

Configuration of the R&S CMW for Bluetooth Low Energy Direct Test Mode Application Note

Products:

- R&S®CMW500
- R&S®CMW270

This document describes the direct test mode mechanisms for testing Bluetooth Low Energy devices and explains how the direct test mode connection is established.

The R&S CMW uses a USB port for the direct test mode connection while the Equipment under Test (EUT) may provide a USB port, a serial port or even a 2-wire UART interface for this purpose. Installing or assigning the right driver for the EUT is the main configuration task on the R&S CMW. For EUTs with USB port, the R&S CMW provides a Bluetooth Low Energy USB driver which has to be assigned to the connected EUT.

Note:

Please find the most up-to-date document on our homepage <http://www.rohde-schwarz.com/appnote/1C105>.

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1 Direct Test Mode

1.1 Basics

The direct test mode uses an extra („direct“) communication channel between R&S CMW¹ and Bluetooth Low Energy EUT to control the EUT. The direct communication over this channel is faster than communication via the RF connection (some Bluetooth protocol layers can be skipped) and allows to minimize the testing times.

Direct test mode communication is applicable for both transmitter (TX) and receiver (RX) tests on the physical layer (LE RF PHY) which are still executed over the RF connection between CMW and EUT. It covers initiating and ending tests, controlling the test status and getting test reports. For example, the direct test mode command for test initiation specifies the test frequency, packet length and the data pattern.

The direct control brings some minor restrictions compared to full RF testing: Only a set of fixed transmit and receive frequencies are used, frequency hopping and whitening are disabled.

The direct test mode is described in the Bluetooth specification, core system package, volume 6, part F. The Bluetooth LE RF PHY test specification uses the direct test mode for all TX and RX test cases.

1.2 Communication Methods and Hardware Interfaces

The Bluetooth specification distinguishes two communication methods for direct test mode:

- Over HCI for EUTs with accessible host controller interface
- Through a 2-wire UART interface for EUTs with non-accessible host controller interface

These methods are represented by the “EUT Comm Protocol” parameter at the CMW.

EUTs of the first case (accessible HCI) provide either a USB port or a serial RS232 port for the direct test mode connection while EUTs of the second case always use a serial 2-wire UART interface. So, taking into account the hardware interface at the EUT, there are three kinds of direct test mode connections, see the following figure.

The CMW uses a USB port for the direct test mode connection in all cases. This leads to a USB-to-USB connection for USB EUTs with accessible HCI and to USB-to-serial connections for the other two cases. The USB-to-serial connections need a USB-to-serial converter between CMW and EUT. The CMW handles both types of serial connections in the same way. Hence, from the CMW point of view, there are only two physical connection types for direct test mode and the CMW distinguishes them with

¹ The R&S®CMW500 or R&S®CMW270 is referred to as CMW in this document.

the “HW Interface” parameter and the values “USB (directly)” and “USB to RS232 adapter”.

The third choice for “HW Interface” is “None (EUT Control Off)” allowing to switch-off the direct test mode.

