

# Using Direct Test Mode

## BL653 Series

Application Note

v1.0

### 1 INTRODUCTION

The BL653 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 BL653 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 BL653 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 BL653
- Using Nordic nRF Connect for Desktop Direct Test Mode tool to BLE radio test the BL653 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 BL653

### 2 REQUIREMENTS

To use DTM, you need the following:

- DVK-BL653-2.0 development board
- Windows PC
- UwTerminalX by Laird (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 for your operating system.

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### 3 SETUP

We assume the DVK-BL653-1.0 development kit has its default out-of-the-box settings as described in the *BL653 Quick Start Guide* (available from the BL653 product page: <https://www.lairdconnect.com/wireless-modules/bluetooth-modules/bluetooth-5-modules/bl653-series-bluetooth-51-802154-nfc-module>). In this mode, it is in AT or interactive mode (no *smartBASIC* application loaded or running) on power up.

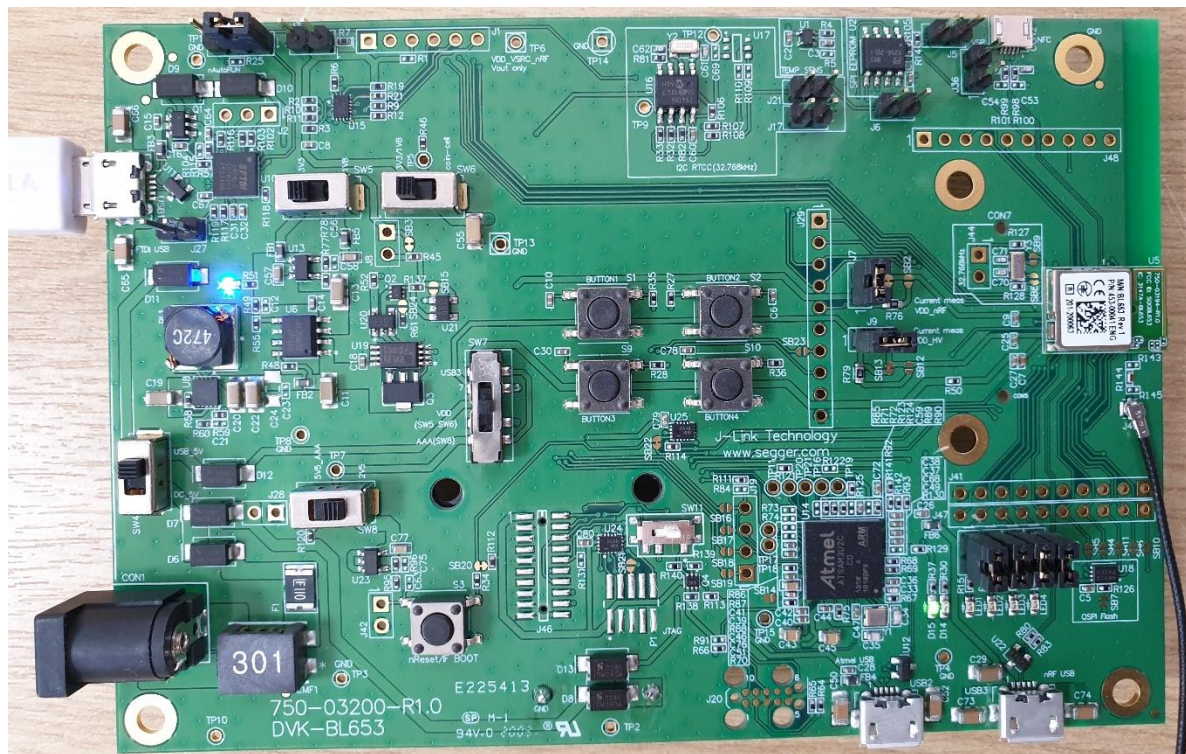


Figure 1: DVK-BL653 switch and jumper positions

