ETSI EN 300 328 V2.2.2 (2019-07)

TEST REPORT

For

ESPRESSIF SYSTEMS (SHANGHAI) CO., LTD

Suite 204, Block 2, 690 Bibo Road, Zhang Jiang Hi-Tech Park, Shanghai, China

Tested Model: ESP32-WROOM-32E

Report Type: Original Report	Product Type: Wi-Fi & Bluetooth Internet of Things Module
Test Engineer:	Chao Gao
Report Number:	RSHD200218007-01C
Report Date:	2020-04-02
Reviewed By:	Oscar Ye EMC Manager
Prepared By:	Bay Area Compliance Laboratories Corp. (Kunshan) No.248 Chenghu Road, Kunshan, Jiangsu province, China Tel: +86-0512-86175000 Fax: +86-0512-88934268 www.baclcorp.com.cn

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GENERAL INFORMATION

Product Description for Equipment under Test (EUT)

Applicant:	ESPRESSIF SYSTEMS (SHANGHAI) CO., LTD
Product Type:	Wi-Fi & Bluetooth Internet of Things Module
Tested Model:	ESP32-WROOM-32E
Power Supply:	DC 3.3V
RF Function:	Classic BT
Operating Band/Frequency:	2402-2480MHz
Channel Number:	79
Channel Separation:	1MHz
Modulation Type:	GFSK, π/4-DQPSK, 8-DPSK
Antenna Type:	PCB antenna
Maximum Antenna Gain:	3.4 dBi

All measurement and test data in this report was gathered from production sample serial number: 20200218007. (Assigned by the BACL. The EUT supplied by the applicant was received on 2020-02-18)

Objective

This report is prepared on behalf of *ESPRESSIF SYSTEMS (SHANGHAI) CO., LTD* in accordance with ETSI EN 300 328 V2.2.2 (2019-07), 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 Directive 2014/53/EU

The objective is to determine the compliance of EUT with ETSI EN 300 328 V2.2.2 (2019-07).

Related Submittal(s)/Grant(s)

No related submittal(s).

Test Methodology

All measurements contained in this report were conducted with ETSI EN 300 328 V2.2.2 (2019-07).

Measurement Uncertainty

Item		Uncertainty
RF Output Power with Power meter		0.5dB
Power Spectral Density, conducted		0.5dB
Unwanted Emissions, conducted		2.34 dB
Radiated emission	30MHz~1GHz	5.91dB
	1GHz~6GHz	4.68dB
	6 GHz ~18 GHz	4.92dB
	18 GHz~40 GHz	5.21dB
Occupied Bandwidth		0.5kHz
Temperature		1.0℃
Humidity		6%
Time		5 %
Supply voltages		0.04%

Otherwise required by the applicant or Product Regulations, Decision Rule in this report did not consider the uncertainty.

Test Facility

The test site used by Bay Area Compliance Laboratories Corp. (Kunshan) to collect test data is located on the No.248 Chenghu Road,Kunshan,Jiangsu province,China.

Bay Area Compliance Laboratories Corp. (Kunshan) Lab is accredited to ISO/IEC 17025 by A2LA (Lab code: 4323.01) and the FCC designation No. CN1185 under the FCC KDB 974614 D01. The facility also complies with the radiated and AC line conducted test site criteria set forth in ANSI C63.4-2014.

SYSTEM TEST CONFIGURATION

Description of Test Configuration

Channel list:

Channel	Frequency (MHz)	Channel	Frequency (MHz)
0	2402	40	2442
1	2403	…	…
2	2404	…	…
…	…	…	…
…	…	78	2480
39	2441	/	/

EUT was tested with Channel 0, 39 and 78.

EUT Exercise Software

RF Test Tool: ESP32

Mode	Power level
GFSK	6
π/4-DQPSK	6
8DPSK	6

Special Accessories

No special accessory.

Equipment Modifications

No modification was made to the EUT.

Support Equipment List and Details

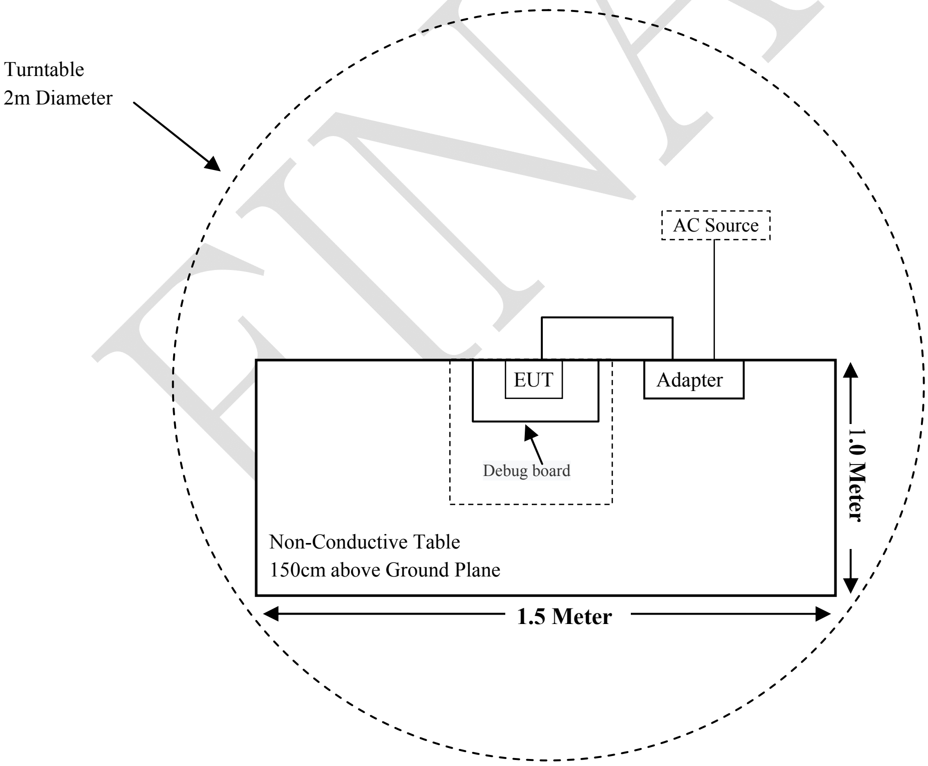
Manufacturer	Description	Model	Serial Number
Something High Electric (Xiamen) Company Inc.	Adapter	P-050B-050200	B2152-1839
/	Debug board	/	/

External I/O Cable

Cable Description	Length (m)	From Port	To
Power Cable	1.0	EUT	Adapter

Block Diagram of Test Setup

For Radiated Emissions(Below 1GHz & Above 1GHz):



SUMMARY OF TEST RESULTS

ETSI EN 300 328 V2.2.2 (2019-07)	Description of Test	Test Result
Clause 4.3.1.2	RF output power	Compliant
Clause 4.3.1.3	Duty Cycle, Tx-sequence, Tx-gap	Not Applicable (See Note1)
Clause 4.3.1.4	Accumulated Transmit Time, Frequency Occupation and Hopping Sequence	Compliant
Clause 4.3.1.5	Hopping Frequency Separation	Compliant
Clause 4.3.1.6	Medium Utilization (MU) factor	Not Applicable (See Note1)
Clause 4.3.1.7	Adaptivity (Adaptive Frequency Hopping)	Not Applicable (See Note1)
Clause 4.3.1.8	Occupied Channel Bandwidth	Compliant
Clause 4.3.1.9	Transmitter unwanted emissions in the out-of-band domain	Compliant
Clause 4.3.1.10	Transmitter unwanted emissions in the spurious domain	Compliant
Clause 4.3.1.11	Receiver spurious emissions	Compliant
Clause 4.3.1.12	Receiver Blocking	Compliant
Clause 4.3.1.13	Geo-location capability	Not Applicable (See Note2)

Note1: The requirement does not apply for equipment with a maximum declared RF Output power of less than 10 dBm e.i.r.p.
Note2: The supplier declared that the equipment is unable to perform this function.

TEST EQUIPMENT LIST

Manufacturer	Description	Model	Serial Number	Calibration Date	Calibration Due Date
Radiated Emission Test(Chamber 1#)					
Rohde & Schwarz	EMI Test Receiver	ESCI	100195	2019-07-11	2020-07-10
HP	Signal Generator	HP 8341B	2624A00116	2019-07-30	2020-07-29
Sunol Sciences	Broadband Antenna	JB3	A090413-1	2017-12-26	2020-12-25
Sunol Sciences	Broadband Antenna	JB3	A090314-2	2019-01-19	2022-01-18
Sonoma Instrunent	Pre-amplifier	310N	171205	2019-08-14	2020-08-13
Rohde & Schwarz	Auto test Software	EMC32	100361	/	/
MICRO-COAX	Coaxial Cable	Cable-8	008	2019-08-14	2020-08-13
MICRO-COAX	Coaxial Cable	Cable-9	009	2019-08-14	2020-08-13
MICRO-COAX	Coaxial Cable	Cable-10	010	2019-08-14	2020-08-13
MICRO-COAX	Coaxial Cable	Cable-7	007	2019-08-14	2020-08-13
Radiated Emission Test(Chamber 2#)					
HP	Signal Generator	HP 8341B	2624A00116	2019-07-30	2020-07-29
Rohde & Schwarz	EMI Test Receiver	ESU40	100207	2019-05-30	2020-05-29
ETS-LINDGREN	Horn Antenna	3115	9207-3900	2017-07-15	2020-07-14
ETS-LINDGREN	Horn Antenna	3115	6229	2017-07-15	2020-07-14
A.H.Systems, inc	Amplifier	2641-1	466	2019-09-11	2020-09-10
Rohde & Schwarz	Auto test Software	EMC32	100361	/	/
MICRO-COAX	Coaxial Cable	Cable-6	006	2019-08-12	2020-08-11
MICRO-COAX	Coaxial Cable	Cable-11	011	2019-08-14	2020-08-13
MICRO-COAX	Coaxial Cable	Cable-12	012	2019-08-14	2020-08-13
MICRO-COAX	Coaxial Cable	Cable-13	013	2019-08-14	2020-08-13
MICRO-COAX	Coaxial Cable	Cable-16	016	2019-08-12	2020-08-11
RF Conducted Test					
Tonscend Corporation	RF Control Unit	JS0806-2	/	2019-08-14	2020-08-31
Tonscend Corporation	RF Test System	JS1120-3	/	N/A	N/A
Rohde & Schwarz	SMBV100A Vector Signal Generator	SMBV100A	261558	2019-07-21	2020-07-20
Rohde & Schwarz	SMB 100A Signal Generator	SMB100A	110390	2019-07-21	2020-07-20
HP	Attenuator/11dB	8494B	011	2019-01-10	2020-01-09
Agilent	Attenuator/110dB	8496B	110	2019-08-15	2020-08-14
Rohde & Schwarz	Signal Analyzer	FSV40	101116	2019-07-23	2020-07-22
Rohde & Schwarz	Pulse limiter	ESH3-Z2	0357.8810.54	2019-08-10	2020-08-09
BACL	Temperature & Humidity Chamber	BTH-150	30023	2019-08-20	2020-08-19
Rohde & Schwarz	Wideband Radio Communication Tester	CMW500	104478	2019-08-05	2020-08-04
ESPRESSIF SYSTEMS (SHANGHAI) CO., LTD	RF Cable	ESPRESSIF SYSTEMS (SHANGHAI) CO., LTD 01	C01	Each Time	/

*** Statement of Traceability:** Bay Area Compliance Laboratories Corp. (Kunshan) attests that all calibrations have been performed in accordance to requirements that traceable to National Primary Standards and International System of Units (SI).

