Shenzhen CTL Testing Technology Co., Ltd.
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TEST REPORT

ETSI EN 300 328 V2.1.1 (2016-11)

Report Reference No. ....: **CTL1906244051-WR02**

Compiled by: (position+printed name+signature)	Happy Guo (File administrators)	Happy Guo
Tested by: (position+printed name+signature)	Nice Nong (Test Engineer)	Nice Nong
Approved by: (position+printed name+signature)	Ivan Xie (Manager)	Ivan Xie

Product Name..............................:	Beaglebone AI
Model/Type reference ....:	Beaglebone AI
List Model(s)................................:	N/A
Trade Mark..................................:	N/A
Applicant's name ....:	**BeagleBoard.org Foundation**
Address of applicant ....:	4467 Ascot Court Oakland Township, Michigan, US 48306
Test Firm ....:	**Shenzhen CTL Testing Technology Co., Ltd.**
Address of Test Firm ....:	Floor 1-A, Baisha Technology Park, No.3011, Shahexi Road, Nanshan District, Shenzhen, China 518055
Test specification........................:	
Standard...:	**ETSI EN 300 328 V2.1.1 (2016-11)**
TRF Originator ....:	Shenzhen CTL Testing Technology Co., Ltd.
Master TRF ....:	Dated 2011-01
Date of receipt of test item.........:	Jun. 26, 2019
Date of sampling..........................:	Jun. 26, 2019
Date of Test Date.........................:	Jun. 26, 2019–Jul. 08, 2019
Data of Issue................................:	Jul. 09, 2019
Result..:	Pass

TEST REPORT

Test Report No. :	**CTL1906244051-WR02**	Jul. 09, 2019 Date of issue

Equipment under Test	:	Beaglebone AI
Model /Type	:	Beaglebone AI
Listed Models	:	N/A
Applicant	:	**BeagleBoard.org Foundation**
Address	:	4467 Ascot Court Oakland Township, Michigan, US 48306
Manufacturer	:	**BeagleBoard.org Foundation**
Address	:	4467 Ascot Court Oakland Township, Michigan, US 48306

Test result	**Pass ***

∗ In the configuration tested, the EUT complied with the standards specified page 5.

The test results presented in this report relate only to the object tested.
This report shall not be reproduced, except in full, without the written approval of the issuing testing laboratory.
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** Modified History **

Revision	Description	Issued Data	Report No.	Remark
Version 1.0	Initial Test Report Release	2019-07-09	CTL1906244051-WR02	Tracy Qi

Contents

1 TEST SUMMARY

1.1 Test Standards

The tests were performed according to following standards:

ETSI EN 300 328 V2.1.1 (2016-11)–Wideband transmission systems; Data transmission equipment operating in the 2,4 GHz ISM band and using wide band modulation techniques; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU

1.2 Test Description

Item	Reference	Result
Maximum transmit power	ETSI EN 300 328 (V2.1.1) Sub-clause 4.3.2.2	PASS
Power Spectral Density	ETSI EN 300 328 (V2.1.1) Sub-clause 4.3.2.3	PASS
Duty Cycle, Tx-sequence, Tx-gap	ETSI EN 300 328 (V2.1.1) Sub-clause 4.3.2.4	N/A$_{\text{note1}}$
Medium Utilisation (MU) factor	ETSI EN 300 328 (V2.1.1) Sub-clause 4.3.2.5	N/A$_{\text{note1}}$
Adaptively	ETSI EN 300 328 (V2.1.1) Sub-clause 4.3.2.6	N/A$_{\text{note2}}$
Occupied Channel Bandwidth	ETSI EN 300 328 (V2.1.1) Sub-clause 4.3.2.7	PASS
Transmitter unwanted emissions in the out-of-band domain	ETSI EN 300 328 (V2.1.1) Sub-clause 4.3.2.8	PASS
Transmitter unwanted emissions in the spurious domain	ETSI EN 300 328 (V2.1.1) Sub-clause 4.3.2.9	PASS
Receiver spurious emissions	ETSI EN 300 328 (V2.1.1) Sub-clause 4.3.2.10	PASS
Receiver Blocking	ETSI EN 300 328 (V2.1.1) Sub-clause 4.3.2.11	PASS
Geo-location capability	ETSI EN 300 328 (V2.1.1) Sub-clause 4.3.2.12	N/A$_{\text{note3}}$

Note1: This requirement does not apply to adaptive equipment.
Note2: Which is not applicable to device with a maximum RF Output power level is less than 10 dBm e.i.r.p.
Note3: This equipment without geo-location capability function.

1.3 Test Facility

1.3.1 Address of the test laboratory

Shenzhen CTL Testing Technology Co., Ltd.
Floor 1-A, Baisha Technology Park, No. 3011, Shahexi Road, Nanshan, Shenzhen 518055 China

There is one 3m semi-anechoic chamber and two line conducted labs for final test. The Test Sites meet the requirements in documents ANSI C63.4 and CISPR 32/EN 55032 requirements.

1.3.2 Laboratory accreditation

The test facility is recognized, certified, or accredited by the following organizations:

CNAS-Lab Code: L7497

Shenzhen CTL Testing Technology Co., Ltd. has been assessed and proved to be in compliance with CNAS-CL01 Accreditation Criteria for Testing and Calibration Laboratories (identical to ISO/IEC 17025: 2005 General Requirements) for the Competence of Testing and Calibration Laboratories.

A2LA-Lab Cert. No. 4343.01

Shenzhen CTL Testing Technology Co., Ltd. EMC Laboratory has been accredited by A2LA for technical competence in the field of electrical testing, and proved to be in compliance with ISO/IEC 17025: 2005 General Requirements for the Competence of Testing and Calibration Laboratories and any additional program requirements in the identified field of testing.

IC Registration No.: 9518B

CAB identifier: CN0041

The 3m alternate test site of Shenzhen CTL Testing Technology Co., Ltd. EMC Laboratory has been registered by Innovation, Science and Economic Development Canada to test to Canadian radio equipment requirements with Registration No.: 9518B on Jan. 22, 2019.

FCC-Registration No.: 399832

Designation No.: CN1216

Shenzhen CTL Testing Technology Co., Ltd. EMC Laboratory has been registered and fully described in a report filed with the (FCC) Federal Communications Commission. The acceptance letter from the FCC is maintained in our files. Registration 399832, December 08, 2017.

1.4 Statement of the measurement uncertainty

The data and results referenced in this document are true and accurate. The reader is cautioned that there may be errors within the calibration limits of the equipment and facilities. The measurement uncertainty was calculated for all measurements listed in this test report acc. to CISPR 16 - 4 „Specification for radio disturbance and immunity measuring apparatus and methods – Part 4: Uncertainty in EMC Measurements“ and is documented in the Shenzhen CTL Testing Technology Co., Ltd. quality system acc. to DIN EN ISO/IEC 17025. Furthermore, component and process variability of devices similar to that tested may result in additional deviation. The manufacturer has the sole responsibility of continued compliance of the device.

Hereafter the best measurement capability for CTL laboratory is reported:

Test Items	Measurement Uncertainty	Notes
Occupied Channel Bandwidth	±2%	(1)
Transmitter power conducted	0.57 dB	(1)
Transmitter power Radiated	2.20 dB	(1)
Conducted spurious emission	1.60 dB	(1)
Radiated spurious emission	2.20 dB	(1)
Temperature	±1℃	(1)

Humidity	±3%	(1)
DC and low frequency voltages	±1.5%	(1)
Time	±2%	(1)
Duty cycle	±2%	(1)

Note 1: This uncertainty represents an expanded uncertainty expressed at approximately the 95% confidence level using a coverage factor of k=1.96.

2 GENERAL INFORMATION

2.1 Environmental conditions

During the measurement the environmental conditions were within the listed ranges:

Temperature	Normal Temperature:	25°C
	High Temperature:	55°C
	Low Temperature:	-20°C
Voltage	Normal Voltage	5.00V
	High Voltage	5.75V
	Low Voltage	4.25V
Other	Relative Humidity	55 %
	Air Pressure	101 kPa

2.2 General Description of EUT

Product Name:	Beaglebone AI
Model/Type reference:	Beaglebone AI
Power supply:	DC 5.0V
Bluetooth LE	
Supported type:	Bluetooth Low Energy
Modulation:	GFSK
Operation frequency:	2402MHz to 2480MHz
Channel number:	40
Channel separation:	2 MHz
Antenna type:	Snap antenna
Antenna gain:	1.5dBi

Note: For more detailed features description, please refer to the manufacturer’s specifications or the User's Manual.

2.3 Receiver categories

This device belongs to the receiver categories as the choice box selected:

	Categorization	Note
☐	Receiver category 1	Adaptive equipment with a maximum RF output power greater than 10 dBm e.i.r.p.
☒	Receiver category 2	Non-adaptive equipment with a Medium Utilization (MU) factor greater than 1 % and less than or equal to 10 % or adaptive equipment with a maximum RF output power of 10 dBm e.i.r.p.
☐	Receiver category 3	Non-adaptive equipment with a maximum Medium Utilization (MU) factor of 1 % or adaptive equipment with a maximum RF output power of 0 dBm e.i.r.p.

2.4 Description of Test Modes and Test Frequency

The EUT has been tested under typical operating condition. The Applicant provides communication tools software to control the EUT for staying in continuous transmitting and receiving mode for testing.

Operation Frequency List：

Channel	Frequency (MHz)
00	**2402**
02	2404
03	2406
⋮	⋮
19	**2440**
⋮	⋮
37	2476
38	2478
39	**2480**

Note: The line display in grey were the channel selected for testing

2.5 Measurement Instruments List

RF output power & PSD & OOB & OBW & Hoping & Duty Cycle, Tx-sequence, Tx-gap & Adaptively						
Item	Test Equipment	Manufacturer	Model No.	Serial No.	Calibration Date	Calibration Due Date
1	Spectrum Analyzer	Agilent	N9020	US46220290	2019/05/24	2020/05/23
2	Signal Generator	Agilent	N5182A	MY47420864	2019/05/24	2020/05/23
3	Signal Generator	Agilent	E4421B	US40051744	2019/05/24	2020/05/23
4	Power Sensor	Agilent	U2021XA	MY5365004	2019/05/24	2020/05/23
5	Power Meter	Agilent	U2531A	TW53323507	2019/05/24	2020/05/23
6	Climate Chamber	ESPEC	EL-10KA	A20120523	2019/05/24	2020/05/23

Transmitter spurious emissions & Receiver spurious emissions						
Item	Test Equipment	Manufacturer	Model No.	Serial No.	Calibration Date	Calibration Due Date
1	ULTRA-ROADBAND ANTENNA	Sunol Sciences Corp.	JB1	A061713	2019/05/24	2020/05/23
2	Horn Antenna	Sunol Sciences Corp.	DRH-118	A062013	2019/05/24	2020/05/23
3	EMI Test Receiver	R&S	ESCI	103710	2019/05/24	2020/05/23
4	Controller	EM Electronics	Controller EM 1000	N/A	2019/05/24	2020/05/23
5	Amplifier	Agilent	8349B	3008A02306	2019/05/24	2020/05/23
6	Amplifier	Agilent	8447D	2944A10176	2019/05/24	2020/05/23
7	Temperature/Hu	Gangxing	CTH-608	02	2019/05/24	2020/05/23

	midity Meter					
8	High-Pass Filter	K&L	9SH10-2700/X12750-O/O	N/A	2019/05/24	2020/05/23
9	High-Pass Filter	K&L	41H10-1375/U12750-O/O	N/A	2019/05/24	2020/05/23
10	RF Cable	HUBER+SUHNER	RG214	N/A	2019/05/24	2020/05/23

The calibration interval is 1 year.