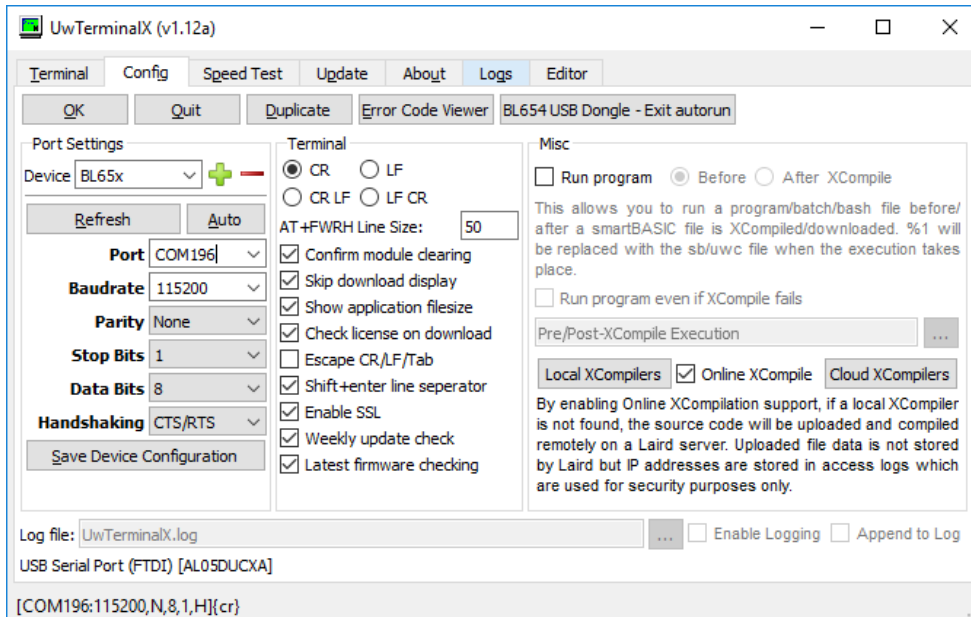
### 4 ENTERING DIRECT TEST MODE

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 to populate the default communications settings.
5. Select the correct COM port.

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

COM Port	Port corresponding to your development kit
Baud Rate	115200
Parity	None
Stop Bits	1
Data Bits	8
Handshaking	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 BL653 is in DTM mode, you can communicate with the BL653 over the UART with UwTerminal 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>	CTS/RTS

### 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>	1

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

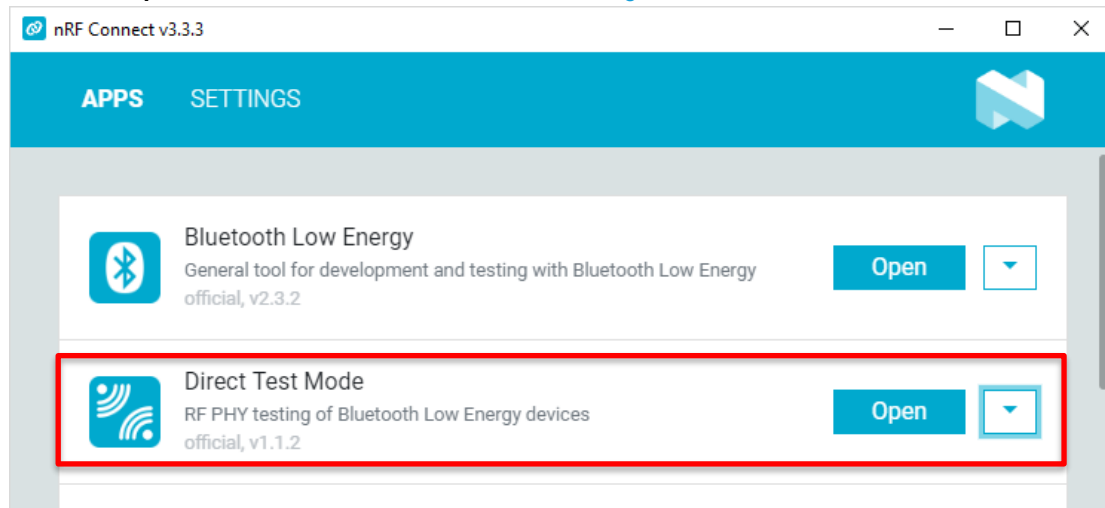
Nordic's **nRF Connect Direct Test Mode** tool allows all BLE PHY data rates to be tested, 1 Mbps, 2 Mbps, and coded PHY 500 kbps (s=2) and 125 kbps (s=8).

To begin using Nordic **nRF Connect Direct Test Mode** tool, follow these steps:

1. Open nRF Connect.

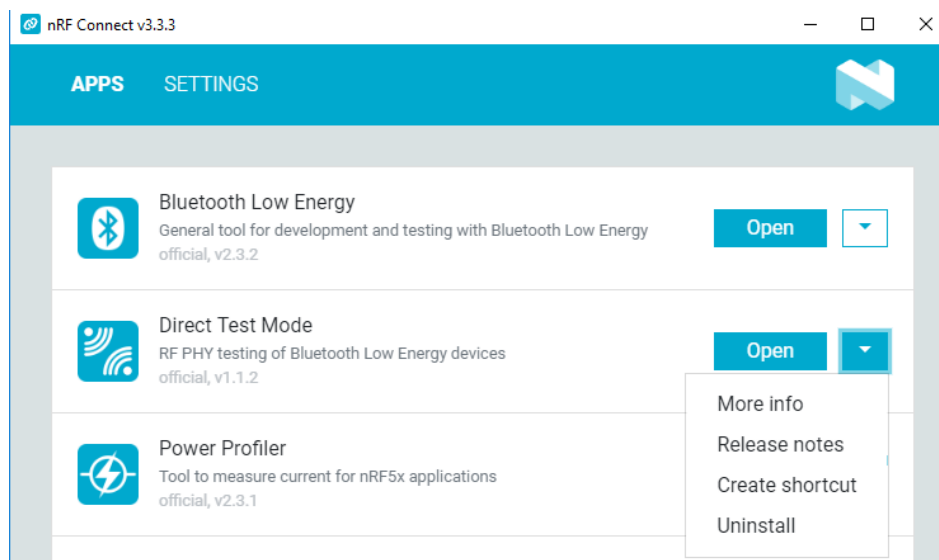
**Note:** If a new version of the app becomes available, an **Update** button displays next to the **Open** button. Click this button to install the latest version.

