

Application Note

DA1469x Bluetooth® Direct Test Mode in RF Testing

AN-B-070

Abstract

This application note explains how to setup RF testing for the DA1469x Bluetooth Low Energy SoC using a Bluetooth tester. Four setups for four different Bluetooth testers are discussed.

Contents

Abstract	1
Contents	2
Figures	2
Tables	3
1 Terms and Definitions	3
2 References	3
3 Introduction	4
4 Setting up Direct Test Mode	5
4.1 Software Setup.....	5
4.1.1 Temperature Triggered RF Re-Calibrations	7
4.2 Hardware Setup	8
4.2.1 R&S CMW270 Bluetooth Tester Setup	9
4.2.2 Anritsu MT8852B Bluetooth Tester Setup	11
4.2.3 R&S CBT Bluetooth Tester Setup	14
4.2.4 Teledyne LeCroy TLF3000 Bluetooth Tester Setup	15
4.3 Bluetooth Low Energy 2 Mbps Testing	17
4.4 Terminal Control.....	18
4.4.1 TX Un-Modulated and More	18
4.4.2 HCI LE Controller Commands	19
4.4.2.1 Bluetooth Core v5.1 LE Controller Specifications	20
5 Production Line Testing	21
6 Bluetooth® PHY Qualification	22
Appendix A Motherboard	24
Appendix B Daughterboard	25
Revision History	26

Figures

Figure 1: Firmware download in RF-Master	5
Figure 2: UART switches positions	6
Figure 3: RF-cable MXHS83QH3000	8
Figure 4: Pro-DK board, RF-connector J7.....	8
Figure 5: R&S CMW270 connections.....	10
Figure 6: Anritsu MT8852B connections	11
Figure 7: MT8852B connection settings	12
Figure 8: COMM Tunnel Setup	12
Figure 9: COMM Tunnel Tool	13
Figure 10: R&S CBT connections	14
Figure 11: TLF3000 connections.....	15
Figure 12: TLF3000 GUI.....	16
Figure 13: DUT control settings for the DA1469x	16
Figure 14: RealTerm Send window	20
Figure 15: DA1469x Pro-DK motherboard	24
Figure 16: DA14695 Pro-DK daughterboard	25

DA1469x Bluetooth® Direct Test Mode in RF Testing

Tables

Table 1: UART GPIOs	6
Table 2: Opcode 0xFC14 parameters	18
Table 3: Received Packet Statistics	19
Table 4: PIXIT entries for Bluetooth Low Energy 1 Mbps	22
Table 5: PIXIT entries for Bluetooth Low Energy 2 Mbps	23

1 Terms and Definitions

Bluetooth® LE	Bluetooth® Low Energy
DTM	Direct Test Mode
DUT	Device Under Test, the Bluetooth Low Energy application.
EUT	Equipment Under Test
GPIB	General Purpose Interface Bus
GPIO	General Purpose Input Output
HCI	Host Controller Interface
OGF	Opcode Group Field
PLT	Production Line Testing
Pro-DK	Professional Development Kit
RF	Radio Frequency
SNC	Sensor Node Controller in the DA1469x
SoC	System on Chip
SWD	Serial Wire Debug
UART	Universal Asynchronous Receiver Transmitter

2 References

- [1] DA1469x-00, Datasheet, Dialog Semiconductor.
https://www.dialog-semiconductor.com/sites/default/files/da1469x_datasheet.pdf
- [2] AN-B-043, DA1468x Bluetooth Direct Test Mode, Application Note, Dialog Semiconductor.
https://www.dialog-semiconductor.com/sites/default/files/an-b-043_da1468x_bluetooth_direct_test_mode_v1.5.pdf
- [3] DA1469x Getting Started Guide, On-line User Manual, Dialog Semiconductor.
http://lpccs-docs.dialog-semiconductor.com/um-b-090-da1469x_getting_started/index.html
- [4] Bluetooth Core specification v 5.1, Bluetooth SIG
<https://www.bluetooth.com/specifications/bluetooth-core-specification/>

DA1469x Bluetooth® Direct Test Mode in RF Testing

3 Introduction

The DA14691-00, DA14695-00, DA14697-00 and the DA14699-00 (DA1469x) are Bluetooth® Low Energy SoC devices, working with extremely low power while providing world-class RF performance, a small footprint and flexible peripheral configurations for a wide range of applications like wearables.

This document describes how to measure the RF performance of the DA1469x family of products using a Bluetooth tester like the R&S CBT, the R&S CMW270, the Teledyne LeCroy TLF3000 and the Anritsu MT8852B using the Bluetooth Low Energy (Bluetooth LE) Direct Test Mode (DTM).

The Direct Test Mode is described in the Bluetooth specification. The Bluetooth LE RF PHY test specification uses DTM for all TX and RX test cases. Frequency hopping and whitening are disabled.

DTM uses a direct communication channel between the Bluetooth LE DUT and the Bluetooth tester to control the DUT. The DA1469x SoC supports Direct Test Mode (DTM) for the RF PHY as specified by the Bluetooth SIG. The DUT, the DA1469x SoC, communicates with the Bluetooth tester over a 2-wire UART.

Details for the software setup and the hardware setup are explained in following sections [4.1](#) and [4.2](#).

Many items discussed in AN-B-043 (*DA1468x Bluetooth Direct Test Mode*) are also applicable for the DA1469x. [\[2\]](#)

Please read this AN-B-043 application note as well. It shows alternative connection possibilities and discusses a larger variety of Bluetooth testers, amongst others the LitePoint IQxel-M.

DA1469x Bluetooth® Direct Test Mode in RF Testing

4 Setting up Direct Test Mode

4.1 Software Setup

For standard Bluetooth LE DTM testing (Bluetooth LE core commands) it is advised to use the SDK (v.10.0.6) BLE_EXTERNAL_HOST project, which can be found in the following path:

```
SDK_10.0.6. . . \Projects\DK_Apps\Demos\Ble_External_Host\
```

Either compile the project for RAM usage and load the binary in RAM using the SmartSnippets Toolbox Booter or the Toolbox RF-Master Firmware Download tool.

Or compile it for QSPI-Flash, and program the firmware in QSPI-Flash using SmartSnippets Studio. The DA1469x Getting Started Guide section 9 explains how to compile and how to program. [3] http://lpcss-docs.dialog-semiconductor.com/um-b-090-da1469x_getting_started/index.html

As example, for downloading the BLE_EXTERNAL_HOST firmware into RAM the SmartSnippets Toolbox RF-Master tool will be used.

Browse to the built binary, select JTAG and press the 'Download' button.

COM4 in below [Figure 1](#) is the COM port used for sending RF-Master commands to the DA1469x.

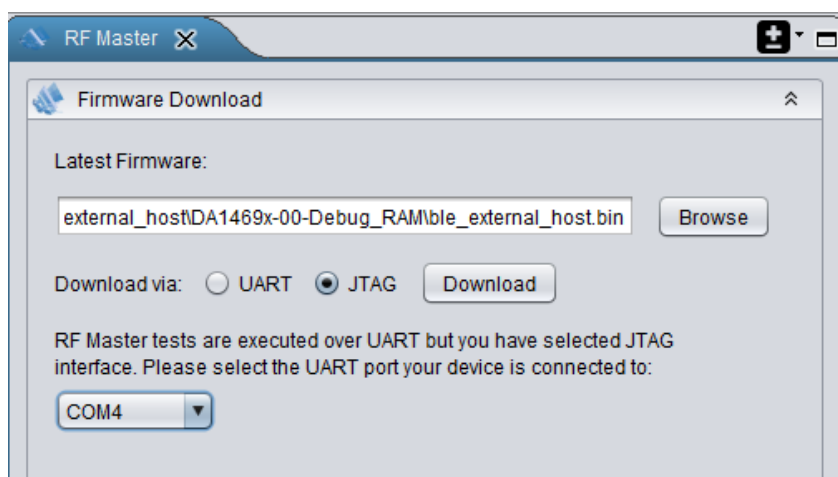


Figure 1: Firmware download in RF-Master

Following should be displayed in the bottom part of the Log window after downloading, indicating the download was successful:

```
[INFO   General      BTLE device selected.
[INFO   General      Successfully connected to JLinkGDBServer on localhost: 2331
[INFO   General      Firmware file \ble_external_host.bin has been successfully
                        uploaded to the device.
[INFO   RF Master    Successfully downloaded firmware file to the board.
```

After downloading the firmware using RF-Master, the RF-Master tool also can be used to set the DA1469x chip in receive or transmit mode, e.g. LE Transmitter Continuous Packet TX. For this, the UART COM port must be selected in the RF-master window, COM4 in [Figure 1](#). When having the Power Profiler running at the same time, the waveform will show the Tx current. Alternatively, a serial terminal program as shown in section 4.4 Terminal Control can be used.