ETSI EN 300 328 V2.2.2 (2019-07) Clause 4.3.1.2 – RF OUTPUT POWER

Applicable Standard

The RF output power is defined as the mean equivalent isotropically radiated power (e.i.r.p.) of the equipment during a transmission burst.

Limit

The maximum RF output power for adaptive Frequency Hopping equipment shall be equal to or less than 20 dBm.

The maximum RF output power for non-adaptive Frequency Hopping equipment, shall be declared by the manufacturer. See clause 5.4.1 m). The maximum RF output power for this equipment shall be equal to or less than the value declared by the manufacturer. This declared value shall be equal to or less than 20 dBm.

This limit shall apply for any combination of power level and intended antenna assembly.

Test Procedure

The test procedure shall be as follows:

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 defined in clause 4.3.1.3.2 or clause 4.3.2.4.2. For adaptive equipment, the measurement duration shall be long enough to ensure a minimum number of bursts (at least 10) is 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 transmit 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 as the new stored data set.

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. The start and stop points shall be included.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.
- If more than one antenna assembly is intended for this power setting, the maximum overall antenna gain (G or G + Y) shall be used.
- The RF Output Power (P) shall be calculated using the formula below:

P = A + G + Y

- This value, which shall comply with the limit given in clauses 4.3.1.2.3 or clause 4.3.2.2.3, shall be recorded in the test report.

Test Data

Environmental Conditions

Temperature:	22.5 ℃
Relative Humidity:	51 %
ATM Pressure:	100.7 kPa

The testing was performed by Chao Gao on 2020-03-29.

Test Mode: Transmitting

Test Result: Compliant

BDR Mode (GFSK):

Test Condition			Reading (dBm)	Antenna gain (dBi)	EIRP (dBm)	Limit (dBm)
Temperature (℃)		Power (V_{DC})				
Hopping	-40	3.3	3.33	3.4	6.73	20
	+25		3.30	3.4	6.70	20
	+85		3.21	3.4	6.61	20

EDR Mode (π/4-DQPSK):

Test Condition			Reading (dBm)	Antenna gain (dBi)	EIRP (dBm)	Limit (dBm)
Temperature (℃)		Power (V_{DC})				
Hopping	-40	3.3	3.16	3.4	6.56	20
	+25		3.08	3.4	6.48	20
	+85		3.01	3.4	6.41	20

EDR Mode (8DPSK):

Test Condition			Reading (dBm)	Antenna gain (dBi)	EIRP (dBm)	Limit (dBm)
Temperature (℃)		Power (V_{DC})				
Hopping	-40	3.3	3.13	3.4	6.53	20
	+25		3.04	3.4	6.44	20
	+85		2.95	3.4	6.35	20

Note :The extreme operating temperature range as declared by the manufacturer.

ETSI EN 300 328 V2.2.2 (2019-07) Clause 4.3.1.4 – ACCUMULATED TRANSMIT TIME, FREQUENCY OCCUPATION AND HOPPING SEQUENCE

Applicable Standard

The Accumulated Transmit Time is the total of the transmitter 'on' times, during an observation period, on a particular hopping frequency.

The Frequency Occupation is the number of times that each hopping frequency is occupied within a given period. A hopping frequency is considered to be occupied when the equipment selects that frequency from the hopping sequence.The equipment may be transmitting, receiving or stay idle during the Time spent on that hopping frequency.

The Hopping Sequence of a frequency hopping equipment is the unrepeated pattern of the hopping frequencies used by the equipment.

Limit:

For Non-adaptive frequency hopping systems:

The Accumulated Transmit Time on any hopping frequency shall not be greater than 15 ms within any observation period of 15 ms multiplied by the minimum number of hopping frequencies (N) that have to be used.

In order for the equipment to comply with the Frequency Occupation requirement, it shall meet either of the following two options:

• Option 1: Each hopping frequency of the hopping sequence shall be occupied at least once within a period
not exceeding four times the product of the dwell time and the number of hopping frequencies in use.

• Option 2: The occupation probability for each frequency shall be between ((1 / U) × 25 %) and 77 % where U is the number of hopping frequencies in use.

The hopping sequence(s) shall contain at least N hopping frequencies where N is either 5 or the result of 15 MHz divided by the minimum Hopping Frequency Separation in MHz, whichever is the greater. According to clause 4.3.1.5.3.1 the minimum Hopping Frequency Separation for non-adaptive equipment is equal to the Occupied Channel Bandwidth with a minimum of 100 kHz.

For Adaptive frequency hopping systems:

Adaptive Frequency Hopping equipment shall be capable of operating over a minimum of 70 % of the band specified in table 1.

The Accumulated Transmit Time on any hopping frequency shall not be greater than 400 ms within any observation period of 400 ms multiplied by the minimum number of hopping frequencies (N) that have to be used.

In order for the equipment to comply with the Frequency Occupation requirement, it shall meet either of the following two options:

• Option 1: Each hopping frequency of the hopping sequence shall be occupied at least once within a period not exceeding four times the product of the dwell time and the number of hopping frequencies in use.

• Option 2: The occupation probability for each frequency shall be between ((1 / U) × 25 %) and 77 % where U is the number of hopping frequencies in use.

The hopping sequence(s) shall contain at least N hopping frequencies at all times, where N is either 15 or the result of 15 MHz divided by the minimum Hopping Frequency Separation in MHz, whichever is the greater.

Test Procedure

The test procedure shall be as follows:

Step 1:

- The output of the transmitter shall be connected to a spectrum analyzer or equivalent.
- The analyzer shall be set as follows:
  - Centre Frequency: Equal to the hopping frequency being investigated
  - Frequency Span: 0 Hz
  - RBW: ~ 50 % of the Occupied Channel Bandwidth
  - VBW: ≥ RBW
  - Detector Mode: RMS
  - Sweep time: Equal to the applicable observation period (see clause 4.3.1.4.3.1 or clause 4.3.1.4.3.2)
  - Number of sweep points: 30 000
  - Trace mode: Clear / Write
  - Trigger: Free Run

Step 2:

- Save the trace data to a file for further analysis by a computing device using an appropriate software application or program.

Step 3:

- Identify the data points related to the frequency being investigated by applying a threshold.

  The data points resulting from transmissions on the hopping frequency being investigated are assumed to have much higher levels compared to data points resulting from transmissions on adjacent hopping frequencies. If a clear determination between these transmissions is not possible, the RBW in step 1 shall be further reduced. In addition, a channel filter may be used.

- Count the number of data points identified as resulting from transmissions on the frequency being investigated and multiply this number by the time difference between two consecutive data points.

Step 4:

- The result in step 3 is the Accumulated Transmit Time which shall comply with the limit provided in clause 4.3.1.4.3.1 or clause 4.3.1.4.3.2 and which shall be recorded in the test report.

Step 5:

NOTE 1: This step is only applicable for equipment implementing Option 1 in clause 4.3.1.4.3.1 or Option 1 in clause 4.3.1.4.3.2 for complying with the Frequency Occupation requirement and the manufacturer decides to demonstrate compliance with this requirement via measurement.

- Make the following changes on the analyser and repeat step 2 and step 3.

Sweep time: 4 ×Dwell Time ×Actual number of hopping frequencies in use.

The hopping frequencies occupied by the equipment without having transmissions during the dwell time (blacklisted frequencies) should be taken into account in the actual number of hopping frequencies in use. If this number cannot be determined (number of blacklisted frequencies unknown) it shall be assumed that the equipment uses the maximum possible number of hopping frequencies.

- The result shall be compared to the limit for the Frequency Occupation defined in clause 4.3.1.4.3.1, Option 1 or clause 4.3.1.4.3.2, Option 1. The result of this comparison shall be recorded in the test report.

Step 6:

- Make the following changes on the analyzer:
  - Start Frequency: 2 400 MHz
  - Stop Frequency: 2 483,5 MHz
  - RBW: ~ 50 % of the Occupied Channel Bandwidth (single hopping frequency)

  - VBW: ≥ RBW
  - Detector Mode: RMS
  - Sweep time: 1 s; this setting may result in long measuring times. To avoid such long measuring times, an FFT analyser may be used
  - Trace Mode: Max Hold
  - Trigger: Free Run

- Wait for the trace to stabilize. Identify the number of hopping frequencies used by the hopping sequence.

- The result shall be compared to the limit (value N) defined in clause 4.3.1.4.3.1 or clause 4.3.1.4.3.2. This value shall be recorded in the test report.

NOTE 2: For equipment with blacklisted frequencies, it might not be possible to verify the number of hopping frequencies in use. However, they shall comply with the requirement for Accumulated Transmit Time and Frequency Occupation assuming the minimum number of hopping frequencies (N) defined in clause 4.3.1.4.3.1 or clause 4.3.1.4.3.2 is used.

Step 7:

- For adaptive frequency hopping equipment, it shall be verified whether the equipment uses 70 % of the band specified in table 1. This verification can be done using the lowest and highest -20 dB points from the total spectrum envelope obtained in step 6. The result shall be recorded in the test report.

Test Data

Environmental Conditions

Temperature:	23.0 ℃
Relative Humidity:	54 %
ATM Pressure:	101.2 kPa

The testing was performed by Chao Gao on 2020-04-01.

Test Mode: Transmitting

Test Result: Compliant

Accumulated Transmit Time:

Mode	Channel	Occupancy Time For Single Hop (ms)	Observed Period (s)	Hops in Observed Period	Accumulated Transmit Time (s)	Limit (s)
DH5	Low	3.975	31.6	75	0.298	≤0.4
	High	3.672	31.6	74	0.272	≤0.4
	Note: Minimum number of hopping frequencies (N)=79 Observed Period= 400 ms the minimum number of hopping frequencies (N) =79*400ms=31.6s*					

Frequency Occupation:

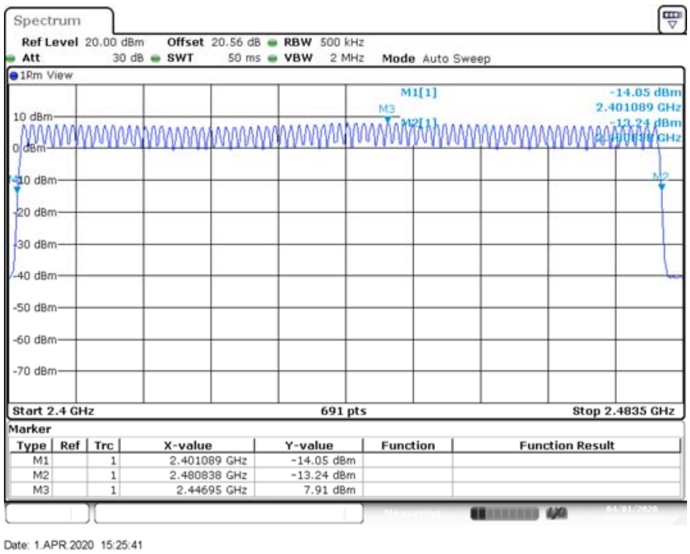
Mode	Channel	Dwell time (ms)	Observed Period (ms)	Hops in Observed Period	Limit
DH5	Low	4.13	1305	2	≥1
	High	4.13	1305	7	≥1
	*Note: Observed Period=Dwell time*79*4(ms)*				

Hopping Sequence:

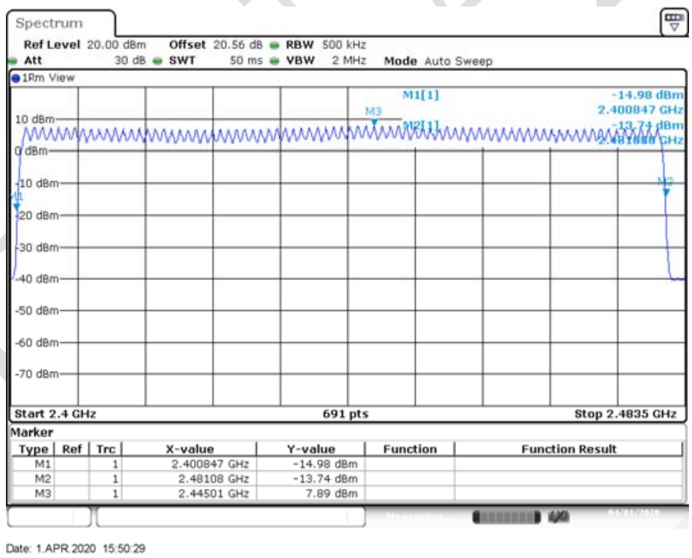
The frequency hopping systems operating in 2400-2483.5 MHz band employ 79 nonoverlapping channels.

