

- Description

  After GRUart sends the LE Modify TX Power Command, it receives reply from the GR55xx SoC, but according to the spectrum analyzer, the power of the existing waves remains the same.

- Analysis

  The LE Modify TX Power Command does not immediately change the power of the current wave.

- Solution

  1. Send the LE Test End Command to end the ongoing task.
  2. Send the LE Modify TX Power Command to modify the TX power.
  3. Send the LE Transmitter Test Command to start a DTM TX test.

Note:

The LE Modify TX Power Command cannot be used in tests with single carrier waves.

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7 Appendix: Common HCI Commands in RF Performance Test

7.1 LE Reset Command

Table 7-1 Command format

Byte Description	Value
HCI Command Packet	0x01
Command Opcode LSB	0x03
Command Opcode MSB	0x0c
Parameter Length	0x00

Table 7-2 Returned events

Byte Description	Value
HCI Event Packet	0x04
Event Code	0x0E
Parameter Length	0x04
Num_HCI_Command_Packets	0x05
Command_Opcode_LSB	0x03
Command_Opcode_MSB	0x0C
Status	0x00: Command succeeded. 0x01 to 0xFF: Command failed. See “Volume 2, Part D: Error Codes” in *Bluetooth Core Spec* for a list of error code and descriptions.

7.2 LE Transmitter Test Command

Table 7-3 Command format

Byte Description	Value
HCI Command Packet	0x01
Command Opcode LSB	0x1E
Command Opcode MSB	0x20
Parameter Length	0x03
Frequency	= (F – 2402)/2, where F ranges from 2402 MHz to 2480 MHz. Range: 0x00 to 0x27
Data Length	0x01 to 0xFF: Length in bytes of payload data in each packet.
Package Type	0x00: Pseudorandom binary sequence 9 0x01: Pattern of alternating bits '11110000'

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Byte Description	Value
	0x02: Pattern of alternating bits '10101010' 0x03: Pseudorandom binary sequence 15 0x04: Pattern of All '1' bits 0x05: Pattern of All '0' bits 0x06: Pattern of alternating bits '00001111' 0x07: Pattern of alternating bits '0101'

Table 7-4 Returned events

Byte Description	Value
HCI Event Packet	0x04
Event Code	0x0E
Parameter Length	0x04
Num_HCI_Command_Packets	0x05
Command_Opcode_LSB	0x1E
Command_Opcode_MSB	0x20
Status	0x00: Command succeeded. 0x01 to 0xFF: Command failed. See “Volume 2, Part D: Error Codes” in *Bluetooth Core Spec* for a list of error code and descriptions.

7.3 LE Enhanced Transmitter Test Command

Table 7-5 Command format

Byte Description	Value
HCI Command Packet	0x01
Command Opcode LSB	0x34
Command Opcode MSB	0x20
Parameter Length	0x04
Frequency	= (F – 2402)/2, where F ranges from 2402 MHz to 2480 MHz. Range: 0x00 to 0x27
Data Length	0x01 to 0xFF: Length in bytes of payload data in each packet.
Package Type	0x00: Pseudorandom binary sequence 9 0x01: Pattern of alternating bits '11110000' 0x02: Pattern of alternating bits '10101010' 0x03: Pseudorandom binary sequence 15 0x04: Pattern of All '1' bits

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Byte Description	Value
	0x05: Pattern of All '0' bits 0x06: Pattern of alternating bits '00001111' 0x07: Pattern of alternating bits '0101'
PHY	0x01: Transmitter set to use the LE 1M PHY 0x02: Transmitter set to use the LE 2M PHY 0x03: Transmitter set to use the LE Coded PHY with S = 8 data coding 0x04: Transmitter set to use the LE Coded PHY with S = 2 data coding.

Table 7-6 Returned events

Byte Description	Value
HCI Event Packet	0x04
Event Code	0x0E
Parameter Length	0x04
Num_HCI_Command_Packets	0x05
Command_Opcode_LSB	0x34
Command_Opcode_MSB	0x20
Status	0x00: Command succeeded. 0x01 to 0xFF: Command failed. See “Volume 2, Part D: Error Codes” in *Bluetooth Core Spec* for a list of error code and descriptions.