DA1469x Bluetooth® Direct Test Mode in RF Testing

The supported RF test modes in the BLE_EXTERNAL_HOST project are:

- Pkt_tx
- Cont_pkt_tx
- Start_pkt_rx
- Stop_test
- Rx_test_stats (get packet statistics like RSSI)
- Un-modulated Tx

By default, the UART baud rate is set to 115200 bit/sec and the UART GPIOs used for control and signaling between the Bluetooth tester and the DUT are shown in below Table 1.

Table 1: UART GPIOs

UART RX	UART TX	UART CTS	UART RTS
P0_08	P0_09	P0_07	P1_00

The UART hardware flow control is enabled by default in the BLE_EXTERNAL_HOST project. To disable the UART flow control, the following line must be set to '0'. Line 227 in `\sdk\middleware\adapters\src\sys_platform_devices_internal.c : .auto_flow_control = 1,`

Summarizing the UART:

- UART Baud Rate: 115200 bit/sec
- HW Flow Control: Enabled, RTS/CTS
- Byte Size: 8
- Stop Bits: 1
- Parity: None

The switches 1 to 4 of the DIP-switch S1 on the Pro-DK motherboard are the UART switches and must be set to 'ON', to the upper position as shown in Figure 2. Switches 5 and 6 are for JTAG/SWD.

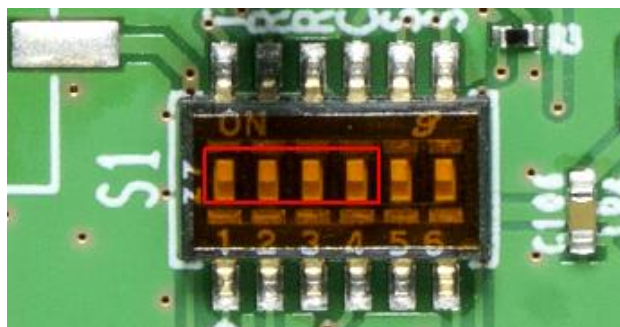


Figure 2: UART switches positions

DA1469x Bluetooth® Direct Test Mode in RF Testing

When using an external Jlink connection for e.g. firmware downloading, the Jlink signals should be connected to the SWD pins of the Pro-DK board. These pins are assigned as follows:
P0_10 for SWDIO,
P0_11 for SWCLK.

These SWD GPIOs are located on the left-hand side of connector J3, which is positioned on the left-hand side of the Pro-DK motherboard, please see [Figure 15](#).

When using the external JLINK connection, please set the SWD switches 5 and 6 of S1 in [Figure 2](#) to 'OFF', to the lower position.

Other relevant jumper settings, for e.g. the supply, are shown in [Appendix A](#). Please check whether the board used for DTM RF-testing is configured as shown in [Figure 15](#).

The USB1 connector on the DA1469x Pro-DK motherboard provides the supply and the 2-wire serial communication to the DA1469x daughterboard.

4.1.1 Temperature Triggered RF Re-Calibrations

Some notes about the temperature triggered RF re-calibrations used in the SDK:

- In the SDK projects temperature triggered RF re-calibrations are provided to make sure the radio is in optimal condition at any temperature. This is realized by shortly waking up the chip at regular intervals at which the SNC is measuring the chip's temperature. When the temperature has decreased or increased 10 degrees centigrade or more, a RF re-calibration will be triggered and executed.
- In DTM mode though, and only in the DTM mode, these temperature triggered RF re-calibrations are not active. This is intentionally, making sure the RF re-calibration is not interfering with a running RF-test, leading to a failing test.
- When RF testing at low and high temperatures is desired, please issue a HW-reset to the chip at which the chip will reboot and will execute a RF re-calibration at the new temperature before the RF test starts. This makes sure the radio is in optimal condition. In this situation it is convenient to have the firmware programmed in the QSPI flash since it will be re-loaded from the flash automatically after a reset. Normally the RF re-calibration would not be needed in the temperature range -20°C to +80°C, but it is advised to trigger a RF re-calibration after a 20 °C temperature change.
- The RX sensitivity is affected first, degrading a bit at low and high temperatures. The TX performance is more robust and will not vary much over temperature.
- As mentioned, in Bluetooth LE mode - advertising or connected - the temperature triggered RF re-calibrations are in place. The radio will be in optimal condition at any temperature.

DA1469x Bluetooth® Direct Test Mode in RF Testing
4.2 Hardware Setup

Three RF test setups will be shown and discussed.

First the R&S CMW270 Bluetooth 5 tester is discussed, where the DA1469x Pro-DK is connected and supplied by a (front) USB port of the CM270. Bluetooth LE signaling is executed over the same USB port.

Section [4.2.1](#).

Secondly, the setup with the Anritsu MT8852B Bluetooth 5 tester is shown.

Here a PC supplies the Pro-DK board and connects the Bluetooth tester and the DUT via a COMM Tunnel tool running on the PC.

Section [4.2.2](#).

As last the R&S CBT setup and connections are shown. Using again the COMM Tunnel tool for convenience instead of an otherwise required level-shifter [\[2\]](#). Bluetooth LE 2 Mbps is not supported by the CBT tester. The PC also supplies the Pro-DK board via its USB connector.

Section [4.2.3](#)

The RF connection between the Pro-DK board and the Bluetooth tester can be established using the on-board muRata miniature RF-switch/connector, type MM8130-2600: J7 in [Figure 4](#) and [Figure 16](#). Following muRata SMA RF-cable type should be used for connecting the DA1469x board to the RF port of the Bluetooth tester: MXHS83QH3000 as shown in [Figure 3](#).



Figure 3: RF-cable MXHS83QH3000



Figure 4: Pro-DK board, RF-connector J7

DA1469x Bluetooth® Direct Test Mode in RF Testing

4.2.1 R&S CMW270 Bluetooth Tester Setup

For the discussed setup the FTDI USB-to-Serial driver for the FTDI chip on the Pro-DK must be installed on the CMW270. When the Pro-DK board is connected, two virtual COM ports will be created, e.g. COM4 and COM5. The first port, COM4 in this example, provides the UART 2-wire connection and this one should be selected in the CMW270's Connection setup (Bluetooth Connection Setup for LE).

Following R&S application note deals with how to do this, in sections 3.3 and 4.2.:

https://www.rohde-schwarz.com/us/applications/configuration-of-the-r-s-cmw-for-bluetooth-low-energy-direct-test-mode-application-note_56280-364865.html

Overview of the required CMW270 Connection Settings:

- USB to RS232 adapter as HW Interface.
- HCI in EUT Communication Protocol.
- RS232 COM port: the virtual COM port, e.g. COM4.
- Baud Rate: 115200
- Flow Control Protocol: set CTS/RTS
- Parity: None
- Stop Bits: 1

The FTDI driver for the FT2232 FTDI chip used on the Pro-DK motherboard can be found at following download link: <https://www.ftdichip.com/Drivers/D2XX.htm>

When using front-panel operation, connecting the Pro-DK debug USB port to a front USB-port of the CMW270 and a RF-cable from the CMW270 RF-port (e.g. RF1 COM) to the Pro-DK RF-connector is all what is needed to run some basic Bluetooth LE Tx and Rx tests. As such, the GPIB connection is not needed.

For script testing using the R&S CMWRUN scripting tool, a GPIB connection between the PC and CMW270 must be established. Please refer to [Figure 5](#) below.

In this setup, programming the firmware in the QSPI-flash memory at forehand is more convenient, even more when planning to execute multiple RF tests. When deciding to download the firmware into RAM, an external Jlink connection must be used. Please refer to [section 4.1](#) for details on downloading the firmware using SWD.