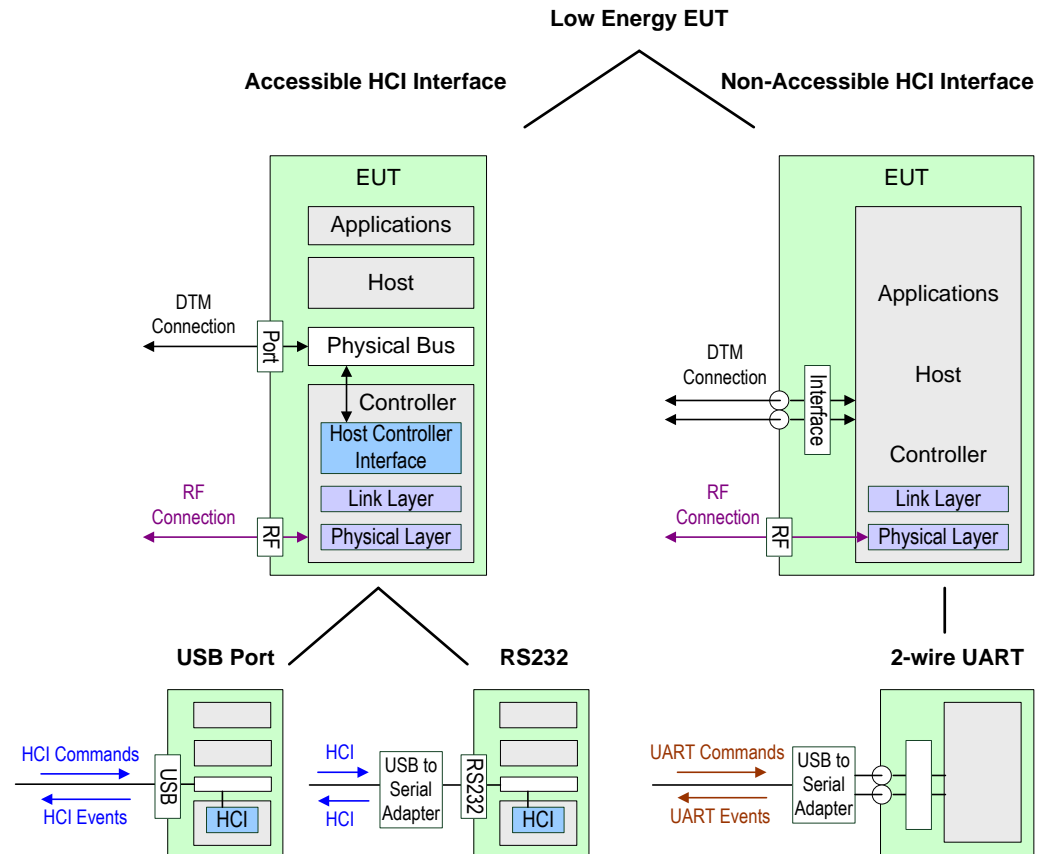


Fig. 1-1 EUT types for direct test mode (DTM)

1.3 Commands and Events

Messages from the CMW to the EUT are denoted as commands while messages from the EUT to the CMW are denoted as events. The communication protocol (HCI or 2-wire UART interface) determines which commands/events are available. During test execution the direct test mode commands/events are translated in RF Test commands/events controlling the EUT behaviour on the physical layer, see the table.

Direct Test Mode Commands/Events			
HCI	2-Wire UART	RF Test Command/Event	Direction
LE_Transmitter_Test	LE_Transmitter_Test	LE_TRANSMITTER_TEST	CMW --> EUT
LE_Receiver_Test	LE_Receiver_Test	LE_RECEIVER_TEST	CMW --> EUT
LE_Test_End	LE_Test_End	LE_TEST_END	CMW --> EUT
Command_Complete_Event	LE_Test_Status	LE_STATUS	CMW <-- EUT
Command_Complete_Event	LE_Packet_Report	LE_PACKET_REPORT	CMW <-- EUT

Table 1-1 Commands and events

The figure shows how the CMW controls the EUT with direct test mode commands and how the EUT responds. The naming convention for the RF test commands/events is used to make the representation valid for both the host controller interface and the 2-wire UART interface.