3 TEST ITEM AND RESULTS

3.1 RF Output Power

Limit

ETSI EN 300 328 (V2.1.1) Sub-clause 4.3.2.2.3

TEST CONDITION	LIMIT
Normal and Extreme	20dBm(e.i.r.p)

Test Procedure

- Step 1: Use a fast power sensor suitable for 2,4 GHz and capable of minimum 1 MS/s. Use the following settings:

  - Sample speed 1 MS/s or faster.

  - The samples shall represent the RMS power of the signal.

  - Measurement duration: For non-adaptive equipment: equal to the observation period. For adaptive equipment, the measurement duration shall be long enough to ensure a minimum number of bursts (at least 10) are captured.

NOTE 1: For adaptive equipment, to increase the measurement accuracy, a higher number of bursts may be used.

- Step 2:For conducted measurements on devices with one transmit chain:

  -Connect the power sensor to the transmit port, sample the transmit signal and store the raw data. Use these stored samples in all following steps.

For conducted measurements on devices with multiple transmit chains:

  - Connect one power sensor to each transmit port for a synchronous measurement on all transmits ports.

  - Trigger the power sensors so that they start sampling at the same time. Make sure the time difference between the samples of all sensors is less than 500 ns.

  - For each individual sampling point (time domain), sum the coincident power samples of all ports and store them. Use these summed samples in all following steps.

- Step 3: Find the start and stop times of each burst in the stored measurement samples.

  The start and stop times are defined as the points where the power is at least 30 dB below the highest value of the stored samples in step 2.

NOTE 2: In case of insufficient dynamic range, the value of 30 dB may need to be reduced appropriately.

- Step 4: Between the start and stop times of each individual burst calculate the RMS power over the burst using the formula below. Save these P_{burst} values, as well as the start and stop times for each burst.

$$P_{burst} = \frac{1}{k}\sum_{n=1}^{k} P_{sample}(n)$$

With 'k' being the total number of samples and 'n' the actual sample number

- Step 5: The highest of all P_{burst} values (value "A" in dBm) will be used for maximum e.i.r.p. calculations.

- Step 6: Add the (stated) antenna assembly gain "G" in dBi of the individual antenna. If applicable, add the additional beamforming gain "Y" in dB using the formula below:

P = A + G + Y

Test Results

GFSK							
Test conditions		Channel	Measured power (dBm)	Antenna Gain (dBi)	EIRP (dBm)	Limit (dBm)	Result
Voltage (V)	Temperature (℃)						
5.0V	25	CH00	2.28	1.50	3.78	20.00	Pass
		CH19	2.15	1.50	3.65		
		CH39	1.65	1.50	3.15		
	-20	CH00	2.19	1.50	3.69		
		CH19	2.07	1.50	3.57		
		CH39	1.44	1.50	2.94		
	+55	CH00	2.13	1.50	3.63		
		CH19	2.01	1.50	3.51		
		CH39	1.57	1.50	3.07		

Note 1. We captured 25 bursts in total and recorded the maximum average power.
2. Measured Power includes the cable loss.

3.2 Power Spectral Density

Limit

ETSI EN 300 328 (V2.1.1) Sub-clause 4.3.2.3.3

TEST CONDITION	LIMIT
Normal	10dBm / MHz

Remark: Power Spectral Density is not applicable to FHSS system device.

Test Procedure

Step 1: Connect the UUT to the spectrum analyzer and use the following settings:

Start Frequency:	2 400 MHz
Stop Frequency:	2 483,5 MHz
Resolution BW:	10 kHz
Video BW:	30 kHz
Sweep Points:	> 8 350
Detector:	RMS
Trace Mode:	Max Hold
Sweep time:	10 s

- **Step 2:** Add up the values for power for all the samples in the file using the formula below:

$$P_{Sum} = \sum_{n=1}^{k} P_{sample}(n)$$

with 'k' being the total number of samples and 'n' the actual sample number

- **Step 3:** Normalize the individual values for power (in dBm) so that the sum is equal to the RF Output Power (e.i.r.p.) measur[ed] ... The following formulas used:

$$C_{Corr} = P_{Sum} - P_{e.i.r.p.}$$

$$P_{Samplecorr}(n) = P_{Sample}(n) - C_{Corr}$$

with 'n' being the actual sample number

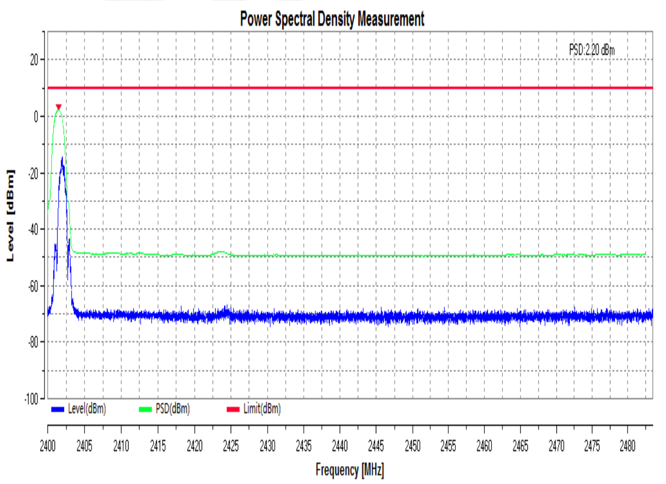
- **Step 4:** Starting from the first sample PSamplecorr(n) (lowest frequency), add up the power (in mW) of the following samples representing a 1 MHz segment and record the results for power and position (i.e. sample #1 to sample #100). This is the Power Spectral Density (e.i.r.p.) for the first 1 MHz segment and recorded.
- **Step 5:** Shift the start point of the samples added up in step 4 by one sample and repeat the procedure in step 4 (i.e. sample #2 to sample #101).
- **Step 6:** Repeat step 5 until the end of the data set and record the Power Spectral Density values for each of the 1 MHz segments.
- **Step 7:** For smart antenna systems repeat the measurement for each of the transmit ports. For each sampling point (frequency domain), add up the coincident power values (in mW) for the different transmit chains.
- **Step 8:** Record the highest value of the maximum Power Spectral Density for the UUT and compare it with the limit.

Test Result

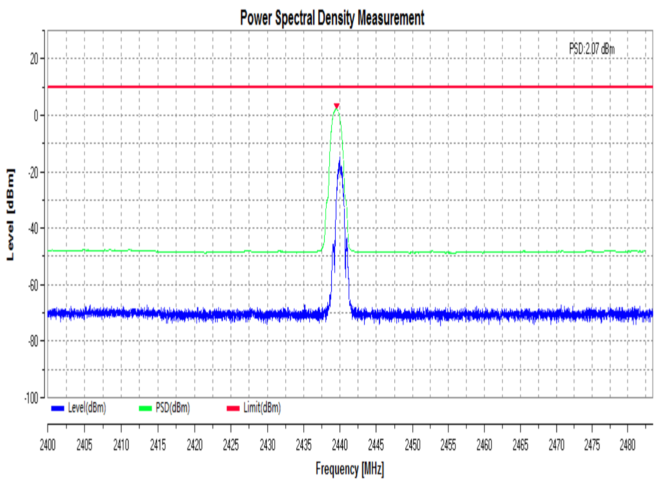
BLE				
Mode	Channel	Measured value (dBm/MHz)	Limit (dBm/MHz)	Result
GFSK	CH00	2.20	10.00	Pass
	CH19	2.07		
	CH39	1.57		

The test plots as follow:

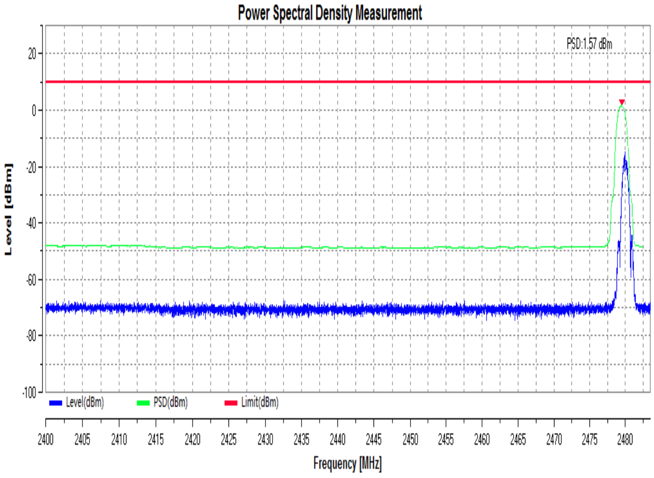
BLE GFSK



CH00



CH19


Power Spectral Density Measurement
PSD:1.57 dBm
Level [dBm]
Level(dBm)
PSD(dBm)
Limit(dBm)
Frequency [MHz]

CH39

3.3 Duty Cycle, Tx-sequence, Tx-gap

Limit

ETSI EN 300 328 (V2.1.1) Sub-clause 4.3.2.4.3

1. For non-adaptive FHSS equipment, the Duty Cycle shall be equal to or less than the maximum value declared by the supplier. In addition, the maximum Tx -sequence time shall be 5 ms while the minimum Tx-gap time shall be 5 ms.
2. For equipment using wide band modulations other than FHSS, the Duty Cycle shall be equal to or less than the maximum value declared by the supplier.
   The Tx-sequence time shall be equal to or less than 10 ms. The minimum Tx-gap time following a Tx-sequence shall be equal to the duration of that proceeding Tx-sequence with a minimum of 3,5 ms.

