Using Direct Test Mode
BL654 Series

Application Note  v1.0

1 INTRODUCTION

The BL654 firmware natively supports Direct Test Mode (DTM) commands as specified in the Bluetooth SIG’s Bluetooth Core Specifications v 5.0 vol. 6 part F - Direct Test Mode, accessible from the following link:
www.bluetooth.com/specifications/bluetooth-core-specification

The purpose of DTM is to test the operation of radio at the physical layers such as for transmit power and receiver sensitivity. This is useful for regulatory EMC testing or for co-located radio testing with another radio system.

This radio test can be carried out by dedicated test equipment (such as Anritsu MT8852 or similar) with the BL654 in DTM mode as the device under test. Alternatively, you can send DTM commands from a PC using a terminal program such as UwTerminalX. In both cases, the DTM commands remain the same.

This document describes BL654 radio testing using the in-built Direct Test Mode (DTM) firmware and Nordic’s nRFgo Studio or Laird BleDtmRfTool.

- Entering DTM mode for the BL654
- Using Nordic nRFgoStudio DTM panel (or Laird BleDtmRfTool) to BLE radio test BL654 in either Transmit or Receive mode.
- Exiting DTM mode for the BL654

2 REQUIREMENTS

To use DTM, you need the following:

- DVK-BL654-1.0 development board
- Windows PC
- UwTerminalX by Laird (available at https://github.com/LairdCP/UwTerminalX/releases
- Laird BleDtmRfTool – This is available from the Documentation section of the BL654 product page.
  Note: You must be logged into your Laird account for the BleDtmRfTool to work.
- Nordic nRFgoStudio application software (the complete install found on the Downloads panel at the following link: http://www.nordicsemi.com/eng/Products/Bluetooth-low-energy/nRF52832

Note: Please install the correct version (32- or 64-bit) for your operating system.

<table>
<thead>
<tr>
<th>Code</th>
<th>Name</th>
<th>Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>nRFgo Studio-Win32</td>
<td>Software tool for nRFgo Starter Kit and Development Kits for 32-bit (x86) Windows XP, Windows Vista, Windows 7, and Windows 8</td>
<td>1.21.2</td>
</tr>
<tr>
<td>nRFgo Studio-Win64</td>
<td>Software tool for nRFgo Starter Kit and Development Kits for 64-bit (x64) Windows Vista, Windows 7, and Windows 8</td>
<td>1.21.2</td>
</tr>
</tbody>
</table>
3 SETUP

We assume the DVK-BL654-1.0 development kit has its default out-of-the-box settings as described in the BL654 Quick Start Guide (available from the BL654 product page: https://www.lairdtech.com/products/bl654-ble-thread-nfc-modules). In this mode, it is in AT or interactive mode (no smartBASIC application loaded or running) on power up.

![Image of the DVK-BL654-1.0 development kit]

*Figure 1: J12 fitted over pins 1 and 2, and SW3 (reset button)*

4 ENTERING DIRECT TEST MODE

To enter DTM, follow these steps:

1. Open UwTerminalX.
2. Ensure you’re using the latest version of UwTerminalX by clicking the Update tab and then, in the UwTerminalX panel, click Check for Updates.
3. When you’re running the newest version of UwTerminalX, open the Config tab.
4. In the device drop down, select BL654 to populate the default communications settings.
5. Select the correct COM port.

If you cannot select BL654, manually select the following UART settings (shown in Figure 2):

<table>
<thead>
<tr>
<th>COM Port</th>
<th>Port corresponding to your development kit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baud Rate</td>
<td>115200</td>
</tr>
<tr>
<td>Parity</td>
<td>None</td>
</tr>
</tbody>
</table>
6. Click OK to connect.
7. Set up the module into Direct Test Mode, you will need to retrieve two sets of four characters each which function as a unique passcode to enter direct test mode. To retrieve the characters, issue the following command:

```
AT I 14
```

You should receive a response such as:

```
10 14 01 123456789ABC
```

Note the characters in the highlighted positions above. In our example in Figure 3, they are CB71 and 7B03.
8. To enter Direct Test Mode, using the characters you found in the previous steps, issue the AT+DTM command as follows:

```
AT+DTM 0xCB717B03
```

The module is now in Direct Test mode.

9. Click **Close Port** to disconnect the development board from UwTerminalX.
5 Using Direct Test Mode

Now that the module is in Direct Test Mode, it accepts DTM commands as specified in the BT SIG Bluetooth Core Specifications. See Bluetooth Core Specifications v 4.1 vol. 6 part F - Direct Test Mode, at https://www.bluetooth.com/specifications/bluetooth-core-specification.