DA1469x Bluetooth® Direct Test Mode in RF Testing

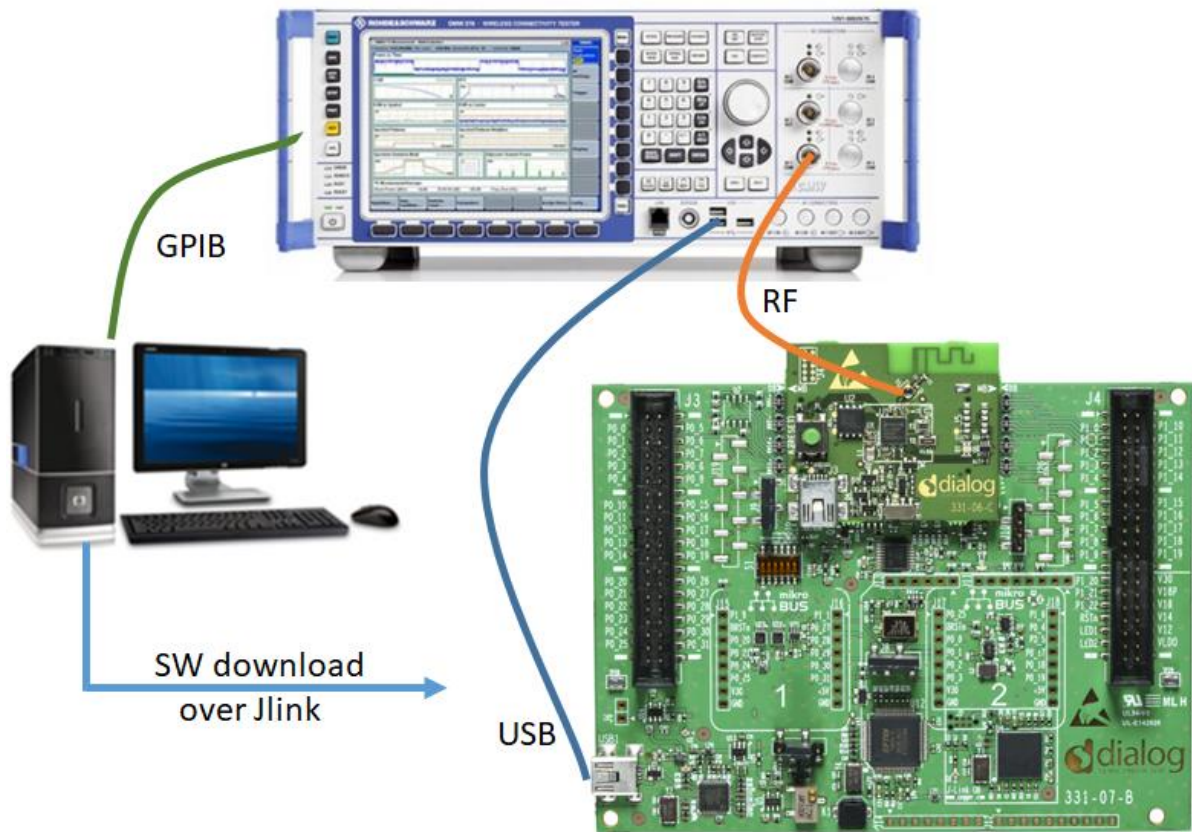


Figure 5: R&S CMW270 connections

DA1469x Bluetooth® Direct Test Mode in RF Testing

4.2.2 Anritsu MT8852B Bluetooth Tester Setup

For this setup case shown in Figure 6, the MT8852B's EUT Control-port cable (supplied with the tester) is to be connected to a physical serial port of the PC, or to an USB port when using a Serial-to-USB converter, e.g. UC232R-10 or Chipi-X10:

<https://www.ftdichip.com/Products/Cables/USBR232.htm>.

The COMM Tunnel tool running on the PC connects the PC's serial port (e.g. COM1) at which the MT8852B EUT port is connected, to the Pro-DK's virtual COM port (e.g. COM4).

The Pro-DK board will create two virtual COM ports on the PC: e.g. COM4 and COM5.

The COM port having the lowest number (COM4 in this example) must be selected for UART.

The 2nd virtual COM port is the SPI channel, used for transmitting the PowerProfiler data from the motherboard to the SmartSnippets Power Profiler tool running on the PC.

Please find screen captures of the COMM Tunnel tool in Figure 8 and in Figure 9.

The version that was used for this document: <http://www.serialporttool.com/CommTunnel.htm>

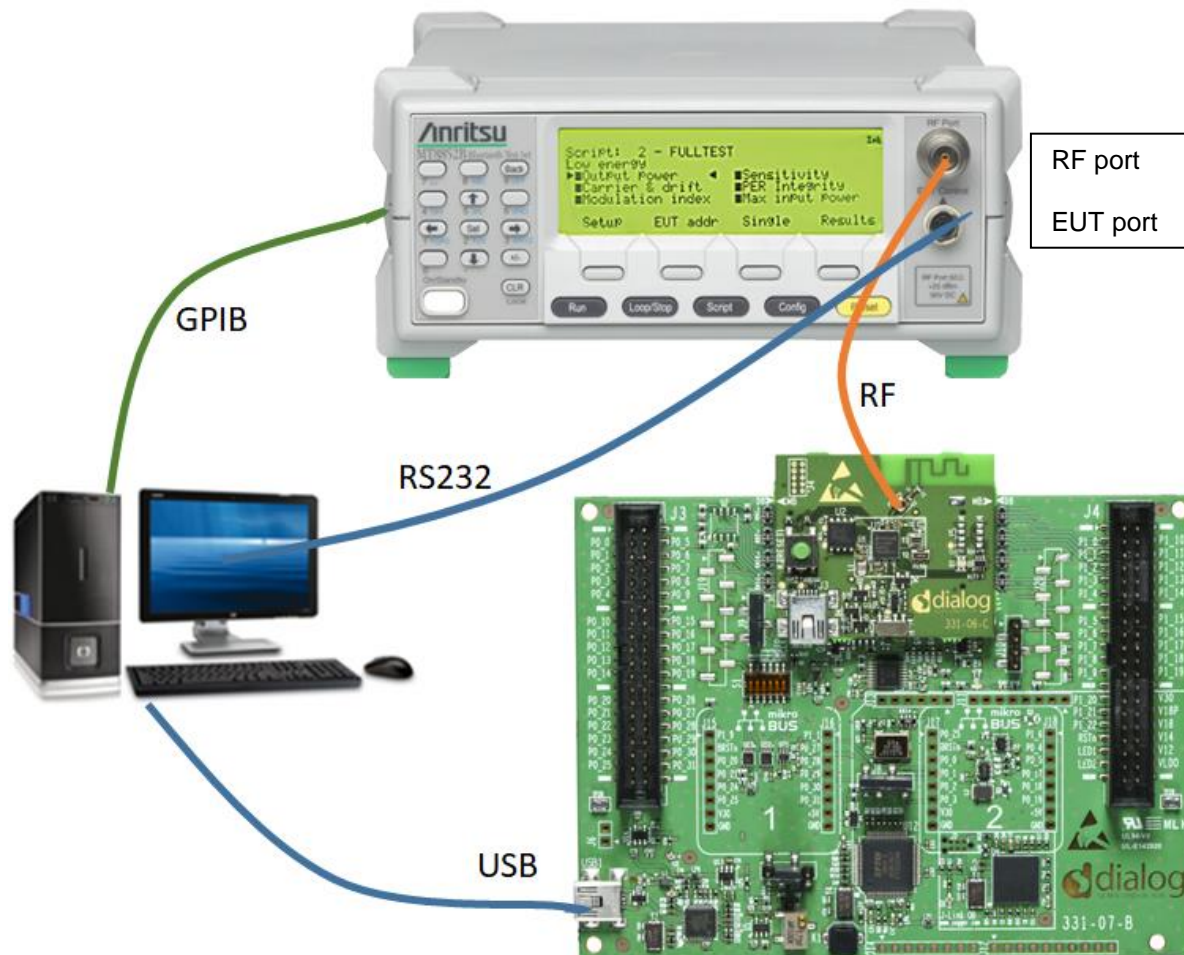


Figure 6: Anritsu MT8852B connections

Figure 6 shows the connections between the MT8852B tester, the DUT and the PC. A COMM Tunnel tool as described before is running on the PC, connecting the MT8852B's EUT Control port to the virtual UART COM port of the Pro-DK board.

