# 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:** | RSHD200218007-01A |
| **Report Date:** | 2020-03-16 |
| **Reviewed By:** | Oscar Ye<br>EMC Manager |
| **Prepared By:** | Bay Area Compliance Laboratories Corp. (Kunshan)<br>No.248 Chenghu Road, Kunshan, Jiangsu province, China<br>Tel: +86-0512-86175000<br>Fax: +86-0512-88934268<br>www.baclcorp.com.cn |

# TABLE OF CONTENTS

# GENERAL INFORMATION

## Product Description for Equipment under Test (EUT)

| | |
|---|---|
| Applicant: | ESPRESSIF SYSTEMS (SHANGHAI) CO., LTD |
| Tested Model: | ESP32-WROOM-32E |
| Product Type: | Wi-Fi & Bluetooth Internet of Things Module |
| Power Supply: | DC 3.3V |
| RF Function: | 2.4G Wi-Fi |
| Operating Band/Frequency: | 2412-2472MHz |
| Channel Number: | 13 |
| Channel Separation: | 5MHz |
| Antenna Type: | PCB Antenna |
| Antenna Gain: | 3.4dBi |

**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 band; Harmonized Standard for access to radio spectrum.

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 | | 0.4% |

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 and CAB identifier CN0004 under the ISED requirement. 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

Test channel list is as below:

For 802.11b, 802.11g and 802.11n-HT20 mode, EUT was tested with Channel 1, 7, and 13;
For 802.11n-HT40 mode, EUT was tested with Channel 3, 7, and 11;

| Channel | Frequency (MHz) | Channel | Frequency (MHz) |
|---|---|---|---|
| 1 | 2412 | 8 | 2447 |
| 2 | 2417 | 9 | 2452 |
| 3 | 2422 | 10 | 2457 |
| 4 | 2427 | 11 | 2462 |
| 5 | 2432 | 12 | 2467 |
| 6 | 2437 | 13 | 2472 |
| 7 | 2442 | / | / |

The worst-case data rates are determined to be as follows for each mode based upon investigation by measuring the average power and PSD across all data rates, bandwidths and modulations.

## EUT Exercise Software

RF test tool: espRFTool

Pre-scan with all the data rates, and the worst case was performed as below:

| Mode | Data Rate | Channel | Power Setting |
|---|---|---|---|
| 802.11b | 1 Mbps | Low | 15 |
| | | Middle | 15 |
| | | High | 15 |
| 802.11g | 6 Mbps | Low | 8 |
| | | Middle | 8 |
| | | High | 8 |
| 802.11n-HT20 | MCS0 | Low | 6 |
| | | Middle | 6 |
| | | High | 6 |
| 802.11n-HT40 | MCS0 | Low | 8 |
| | | Middle | 8 |
| | | High | 8 |

## Special Accessories

No special accessory.

## Equipment Modifications

No modification was made to the EUT.

## Support Equipment List and Details

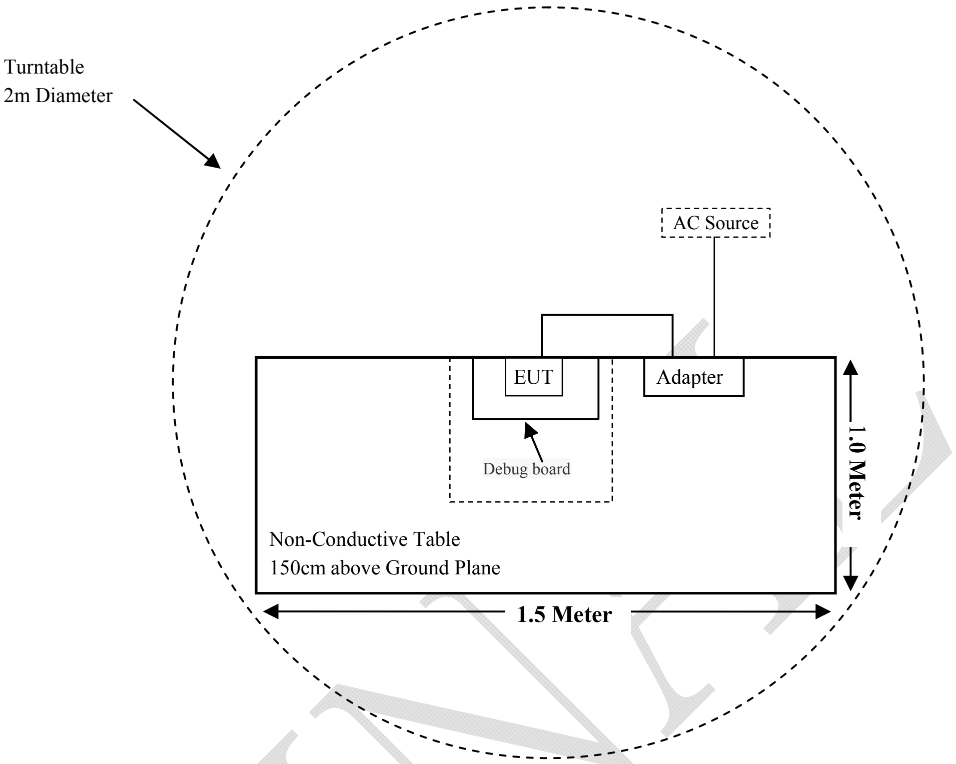
| Manufacturer | Description | Model | Serial Number |
|---|---|---|---|
| Something High Electric (Xiamen) Company Inc. | Adapter | P-050B-050200 | B2152-1839 |
| / | Debug board | / | / |

## 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 4.3.2.2 | RF Output Power | Compliant |
| Clause 4.3.2.3 | Power Spectral Density | Compliant |
| Clause 4.3.2.4 | Duty Cycle, Tx-sequence, Tx-gap | Not Applicable (See Note1) |
| Clause 4.3.2.5 | Medium Utilization (MU) Factor | Not Applicable (See Note1) |
| Clause 4.3.2.6 | Adaptivity (non-FHSS) | Compliant |
| Clause 4.3.2.7 | Occupied Channel Bandwidth | Compliant |
| Clause 4.3.2.8 | Transmitter Unwanted Emissions in the Out-of-band Domain | Compliant |
| Clause 4.3.2.9 | Transmitter Unwanted Emissions in the Spurious Domain | Compliant |
| Clause 4.3.2.10 | Receiver Spurious Emissions | Compliant |
| Clause 4.3.2.11 | Receiver Blocking | Compliant |
| Clause 4.3.2.12 | Geo-location Capability | Not Applicable (See Note2) |

**Note1:** The EUT is adaptive equipment, while this item is only for non-adaptive mode.

**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 | Bilog antenna | JB3 | A060217 | 2017-08-04 | 2020-08-03 |
| Sonoma Instrunent | Pre-amplifier | 310N | 171205 | 2019-08-14 | 2020-08-13 |
| Rohde & Schwarz | Auto test Software | EMC32 | 100361 | N/A | N/A |
| 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 | 491 | 2019-02-20 | 2020-02-19 |
| Rohde & Schwarz | Auto test Software | EMC32 | 100361 | N/A | N/A |
| 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 | N/A | N/A |
| **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 | N/A | 2019-01-10 | 2022-01-09 |
| Agilent | Attenuator/110dB | 8496B | N/A | 2019-01-10 | 2022-01-09 |
| Narda | Attenuator | 10dB | 010 | 2019-08-15 | 2020-08-14 |
| Rohde & Schwarz | Signal Analyzer | FSV40 | 101116 | 2019-07-23 | 2020-07-22 |
| 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 C01 | 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 4.3.2.2 – 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

For adaptive equipment using wide band modulations other than FHSS, the maximum RF output power shall be 20 dBm.
The maximum RF output power for non-adaptive equipment shall be declared by the manufacturer and shall not exceed 20 dBm. See clause 5.4.1 m). For non-adaptive equipment using wide band modulations other than FHSS, the maximum RF output power shall be equal to or less than the value declared by the manufacturer.
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:

$$\mathbf{P = A + G + Y}$$

- 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:** | 22.5~22.7 ℃ |
| **Relative Humidity:** | 49~50 % |
| **ATM Pressure:** | 100.5~101.7 kPa |

*The testing was performed by Chao Gao from 2020-03-10 to 2020-03-13.*

*Test Mode: Transmitting*

**802.11b Mode**

| Test Condition | | | EIRP (dBm) | Limits (dBm) | Test Results |
|---|---|---|---|---|---|
| Channel | Temperature (℃) | Voltage ($V_{DC}$) | | | |
| Low | -40 | 3.3 | 18.77 | 20 | Compliant |
| | +22.5 | | 18.19 | 20 | Compliant |
| | +85 | | 17.43 | 20 | Compliant |
| Middle | -40 | | 19.19 | 20 | Compliant |
| | +22.5 | | 18.64 | 20 | Compliant |
| | +85 | | 18.06 | 20 | Compliant |
| High | -40 | | 19.11 | 20 | Compliant |
| | +22.5 | | 18.37 | 20 | Compliant |
| | +85 | | 17.99 | 20 | Compliant |

**802.11g Mode**

| Test Condition | | | EIRP (dBm) | Limits (dBm) | Test Results |
|---|---|---|---|---|---|
| Channel | Temperature (℃) | Voltage ($V_{DC}$) | | | |
| Low | -40 | 3.3 | 19.40 | 20 | Compliant |
| | +22.5 | | 18.52 | 20 | Compliant |
| | +85 | | 17.69 | 20 | Compliant |
| Middle | -40 | | 19.68 | 20 | Compliant |
| | +22.5 | | 18.87 | 20 | Compliant |
| | +85 | | 18.39 | 20 | Compliant |
| High | -40 | | 19.15 | 20 | Compliant |
| | +22.5 | | 18.64 | 20 | Compliant |
| | +85 | | 17.95 | 20 | Compliant |

**802.11n-HT20 Mode**

| Test Condition | | | EIRP (dBm) | Limits (dBm) | Test Results |
|---|---|---|---|---|---|
| Channel | Temperature (℃) | Voltage ($V_{DC}$) | | | |
| Low | -40 | 3.3 | 19.35 | 20 | Compliant |
| | +22.5 | | 18.69 | 20 | Compliant |
| | +85 | | 18.27 | 20 | Compliant |
| Middle | -40 | | 19.52 | 20 | Compliant |
| | +22.5 | | 19.03 | 20 | Compliant |
| | +85 | | 18.24 | 20 | Compliant |
| High | -40 | | 19.22 | 20 | Compliant |
| | +22.5 | | 18.73 | 20 | Compliant |
| | +85 | | 18.42 | 20 | Compliant |

**802.11n-HT40 Mode**

| Test Condition | | | EIRP (dBm) | Limits (dBm) | Test Results |
|---|---|---|---|---|---|
| Channel | Temperature (℃) | Voltage ($V_{DC}$) | | | |
| Low | -40 | 3.3 | 19.50 | 20 | Compliant |
| | +22.5 | | 18.64 | 20 | Compliant |
| | +85 | | 18.04 | 20 | Compliant |
| Middle | -40 | | 19.35 | 20 | Compliant |
| | +22.5 | | 18.87 | 20 | Compliant |
| | +85 | | 18.10 | 20 | Compliant |
| High | -40 | | 19.53 | 20 | Compliant |
| | +22.5 | | 18.78 | 20 | Compliant |
| | +85 | | 17.96 | 20 | Compliant |

**Note**: Antenna gain was 3.4dBi.

# ETSI EN 300 328 V2.2.2 (2019-07) Clause 4.3.2.3 - POWER SPECTRAL DENSITY

## Applicable Standard

According to ETSI EN 300 328 V2.2.2 (2019-07) Clause4.3.2.3.1, this requirement applies to all types of equipment using wide band modulations other than FHSS.

The Power Spectral Density is the mean equivalent isotropically radiated power (e.i.r.p.) spectral density in a 1 MHz bandwidth during a transmission burst.

For equipment using wide band modulations other than FHSS, the maximum Power Spectral Density is limited to 10 dBm per MHz.

## Test Procedure

**Option 1**: For equipment with continuous and non-continuous transmissions

The transmitter shall be connected to a spectrum analyser and the Power Spectral Density as defined in clause 4.3.2.3 shall be measured and recorded.

The test procedure shall be as follows:

**Step 1:**

Connect the UUT to the spectrum analyser 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

NOTE: For spectrum analysers not supporting this number of sweep points, the frequency band may be segmented.

- Detector: RMS
- Trace Mode: Max Hold
- Sweep time: For non-continuous transmissions: 2 × Channel Occupancy Time × number of Sweep points
  For continuous transmissions: 10 s; the sweep time may be increased further until a value where the sweep time has no further impact anymore on the RMS value of the signal.

NOTE: For non-continuous signals, wait for the trace to stabilize.

Save the data (trace data) set to a file.

**Step 2:**

For conducted measurements on smart antenna systems using either operating mode 2 or operating mode 3 (see clause 5.3.2.2), 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 and use this as the new data set.

**Step 3:**

Add up the values for power for all the samples in the file using the formula below.

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

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

**Step 4:**

Normalize the individual values for power (in dBm) so that the sum is equal to the RF Output Power (e.i.r.p.) measured in clause 5.4.2 and save the corrected data. The following formulas can be 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 5:**

Starting from the first sample $P_{Samplecorr}(n)$ (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 which shall be recorded.

**Step 6:**

Shift the start point of the samples added up in step 5 by one sample and repeat the procedure in step 5 (i.e. sample #2 to sample #101).

**Step 7:**

Repeat step 6 until the end of the data set and record the Power Spectral Density values for each of the 1 MHz segments.

From all the recorded results, the highest value is the maximum Power Spectral Density for the UUT. This value, which shall comply with the limit given in clause 4.3.2.3.3, shall be recorded in the test report.

**Option 2**: For equipment with continuous transmission capability or for equipment operating (or with the capability to operate) with a constant duty cycle (e.g. Frame Based equipment)

This option is for equipment that can be configured to operate in a continuous transmit mode (100 % DC) or with a constant Duty Cycle (DC).

**Step 1:**

Connect the UUT to the spectrum analyser and use the following settings:

- Centre Frequency: The centre frequency of the channel under test
- RBW: 1 MHz
- VBW: 3 MHz
- Frequency Span: 2 × Nominal Bandwidth (e.g. 40 MHz for a 20 MHz channel)
- Detector Mode: Peak
- Trace Mode: Max Hold

**Step 2:**

When the trace is complete, find the peak value of the power envelope and record the frequency.

**Step 3:**

Make the following changes to the settings of the spectrum analyser:

- Centre Frequency: Equal to the frequency recorded in step 2
- Frequency Span: 3 MHz
- RBW: 1 MHz
- VBW: 3 MHz
- Sweep Time: 1 minute
- Detector Mode: RMS
- Trace Mode: Max Hold

**Step 4:**

When the trace is complete, the trace shall be captured using the "Hold" or "View" option on the spectrum analyser.

Find the peak value of the trace and place the analyser marker on this peak. This level is recorded as the highest mean power (power spectral density) D in a 1 MHz band.

Alternatively, where a spectrum analyser is equipped with a function to measure power spectral density, this function may be used to display the power spectral density D in dBm / MHz.

In case of conducted measurements on smart antenna systems operating in a mode with multiple transmit chains active simultaneously, the power spectral density of each transmit chain shall be measured separately to calculate the total power spectral density (value D in dBm / MHz) for the UUT.

