

# Using Direct Test Mode

## BL653μ Series

Application Note

v1.2

### 1 INTRODUCTION

The BL653μ 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](http://www.bluetooth.com/specifications/bluetooth-core-specification)

The purpose of DTM is to test the radio operation 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 RF Creations Moreph30, Anritsu MT8852, or similar) with the BL653μ 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 BL653μ radio testing using the in-built Direct Test Mode (DTM) firmware and Nordic nRF Connect for Desktop Direct Test Mode tool.

- Entering DTM mode for the BL653μ
- Using Nordic nRF Connect for Desktop Direct Test Mode tool to BLE radio test the BL653μ in either BLE transmit or BLE receive mode
- How to manually send DTM command (via UwTerminalX) to produce continuous wave [CW] RF TX signal
- Exiting DTM mode for the BL653μ

### 2 REQUIREMENTS

To use DTM, you need the following:

- Customer's host board with BL653μ module fitted (and access to BL653μ UART)
- Windows PC
- UwTerminalX by Laird Connectivity (available at <https://github.com/LairdCP/UwTerminalX/releases>)

Nordic **nRF Connect for Desktop Direct Test Mode** tool – This Nordic Direct Test Mode tool is installed when the Nordic **nRF Connect** is installed.

Nordic **nRF Connect for Desktop** application software (the complete install) found at the following link:

<https://www.nordicsemi.com/Software-and-Tools/Development-Tools/nRF-Connect-for-desktop>

<https://www.nordicsemi.com/Software-and-tools/Development-Tools/nRF-Connect-for-desktop/Download#infotabs>

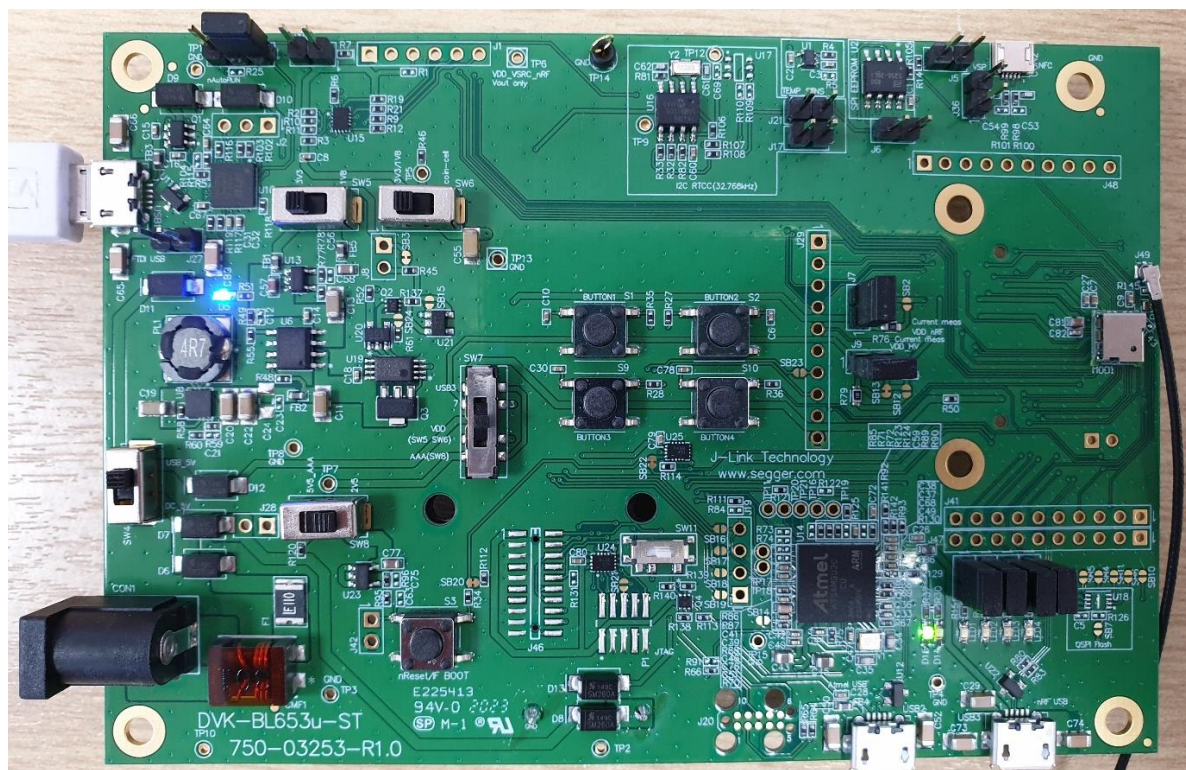
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**Note:** Please install the correct version (32- or 64-bit) for your operating system.

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### 3 SETUP

We assume the customer has BL653 $\mu$  module on a customer's own host board (or end product design). The BL653 $\mu$  module should set to be in AT or interactive mode (no *smartBASIC* application loaded or running) on power up. **Below example is BL653 $\mu$  on Laird Connectivity internal host devboard (not commercially available).**



**Figure 1: Laird Connectivity internal devboard BL653 $\mu$  switch and jumper positions**

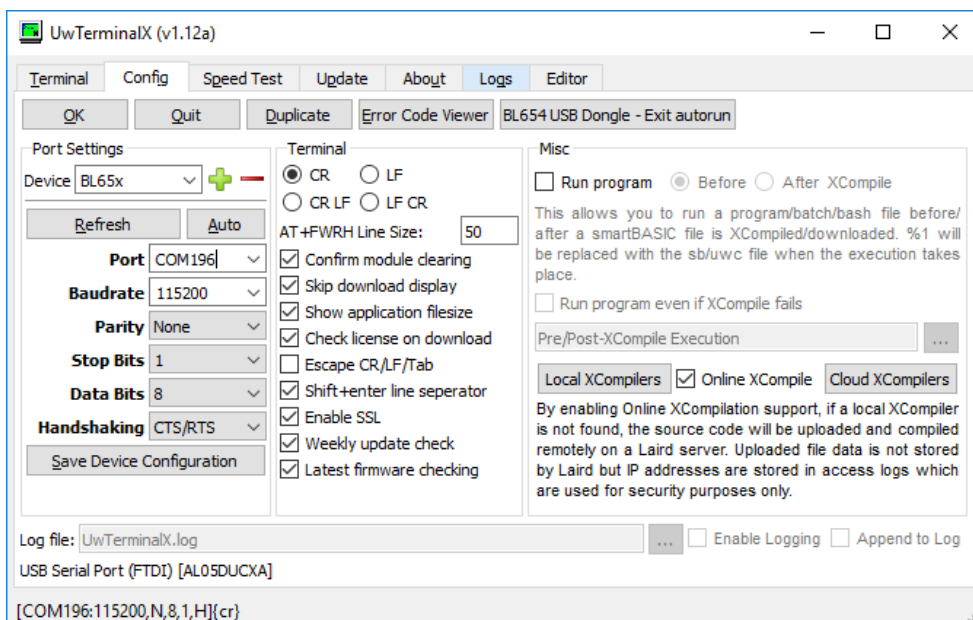
### 4 ENTERING DIRECT TEST MODE

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 BL653 $\mu$  to populate the default communications settings.
5. Select the correct COM port.

