DISTANCE PERFORMANCE ON THE FIELD
KW45 / K32W1
BLUETOOTH LE & 15.4

SE TEAM

SEPTEMBER 2023

SECURE CONNECTIONS
FOR A SMARTER WORLD

TESTS ON THE FIELD

- The tests take place in a large empty area to respect the line of sight: WW2 beach

- Two environment conditions in summer 2023:
  - Nobody on the beach

- The laptops used in the tests are in 'Airplane mode’.
  BLE & WiFi on mobile phones in our pocket are also Off.
  Please note the antennas direction were taken into account also.

On the beach at Merville/Franceville near Caen (Normandy - France)

BLUETOOTH LE

KW45 TESTS ON THE FIELD

Setup:

- KW45 are flashed with RFP Connectivity Test software
- 2x KW45-EVK boards are placed on top of a 3m pole length
  - Brd 1: VV22281110 (Tx)
  - Brd 2: VV22281115 (Rx)
- One board is in transmission mode (Tx) and another one is in reception mode (Rx) to evaluate the **maximum distance of communication**.
- Bluetooth LE mode considered: 1Mbps, 2Msps, LR S=2 & S=8
- Tx output power is set at +10 dBm.

Note: Similar results are expected on K32W148.

How the communication distance is measured :

- The 1st chip transmits in “advertising” and “connect” mode as the “Master”.
- The 2nd chip is “scanning” and “connect” to the 1st chip as the “Slave”.
- When the communication is established the two chips alternatively transmit and receive to communicate.
- The “Master” remains fixed and the “Slave” moves until the data transmit reach PER=30.8% and then when the communication is lossed (distance variation).
- GPS coordinates are considered to calculate the distance between them (+/-50m of accuracy)

How the communication distance is measured :

Software used : Connectivity test (SDK 2.12.5 MR2)

“Master”

```
Generic FSK Connectivity Test Demo

SW versions:
XCVR:
     release_fuk_ksdk_2.6_ku37a_5.7.6_RC3
     2d3aa484b90895e9da8f705b704ee821D09530fb (Fri Apr 17 10:44:45 2020 +0200)
GENFSK:
     release_genfsk_ksdk_2.6_ku37a_3.0.3_RC4
     688b928e812ed41d6bc9af87eb64678a888c3e45 (Tue Apr 28 15:07:10 2020 +0200)

-Press enter to start
 Connectivity Test Interface short cuts
-------------------------------------
-Press [t] for Tx operation
-Press [r] for Rx operation
-Press [z] to increase mode (GENFSK, BLE) and rate
-Press [x] to decrease mode (GENFSK, BLE) and rate
-Press [c] to toggle between fixed or per channel whitening (for BLE only)
-Press [q] for channel up
-Press [w] for channel down
-Press [a] for Power up
-Press [s] for Power down
-Press [n] to increase the Payload
-Press [m] to decrease the Payload
-Press [d] to increase the XTAL Trim value
-Press [f] to decrease the XTAL Trim value
These keys can be used all over the application to change
the test parameters

 Select the Test to perform
-Press [1] Continuous tests
-Press [2] Packet Error Rate test
-Press [3] Range test
-Press [!] Reset MCU

Mode TX, Rate      BLE 1Mbps, Whiten Fixed, Channel 42, Hi Power 31, Payload 37, XtalTrim 58>

-------------------------------------------------------------
 [t] Tx  [z] Mode/Rate+  [c] Fix/Ch whit.  [q] Ch+  [a] Pu+
 [r] Rx  [x] Mode/Rate-                    [w] Ch-  [s] Pu-

 [n] Pyld+  [d] XtalTrim+
 [m] Pyld-  [f] XtalTrim-
-------------------------------------------------------------

 PER Tx Test Menu

 Choose the amount of packets to send:
[0] - 1     Packet     [1] - 25    Packets
[2] - 100   Packets    [3] - 500   Packets
[4] - 1000  Packets    [5] - 2000  Packets
[6] - 5000  Packets    [7] - 10000 Packets
[8] - 65535 Packets

-Press any push button to stop Transmiting Packets
-Press [p] Previous Menu

Mode TX, Rate      BLE 1Mbps, Whiten Fixed, Channel 42, Hi Power 31, Payload 37, XtalTrim 58>
```