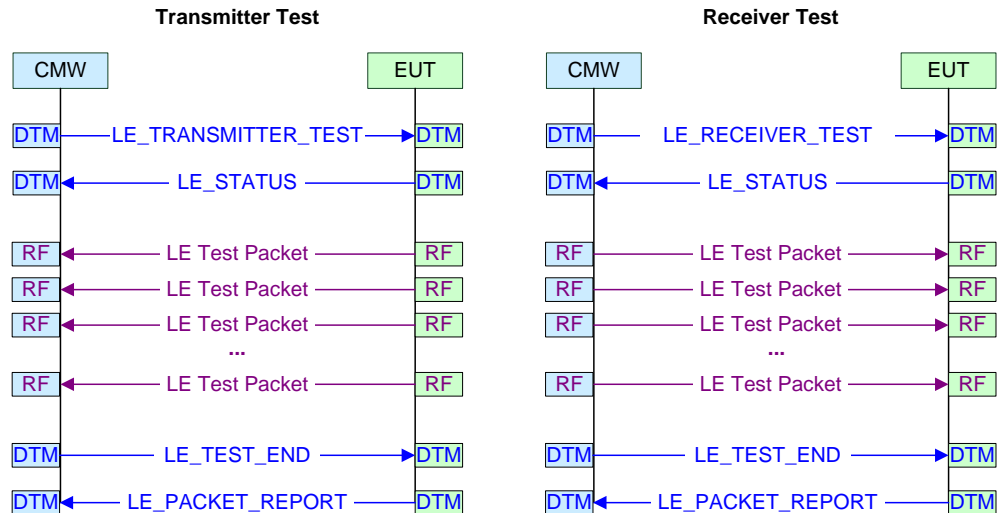


Fig. 1-2: Message sequence charts (DTM: Direct Test Mode)

The following table describes the main information sent by the commands/events.

Command/Event	Direction	Content
LE_TRANSMITTER_TEST	CMW --> EUT	TX Frequency, Length of Test Data, Packet Payload
LE_RECEIVER_TEST	CMW --> EUT	RX Frequency
LE_TEST_END	CMW --> EUT	---
LE_STATUS	CMW <-- EUT	Status, Number of allowed HCI Command Packets, Command Opcode
LE_PACKET_REPORT	CMW <-- EUT	Number of allowed HCI Command Packets, Command Opcode, Return Parameters according to the Command Opcode value

Table 1-2: Content of commands and events

You can see that only a small set of parameters is controlled via direct test mode.

2 Connection Properties, Drivers

The USB ports of the CMW are controlled by the Windows operating system and Windows needs an appropriate driver to communicate with any device connected via USB port. The driver selection and related actions depend on the type of the direct test mode connection.

USB to USB

Windows has own drivers for Bluetooth USB devices but these are not appropriate for Bluetooth Low Energy (LE) testing. So, Rohde & Schwarz provides a customized driver for Bluetooth LE USB devices which is delivered together with the Bluetooth Signaling application beginning with version 3.5.30. The R&S driver covers devices of the USB classes "Wireless Controller" (class E0h) and "CDC/ACM" (class 02h).

When connecting the USB EUT with the CMW, Windows automatically assigns one of its own USB drivers to the EUT but not the desired R&S USB Bluetooth LE driver. So, the driver of the Bluetooth application has to be assigned manually to the EUT. After driver assignment, the USB EUT appears in the Windows Device Manager as "Bluetooth HCI USB Device".

A Bluetooth Signaling application beginning with version 3.5.30 supports the R&S Bluetooth LE USB driver. It detects the USB connections to Bluetooth HCI USB devices and shows them in the "EUT Control" tab in the Bluetooth Signaling view as items "USB0", "USB1", ... for the "USB Device" parameter.

USB-to-serial

A USB-to-serial converter is used for EUTs with serial RS232 port and 2-wire UART interface. Hence, the driver for this converter has to be installed on the CMW. Having installed this driver, Windows may assign the driver correctly to the connected converter and assigns a virtual COM port. If the assignment was not correct, it has to be done manually.

The USB-to-serial converter appears in the Windows Device Manager under "Ports (COM & LPT)". Several parameters are related to the serial connection which you can inspect by opening the context menu (right-click the entry) and selecting the "Settings" tab. The serial connection parameters are also available in the Bluetooth Signaling view.

The Bluetooth Signaling application detects the USB-to-serial connections and shows them in the "EUT Control" tab in the Bluetooth Signaling view as items "COM3", "COM4", ... for the "Virtual COM Port" parameter.

Set the serial connection parameters in the Bluetooth Signaling view!

Only the settings within Bluetooth Signaling are used for the direct test mode communication. Note that the "Virtual COM Port" number used by the Bluetooth Signaling application can be different from the COM port number assigned during the installation of the USB-to-serial driver.