Test Procedure

The test procedure, which shall only be performed for non-adaptive systems, shall be as follows:

- **Step 1:** Use the same stored measurement samples from the procedure described in RF output power measurement
- **Step 2:** Between the saved start and stop times of each individual burst, calculate the TxOn time. Save these TxOn values.
- **Step 3:** Al TxOn times between the end of the first gap (which is the start of the first burst within the observation period) and the start of the last burst (within this observation period) divided by the observation period.
- **Step 4:**

  Identify any TxOff time that is equal to or greater than the minimum Tx-gap time. These are the potential valid gap times to be further considered in this procedure.

  Starting from the second identified gap, calculate the time from the start of this gap to the end of the preceding ap. This time is the Tx-sequence time for this transmission. Repeat this procedure until the last identified gap ithin the observation period is reached.

Test Results

Not applicable to this device which was adaptive equipment and cannot operate in a non-adaptive mode.

3.4 Medium Utilisation (MU) factor

Limit

ETSI EN 300 328 (V2.1.1) Sub-clause 4.3.2.5.3

The maximum Medium Utilisation factor for non-adaptive equipment shall be 10 %.

Definition

The Medium Utilisation (MU) factor is a measure to quantify the amount of resources (Power and Time) used by non-adaptive equipment. The Medium Utilisation factor is defined by the formula:

$$MU = (P/100\ mW) \times DC$$

Where: MU is Medium Utilisation factor in %.

P is the RF output power expressed in mW.

DC is the Duty Cycle expressed in %.

NOTE: The equipment may have dynamic behaviour with regard to duty cycle and corresponding power level.

Test Results

Not applicable to this device which cannot operation in a non-adaptive mode.

3.5 Occupied Channel Bandwidth

Limit

ETSI EN 300 328 (V2.1.1) Sub-clause 4.3.2.7.3

The Occupied Channel Bandwidth for each hopping frequency shall fall completely within the band 2.4GHz-2.4835GHz.

Test Procedure

1. The measurement shall be performed only on the lowest and the highest frequency within stated frequency range
2. The test procedure shall be follows:

Step1: Connect the UUT to the spectrum analyzer and use the following settings

Centre Frequency:	The centre frequency of the channel under test
Resolution BW:	~ 1% of the span without going below 1 %
Video BW:	3 × RBW
Frequency Span:	2 × Occupied Channel Bandwidth (e.g. 40 MHz for a 20 MHz channel)
Detector Mode:	RMS
Trace Mode:	MaxHold
Sweep time:	1s

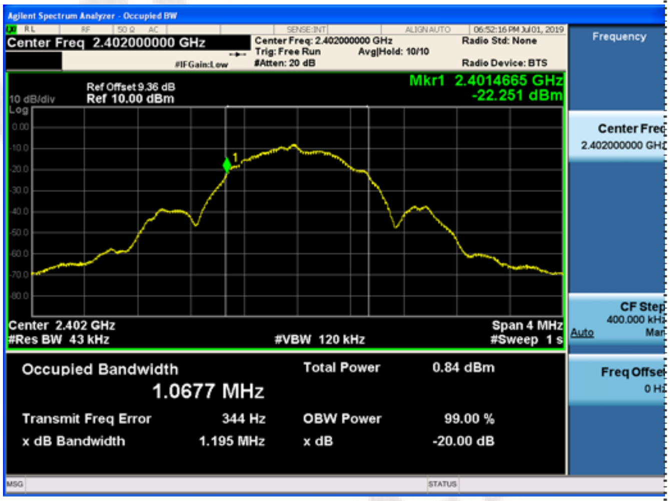
Step 2: Wait until the trace is completed. Find the peak value of the trace and place the analyzer marker on this peak.

Step 3: Use the 99 % bandwidth function of the spectrum analyzer to measure the Occupied Channel Bandwidth of the EUT.

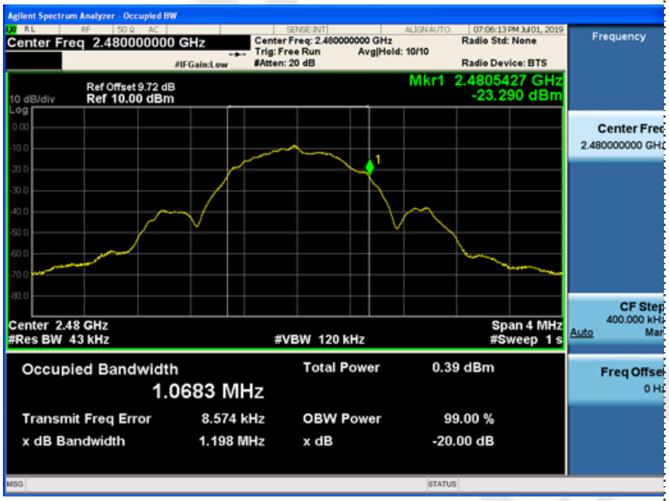
Test Result

Mode	Channel	Occupied Channel Bandwidth (MHz)	f_L (MHz)	f_H (MHz)	Limit	Result
GFSK	CH00	1.0677	2401.466	2480.543	$f_L \geqq$ 2.4GHz and $f_H \leqq$ 2.4835GHz	Pass
	CH39	1.0683				

GFSK



CH00



CH39

3.6 Transmitter unwanted emissions in the out-of-band domain

Limit

ETSI EN 300 328 (V2.1.1) Sub-clause 4.3.2.8.3

The transmitter unwanted emissions in the out-of-band domain but outside the allocated band, shall not exceed the values provided by the mask in figure 1.

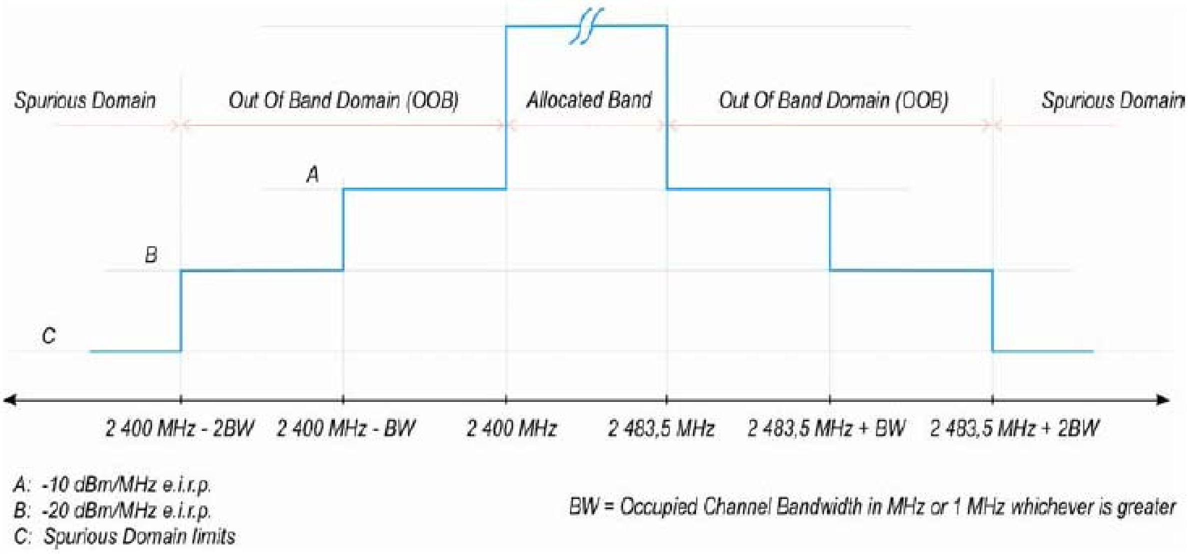


Figure 1: Transmit mask

Test Procedure

1. The measurements shall be performed at both normal environmental conditions and at the extremes of the operating temperature range.
2. For conducted measurements on devices with multiple transmit chains using the results for each of the transmit chains for the corresponding 1MHz segments shall be added and compared with the transmit mask limit.
3. The analyzer shall be set as follows:

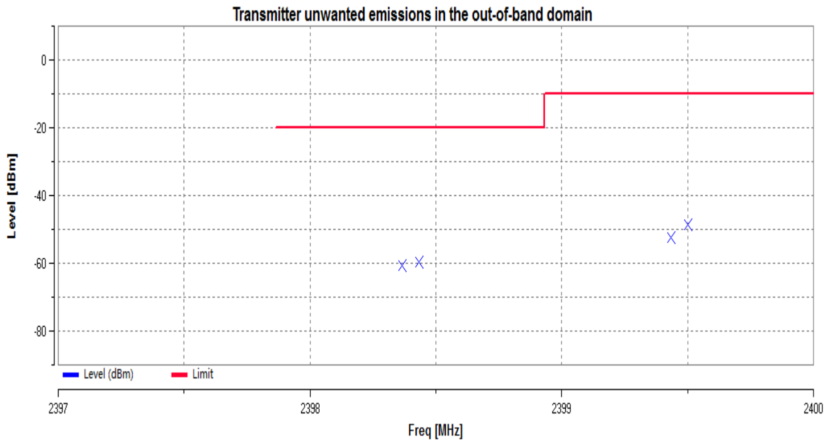
Centre Frequency:	Center of each segments
Frequency Span:	0 Hz
RBW:	1M
VBW:	3M
Filter mode:	Channel filter
Trace Mode:	Clear / Write
Detector Mode:	RMS
Number of sweep points:	5 000
Sweep mode:	Continuous
Trigger:	Video trigger
Sweep Time:	> 120 % of the duration of the longest burst detected

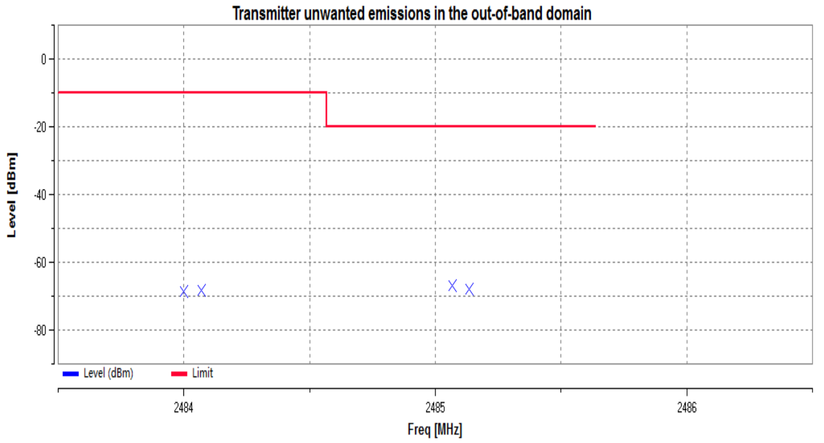
4. Save the value measured of each segments.