Before starting the Comm Tunnel program, the RF-test firmware can be downloaded in e.g. RAM

DA1469x Bluetooth® Direct Test Mode in RF Testing

using the same PC USB port and the Pro-DK virtual COM port. Please refer to section 4.1. After the firmware download, the COMM Tunnel can be started and RF-testing can begin.

Front-panel operation is available for basic Tx and Rx tests. For this, the COMM Tunnel should be started, but the GPIB connection is not needed.

When e.g. running Anritsu's Bluetooth LE Measurement Software, script testing can be executed and a test-report could be created [2]. The GPIB connection between the tester and the PC is required for this test case.

The MT8852B Connection settings in the Anritsu Bluetooth LE Measurement Software: [Figure 7](#).

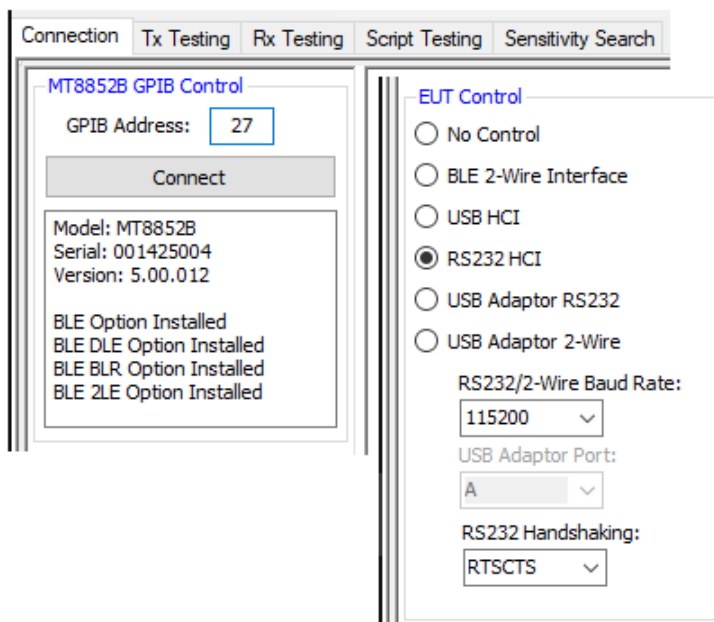


Figure 7: MT8852B connection settings

Comm Tunnel settings: below [Figure 8](#) (Setting) appears when selecting 'Setting' in 'Endpoint 1' (tester) or 'Endpoint 2' (DUT) in [Figure 9](#). After entering the correct values, press the 'Start' button.

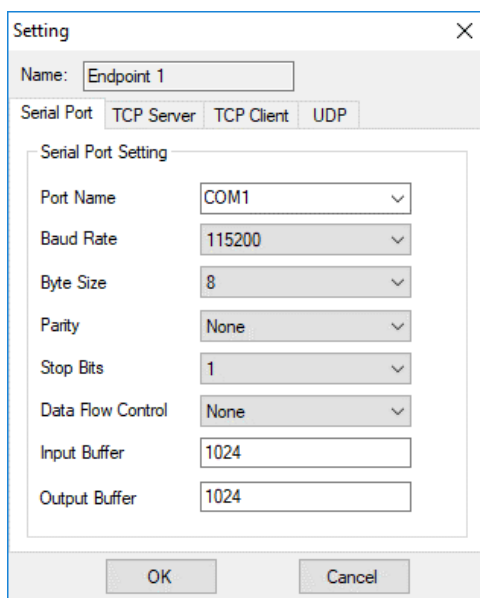


Figure 8: COMM Tunnel Setup

DA1469x Bluetooth® Direct Test Mode in RF Testing

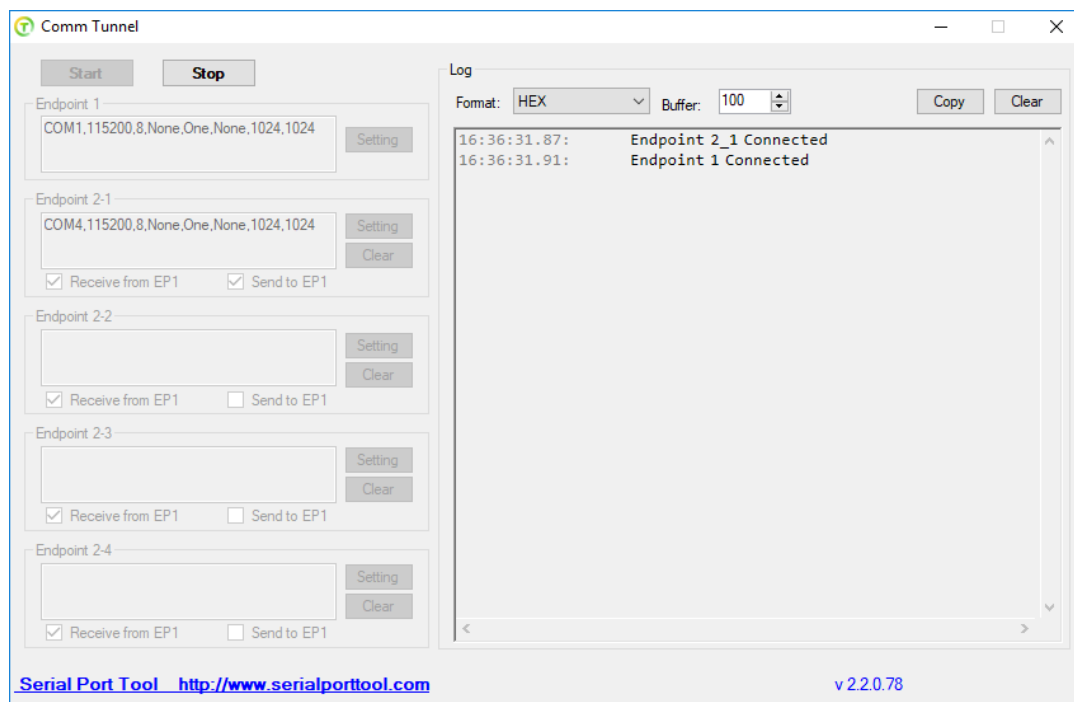


Figure 9: COMM Tunnel Tool

DA1469x Bluetooth® Direct Test Mode in RF Testing

4.2.3 R&S CBT Bluetooth Tester Setup

The R&S CBT setup basically is similar to the MT8852B setup in section 4.2.2. The CBT's COM port at the back is connected to a serial port on the PC, and the Comm Tunnel program connects the CBT COM port to the UART/HCI port of the DA1469x DUT by means of the virtual COM port created by the DA1469x Pro-DK board. Please refer to below Figure 10 for the connections.

In case the PC does not have a physical serial port, a Serial-to-USB converter can be applied.

For details on this and the Comm Tunnel usage, please read section 4.2.2.

The PC can be used to download the RF-test firmware to the DA1469x chip, e.g. into RAM.

After starting the Comm Tunnel tool, the same USB port is used for Bluetooth signaling.