Test Mode	Frequency Range (MHz)	Number of Hopping Channel	Limit	Band Allocation (%)	Limit Band Allocation (%)
GFSK	2400.0-2483.5	79	≥15	95.51	≥70
π/4-DQPSK		79		96.09	
8DPSK		79		96.09	

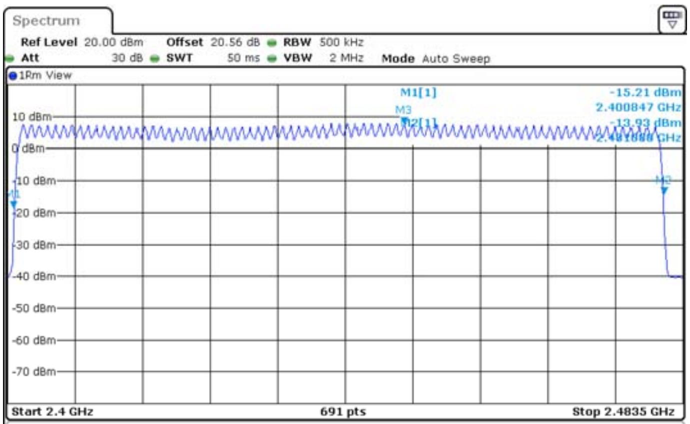
BDR Mode (GFSK): Number of Hopping Channels



EDR Mode(π/4-DQPSK): Number of Hopping Channels



EDR Mode(8DPSK): Number of Hopping Channels



Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1		1	2.400847 GHz	-15.21 dBm		
M2		1	2.48108 GHz	-13.93 dBm		
M3		1	2.449 GHz	7.84 dBm		

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ETSI EN 300 328 V2.2.2 (2019-07) Clause 4.3.1.5 – HOPPING FREQUENCY SEPARATION

Applicable Standard

The Hopping Frequency Separation is the frequency separation between two adjacent hopping frequencies.

Limit:

For Non-adaptive frequency hopping systems

For non-adaptive Frequency Hopping equipment, the Hopping Frequency Separation shall be equal to or greater than the Occupied Channel Bandwidth (see clause 4.3.1.8), with a minimum separation of 100 kHz.

For equipment with a maximum declared RF Output power level of less than 10 dBm e.i.r.p. or for non-adaptive Frequency Hopping equipment operating in a mode where the RF Output power is less than 10 dBm e.i.r.p. only the minimum Hopping Frequency Separation of 100 kHz applies.

For Adaptive frequency hopping systems

The minimum Hopping Frequency Separation shall be 100 kHz.

Adaptive Frequency Hopping equipment that switched to a non-adaptive mode for one or more hopping frequencies because interference was detected on these hopping frequencies with a level above the threshold level defined in clause 4.3.1.7.2.2, point 5 or clause 4.3.1.7.3.2, point 5, is allowed to continue to operate with a minimum Hopping Frequency Separation of 100 kHz as long as the interference remains present on these hopping frequencies. The equipment shall continue to operate in an adaptive mode on other hopping frequencies.

Adaptive Frequency Hopping equipment which decided to operate in a non-adaptive mode on one or more hopping frequencies without the presence of interference, shall comply with the limit for Hopping Frequency Separation for non-adaptive equipment defined in clause 4.3.1.5.3.1 (first paragraph) for these hopping frequencies as well as with all other requirements applicable to non-adaptive frequency hopping equipment.

Test Procedure

Option 1, the test procedure shall be as follows:

Step 1:

- The output of the transmitter shall be connected to a spectrum analyzer or equivalent.
- The analyzer shall be set as follows:
  - Centre Frequency: Centre of the two adjacent hopping frequencies
  - Frequency Span: Sufficient to see the complete power envelope of both hopping frequencies
  - RBW: 1 % of the Span
  - VBW: 3 × RBW
  - Detector Mode: Max Peak
  - Trace Mode: Max Hold
  - Sweep time: Auto

Step 2:

- Wait for the trace to stabilize.

- Use the marker function of the analyser to define the frequencies corresponding to the lower -20 dBr point and the upper -20 dBr point for both hopping frequencies F1 and F2. This will result in $F1_L$ and $F1_H$ for hopping frequency F1 and in $F2_L$ and $F2_H$ for hopping frequency F2. These values shall be recorded in the report.

Step 3:

- Calculate the centre frequencies $F1_C$ and $F2_C$ for both hopping frequencies using the formulas below. These values shall be recorded in the report.

$$F1_C = \frac{F1_L + F1_H}{2} \quad F2_C = \frac{F2_L + F2_H}{2}$$

- Calculate the Hopping Frequency Separation (FHS) using the formula below. This value shall be recorded in the report.

$$F_{HS} = F2_C - F1_C$$

- Compare the measured Hopping Frequency Separation with the limit defined in clause 4.3.1.5.3. In addition, for non-Adaptive Frequency Hopping equipment, the Hopping Frequency Separation shall be equal to or greater than the Occupied Channel Bandwidth as defined in clause 4.3.1.8 or:

$$F_{HS} \geq \text{Occupied Channel Bandwidth}$$

- See figure 4:

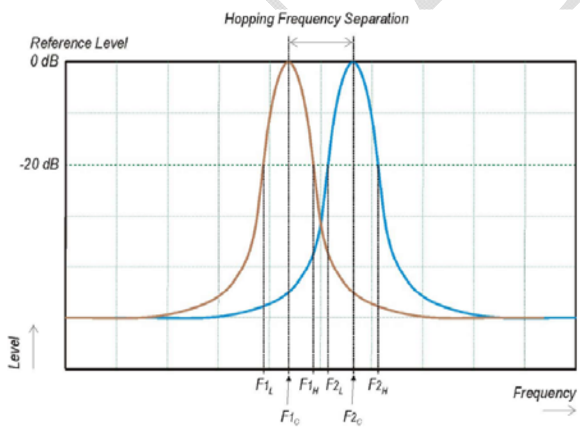


Figure 4: Hopping Frequency Separation

For adaptive systems, in case of overlapping channels which prevents the definition of the -20 dBr reference points $F1_H$ and $F2_L$, a higher reference level (e.g. -10 dBr or - 6 dBr) may be chosen to define the reference points $F1_L$; $F1_H$; $F2_L$ and $F2_H$.

Alternatively, special test software may be used to:

- force the UUT to hop or transmit on a single Hopping Frequency by which the -20 dBr reference points can be measured separately for the two adjacent Hopping Frequencies; and/or;

- force the UUT to operate without modulation by which the centre frequencies $F1_C$ and $F2_C$ can be measured directly.

The method used to measure the Hopping Frequency Separation shall be documented in the test report.

Option 2, the test procedure shall be as follows:

Step 1:

- The output of the transmitter shall be connected to a spectrum analyzer or equivalent.
- The analyzer shall be set as follows:
  - Centre Frequency: Centre of the two adjacent hopping frequencies
  - Frequency Span: Sufficient to see the complete power envelope of both hopping frequencies
  - RBW: 1 % of the Span
  - VBW: 3 × RBW
  - Detector Mode: Max Peak
  - Trace Mode: Max Hold
  - Sweep Time: Auto

Step 2:

- Wait for the trace to stabilize.
- Use the marker-delta function to determine the Hopping Frequency Separation between the centres of the two adjacent hopping frequencies (e.g. by identifying peaks or notches at the centre of the power envelope for the two adjacent signals). This value shall be compared with the limits defined in clause 4.3.1.5.3 and shall be recorded in the test report.

Test Data

Environmental Conditions

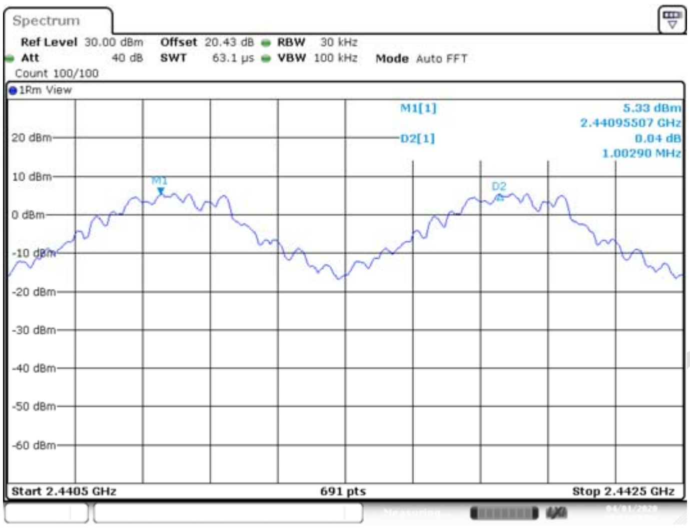
Temperature:	23.0 ℃
Relative Humidity:	54 %
ATM Pressure:	101.2 kPa

The testing was performed by Chao Gao on 2020-04-01.