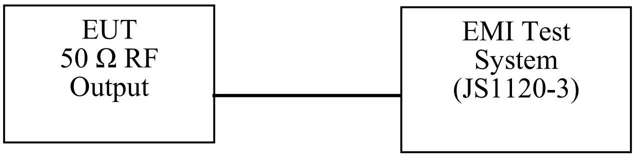
**Step 5:**

The maximum Power Spectral Density (PSD) e.i.r.p. is calculated from the above measured power spectral density D, the observed Duty Cycle (DC) (see clause 5.4.2.2.1.3, step 4), the applicable antenna assembly gain G in dBi and if applicable the beamforming gain Y in dB, according to the formula below. This value shall be recorded in the test report. If more than one antenna assembly is intended for this power setting, the gain of the antenna assembly with the highest gain shall be used.

$$PSD = D + G + Y + 10 \times \log(1 / DC) \text{ (dBm / MHz)}$$

## Test Setup Block diagram

802.11b/g/n




## Test Data

### Environmental Conditions

| | |
|---|---|
| **Temperature:** | 22.5~22.7 ℃ |
| **Relative Humidity:** | 49~50 % |
| **ATM Pressure:** | 100.5~101.7 kPa |

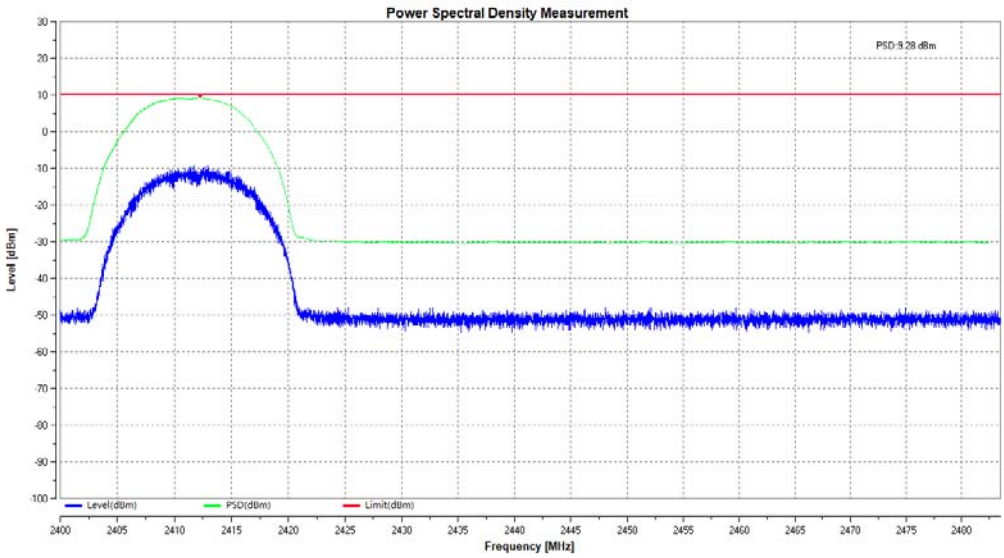
*The testing was performed by Chao Gao from 2020-03-10 to 2020-03-13.*

*Test Mode: Transmitting*

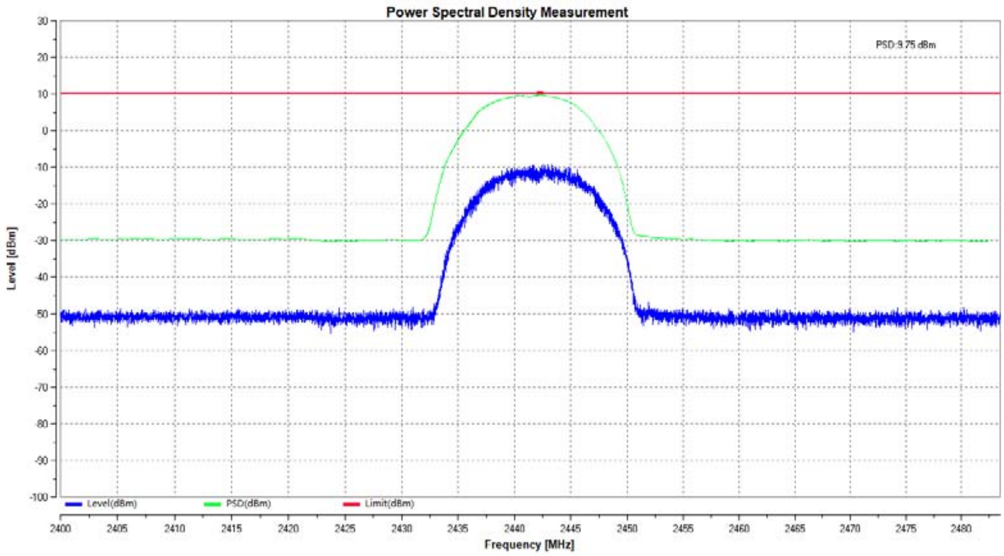
| Frequency (MHz) | Power Spectral Density e.i.r.p.(dBm/MHz) | Limit (dBm/MHz) | Result |
|---|---|---|---|
| **802.11b Mode** | | | |
| 2412 | 9.28 | <= 10.0 | PASS |
| 2442 | 9.75 | <= 10.0 | PASS |
| 2472 | 9.42 | <= 10.0 | PASS |
| **802.11g Mode** | | | |
| 2412 | 7.09 | <= 10.0 | PASS |
| 2442 | 7.35 | <= 10.0 | PASS |
| 2472 | 7.17 | <= 10.0 | PASS |
| **802.11n-HT20 Mode** | | | |
| 2412 | 7.09 | <= 10.0 | PASS |
| 2442 | 7.25 | <= 10.0 | PASS |
| 2472 | 7.08 | <= 10.0 | PASS |
| **802.11n-HT40 Mode** | | | |
| 2422 | 4.07 | <= 10.0 | PASS |
| 2442 | 4.03 | <= 10.0 | PASS |
| 2462 | 4.30 | <= 10.0 | PASS |

**Note**: Antenna gain was 3.4dBi.

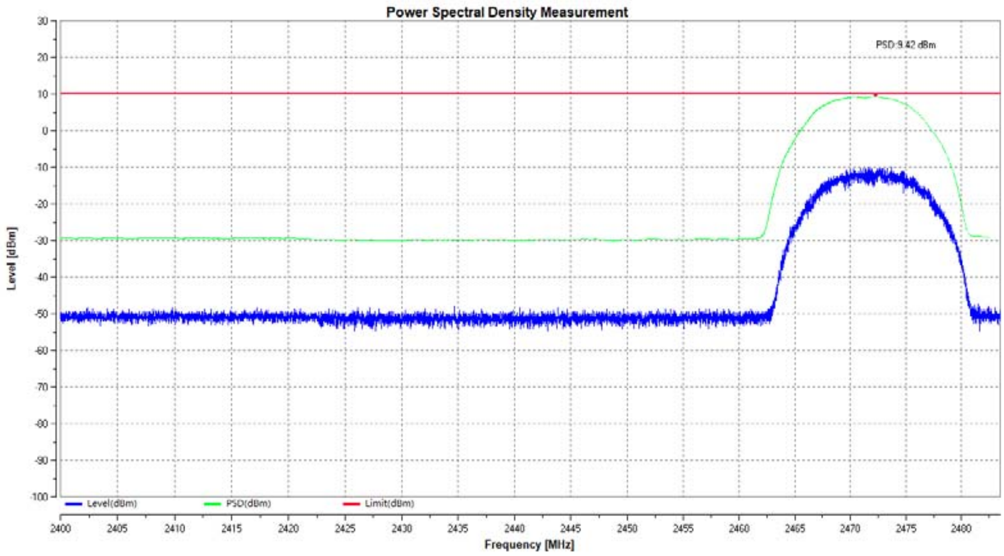
**802.11b Mode Low Channel: 2412 MHz**



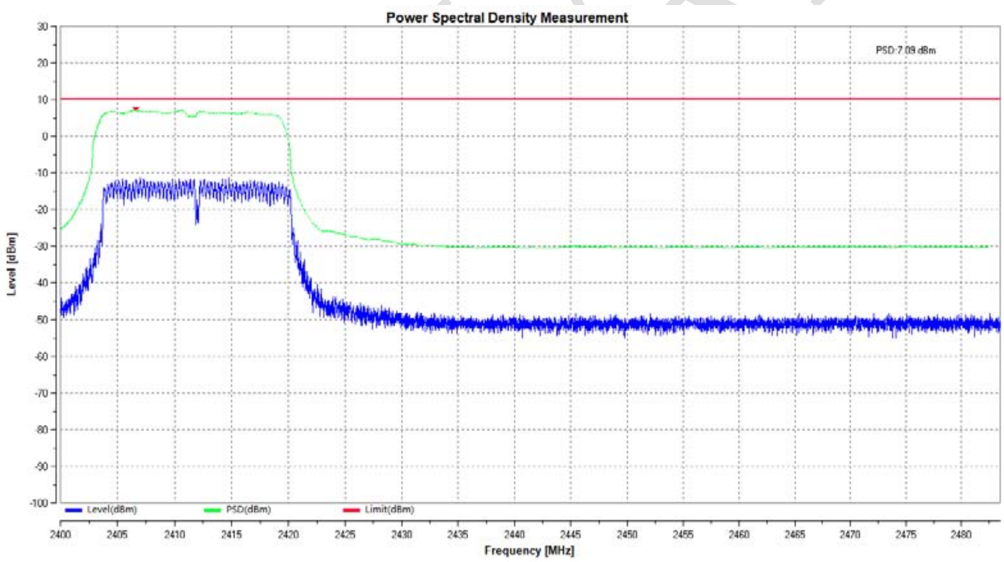

**802.11b Mode Middle Channel: 2442 MHz**



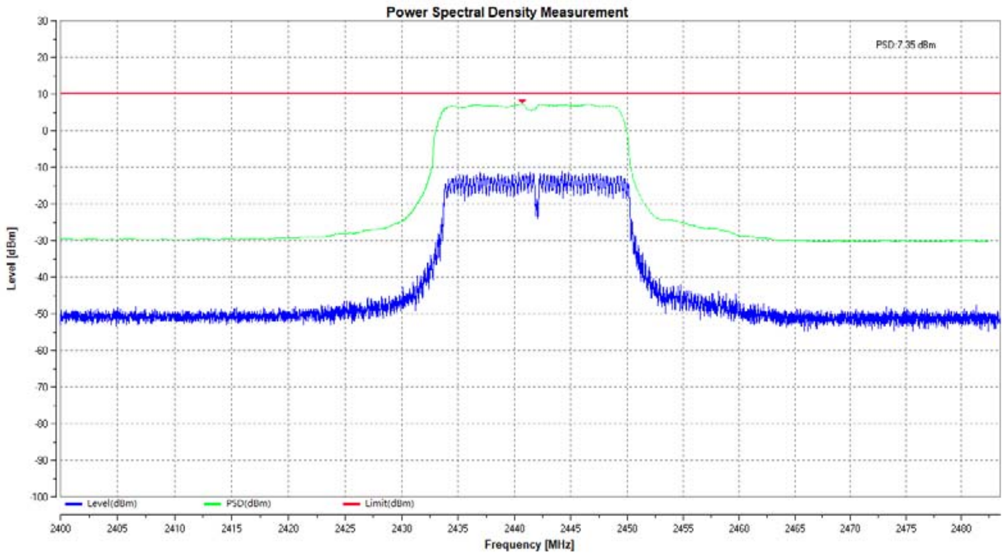
**802.11b Mode High Channel: 2472 MHz**



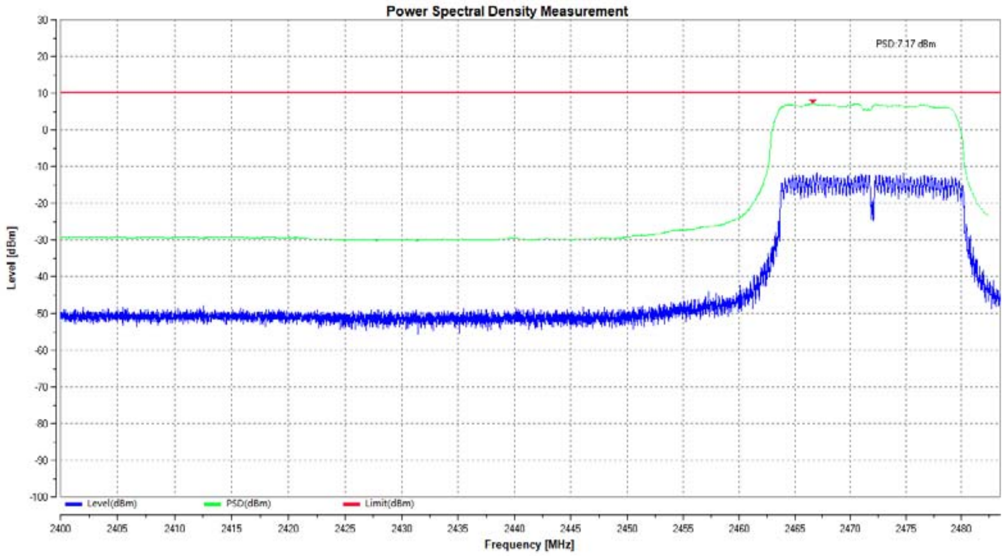

**802.11g Mode Low Channel: 2412 MHz**



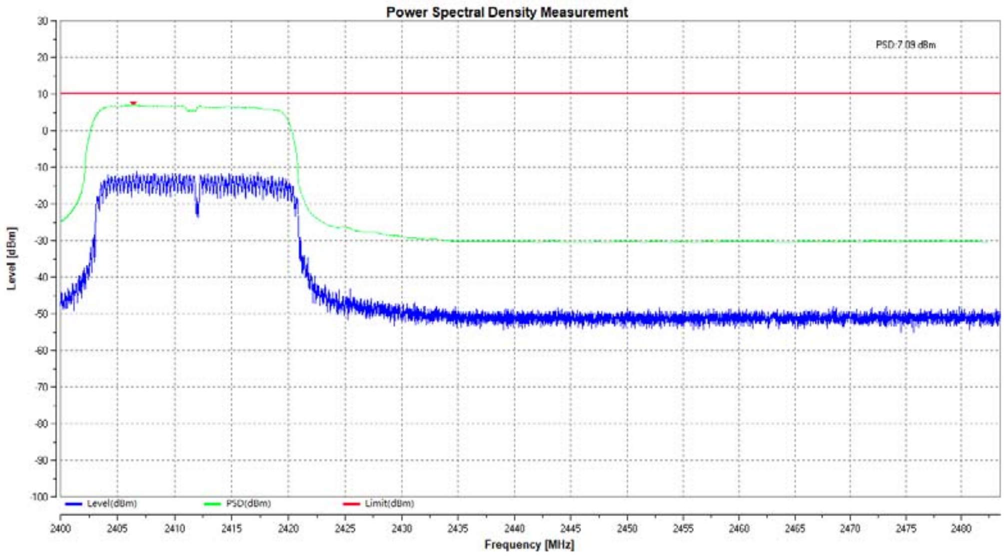
## 802.11g Mode Middle Channel: 2442 MHz