Test Result

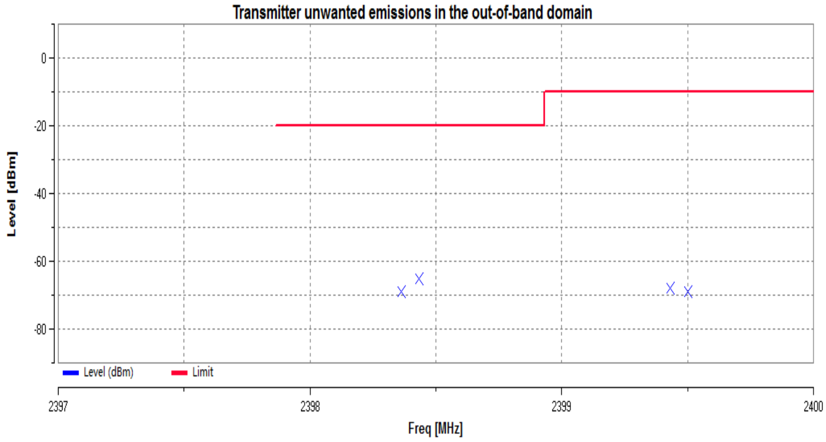
Remark: The datum recorded below represents the worst emission level in each segment and the plot for normal condition.

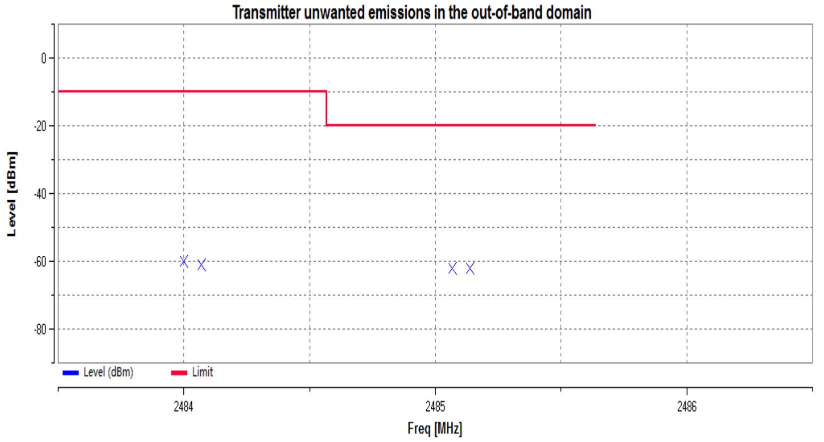
BLE GFSK CH00								
Test Condition			OOB Frequency (MHz)	Measured Level (dBm)	Antenna Gain (dBi)	Results (dBm)	Limit (dBm)	Result
BW (MHz)	Voltage (V)	Temperature (℃)						
1.0677	5.0	25	2398.432	-59.64	0.00	-59.64	-20	PASS
			2399.500	-48.52	0.00	-48.52	-10	PASS
			2484.068	-68.39	0.00	-68.39	-10	PASS
			2485.068	-66.86	0.00	-66.86	-20	PASS





BLE GFSK CH39								
Test Condition			OOB Frequency (MHz)	Measured Level (dBm)	Antenna Gain (dBi)	Results (dBm)	Limit (dBm)	Result
BW (MHz)	Voltage (V)	Temperature (℃)						
1.0683	5.0	25	2398.432	-65.18	0.00	-65.18	-20	PASS
			2399.432	-67.91	0.00	-67.91	-10	PASS
			2484.000	-59.94	0.00	-59.94	-10	PASS
			2485.068	-62.18	0.00	-62.18	-20	PASS





3.7 Transmitter unwanted emissions in the spurious domain

Limit

ETSI EN 300 328 (V2.1.1) Sub-clause 4.3.2.9.3

The transmitter unwanted emissions in the spurious domain shall not exceed the values given in table

Table 1: Transmitter limits for spurious emissions

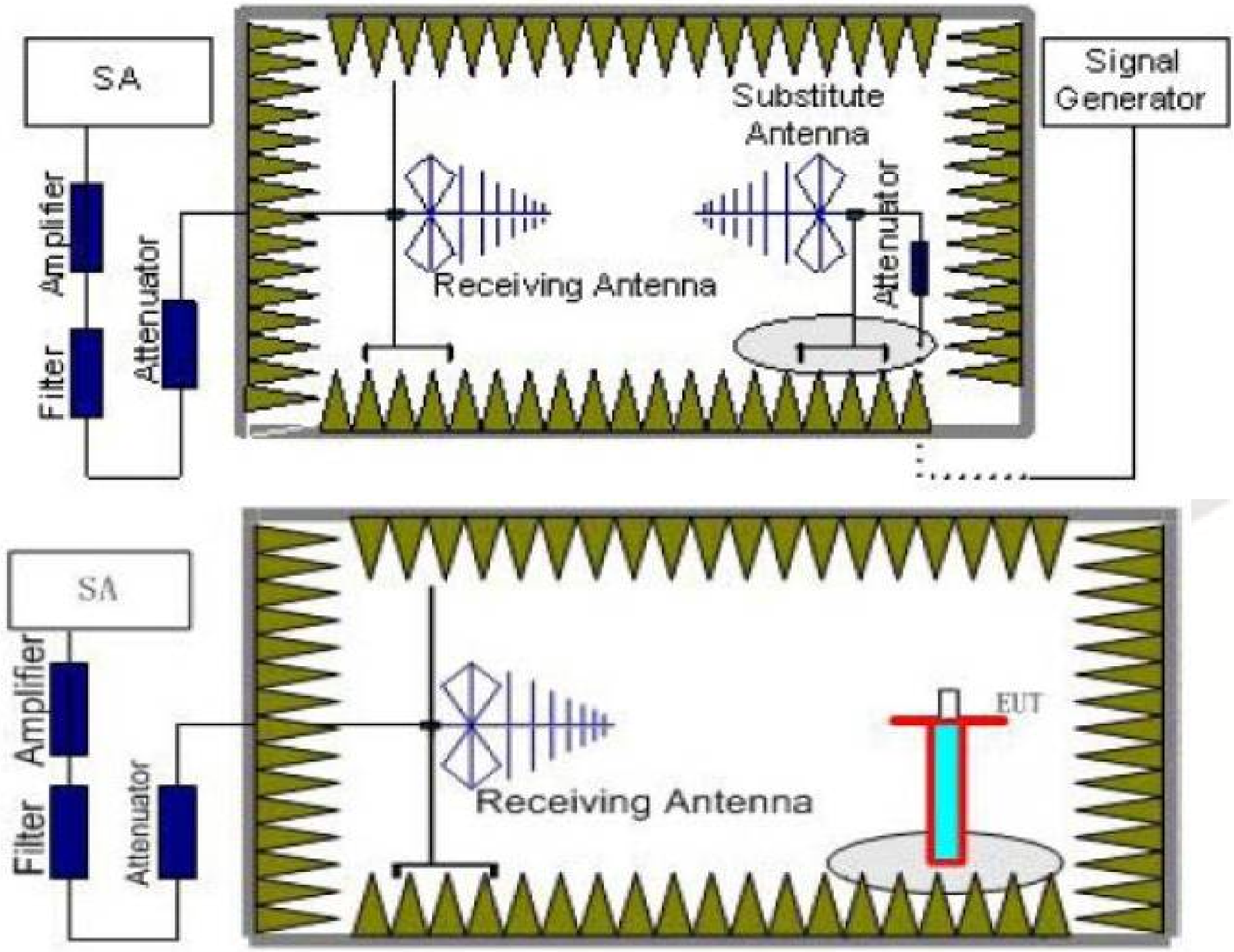
Frequency Range	Maximum power e.r.p.(≤1 GHz) e.i.r.p.(＞1 GHz)	Bandwidth
30 MHz to 47 MHz	-36 dBm	100 KHz
47 MHz to 74 MHz	-54 dBm	100 KHz
74MHz to 87.5 MHz	-36 dBm	100 KHz
87.5 MHz to 118 MHz	-54 dBm	100 KHz
118 MHz to 174 MHz	-36 dBm	100 KHz
174 MHz to 230 MHz	-54 dBm	100 KHz
230 MHz to 470 MHz	-36 dBm	100 KHz
470 MHz to 862 MHz	-54 dBm	100 KHz
862 MHz to 1 GHz	-36 dBm	100 KHz
1 GHz to 12.75 GHz	-30 dBm	1 MHz

Test Procedure

1. The measurement performed at the lowest and the highest channel on which the equipment can operate.
2. The EUT was placed on a turntable with 1.5m height.
3. The test distance between the receiving antenna and the EUT is 3 meter, while the receiving (test) antenna is kept at 1.5 meter height.
4. Set EUT in continuous transmitting with maximum output power.
5. The table was rotated from 0 to 360 degree to search the highest radiated emission.
6. Repeat step 3 to 5 for each polarization and channel to find the worst emission level.
7. The results obtained are compared to the limits in order to prove compliance with the requirement.

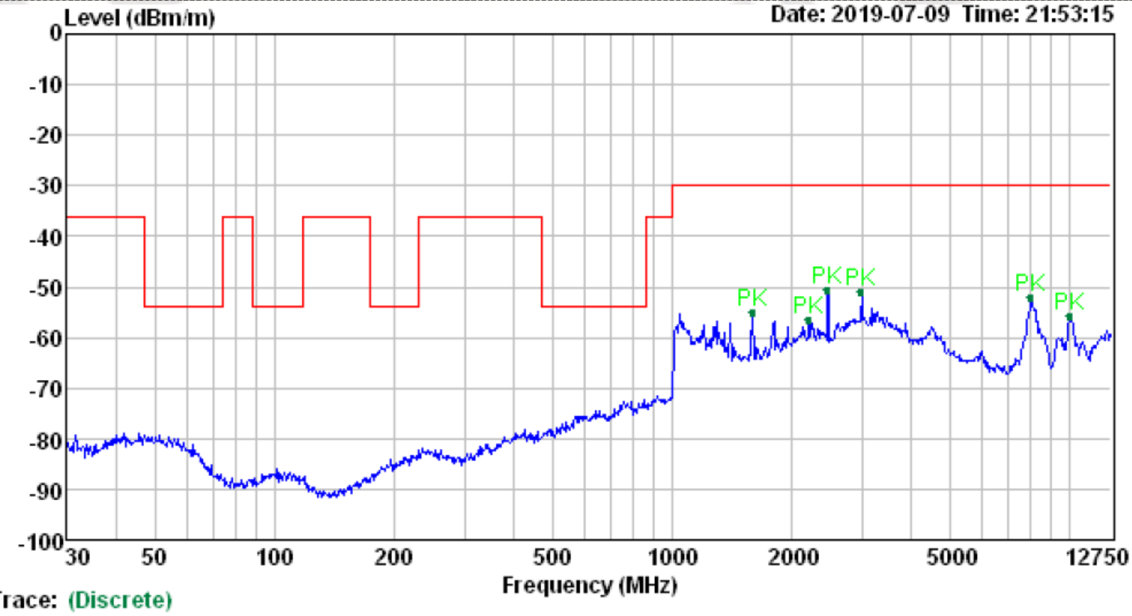
Test Configuration

Effective Radiated Power measurement (30 MHz to 12.75 GHz)