Parameter	Description	RS232 Value Range	2-Wire UART Value Range
Virtual COM Port	The port to which the used USB port has been mapped	3, 4, ...	3, 4, ...
Baud Rate	Data transmission rate in bit/s	110, 300, 600, 1200, 2400, 4800, 9600, 14400, 19200, 28800, 38400, 57600, 115200	1200, 2400, 9600, 14400, 19200, 38400, 57600, 115200
Data Bits	Number of data bits	7..8	8
Stop Bits	Number of bits used for stop indication	1 2	1
Parity	Number of parity bits	None Odd Even	None
Protocol	Flow control	XonXoff CtsRts None	CtsRts None

Table 2-1 Serial connection parameters (as named in the Bluetooth Signaling application)

3 Test Setups

3.1 EUT with USB Port

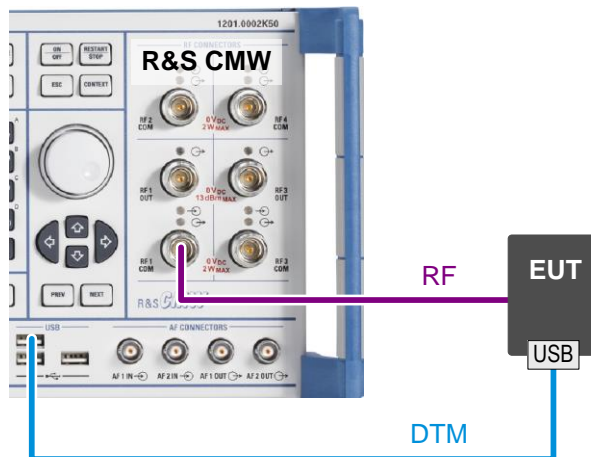


Fig. 3-1 Test setup with USB EUT

Note: Some EUTs can be connected directly to a CMW's USB port without USB cable.

3.2 EUT with RS232 Port

A USB-to-serial converter/adaptor is required.

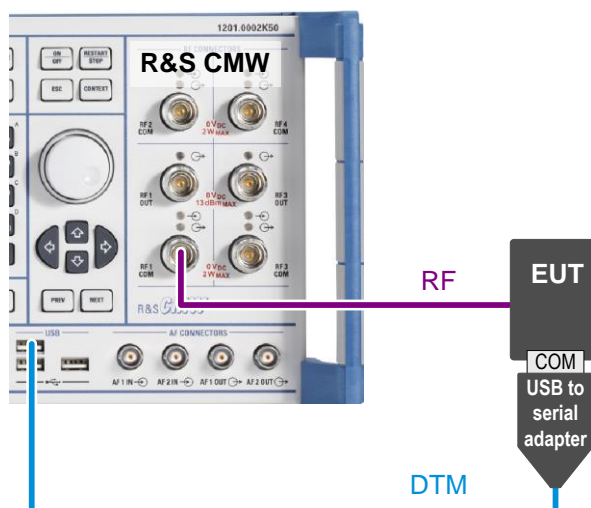


Fig. 3-2 Test setup with RS232 EUT

The USB-to-serial converter UC-232A from ATEN International Co., Ltd. is recommended (for more information, see <http://aten.com>).



Fig. 3-3 ATEN USB-to-serial converter

3.3 EUT with 2-Wire UART Interface

A USB-to-serial converter/adaptor is required.