If you cannot select BL653 $\mu$ , manually select the following UART settings (shown in Figure 2):

|                    |  |
|--------------------|--|
| <b>COM Port</b>    | Port corresponding to your development kit |
| <b>Baud Rate</b>   | 115200                                     |
| <b>Parity</b>      | None                                       |
| <b>Stop Bits</b>   | 1  |
| <b>Data Bits</b>   | 8  |
| <b>Handshaking</b> | CTS/RTS                                    |



**Figure 2: UwTerminalX settings**

6. Click **OK** to connect.
7. Set up the module into Direct Test Mode. You must 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 EF35 and 4A0D.



**Figure 3: Return from at i 14**

- To enter Direct Test Mode, using the characters you found in the previous steps, issue the AT+DTM command as follows:

```
AT+DTM 0xEF354A0D
```

The module is now in Direct Test mode.

- 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 5.0 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 **nRF Connect Direct Test Mode** tool, found at: <https://www.nordicsemi.com/Software-and-Tools/Development-Tools/nRF-Connect-for-desktop> then Download tab.

Once the BL653μ is in DTM mode, you can communicate with the BL653μ over the UART with UwTerminalX using the following communications settings:

|                    |                |
|--------------------|----------------|
| <b>COM Port</b>    | Same as before |
| <b>Baud Rate</b>   | 19200          |
| <b>Parity</b>      | None           |
| <b>Stop Bits</b>   | 1              |
| <b>Data Bits</b>   | 8              |
| <b>Handshaking</b> | None           |

### 5.1 Configuration of Module Settings (Optional)

Before entering DTM Mode, you may configure TX power, baud rate, and DCDC (REG1). Changing these values is optional. However, if you choose, you may set these values as follows:

#### *TX RF Power (dBm)*

|                     |  |
|---------------------|--|
| <b>Command</b>      | AT+DTMCFG 1 n                                      |
| <b>Values for n</b> | 8, 7, 6, 5, 4, 3, 2, 0, -4, -8, -12, -16, -20, -40 |
| <b>Default</b>      | 8  |

#### *Baud Rate (bps)*

|                     |  |
|---------------------|--|
| <b>Command</b>      | AT+DTMCFG 2 n                            |
| <b>Values for n</b> | 9600, 14400, 19200, 38400, 57600, 115200 |
| <b>Default</b>      | 19200                                    |

#### *DCDC (REG1) (for Normal Voltage Mode operation)*

|                     |                           |
|---------------------|---------------------------|
| <b>Command</b>      | AT+DTMCFG 3 n             |
| <b>Values for n</b> | 0 (Disabled), 1 (enabled) |
| <b>Default</b>      | 1                         |

#### *Enable 32KHz Crystal based LF Clock*

|                     |                           |
|---------------------|---------------------------|
| <b>Command</b>      | AT+DTMCFG 4 n             |
| <b>Values for n</b> | 0 (Disabled), 1 (enabled) |
| <b>Default</b>      | 0                         |

Additionally, current configuration can be queried by using a question mark (?) instead of a new value (on firmware version 30.2.3.0 or newer only), e.g. "AT+DTMCFG 2 ?" will output the baud rate setting.

Refer to the [Appendix](#), for setting a GPIO if it needs to be set for some particular purpose whilst in DTM mode.

## 5.2 Start Direct Test Mode Tool Within nRF Connect

Nordic's **nRF Connect Direct Test Mode** tool allows all BLE 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 Nordic **nRF Connect Direct Test Mode** tool, follow these steps:

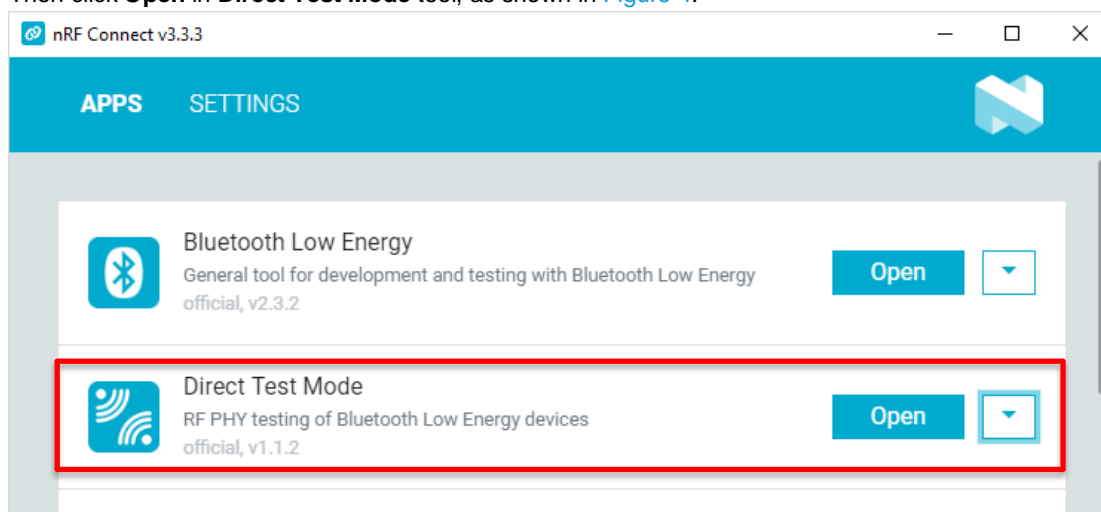
1. Open nRF Connect.

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**Note:** If a new version of the app becomes available, an **Update** button displays next to the **Open** button. Click this button to install the latest version.

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2. Then click **Open** in **Direct Test Mode** tool, as shown in [Figure 4](#).



**Figure 4: Click Open in Direct Test Mode**

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**Note:** Press the drop-down arrow to view release notes or more information (recommended).