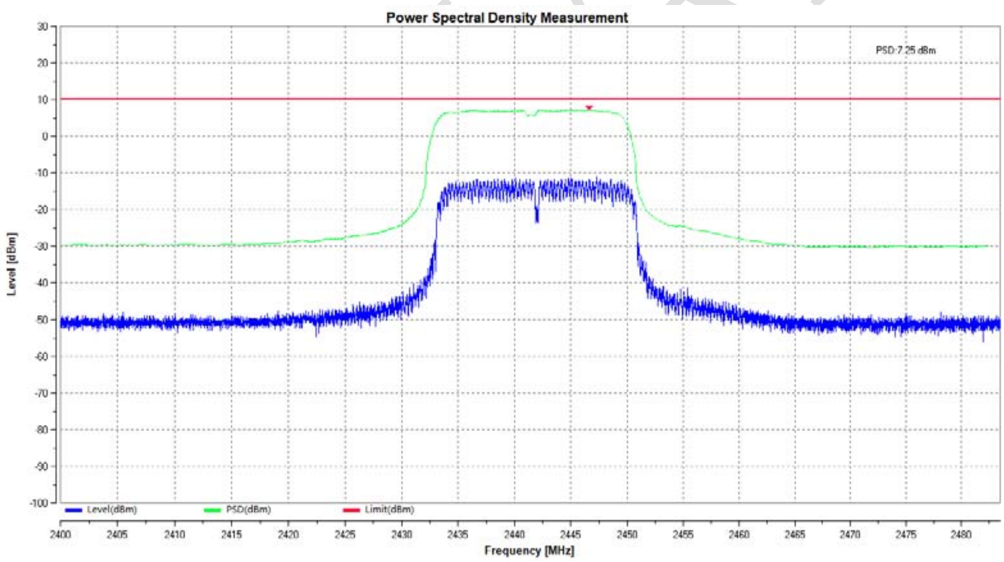

## 802.11g Mode High Channel: 2472 MHz



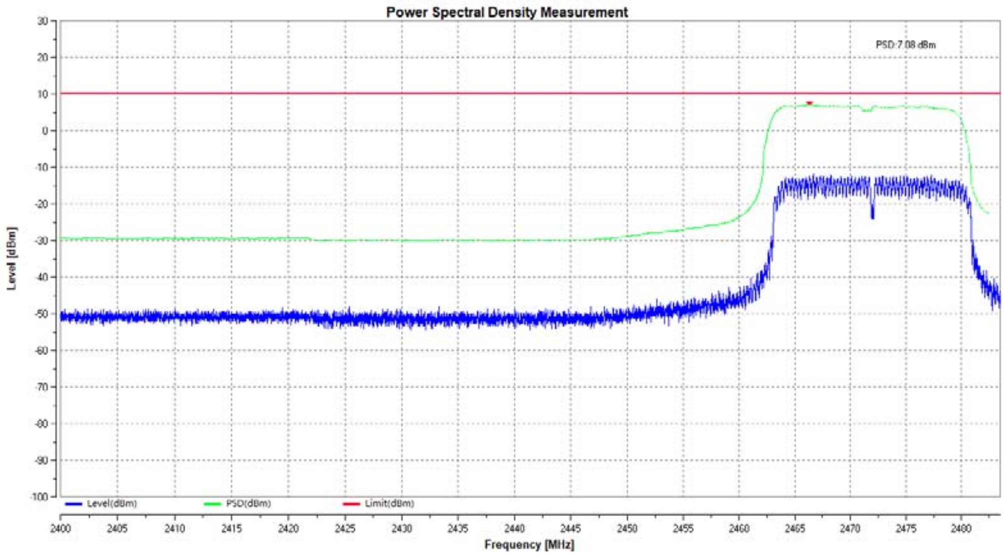
**802.11n-HT20 Mode Low Channel: 2412 MHz**



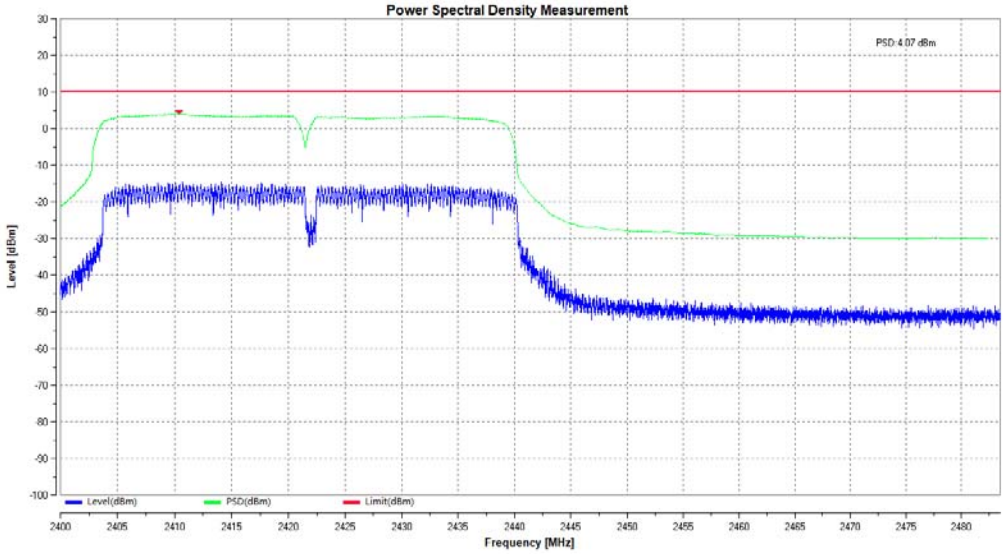

**802.11n-HT20 Mode Middle Channel: 2442 MHz**



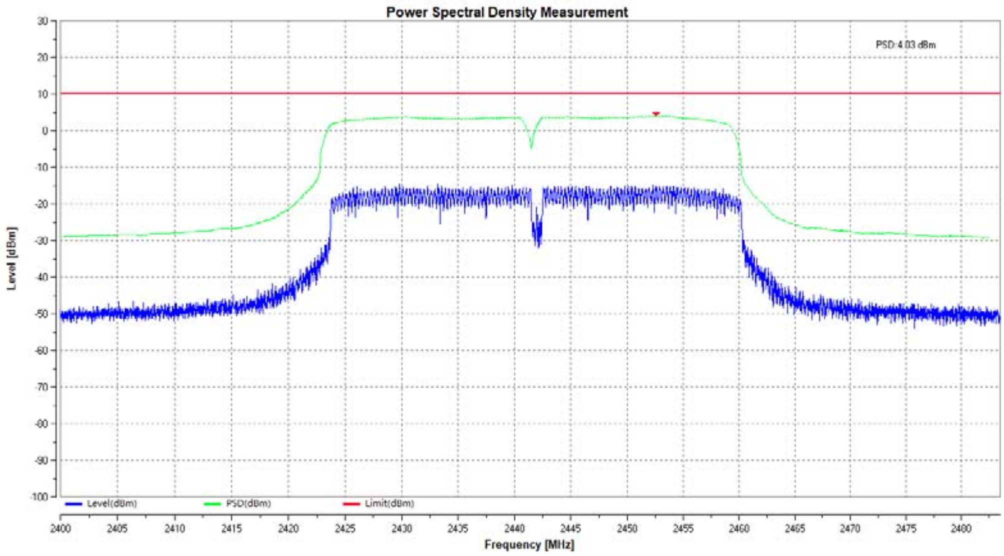
**802.11n-HT20 Mode High Channel: 2472 MHz**



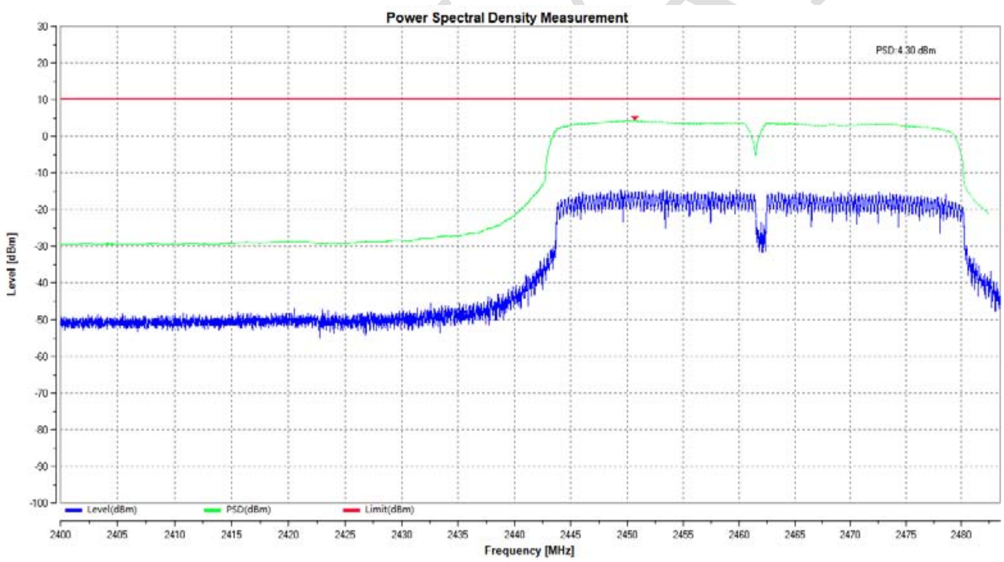

**802.11n-HT40 Mode Low Channel: 2422 MHz**



**802.11n-HT40 Mode Middle Channel: 2442 MHz**




**802.11n-HT40 Mode High Channel: 2462 MHz**



# ETSI EN 300 328 V2.2.2 (2019-07) Clause 4.3.2.6 – ADAPTIVITY

## Applicable Standard

Non-LBT based Detect and Avoid:

Non-LBT based Detect and Avoid is a mechanism for equipment using wide band modulations other than FHSS and by
which a given channel is made 'unavailable' because an interfering signal was reported after the transmission in that channel. This mechanism shall operate as intended in the presence of an unwanted signal on frequencies other than those of the operating band.

LBT based Detect and Avoid:

LBT based Detect and Avoid is a mechanism by which equipment using wide band modulations other than FHSS, avoids transmissions in a channel in the presence of an interfering signal in that channel. This mechanism shall operate
as intended in the presence of an unwanted signal on frequencies other than those of the operating band.

Limit:
According to ETSI EN 300 328 V2.2.2 (2019-07) Clause4.3.2.6.2.2 & 4.3.2.6.3.2

Adaptive equipment using wide band modulations other than FHSS, shall comply with the requirements defined in clause 4.3.2.6.2 (non-LBT based DAA) or clause 4.3.2.6.3 (LBT based DAA).

## Test Procedure

According to ETSI EN 300 328 V2.2.2 (2019-07) Clause5.4.6.2

## Test Setup Block diagram

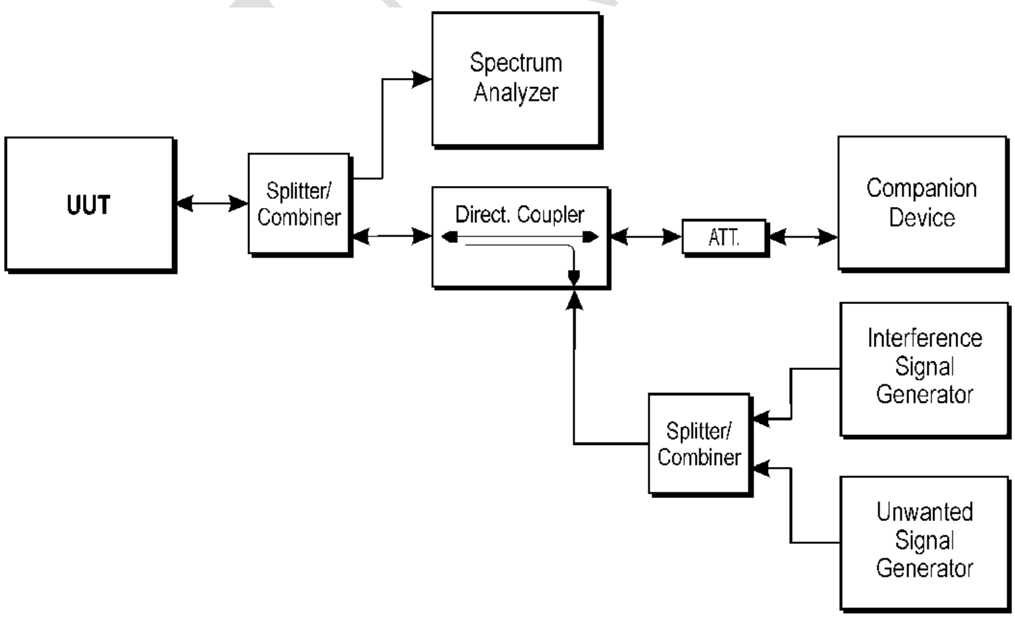



**Figure 5: Test set-up for verifying the adaptivity of an equipment**

## Test data

**Environmental Conditions**

| | |
|---|---|
| **Temperature:** | 22.5~22.7 ℃ |
| **Relative Humidity:** | 49~50 % |
| **ATM Pressure:** | 100.5~101.7 kPa |

*The testing was performed by Chao Gao from 2020-03-09 to 2020-03-13.*

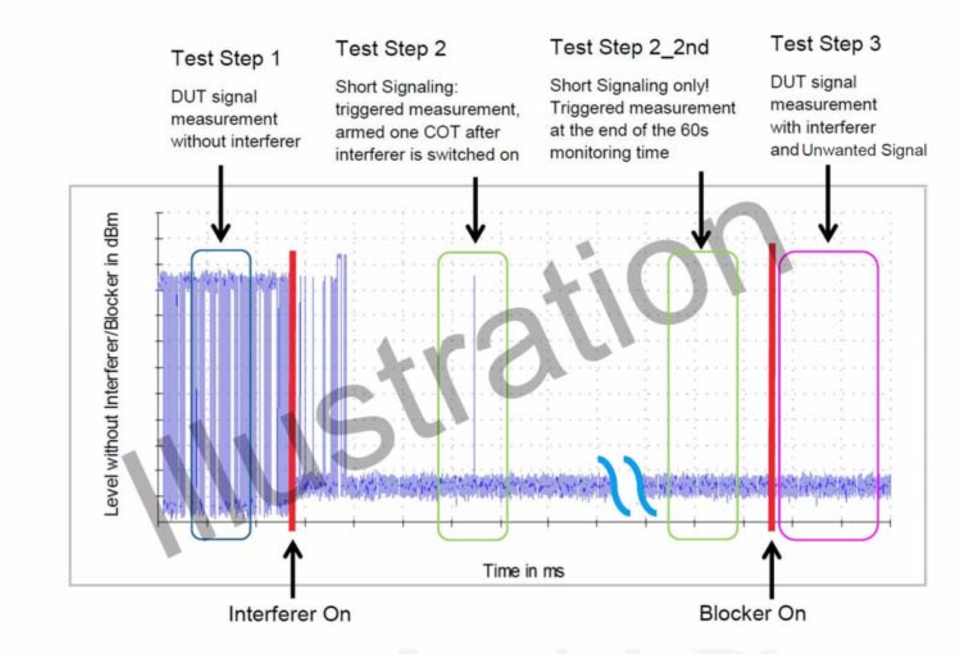
*Test Mode: Transmitting in 802.11b mode.*

***Note**: We tested 802.11b, 802.11g, 802.11n-HT20 and 802.11n-HT40, only 802.11b data was recorded in report.*

| Test Mode | Frequency (MHz) | Max.COT (ms) | Limit (ms) | Min. Idel Time (ms) | Min. Idel Time Limit (ms) | Result |
|---|---|---|---|---|---|---|
| 802.11b | 2412 | 0.304 | <13.000 | 0.057 | > 0.018 | PASS |
| | 2472 | 0.203 | <13.000 | 0.057 | > 0.018 | PASS |

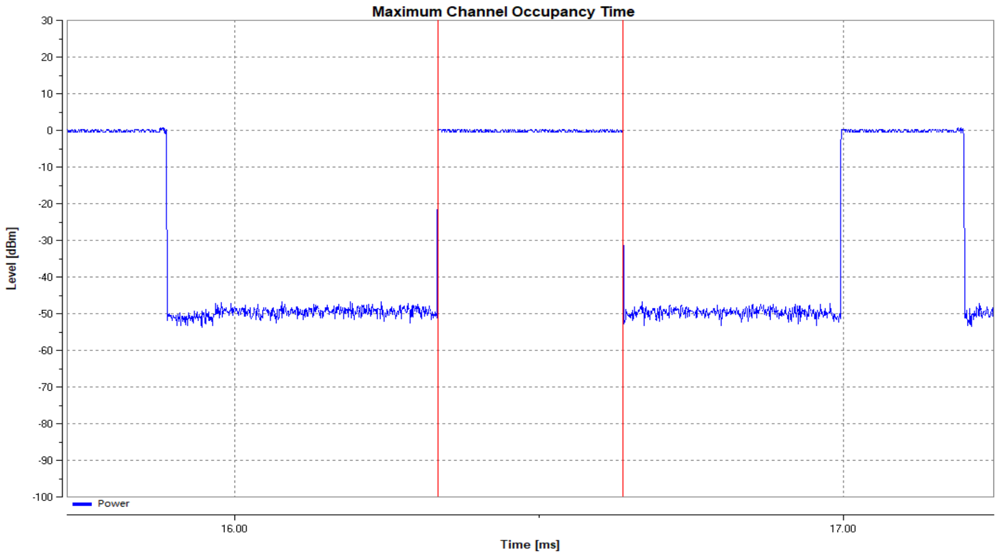
| Test Mode | Frequency (MHz) | Add Signal Type | Add Signal Time(ms) | Max. Short Time (%) | Limit (%) | Result |
|---|---|---|---|---|---|---|
| 802.11b | 2412 | AWGN | 2001 | 0.00 | <10.0 | PASS |
| | | CW | 62000 | 0.00 | <10.0 | PASS |
| | 2472 | AWGN | 2001 | 0.00 | <10.0 | PASS |
| | | CW | 62000 | 0.00 | <10.0 | PASS |