Test Results

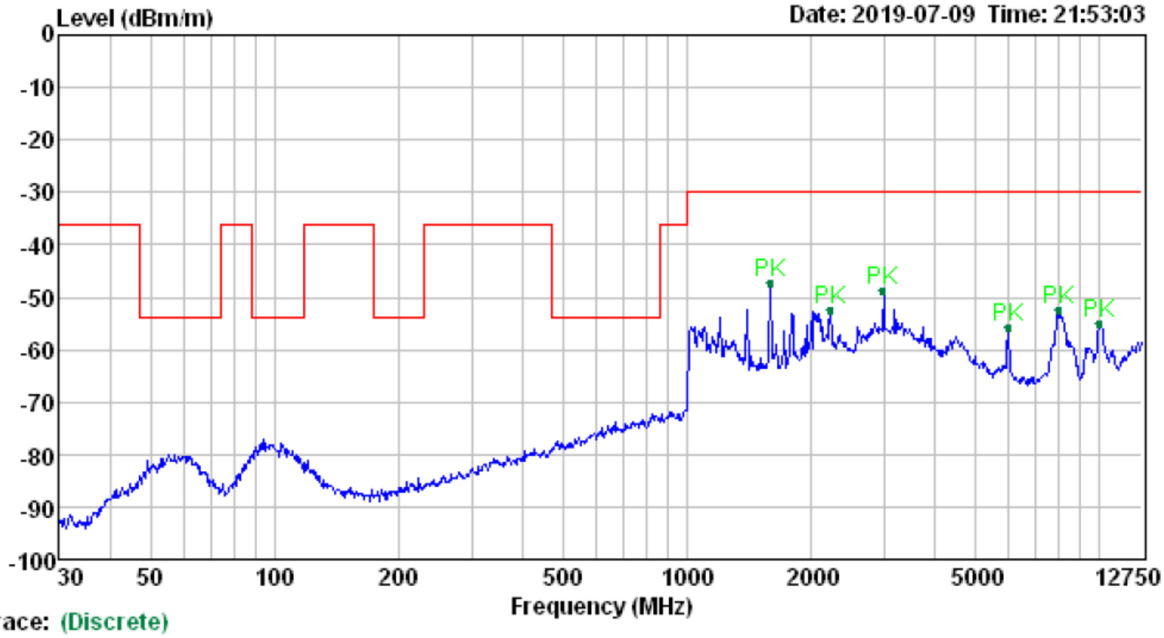
BLE GFSK			
Channel:	CH00	Polarity:	Horizontal



Trace: (Discrete)

Mark	Freq MHz	RD dBm	C.F dB	Result dBm	Limit dBm	Margin dB	Det.	Polarity
1	1594.94	-46.93	-7.92	-54.85	-30.00	24.85	Peak	HORIZONTAL
2	2199.45	-53.33	-3.27	-56.60	-30.00	26.60	Peak	HORIZONTAL
3	2466.95	-49.47	-1.00	-50.47	-30.00	20.47	Peak	HORIZONTAL
4	2994.64	-51.47	0.56	-50.91	-30.00	20.91	Peak	HORIZONTAL
5	8015.14	-60.44	8.30	-52.14	-30.00	22.14	Peak	HORIZONTAL
6	10006.45	-65.68	9.80	-55.88	-30.00	25.88	Peak	HORIZONTAL

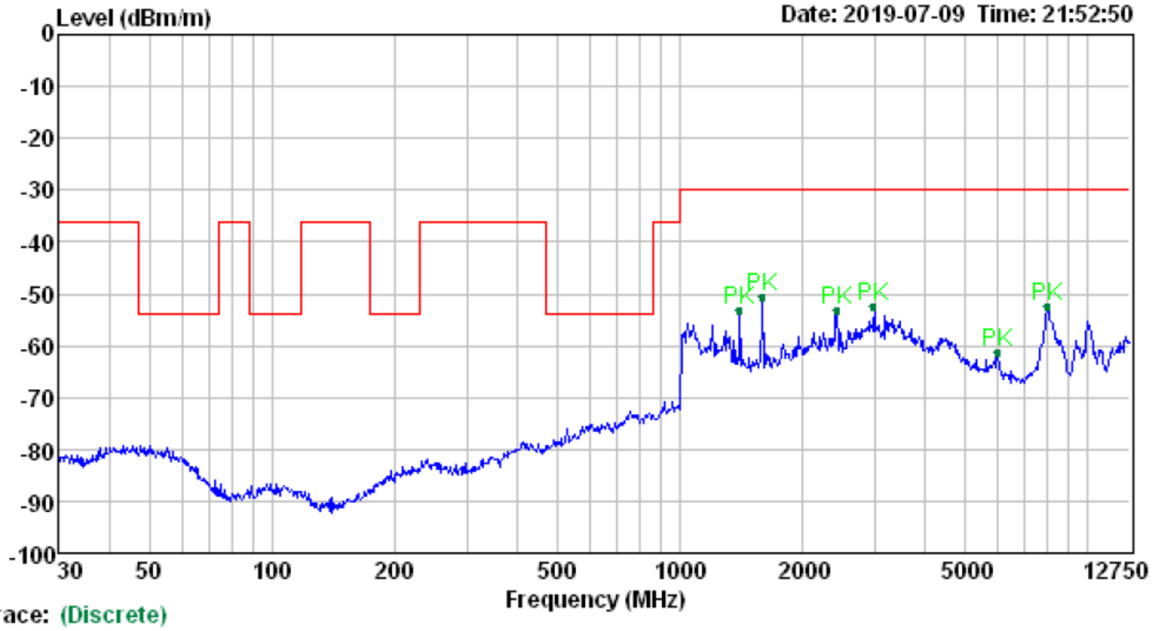
Channel:	CH00	Polarity:	Vertical



Trace: (Discrete)

Mark	Freq MHz	RD dBm	C.F dB	Result dBm	Limit dBm	Margin dB	Det.	Polarity
1	1599.02	-39.16	-7.90	-47.06	-30.00	17.06	Peak	VERTICAL
2	2216.34	-49.43	-3.14	-52.57	-30.00	22.57	Peak	VERTICAL
3	2994.64	-49.37	0.56	-48.81	-30.00	18.81	Peak	VERTICAL
4	5992.87	-51.60	-4.10	-55.70	-30.00	25.70	Peak	VERTICAL
5	8015.14	-60.71	8.30	-52.41	-30.00	22.41	Peak	VERTICAL
6	10006.45	-64.92	9.80	-55.12	-30.00	25.12	Peak	VERTICAL

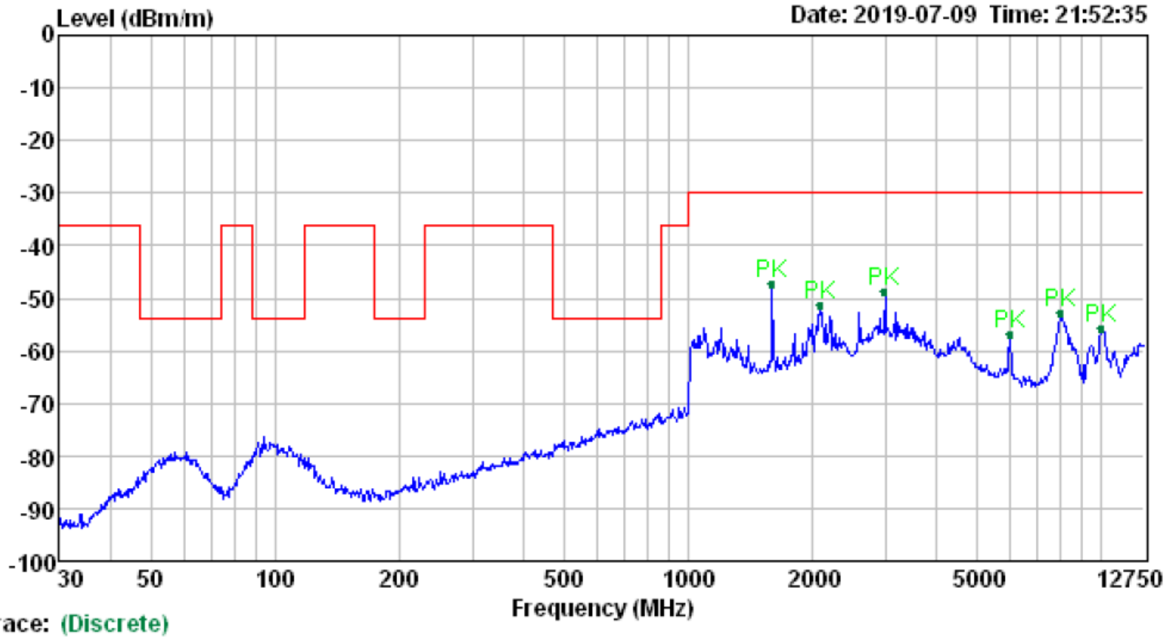
BLE GFSK			
Channel:	CH39	Polarity:	Horizontal



Trace: (Discrete)

Mark	Freq MHz	RD dBm	C.F dB	Result dBm	Limit dBm	Margin dB	Det.	Polarity
1	1396.84	-45.34	-7.68	-53.02	-30.00	23.02	Peak	HORIZONTAL
2	1594.94	-42.45	-7.92	-50.37	-30.00	20.37	Peak	HORIZONTAL
3	2417.12	-51.95	-1.33	-53.28	-30.00	23.28	Peak	HORIZONTAL
4	2994.64	-53.00	0.56	-52.44	-30.00	22.44	Peak	HORIZONTAL
5	6008.17	-57.32	-4.06	-61.38	-30.00	31.38	Peak	HORIZONTAL
6	8015.14	-60.86	8.30	-52.56	-30.00	22.56	Peak	HORIZONTAL

Channel:	CH39	Polarity:	Vertical



Trace: (Discrete)