Press [2] PER test

```
-------------------------------------------------------------
 [t] Tx  [z] Mode/Rate+  [c] Fix/Ch whit.  [q] Ch+  [a] Pu+
 [r] Rx  [x] Mode/Rate-                    [w] Ch-  [s] Pu-

 [n] Pyld+  [d] XtalTrim+
 [m] Pyld-  [f] XtalTrim-
-------------------------------------------------------------

 PER Tx Test Menu

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[0] - 1     Packet     [1] - 25    Packets
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[6] - 5000  Packets    [7] - 10000 Packets
[8] - 65535 Packets

-Press any push button to stop Transmiting Packets
-Press [p] Previous Menu

Mode TX, Rate      BLE 1Mbps, Whiten Fixed, Channel 42, Hi Power 31, Payload 37, XtalTrim 58>
Please type TX interval in miliseconds ( > 6 ms ) and press [ENTER]
1100

Running PER Tx, Number of packets: 2000
Packet 1
Packet 2
Packet 3
Packet 4
Packet 5
Packet 6
Packet 7
Packet 8
Packet 9
Packet 10
```

Transmission interval: 10ms

Packets: 2000

Mode Transmit, BLE 1Mbps, maximum RF power (Hi power 31), Payload 37

“Slave”

```
Generic FSK Connectivity Test Demo

SW versions:
XCVR:
     release_fuk_ksdk_2.6_ku37a_5.7.6_RC3
     2d3aa484b90895e9da8f705b704ee821D09530fb (Fri Apr 17 10:44:45 2020 +0200)
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     release_genfsk_ksdk_2.6_ku37a_3.0.3_RC4
     688b928e812ed41d6bc9af87eb64678a888c3e45 (Tue Apr 28 15:07:10 2020 +0200)

-Press enter to start
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-Press [c] to toggle between fixed or per channel whitening (for BLE only)
-Press [q] for channel up
-Press [w] for channel down
-Press [a] for Power up
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-Press [n] to increase the Payload
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-Press [d] to increase the XTAL Trim value
-Press [f] to decrease the XTAL Trim value
These keys can be used all over the application to change
the test parameters

 Select the Test to perform
-Press [1] Continuous tests
-Press [2] Packet Error Rate test
-Press [3] Range test
-Press [!] Reset MCU

Mode RX, Rate      BLE 1Mbps, Whiten Fixed, Channel 42, Hi Power 31, Payload 37, XtalTrim 58>

-------------------------------------------------------------
 [t] Tx  [z] Mode/Rate+  [c] Fix/Ch whit.  [q] Ch+  [a] Pu+
 [r] Rx  [x] Mode/Rate-                    [w] Ch-  [s] Pu-

 [n] Pyld+  [d] XtalTrim+
 [m] Pyld-  [f] XtalTrim-
-------------------------------------------------------------

 PER Rx Test Menu

-Press [space bar] to start/stop Receiving Packets
-Press any push button to stop Receiving Packets
-Press [p] Previous Menu

Mode RX, Rate      BLE 1Mbps, Whiten Fixed, Channel 42, Hi Power 31, Payload 37, XtalTrim 58>
```

Press [2] PER test

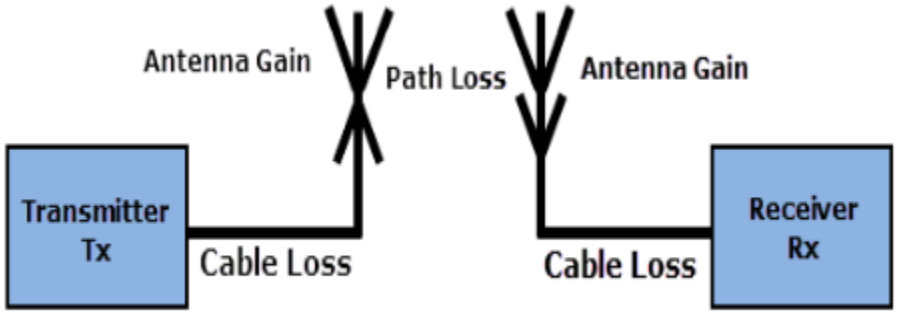
```
-------------------------------------------------------------
 [t] Tx  [z] Mode/Rate+  [c] Fix/Ch whit.  [q] Ch+  [a] Pu+
 [r] Rx  [x] Mode/Rate-                    [w] Ch-  [s] Pu-

 [n] Pyld+  [d] XtalTrim+
 [m] Pyld-  [f] XtalTrim-
-------------------------------------------------------------

 PER Rx Test Menu

-Press [space bar] to start/stop Receiving Packets
-Press any push button to stop Receiving Packets
-Press [p] Previous Menu

Mode RX, Rate      BLE 1Mbps, Whiten Fixed, Channel 42, Hi Power 31, Payload 37, XtalTrim 58>
'ER Test Rx Running

'acket 1. Packet index: 1. Rssi: -90. Timestamp: 103724261
'acket 2. Packet index: 2. Rssi: -87. Timestamp: 103738876
'acket 3. Packet index: 3. Rssi: -92. Timestamp: 103750331
'acket 4. Packet index: 4. Rssi: -91. Timestamp: 103761788
'acket 5. Packet index: 5. Rssi: -88. Timestamp: 103773244
'acket 6. Packet index: 6. Rssi: -90. Timestamp: 103784701
'acket 7. Packet index: 9. Rssi: -88. Timestamp: 103819070
'acket 8. Packet index: 10. Rssi: -89. Timestamp: 103830526
'acket 9. Packet index: 14. Rssi: -90. Timestamp: 103876701
'acket 10. Packet index: 15. Rssi: -89. Timestamp: 103888245
'acket 11. Packet index: 16. Rssi: -88. Timestamp: 103899788
'acket 12. Packet index: 17. Rssi: -89. Timestamp: 103911332
'acket 13. Packet index: 18. Rssi: -89. Timestamp: 103922876
'acket 14. Packet index: 19. Rssi: -90. Timestamp: 103934419
'acket 15. Packet index: 20. Rssi: -90. Timestamp: 103945963
'acket 16. Packet index: 21. Rssi: -90. Timestamp: 103957506
'acket 17. Packet index: 22. Rssi: -90. Timestamp: 103969050
'acket 18. Packet index: 23. Rssi: -90. Timestamp: 103980594
```

