Laird Range Testing

BL654 Development Kit

Application Note *v1.1*

1 Introduction

Bluetooth Low Energy is designed for use within Personal Area Networks (PANs). A BLE connection is typically only meant to cover a maximum range of 50 meters and is often meant for much shorter distances.

However, utilizing Bluetooth v5 and feature called LE coded; BLE connections are now capable of a much greater range than previously imagined. In fact, in recent Bluetooth field testing, a Laird engineer was able to sustain communications up to almost 1.9km with the BL654 development kit at both ends (running the Nordic Long Range demo application).

This application note describes the setup, procedure, and results of the successful range test of two BL654 development kits, part number 455-00001 (development kit for the 451-00001 integrated PCB trace antenna module-) for the following test cases:

- 1 Mbps BLE in a connection
- 125 kbps BLE coded PHY (s=8) in a connection
- For each of the above, range was measured with both DUT's at a height of 1.25 meters and then 2.5 meters above the ground
- The DUT (at each end) was orientated so that the BL654 module with the integrated PCB trace antennae were aligned (as best as possible) for peak radiation from the on-board BL654 PCB Trace antenna

2 Environmental Details

Location: Brean Down, North Somerset, UK (7 km beach length, line of sight)

Weather conditions: Dry, warm, sunny, maximum temperature 29°C, maximum relative humidity 66%

3 Hardware and Application Software

The following hardware, hardware settings, and application software are required:

- Two BL654 development kits, part number 455-00001 (development kit for the 451-00001 – BL654 module with an integrated PCB trace antenna) from production
- All jumpers in default production settings
- Nordic Long Range demo application running on both development boards – Available from https://github.com/NordicPlayground/nRF52-ble-long-range-demo/ and accompanying blog post https://devzone.nordicsemi.com/b/blog/posts/testing-long-range-coded-phy-with-nordic-solution-it-simply-works-922075585
- Both development boards 455-00001 orientated for peak radiation from the integrated PCB trace antenna

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- The Nordic Long Range demo application allows the following configurations to be selectable with buttons on the development boards. The status of the selected configurations and connection status (whether data such as RSSI was coming through) is monitored on UwTerminal.

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<table>
<tr><th colspan="2">Development Board #P2 (peripheral end) – The stationary end for the range test</th><th colspan="2">Development Board #C2 (central end) – The moving end for the range test</th></tr>
<tr><td>Configurations selectable by pushing a button:
BUTTON1</td><td>Switch between coded PHY (125 kbps) BLE and 1 Mbps BLE</td><td colspan="2">Configurations selectable by pushing a button:
BUTTON1 Switch between coded PHY (125 kbps) BLE and 1 Mbps BLE
BUTTON2 Switch between 0 dBm and 8 dBm
BUTTON3 Switch between [scanning] and scanning, trying to connect</td></tr>
<tr><td>BUTTON2</td><td>Switch between 0 dBm and 8 dBm</td><td colspan="2"></td></tr>
<tr><td>BUTTON3</td><td>Switch between non-connectable and connectable advertising</td><td colspan="2"></td></tr>
<tr><td colspan="2">Actual status indicated by LED’s and on UwTerminal:
LED1 [on] Coded PHY (125 kbps) BLE
LED1 [slow blinking] 1 Mbps BLE
LED2 [on] 0 dBm
LED2 [slow blinking] 8 dBm
LED3 [fast blinking] Non-connectable advertising
LED4 [fast blinking] Connectable advertising
LED4 [on] Connected state
Since the DUT samples are high on a pole, LED’s cannot be observed. Hence, UwTerminal was used to monitor the connection status and whether data is coming through.</td><td colspan="2">Actual status indicated by LED’s and on UwTerminal:
LED1 [on] Coded PHY (125 kbps) BLE
LED1 [slow blinking] 1 Mbps BLE
LED2 [on] 0 dBm
LED2 [slow blinking] 8 dBm
LED3 [slow blinking] Scanning
LED4 [blinking] Change state upon received ADV report
LED4 [on] Connected state
Since the DUT samples are high on a pole, LED’s cannot be observed. Hence, UwTerminal was used to monitor the connection status and whether data (such as RSSI) is coming through.</td></tr>
<tr><td colspan="2">Default peripheral parameters:
▪ Coded PHY (125 kbps) BLE
▪ 8 dBm
▪ Connectable advertising</td><td colspan="2">Default central parameters:
▪ Coded PHY (125 kbps) BLE
▪ 8 dBm
▪ Scanning only
▪ Since connected to laptop, the data in a connection (such as RSSI) is displayed</td></tr>
</table>