Mark	Freq MHz	RD dBm	C.F dB	Result dBm	Limit dBm	Margin dB	Det.	Polarity
1	1594.94	-39.18	-7.92	-47.10	-30.00	17.10	Peak	VERTICAL
2	2079.43	-47.23	-3.89	-51.12	-30.00	21.12	Peak	VERTICAL
3	2994.64	-49.28	0.56	-48.72	-30.00	18.72	Peak	VERTICAL
4	5992.87	-52.54	-4.10	-56.64	-30.00	26.64	Peak	VERTICAL
5	8015.14	-60.99	8.30	-52.69	-30.00	22.69	Peak	VERTICAL
6	10006.45	-65.48	9.80	-55.68	-30.00	25.68	Peak	VERTICAL

3.8 Receiver spurious emissions

LIMIT

ETSI EN 300 328 (V2.1.1) Sub-clause 4.3.2.10.3

The spurious emissions of the receiver shall not exceed the values given below:

Spurious emission limits for receivers

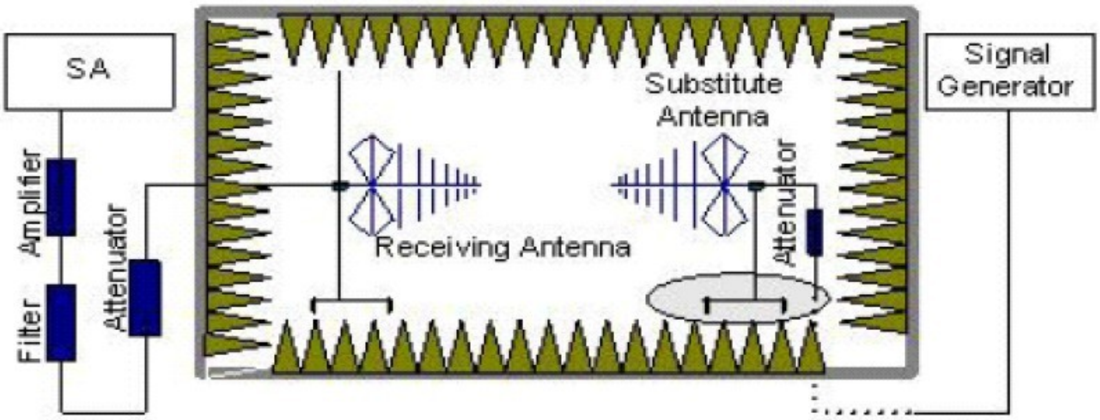
Frequency	Maximum power, e.r.p.	Measurement bandwidth
30 MHz to 1 GHz	-57 dBm	100 KHz
30 MHz to 12.75 GHz	-47 dBm	1 MHz

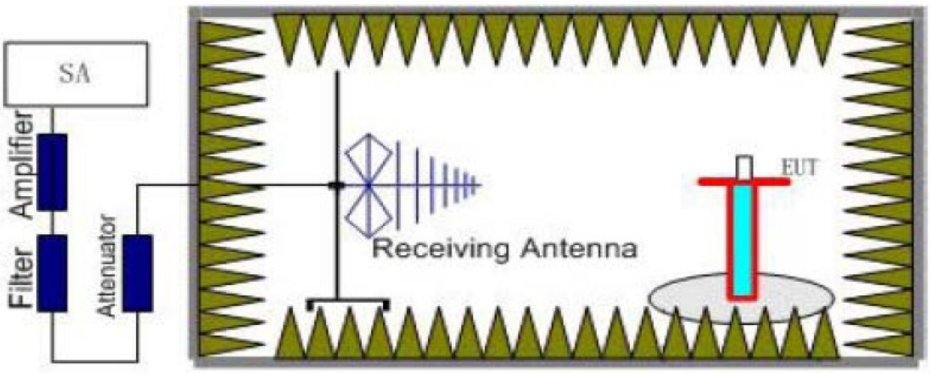
Test Procedure

The same as clause 3.7

Test Configuration

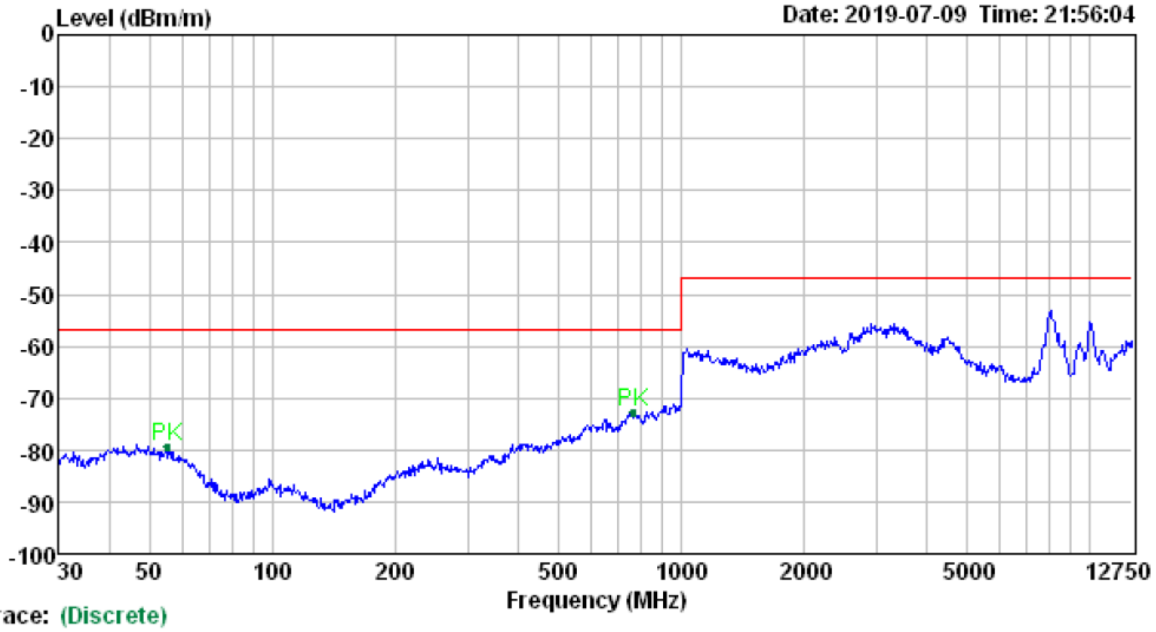
Effective Radiated Power measurement (30 MHz to 12.75 GHz)





Test Results

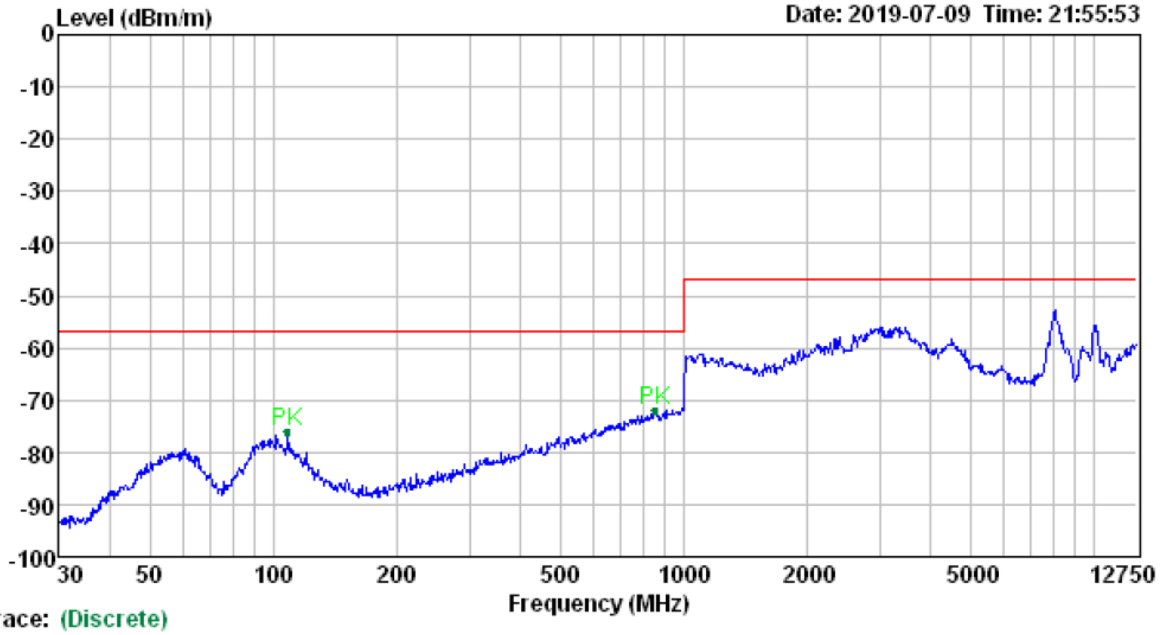
BLE GFSK			
Channel:	CH00	Polarity:	Horizontal



Trace: (Discrete)

Mark	Freq MHz	RD dBm	C.F dB	Result dBm	Limit dBm	Margin dB	Det.	Polarity
1	55.03	-78.14	-1.19	-79.33	-57.00	22.33	Peak	HORIZONTAL
2	760.70	-78.28	5.56	-72.72	-57.00	15.72	Peak	HORIZONTAL

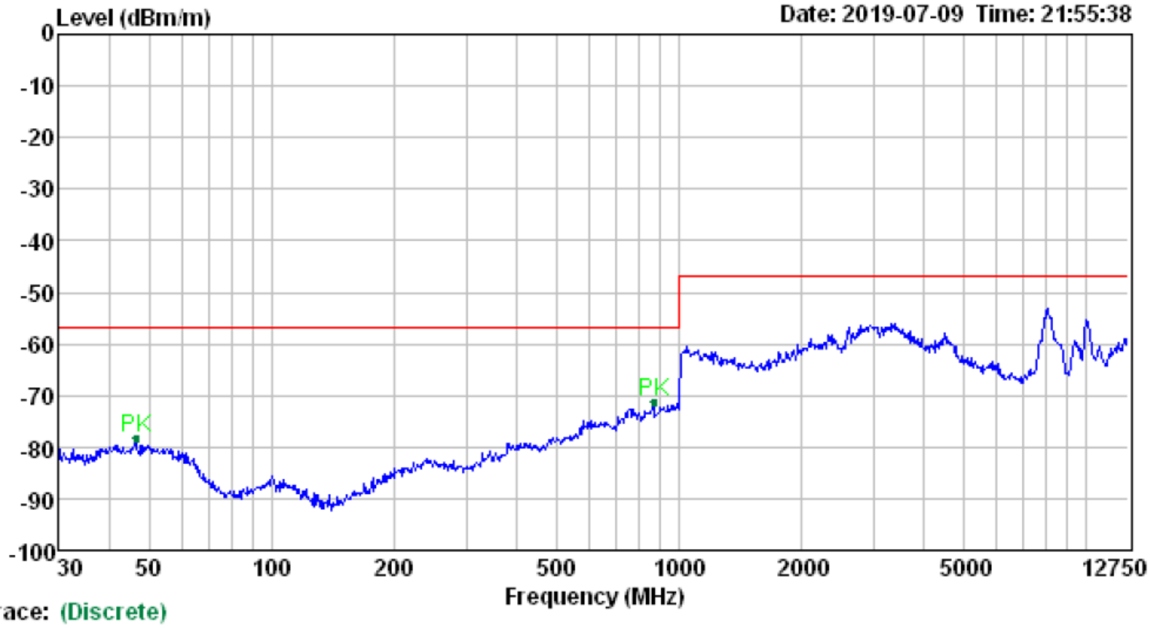
Channel:	CH00	Polarity:	Vertical



Trace: (Discrete)