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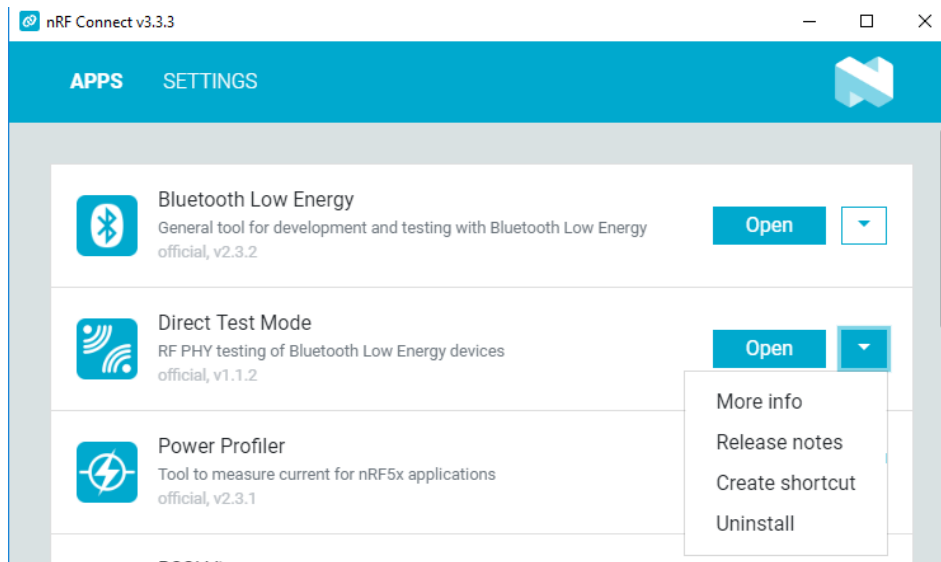


Figure 5: Access release notes and more information

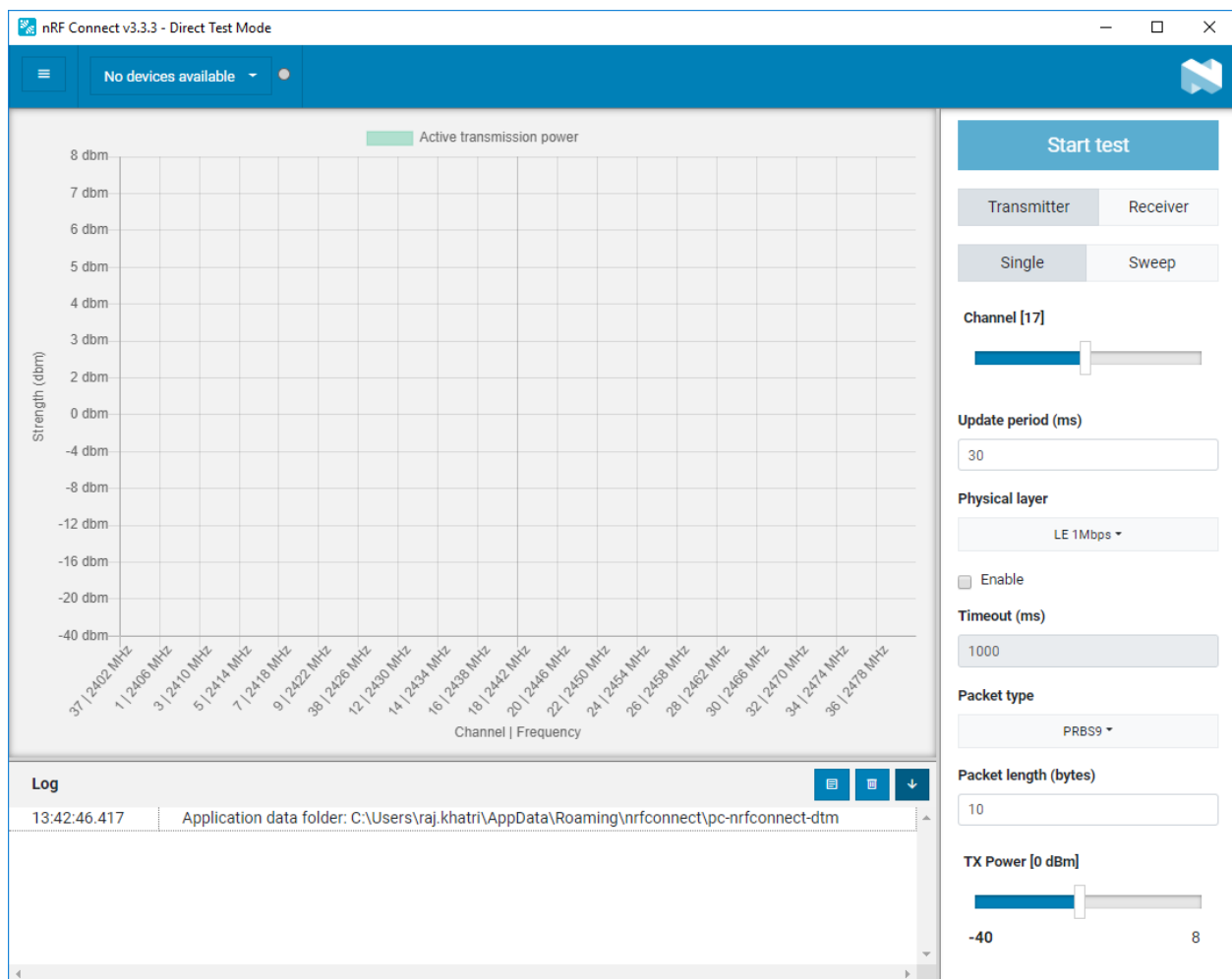
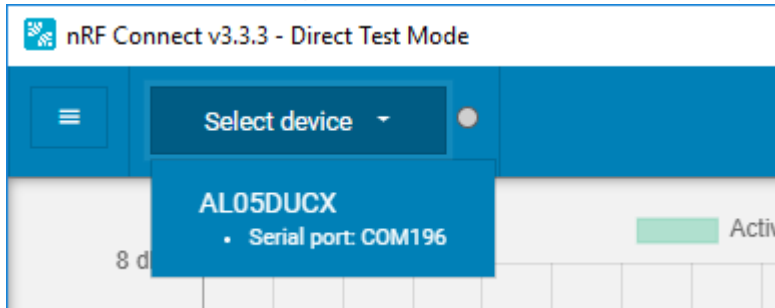


Figure 6: Opening the Nordic nRF Connect Direct Test Mode tool



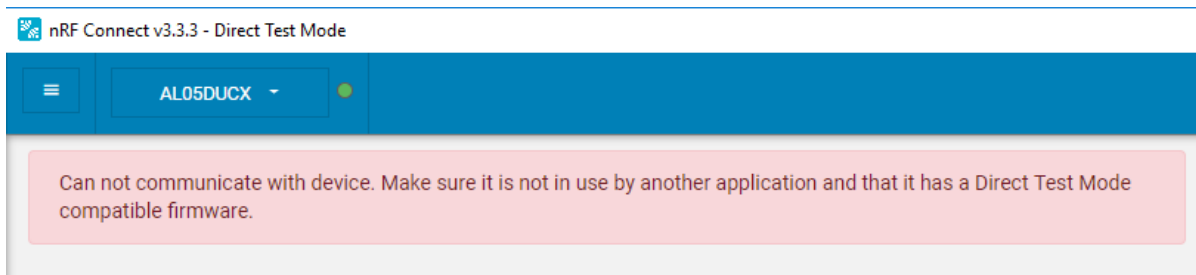
3. **Select device** for the COM port of the connected Device Under test (from the drop-down menu).