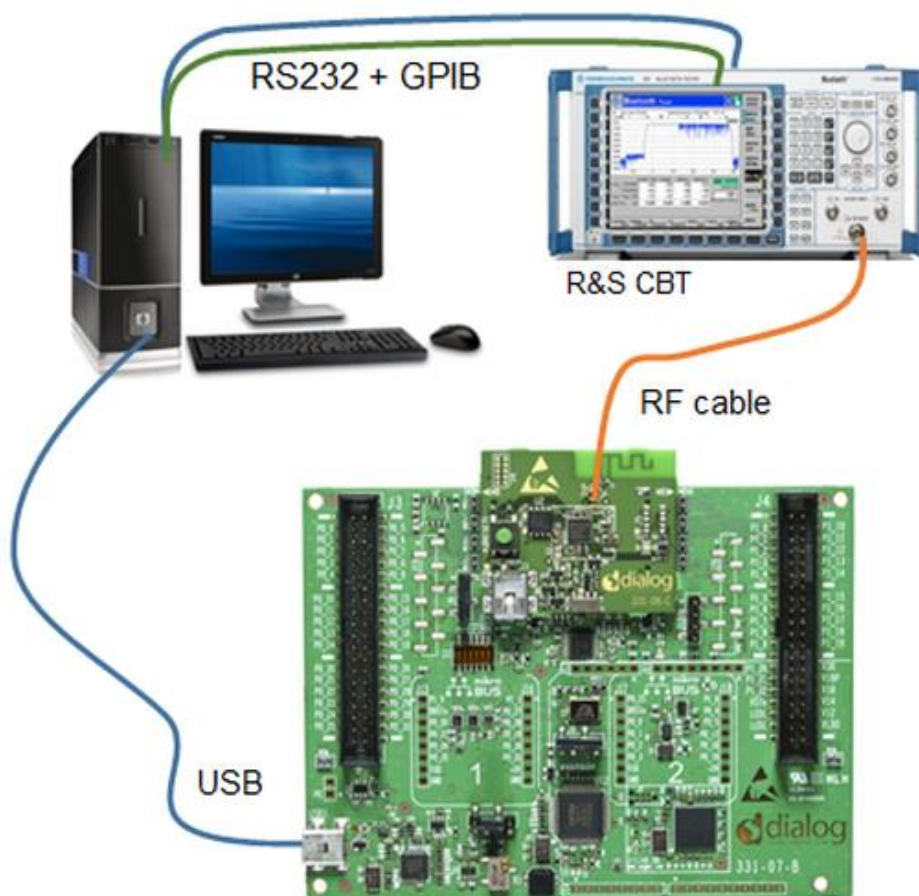


Figure 10: R&S CBT connections

Basic testing like LE TX modulation performance can be executed from the front panel and viewed in the CBT's display. GPIB interfaces and a GPIB cable will not be needed.

Extended script testing can be done using the R&S CBT-Go tool, which runs on the PC.

The CBT-Go tool can also generate an extensive test report.

A GPIB cable must be connected between the PC and the CBT for using CBT-Go.

The CBT communication settings, to be set in the CBT or in the CBT-Go control program:

EUT Protocol: HCI ; Baud Rate: 115200 ;

Bits: 8 ; Stop bits: 1 ; Parity: None ;

Flow Control: CTS/RTS

DA1469x Bluetooth® Direct Test Mode in RF Testing

4.2.4 Teledyne LeCroy TLF3000 Bluetooth Tester Setup

The TLF3000 is a fast and flexible Bluetooth tester for the standard transmitter and receiver tests, and also featuring integrated C/I and blocking measurements up to 6 GHz. The application GUI is installed on the PC. Connection from the TLF3000 tester to the USB port on the PC is from the USB socket on the backside of the TLF3000. The control of the TLF3000 is from the PC GUI. The DA1469x Pro DK board also is to be connected to the PC, and two virtual COM ports are established. Now it is possible to select the first listed COM port in the TLF3000 GUI and run the UART communication between the PC GUI and the DUT. [Figure 12](#) shows the GUI interface. No additional interfacing hardware or a Comm Tunnel tool is needed. Connect the RF cable for conducted RF tests between the DUT antenna and the Tx/Rx connection (SMA) on the front of the TLF3000 tester. Please refer to [Figure 11](#).

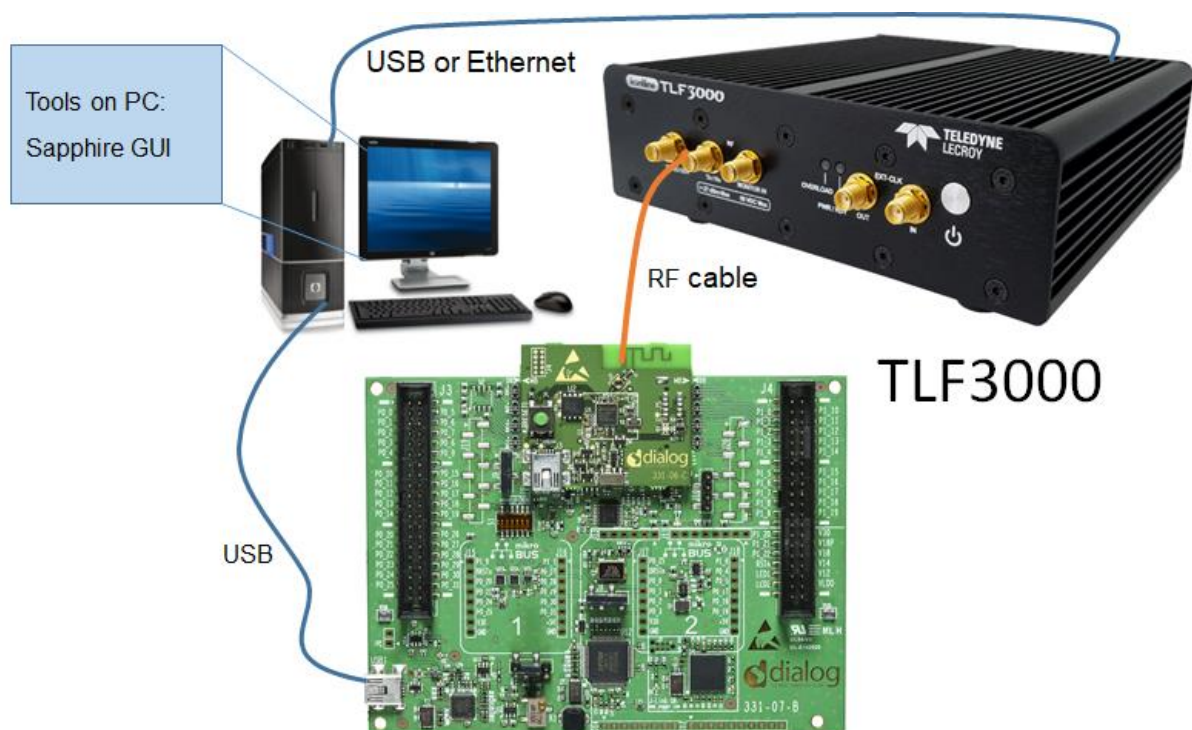


Figure 11: TLF3000 connections

Communication between the TLF3000 application is seen from the 'Phy Tester' mode, on the GUI, and the DUT setup. It is possible to have proof of communication between the TLF3000 Application GUI and the DUT by pressing the 'Query DUT' button on the 'DUT Features' window. As shown in [Figure 13](#), 'Query DUT' is a feature of the Direct Test Mode (DTM) functionality, the DA1469x chip supports the 'Query DUT' functionality.

For more information on the Teledyne LeCroy TLF3000: <http://fte.com/products/tlf3000.aspx>
 The User's Manual on the TLF3000: http://fte.com/docs/UserManual_LE_TLF3000.pdf