For further information of the Nordic Long Range demo application, refer to https://github.com/NordicPlayground/nRF52-ble-long-range-demo/ and accompanying blog post https://devzone.nordicsemi.com/b/blog/posts/testing-long-range-coded-phy-with-nordic-solution-it-simply-works-922075585

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- Distance recorded with standalone GPS receiver (Garmin Geko 201). Using space-based augmentation (SBAS) to provide differential correction data, reported accuracy was between 3 meters to 7 meters during the test.

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4 Test Setup and Procedure

We used the following test procedure:

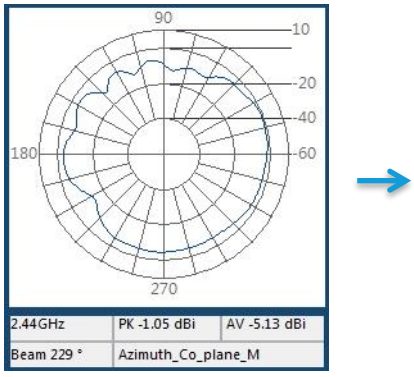
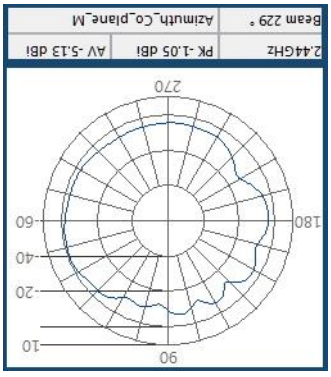
BL654 Development Kit (peripheral role) – Stationary end on the tripod	**BL654 Development Kit (central role) –** Mobile end on trolley (which is walked away)
Development Board (peripheral) Orientation	**Development Board (central) Orientation**
Facing the BL654 central role development board (in the right column) as shown below:	Facing the BL654 peripheral role development (in the left column) as shown below:
	
Orientated for peak radiation from the integrated PCB trace antenna.	Orientated for peak radiation from the integrated PCB trace antenna.
	
	Maintain orientation and line of sight whilst moving away from the stationary end.

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Table 1: Assumed link budget for DUT's

	Conducted TX Power	Conducted RX Sensitivity	TX Antenna Loss	RX Antenna Loss	Link Budget
1 Mbps BLE	8 dBm	-95 dBm	-1.05 dB	-1.05 dB	100.9 dB
125 kps coded PHY BLE	8 dBm	-103 dBm	-1.05 dB	-1.05 dB	108.9 dB

Development board setup (peripheral role) –

- Mounted on foam stand on top of a tripod-mounted plastic pole that is either 1.25 meter or 2.5 meters above ground.
- BL654 development board connected to a laptop which is kept more than two meters away from the pole base.
- All mobile phones' Wi-Fi turned off.

Development board setup (central role) –

- Mounted on foam stand on top of a tripod-mounted plastic pole that is either 1.25 meter or 2.5 meters above ground.
- BL654 development board connected to a laptop which is resting on the edge of the trolley (the laptop is kept less than one meter away from the pole base).
- All mobile phones' Wi-Fi turned off.

Mobile end (on the trolley)

- DUT (central) on top of a plastic pole on foam base
- DUT 1.25 meters above ground
- Laptop sitting on edge for trolley

Figure 1: Set up photo - 1.25 meters above the ground

Stationary end (on the tripod)

- DUT (peripheral) on top of pole on foam base
- DUT 1.25 meters above ground
- Laptop kept more than two meters from the base of the pole

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Stationary end (on tripod)

- DUT (peripheral) on top of a plastic pole on foam base
- DUT 1.25 meters above the ground
- Laptop sitting >2m away from base of pole.