2. Then click **Open** in **Direct Test Mode** tool, as shown in [Figure 6](#).



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

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



**Figure 5: Access release notes and more information**

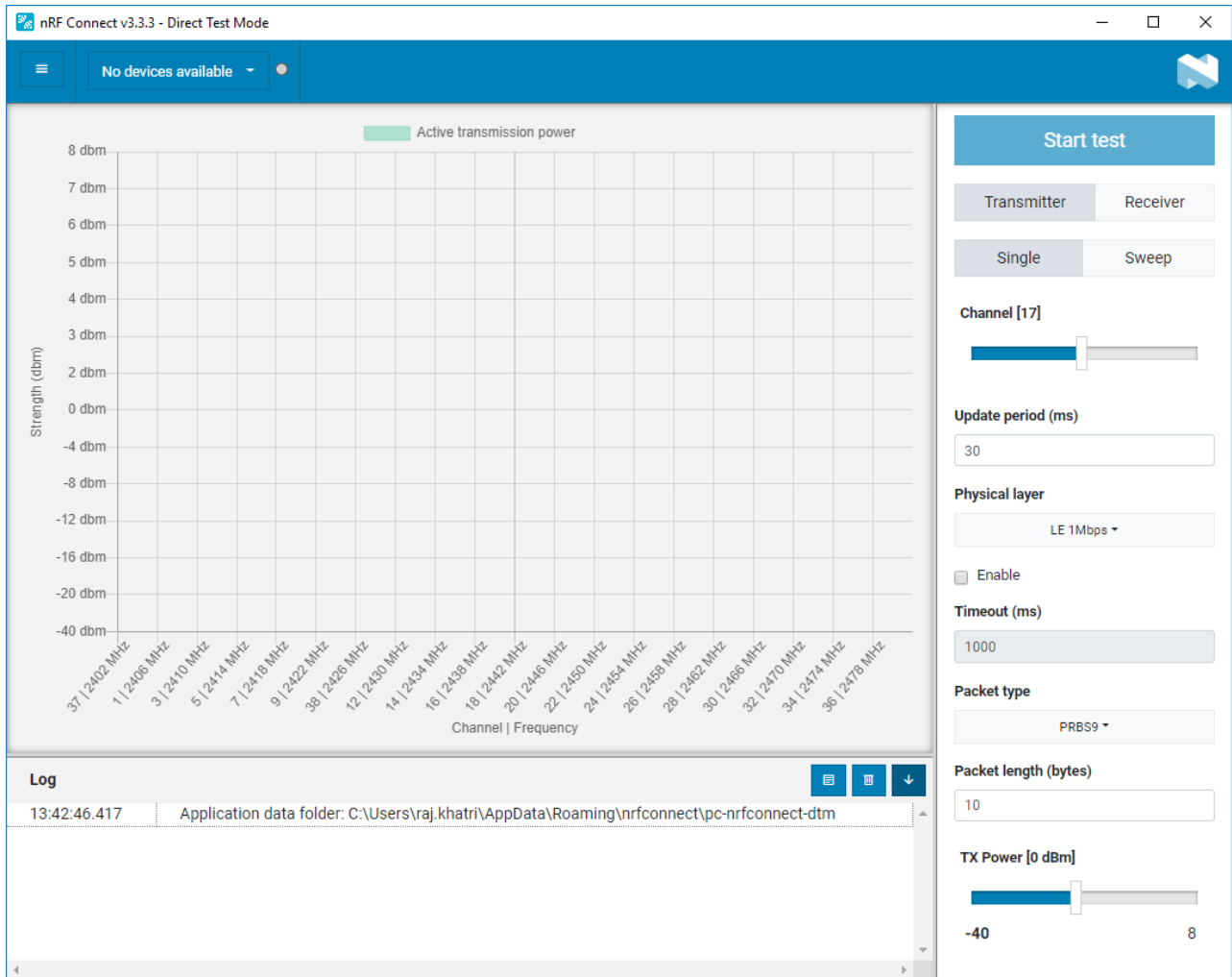


Figure 6: Opening the Nordic nRF Connect Direct Test Mode tool