DA1469x Bluetooth® Direct Test Mode in RF Testing

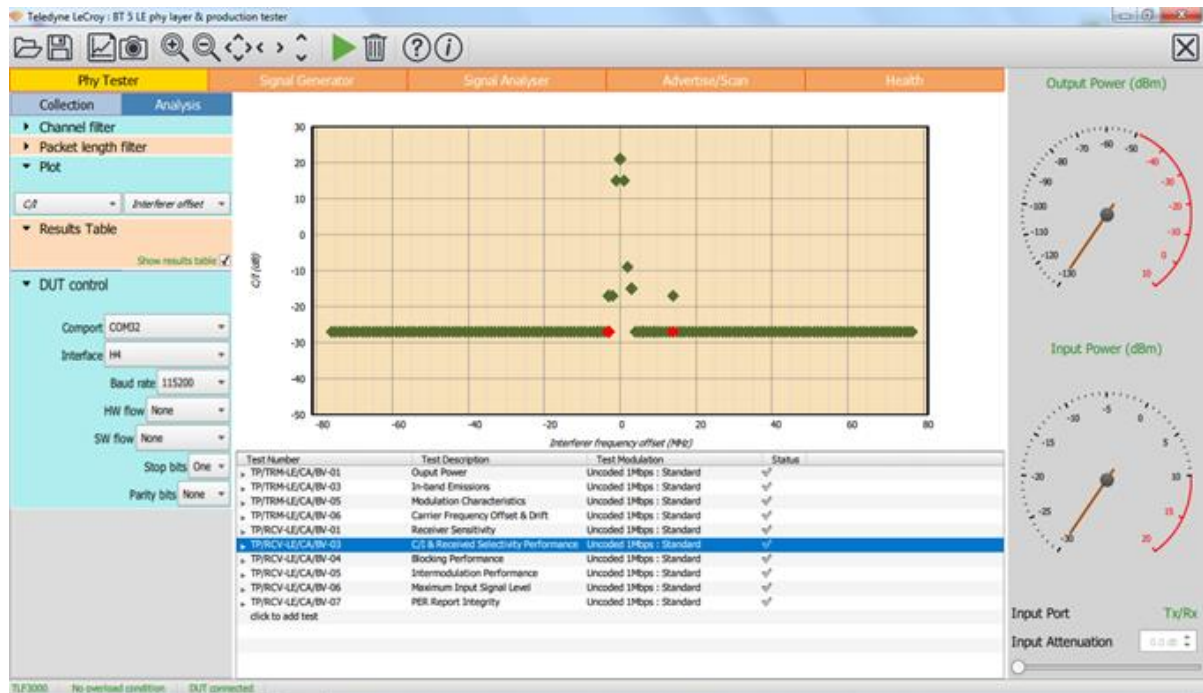


Figure 12: TLF3000 GUI

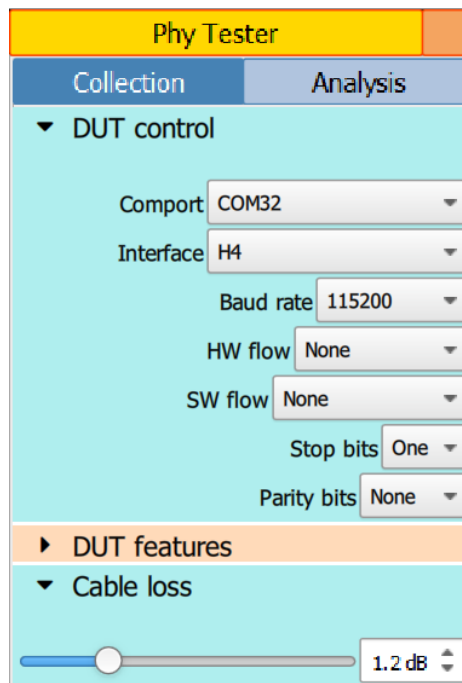


Figure 13: DUT control settings for the DA1469x

4.3 Bluetooth Low Energy 2 Mbps Testing

As mentioned in section 4.2, the R&S CBT Bluetooth tester does not support Bluetooth Low Energy 2 Mbps testing, only the 1 Mbps PHY is supported.

For Bluetooth Low Energy 2 Mbps testing, either the R&S CMW270 tester with the proper licenses, the Anritsu MT8852B tester having firmware 5.00.xxx, the Teledyne LeCroy TLF3000 tester or any other Bluetooth 5 capable tester should be used.

DA1469x Bluetooth® Direct Test Mode in RF Testing
4.4 Terminal Control

An example using the RealTerm terminal program is shown and explains how to set the DA1469x chip in e.g. TX unmodulated mode. This mode can be used to check the TX frequency accuracy or used to measure the TX harmonic levels. Also, other parameters of this HCI command are discussed showing to put it in e.g. finite packetized TX mode, to send a certain limited number of packets.

These vendor specific HCI commands (OGF=0x3F, OCF=0x14) are different from the ones needed for the DA1468x, so the HCI commands listed in [2] cannot be used for the DA1469x non-standard Bluetooth LE tests.

The BLE_EXTERNAL_HOST project or the PLT_FW project must have been loaded into RAM or programmed into the QSPI Flash. Please check software section 4.1.

4.4.1 TX Un-Modulated and More

The required HCI test command using the vendor specific opcode 0xFC14 for starting continuous un-modulated TX at Ch.0 (2402 MHz) is as follows:

```
0x01 0x14 0xFC 0x0B 0x00(Ch) 0x25 0x01 0x01 0x04(unmod) 0xF4 0x01 0x71 0x02 0x00 0x00
```

0x00 (Ch) indicates the Bluetooth LE RF channel number: channel 0 (2402 MHz).

0x04 (unmod) indicates the TX output signal will be un-modulated.

Expected reply from the chip: 0x04 0x0E 0x04 0x07 0x14 0xFC 0x00.

StopTest command: 0x01 0x1F 0x20 0x00

Reply from the chip: 0x04 0x0E 0x06 0x07 0x1F 0x20 0x00 (succeeded) 0x00 0x00

The same opcode (0xFC14) with other modulation parameter values may also be used to set the DA1469x chip into Finite or Continuous Modulated Packetized, or Cont. Non-packetized TX mode:

The HCI command for starting Finite Modulated Packetized TX at Ch.00 (2402 MHz):

```
0x01 0x14 0xFC 0x0B 0x00(Ch) 0x25 0x00 0x01 0x03(pkt) 0xF4 0x01 0x71 0x02 0x00 0x00
```

The above command results in sending 0x01F4 (500) packets and then stops transmitting packets.

StopTest reply: 0x04 0x0E 0x06 0x07 0x1F 0x20 0x00 (succeeded) 0xF4 0x01 (500 pkts sent)

The HCI command for starting Continuous Modulated Non-Packetized TX at Ch.19 (2440 MHz):

```
0x01 0x14 0xFC 0x0B 0x13(Ch) 0x25 0x00 0x01 0x02(nonpkt) 0xF4 0x01 0x71 0x02 0x00 0x00
```

The HCI command for starting Continuous Modulated Packetized TX at Ch.39 (2480 MHz):

```
0x01 0x14 0xFC 0x0B 0x27(Ch) 0x25 0x00 0x01 0x01(compkt) 0xF4 0x01 0x71 0x02 0x00 0x00
```

Table 2 shows the structure of the HCI TX enhanced command having opcode 0xFC14.

Table 2: Opcode 0xFC14 parameters

Parameter:	Value:	Notes:
Command length	0x0B	# Bytes that follow
TX channel number	0x13	e.g. Channel 19 (2440 MHz)
Data Length	0x25	e.g. 37 Bytes (upto 0xFF/255)
Payload Type	0x00 (PRBS9)	0x01 for '11110000', 0x02 for '10101010'
PHY	0x01	0x01 for 1Mbps, 0x02 for 2 Mbps
Test Type	0x04 (un-modulated)	1: cont.pkt, 2: non-pkt, 3: # pkts, 4: un-mod
# of TX packets	0x01F4 (500 pkts)	LSB comes first
Packet interval time:	0x0271 (625 µsec)	LSB comes first

DA1469x Bluetooth® Direct Test Mode in RF Testing

4.4.2 HCI LE Controller Commands

The LE Controller HCI commands (OGF = 0x08) for the LE (v1) or LE Enhanced (v2) Transmitter Test and Receiver Test used in DTM RF testing as for instance sent by a Bluetooth tester are as follows:

TX: the HCI commands for LE Cont_Pkt_TX, 1 Mbps or 2 Mbps, Ch.0 (0x00), Payload 37 Byte (0x25) and using PRBS9 (0x00) are:

1 Mbps: 0x01 0x1E 0x20 0x03 0x00 (Ch) 0x25 0x00

2 Mbps: 0x01 0x34 0x20 0x04 0x00 (Ch) 0x25 0x00 0x02 (PHY) (LE v2 command).

StopTest command: 0x01 0x1F 0x20 0x00

Expected reply: 0x04 0x0E 0x06 0x07 0x1F 0x20 0x00 0xnn 0xnn (nn : number of sent packets).

RX: the required HCI commands for LE Pkt_RX, 1 Mbps or 2 Mbps, Ch.39 (0x27) are:

1 Mbps: 0x01 0x1D 0x20 0x01 0x27 (Ch)

2 Mbps: 0x01 0x33 0x20 0x03 0x27 (Ch) 0x02 (PHY) 0x00 (LE v2 command).

StopTest command: 0x01 0x1F 0x20 0x00

Reply example from the StopTest: 0x04 0x0E 0x06 0x07 0x1F 0x20 0x00 0xDC 0x05.

The last two words represent the number of received packets, LSB and MSB respectively.

In the shown reply: 0x05DC => 1500 packets received.

Of course, the number of received packets can be any other value.