Mobile end (on trolley)

- DUT (central) on top of a plastic pole on foam base.
- DUT 1.25m above ground.
- Laptop sitting on edge of trolley.

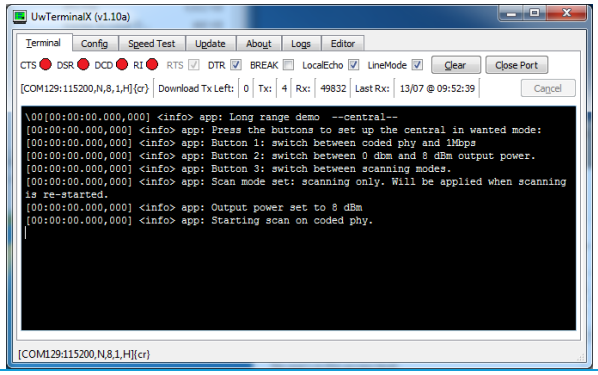
Figure 2: Setup photo - 2.5 meters above the ground

DUT (peripheral role) stationary end (on tripod) – Making a connection in 125 kbps coded PHY BLE

DUT (central role) mobile end (on trolley) – Making a connection in 125 kbps coded PHY BLE

On power up, the screen shows the following:

- TX power is 8 dBm and
- 125 kbps coded PHY BLE
- Central end starts scanning



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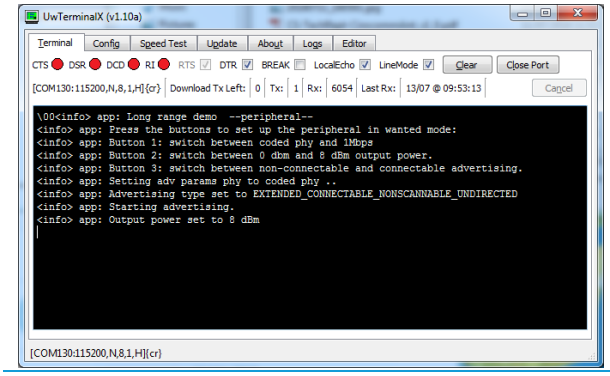
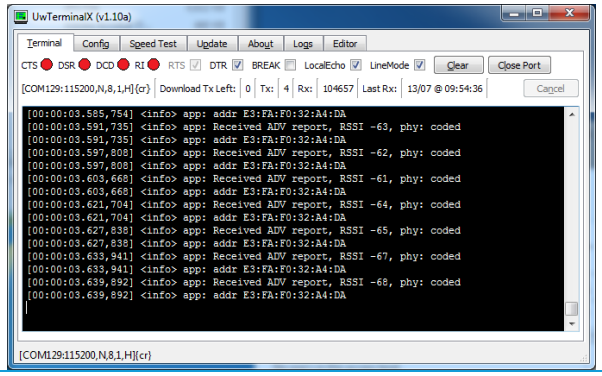
On power up, the screen shows the following:

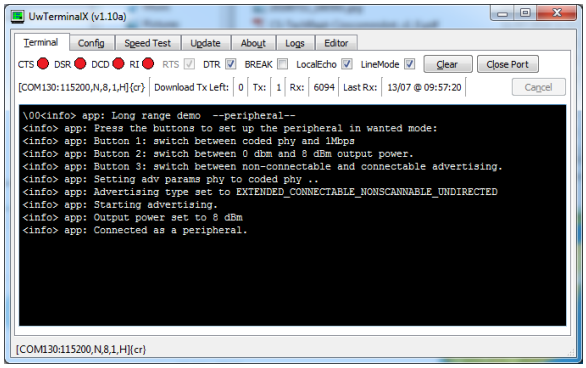
- TX power is 8 dBm and
- 125 kbps coded PHY BLE
- Peripheral end starts advertising