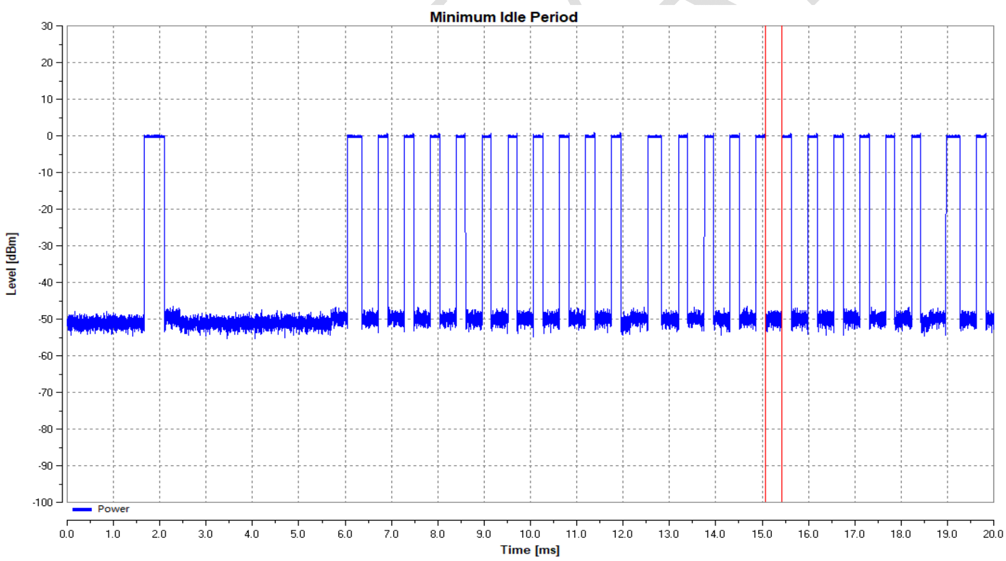
**Adaptively Test Schematic Graphic**

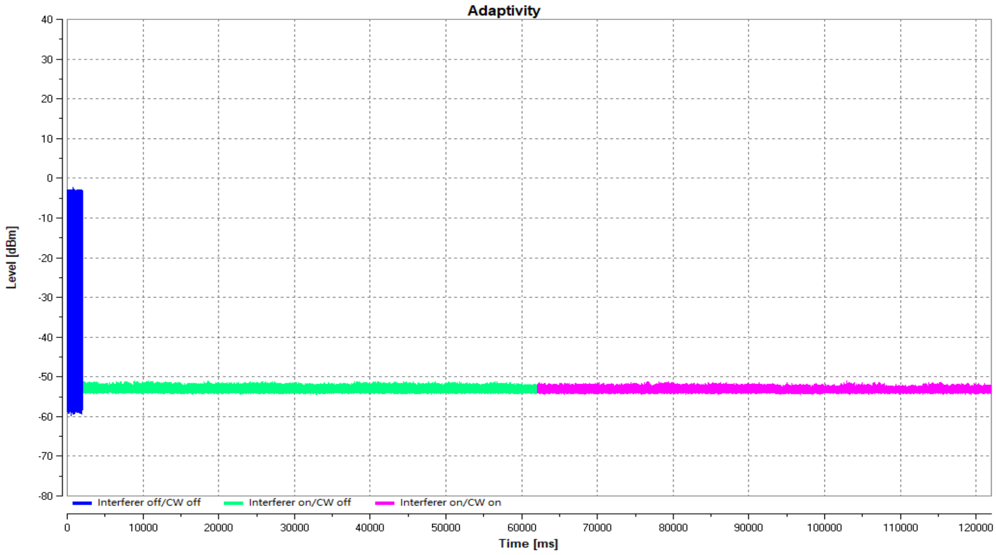


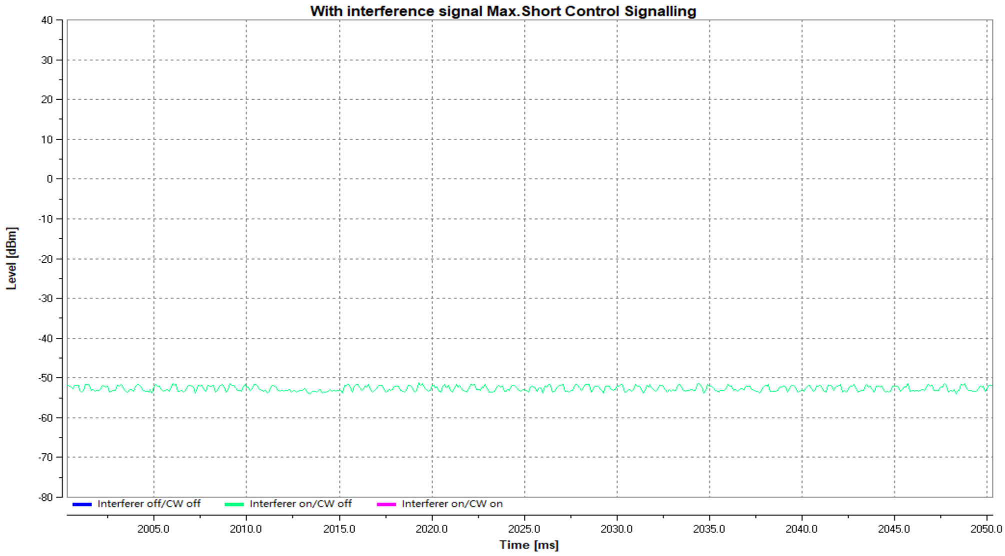
***802.11b mode:***

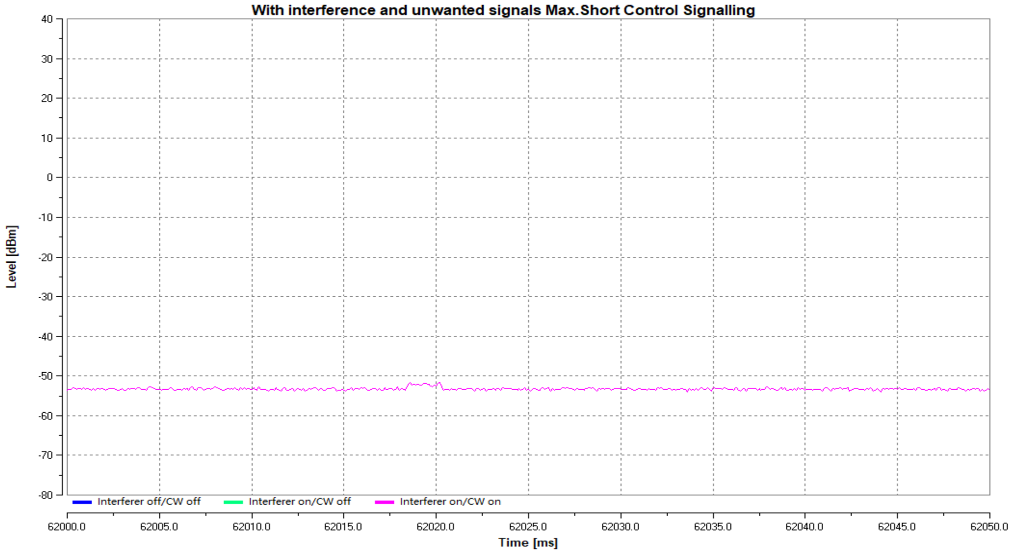
**802.11b - Low Channel**



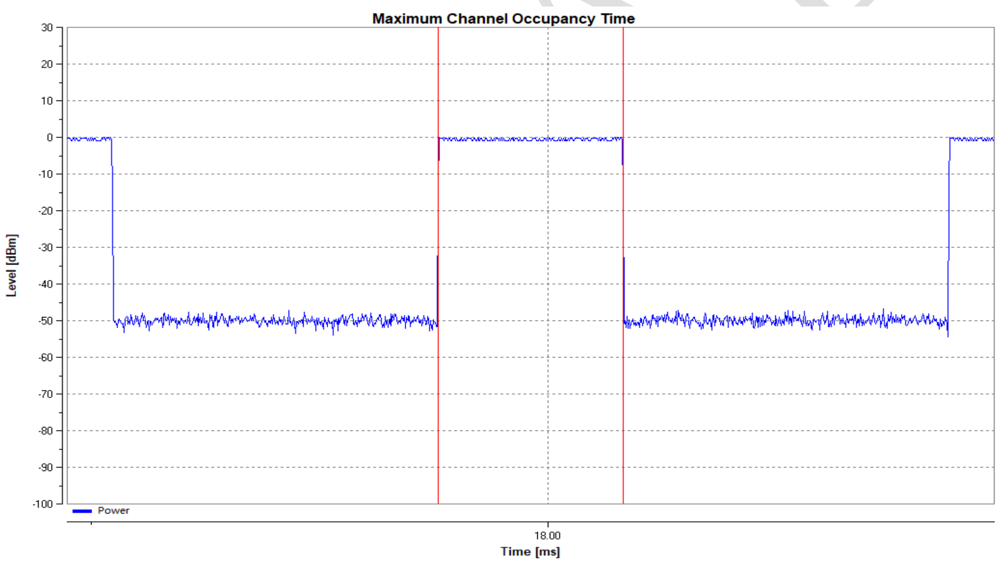



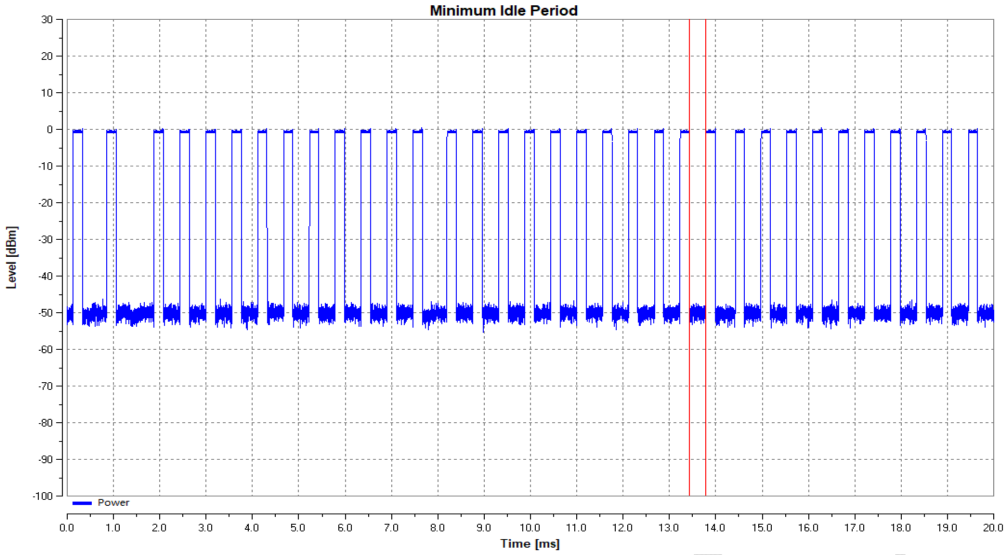

Adaptivity
Level [dBm]
Time [ms]
Interferer off/CW off
Interferer on/CW off
Interferer on/CW on

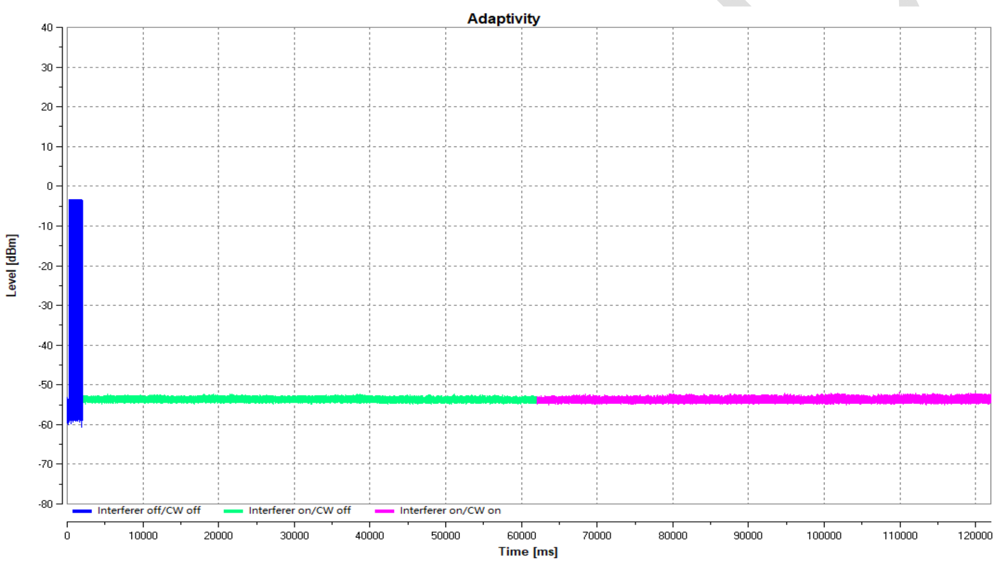

With interference signal Max.Short Control Signalling
Level [dBm]
Time [ms]
Interferer off/CW off
Interferer on/CW off
Interferer on/CW on

