TEST REPORT OF THE
Inventek Systems
2.4 GHz e-BT SIP Module
Models: ISM4343-X
IN CONFORMANCE WITH
ETSI EN 300 328 V2.1.1 (2016-11)
Harmonized EN covering essential requirements under article 3.2 of the Radio Equipment Directive (RED) 2014/53/EU

Remarks:

| | |
|---|---|
| **Equipment complied with the specification** | ☒ |
| **Equipment did not comply with the specification** | ☐ |
| **Results were within measurement uncertainties** | ☒ |

| | |
|---|---|
| This report is issued Under the Authority of: Alan Ghasiani | Signature: |
| Tested By: Afzal Fazal | Signature |
| **Issue Date:** December 18, 2018 | **Test Dates:** November 2, 2018 to December 6, 2018 |

TESTING
NVLAP LAB CODE 200162-0



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## 1 Purpose of the Test Report

This test report is being generated to show that the Inventek 2.4 GHz e-BT SIP Module Model: ISM4343-X complies with the requirements of ETSI EN 300 328 V2.1.1 (2016-11). The module is designed to transmit from either an etched integrated antenna or through the u.fl port. For u.fl transmission the module is being evaluated with two options of antennas, with the following gain: +3.2 dBi. Additional details on the module and antenna is presented in the test report.

## 2 Identification and Characteristics of Equipment Under Test

This section contains the unmodified Application Form submitted by the Manufacturer. The Application Form contains 13 pages, which are included in the total number of pages of this report.

The Equipment Under Test (EUT) is the Inventek 2.4 GHz e-BT SIP Module Model: ISM4343-X. The EUT is an embedded wireless Bluetooth (BT) connectivity device, based on the Renesas ISM4343-WBM-L54 microcomputer incorporating the WBM-L54 CPU core and low power consumption RF transceiver supporting the Bluetooth ver.4.1 (Low Energy Single mode) specifications. The Inventek ISM4343 WBM-L54 CPU core is a 3-stage pipeline CISC architecture with an integrated BLE Radio, on-board chip antenna, and 256 KB ROM. The module provides a number of features and standard peripheral interfaces, enabling connection to an embedded design. The low cost, small foot print, 11mm x 13mm 31-Pin LGA package and ease of design-in make it ideal for a range of embedded applications. The module provides UART, I2C.

Radio: Bluetooth 2
Range: 2400-2483.5 MHz ISM Band
Modulation: GFSK, QPSK
RF Output Power (EIRP): +8 dBm
Data Rate: Mbps (Max): 3 Mbps
Channels: 79

For marketing purposes, the Module will bear the following Model Numbers:

ISM43364-W-L151
ISM43364-W-L54C
ISM43364-W-L54U
ISM43364-WM411-L151
ISM43364-WM411-L54C
ISM43364-WM411-L54U
ISM43364-WM-L151
ISM43364-WM-L54C
ISM43364-WM-L54U
ISM4343-WB-L151
ISM4343-WB-L54C
ISM4343-WB-L54U
ISM4343-WBM411-L151
ISM4343-WBM411-L54C
ISM4343-WBM411-L54U
ISM4343-WBM-L151
ISM4343-WBM-L54C
ISM4343-WBM-L54U

# 3 Standard Specific Transmitter Requirements

## E.1 Information as required by EN 300 328 V2.1.1, clause 5.4.1

In accordance with EN 300 328, clause 5.4.1, the following information is provided by the 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: N/A

- In case of Adaptive Frequency Hopping Equipment:

  The maximum number of Hopping Frequencies: 79

  The minimum number of Hopping Frequencies: 79

- The Dwell Time:2.80 msec
- The Minimum Channel Occupation Time: N/A msec

**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

☐ Not Assessed. EIRP ≤ 10 dBm

**d) In case of adaptive equipment:**

The Channel Occupancy Time implemented by the equipment: N/A

☐ 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 value q as referred to in clause