To use Direct Test Mode, you need Nordic’s nRFgo Studio, found at: http://www.nordicsemi.com/eng/Products/Bluetooth-low-energy/nRF52832

Once the BL654 is in DTM mode, you can communicate with the BL654 over the UART with UwTerminal using the following communications settings:

<table>
<thead>
<tr>
<th>COM Port</th>
<th>Same as before</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baud Rate</td>
<td>19200</td>
</tr>
<tr>
<td>Parity</td>
<td>None</td>
</tr>
<tr>
<td>Stop Bits</td>
<td>1</td>
</tr>
<tr>
<td>Data Bits</td>
<td>8</td>
</tr>
<tr>
<td>Handshaking</td>
<td>CTS/RTS</td>
</tr>
</tbody>
</table>

5.1 Configuration of Module Settings (Optional)

Before entering DTM Mode, you may configure TX Power, Baud Rate, and DCDC. Changing these values is optional. However, if you choose, you may set these values as follows:

**TX Power**

<table>
<thead>
<tr>
<th>Command</th>
<th>AT+DTMCFG 1 n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Values for n</td>
<td>8, 7, 6, 5, 4, 3, 2, 0, -4, -8, -12, -16, -20, -40</td>
</tr>
<tr>
<td>Default</td>
<td>8</td>
</tr>
</tbody>
</table>

**Baud Rate**

<table>
<thead>
<tr>
<th>Command</th>
<th>AT+DTMCFG 2 n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Values for n</td>
<td>9600, 14400, 19200, 38400, 57600, 115200</td>
</tr>
<tr>
<td>Default</td>
<td>19200</td>
</tr>
</tbody>
</table>

**DCDC (for Normal Voltage Mode operation)**

<table>
<thead>
<tr>
<th>Command</th>
<th>AT+DTMCFG 3 n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Values for n</td>
<td>0 (Disabled), 1 (enabled)</td>
</tr>
<tr>
<td>Default</td>
<td>1</td>
</tr>
</tbody>
</table>
5.2 Start Direct Test Mode with nRFgo Studio

nRFgoStudio does not allow datarate to be changed and default is 1Mbps and other PHY datarates 2Mbps, coded PHY 500kbps (s=2) and 125kbps (s=8) cannot be selected.

To begin using Direct Test Mode, follow these steps:

1. Open Nordic nRFgo Studio.
2. In nRFgo Studio, click Direct Test Mode in the features panel to open the Direct Test Mode panel as shown in Figure 4.

   ![Opening the Direct Test Mode panel](image)

3. From there, you can place the module in constant TX or RX mode. Consult the nRFgo Studio built-in help for more information.

5.2.1 Transmit Test

To conduct a transmit test, configure the options in the Direct Test Mode panel as follows:

<table>
<thead>
<tr>
<th><strong>COM Port</strong></th>
<th>Same as previous</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mode</strong></td>
<td>Transmit</td>
</tr>
<tr>
<td><strong>Channel</strong></td>
<td>19 (2440 MHz)</td>
</tr>
<tr>
<td><strong>Payload Model</strong></td>
<td>PRBS9 – If a BLE-modulated TX signal is required or Constant Carrier – If a continuous [CW] TX signal is required</td>
</tr>
<tr>
<td><strong>Payload Length</strong></td>
<td>37 bytes</td>
</tr>
</tbody>
</table>

Once configured, click Start Test. If successful, no errors should show, as illustrated in Figure 5.
With the module in a Transmit test, you can measure the signal on a spectrum analyzer.

5.2.2 Receive Test

To conduct a receive test, configure the options in the Direct Test Mode panel as follows:

<table>
<thead>
<tr>
<th>COM Port</th>
<th>Same as previous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode</td>
<td>Receive</td>
</tr>
<tr>
<td>Channel</td>
<td>0 (2402 MHz)</td>
</tr>
</tbody>
</table>

Once configured, click Start Test. If successful, no errors should show.

**Note:** Rx Mode produces an RX LO leakage at the following frequency: $2 \times f_{Rx} - 1\text{MHz}$. 
5.3 Start Direct Test Mode Laird BleDtmRfTool

Laird’s BleDtmRfTool allows all BT PHY data rates to be tested, 1 Mbps, 2 Mbps and coded PHY 500 kbps (s=2) and 125 kbps (s=8).

To begin using Direct Test Mode, follow these steps:

1. Open Laird BleDtmRfTool (Figure 6).

![Figure 6: BleDtmRfTool UART communication settings](image)

2. In BleDtmRfTool, click DTM button located in the top right to open the Direct Test Mode panel as shown in Figure 7.

![Figure 7: BleDtmRfTool](image)
3. In BleDtmRfTool DTM panel, there are two ways to use BleDtmRfTool, either manual entry or pressing buttons (Figure 8).

![Figure 8: Opening the Direct Test Mode panel in BleDtmRfTool](image)
5.3.1 Transmit Test

To perform a transmit test, follow these steps:

1. Always start by pressing **LE RESET**.
2. Configure the applicable options in the Direct Test Mode. See Figure 9 for an example.