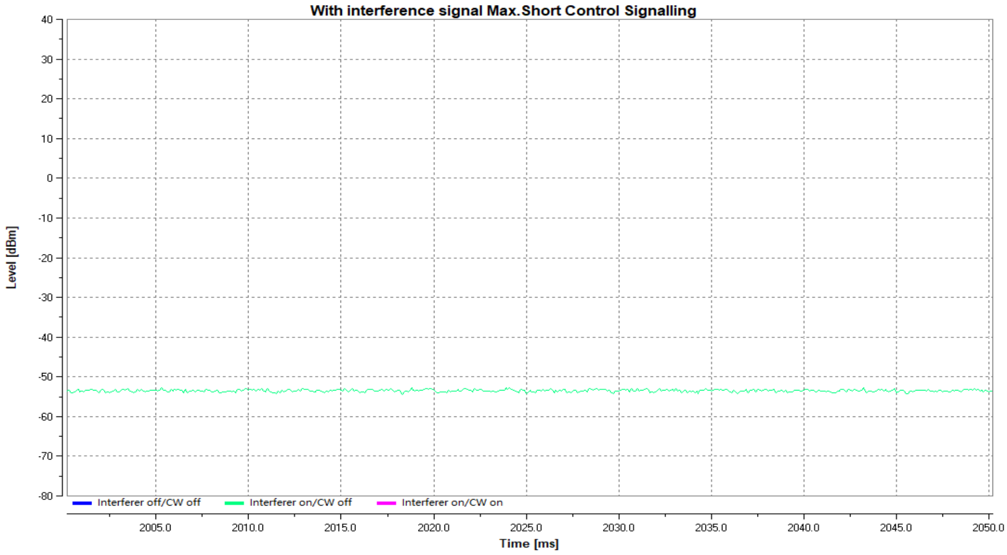


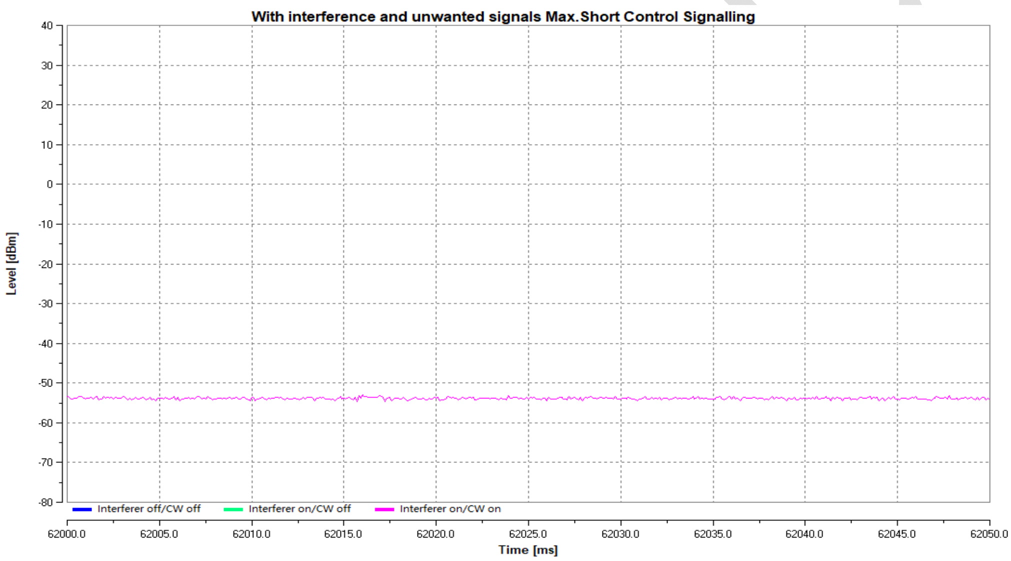

## 802.11b - High Channel




Minimum Idle Period
Level [dBm]
Power
Time [ms]


Adaptivity
Level [dBm]
Interferer off/CW off
Interferer on/CW off
Interferer on/CW on
Time [ms]


With interference signal Max.Short Control Signalling
Level [dBm]
Time [ms]
Interferer off/CW off
Interferer on/CW off
Interferer on/CW on


With interference and unwanted signals Max.Short Control Signalling
Level [dBm]
Time [ms]
Interferer off/CW off
Interferer on/CW off
Interferer on/CW on

# ETSI EN 300 328 V2.2.2 (2019-07) Clause 4.3.2.7 - OCCUPIED CHANNEL BANDWIDTH

## Applicable Standard

According to ETSI EN 300 328 V2.2.2 (2019-07) Clause4.3.2.7.2, the occupied channel bandwidth is the bandwidth that contains 99 % of the power of the signal.

Limit:

The Occupied Channel Bandwidth shall fall completely within the band given in table 1.
In addition, for non-adaptive equipment using wide band modulations other than FHSS and with e.i.r.p greater than 10 dBm, the occupied channel bandwidth shall be less than 20 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:** | 22.5 ℃ |
| **Relative Humidity:** | 50 % |
| **ATM Pressure:** | 101.6 kPa |

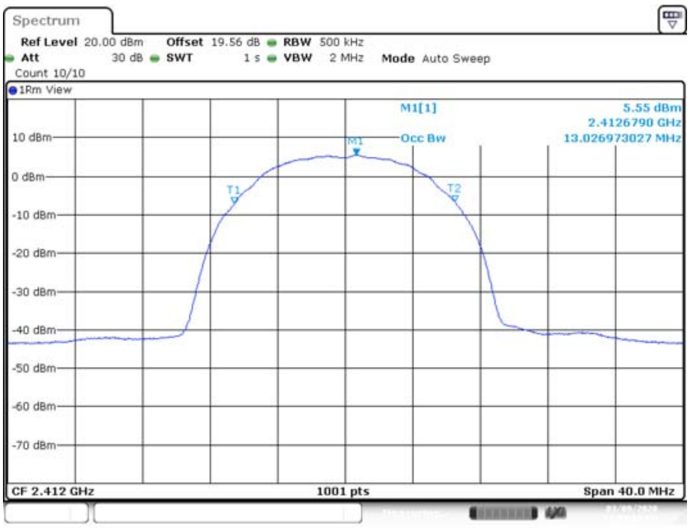
*The testing was performed by Chao Gao on 2020-03-09.*

*Test Mode: Transmitting*

**Test Result:** Compliant

| Channel | Frequency (MHz) | Occupied Bandwidth (MHz) |
|---|---|---|
| **802.11b Mode** | | |
| Low | 2412 | 13.027 |
| High | 2472 | 13.067 |
| **802.11g Mode** | | |
| Low | 2412 | 16.543 |
| High | 2472 | 16.543 |
| **802.11n-HT20 Mode** | | |
| Low | 2412 | 17.383 |
| High | 2472 | 17.423 |
| **802.11n-HT40 Mode** | | |
| Low | 2422 | 36.364 |
| High | 2462 | 36.284 |

**802.11b Mode: 2412 MHz**

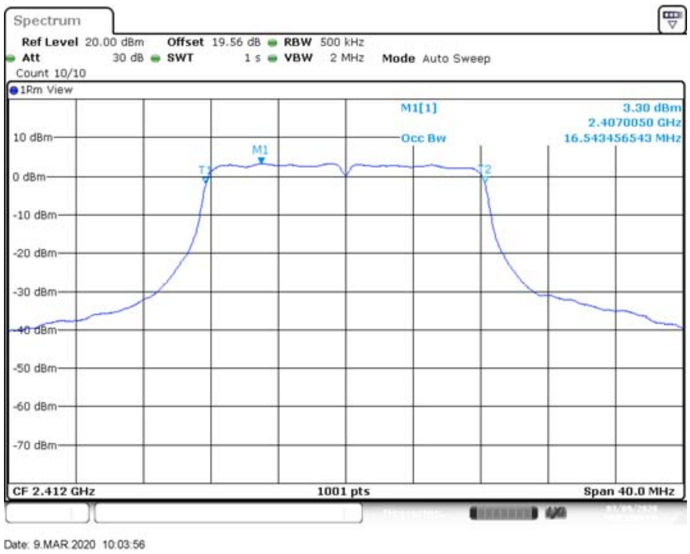


Date: 9.MAR.2020 11:04:33

**802.11b Mode: 2472 MHz**

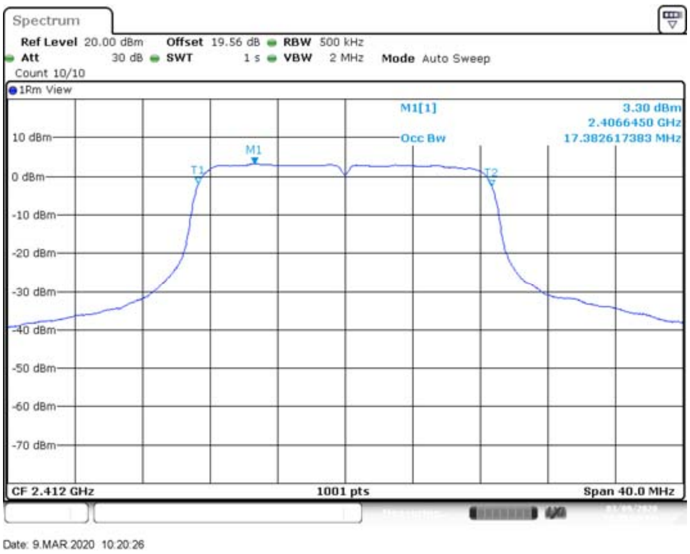
Date: 9.MAR.2020 09:56:43

**802.11g Mode: 2412 MHz**



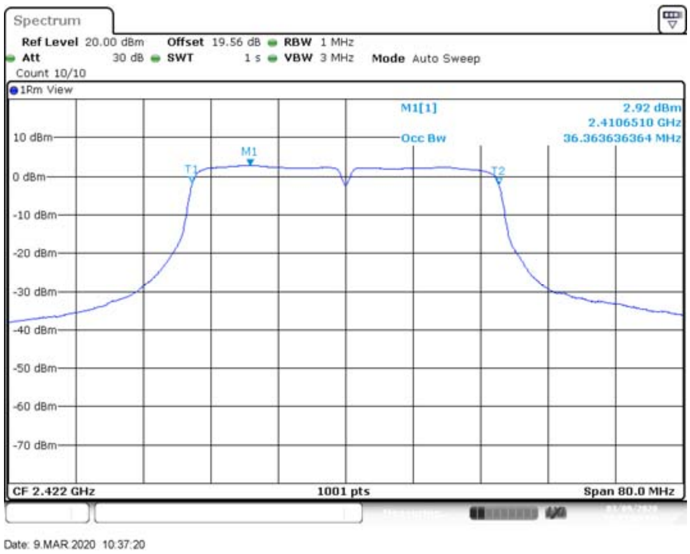

**802.11g Mode: 2472 MHz**

**802.11n-HT20 Mode: 2412 MHz**




**802.11n-HT20 Mode: 2472 MHz**

**802.11n-HT40 Mode: 2422 MHz**




**802.11n-HT40 Mode: 2462 MHz**

# ETSI EN 300 328 V2.2.2 (2019-07) Clause 4.3.2.8 – TRANSMITTER UNWANTED EMISSION IN THE OUT-OF-BAND DOMAIN

## Applicable Standard

According to ETSI EN 300 328 V2.2.2 (2019-07) Clause4.3.2.8.2, 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 3.

Within the band specified in table 1, the Out-of-band emissions are fulfilled by compliance with the Occupied Channel Bandwidth requirement in clause 4.3.2.7.

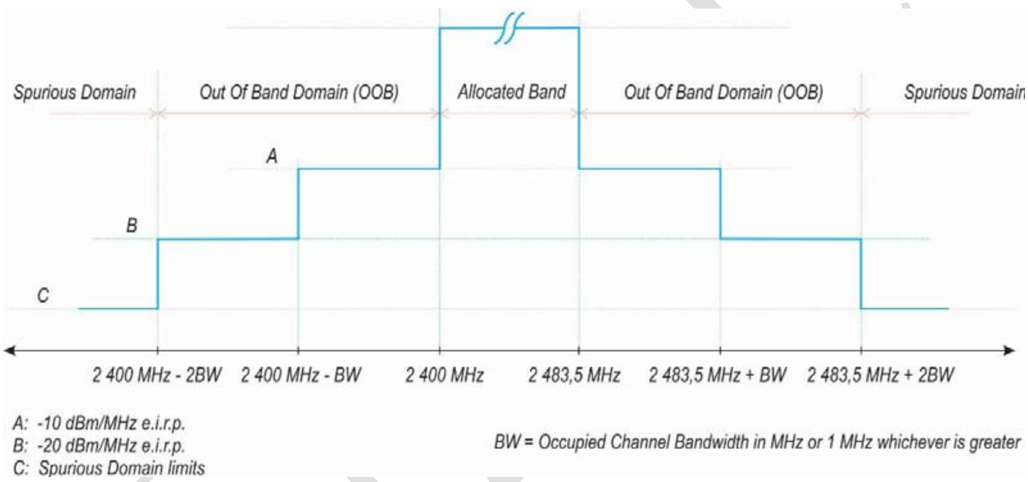



Figure 3: Transmit mask

## 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: 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; 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 - BW + 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 figure 1 or figure 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 figure 1 or figure 3.

  - Option 2: the limits provided by the mask given in figure 1 or figure 3 shall be reduced by 10 × log10(Ach) 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: Ach refers to the number of active transmit chains.

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

## Test Data

### Environmental Conditions

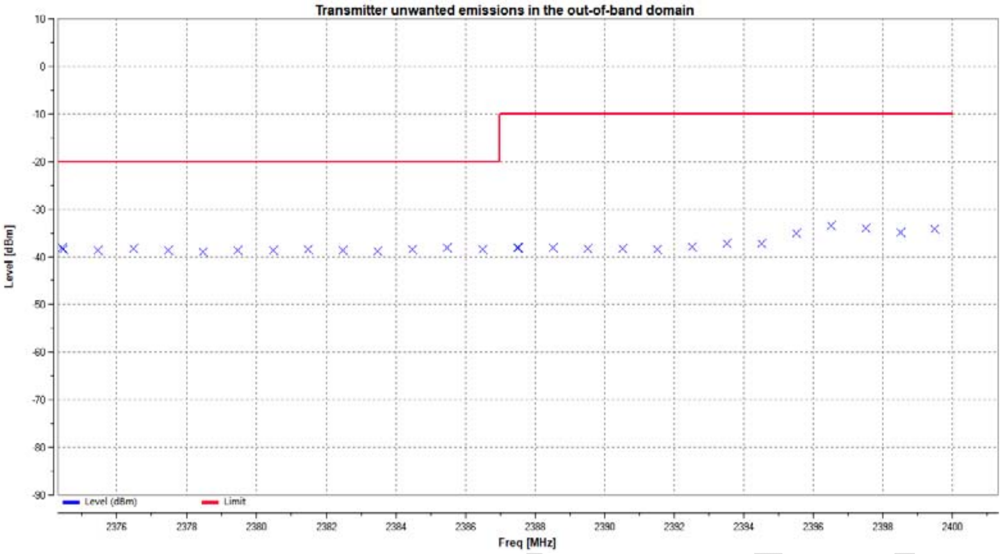
| | |
|---|---|
| **Temperature:** | 22.5~22.7 ℃ |
| **Relative Humidity:** | 49~50 % |
| **ATM Pressure:** | 100.5~101.7 kPa |

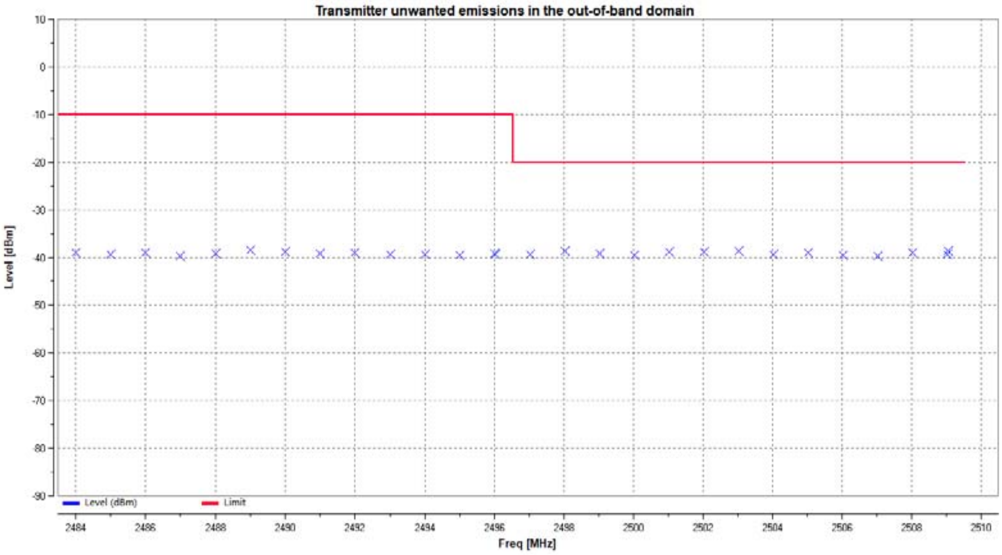
*The testing was performed by Chao Gao from 2020-03-09 to 2020-03-13.*