Test Mode: Transmitting

BDR Mode (GFSK)

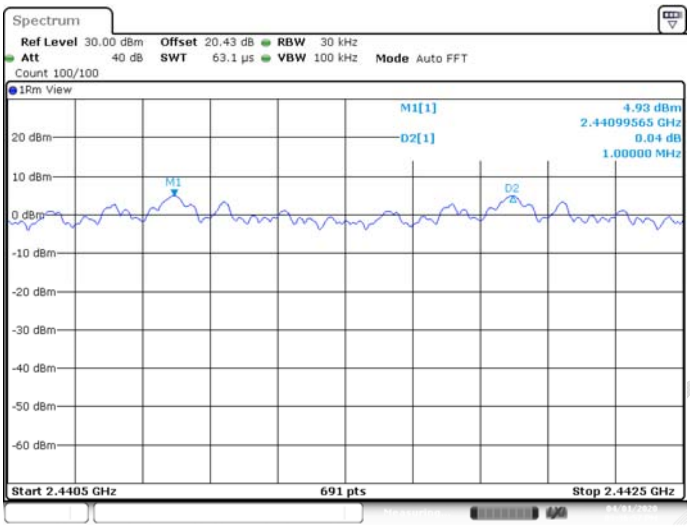
Center Frequency of Separation (MHz)	Hopping Frequency Separation (kHz)	Limit (kHz)	Result
2441.50	1003.00	⩾100	Pass



Date: 1.APR.2020 15:13:58

EDR Mode (π/4-DQPSK):

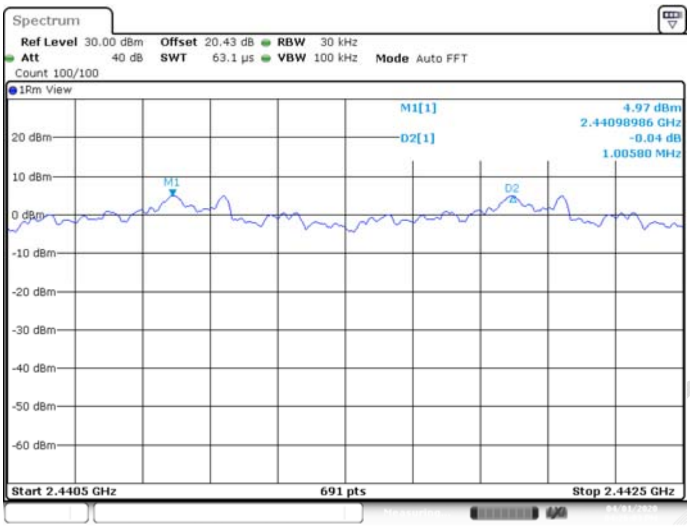
Center Frequency of Separation (MHz)	Hopping Frequency Separation (kHz)	Limit (kHz)	Result
2441.50	1000.00	⩾100	Pass



Date: 1.APR.2020 15:36:57

EDR Mode (8DPSK):

Center Frequency of Separation (MHz)	**Hopping Frequency Separation (kHz)**	**Limit (kHz)**	**Result**
2441.50	1006.00	⩾100	Pass



Date: 1.APR.2020 16:26:03

ETSI EN 300 328 V2.2.2 (2019-07) Clause 4.3.1.8 – OCCUPIED CHANNEL BANDWIDTH

Applicable Standard

The Occupied Channel Bandwidth is the bandwidth that contains 99 % of the power of the signal when considering a single hopping frequency.

Limit:

The Occupied Channel Bandwidth for each hopping frequency shall fall completely within the band given in table 1.

For non-adaptive Frequency Hopping equipment with e.i.r.p. greater than 10 dBm, the Occupied Channel Bandwidth for every occupied hopping frequency shall be equal to or less than the Nominal Channel Bandwidth declared by the manufacturer. See clause 5.4.1 j). This declared value shall not be greater than 5 MHz.

Test Procedure

The measurement procedure shall be as follows:

Step 1:

Connect the UUT to the spectrum analyser 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 × Nominal Channel Bandwidth
- Detector Mode: RMS
- Trace Mode: Max Hold
- Sweep time: 1 s

Step 2:

Wait for the trace to stabilize.

Find the peak value of the trace and place the analyser marker on this peak.

Step 3:

Use the 99 % bandwidth function of the spectrum analyser to measure the Occupied Channel Bandwidth of the UUT. This value shall be recorded.

NOTE: Make sure that the power envelope is sufficiently above the noise floor of the analyser to avoid the noise signals left and right from the power envelope being taken into account by this measurement.

Test Data

Environmental Conditions

Temperature:	23.0 ℃
Relative Humidity:	54 %
ATM Pressure:	101.2 kPa

The testing was performed by Chao Gao on 2020-04-01.

Test Mode: Transmitting

Test Result: Compliant

BDR Mode (GFSK):

Channel	Frequency (MHz)	Occupied Bandwidth (MHz)
Low	2402	0.851
High	2480	0.849

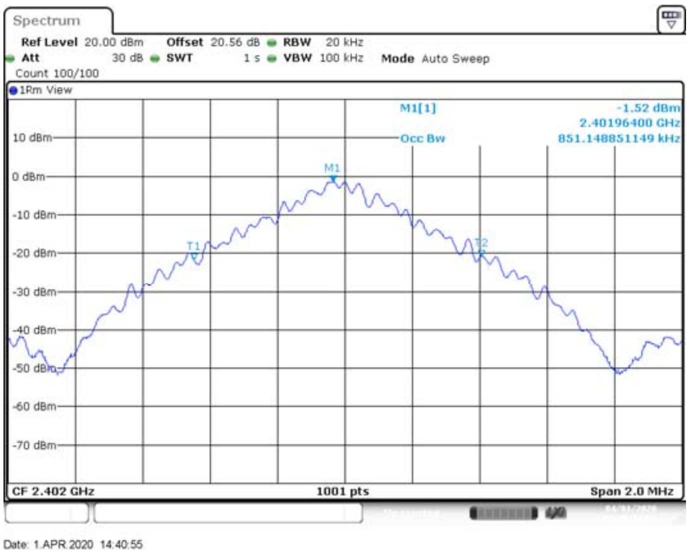
EDR Mode (π/4-DQPSK):

Channel	Frequency (MHz)	Occupied Bandwidth (MHz)
Low	2402	1.187
High	2480	1.187

EDR Mode (8DPSK):

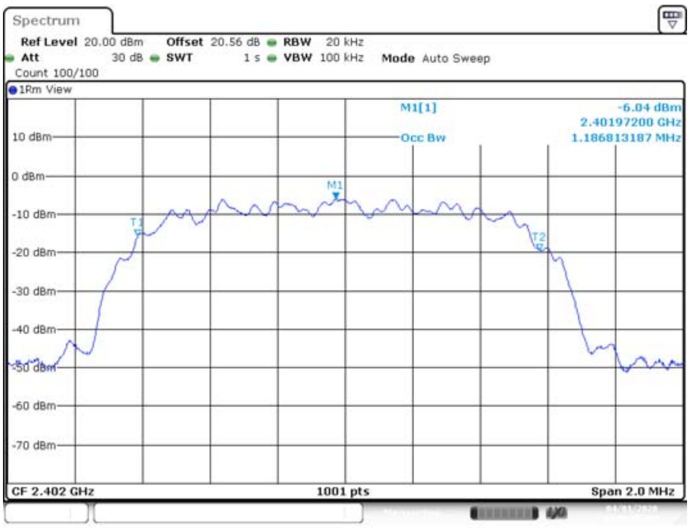
Channel	Frequency (MHz)	Occupied Bandwidth (MHz)
Low	2402	1.197
High	2480	1.197

BDR Mode (GFSK) Low Channel



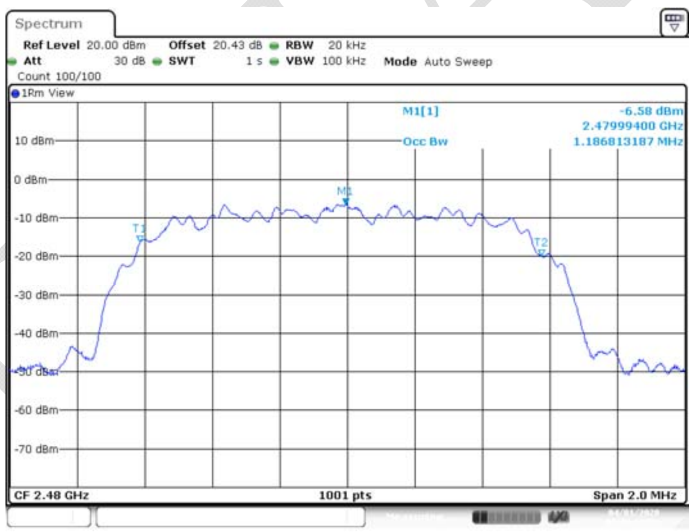
BDR Mode (GFSK) High Channel

EDR Mode (π/4-DQPSK) Low Channel



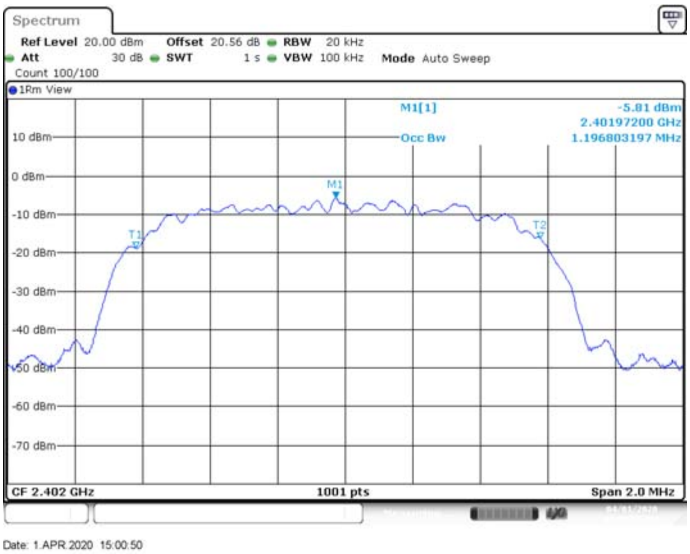
Date: 1.APR.2020 14:50:55

EDR Mode (π/4-DQPSK) High Channel

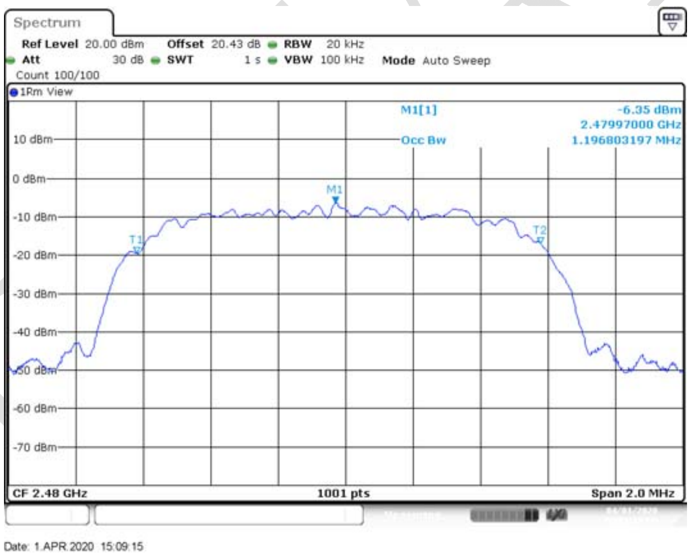


Date: 1.APR.2020 14:56:44

EDR Mode (8DPSK) Low Channel



EDR Mode (8DPSK) High Channel



ETSI EN 300 328 V2.2.2 (2019-07) Clause 4.3.1.9 – TRANSMITTER UNWANTED EMISSION IN THE OUT-OF-BAND DOMAIN

Applicable Standard

Transmitter unwanted emissions in the out-of-band domain are emissions when the equipment is in Transmit mode, on frequencies immediately outside the necessary bandwidth which results from the modulation process, but excluding spurious emissions.

Limit:

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.

Within the band specified in table 1, the Out-of-band emissions are fulfilled by compliance with the Occupied Channel Bandwidth requirement in clause 4.3.1.8.

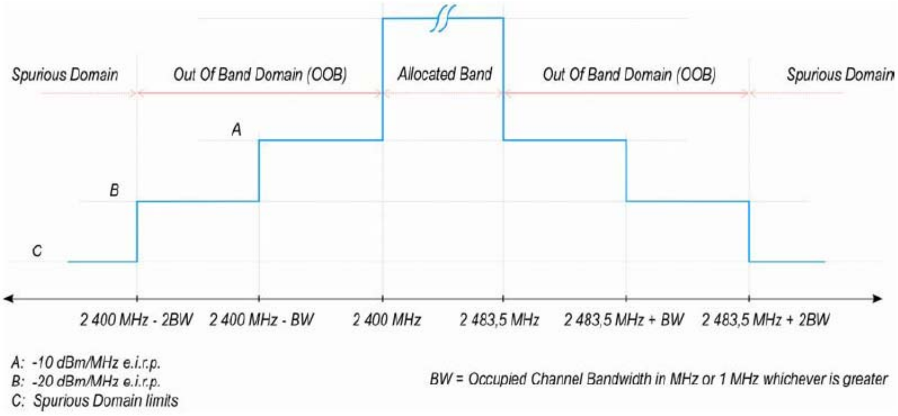


Figure 1: Transmit mask

Test Procedure

Conducted measurement:

The applicable mask is defined by the measurement results from the tests performed under clause 5.4.7 (Occupied Channel Bandwidth).