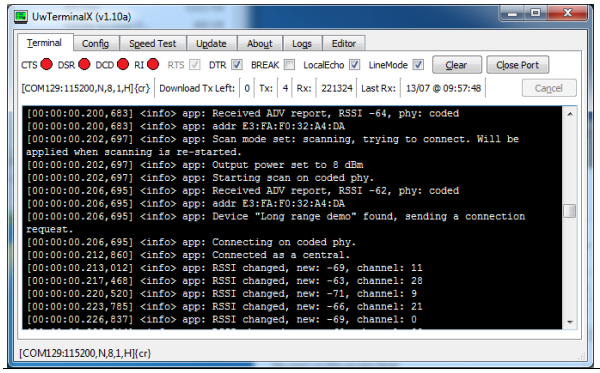
The following screen shows scanned adverts from the peripheral end for 125 kbps coded PHY BLE.



The following shows the screen after BUTTON3 is pressed on the central end, message ***Connected as a peripheral*** is displayed.



The following shows the screen after BUTTON3 is pressed on the central end to establish a connection.



Note: For range testing, the RSSI data is seen as an indication of data connection. When the connection breaks, the message *DISCONNECTED* is displayed.

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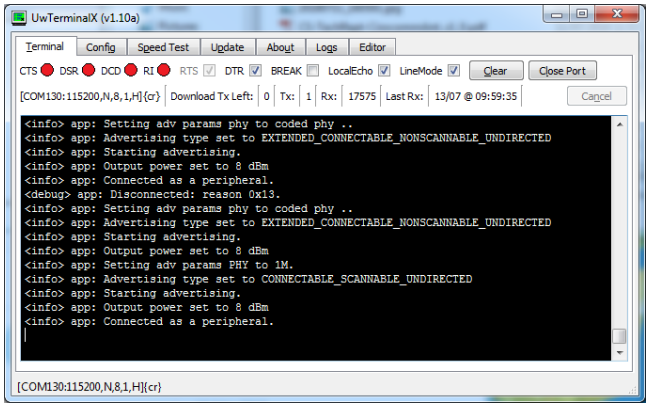
Making a connection in 1 Mbps BLE (when already in a connection in 125 kbps coded PHY BLE)

- Press **BUTTON1** to change from 125 kbps coded PHY BLE to 1 Mbps BLE



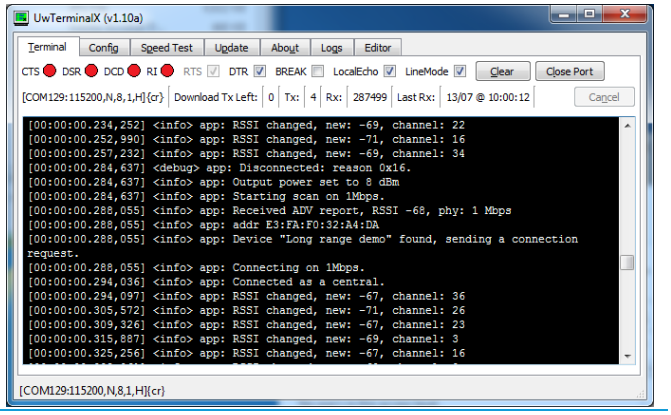
Range Test Process

DUT (peripheral role) stationary end (on the tripod):

1. Monitor any messages on UwTerminal.

Making a connection in 1 Mbps BLE (when already in a connection in 125 kbps coded PHY BLE)

- Press **BUTTON1** to change from 125 kbps coded PHY BLE to 1 Mbps BLE



Range Test Process

DUT (central role) mobile end (on the trolley):

1. Once in a connection (either 1 Mbps BLE or 125 kbps coded PHY BLE), walk the trolley away from stationary (peripheral) end.

   Note: For range testing, the RSSI data is seen as an indication of data connection. When the connection is broken, the message *DISCONNECTED* is displayed.

2. At regular separation distances, view the laptop screen to observe the RSSI data is coming through regularly.
3. Maintain DUT orientation (peak radiation from the integrated PCB trace antenna) and line of sight whilst moving the DUT (central end) trolley away from stationary end.

   Getting a perfect alignment on the peak antenna radiation of the two ends is challenging because the other end is not visible… even with binoculars.