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

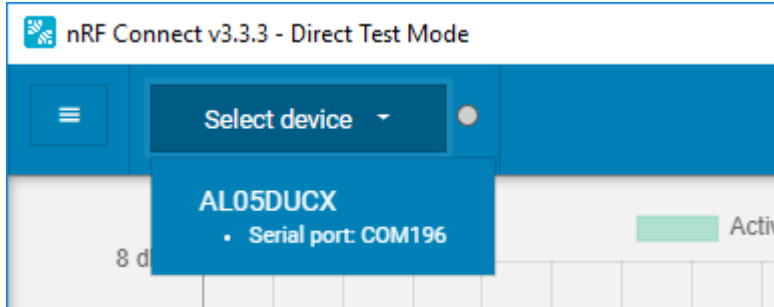
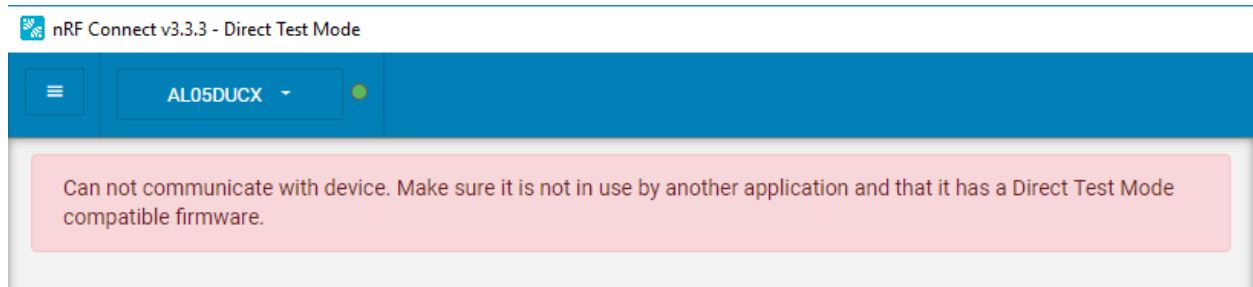


Figure 7: Device selection

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

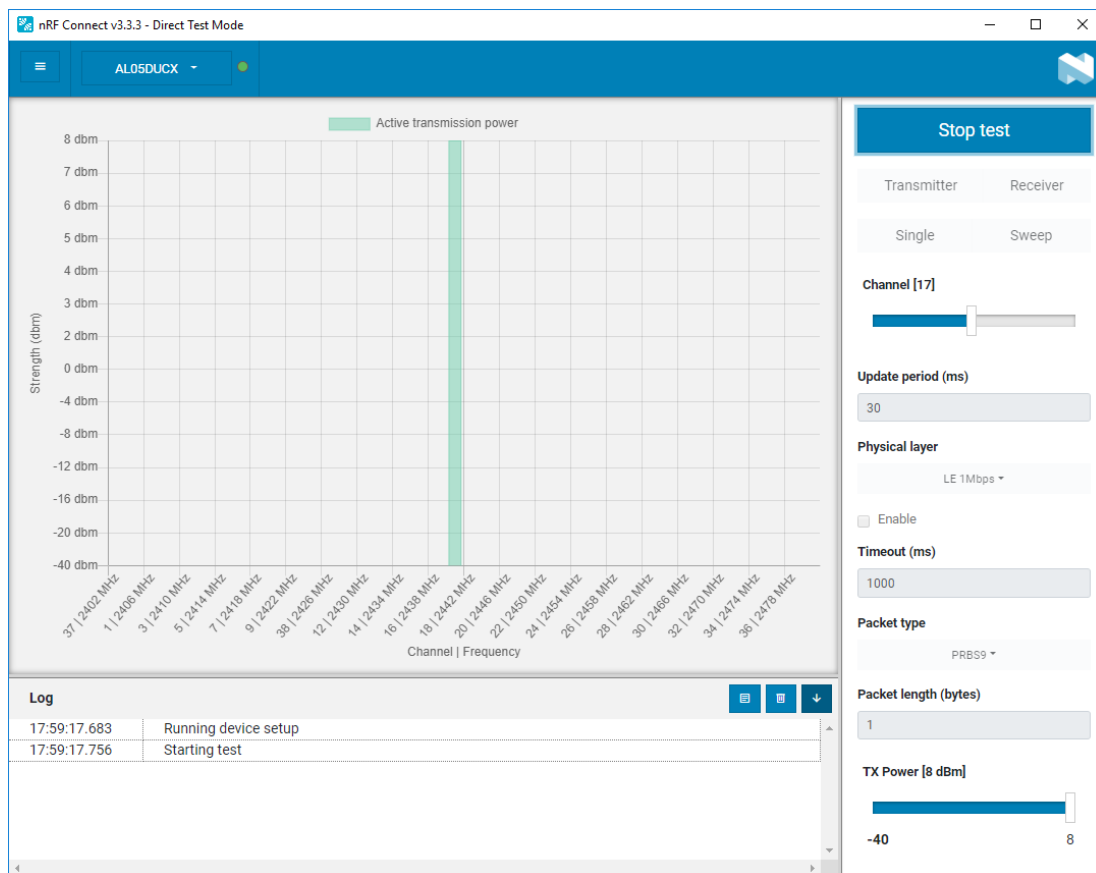
To perform a transmit test, follow these steps:

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.	
<b>Packets Type</b>	<b>Packet Type Value</b>	<b>Description</b>
	PRBS9	PRBS9 Packet Payload (Pkt Type 00)
	11110000	11110000 Packet Payload (Pkt Type 01)
	10101010	10101010 Packet Payload (Pkt Type 10)
	TBD	Vendor-specific (Pkt Type 11)
Currently Nordic nRF Connect for Desktop Direct Test Mode tool does not have vendor-specific type that produces a 100% ON continuous wave (CW) RF TX signal. Refer to the <i>DTM Command to Produce CW RF Tx Signal</i> for additional information on how to do this.		
<b>Payload Length (bytes)</b>	Options range from 1 byte to 255 bytes.	
<b>TX Power [ dBm]</b>	Options include: 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.	
<b>TRANSMIT</b>	To start TX test, press <b>Start test</b> .	

- Once configured, click **Start test**. Figure 8 shows an active BLE transmitter test.



**Figure 8: 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:

- 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> .

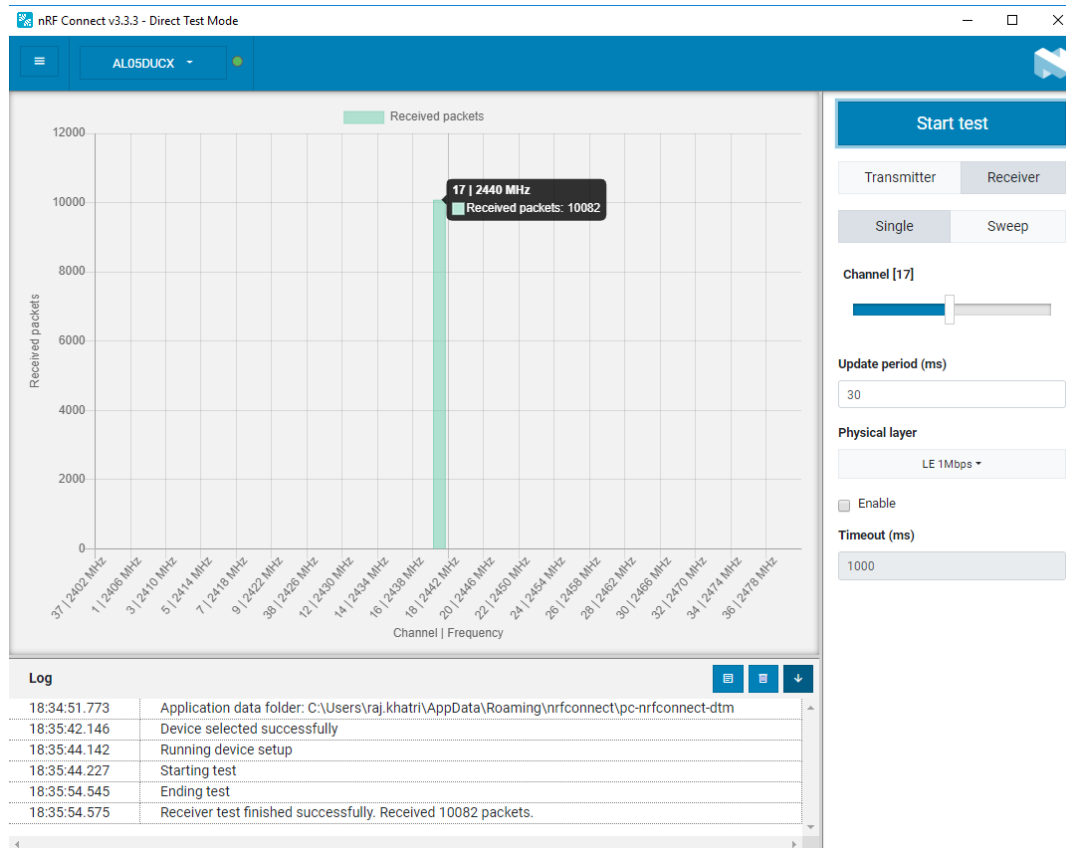
**Figure 9: Receiver test Direct Test Mode options**



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

- Once configured, to start Receiver test, click **Start test**. Figure 9 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 9: 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 upcoming version of nRF Connect Direct Test Mode tool.