Mark	Freq MHz	RD dBm	C.F dB	Result dBm	Limit dBm	Margin dB	Det.	Polarity
1	107.89	-75.81	-0.07	-75.88	-57.00	18.88	Peak	VERTICAL
2	851.04	-78.00	5.98	-72.02	-57.00	15.02	Peak	VERTICAL

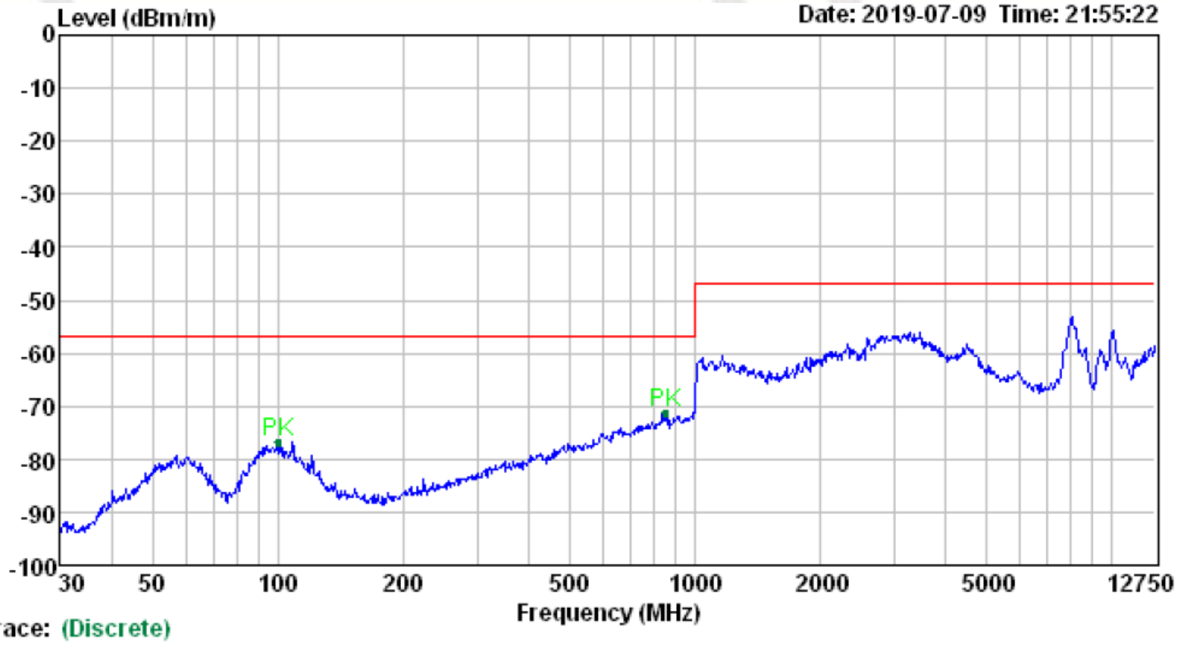
BLE GFSK			
Channel:	*CH39*	*Polarity:*	*Horizontal*



Trace: (Discrete)

Mark	Freq MHz	RD dBm	C.F dB	Result dBm	Limit dBm	Margin dB	Det.	Polarity
1	46.34	-77.71	-0.45	-78.16	-57.00	21.16	Peak	HORIZONTAL
2	866.09	-76.84	5.69	-71.15	-57.00	14.15	Peak	HORIZONTAL

Channel:	*CH39*	*Polarity:*	*Vertical*



Trace: (Discrete)

Mark	Freq MHz	RD dBm	C.F dB	Result dBm	Limit dBm	Margin dB	Det.	Polarity
1	100.23	-77.76	1.07	-76.69	-57.00	19.69	Peak	VERTICAL
2	851.04	-77.25	5.98	-71.27	-57.00	14.27	Peak	VERTICAL

3.9 Adaptivity

Limits

For Requirements and Limits please refer to ETSI EN 300 328 V2.1.1 Sub - clause 4.3.2.6.2.2 & 4.3.2.6.3.2.

Test Procedure

1. The measurement procedure follows the clause 5.4.6.2.1 of the ETSI EN 300 328 V2.1.1 (2016-03).
2. For conducted measurements on device with multiple transmit chains and receive chains. The power splitter/combiner shall be used to combine all the transmit/receive chains (antenna outputs) into a single test point. The insertion loss of the power splitter/combiner shall be taken into account.
3. Interference signal shall be a100 % duty cycle interference signal is injected on the current operating channel of the UUT. This interference signal shall meet the requirements as follow:

   The 99 % bandwidth (the bandwidth containing 99 % of the power) of this inference signal shall be within a range from 120 % to 200 % of the Occupied Channel Bandwidth of the UUT with a minimum of 5 MHz, while the difference between the lowest and highest level within the Occupied Channel Bandwidth of the UUT shall be maximum 4 dB.
4. Blocking signal shell be a 100 % duty cycle CW signal, and The frequency and level shell be set as follow:

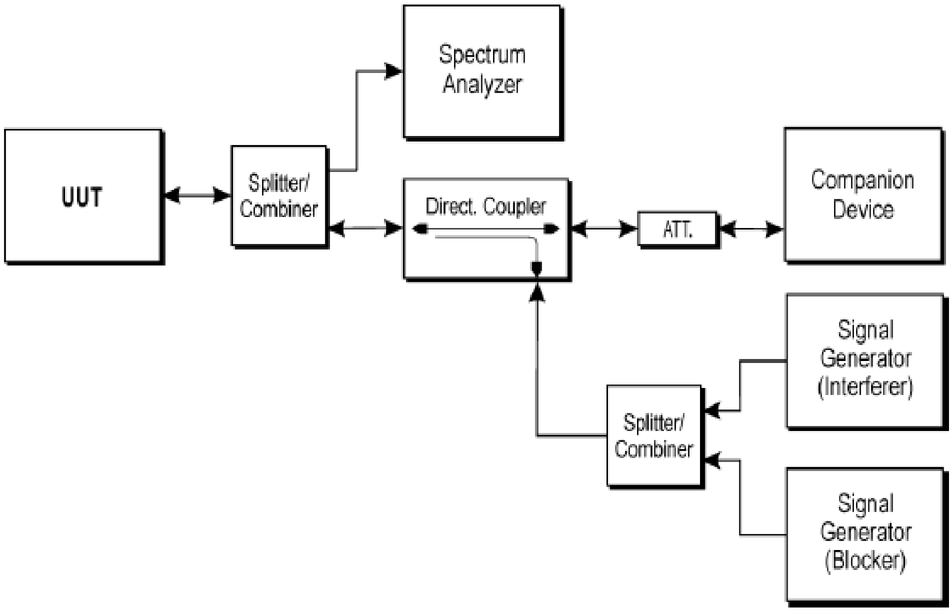
Equipment Type (LBT / non- LBT)	Wanted signal mean power from companion device	Blocking signal frequency [MHz]	Blocking signal power [dBm]	Type of interfering signal
LBT	sufficient to maintain the link (see note 2)	2 395 or 2 488,5 (see note 1)	-35	CW
Non-LBT	-30 dB			

NOTE 1: The highest frequency shall be used for testing operating channels within the range 2 400 MHz to 2 442 MHz, while the lowest frequency shall be used for testing operating channels within the range 2 442 MHz to 2 483,5 MHz.

NOTE 2: A typical value which can be used in most cases is-50 dBm/MHz.

5. The test not applicable to none-adaptive equipment and adaptive equipment which maximum RF Output power level is less than 10 dBm e.i.r.p.

Test Configuration



Test Results

Not applicable to this device which maximum RF Output power level is less than 10 dBm e.i.r.p.

3.10 Receiver Blocking

Limits

While maintaining the minimum performance criteria (The minimum performance criterion shall be a PER less than or equal to 10 %. The manufacturer may declare alternative performance criteria as long as that is appropriate for the intended use of the equipment), the blocking levels at specified frequency offsets shall be equal to or greater than the limits defined for the applicable receiver category provided in below:

Receiver blocking parameters for Receiver Category 1 equipment

Wanted signal mean power from companion device (dBm)	Blocking signal frequency (MHz)	Blocking signal power (dBm)	Type of blocking signal
P_{min} + 6 dB	2 380 2 503,5	-53	CW
P_{min} + 6 dB	2 300 2 330 2 360	-47	CW
P_{min} + 6 dB	2 523,5 2 553,5 2 583,5 2 613,5 2 643,5 2 673,5	-47	CW
NOTE: P_{min} is the minimum level of wanted signal (in dBm) required to meet the minimum performance criteria as defined in clause 4.3.1.12.3 and/or 4.3.2.11.3 in the absence of any blocking signal.			

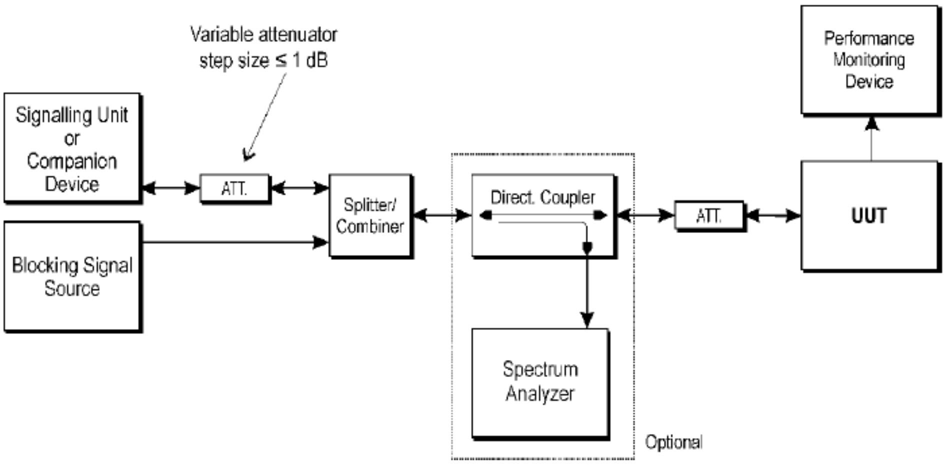
Receiver blocking parameters receiver category 2 equipment

Wanted signal mean power from companion device (dBm)	Blocking signal frequency (MHz)	Blocking signal power (dBm)	Type of blocking signal
P_{min} + 6 dB	2 380 2 503,5	-57	CW
P_{min} + 6 dB	2 300 2 583,5	-47	CW
NOTE: P_{min} is the minimum level of wanted signal (in dBm) required to meet the minimum performance criteria as defined in clause 4.3.1.12.3 and/or 4.3.2.11.3 in the absence of any blocking signal.			