☒ The equipment has implemented a non-LBT based mechanism

☐ The equipment can operate in more than one adaptive mode

☐ Not Assessed. EIRP ≤ 10 dBm

**e) In case of non-adaptive Equipment:**

The maximum RF Output Power (e.i.r.p.): N/A dBm (as measured)

The maximum (corresponding) Duty Cycle: N/A% (as measured)

Equipment with dynamic behavior, that behavior is described here. (e.g. the different combinations of duty cycle and corresponding power levels to be declared): N/A

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

RF Output Power

8.39 dBm

Power Spectral Density

N/A

Duty cycle, Tx-Sequence, Tx-gap

N/A

Dwell time, Minimum Frequency Occupation & Hopping Sequence (only for FHSS equipment)

33.6 msec, N/A msec, 79 channel sequence

Hopping Frequency Separation (only for FHSS equipment)

997.5 kHz

Medium Utilization

N/A

Adaptivity & Receiver Blocking

See Section 4.3.7

Occupied Channel Bandwidth

901.2 kHz

Transmitter unwanted emissions in the OOB domain

See Section 5.3.8

Transmitter unwanted emissions in the spurious domain

See Section 5.3.9

Receiver spurious emissions

See Section 5.3.10

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

☒ Operating mode **1**: Single Antenna Equipment

☒ Equipment with only 1 antenna

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

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

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

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

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

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

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 chain: N/A
- The number of Transmit chains: N/A

☐ symmetrical power distribution

☐ asymmetrical power distribution

In case of beam forming, the maximum beam forming gain:

NOTE: 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) Occupied Channel Bandwidth(s):**

- Occupied Channel Bandwidth 1: 901.2 kHz
- Occupied Channel Bandwidth 2: N/A kHz
- Occupied Channel Bandwidth 3: N/A kHz

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 extreme operating conditions that apply to the equipment:**

Operating temperature range: -40 ° C to 85 ° C

Operating voltage range: 3.3 V to 3.3 V ☐AC ☒DC

Details provided are for the:

☐ stand-alone equipment

☒ combined (or host) equipment

☐ test jig

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

• Antenna Type:

☒ Integral Antenna

Antenna Gain: 1.4 dBi (Chip) 3.2 dBi (U.FL)

If applicable, additional beamforming gain (excluding basic antenna gain): N/A 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 beam-forming gain (Y) if applicable

Power Level 1: 5.19 dBm + 3.2 dBi = 8.39 dBm (E.I.R.P.)
Number of antenna assemblies provided for this power level:

| Assembly # | Gain (dBi) | e.i.r.p. (dBm) | Part number or model name |
|---|---|---|---|
| 1 | 1.4 | | W24-SC (Chip antenna) |
| 2 | 3.2 | | W24P-U (external trace antenna) |
| 3 | N/A | N/A | N/A |
| 4 | N/A | N/A | N/A |

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

Power Level 2: N/A dBm

Number of antenna assemblies provided for this power level:

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

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

Power Level 3: N/A dBm

Number of antenna assemblies provided for this power level:

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

NOTE: 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 – 5.0 V

In case of DC, indicate the type of power source

- ☐ Internal Power Supply
- ☒ External Power Supply or AC/DC adapter
- ☐ Battery
- ☒ Other: powered via laptop USB port

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

State 1: The EUT was able to continuously transmit on one of the individual channels.
State 2: The EUT was able to continuously hop on one of the individual channels.
State 3: The EUT was able to continuously hop on all of the channels.
State 4: The EUT was able to receive on a channel.

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

Bluetooth technology

**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

**f) Describe the minimum performance criteria that apply to the equipment (see clause 4.3.1.12.3 or clause 4.3.2.11.3):**

## E.2 Combination for testing (see clause 5.3.2.3 of EN 300 328 V2.1.1)

From all combinations of conducted power settings and intended antenna assembly (ies) specified in clause 3.1 m), specify the combination resulting in the highest e.i.r.p. for the radio equipment.