## 6 DTM COMMAND TO PRODUCE CW RF TX SIGNAL

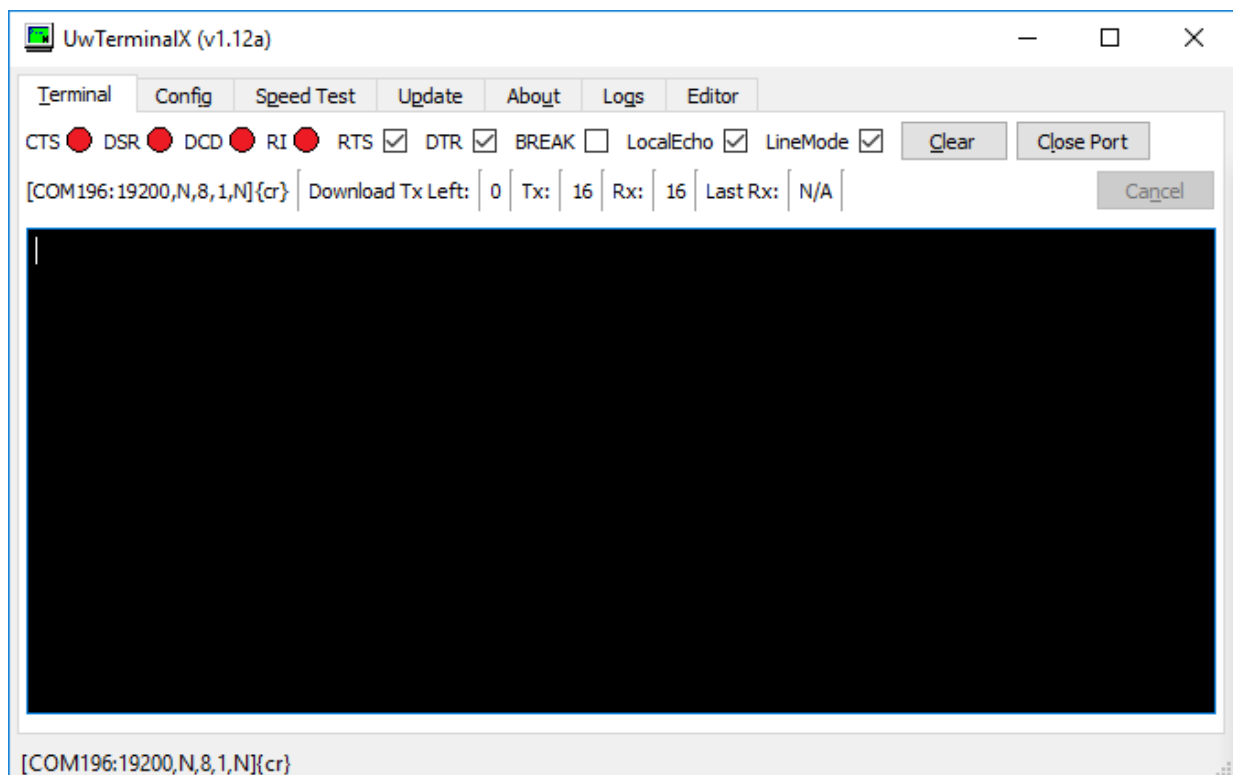
**nRF Connect for Desktop Direct Test Mode** tool currently (20 May 2020) does not have a way to produce continuous wave (CW) RF Transmit signal. You can send a DTM command manually using UwTerminalX to produce continuous wave (CW) RF Transmit signal.

To do this, follow these steps:

1. Open UwTerminalX with the following settings:

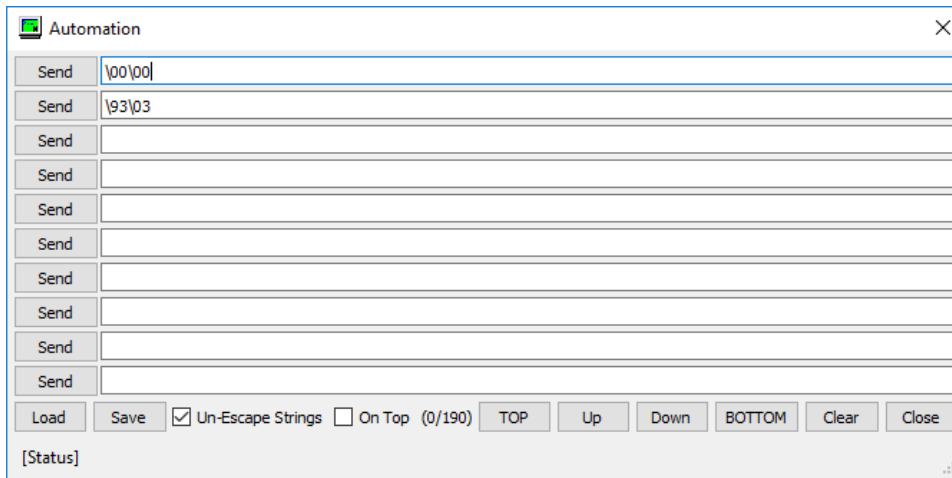
COM Port	Same as previous
Baud Rate	19200
Parity	None
Stop Bits	1
Data Bits	8
Handshaking	None