**Figure 7: Device selection**

4. From here, you can place the module in BLE (duty cycled) TX or CW (sine wave) TX or BLE RX mode.

**Note:** If at any time, the Nordic nRF Connect for Desktop Direct Test Mode tool is not responding or there is unexpected behavior (see example in [Figure 8](#)), press **CTRL+R** to refresh the **nRF Connect for Desktop Direct Test Mode** tool.



**Figure 8: Unexpected behavior when opening or running the Nordic nRF Connect for Desktop Direct Test Mode tool**

## 5.3 Nordic nRF Connect Direct Test Mode tool TX and RX Tests

nRF Connect for Desktop Direct Test Mode tool allows all BLE PHY data rates to be tested, 1 Mbps, 2 Mbps, and coded PHY 500 kbps (s=2) and 125 kbps (s=8).

### 5.3.1 Transmit Test

To perform a transmit test, follow these steps:

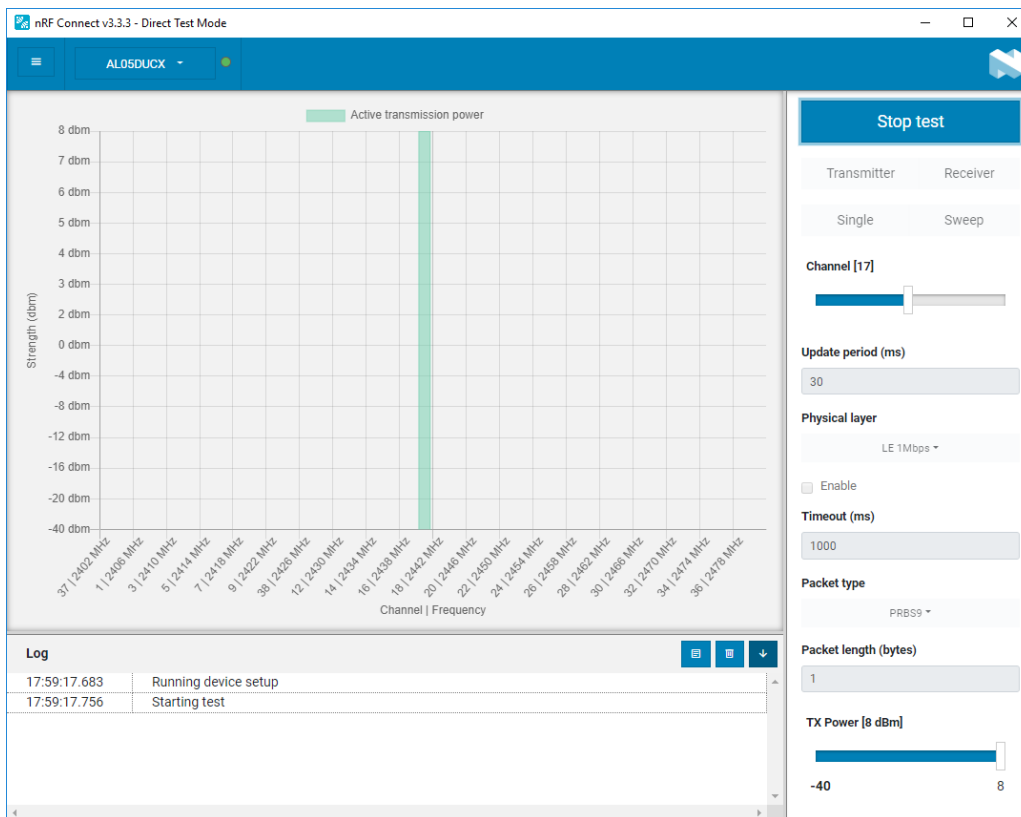
1. Configure the applicable BLE transmitter options in the **nRF Connect for Desktop Direct Test Mode** tool.

**Table 1: Transmitter test Direct Test Mode options**

|                           |   |
|---------------------------|---|
| <b>COM Port</b>           | D.U.T COM port  |
| <b>Test Type</b>          | Select <b>Transmitter, Single</b>   |
| <b>Channel</b>            | 17 (2440 MHz, for example)  |
| <b>Update period (ms)</b> | 30 (default)  |
| <b>Physical layer</b>     | Select <i>LE 1 Mbps</i> (as an example). Other options are LE 2 Mbps, LE Coded S8 (500 kbps), LE Coded S2 (125 kbps).                   |
| <b>Timeout (ms)</b>       | Not enabled. This is a timeout for the specific command. Setting timeout to 1000 ms stops the current operation when the timer expires. |

| Packets Type  | Packet Type Value   | Description                           |
|---|---|---------------------------------------|
|   | PRBS9   | PRBS9 Packet Payload (Pkt Type 00)    |
|   | 11110000  | 11110000 Packet Payload (Pkt Type 01) |
|   | 10101010  | 10101010 Packet Payload (Pkt Type 10) |
|   | Constant Carrier  | Vendor-specific (Pkt Type 11)         |
| Prior to Nordic nRF Connect for Desktop (version 1.1.5) Direct Test Mode tool did not have vendor-specific type that produces a 100% ON continuous wave (CW) RF TX signal. Refer to the <a href="#">DTM Command to Produce CW RF TX Signal</a> section for additional information on how to do this manually without nRF Connect. |   |                                       |
| Payload Length (bytes)  | Options range from 1 byte to 255 bytes.   |                                       |
| TX Power [ dBm]   | Options include: 8 dBm, 7 dBm, 6 dBm, 5 dBm, 4 dBm, 3 dBm, 2 dBm, 0 dBm, -4 dBm, -8 dBm, 12 dBm, -16 dBm, -20 dBm, -40 dBm. |                                       |
| TRANSMIT  | To start TX test, press <b>Start test</b> .   |                                       |

- Once configured, click **Start test**. [Figure 9](#) shows an active BLE transmitter test.