Packet index received, RSSI level, Timestamp information

Mode Reception, BLE 1Mbps, maximum RF power (Hi power 31), Payload 37

How to evaluate the theorical maximum distance between 2x KW45

- Free Space Path Loss expression from the Friis formula is used:
  - $A = 20*\log(\frac{4\pi d}{Lambda})$
    - A is the Attenuation or Free Space Path Loss (dB)
    - d is the distance (km)
    - Lambda is the wavelength (m)
- Also another expression of the Attenuation depending on the frequency could be used:
  - $A = 20*\log(d) + 20*\log(f) + 32.45 - G_{Tx} - G_{Rx}$
    - d is the distance in km
    - f is the frequency in MHz
    - G_{Tx} is the gain of the transmitting antenna
    - G_{Rx} is the gain of the receiving antenna



How to evaluate the theorical maximum distance between 2x KW45

- In our case, we will define the attenuation as:
  - A = $P_{out,TX\ chip}$ - $Sensitivity_{Rx,chip}$
  - The max free space attenuation is the link budget

- We consider the contribution of the antennas for now :
  Printed IFA antenna
  - G_{Tx} = 1 dBi
  - G_{Rx} = 1 dBi

Bluetooth LE : Theorical distance estimation using the KW45-EVK

Characteristic	Theorical calculation				
	2Mbps	1Mbps	500kbps	125kbps	Unit
Board 1 Maximum Output Power	10	10	10	10	dBm
Board 2 Sensitivity	-95.5	-98	-102	-106	dBm
Attenuation/link budget	105.5	108	112	116	dB
Estimated distance	**1.9**	**2.5**	**3.95**	**6.3**	**km**

Bluetooth LE: Distance measurement results

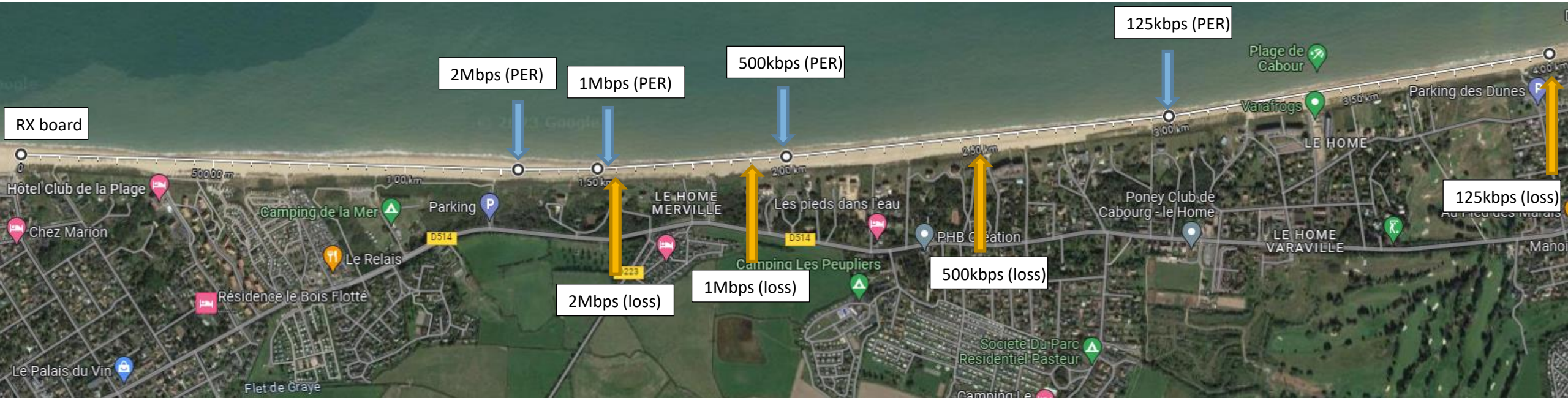
Environment condition: Nobody on the beach