2. Click **OK** to connect.



**Figure 10: Opened UwTerminalX**

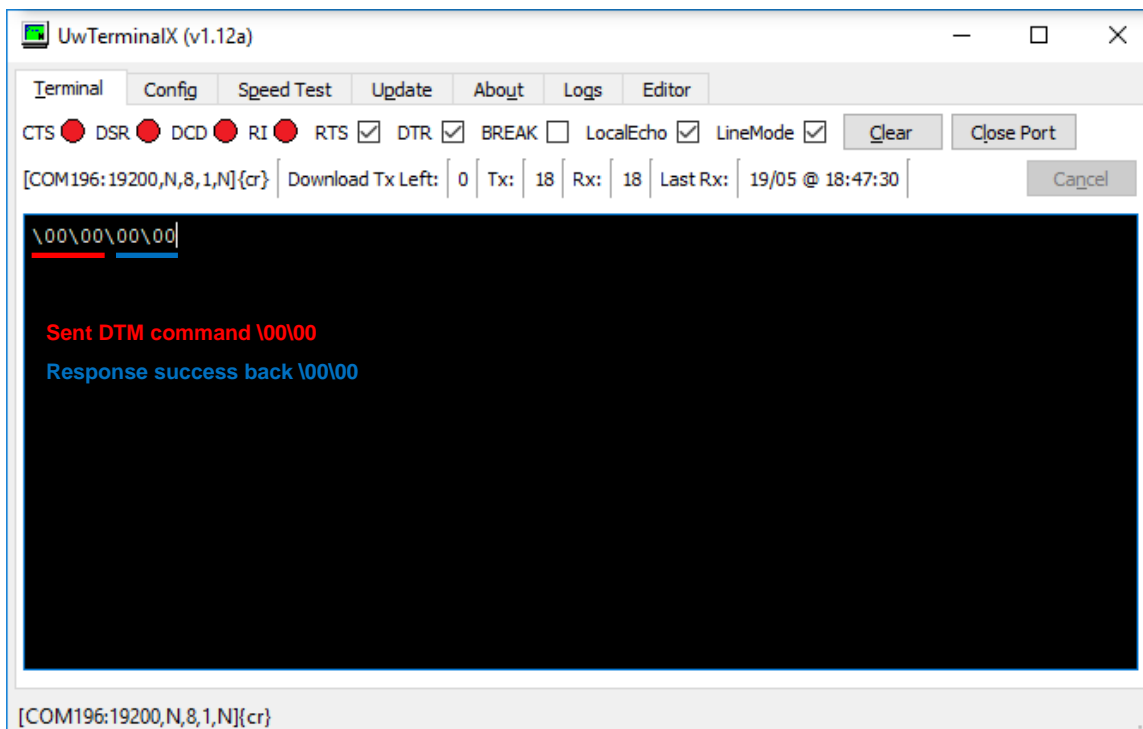
3. Right-click the terminal screen and in the context menu, click **Automation**.
4. In the following screen, modify the fields as shown in [Figure 11](#).
  - In the first field, enter **\00\00** (the DTM command for reset)
  - In the second field, enter **\93\00** (the DTM command to produce a CW RF transmit signal)  
For example, at frequency **2440 MHz**.
  - Tick the box for De-Escape Strings.