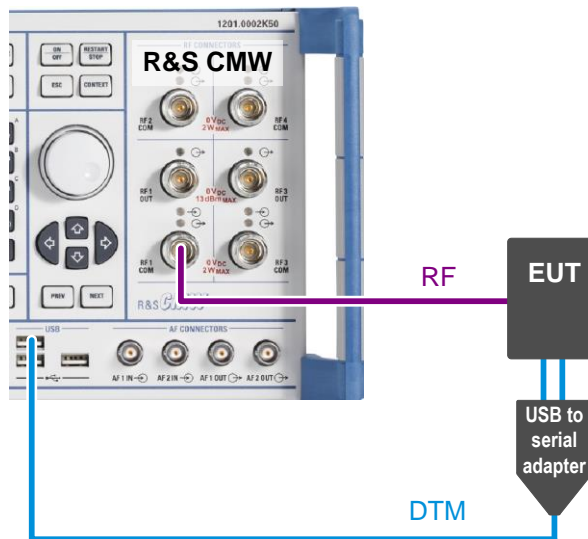


Fig. 3-4 Test setup with 2-wire UART EUT

4 Procedures

4.1 EUT with USB Port

4.1.1 Installing and Assigning the Bluetooth USB Driver to the EUT

The installation file of the Bluetooth LE USB driver for HCI communication is provided together with the Bluetooth Signaling application. The driver has to be installed and then to be assigned to the EUT manually. This is done via the Windows Device Manager.

The procedure is similar for Windows XP and Windows 7. The following descriptions refer to Windows XP (deviations for Windows 7 are put in brackets) and version 3.5.40 of the Bluetooth Signaling application for which the driver installation file is available in the Bluetooth installation directory – version 3.5.30 is the earliest version which supports the Bluetooth LE USB driver and provides the driver installation file on the desktop.

Starting situation

- The CMW is running, the Bluetooth Signaling application is loaded and a Bluetooth view is displayed.
- A mouse is connected to the CMW.

Procedure

Installing the Bluetooth LE USB driver:

1. Press the “System” hardkey to get the Windows desktop.
2. Right-click the Windows “Start” button and click “Open ‘Windows Explorer’”.
3. Navigate to “C:\Program Files\Rohde-Schwarz\CMW\3.5\rs.bluetooth_sig\drivers” (Windows 7: “C:\Program Files (x86)\...”).
4. Double-click the “hciusb” file (Windows 7: “hciusb_64” file) to install the Bluetooth LE USB driver.

Detecting the EUT in the Device Manager:

5. Click the Windows “Start” button, select “Control Panel” and then “System”. In the “System Properties” dialog select the “Hardware” tab and then click the “Device Manager” button.
The “Device Manager” window is opened.
6. Connect the USB EUT with the CMW using a free USB port at the CMW.
The operating system tries to identify the new device and to assign a driver to it.
The new device is added in the Device Manager.
7. Find the entry for the EUT in the Device Manager.
Depending on the type of EUT its entry may appear in the “Other” section, under “Network Adapter”, “USB Controller” or “USB Radio”. If Windows automatically

assigns a driver, the driver-related device name is shown as subordinate entry (for example “Generic Bluetooth Radio”).

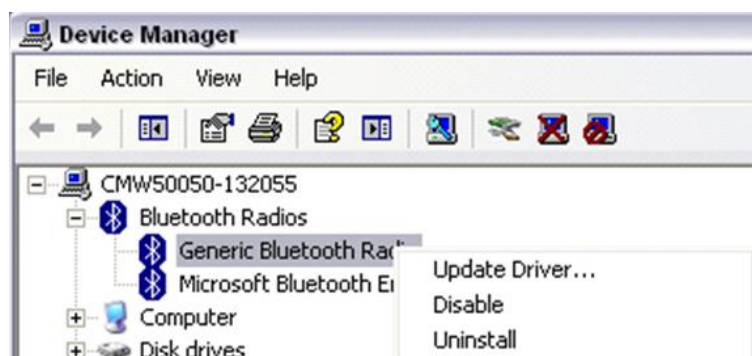


Fig. 4-1 Device Manager

8. If you cannot find the EUT immediately, disconnect and reconnect the EUT again and look for changes in the Device Manager.

Assigning the right USB driver:

9. Right-click the entry for the EUT in the Device Manager to open the context menu.
10. Select “Update Driver...”.
The “Hardware Update Wizard” opens.
11. Select “No, not this time” and click “Next”.



Fig. 4-2 Hardware update wizard, welcome view

12. Select “Install from a list or specific location (Advanced)” and click “Next”.
13. Select “Don’t search. I will choose the driver to install.” and click “Next”.