*Test Mode: Transmitting*

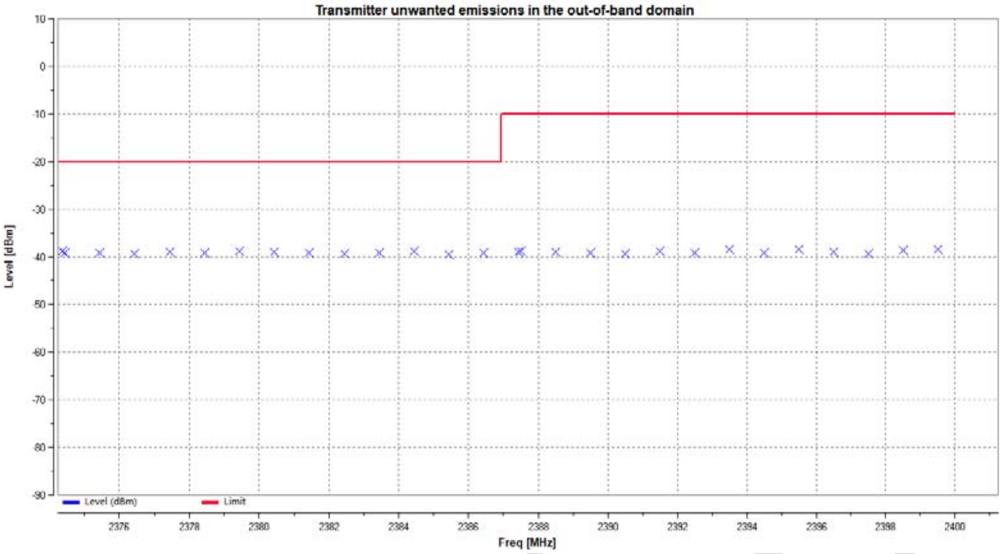
**Test Result:** Compliant

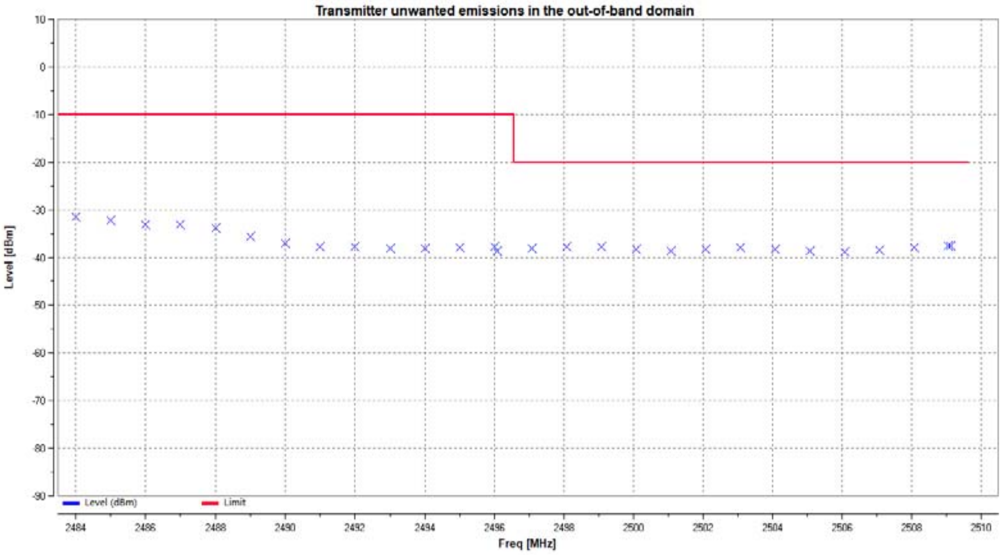
**802.11b Mode: 2412 MHz**



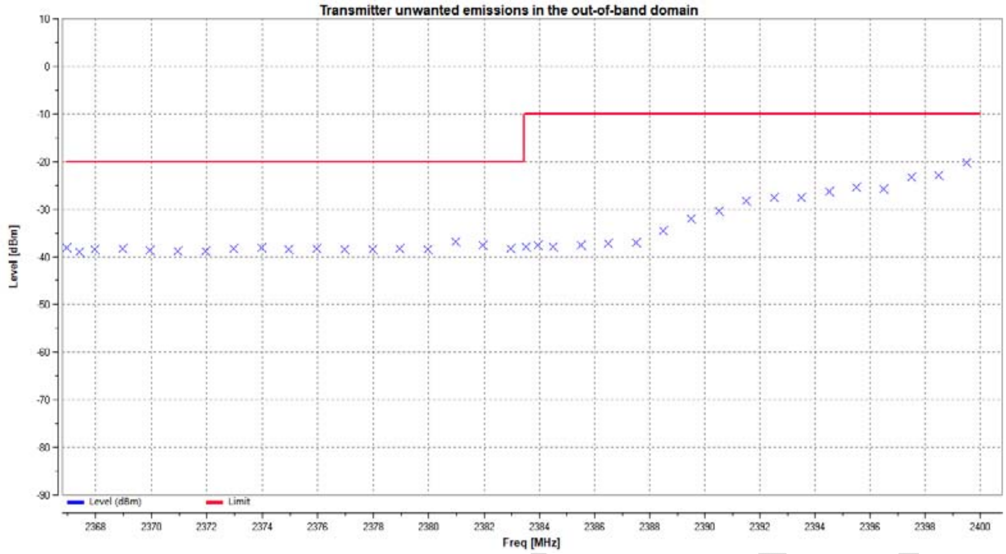



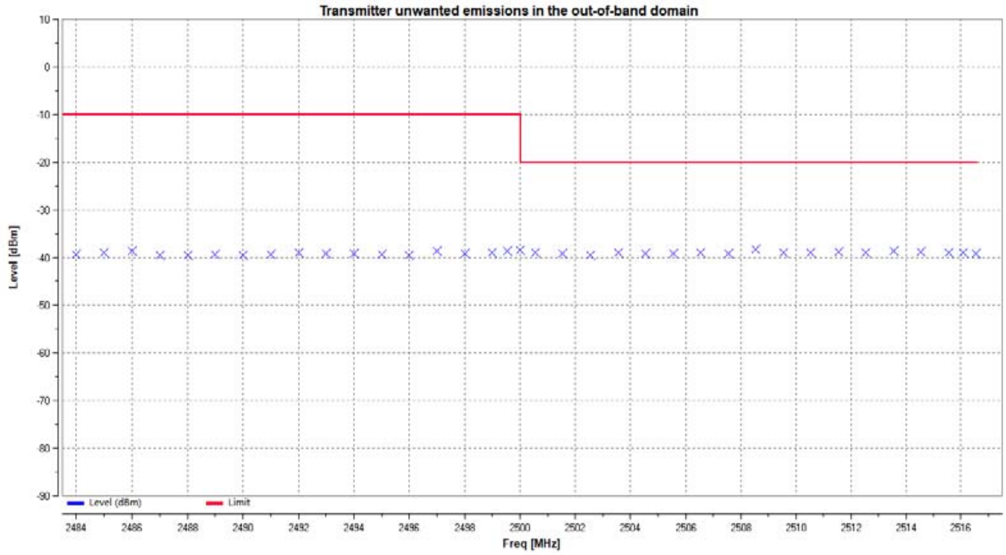
**802.11b Mode: 2472 MHz**



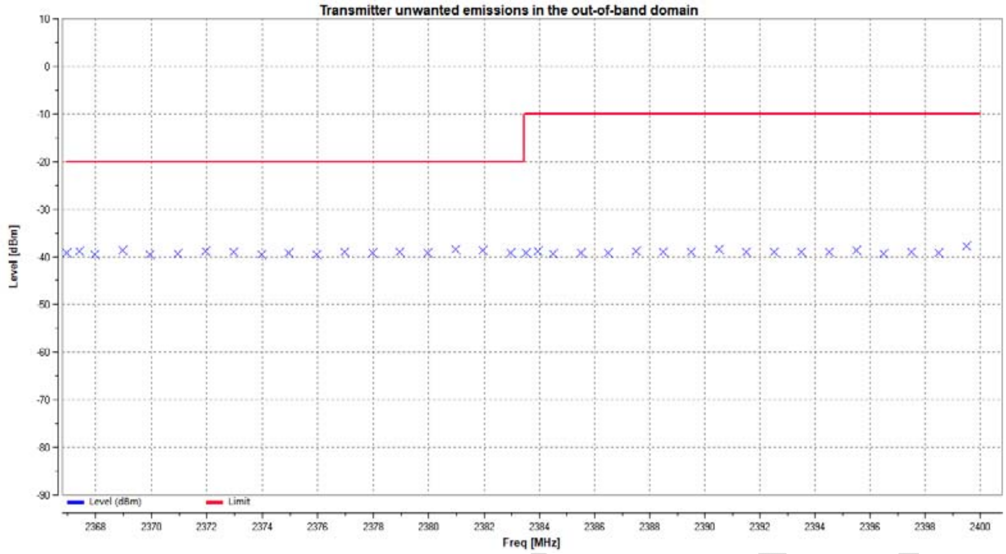



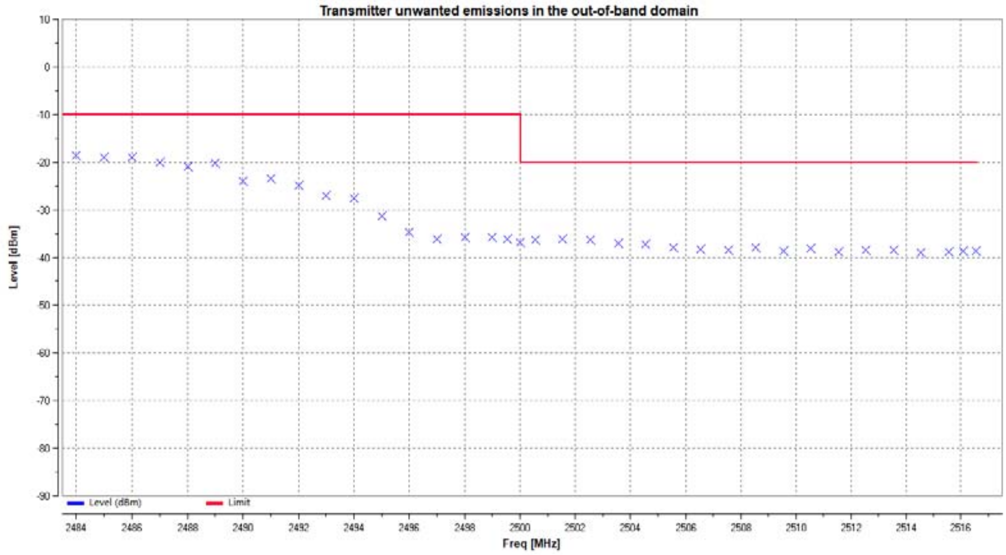
**802.11g Mode: 2412 MHz**



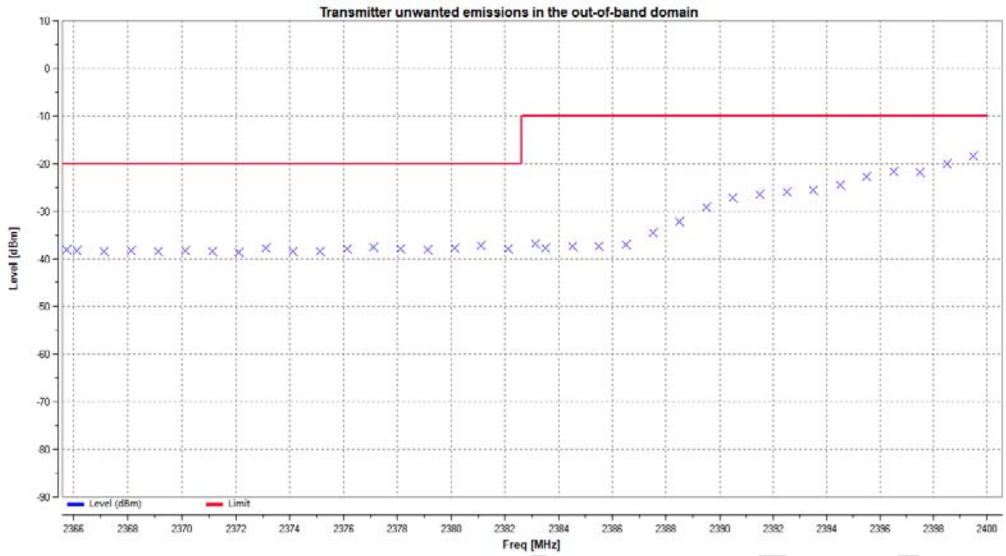



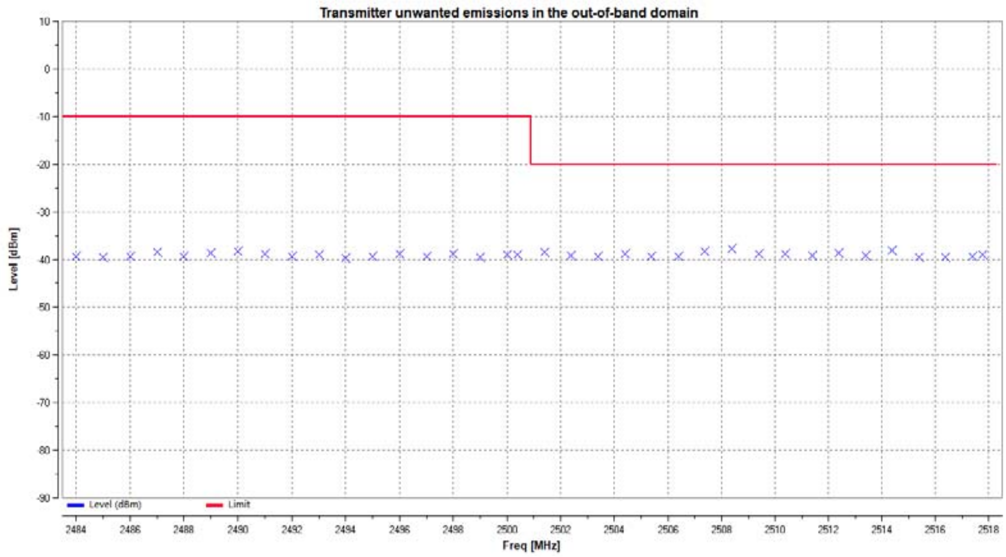
**802.11g Mode: 2472 MHz**



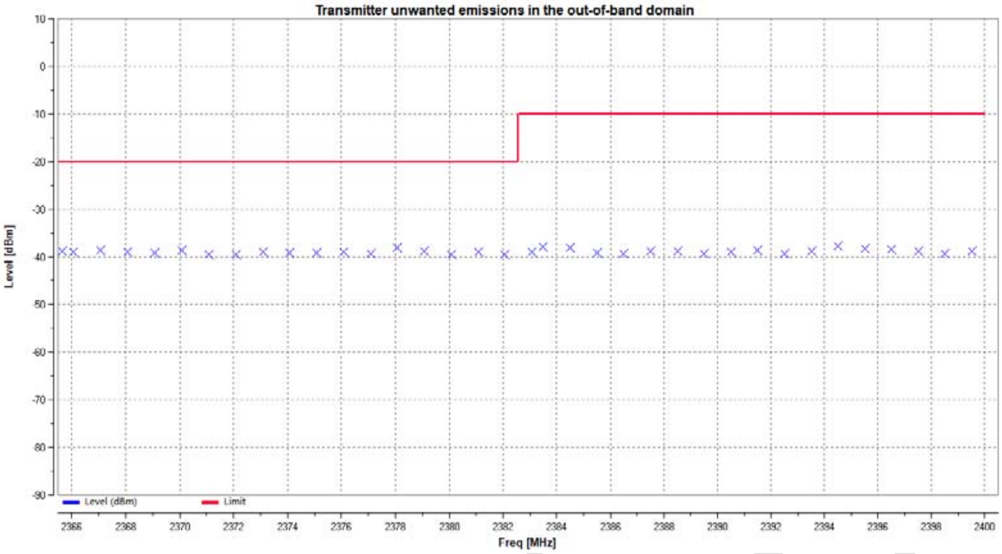



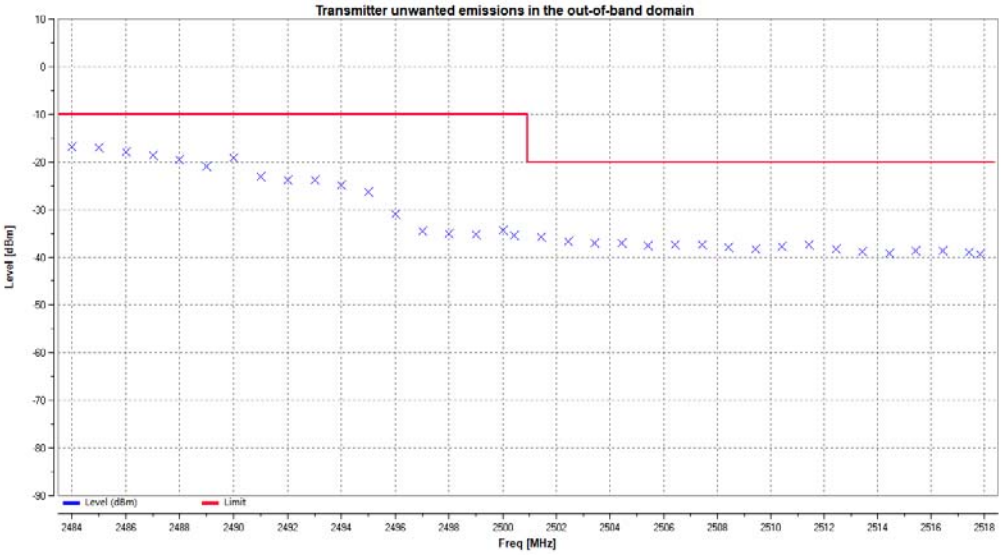
**802.11n-HT20 Mode: 2412 MHz**



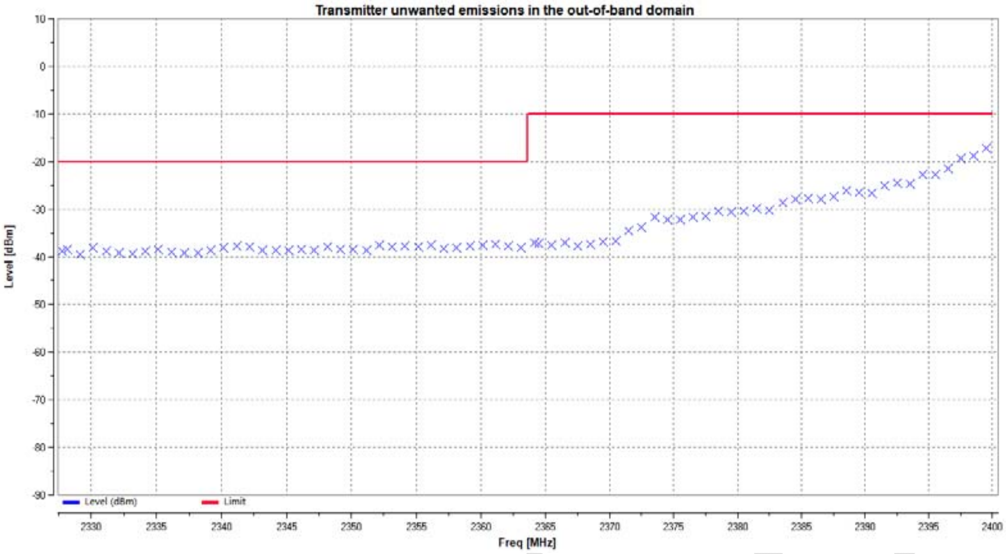



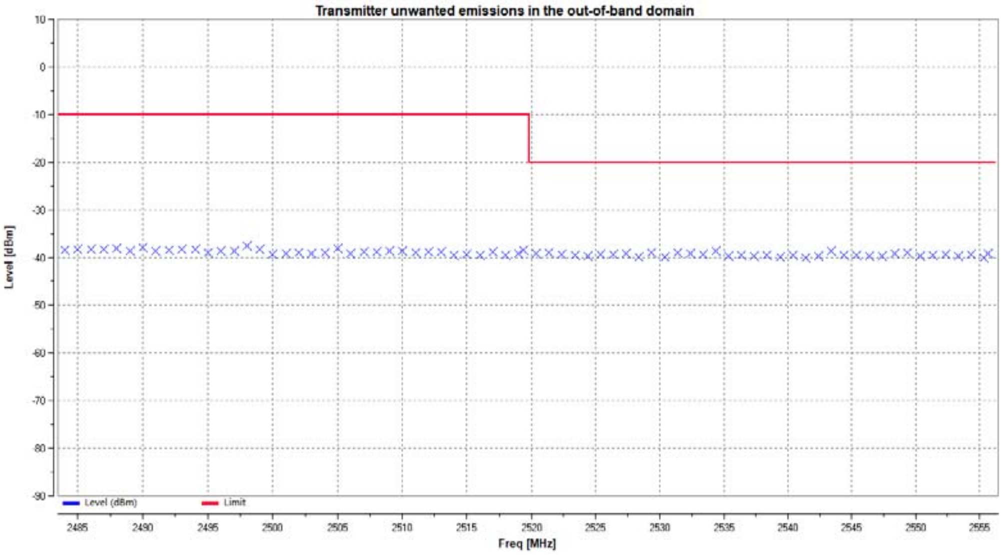
**802.11n-HT20 Mode: 2472 MHz**



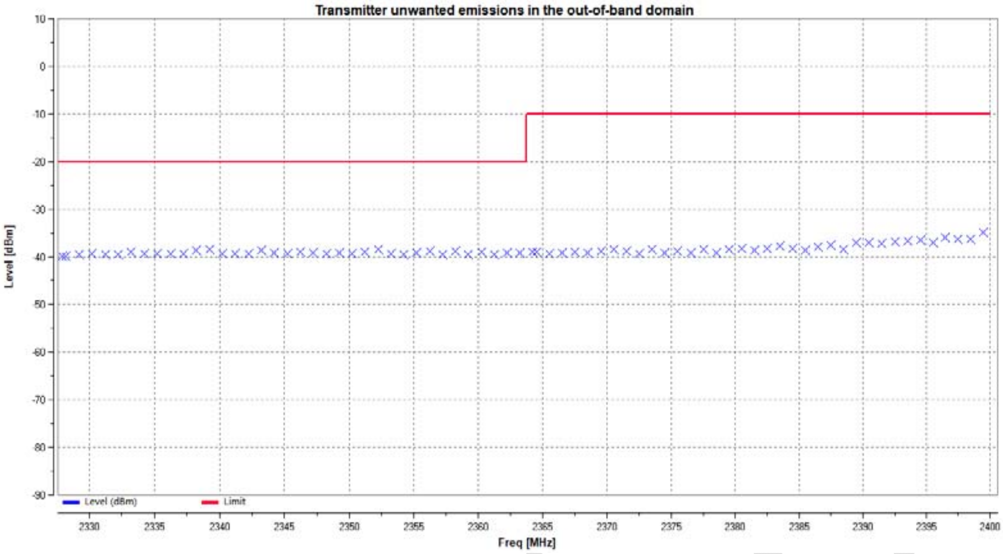



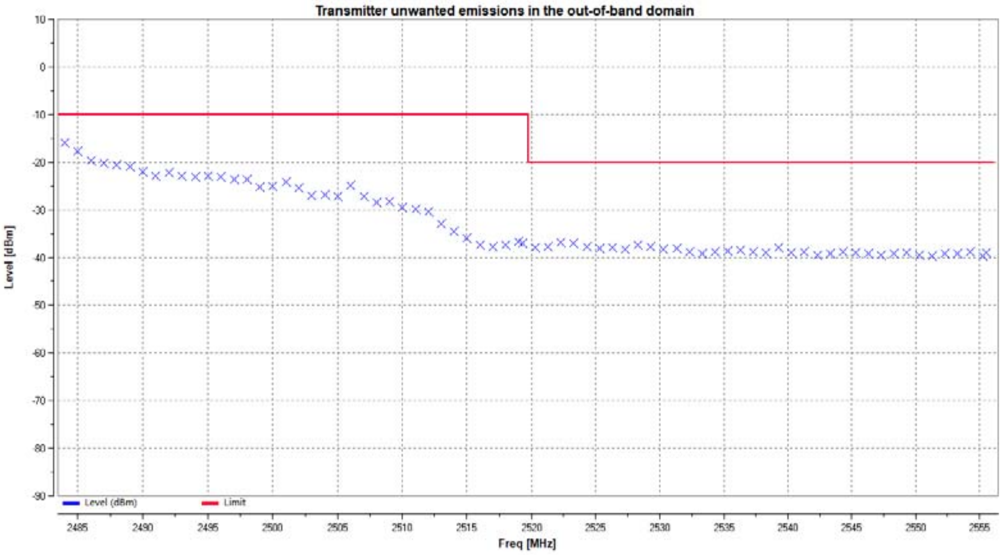
**802.11n-HT40 Mode: 2422 MHz**



**802.11n-HT40 Mode: 2462 MHz**



# ETSI EN 300 328 V2.2.2 (2019-07) Clause 4.3.2.9 - 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 3 when the equipment is in Transmit mode.

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

**Transmitter limits for spurious emissions**

| Frequency Range | Maximum power<br>e.r.p (≤ 1 GHz)<br>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 |

NOTE: 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 as e.i.r.p. for emissions above 1 GHz.



## Test Procedure

**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 spectrum analyser 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 receive chains), step 2 and step 3 need to be repeated for each of the active receive chains AchThe limits used to identify emissions during this pre-scan need to be reduced by 10 × log10 Ach.

**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 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

**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.

## Test Data

### Environmental Conditions

| | |
|---|---|
| **Temperature:** | 22.5~22.7 ℃ |
| **Relative Humidity:** | 49~50 % |
| **ATM Pressure:** | 100.5~101.7 kPa |

*The testing was performed by Chao Gao from 2020-03-09 to 2020-03-13.*

*Test Mode: Transmitting in 802.11g mode (worst case).*

**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** | | | | | | | | | | |
| 66.13 | 38.68 | 158 | 100 | H | -64.66 | 0.28 | -9.85 | -74.79 | -54 | 20.79 |
| 66.13 | 39.75 | 54 | 100 | V | -66.09 | 0.28 | -9.85 | -76.22 | -54 | 22.22 |
| 4824.00 | 40.42 | 22 | 150 | H | -62.95 | 1.06 | 10.16 | -53.85 | -30 | 23.85 |
| 4824.00 | 41.23 | 265 | 150 | V | -62.24 | 1.06 | 10.16 | -53.14 | -30 | 23.14 |
| **High Channel** | | | | | | | | | | |
| 66.86 | 38.73 | 71 | 100 | H | -64.8 | 0.28 | -9.73 | -74.81 | -54 | 20.81 |
| 66.86 | 39.17 | 111 | 100 | V | -66.75 | 0.28 | -9.73 | -76.76 | -54 | 22.76 |
| 4944.00 | 39.89 | 70 | 200 | H | -63.17 | 1.07 | 10.26 | -53.98 | -30 | 23.98 |
| 4944.00 | 40.53 | 0 | 200 | V | -62.66 | 1.07 | 10.26 | -53.47 | -30 | 23.47 |