**Figure 11: Automation dialogue for entering DTM commands**

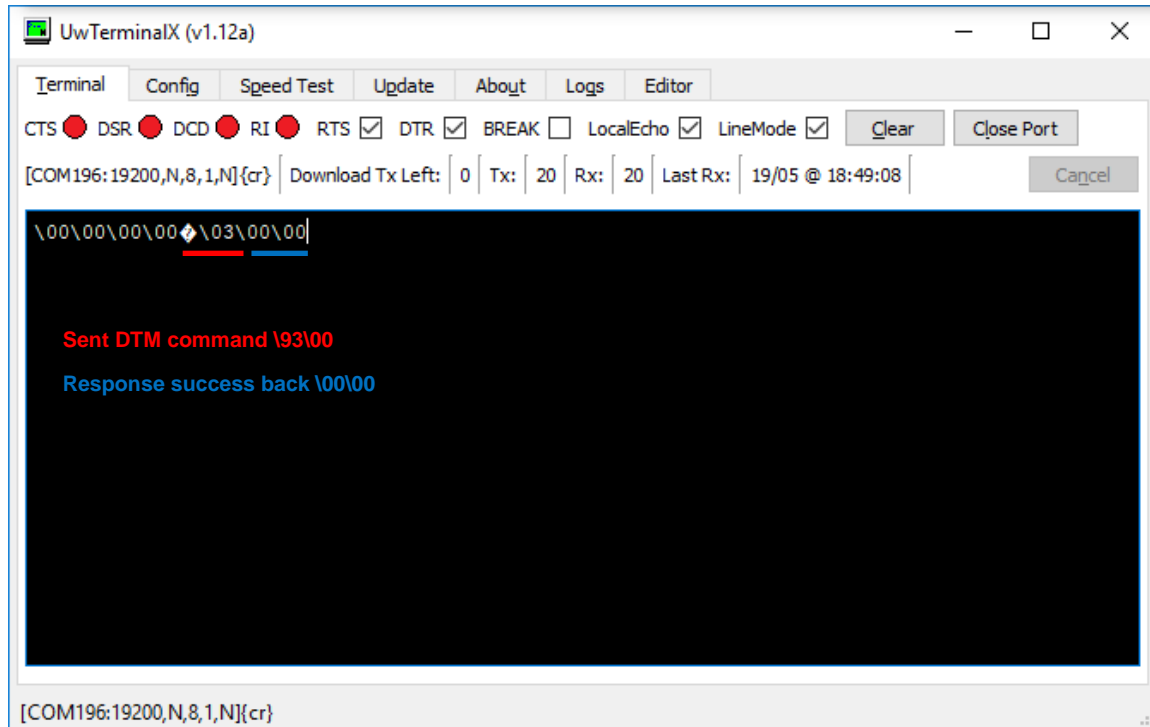
- Click **Send** to send DTM command **\00\00** for reset (always do this first).

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



**Figure 12: 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 13: Automation dialogue DTM command \93\00 to produce continuous wave (CW) RF Transmit signal at frequency 2440MHz 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 RF Transmit Signal Frequency	DTM Command	Continuous Wave RF Transmit Signal Frequency	DTM Command	Continuous Wave RF Transmit Signal Frequency	DTM Command
2402 MHz	\80\00	2430 MHz	\8F\00	2458 MHz	\9C\00
2404 MHz	\81\00	2432 MHz	\90\00	2460 MHz	\9D\00
2406 MHz	\82\00	2434 MHz	\91\00	2462 MHz	\9E\00
2408 MHz	\84\00	2436 MHz	\92\00	2464 MHz	\9F\00
2410 MHz	\85\00	2438 MHz	\93\00	2466 MHz	\A0\00
2412 MHz	\86\00	2440 MHz	\94\00	2468 MHz	\A1\00
2414 MHz	\87\00	2442 MHz	\94\00	2470 MHz	\A2\00
2416 MHz	\88\00	2444 MHz	\95\00	2472 MHz	\A3\00
2418 MHz	\89\00	2446 MHz	\96\00	2474 MHz	\A4\00
2420 MHz	\8A\00	2448 MHz	\97\00	2476 MHz	\A5\00
2422 MHz	\8B\00	2450 MHz	\98\00	2478 MHz	\A6\00
2424 MHz	\8C\00	2452 MHz	\99\00	2480 MHz	\A7\00
2426 MHz	\8D\00	2454 MHz	\9A\00		
2428 MHz	\8E\00	2456 MHz	\9B\00		

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## 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
5. [Figure 14](#): Automation dialogue.
6. In the first field, enter **\3F\FF**.
7. Tick the box for **De-Escape Strings**.
8. Click **Send**.

**Figure 14: Automation dialogue**

9. After this command is complete, close UwTerminalX. Then re-open it and connect to the BL653 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

10. Click **OK** to connect.
11. Check that you get a response by pressing **Enter** in the terminal window. You should the following response:

```
00
```

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

```
at&f*
```

The module erases its file system and reboot, as shown in [Figure 15](#).

```
00
at&f*

FFS Erased, Rebooting...
00
```

**Figure 15:** *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 <i>n</i></b>	0 (Disabled), 1 (enabled)
<b>Default</b>	0

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

This will be ignored if AT+DTMCFG 5 is set to 0 (which is the default). 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 <i>n</i></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 (which is the default). 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 <i>n</i></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 (which is the default). 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.

<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 (which is the default). 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 (which is the default). 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 (which is the default). 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.

<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	27 May 2020	Initial Release	Raj Khatri	Jonathan Kaye
1.1	03 June 2020	Fixed to missing links	Raj Khatri	Jonathan Kaye