**Figure 9: Successful initiation of BLE transmitter test**

With the module is in a transmit test, you can measure the RF Tx signal on a spectrum analyzer. Check the RF Tx packet duration of your RF transmission (using zero span mode on the spectrum analyzer). The RF Tx signal is NOT 100% on and has a Tx duty cycle as per *BT SIG Bluetooth Core Specifications*. See *Bluetooth Core Specifications v 5.0 vol. 6 Part F - Direct Test Mode*.



## 5.3.2 Receive Test

To conduct the BLE receive test, do the following:

1. Configure the applicable BLE receiver options in the nRF Connect for Desktop Direct Test Mode tool.

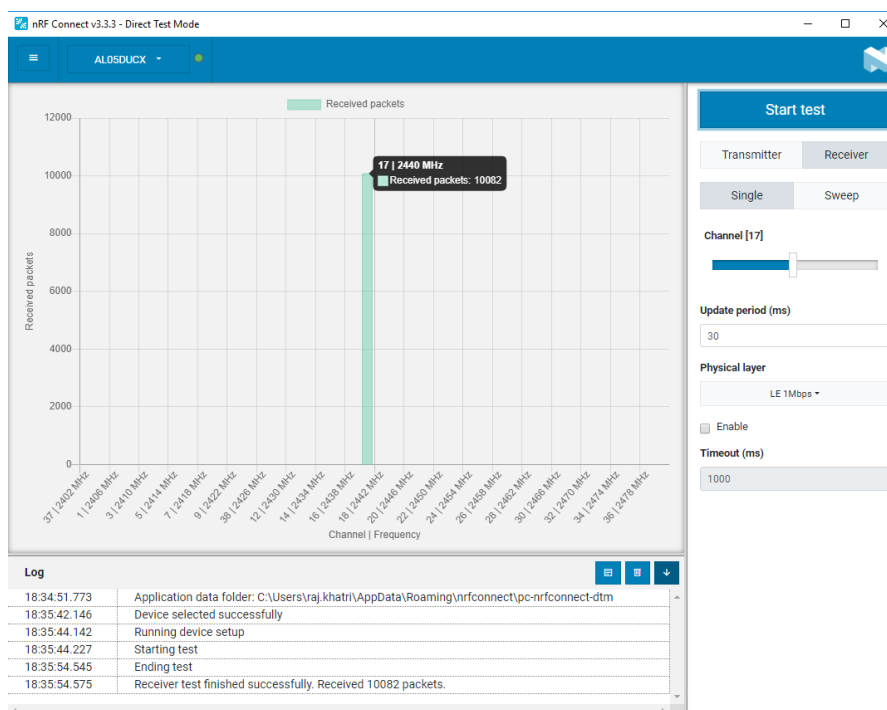
**Table 2: Receive test Direct Test Mode options**

|                           |   |
|---------------------------|---|
| <b>COM Port</b>           | DUT COM port  |
| <b>Test Type</b>          | Select <b>Receiver, Single</b>  |
| <b>Channel</b>            | 17 (2440 MHz, for example)  |
| <b>Update period (ms)</b> | 30 (default)  |
| <b>Physical layer</b>     | Options include: LE 2 Mbps, LE Coded S8 (500 kbps), LE Coded S2 (125 kbps)  |
| <b>Timeout (ms)</b>       | Not enabled. This is a timeout for the specific command. Setting timeout to 1000 ms will stop the current operation when the timer expires. |
| <b>RECEIVER</b>           | To start RX test, press <b>Start test</b> .   |

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

2. Once configured, to start Receiver test, click **Start test**. Figure 10 shows a BLE receiver test running.

The **Received packets** shows how many packets are received. Since the number of packets sent per second by transmitter is known (as per Bluetooth SIG's *Bluetooth Core Specifications v 5.0 vol. 6 part F - Direct Test Mode*), the DUT received packets Rx Packet Error Rate can be calculated.



**Figure 10: Successful initiation of BLE receiver test (received packets)**

**Note:** nRF Connect v3.3.3 Direct Test Mode 1.1.2 has a known issue with counting **Received packets** inaccurately. Please look out for a fix from Nordic in future version of nRF Connect Direct Test Mode tool.

## 6 DTM COMMAND TO PRODUCE CW RF TX SIGNAL

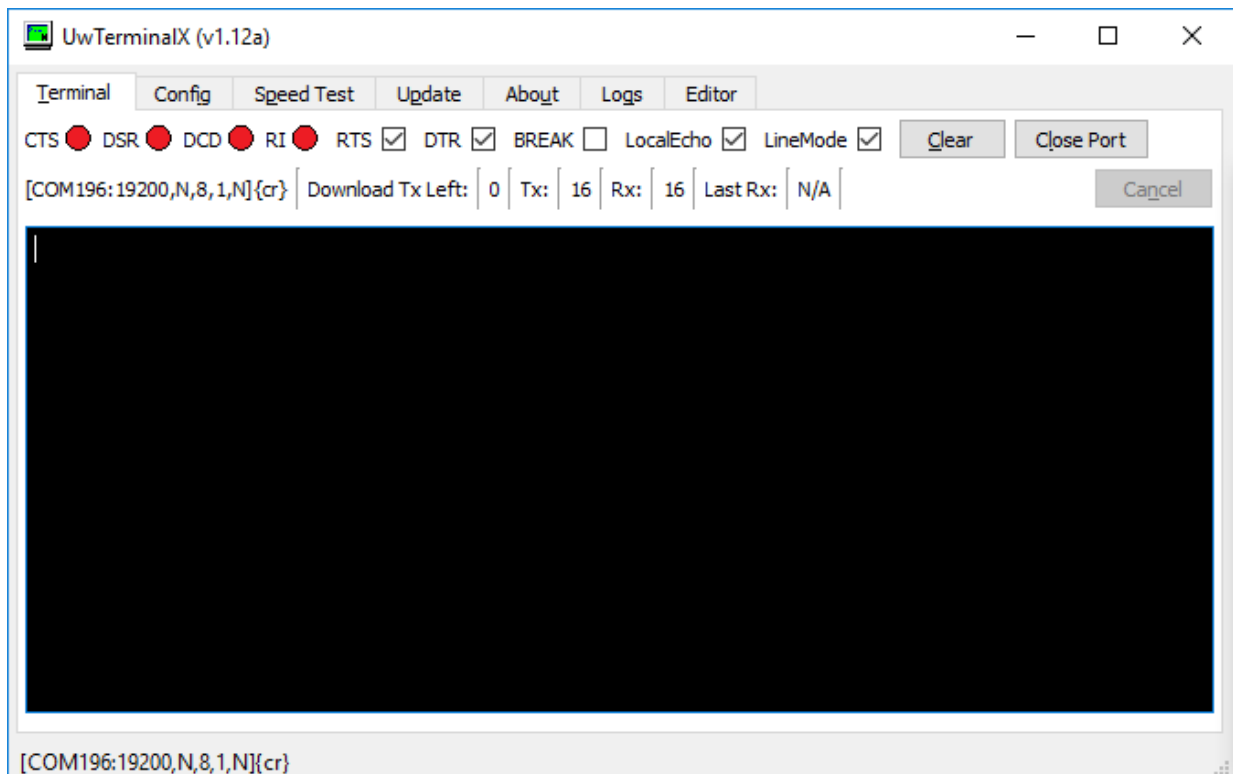
**nRF Connect for Desktop (version 1.1.5) Direct Test Mode** tool added Constant carrier (sine wave for transmitter. Prior to version 1.1.5 of the **nRF Connect for Desktop Direct Test Mode** tool, it did not have a way to produce continuous wave (CW) RF Transmit signal. You can manually send a DTM command using UwTerminalX to produce continuous wave (CW) RF Transmit signal.