14. Deactivate “Show compatible hardware” (if it is not already deactivated). In the “Manufacturer” area, select “Rohde & Schwarz ...”, then select “Bluetooth HCI USB Device” in the “Model” area and click “Next”.

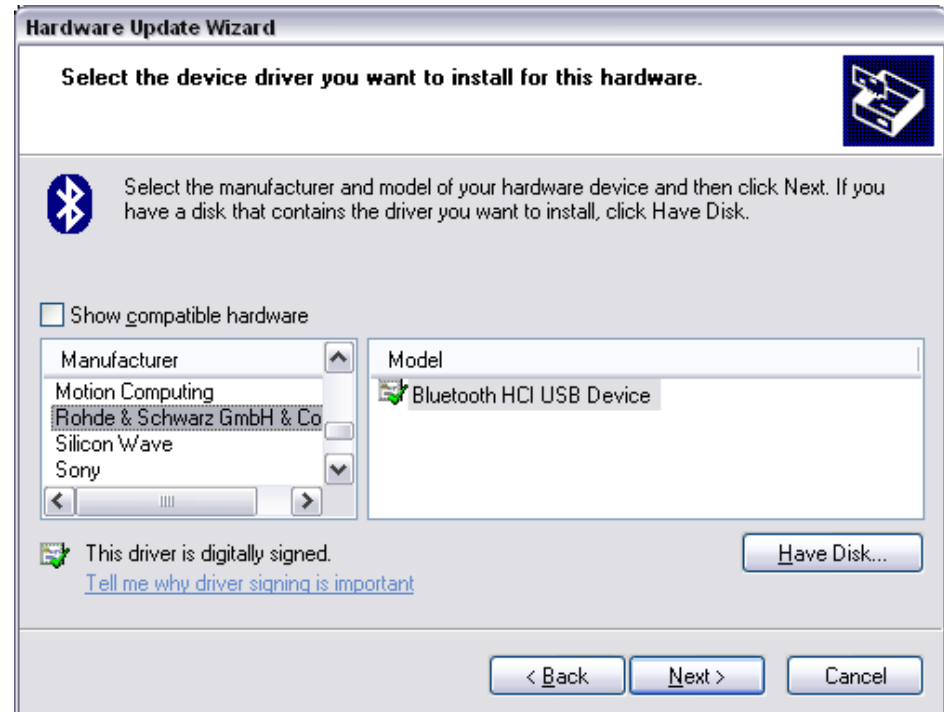


Fig. 4-3 Hardware update wizard, select device driver

After clicking “Next” the “Update Driver Warning” window opens.

15. Click “Yes” to continue updating the driver.
16. Click “Finish”.

Result

The EUT is displayed in the Device Manager as “Bluetooth HCI USB Device”. Any previous entry for the EUT has vanished. Back in the Bluetooth Signaling view (available after pressing the “System” softkey again), in the “EUT Control” tab, you find the entry “USB0” for the “USB Device” (if only one Bluetooth HCI USB device has been connected).



Fig. 4-4 Device Manager after driver assignment

Further actions, variants

- If you disconnect and reconnect the EUT again after the “Bluetooth HCI USB Device” driver has been assigned to the EUT, Windows correctly re-assigns this driver to the EUT. Usually, you can even change the USB port at the CMW and get the right driver assignment.
- If you connect a second EUT of the same type with the CMW after the “Bluetooth HCI USB Device” driver has been assigned to the EUT, Windows does not automatically assign this driver to the second EUT. So, you have to assign the “Bluetooth HCI USB Device” driver to the second EUT in the same way as for the first EUT.
- If you change direct test mode connections with different EUTs and USB ports, Windows might lose the right USB driver assignment (depending on the EUTs). So you have to re-assign the “Bluetooth HCI USB Device” driver to the EUTs.
- If you disconnect the EUT with correctly assigned driver and then shutdown the CMW, Windows usually remembers the right USB driver assignment after restart of the CMW and reconnection of the EUT.