The Out-of-band emissions within the different horizontal segments of the mask provided in figures 1 and 3 shall be measured using the procedure in step 1 to step 6 below. This method assumes the spectrum analyser is equipped with the Time Domain Power option.

Step 1:

- Connect the UUT to the spectrum analyser and use the following settings:
  - Centre Frequency: 2 484 MHz
  - Span: 0 Hz

- Resolution BW: 1 MHz
- Filter mode: Channel filter
- Video BW: 3 MHz
- Detector Mode: RMS
- Trace Mode: Max Hold
- Sweep Mode: Continuous
- Sweep Points: Sweep Time [s] / (1 µs) or 5 000 whichever is greater
- Trigger Mode: Video trigger
  NOTE 1: In case video triggering is not possible, an external trigger source may be used.
- Sweep Time: > 120 % of the duration of the longest burst detected during the measurement of the RF Output Power.

Step 2: (segment 2 483,5 MHz to 2 483,5 MHz + BW)

- Adjust the trigger level to select the transmissions with the highest power level.
- For frequency hopping equipment operating in a normal hopping mode, the different hops will result in signal bursts with different power levels. In this case the burst with the highest power level shall be selected.
- Set a window (start and stop lines) to match with the start and end of the burst and in which the RMS power shall be measured using the Time Domain Power function.
- Select RMS power to be measured within the selected window and note the result which is the RMS power within this 1 MHz segment (2 483,5 MHz to 2 484,5 MHz). Compare this value with the applicable limit provided by the mask.
- Increase the centre frequency in steps of 1 MHz and repeat this measurement for every 1 MHz segment within the range 2 483,5 MHz to 2 483,5 MHz + BW. The centre frequency of the last 1 MHz segment shall be set to 2 483,5 MHz + BW - 0,5 MHz (which means this may partly overlap with the previous 1 MHz segment).

Step 3: (segment 2 483,5 MHz + BW to 2 483,5 MHz + 2BW)

- Change the centre frequency of the analyser to 2 484 MHz + BW and perform the measurement for the first 1 MHz segment within range 2 483,5 MHz + BW to 2 483,5 MHz + 2BW. Increase the centre frequency in 1 MHz steps and repeat the measurements to cover this whole range. The centre frequency of the last 1 MHz segment shall be set to 2 483,5 MHz + 2 BW - 0,5 MHz. (which means this may partly overlap with the previous 1 MHz segment).

Step 4: (segment 2 400 MHz - BW to 2 400 MHz)

- Change the centre frequency of the analyser to 2 399,5 MHz and perform the measurement for the first 1 MHz segment within range 2 400 MHz - BW to 2 400 MHz Reduce the centre frequency in 1 MHz steps and repeat the measurements to cover this whole range. The centre frequency of the last 1 MHz segment shall be set to 2 400 MHz - 2BW + 0,5 MHz. (which means this may partly overlap with the previous 1 MHz segment).

Step 5: (segment 2 400 MHz - 2BW to 2 400 MHz - BW)

- Change the centre frequency of the analyser to 2 399,5 MHz - BW and perform the measurement for the first 1 MHz segment within range 2 400 MHz - 2BW to 2 400 MHz - BW. Reduce the centre frequency in 1 MHz steps and repeat the measurements to cover this whole range. The centre frequency of the last 1 MHz segment shall be set to 2 400 MHz - 2BW + 0,5 MHz. (which means this may partly overlap with the previous 1 MHz segment).

Step 6:

- In case of conducted measurements on equipment with a single transmit chain, the declared antenna assembly gain "G" in dBi shall be added to the results for each of the 1 MHz segments and compared with the limits provided by the mask given in figures 1 or 3. If more than one antenna assembly is intended for this power setting, the antenna with the highest gain shall be considered.
- In case of conducted measurements on smart antenna systems (equipment with multiple transmit chains), the measurements need to be repeated for each of the active transmit chains. The declared antenna assembly gain "G" in dBi for a single antenna shall be added to these results. If more than one antenna assembly is intended for this power setting, the antenna with the highest gain shall be considered. Comparison with the applicable limits shall be done using any of the options given below:

  - Option 1: the results for each of the transmit chains for the corresponding 1 MHz segments shall be added. The additional beamforming gain "Y" in dB shall be added as well and the resulting values compared with the limits provided by the mask given in figures 1 or 3.

  - Option 2: the limits provided by the mask given in figures 1 or 3 shall be reduced by 10 x $\log_{10}(A_{ch})$ and the additional beamforming gain "Y" in dB. The results for each of the transmit chains shall be individually compared with these reduced limits.

NOTE 2: A_{ch} refers to the number of active transmit chains.

It shall be recorded whether the equipment complies with the mask provided in figures 1 or 3.

Radiated measurement:

The test set up as described in annex B and the applicable measurement procedures described in annex C shall be used.Alternatively a test fixture may be used.

The test procedure is as described under clause 5.4.8.2.1.

Test Data

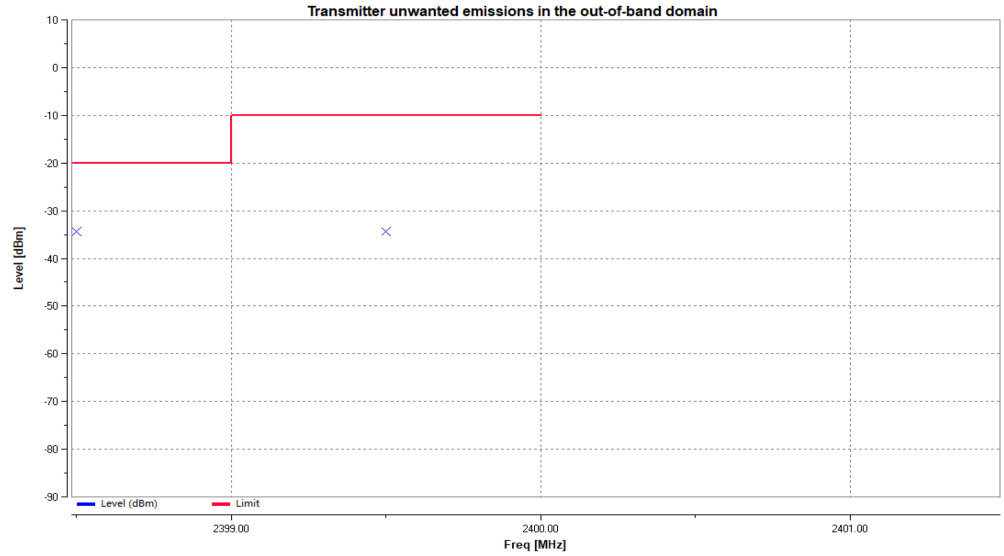
Environmental Conditions

Temperature:	22.7 ℃
Relative Humidity:	50 %
ATM Pressure:	100.7 kPa

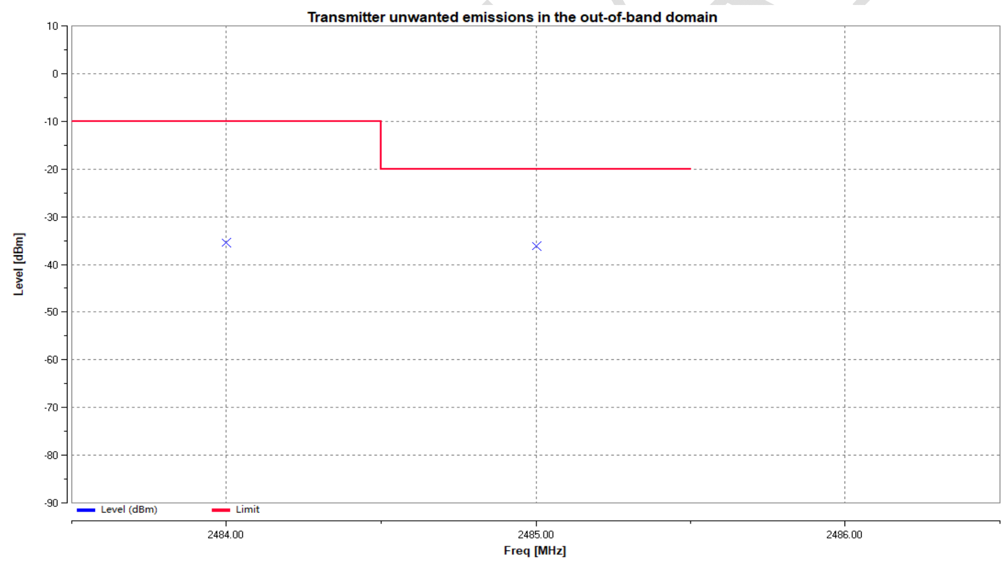
The testing was performed by Chao Gao on 2020-03-29.