**Note:**
Antenna gain is dBd for frequency below 1GHz and 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 4.3.2.10 – RECEIVER SPURIOUS EMISSIONS

## Applicable Standard

According to ETSI EN 300 328 V2.2.2 (2019-07) Clause4.3.2.10.2, the receiver spurious emissions are emissions at any frequency when the equipment is in receive mode.

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

| Frequency range | Maximum power, e.r.p. | Measurement bandwidth |
|---|---|---|
| 30 MHz to 1 GHz | -57 dBm | 100 kHz |
| 1 GHz to 12,75 GHz | -47 dBm | 1 MHz |

NOTE: In case of equipment with antenna connectors, these limits apply to emissions at the antenna port (conducted). For emissions radiated by the cabinet or for 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.

## Test Procedure

**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 spectrum analyser 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

**Note:** 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 receive chains), step 2 and step 3 need to be repeated for each of the active receive chains AchThe limits used to identify emissions during this pre-scan need to be reduced by 10 × log10 Ach.

**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 the start and stop times of the sweep.

**Step 3:**

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

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

**Step 4:**

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

## Test Data

### Environmental Conditions

| | |
|---|---|
| **Temperature:** | 22.5~22.7 ℃ |
| **Relative Humidity:** | 49~50 % |
| **ATM Pressure:** | 100.5~101.7 kPa |

*The testing was performed by Chao Gao from 2020-03-09 to 2020-03-13.*

*Test Mode: Receiving in 802.11g mode (worst case).*

**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** | | | | | | | | | | |
| 65.41 | 38.75 | 271 | 100 | H | -64.41 | 0.28 | -9.96 | -74.65 | -57 | 17.65 |
| 65.41 | 39.22 | 50 | 100 | V | -66.54 | 0.28 | -9.96 | -76.78 | -57 | 19.78 |
| 1594.55 | 46.16 | 3 | 200 | H | -65.35 | 0.83 | 8.35 | -57.83 | -47 | 10.83 |
| 1594.55 | 49.58 | 294 | 200 | V | -62.16 | 0.83 | 8.35 | -54.64 | -47 | 7.64 |
| **High Channel** | | | | | | | | | | |
| 65.53 | 38.51 | 329 | 100 | H | -64.68 | 0.28 | -9.94 | -74.9 | -57 | 17.9 |
| 65.53 | 38.94 | 117 | 100 | V | -66.83 | 0.28 | -9.94 | -77.05 | -57 | 20.05 |
| 1587.5 | 46.55 | 331 | 200 | H | -64.87 | 0.83 | 8.35 | -57.35 | -47 | 10.35 |
| 1587.5 | 49.95 | 288 | 200 | V | -62 | 0.83 | 8.35 | -54.48 | -47 | 7.48 |

**Note:**
Antenna gain is dBd for frequency below 1GHz and 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 4.3.2.11 – 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) at frequencies other than those of the operating band.

While maintaining the minimum performance criteria as defined in clause 4.3.2.11.3, 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 14, table 15 or table 16.