4.1.2 Establishing Direct Test Mode on the Bluetooth Signaling GUI

Starting situation

- The EUT is connected with the CMW and the USB driver has been assigned to the EUT as described in the previous procedure.
- The Bluetooth Signaling application is ON.

Procedure

At the Bluetooth Signaling view, proceed as follows:

1. In the “General Setup” area, select “Low Energy” for the “Burst Type”.

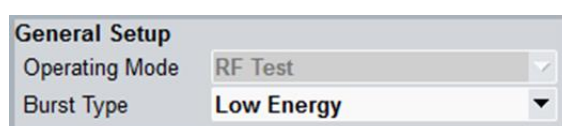


Fig. 4-5 General setup

2. Select the “EUT Control” tab on the left side and there select “USB” for the “HW Interface”.

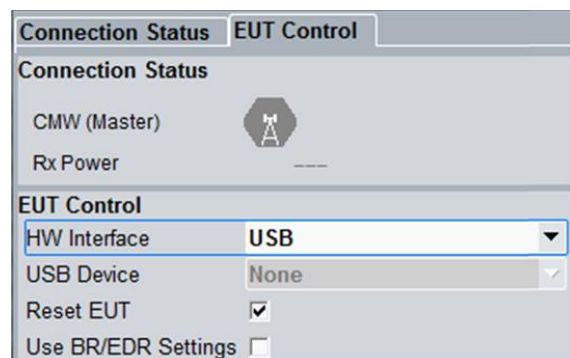


Fig. 4-6 Hardware interface: USB

3. Activate “Reset EUT”. This eliminates any previous EUT settings and puts the EUT in its reproducible initial state.
4. Press the “Refresh Devices” hotkey (which is available if the EUT has been connected and the right driver has been assigned).
The USB connections with EUTs are detected. If you have connected one EUT the “USB Device” displays the value “USB0”.
If you have connected several USB EUTs, then “USB Device” offers a list of values (“USB0”, “USB1”, ...).
5. In case of several USB connections with EUTs, select the desired value for “USB Device”.
6. Press the hotkey "Connection Check" (which is available with at least one value for “USB Device”) to verify that the USB connection has successfully been established.

Result: The direct test mode is active.

4.2 EUT with RS232 Port or 2-Wire UART Interface

A USB-to-serial converter is used.

4.2.1 Installing and Assigning the Driver for the Converter

The installation file for the driver is delivered together with the converter on the installation disk. It can also be downloaded from the vendor's website including the installation instructions.

Proceed as follows:

1. Copy the installation file via USB or LAN to the CMW.
2. Double-click the installation file on the CMW.

4.2.2 Verifying that the Driver is Properly Installed

Proceed as follows:

1. Get the Windows desktop ("System" hardkey or "Windows sign + D").
2. Open the Device Manager (for example: "Start > Control Panel > System", then "System Properties > Hardware > Device Manager").
3. Connect the USB-to-serial converter with the CMW using a free USB port at the CMW.
4. Verify that the USB-to-serial converter is available under "Ports (COM & LPT)" e.g. "ATEN USB-to-serial Bridge (COM4)".
The COM port number depends on the USB port which the converter is connected to.

If the USB-to-serial converter is displayed elsewhere in the Device Manager and with a name not related to the manufacturer, Windows could not assign the right driver to the converter. In this case you have to assign the driver manually. Proceed analogously as for the HCI USB driver (beginning with right-click on the entry in the Device Manager and selecting "Update Driver ...").

4.2.3 Establishing Direct Test Mode on the Bluetooth Signaling GUI

Starting situation

- The EUT is connected with the CMW via the USB-to-serial converter.
- The driver for the converter has been assigned to the EUT correctly.
- The Bluetooth Signaling application is ON.

Procedure

At the Bluetooth Signaling view, proceed as follows:

1. In the "General Setup" area, select "Low Energy" for the "Burst Type".

- Select the “EUT Control” tab on the left side and there select “USB to RS232 adapter” for the “HW Interface”.