To do this, follow these steps:

1. Open UwTerminalX with the following settings:

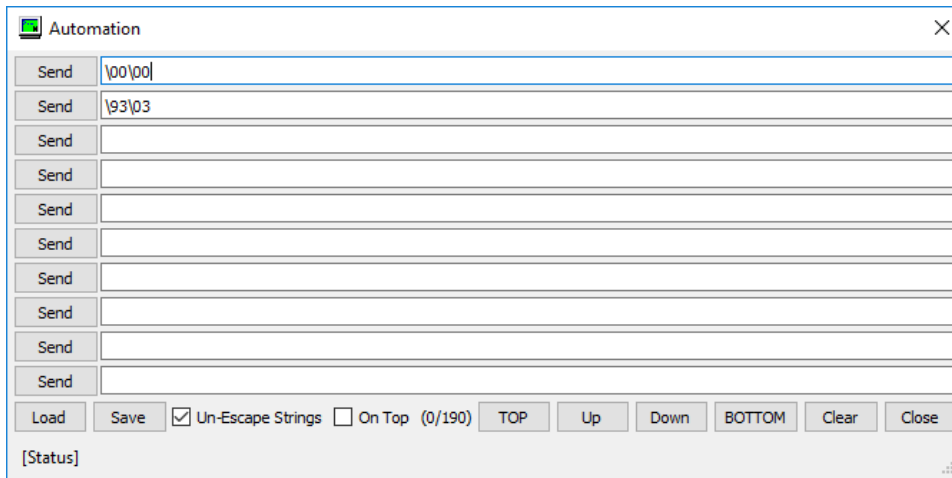
|                    |                  |
|--------------------|------------------|
| <b>COM Port</b>    | Same as previous |
| <b>Baud Rate</b>   | 19200            |
| <b>Parity</b>      | None             |
| <b>Stop Bits</b>   | 1                |
| <b>Data Bits</b>   | 8                |
| <b>Handshaking</b> | None             |

2. Click **OK** to connect.



**Figure 11: Opened UwTerminalX**

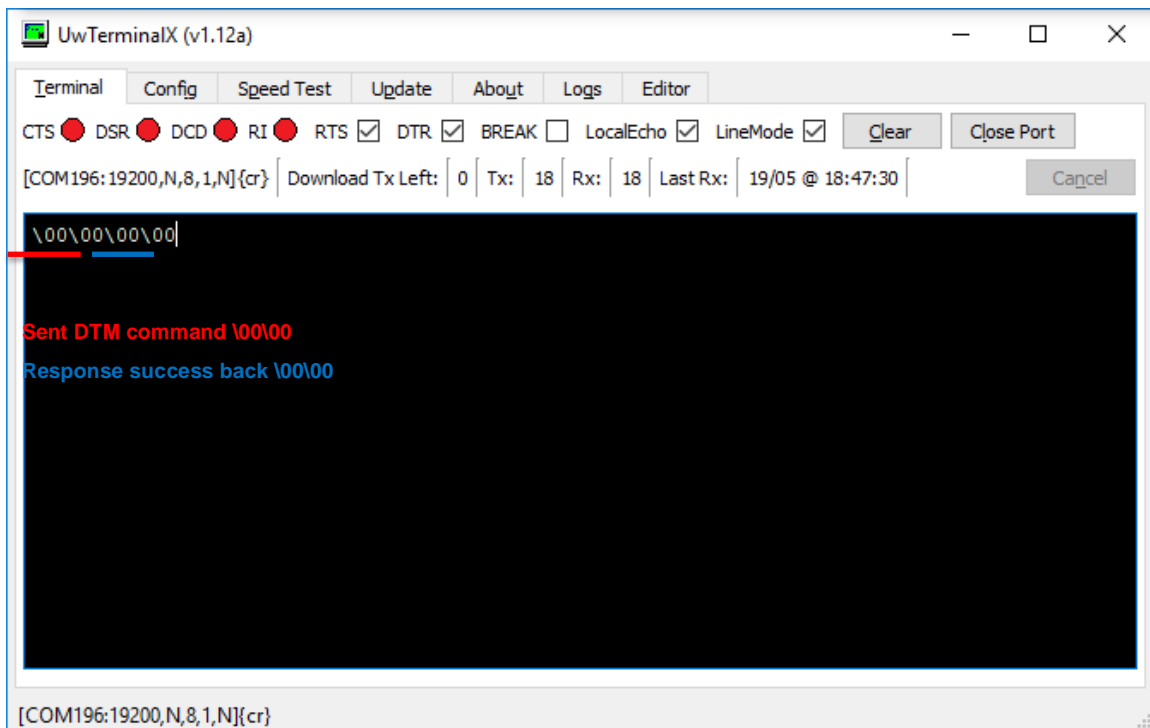
3. Right-click the terminal screen and in the context menu, click **Automation**.
4. In the following screen, modify the fields as shown in [Figure 12](#).
  - In the first field, enter **100100** (the DTM command for reset)
  - In the second field, enter **193100** (the DTM command to produce a CW RF transmit signal) For example, at frequency **2440 MHz**.
  - Tick the box for De-Escape Strings.