**Table 14: 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<br>2 504 | -34 | CW |
| (-139 dBm + 10 × $\log_{10}$(OCBW)) or -74 dBm whichever is less (see note 3) | 2 300<br>2 330<br>2 360<br>2 524<br>2 584<br>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 15: 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<br>2 504<br>2 300<br>2 584 | -34 | CW |
| NOTE 1: OCBW is in Hz.<br>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.<br>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. | | | |

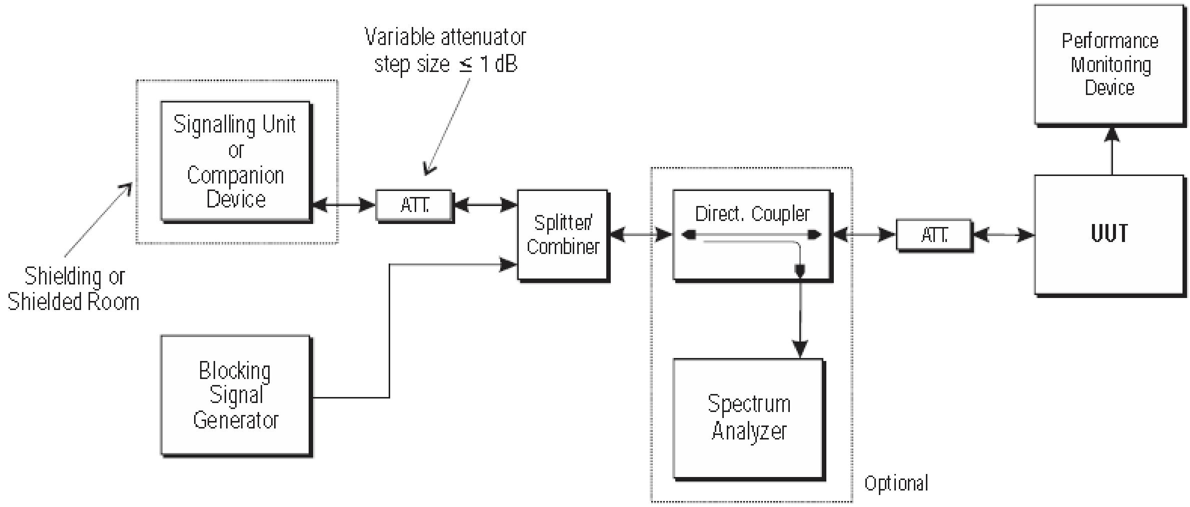
**Table 16: Receiver Blocking parameters receiver Category 3 equipment**

| 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<br>2 504<br>2 300<br>2 584 | -34 | CW |
| NOTE 1: OCBW is in Hz.<br>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 $P_{min}$ + 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.<br>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




### Test data

#### Environmental Conditions

| | |
|---|---|
| **Temperature:** | 22.5~22.7 ℃ |
| **Relative Humidity:** | 49~50 % |
| **ATM Pressure:** | 100.5~101.7 kPa |

*The testing was performed by Chao Gao from 2020-03-09 to2020-03-13.*

*Test Mode: Receiving in 802.11b mode*
*(**Note**: PER can be read by the 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 (%) |
|---|---|---|---|---|---|---|
| 1 (See Note1) | Low | -64.6 | 2380 | -30.6 (See Note2) | 3.37 | ≤10.00 |
| | | | 2504 | | 3.25 | ≤10.00 |
| | | -70.6 | 2300 | | 3.33 | ≤10.00 |
| | | | 2330 | | 3.15 | ≤10.00 |
| | | | 2360 | | 3.03 | ≤10.00 |
| | | | 2524 | | 3.31 | ≤10.00 |
| | | | 2584 | | 3.42 | ≤10.00 |
| | | | 2674 | | 3.11 | ≤10.00 |
| | High | -64.6 | 2380 | -30.6 (See Note2) | 3.27 | ≤10.00 |
| | | | 2504 | | 3.11 | ≤10.00 |
| | | -70.6 | 2300 | | 3.28 | ≤10.00 |
| | | | 2330 | | 3.10 | ≤10.00 |
| | | | 2360 | | 3.12 | ≤10.00 |
| | | | 2524 | | 3.05 | ≤10.00 |
| | | | 2584 | | 3.41 | ≤10.00 |
| | | | 2674 | | 3.43 | ≤10.00 |

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

# EXHIBIT A - E.1 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:______;
The minimum number of Hopping Frequencies: ________;

The (average) Dwell Time: _____;

**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: 0.304 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: 57ms

☐ 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: ______19.68dBm__________________________;
Power Spectral Density__________9.75dBm/MHz______________;
Duty cycle, Tx-Sequence, Tx-gap __________N/A________________;
Accumulated Transmit time, Frequency Occupation & Hopping Sequence (only for FHSS equipment)___N/A____;
Hopping Frequency Separation (only for FHSS equipment)______N/A____;
Medium Utilisation__________N/A______________________________;
Adaptivity____________Compliant________;
Receiver Blocking_______Compliant______________________;
Nominal Channel Bandwidth_____36.364MHz______________________;
Transmitter unwanted emissions in the OOB domain____-15.88dBm/MHz___;
Transmitter unwanted emissions in the spurious domain___-74.79dBm__;
Receiver spurious emissions____-54.48dBm______________________;

**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:__2412____ MHz to __2472____MHz
Operating Frequency Range 2:__2422____ MHz to __2462____ MHz

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

**j) Nominal Channel Bandwidth(s):**

Nominal Channel Bandwidth 1:___13.067_MHz
Nominal Channel Bandwidth 2:___16.543_MHz
Nominal Channel Bandwidth 3:___17.423__MHz
Nominal Channel Bandwidth 4:___36.364____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:___22.5___° 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 ____3~3.6____ 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 transmitting and normal operation____________________.

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

______IEEE 802.11™ [i.4]____________________.

**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)**

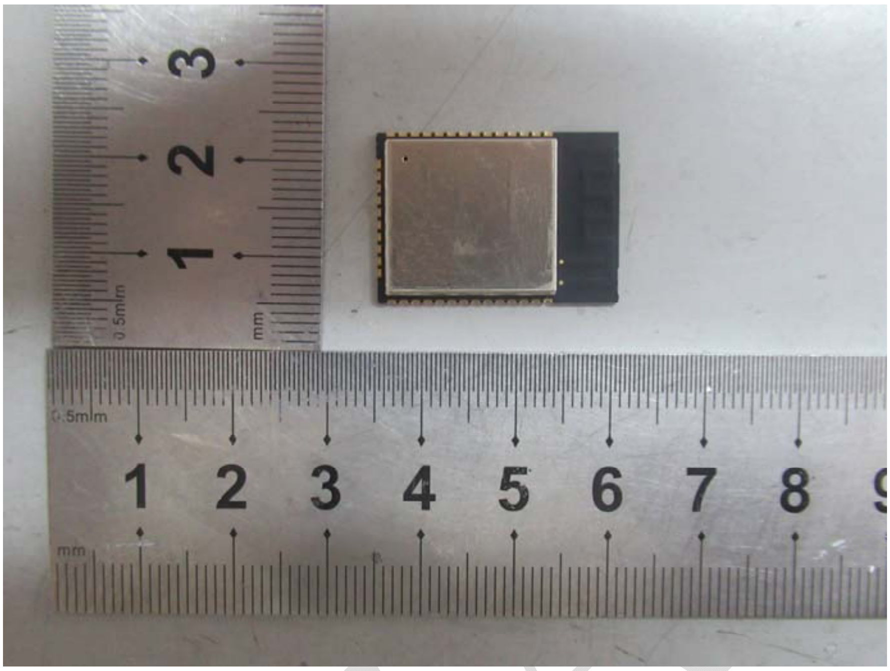
(to be provided as separate attachment)

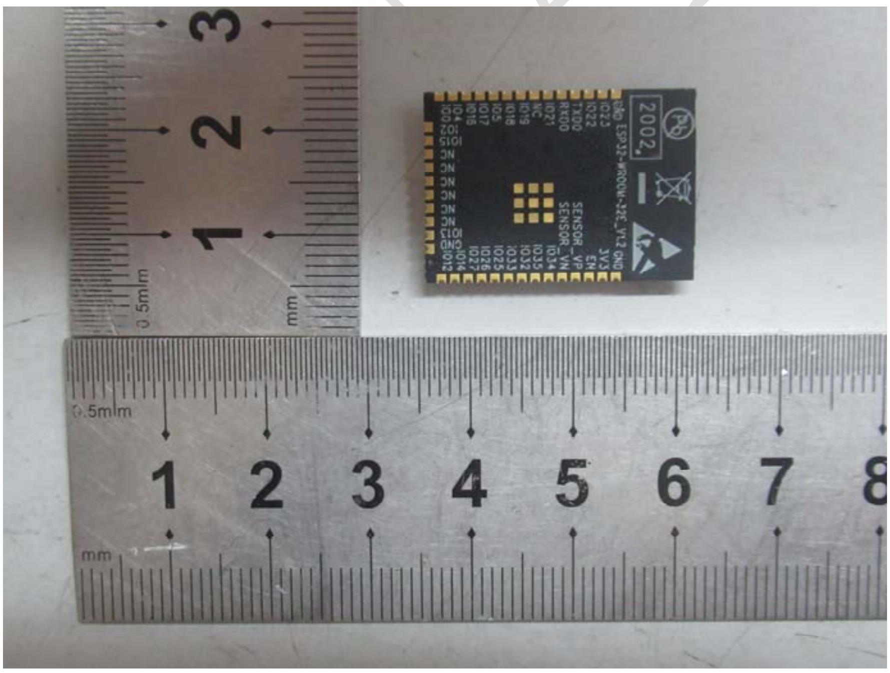
**s) Geo-location capability supported by the equipment:**

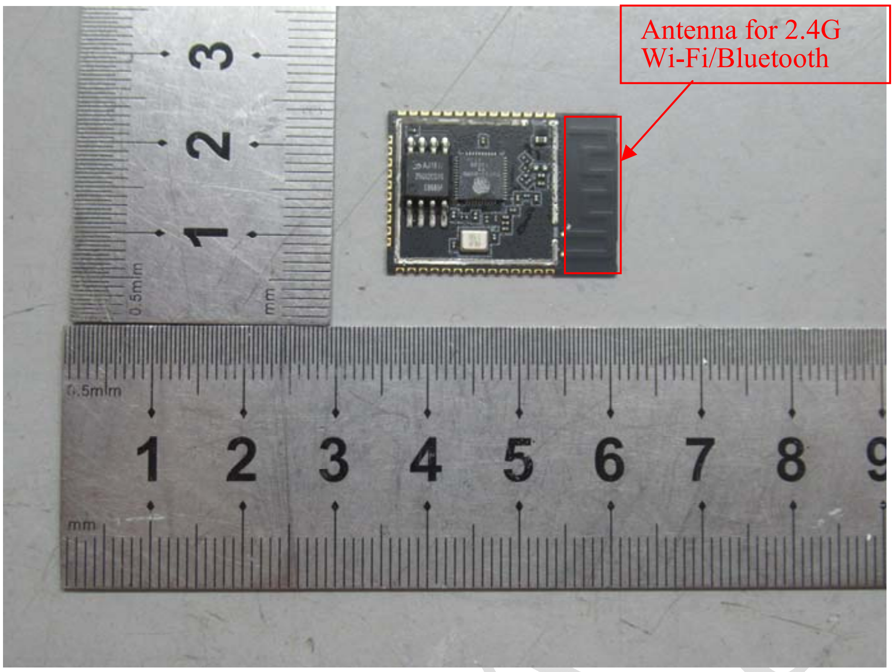
☐ Yes
☐ The geographical location determined by the equipment as defined in clause 4.3.1.13.2 or clause 4.3.2.12.2 is not accessible to the user.

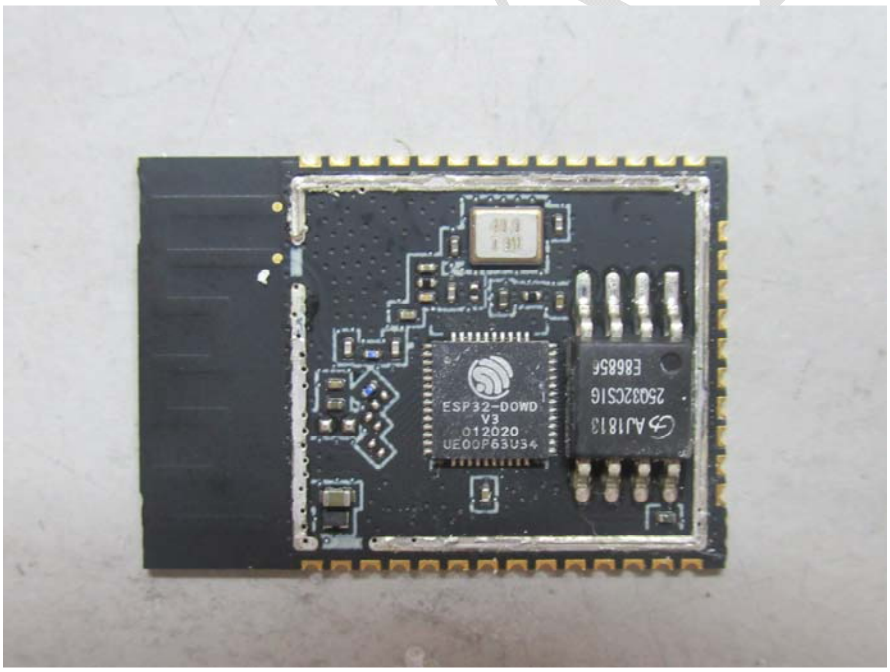
☒ No

# EXHIBIT B - EUT PHOTOGRAPHS



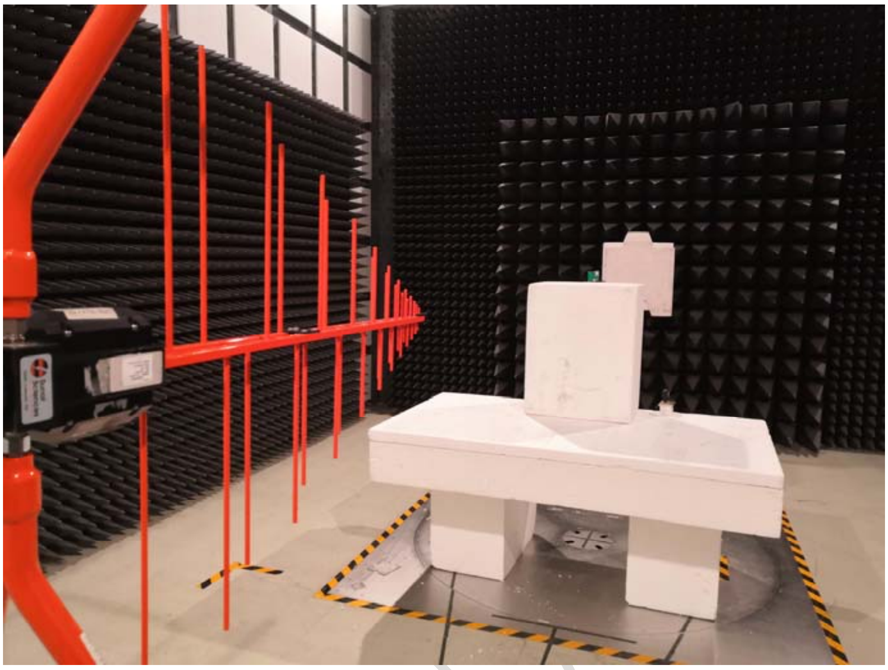



Antenna for 2.4G
Wi-Fi/Bluetooth

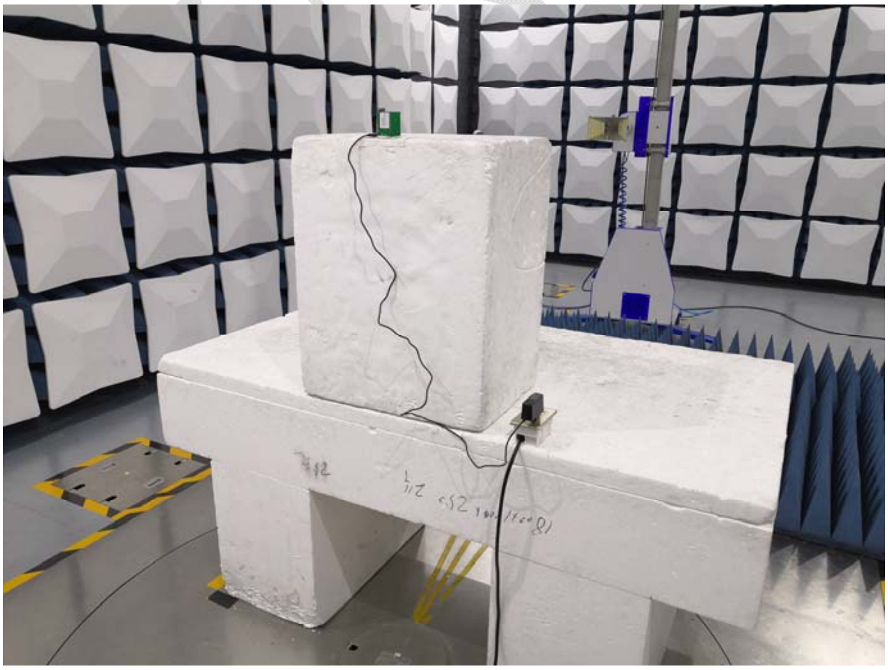

ESP32-DOWD
V3
012020

# EXHIBIT C - TEST SETUP PHOTOGRAPHS

**Radiated Spurious Emissions Test View (Below 1GHz)**



**Radiated Spurious Emissions Test View (Above 1GHz)**



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