Following vendor specific HCI command can be used to get statistics for the received packets: packets having CRC errors, having Sync errors and the RSSi value of the received packets. This command uses opcode 0xFC16, and must be executed after a regular RX test.

Get RX Test Stats HCI command: 0x01 0x16 0xFC 0x00.

Reply example: 04 0E 0E 07 16 FC 00 E8 03 00 00 00 00 00 00 8E 00.

The data we are interested in follows after FC 00, in pairs, LSB first.

In above example the following values are read respectively: [Table 3](#).

Table 3: Received Packet Statistics

Parameter:	Value:	Notes:
Total number of received packets :	0x03E8	1000 packets received
Number of packets having SYNC error :	0x0000	0 packets having SYNC error
Number of packets having Length error :	0x0000	0 packets having Length error
Number of packets having CRC error :	0x0000	0 packets having CRC error
RSSi value of the received packets :	0x008E	142, corresponds to -49 dBm

The RSSi equation for calculating RSSi in dBm is: $RSSi [dBm] = RSSi_Value/2 - 120$.

The equation is valid for the monotonous RF input power range: -90 dBm to -20 dBm.

All the above commands can be copied and pasted into the Send fields of the terminal program, please refer to [Figure 14](#).

Note 1 Please, when copying/pasting the above HCI commands, do not forget to delete the inserted descriptive text: (Ch), (pkt), (unmod), (PHY) etc. Else it will result in errors.

DA1469x Bluetooth® Direct Test Mode in RF Testing

Note 2 The applied TX packet data length in all the above examples is 0x25 (37 Bytes), it is given in the field after the channel number. The data length can be as long as 0xFF (255 Bytes).
 For a data length = 255 Bytes, enter the value 0xFF instead of 0x25.

Figure 14 here below shows the terminal's interface. Both commands for starting TX un-modulated at Ch.19 (0x13 in the upper field) and stopping the test (in the lower field) are shown in the Send tabs. After entering the HCI commands, pressing the 'Send Numbers' button will send the command to the chip. The chip should reply. The replies are shown in the top window part (in yellow color). The terminal's Display setting is best set to 'Hex [space]'. The terminal's Port settings in the Port tab are as follows:
 Baud rate: 115200, Parity: None, 8 Data-bits, 1 Stop-bit.
 When having the Hardware Flow Control enabled in the software, RTS/CTS should be set.

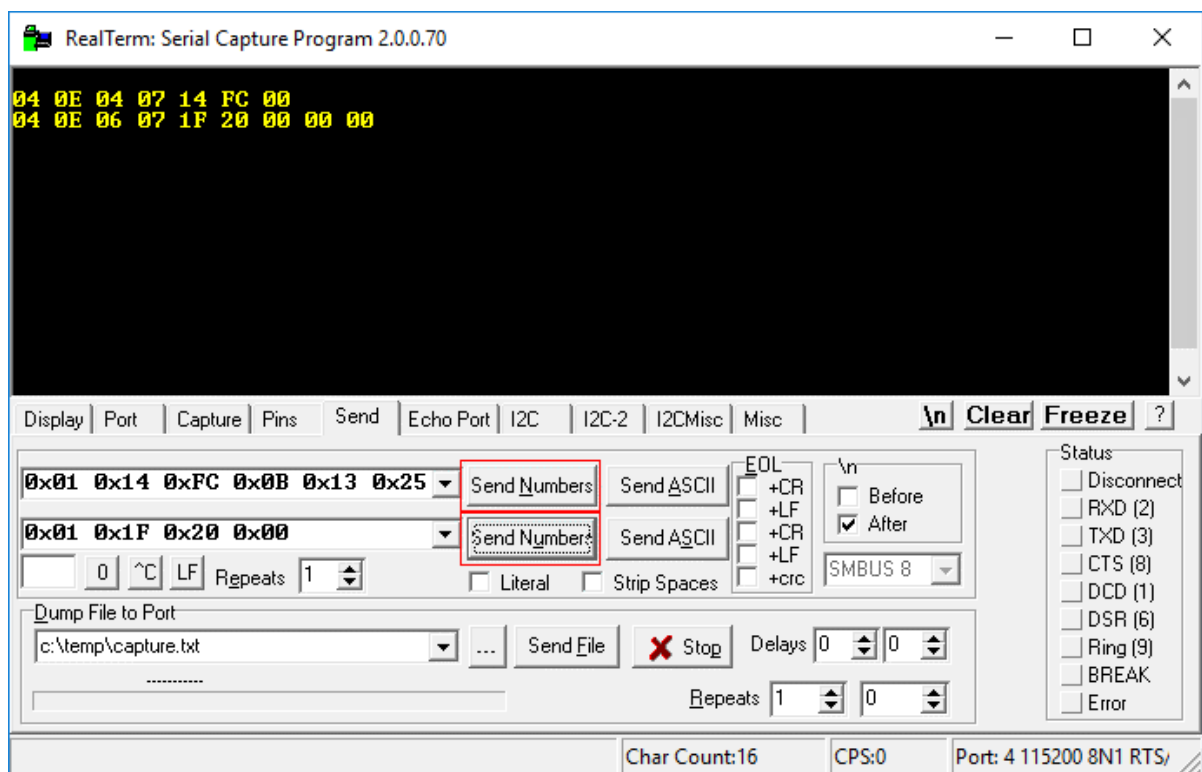


Figure 14: RealTerm Send window

4.4.2.1 Bluetooth Core v5.1 LE Controller Specifications

LE Receiver/Transmitter Test (v1) as defined in Bluetooth Core v5.1/Vol.2/Part E/7.8.28 and 7.8.29.
 LE Test_End (StopTest) as defined in Bluetooth Core v5.1/Vol.2/Part E/7.8.30.
 LE Enhanced Test command (v2) as defined in Bluetooth Core v5.1/Vol.2/Part E/7.8.50 and 7.8.51.
 LE Enhanced Test command (v3) as defined in Bluetooth Core v5.1/Vol.2/Part E/7.8.78 and 7.8.79.
 The v1 set of commands support the 1Mbps Phy only, the LE Enhanced v2 and v3 sets also support the 2 Mbps Phy. [4].

DA1469x Bluetooth® Direct Test Mode in RF Testing

5 Production Line Testing

For other than standard Bluetooth LE tests and e.g. automatic 32 MHz crystal oscillator trimming, the BLE_EXTERNAL_HOST project cannot be used. It does not support these features.

Instead, the PLT_FW project must be used.

The PLT_FW project is targeted to Production Line Testing.

It supports DTM testing and amongst others 32 MHz crystal trimming.

By default, UART hardware flow control is not enabled in the PLT_FW project.

The PLT_FW project is not included in the SDK but can be downloaded from the support portal, under Software Applications and Examples.

Link: <https://www.dialog-semiconductor.com/products/da1469x-product-family>

DA1469x Bluetooth® Direct Test Mode in RF Testing

6 Bluetooth® PHY Qualification

In order to release a Bluetooth application to the market, the application needs to be Qualified. The Dialog Semiconductor Bluetooth Low Energy SoCs have Qualified Design Listings (QDL) with corresponding Qualified Design Identification (QDID) for all Host Subsystems and Controller Subsystems. Enter 'Dialog Semiconductor' in the search field for finding all Dialog Semiconductor listings. By referring to the Dialog Semiconductor QDIDs, the amount of testing required to list a Bluetooth low energy application is greatly reduced.

Typically, Bluetooth PHY testing must be done for new hardware, meaning that Bluetooth PHY testing done by Dialog Semiconductor on the evaluation kits cannot be re-used. This PHY testing has to be done by an authorized test house.

Table 4 and Table 5 display the Protocol Implementation Extra Information for Test (PIXIT) entries that the test house needs for PHY qualification.