Test Mode: Transmitting

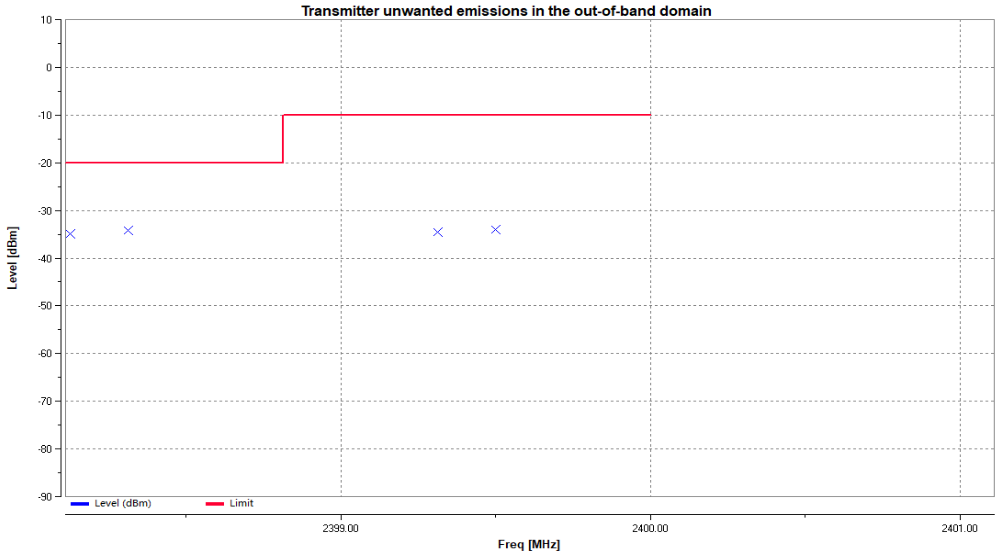
GFSK Low Frequency



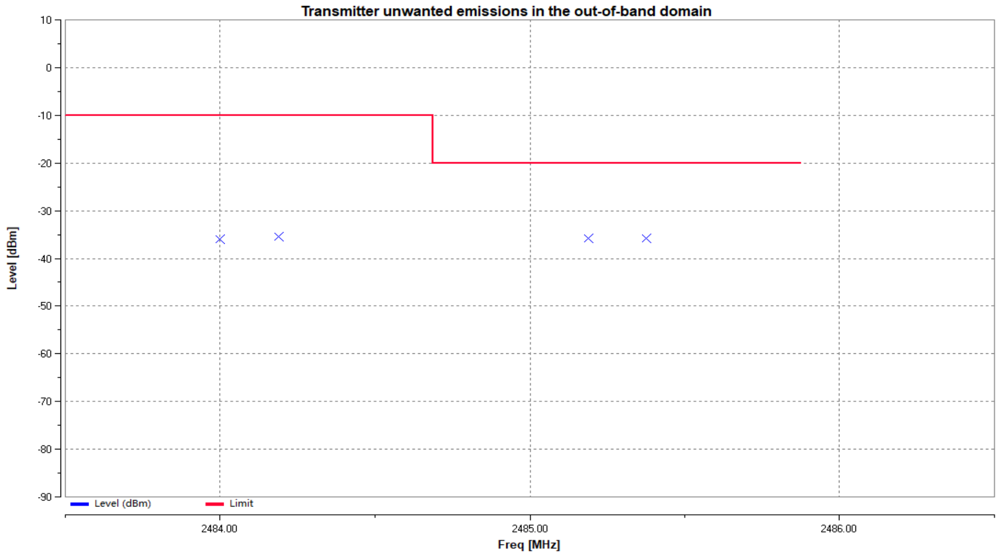
GFSK High Frequency



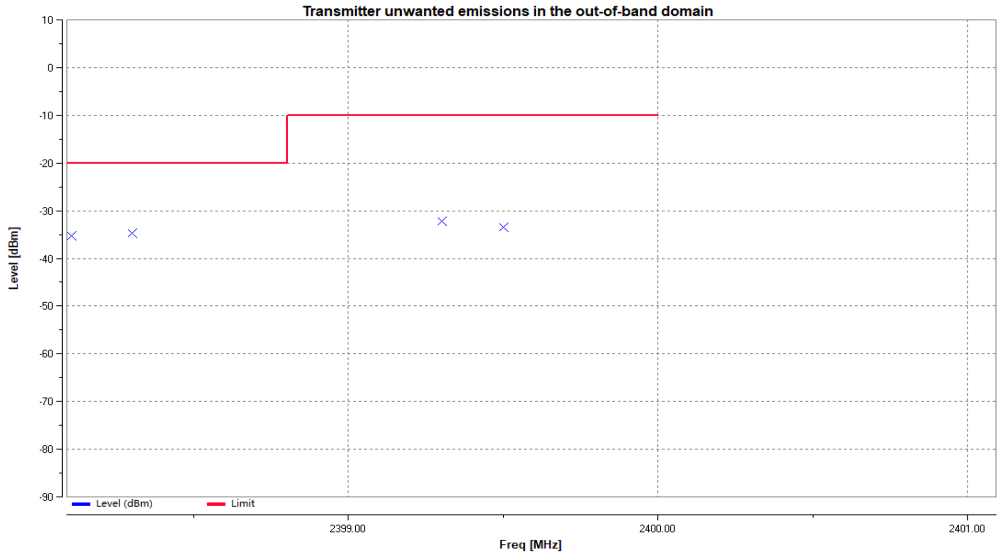
π/4-DQPSK Low Frequency



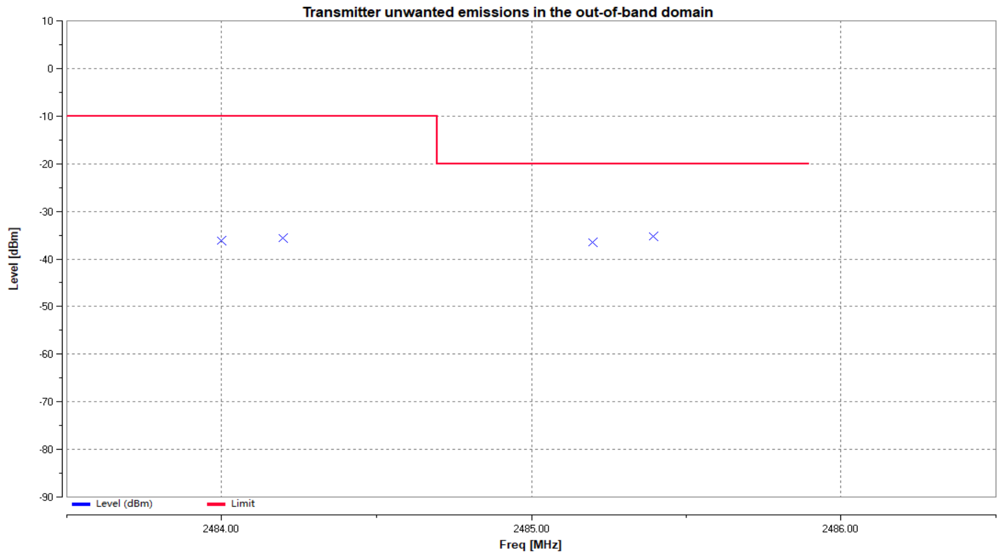
π/4-DQPSK High Frequency



8DPSK Low Frequency



8DPSK High Frequency



ETSI EN 300 328 V2.2.2 (2019-07) Clause 4.3.1.10 – TRANSMITTER UNWANTED EMISSION IN THE SPURIOUS DOMAIN

Applicable Standard

Transmitter unwanted emissions in the spurious domain are emissions outside the allocated band and outside the out-of-band domain as indicated in figure 1 when the equipment is in Transmit mode.

In case of equipment with antenna connectors, these limits apply to emissions at the antenna port (conducted). For emissions radiated by the cabinet or emissions radiated by integral antenna equipment (without antenna connectors), these limits are e.r.p. for emissions up to 1 GHz and e.i.r.p. for emissions above 1 GHz.

The spurious emissions of the transmitter shall not exceed the values in the following table:

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
74 MHz 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 694 MHz	-54 dBm	100 kHz
694 MHz to 1 GHz	-36 dBm	100 kHz
1 GHz to 12.75 GHz	-30 dBm	1 MHz

Test Procedure

Conducted measurement:

The spectrum in the spurious domain (see figure 1 or figure 3) shall be searched for emissions that exceed the limit values given in table 4 or table 12 or that come to within 6 dB below these limits. Each occurrence shall be recorded.

The measurement procedure contains 2 parts.

Pre-scan:

The procedure in step 1 to step 4 below shall be used to identify potential unwanted emissions of the UUT.

Step 1:

The sensitivity of the measurement set-up should be such that the noise floor is at least 12 dB below the limits given in table 4 or table 12.

Step 2:

The emissions over the range 30 MHz to 1 000 MHz shall be identified.

Spectrum analyser settings:

- Resolution bandwidth: 100 kHz
- Video bandwidth: 300 kHz
- Filter type: 3 dB (Gaussian)
- Detector mode: Peak
- Trace Mode: Max Hold
- Sweep Points: ≥ 19 400; for spectrum analysers not supporting this high number of sweep points, the frequency band may be segmented
- Sweep time: -For non continuous transmissions (duty cycle less than 100 %), the sweep time shall be sufficiently long, such that for each 100 kHz frequency step, the measurement time is greater than two transmissions of the UUT, on any channel
  -For Frequency Hopping equipment operating in a normal operating (hopping not disabled) mode, the sweep time shall be further increased to capture multiple transmissions on any of the hopping frequencies
  -The above sweep time setting may result in long measuring times in case of frequency hopping equipment. To avoid such long measuring times, an FFT analyser may be used

Allow the trace to stabilize. Any emissions identified during the sweeps above and that fall within the 6 dB range below the applicable limit or above, shall be individually measured using the procedure in clause 5.4.9.2.1.3 and compared to the limits given in table 4 or table 12.

Step 3:

The emissions over the range 1 GHz to 12,75 GHz shall be identified.

Spectrum analyser settings:

- Resolution bandwidth: 1 MHz
- Video bandwidth: 3 MHz
- Filter type: 3 dB (Gaussian)
- Detector mode: Peak
- Trace Mode: Max Hold
- Sweep Points: ≥ 23 500; for spectrum analysers not supporting this high number of sweep points, the frequency band may be segmented
- Sweep time: - For non continuous transmissions (duty cycle less than 100 %), the sweep time shall be sufficiently long, such that for each 1 MHz frequency step, the measurement time is greater than two transmissions of the UUT, on any channel
  - For Frequency Hopping equipment operating in a normal operating (hopping not disabled) mode, the sweep time shall be further increased to capture multiple transmissions on any of the hopping frequencies
  - The above sweep time setting may result in long measuring times in case of frequency hopping equipment. To avoid such long measuring times, an FFT analyser may be used

Allow the trace to stabilize. Any emissions identified during the sweeps above that fall within the 6 dB range below the applicable limit or above, shall be individually measured using the procedure in clause 5.4.9.2.1.3 and compared to the limits given in table 4 or table 12.

Frequency Hopping equipment may generate a block (or several blocks) of spurious emissions anywhere within the spurious domain. If this is the case, only the highest peak of each block of emissions shall be measured using the procedure in clause 5.4.9.2.1.3.

Step 4:

In case of conducted measurements on smart antenna systems (equipment with multiple transmit chains), step 2 and step 3 need to be repeated for each of the active transmit chains (Ach).The limits used to identify emissions during this pre-scan need to be reduced by $10 \times \log_{10} (A_{ch})$.

Measurement of the emissions identified during the pre-scan:

The procedure in step 1 to step 4 below shall be used to accurately measure the individual unwanted emissions identified during the pre-scan measurements above. This method assumes the spectrum analyser has a Time Domain Power function.

Step 1:

The level of the emissions shall be measured using the following spectrum analyser settings:

- Measurement Mode: Time Domain Power
- Centre Frequency: Frequency of the emission identified during the pre-scan
- Resolution Bandwidth: 100 kHz (< 1 GHz) / 1 MHz (> 1 GHz)
- Video Bandwidth: 300 kHz (< 1 GHz) / 3 MHz (> 1 GHz)
- Frequency Span: Zero Span
- Sweep mode: Single Sweep
- Sweep time: > 120 % of the duration of the longest burst detected during the measurement of the RF Output Power
- Sweep points: Sweep time [µs] / (1 µs) with a maximum of 30 000
- Trigger: Video (burst signals) or Manual (continuous signals)
- Detector: RMS

Allow the trace to stabilize. Any emissions identified during the sweeps above and that fall within the 6 dB range below the applicable limit or above, shall be individually measured using the procedure in clause 5.4.9.2.1.3 and compared to the limits given in table 4 or table 12.

Step 2:

Set a window where the start and stop indicators match the start and end of the burst with the highest level and record the value of the power measured within this window. If the spurious emission to be measured is a continuous transmission, the measurement window shall be set to match the start and stop times of the sweep.

Step 3:

In case of conducted measurements on smart antenna systems (equipment with multiple transmit chains), step 2 needs to be repeated for each of the active transmit chains (A_{ch}).

Sum the measured power (within the observed window) for each of the active transmit chains.

Step 4:

The value defined in step 3 shall be compared to the limits defined in table 4 or table 12.

Radiated measurement:

The test site as described in annex B and applicable measurement procedures as described in annex C shall be used.

The test procedure is further as described under clause 5.4.9.2.1.

Test Data

Environmental Conditions

Temperature:	22.7 ℃
Relative Humidity:	50 %
ATM Pressure:	100.7 kPa

The testing was performed by Chao Gao on 2020-03-29.