Long Range

	Characteristic	Field measurements				
		2Mbps	1Mbps	500kbps	125kbps	Unit
KW45	Field distance (PER)	1.3	1.55	2.0	3.0	kms
	Field distance (Loss)	1.6	1.8	2.5	4.0	kms
	Friiz	1.9	2.5	4.0	6.3	kms

Environment condition: Nobody on the beach

	Characteristic	Theorical calculation				
		2Mbps	1Mbps	500kbps	125kbps	Unit
KW45	Field distance estimation (PER)	1.3	**1.55**	**2**	**3**	kms
	Field distance estimation (Loss)	**1.6**	**1.8**	**2.5**	**4**	kms
	Friiz	**1.9**	**2.5**	4	**6.3**	kms



Conclusion

- In general, the distance measured doesn’t correlate quite well with the calculated one. Anyway the expected distances according to the PHY mode are relevant and confirmed.

- Distances reached in Bluetooth LE (PER=30.8%) are from 1.3kms (2Mbps data rate) to 3kms (125kHz data rate).
  Those distances go up from 1.6kms (2Mbps data rate) to 4kms (LR 125kHz data rate) to reach the loss of transmission (line of sight use case).

- Difficulties are:
  - Keep the antennas in an optimized direction
  - Evaluate the interferers level coming from people with their mobile phone (Wifi, BLE)

15.4

K32W1 TESTS ON THE FIELD

Setup:

- K32W1 are flashed with RFP 15.4 Connectivity Test software
- 2x K32W1-EVK boards are placed on top of a 3m pole length
  - Brd 1: VV22281110 (Tx)
  - Brd 2: VV22281115 (Rx)
- One board is in transmission mode (Tx) and another one is in reception mode (Rx) to evaluate the **maximum distance of communication**.
- Protocol: 15.4
- Tx output power is set at +10 dBm.

How the communication distance is measured :

- The 1st chip transmits in “advertising” and “connect” mode as the “Master”.
- The 2nd chip is “scanning” and “connect” to the 1st chip as the “Slave”.
- When the communication is established the two chips alternatively transmit and receive to communicate.
- The “Master” remains fixed and the “Slave” moves until the data transmit reach PER=1% and then when the communication is lossed (distance variation).
- GPS coordinates are considered to calculate the distance between them (+/-50m of accuracy)

How to evaluate the theorical maximum distance between 2xK32W1

- In our case, we will define the attenuation as:
  - A = $P_{out,TX\ chip}$ - $Sensitivity_{Rx,chip}$
  - The max free space attenuation is the link budget

- We consider the contribution of the antennas for now :
  Printed IFA antenna
  - G_{Tx} = 1 dBi
  - G_{Rx} = 1 dBi

15.4: Theorical distance estimation using the K32W1-EVK

Characteristic	Theorical calculation	
	1Mbps	Unit
Board 1 Maximum Output Power	10	dBm
Board 2 Sensitivity	-101	dBm
Attenuation/link budget	111	dB
Estimated distance	**3.5**	**km**

15.4: Distance measurement results

Environment condition: Nobody on the beach

Characteristic	Field measurements	
	1Mbps	Unit
Field distance (PER 1%)	0.5	kms
Field distance (Loss)	3.3	kms
Friiz	**3.5**	**kms**

Conclusion

- In general, the distances measured doesn’t correlate quite well with the calculated one.
  Anyway the expected distances according to the PHY mode are relevant and confirmed.

- Distance reached in 15.4 (PER=1%) is 500m (250kbps data rate).
  This distance go up from 3.3kms to reach the loss of transmission (line of sight use case).

- Difficulties are:
  - Keep the antennas in an optimized direction
  - Evaluate the interferers level coming from people with their mobile phone (Wifi, BLE)

CONCLUSION

Conclusion

- In general, the distance measured doesn't correlate quite well with the calculated one. Anyway the expected distances according to the PHY mode are relevant and confirmed.

- Bluetooth LE

  Distances reached in Bluetooth LE (PER=30.8%) are from 1.3kms (2Mbps data rate) to 3kms (125kHz data rate).
  Those distances go up from 1.6kms (2Mbps data rate) to 4kms (LR 125kHz data rate) to reach the loss of transmission (line of sight use case).

- 15.4

  Distance reached in 15.4 (PER=1%) is 500m (250kbps data rate).
  This distance go up from 3.3kms to reach the loss of transmission (line of sight).

- Difficulties are:
  - Keep the antennas in an optimized direction
  - Evaluate the interferers level coming from people with their mobile phone (Wifi, BLE)

SECURE CONNECTIONS
FOR A SMARTER WORLD