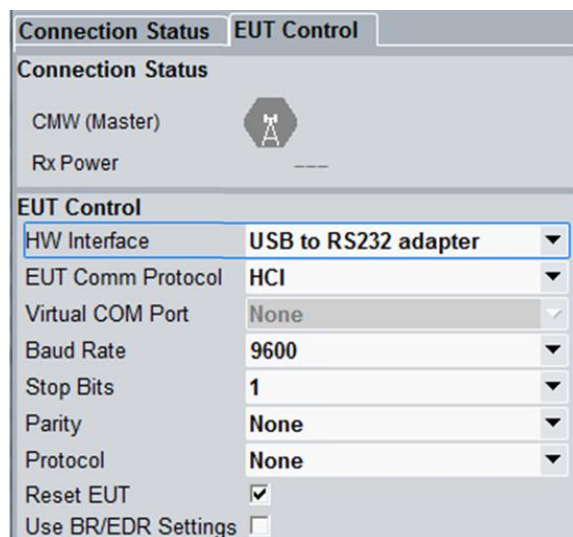


Fig. 4-7 Hardware interface: USB to RS232 adapter

- Select the “EUT Comm Protocol”: “HCI” or “2-wire” according to your test setup.
- Press the "Refresh Devices" hotkey.
The virtual COM ports assigned by Windows are automatically fetched and available as list at the “Virtual COM Port” parameter.
- Select the desired port from the “Virtual COM Port” list (if there is more than one list item).
- Set the serial connection parameters “Baud Rate”, “Stop Bits”, “Parity”, “Protocol” according to your serial connection. In many cases you can just keep the default values.
- Activate “Reset EUT”. This eliminates any previous EUT settings and puts the EUT in its reproducible initial state.
- Press the hotkey "Connection Check" to verify that the direct test mode connection has successfully been established.

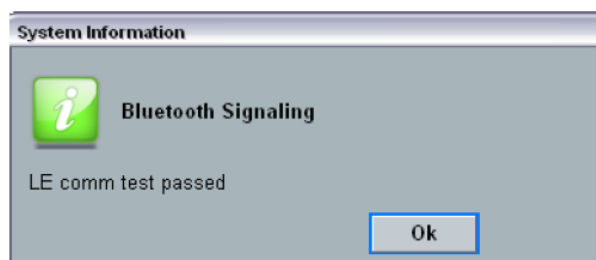


Fig. 4-8 Result of the connection check

It is checked whether the EUT has executed the reset command. If an error is indicated, reconfigure the transmission parameters (typically the baud rate) and repeat the "Connection Check" again.

Result: The direct test mode is active.

5 Troubleshooting

Manual assignment of the Bluetooth LE USB driver has failed

Windows could have failed to execute the manual driver assignment launched with the “Hardware Update Wizard”. This failure is indicated with a prompt stating for example that the “hciusb.sys” file cannot be found.

Solution:

1. Press the “System” hardkey to get the Windows desktop.
2. Right-click the Windows “Start” button and click “Open Windows Explorer”.
3. Navigate to “C:\Program Files\Rohde-Schwarz\CMW\3.5\rs.bluetooth_sig\drivers” (Windows 7: “C:\Program Files (x86)\...””) and right-click the “hciusb” file (Windows 7: “hciusb_64” file) to open the context dialog.
4. Select “Uninstall” to remove the installed driver (not the installer file itself).
Re-install the driver.
5. Repeat the manual assignment of the Bluetooth LE USB driver via Device Manager as described in chapter “Installing and Assigning the Bluetooth USB Driver to the EUT”.

The failure does not occur again after the uninstallation and re-installation cycle.

6 Ordering Information

CMW Hardware		
Designation	Type	Order No.
Radio Communication Tester	R&S®CMW500	1201.0002K50
	R&S®CMW270	1201.0002K75
Basic Assembly	CMW-PS503 (CMW500)	1202.5408.02
	CMW-PS272 (CMW270)	1202.9303.02

CMW Software		
Designation	Type	Order No.
Bluetooth Low Energy Signaling	CMW-KS611	1207.8805.02
Bluetooth, Low Energy, TX Measurement	CMW-KM611	1203.9307.02