Test mode: Transmitting in GFSK mode (worst case)

Test Result: Compliant

30 MHz ~ 12.75 GHz:

Frequency (MHz)	Receiver Reading (dBμV)	Turntable Angle Degree	Rx Antenna		Substituted			Absolute Level (dBm)	EN 300 328	
			Height (cm)	Polar (H/V)	Submitted Level (dBm)	Cable Loss (dB)	Antenna Gain (dBd/dBi)		Limit (dBm)	Margin (dB)
Low Channel										
693.51	37.69	174	150	H	-62.03	0.62	-1.68	-64.33	-54	10.33
693.51	37.28	19	150	V	-62.37	0.62	-1.68	-64.67	-54	10.67
4804.00	48.96	62	150	H	-57.52	1.06	10.14	-48.44	-30	18.44
4804.00	49.03	215	150	V	-57.45	1.06	10.14	-48.37	-30	18.37
High Channel										
693.27	37.95	8	150	H	-61.75	0.62	-1.68	-64.05	-54	10.05
693.27	37.35	107	150	V	-62.31	0.62	-1.68	-64.61	-54	10.61
4960.00	48.71	184	150	H	-57.4	1.08	10.27	-48.21	-30	18.21
4960.00	48.89	6	150	V	-57.22	1.08	10.27	-48.03	-30	18.03

Note:
Antenna gain is dBd for frequency below 1GHz and is dBi for frequency above 1GHz.
Absolute Level = Submitted Level - Cable loss + Antenna Gain
Margin = Limit- Absolute Level

ETSI EN 300 328 V2.2.2 (2019-07) Clause 4.3.1.11 - RECEIVER SPURIOUS EMISSIONS

Applicable Standard

Receiver spurious emissions are emissions at any frequency when the equipment is in receive mode.

Limit:

The spurious emissions of the receiver shall not exceed the values given in table 5.

In case of equipment with antenna connectors, these limits apply to emissions at the antenna port (conducted). For emissions radiated by the cabinet or emissions radiated by integral antenna equipment (without antenna connectors), these limits are e.r.p. for emissions up to 1 GHz and e.i.r.p. for emissions above 1 GHz.

Table 5: Spurious emission limits for receivers

Frequency range	Maximum power e.r.p.((≤ 1 GHz) e.i.r.p. (> 1 GHz	Measurement bandwith
30 MHz to 1GHz	-57 dBm	100 kHz
1 GHz to 12.75GHz	-47 dBm	1 MHz

Test Procedure

Conducted measurement:

In case of conducted measurements, the radio equipment shall be connected to the measuring equipment via an attenuator.
The spectrum in the spurious domain (see figure 1 or figure 3) shall be searched for emissions that exceed the limit values given in table 5 or table 13 or that come to within 6 dB below these limits. Each occurrence shall be recorded.

The measurement procedure contains 2 parts.

Pre-scan:

The procedure in step 1 to step 4 below shall be used to identify potential unwanted emissions of the UUT.

Step 1:

The sensitivity of the measurement set-up should be such that the noise floor is at least 12 dB below the limits given in table 5 or table 13.

Step 2:

The emissions over the range 30 MHz to 1 000 MHz shall be identified.

Spectrum analyser settings:

- Resolution bandwidth: 100 kHz
- Video bandwidth: 300 kHz
- Filter type: 3 dB (Gaussian)
- Detector mode: Peak
- Trace Mode: Max Hold
- Sweep Points: ≥ 19 400
- Sweep time: Auto

Wait for the trace to stabilize. Any emissions identified during the sweeps above and that fall within the 6 dB range below the applicable limit or above, shall be individually measured using the procedure in clause 5.4.10.2.1.3 and compared to the limits given in table 5 or table 13.

Step 3:

The emissions over the range 1 GHz to 12,75 GHz shall be identified.

Spectrum analyser settings:

- Resolution bandwidth: 1 MHz
- Video bandwidth: 3 MHz
- Filter type: 3 dB (Gaussian)
- Detector mode: Peak
- Trace Mode: Max Hold
- Sweep Points: ≥ 23 500; for spectrum analysers not supporting this high number of sweep points, the frequency band may be segmented
- Sweep time: Auto

Wait for the trace to stabilize. Any emissions identified during the sweeps above that fall within the 6 dB range below the applicable limit or above, shall be individually measured using the procedure in clause 5.4.10.2.1.3 and compared to the limits given in table 5 or table 13.

Frequency Hopping equipment may generate a block (or several blocks) of spurious emissions anywhere within the spurious domain. If this is the case, only the highest peak of each block of emissions shall be measured using the procedure in clause 5.4.10.2.1.3.

Step 4:

In case of conducted measurements on smart antenna systems (equipment with multiple transmit chains), step 2 and step 3 need to be repeated for each of the active transmit chains (A_{ch}).The limits used to identify emissions during this pre-scan need to be reduced by $10 \times \log_{10} (A_{ch})$.

Measurement of the emissions identified during the pre-scan:

The procedure in step 1 to step 4 below shall be used to accurately measure the individual unwanted emissions identified during the pre-scan measurements above. This method assumes the spectrum analyser has a Time Domain Power function.

Step 1:

The level of the emissions shall be measured using the following spectrum analyser settings:

- Measurement Mode: Time Domain Power
- Centre Frequency: Frequency of the emission identified during the pre-scan
- Resolution Bandwidth: 100 kHz (< 1 GHz) / 1 MHz (> 1 GHz)
- Video Bandwidth: 300 kHz (< 1 GHz) / 3 MHz (> 1 GHz)
- Frequency Span: Zero Span
- Sweep mode: Single Sweep
- Sweep time: 30 ms
- Sweep points: ≥ 30 000
- Trigger: Video (for burst signals) or Manual (for continuous signals)
- Detector: RMS

Step 2:

Set a window where the start and stop indicators match the start and end of the burst with the highest level and record the value of the power measured within this window. If the spurious emission to be measured is a continuous transmission, the measurement window shall be set to match the start and stop times of the sweep.

Step 3:

In case of conducted measurements on smart antenna systems (equipment with multiple transmit chains), step 2 needs to be repeated for each of the active transmit chains (A_{ch}).

Sum the measured power (within the observed window) for each of the active transmit chains.

Step 4:

The value defined in step 3 shall be compared to the limits defined in table 5 or table 13.

Radiated measurement:

The test site as described in annex B and applicable measurement procedures as described in annex C shall be used.

The test procedure is further as described under clause 5.4.10.2.1.

Test Data

Environmental Conditions

Temperature:	22.7 ℃
Relative Humidity:	50 %
ATM Pressure:	100.7 kPa

The testing was performed by Chao Gao on 2020-03-29.

Test mode: Receiving in GFSK Mode (worst case)

Test Result: Compliant

30 MHz ~ 12.75 GHz

Frequency (MHz)	Receiver Reading (dBµV)	Turntable Angle Degree	Rx Antenna		Substituted			Absolute Level (dBm)	EN 300 328	
			Height (cm)	Polar (H/V)	Submitted Level (dBm)	Cable Loss (dB)	Antenna Gain (dBd/dBi)		Limit (dBm)	Margin (dB)
Low Channel										
693.46	37.42	277	150	H	-62.3	0.62	-1.68	-64.60	-57	7.60
693.46	37.19	338	150	V	-62.46	0.62	-1.68	-64.76	-57	7.76
1591.35	49.31	262	150	H	-64.43	0.86	9.28	-56.01	-47	9.01
1591.35	49.52	154	150	V	-64.22	0.86	9.28	-55.8	-47	8.8
High Channel										
693.19	37.31	230	150	H	-62.38	0.62	-1.68	-64.68	-57	7.68
693.19	37.06	36	150	V	-62.6	0.62	-1.68	-64.90	-57	7.9
1596.15	49.16	188	150	H	-64.55	0.86	9.28	-56.13	-47	9.13
1596.15	48.95	275	150	V	-64.76	0.86	9.28	-56.34	-47	9.34

Note:
Antenna gain is dBd for frequency below 1GHz and is dBi for frequency above 1GHz.
Absolute Level = Submitted Level - Cable loss + Antenna Gain
Margin = Limit- Absolute Level

ETSI EN 300 328 V2.2.2 (2019-07) Clause 4.3.1.12 – RECEIVER BLOCKING

Applicable Standard

Receiver blocking is a measure of the ability of the equipment to receive a wanted signal on its operating channel without exceeding a given degradation in the presence of an unwanted signal (blocking signal) on frequencies other than those of the operating band provided in table 1.

While maintaining the minimum performance criteria as defined in clause 4.3.1.12.3, the blocking levels at specified frequency offsets shall be equal to or greater than the limits defined for the applicable receiver category provided in table 6, table 7 or table 8.

Table 6: Receiver Blocking parameters for Receiver Category 1 equipment

Wanted signal mean power from companion device (dBm) (see notes 1 and 4)	Blocking signal frequency (MHz)	Blocking signal power (dBm) (see note 4)	Type of blocking signal
(-133 dBm + 10 × $\log_{10}$(OCBW)) or -68 dBm whichever is less (see note 2)	2 380 2 504	-34	CW
(-139 dBm + 10 × $\log_{10}$(OCBW)) or -74 dBm whichever is less (see note 3)	2 300 2 330 2 360 2 524 2 584 2 674		

NOTE 1: OCBW is in Hz.
NOTE 2: In case of radiated measurements using a companion device and the level of the wanted signal from the companion device cannot be determined, a relative test may be performed using a wanted signal up to P_{min} + 26 dB where P_{min} is the minimum level of wanted signal required to meet the minimum performance criteria as defined in clause 4.3.1.12.3 in the absence of any blocking signal.
NOTE 3: In case of radiated measurements using a companion device and the level of the wanted signal from the companion device cannot be determined, a relative test may be performed using a wanted signal up to P_{min} + 20 dB where P_{min} is the minimum level of wanted signal required to meet the minimum performance criteria as defined in clause 4.3.1.12.3 in the absence of any blocking signal.
NOTE 4: The level specified is the level at the UUT receiver input assuming a 0 dBi antenna assembly gain. In case of conducted measurements, this level has to be corrected for the (in-band) antenna assembly gain (G). In case of radiated measurements, this level is equivalent to a power flux density (PFD) in front of the UUT antenna with the UUT being configured/positioned as recorded in clause 5.4.3.2.2.

Table 7: Receiver Blocking parameters receiver Category 2 equipment

Wanted signal mean power from companion device (dBm) (see notes 1 and 3)	Blocking signal frequency (MHz)	Blocking signal power (dBm) (see note 3)	Type of blocking signal
(-139 dBm + 10 × $\log_{10}$(OCBW) + 10 dB) or (-74 dBm + 10 dB) whichever is less (see note 2)	2 380 2 504 2 300 2 584	-34	CW

NOTE 1: OCBW is in Hz.
NOTE 2: In case of radiated measurements using a companion device and the level of the wanted signal from the companion device cannot be determined, a relative test may be performed using a wanted signal up to P_{min} + 26 dB where P_{min} is the minimum level of wanted signal required to meet the minimum performance criteria as defined in clause 4.3.1.12.3 in the absence of any blocking signal.
NOTE 3: The level specified is the level at the UUT receiver input assuming a 0 dBi antenna assembly gain. In case of conducted measurements, this level has to be corrected for the (in-band) antenna assembly gain (G). In case of radiated measurements, this level is equivalent to a power flux density (PFD) in front of the UUT antenna with the UUT being configured/positioned as recorded in clause 5.4.3.2.2.