![Figure 9: Direct Test Mode options](image)

**COM Port** | Same as previous
---|---
**LE RESET** | First start by pressing **LE RESET**.

**Data rate** | Select data rate from 1 MPH or 2 MPH or LE CODED (S=8) or LE CODED (S=2) or selecting continuous CW select 1 MPH

**Standard or Stable Modulation Index** | BL654 series BLE module currently does support standard modulation index, so press **MOD’N INDEX (STD)**

**Channel** | 19 (2440 MHz)

**Payload Model i.e. Pkt Type** | **Pkt Type Value** | **Parameter Description**
---|---|---
00 | PRBS9 Packet Payload
01 | 11110000 Packet Payload
10 | 10101010 Packet Payload
11 | on the LE Uncoded PHYs: Vendor Specific on the LE Coded PHY: 11111111

Pkt Type 00 – If a BLE-modulated TX signal is required with PRBS9 Packet payload
-or-

Pkt Type 11 – If a continuous [CW] TX signal is required
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Payload Length | 0 bytes to 63 bytes
Set Length to 0 – If a continuous [CW] TX signal is required

| TRANSMIT | To start TX test press TRANSMIT |

3. Once configured, click TRANSMIT. If successful, no errors should show, as illustrated in Figure 5. Figure 8 shows a TX CW test.

Figure 8: Successful initiation of TX Test

With the module in a Transmit test, you can measure the signal on a spectrum analyzer.

5.3.2 Receive Test

To conduct a receive test, configure the options in the Direct Test Mode panel as follows:

<table>
<thead>
<tr>
<th>COM Port</th>
<th>Same as previous</th>
</tr>
</thead>
<tbody>
<tr>
<td>LE RESET</td>
<td>First start by pressing “LE RESET”.</td>
</tr>
<tr>
<td>Data rate</td>
<td>1MPHY or 2MPHY or LE CODED (S=8) or LE CODED (S=2)</td>
</tr>
<tr>
<td>Standard or Stable Modulation Index</td>
<td>BL654 series BLE module currently does support standard modulation index, so press MOD’N INDEX (STD)</td>
</tr>
<tr>
<td>Channel (fRx)</td>
<td>19 (2440 MHz)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Payload Model (such as Pkt Type)</th>
<th>Pkt Type Value</th>
<th>Parameter Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>PRBS9 packet payload</td>
<td></td>
</tr>
<tr>
<td>01</td>
<td>11110000 packet payload</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>10101010 packet payload</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>On the LE Uncoded PHYs – Vendor Specific On the LE Coded PHY – 11111111</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pkt Type 00 – If a BLE-modulated RX signal is required with PRBS9 Packet payload</td>
<td></td>
</tr>
</tbody>
</table>
**Payload Length** | 0 bytes to 63 bytes  
Set Length to 0 – If a continuous [CW] TX signal is required  
**RECEIVE** | To start RX test press RECEIVE

Once configured, click **RECEIVE**. If successful, no errors should show. The RX Event shows how many packets are received.

**Note**: Rx Mode produces an RX LO leakage at the following frequency: \(2 \times f_{Rx} - 1\)MHz.

## 6 Exiting DTM Mode

To exit DTM, follow these steps:

1. Open UwTerminalX with the following settings:
   - **COM Port**: Same as previous
   - **Baud Rate**: 19200
   - **Parity**: None
   - **Stop Bits**: 1
   - **Data Bits**: 8
   - **Handshaking**: None

2. Click **OK** to connect.
3. Right-click the terminal screen and in the context menu, click **Automation**.
4. In the following screen, modify the fields as shown in **Figure 10**.
   - In the first field, enter `\3F\FF`.
   - Tick the box for De-Escape Strings.
5. Click **Send**.

![Automation dialogue](image)

**Figure 10: Automation dialogue**

6. After this command is complete, close UwTerminalX. Then re-open it and connect to the BL654 with the following default parameters:
   - **COM Port**: Same as previous
   - **Baud Rate**: 115200
7. Click **OK** to connect.

8. Check that you get a response by pressing **Enter** in the terminal window. You should the following response:

```
00
```

9. Issue the following command to erase non-volatile data and the module's file system:

```
at&f*
```

The module erases its file system and reboots, as shown in **Figure 11**.

*Figure 11: at&f* to erase and reboot module*

7 **Revision History**

<table>
<thead>
<tr>
<th>Version</th>
<th>Date</th>
<th>Notes</th>
<th>Contributor(s)</th>
<th>Approver</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>25 June 2018</td>
<td>Initial Release</td>
<td>Raj Khatri</td>
<td>Jonathan Kaye</td>
</tr>
</tbody>
</table>