Unless otherwise specified in EN 300 328, this power setting is to be used for testing against the requirements of EN 300 328. In case there is more than one such conducted power setting resulting in the same (highest) e.i.r.p. level, the highest power setting is to be used for testing. See also EN 300 328, clause 5.3.2.3.

This has been considered. The EUT is programmed to operate at it maximum output setting for this mode of operation.

## E.3 Additional information provided by the applicant

### E.3.1 Modulation

ITU Class(es) of emission:

Can the transmitter operate unmodulated?

☐ Yes

☒ No

### E.3.2 Duty Cycle

The transmitter is intended for:

☐ Continuous duty

☐ Intermittent duty

☒ Continuous operation possible for testing purposes

### E.3.3 About the UUT

☒ The equipment submitted is representative production models

☐ If not, the equipment submitted is pre-production models?

☐ If pre-production equipment are submitted, the final production equipment will be identical in all respects with the equipment tested

☐ If not, supply full details

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### E.3.4 Additional items and/or supporting equipment provided

☐ Spare batteries (e.g. for portable equipment)

☐ Battery charging device

☒ External Power Supply or AC/DC adapter

☐ Test Jig or interface box

☐ RF test fixture (for equipment with integrated antennas)

☒ Host System

- Manufacturer: Inventek Systems
- Model #: ISM4343-X
- Model name: 2.4 GHz eS-WiFi Module

☐ Combined equipment

- Manufacturer:
- Model #:
- Model name:

☒ User Manual

☒ Technical documentation (Handbook and circuit diagrams)

# 4 Technical Summary

## Applicant information

| | | |
|---|---|---|
| Applicant's representative | : | Martin Tierney |
| Company | : | Inventek |
| Address | : | 2 Republic Road |
| City | : | Billerica |
| State | : | MA |
| Postal code | : | 01862 |
| Country | : | United States |
| Telephone number | : | +1 978-667-1962 |
| Fax number | : | N/A |

## Description of test item

| | | |
|---|---|---|
| Test item | : | ISM4343X-WBM-L54 |
| Manufacturer | : | Inventek Systems |
| Power Characteristics | : | 8.0 dBm |
| Frequency Characteristics | : | 2.402 – 2.480 GHz |
| Type | : | Bluetooth 4.0 |
| Modulation Type | : | FHSS |
| Temperature Range | : | -40˚C to 85˚C |
| Specification(s) | : | None |
| Model Name | : | 2.4 GHz eS-WiFi Module |
| Model Number | : | ISM4343-X |
| Serial number | : | ENGINEERING SAMPLE |
| Revision | : | Rev. 0 |
| Receipt number | : | 18-0329 |
| Receipt date | : | September 17, 2018 |

## Test(s) performed

| | | |
|---|---|---|
| Location | : | US Tech |
| Tests started | : | November 2, 2018 |
| Tests completed | : | December 6, 2018 |
| Purpose of tests | : | Compliance with standard |
| Test specifications | : | ETSI EN 300 328 V2.1.1 (2016-11) |
| Test engineer(s) | : | Afzal Fazal, Mark Afroozi, George Yang |
| Project leader | : | George Yang |
| Report written by | : | Afzal Fazal |
| Report approved by | : | Alan Ghasiani |
| Report date | : | December 18, 2018 |

# 5 Measurements, Examinations and Derived Results

## 5.1 Tests Required

The following Tests are required per EN 300 328 V2.1.1:

**Table 1. Transmitter Test Suites and Overview of Results**

| Essential Radio Test suite | Applicable | Reference Clause in Standard | Compliance Results |
|---|---|---|---|
| RF Output Power | Yes | 4.3.2.2 | Compliant |
| Power Spectral Density | No | 4.3.2.3 | N/A |
| Duty Cycle, TX-Sequence, TX-Gap | No | 4.3.2.4 | N/A |
| Accumulated Transmit Time, Frequency Occupation and Hopping Sequence | No | 4.3.1.4 | N/A |
| Hopping Frequency Separation | Yes | 4.3.1.5 | Compliant |
| Medium Utilization | No | 4.3.2.5 | N/A |
| Occupied Channel Bandwidth | Yes | 4.3.2.7 | Compliant |
| Transmitter Unwanted Emissions in the OOB Domain | Yes | 4.3.2.8 | Compliant |
| Transmitter Unwanted Emissions in the Spurious Domain | Yes | 4.3.2.9 | Compliant |