Table 4: PIXIT entries for Bluetooth Low Energy 1 Mbps

PIXIT Reference	Identifier	Sub-Identifier (Optional)	Value	Units
RF-PHY:P1:1	Inband Image frequency	Low frequency	2	MHz
RF-PHY:P1:2		Middle frequency	2	MHz
RF-PHY:P1:3		High frequency	2	MHz
RF-PHY:P2:1	Value n for Intermodulation test	Low frequency	3	Integer
RF-PHY:P2:2		Middle frequency	3	Integer
RF-PHY:P2:3		High frequency	3	Integer
RF-PHY:P3	Type of power source			
RF-PHY:P4:1	Power source voltage	Nominal (NOC)	End product spec	V
RF-PHY:P4:2		Maximum (EOC)	End product spec	V
RF-PHY:P4:3		Minimum (EOC)	End product spec	V
RF-PHY:P5:1	Operating temperature	Nominal (NOC)	End product spec	°C
RF-PHY:P5:2		Maximum (EOC)	End product spec	°C
RF-PHY:P5:3		Minimum (EOC)	End product spec	°C
RF-PHY:P6:1	Air humidity range (relative)	Maximum (EOC)	End product spec	%
RF-PHY:P6:2		Minimum (EOC)	End product spec	%
RF-PHY:P6:3		Air humidity level for NOC/EOC tests	End product spec	%
RF-PHY:P7:1	Test interface implementation	HCI or 2-wire UART	HCI	
RF-PHY:P7:2		Datarate	115000	bps
RF-PHY:P8	Antenna gain	Low	End product spec	dBi
		Middle	End product spec	dBi
		High	End product spec	dBi

DA1469x Bluetooth® Direct Test Mode in RF Testing
Table 5: PIXIT entries for Bluetooth Low Energy 2 Mbps

PIXIT Reference	Identifier	Sub-Identifier (Optional)	Value	Units
RF-PHY:P1:1	Inband Image frequency	Low frequency	4	MHz
RF-PHY:P1:2		Middle frequency	4	MHz
RF-PHY:P1:3		High frequency	4	MHz
RF-PHY:P2:1	Value n for Intermodulation test	Low frequency	3	Integer
RF-PHY:P2:2		Middle frequency	3	Integer
RF-PHY:P2:3		High frequency	3	Integer
RF-PHY:P3	Type of power source			
RF-PHY:P4:1	Power source voltage	Nominal (NOC)	End product spec	V
RF-PHY:P4:2		Maximum (EOC)	End product spec	V
RF-PHY:P4:3		Minimum (EOC)	End product spec	V
RF-PHY:P5:1	Operating temperature	Nominal (NOC)	End product spec	°C
RF-PHY:P5:2		Maximum (EOC)	End product spec	°C
RF-PHY:P5:3		Minimum (EOC)	End product spec	°C
RF-PHY:P6:1	Air humidity range (relative)	Maximum (EOC)	End product spec	%
RF-PHY:P6:2		Minimum (EOC)	End product spec	%
RF-PHY:P6:3		Air humidity level for NOC/EOC tests	End product spec	%
RF-PHY:P7:1	Test interface implementation	HCI or 2-wire UART	HCI	
RF-PHY:P7:2		Datarate	115000	bps
RF-PHY:P8	Antenna gain	Low	End product spec	dBi
		Middle	End product spec	dBi
		High	End product spec	dBi

Appendix A Motherboard

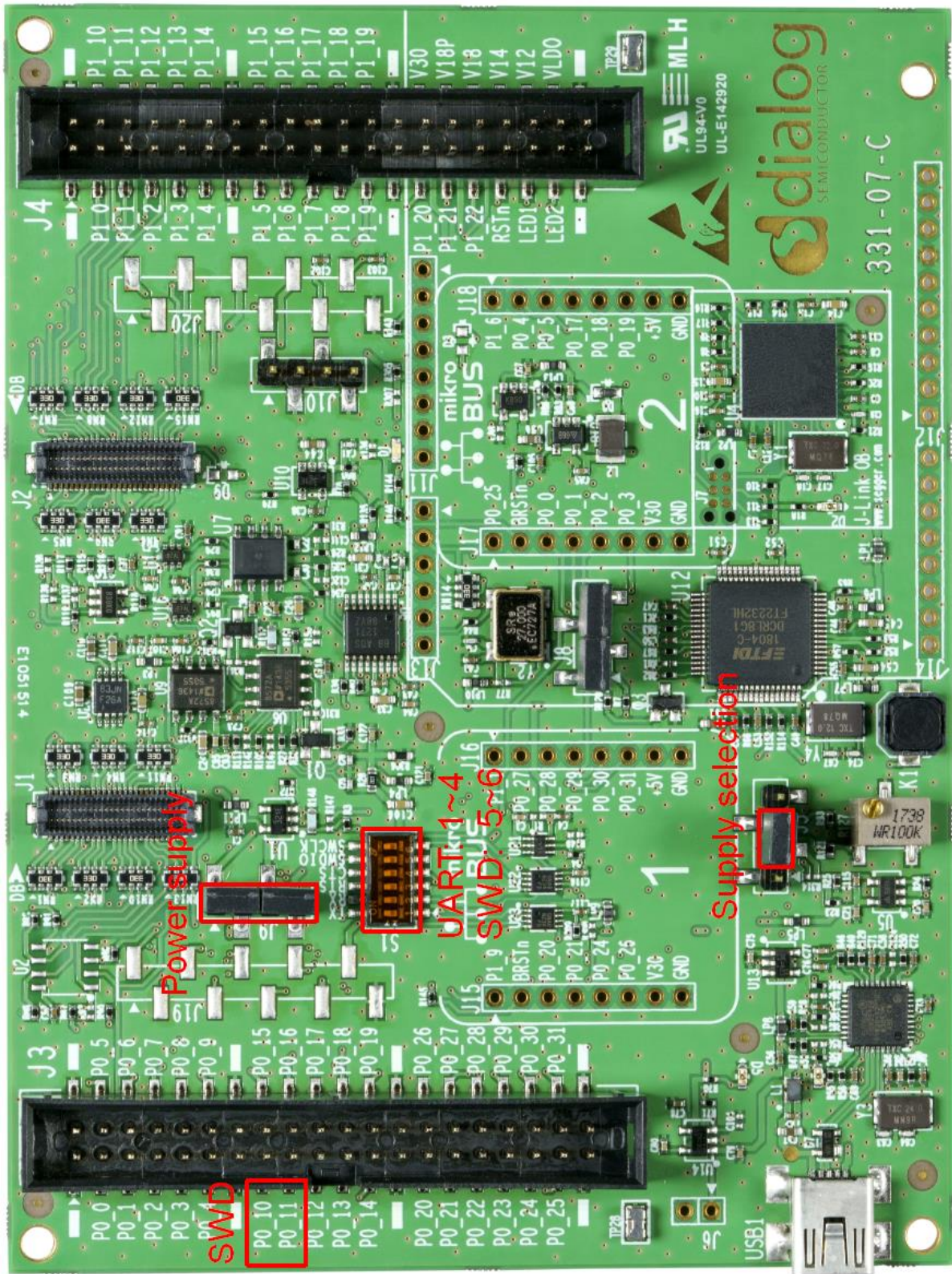


Figure 15: DA1469x Pro-DK motherboard

Appendix B Daughterboard



Figure 16: DA14695 Pro-DK daughterboard

DA1469x Bluetooth® Direct Test Mode in RF Testing
Revision History

Revision	Date	Description
1.6	22-Feb-2022	Updated logo, disclaimer, copyright.
1.5	20-Apr-2020	Adding the Teledyne LeCroy TLF3000 tester in section 4.2.4.
1.4	20-Sep-2019	Updated section 4.1.1. Adding Get Rx Statistics HCI command in section 4.4.2. Comply to Bluetooth® Brand Guide 2019.
1.3	20-Jun-2019	Section 4.4 has been split in two parts, added Table 2. Details 1.3: section 4.4, separating the non-standard HCI commands part from the HCI LE Core commands part.
1.2	01-May-2019	Updates in the Terminal section 4.4, and adding information about temperature triggered RF re-calibrations in section 4.1.1. Details 1.2: adding commands for Pkt_TX, Cont_Pkt_TX, Cont_TX_Non-packet
1.1	11-Mar-2019	Corrections and updates Details 1.1: corrected a few links. Adding LE TX and LE RX commands for 1 Mbps and 2 Mbps.
1.0	21-Feb-2019	Approved version
	14-Feb-2019	Draft version.

DA1469x Bluetooth® Direct Test Mode in RF Testing

Status Definitions

Status	Definition
DRAFT	The content of this document is under review and subject to formal approval, which may result in modifications or additions.
APPROVED or unmarked	The content of this document has been approved for publication.