Receiver blocking parameters receiver category 3 equipment

Wanted signal mean power from companion device (dBm)	Blocking signal frequency (MHz)	Blocking signal power (dBm)	Type of blocking signal
P_{min} + 12 dB	2 380 2 503,5	-57	CW
P_{min} + 12 dB	2 300 2 583,5	-47	CW
NOTE: P_{min} is the minimum level of wanted signal (in dBm) required to meet the minimum performance criteria as defined in clause 4.3.1.12.3 and/or 4.3.2.11.3 in the absence of any blocking signal.			

Test Configuration



Test Procedure

1. For systems using multiple receive chains only one chain (antenna port) need to be tested. All other receiver inputs shall be terminated.
2. For non-frequency hopping equipment, the UUT shall be set to the lowest operating channel.
3. The blocking signal generator is set to the first frequency as defined in the appropriate table corresponding to the receiver category and type of equipment.
4. With the blocking signal generator switched off, a communication link is established between the UUT and the associated companion device. The variable attenuator is set to a value that achieves the minimum performance criteria with a resolution of at least 1 dB. The resulting level for the wanted signal at the input of the UUT is P_{min}. This value shall be measured and recorded in the test report.
5. The signal level is increased by the value provided in the table corresponding to the receiver category and type of equipment.
6. The blocking signal at the UUT is set to the level provided in the table corresponding to the receiver category and type of equipment. It shall be verified and recorded in the test report that the performance criteria is met.
7. Repeat step 6 for each remaining combination of frequency and level for the blocking signal as provided in the table corresponding to the receiver category and type of equipment.
8. For non-frequency hopping equipment, repeat step 2 to step 7 with the UUT operating at the highest operating channel.

<u>**Test result**</u>

Remark:

1. *According to the Power measurement the device belongs to Receiver category 2.*
2. *With the blocking signal generator switched off, adjust variable attenuator value by 1dB until to communication once cannot maintains. Then replace EUT by a power sensor, measure the power and recorded as $P_{min.}$*

Test Frequency (MHz)	Wanted signal mean power from companion device (dBm)	Blocking signal frequency (MHz)	Blocking signal power (dBm)	PER
2402	P_{min} + 6dB	2380	-57	4.3%
	P_{min} + 6dB	2503.5	-57	4.2%
	P_{min} + 6dB	2300	-47	5.0%
	P_{min} + 6dB	2583.5	-47	4.6%
2480	P_{min} + 6dB	2380	-57	4.7%
	P_{min} + 6dB	2503.5	-57	5.1%
	P_{min} + 6dB	2300	-47	4.8%
	P_{min} + 6dB	2583.5	-47	5.1%

Note: P_{min}=-66dBm

4 Test Setup Photos of the EUT

5 External and Internal Photos of the EUT

Reference to the test report No. CTL1906244051-WE

********************** End of Report **********************

6 ANNEX E

Information as required by EN 300 328 V2.1.1, clause 5.4.1

In accordance with EN 300 328, clause 5.4.1, the following information is provided by the supplier.

a) The type of modulation used by the equipment:

☒FHSS
☐Other forms of modulation

b) In case of FHSS modulation:

- In case of non-Adaptive Frequency Hopping equipment:
  The number of Hopping Frequencies:
- In case of Adaptive Frequency Hopping Equipment:
  The maximum number of Hopping Frequencies: 79
  The minimum number of Hopping Frequencies: 15
- The (average) Dwell Time: 3.75ms

c) Adaptive / non-adaptive equipment:

☐Non-adaptive Equipment
☒Adaptive Equipment without the possibility to switch to a non-adaptive mode
☐Adaptive Equipment which can also operate in a non-adaptive mode

d) In case of adaptive equipment:

The Channel Occupancy Time implemented by the equipment: ms
☒The equipment has implemented an LBT based DAA mechanism

- In case of equipment using modulation different from FHSS:
  ☐The equipment is Frame Based equipment
  ☒The equipment is Load Based equipment
  ☐The equipment can switch dynamically between Frame Based and Load Based equipment
  The CCA time implemented by the equipment:

☐The equipment has implemented an non-LBT based DAA mechanism
☐The equipment can operate in more than one adaptive mode

e) In case of non-adaptive Equipment:

The maximum RF Output Power (e.i.r.p.): dBm
The maximum (corresponding) Duty Cycle: %
Equipment with dynamic behaviour, that behaviour is described here. (e.g. the different combinations of duty cycle and corresponding power levels to be declared):

f) The worst case operational mode for each of the following tests:

- RF Output Power
  BLE
- Power Spectral Density
  BLE
- Duty cycle, Tx-Sequence, Tx-gap
  N/A
- Dwell time, Minimum Frequency Occupation & Hopping Sequence (only for FHSS equipment)
  N/A
- Hopping Frequency Separation (only for FHSS equipment)
  N/A
- Medium Utilisation
  N/A
- Adaptivity
  N/A
- Occupied Channel Bandwidth

BLE

- Transmitter unwanted emissions in the OOB domain

  BLE

- Transmitter unwanted emissions in the spurious domain

  BLE

- Receiver spurious emissions

  BLE

- Receiver Blocking

  BLE

g) The different transmit operating modes (tick all that apply):

☒Operating mode 1: Single Antenna Equipment

☒Equipment with only 1 antenna

☐Equipment with 2 diversity antennas but only 1 antenna active at any moment in time

☐Smart Antenna Systems with 2 or more antennas, but operating in a (legacy) mode where only 1 antenna is used. (e.g. IEEE 802.11™ [i.3] legacy mode in smart antenna systems)

☐Operating mode 2: Smart Antenna Systems - Multiple Antennas without beam forming

☐Single spatial stream / Standard throughput / (e.g. IEEE 802.11™ [i.3] legacy mode)

☐High Throughput (> 1 spatial stream) using Occupied Channel Bandwidth 1

☐High Throughput (> 1 spatial stream) using Occupied Channel Bandwidth 2

☐Operating mode 3: Smart Antenna Systems - Multiple Antennas with beam forming

☐Single spatial stream / Standard throughput (e.g. IEEE 802.11™ [i.3] legacy mode)

☐High Throughput (> 1 spatial stream) using Occupied Channel Bandwidth 1

☐High Throughput (> 1 spatial stream) using Occupied Channel Bandwidth 2

h) In case of Smart Antenna Systems:

- The number of Receive chains:
- The number of Transmit chains:

☐Symmetrical power distribution

☐Asymmetrical power distribution

In case of beam forming, the maximum (additional) beam forming gain:

i) Operating Frequency Range(s) of the equipment:

- Operating Frequency Range 1: 2402MHz to2480MHz
- Operating Frequency Range 2: MHz to MHz

NOTE: Add more lines if more Frequency Ranges are supported.

j) Occupied Channel Bandwidth(s):

- Occupied Channel Bandwidth 1: 2MHz
- Occupied Channel Bandwidth 2: MHz

k) Type of Equipment (stand-alone, combined, plug-in radio device, etc.):

☒Stand-alone

☐Combined Equipment (Equipment where the radio part is fully integrated within another type of equipment)

☐Plug-in radio device (Equipment intended for a variety of host systems)

☐Other

l) The extreme operating conditions that apply to the equipment:

Operating temperature range: -20° C to +55° C

Operating voltage range: 4.25V to 5.75V ☐AC ☒DC

Details provided are for the: ☒stand-alone equipment

☐Combined (or host) equipment

☐Test jig

m) The intended combination(s) of the radio equipment power settings and one or more antenna assemblies and their corresponding e.i.r.p levels:

- Antenna Type:

☒ Snap Antenna

Antenna Gain: 1.5dBi

If applicable, additional beamforming gain (excluding basic antenna gain): dB

☒Temporary RF connector provided

☐No temporary RF connector provided

☐Dedicated Antennas (equipment with antenna connector)

☐Single power level with corresponding antenna(s)

☐Multiple power settings and corresponding antenna(s)

Number of different Power Levels:

Power Level 1:		dBm
Power Level 2:		dBm
Power Level 3:		dBm

n) For each of the Power Levels, provide the intended antenna assemblies, their corresponding gains (G) and the resulting e.i.r.p. levels also taking into account the beamforming gain (Y) if applicable

Power Level 1: dBm

Number of antenna assemblies provided for this power level:

Assembly #	Gain (dBi)	e.i.r.p. (dBm)	Part number or model name
1			
2			
3			
4			

Power Level 2: dBm

Number of antenna assemblies provided for this power level:

Assembly #	Gain (dBi)	e.i.r.p. (dBm)	Part number or model name
1			
2			
3			
4			

Power Level 3: dBm

Number of antenna assemblies provided for this power level:

Assembly #	Gain (dBi)	e.i.r.p. (dBm)	Part number or model name
1			
2			
3			
4			

o) The nominal voltages of the stand-alone radio equipment or the nominal voltages of the combined (host) equipment or test jig in case of plug-in devices:

Details provided are for the: ☒stand-alone equipment
☐combined (or host) equipment
☐test jig

Supply Voltage ☐AC mains State AC voltage V
☒DC State DC voltage 5.0V

In case of DC, indicate the type of power source
☐Internal Power Supply
☒External Power Supply or AC/DC adapter
☐Battery
☐Other: DC 5V from PC

p) Describe the test modes available which can facilitate testing:

q) The equipment type (e.g. Bluetooth®, IEEE 802.11™ [i.3], proprietary, etc.):
Bluetooth®

r) Geo-location capability supported by the equipment:
☐Yes
☐The geographical location determined by the equipment as defined in clause 4.3.1.13.2 or clause 4.3.2.12.2 is not accessible to the user
☒No

s) Describe the minimum performance criteria that apply to the equipment (see clause 4.3.1.12.3 or clause 4.3.2.11.3):
N/A