7.4 LE Receiver Test Command

Table 7-7 Command format

Byte Description	Value
HCI Command Packet	0x01
Command Opcode LSB	0x1D
Command Opcode MSB	0x20
Parameter Length	0x01
Frequency	= (F – 2402)/2, where F ranges from 2402 MHz to 2480 MHz. Range: 0x00 to 0x27

Table 7-8 Returned events

Byte Description	Value
HCI Event Packet	0x04
Event Code	0x0E

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Byte Description	Value
Parameter Length	0x04
Num_HCI_Command_Packets	0x05
Command_Opcode_LSB	0x1D
Command_Opcode_MSB	0x20
Status	0x00: Command succeeded. 0x01 to 0xFF: Command failed. See “Volume 2, Part D: Error Codes” in *Bluetooth Core Spec* for a list of error code and descriptions.

7.5 LE Enhanced Receiver Test Command

Table 7-9 Command format

Byte Description	Value
HCI Command Packet	0x01
Command Opcode LSB	0x33
Command Opcode MSB	0x20
Parameter Length	0x03
Frequency	= (F – 2402)/2, where F ranges from 2402 MHz to 2480 MHz. Range: 0x00 to 0x27
PHY	0x01: Receiver set to use the LE 1M PHY 0x02: Receiver set to use the LE 2M PHY 0x03: Receiver set to use the LE Coded PHY
Modulation index	0x00: Assume transmitter will have a standard modulation index 0x01: Assume transmitter will have a stable modulation index

Table 7-10 Returned events

Byte Description	Value
HCI Event Packet	0x04
Event Code	0x0E
Parameter Length	0x04
Num_HCI_Command_Packets	0x05
Command_Opcode_LSB	0x33
Command_Opcode_MSB	0x20
Status	0x00: Command succeeded. 0x01 to 0xFF: Command failed. See “Volume 2, Part D: Error Codes” in *Bluetooth Core Spec* for a list of error code and descriptions.

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7.6 LE Test End Command

Table 7-11 Command format

Byte Description	Value
HCI Command Packet	0x01
Command Opcode LSB	0x1F
Command Opcode MSB	0x20
Parameter Length	0x00

Table 7-12 Returned events

Byte Description	Value
HCI Event Packet	0x04
Event Code	0x0E
Parameter Length	0x06
Num_HCI_Command_Packets	0x05
Command_Opcode_LSB	0x1F
Command_Opcode_MSB	0x20
Status	0x00: Command succeeded. 0x01 to 0xFF: Command failed. See “Volume 2, Part D: Error Codes” in *Bluetooth Core Spec* for a list of error code and descriptions.
Number of packets received (LSB)	0xXX
Number of packets received (MSB)	0xXX

7.7 LE Generate Signal Carrier Wave Command

Table 7-13 Command format

Byte Description	Value
HCI Command Packet	0x01
Command Opcode LSB	0x31
Command Opcode MSB	0xFC
Parameter Length	0x06
Reserved	0xFFFF
Private Command	0x0001: Generate signal carrier wave.
Frequency	= (F – 2402)/2, where F ranges from 2402 MHz to 2480 MHz. Range: 0x0000 - 0x0027

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Table 7-14 Returned events

Byte Description	Value
HCI Event Packet	0x04
Event Code	0x0E
Parameter Length	0x06
Num_HCI_Command_Packets	0x05
Command_Opcode_LSB	0x31
Command_Opcode_MSB	0xFC
Status	0x00: Command succeeded. 0x01 - 0xFF: Command failed. See "Volume 2, Part D –Error Codes" in *Bluetooth Core Spec* for a list of error code and descriptions.
Reserved	0xFFFF

7.8 LE Modify TX Power Command

Table 7-15 Command format

Byte Description	Value
HCI Command Packet	0x01
Command Opcode LSB	0x31
Command Opcode MSB	0xFC
Parameter Length	0x06
Reserved	0xFFFF
Private Command	0x0002: Modify TX power.
TX power	Range: 0x0000 - 0x0007 dbm

Table 7-16 Returned events

Byte Description	Value
HCI Event Packet	0x04
Event Code	0x0E
Parameter Length	0x06
Num_HCI_Command_Packets	0x05
Command_Opcode_LSB	0x31
Command_Opcode_MSB	0xFC
Status	0x00: Command succeeded. 0x01 - 0xFF: command failed. See "Volume 2, Part D –Error Codes" in *Bluetooth Core Spec* for a list of error codes and descriptions.

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Byte Description	Value
Reserved	0xFFFF

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