   When the connection is broken, message *DISCONNECTED* is displayed

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5 Test Results

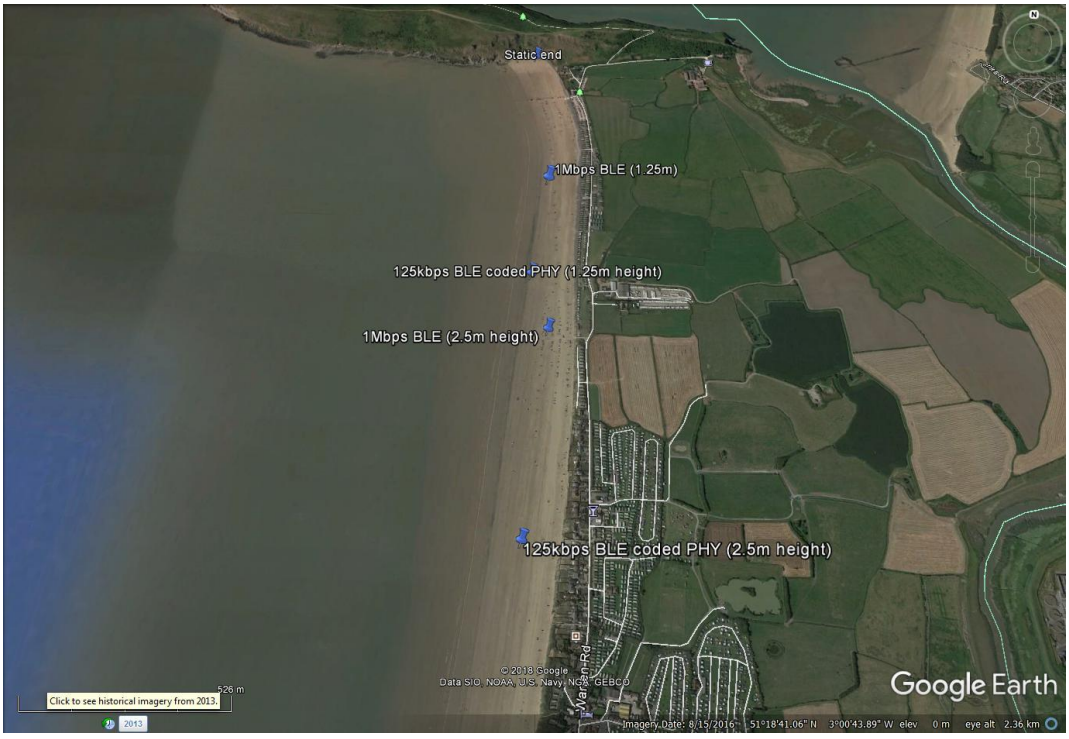
We accomplished the following range distances when both development boards were facing each other (to align the peak radiation from the BL654 PCB trace antenna).

Range test with the BL654 module with the integrated PCB trace antenna	Range with DUT 1.25 meters above Ground	Range with DUT 2.5 meters above Ground
1 Mbps BLE in a connection	625 m	1.2 km
125 kbps BLE coded PHY in a connection	1 km	1.9 km

5.1 Summary

Note the following:

- The range doubles when going from 1 Mbps BLE connection to 125 kbps coded PHY BLE connection.
- The height above the ground at both ends is very important. Each time the antenna height above the ground doubles (at both ends), the range doubles (6 dB improvement in link budget). The height effect is predicted by the two-ray ground reflection model of propagation.
- Getting a perfect alignment on the peak antenna radiation of the two ends is challenging because the other end is not visible (even with binoculars). A compass may be helpful next time.



6 REFERENCES

1. Acknowledgement to John Gisborne for helping with Range Test apparatus and valuable discussion on antennae and propagation.

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7 Revision History

Version	Date	Notes	Contributor(s)	Approver
1.0	16 July 2018	Initial Release	Raj Khatri	Jonathan Kaye
1.1	16 Sept 2019	Updated Formatting	-	Dave Drogowski

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