Table 8: Receiver Blocking parameters receiver Category 3 equipment

Wanted signal mean power from companion device (dBm) (see notes 1 and 3)	Blocking signal frequency (MHz)	Blocking signal power (dBm) (see note 3)	Type of blocking signal
(-139 dBm + 10 × $\log_{10}$(OCBW) + 20 dB) or (-74 dBm + 20 dB) whichever is less (see note 2)	2 380 2 504 2 300 2 584	-34	CW

NOTE 1: OCBW is in Hz.
NOTE 2: In case of radiated measurements using a companion device and the level of the wanted signal from the companion device cannot be determined, a relative the test may be performed using a wanted signal up to P_{min} + 30 dB where P_{min} is the minimum level of wanted signal required to meet the minimum performance criteria as defined in clause 4.3.1.12.3 in the absence of any blocking signal.
NOTE 3: The level specified is the level at the UUT receiver input assuming a 0 dBi antenna assembly gain. In case of conducted measurements, this level has to be corrected for the (in-band) antenna assembly gain (G). In case of radiated measurements, this level is equivalent to a power flux density (PFD) in front of the UUT antenna with the UUT being configured/positioned as recorded in clause 5.4.3.2.2.

Test Procedure

According to ETSI EN 300 328 V2.2.2 (2019-07) Clause5.4.11.2

Test Setup Block diagram

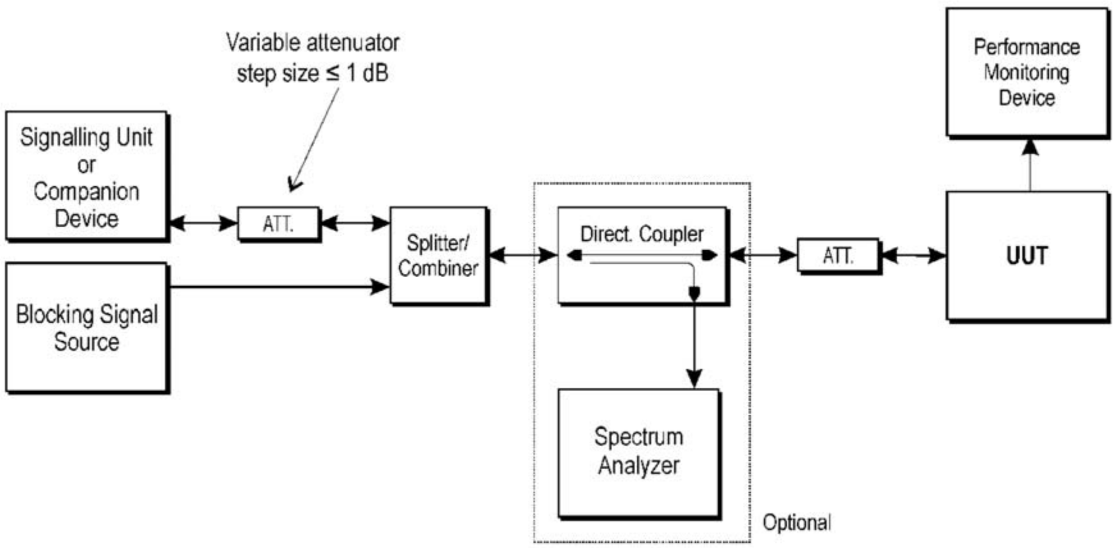


Figure 6: Test Set-up for receiver blocking

Test data

Environmental Conditions

Temperature:	22.7 ℃
Relative Humidity:	50 %
ATM Pressure:	100.7 kPa

The testing was performed by Chao Gao on 2020-03-29.

Test Mode: Receiving in GFSK Mode
*(**Note**: CMW500 sends packets to the EUT, PER can be read by CMW500)*

Test Result: Compliant

Receiver category	Channel	Wanted signal mean power from companion device (dBm)	Blocking signal Frequency (MHz)	Blocking signal Power(dBm)	PER (%)	Limit (%)
2 (See Note1)	Hopping	-64.5	2380	-30.6 (See Note2)	1.15	≤10.00
			2504		5.51	≤10.00
			2300		2.53	≤10.00
			2584		3.16	≤10.00

Note1: The 0dBm＜e.i.r.p ＜10dBm.
Note2: The actual assembly gain is 3.4 dBi.

EXHIBIT A - E.2 INFORMATION AS REQUIRED BY ETSI EN 300 328 V2.2.2, Clause 5.4.1

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

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: _79_______;

The (average) Dwell Time: 4.13 ;

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 maximum 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: _____μs

☐ The equipment has implemented a 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: 6.73dBm ;
Power Spectral Density N/A ;
Duty cycle, Tx-Sequence, Tx-gap N/A ;
Accumulated Transmit time, Frequency Occupation & Hopping Sequence (only for FHSS equipment) 0.298s, 2, 79 ;
Hopping Frequency Separation (only for FHSS equipment) 1006.00kHz ;
Medium Utilisation N/A ;
Adaptivity Not Applicable ;
Receiver Blocking Compliance ;
Nominal Channel Bandwidth 1.197MHz ;
Transmitter unwanted emissions in the OOB domain -32.23 dBm/MHz ;
Transmitter unwanted emissions in the spurious domain -64.05dBm ;
Receiver spurious emissions -64.60dBm ;

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 one 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
Note: Add more lines if more channel bandwidths are supported.

☐ 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
Note: Add more lines if more channel bandwidths are supported.

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: N/A ;

Note: The additional beam forming gain does not include the basic gain of a single antenna.

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

Operating Frequency Range 1:__2402____ MHz to __2480____ MHz
Operating Frequency Range 2:__________ MHz to __________ MHz

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

j) Nominal Channel Bandwidth(s):

Nominal Channel Bandwidth 1:___0.851__ MHz
Nominal Channel Bandwidth 2:___1.187__ MHz
Nominal Channel Bandwidth 3:___1.197__ MHz
Nominal Channel Bandwidth 4:_________ MHz

Note: Add more lines if more channel bandwidths are supported.

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 normal and extreme operating conditions that apply to the equipment:

Normal operating conditions (if applicable):

Operating temperature:___25____° C

Other (please specify if applicable):

Extreme operating conditions:

Operating temperature range: Minimum:___-40___ ° C Maximum: ___+85__° C

Other (please specify if applicable): …… Minimum: …… Maximum ……

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:

☒ Integral Antenna (information to be provided in case of conducted measurements)

Antenna Gain:__3.4___ dBi

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

Note 1: Add more lines in case the equipment has more power levels.
Note 2: These power levels are conducted power levels (at antenna connector).

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			

NOTE 3: Add more rows in case more antenna assemblies are supported for this power level.

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			

NOTE 4: Add more rows in case more antenna assemblies are supported for this power level.

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			

NOTE 5: Add more rows in case more antenna assemblies are supported for this power level.

n) 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 3.0~3.6 V

In case of DC, indicate the type of power source
☐ Internal Power Supply
☒ External Power Supply or AC/DC adapter______________________.
☐ Battery______________________________.
☐ Other:____________________________________.

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

Continuous transmiting and normal operation.

p) The equipment type (e.g. Bluetooth®, IEEE 802.11™ [i.3], IEEE 802.15.4™ [i.4], proprietary, etc.):

Bluetooth®.

q) If applicable, the statistical analysis referred to in clause 5.4.1 q)

(to be provided as separate attachment)

r) If applicable, the statistical analysis referred to in clause 5.4.1 r)

(to be provided as separate attachment)

s) 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.

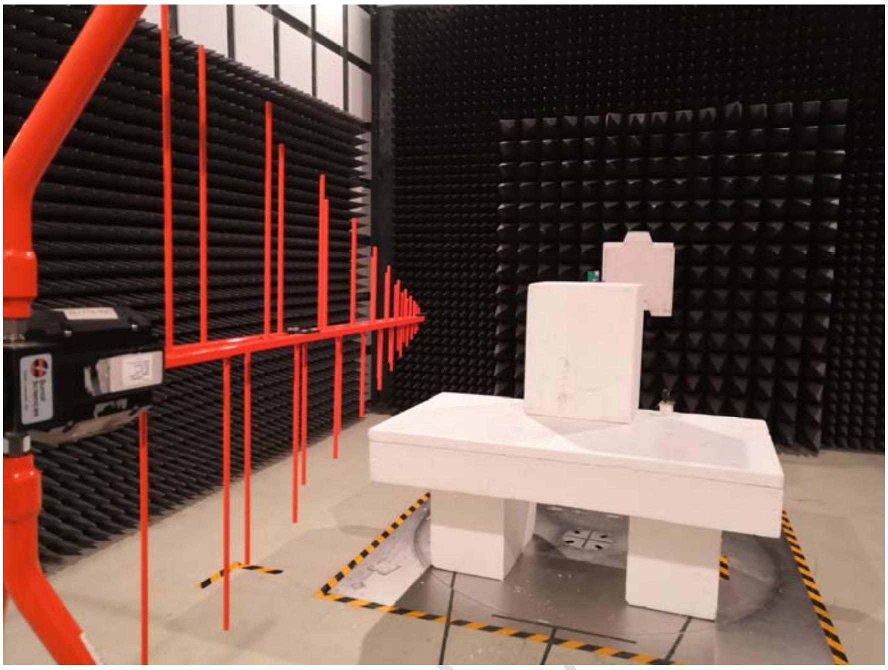
☒ No

EXHIBIT B - EUT PHOTOGRAPHS

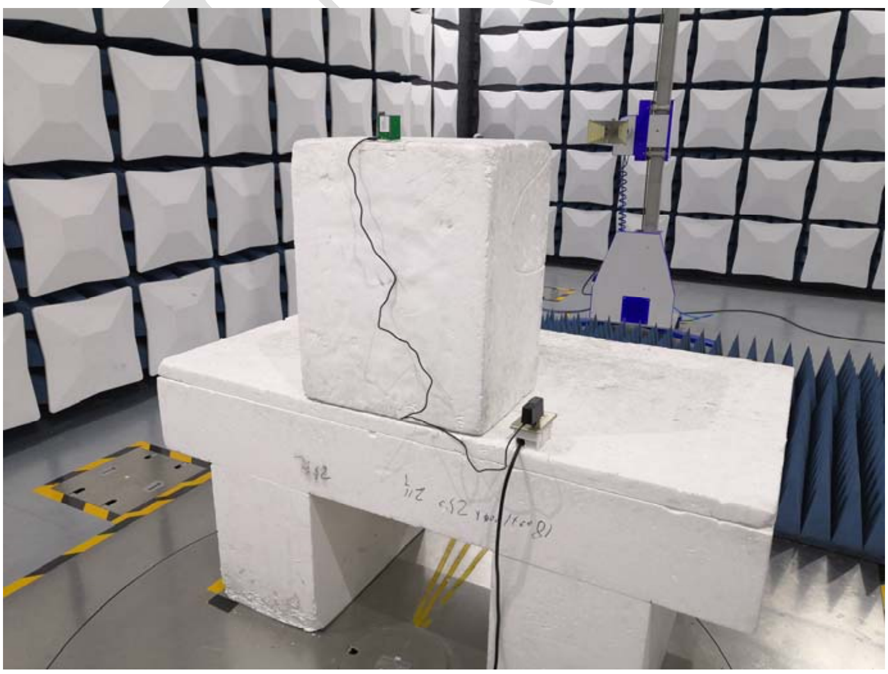
Please refer to report No.: RSHD200218007-01A which was issued by BACL (Kunshan).

EXHIBIT C - TEST SETUP PHOTOGRAPHS

Radiated Spurious Emissions View (Below 1 GHz)



Radiated Spurious Emissions View (Above 1 GHz)



******* END OF REPORT *******