**Figure 12: Automation dialogue for entering DTM commands**

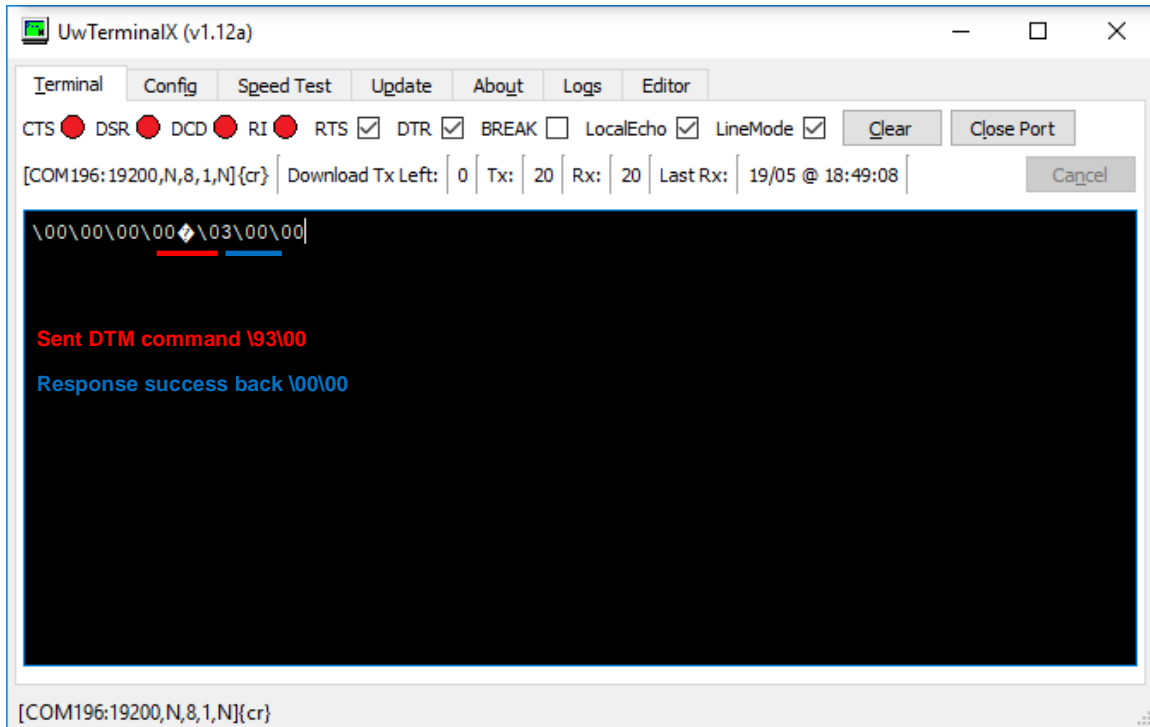
- Click **Send** to send DTM command **\00\00** for reset (always do this first).

If successful you should get a response back **\00\00**.



**Figure 13: Automation dialogue DTM command \00\00 for reset and response.**

- Click **Send** to send DTM command **\93\00** to produce a CW RF transmit signal at frequency 2440 MHz. If successful, you should get a response back **\00\00**.



**Figure 14: Automation dialogue DTM command \93\00 to produce continuous wave (CW) RF Transmit signal at frequency 2440 MHz and response.**

The following table (Table 3) shows the DTM command to produce continuous wave (CW) RF TX signal frequency.

**Table 3: DTM command to send for each RF TX frequency to produce a CW RF transmit signal**

| Continuous Wave<br>RF Transmit<br>Signal Frequency | DTM<br>Command | Continuous Wave<br>RF Transmit<br>Signal Frequency | DTM<br>Command | Continuous Wave<br>RF Transmit<br>Signal Frequency | DTM<br>Command |
|--|----------------|--|----------------|--|----------------|
| 2402 MHz   | \80\03         | 2430 MHz   | \8E\03         | 2458 MHz   | \9C\03         |
| 2404 MHz   | \81\03         | 2432 MHz   | \8F\03         | 2460 MHz   | \9D\03         |
| 2406 MHz   | \82\03         | 2434 MHz   | \90\03         | 2462 MHz   | \9E\03         |
| 2408 MHz   | \83\03         | 2436 MHz   | \91\03         | 2464 MHz   | \9F\03         |
| 2410 MHz   | \84\03         | 2438 MHz   | \92\03         | 2466 MHz   | \A0\03         |
| 2412 MHz   | \85\03         | 2440 MHz   | \93\03         | 2468 MHz   | \A1\03         |
| 2414 MHz   | \86\03         | 2442 MHz   | \94\03         | 2470 MHz   | \A2\03         |
| 2416 MHz   | \87\03         | 2444 MHz   | \95\03         | 2472 MHz   | \A3\03         |
| 2418 MHz   | \88\03         | 2446 MHz   | \96\03         | 2474 MHz   | \A4\03         |
| 2420 MHz   | \89\03         | 2448 MHz   | \97\03         | 2476 MHz   | \A5\03         |
| 2422 MHz   | \8A\03         | 2450 MHz   | \98\03         | 2478 MHz   | \A6\03         |
| 2424 MHz   | \8B\03         | 2452 MHz   | \99\03         | 2480 MHz   | \A7\03         |
| 2426 MHz   | \8C\03         | 2454 MHz   | \9A\03         |  |                |
| 2428 MHz   | \8D\03         | 2456 MHz   | \9B\03         |  |                |

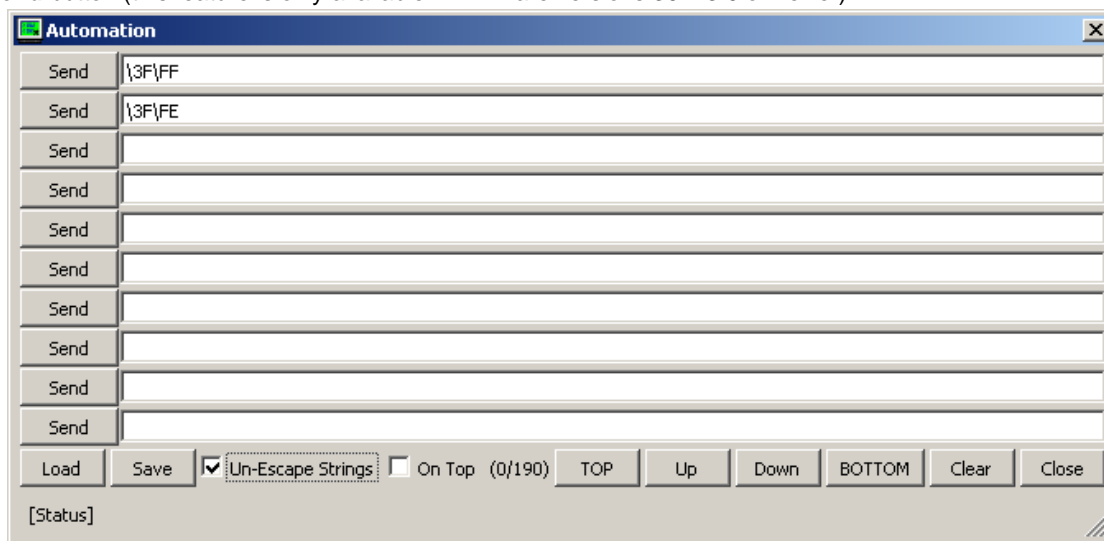
## 7 EXITING DTM MODE

To exit DTM, follow these steps:

1. Open UwTerminalX with the following settings:

|                    |                  |
|--------------------|------------------|
| <b>COM Port</b>    | Same as previous |
| <b>Baud Rate</b>   | 19200            |
| <b>Parity</b>      | None             |
| <b>Stop Bits</b>   | 1                |
| <b>Data Bits</b>   | 8                |
| <b>Handshaking</b> | 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 15.
  - In the first field, enter **\3F\FF**.
  - In the second field, enter **\3F\FE**.
  - Tick the box for **De-Escape Strings**.
5. To temporally go back into smartBASIC interactive mode which will go back to DTM mode after a reset or power cycle, click the first **Send** button, to permanently exit DTM mode and return to smartBASIC interactive mode, click the second **Send** button (this feature is only available in firmware versions 30.2.3.0 or newer).



**Figure 15: Automation dialogue**

6. After this command is complete, close UwTerminalX. Then re-open it and connect to the BL653μ with the following default parameters:

|                    |                  |
|--------------------|------------------|
| <b>COM Port</b>    | Same as previous |
| <b>Baud Rate</b>   | 115200           |
| <b>Parity</b>      | None             |
| <b>Stop Bits</b>   | 1                |
| <b>Data Bits</b>   | 8                |
| <b>Handshaking</b> | CTS/RTS          |

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. If you wish to change any DTM configuration, you may do so now, you can also query what the current DTM configuration is by using the “at+dtmcfg X?” where X is the index to query, as specified in the [Configuration of Module Settings \(Optional\)](#) section.
10. If you want to clear the DTM configuration and restore the module to factory defaults, issue the following command, alternatively, configuration can be changed and DTM re-used if needed:

```
at&f*
```

The module erases its file system and reboot, as shown in [Figure 16](#).

```
00
at&f*

FFS Erased, Rebooting...
00
```

**Figure 16: at&f\* to erase and reboot module**



## 8 APPENDIX

This section describes how to set a GPIO if necessary whilst in DTM mode.

### 8.1 Configuration of Module GPIO Settings (Optional)

#### *GPIO control enable*

|                     |                           |
|---------------------|---------------------------|
| <b>Command</b>      | AT+DTMCFG 5 <i>n</i>      |
| <b>Values for n</b> | 0 (Disabled), 1 (enabled) |
| <b>Default</b>      | 1                         |

#### *GPIO (0..31) Enable Bitmask*

This will be ignored if **AT+DTMCFG 5** is set to 0. If a bit is set then the bit number corresponds to the GPIO number which is enabled.

|                     |  |
|---------------------|--|
| <b>Command</b>      | AT+DTMCFG 6 bitmask  |
| <b>Values for n</b> | 0x00000000 to 0xFFFFFFFF (bit 0 is the lowest significant bit) |
| <b>Default</b>      | 0  |

#### *GPIO (0..31) Direction Bitmask*

This will be ignored if **AT+DTMCFG 5** is set to 0. If a bit is set then the bit number corresponds to the GPIO number will have the direction input when the bit is 0 and an output when the bit is 1.

|                     |  |
|---------------------|--|
| <b>Command</b>      | AT+DTMCFG 7 bitmask  |
| <b>Values for n</b> | 0x00000000 to 0xFFFFFFFF (bit 0 is the lowest significant bit) |
| <b>Default</b>      | 0  |

#### *GPIO (0..31) State Bitmask*

This will be ignored if **AT+DTMCFG 5** is set to 0. If a bit is set then the bit number corresponds to the GPIO number will have the output set to this value if DTMCFG 7 was used to set the direction as output; or enables a pull-up resistor if the bit is set and DTMCFG 7 is used to set the direction as input.

|                     |  |
|---------------------|--|
| <b>Command</b>      | AT+DTMCFG 8 bitmask  |
| <b>Values for n</b> | 0x00000000 to 0xFFFFFFFF (bit 0 is the lowest significant bit) |
| <b>Default</b>      | 0xFFFFFFFF   |

#### *GPIO (32..47) Enable Bitmask*

This will be ignored if **AT+DTMCFG 5** is set to 0. If a bit is set then the bit number corresponds to the GPIO number which is enabled.

|                     |  |
|---------------------|--|
| <b>Command</b>      | AT+DTMCFG 16 bitmask                                   |
| <b>Values for n</b> | 0x0000 to 0xFFFF (bit 0 is the lowest significant bit) |
| <b>Default</b>      | 0  |

### *GPIO (32..47) Direction Bitmask*

This will be ignored if **AT+DTMCFG 5** is set to 0. If a bit is set then the bit number corresponds to the GPIO number will have the direction input when the bit is 0 and an output when the bit is 1.

|                     |  |
|---------------------|--|
| <b>Command</b>      | AT+DTMCFG 17 bitmask                                   |
| <b>Values for n</b> | 0x0000 to 0xFFFF (bit 0 is the lowest significant bit) |
| <b>Default</b>      | 0  |

### *GPIO (32..47) State Bitmask*

This will be ignored if **AT+DTMCFG 5** is set to 0. If a bit is set then the bit number corresponds to the GPIO number will have the output set to this value if DTMCFG 7 was used to set the direction as output; or enables a pull-up resistor if the bit is set and DTMCFG 7 is used to set the direction as input.

|                     |  |
|---------------------|--|
| <b>Command</b>      | AT+DTMCFG 18 bitmask                                   |
| <b>Values for n</b> | 0x0000 to 0xFFFF (bit 0 is the lowest significant bit) |
| <b>Default</b>      | 0xFFFFFFFF   |

## 9 REVISION HISTORY

| Version | Date         | Notes  | Contributor(s)              | Approver      |
|---------|--------------|--|-----------------------------|---------------|
| 1.0     | 13 Aug 2020  | Initial Release  | Raj Khatri                  | Jonathan Kaye |
| 1.1     | 25 Jan 2021  | Corrected default configuration values, added permanent DTM exit command, added note to say version 1.1.5 of <b>nRF Connect for Desktop Direct Test Mode</b> tool, has added support for constant sine wave for transmitter. | Jamie McCrae,<br>Raj Khatri | Jonathan Kaye |
| 1.2     | 21 July 2021 | Added note for at+dtmcfgr X.   | Raj Khatri                  | Jonathan Kaye |