**Table 2. Receiver Test Suites and Overview Results**

| Essential Radio Test suite | Applicable | Reference clause in this report | Compliance Results |
|---|---|---|---|
| Adaptivity | N/A | 4.3.2.6 | N/A |
| Receiver Spurious Emissions | Yes | 4.3.2.10 | Compliant |
| Receiver Blocking | Yes | 4.3.2.11 | Compliant |

## 5.2 General Comments

This section contains the test results and derived data. Details of the test methods used have been recorded and are kept on file by the laboratory. Wherever possible, the test methods described in ETSI document ETR 027 have been used.

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k = 2, providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

The testing preformed requires the uncertainty levels to be below the listed values in section 5.2 of ESTI 300 328 v2.1.1. The following table lists the limit of uncertainty per test and the current uncertainty of the testing done

**Table 3. Measurement Uncertainty**

| Parameter | Uncertainty Requirement | Uncertainty of Testing |
|---|---|---|
| Occupied Channel Bandwidth | ±5.0% | Less Than ±0.1dB |
| RF Output power, Conducted | ±1.5dB | ±0.47dB |
| Power Spectral Density, Conducted | ±3.0dB | ±0.47dB |
| Unwanted Emissions, Conducted | ±3.0dB | ±2.80dB |
| All Emissions, Radiated | ±6.0dB | 30MHz - 200MHz, ±5.39dB<br>200MHz - 1GHz, ±5.18dB<br>1GHz -18GHz, ±5.21dB |
| Temperature | ±1.0°C | ±0.55°C |
| Humidity | ±5.0% | ±5.00% |
| DC and Low Frequency Voltages | ±3.0% | ±0.05% |
| Time | ±5.0% | ±1.00% |
| Duty Cycle | ±5.0% | ±1.00% |

The purpose of testing was to demonstrate compliance with the latest version of the test specification.

Date of receipt of test sample(s): September 15, 2018

Measurements were performed between the following dates(s):

Start Date: November 2, 2018

Completion Date: December 6, 2018

All of the measurements described in this report were performed at the premises of US Tech, 3505 Francis Circle, Alpharetta, GA 30004 USA.

## 5.3 Test Results

### 5.3.1 RF Output Power (Clause 4.3.2.2)

The RF Output Power was measured at the lowest, the middle, and the highest channel and at normal and extreme operating temperatures. The measurements were performed per the procedures of ETSI EN 300 328 section 5.4.2. The test equipment was set to a center frequency at which the EUT will transmit. The span was set to 10 MHz and the RBW and VBW were set to 1 MHz and 3 MHz, respectively.

In accordance with ETSI EN 300 328 section 4.3.2.2, for adaptive equipment using wide band modulations other than FHSS, the maximum RF output power shall be 20 dBm. This limit shall apply for any combination of power level and intended antenna assembly.

**Maximum Antenna Assembly Gain: +3.2 dBi**
**Beam-forming Gain: 0 dBi**
**Correction factor/cable loss: 12.2 dB**

**Table 4. RF Output Power Measurement**

| Frequency (MHz) | Measured Result (dBm) A | Combination of Power Level and Antenna Gain (dBm) A+G+Y | Limit (dBm) | Margin (dB) |
|---|---|---|---|---|
| Measured at **-**40˚C | | | | |
| 2402 | -3.81 | 8.39 | 20.0 | 11.6 |
| 2440 | -4.10 | 8.10 | 20.0 | 11.9 |
| 2480 | -4.30 | 7.90 | 20.0 | 12.1 |
| Measured at **25**˚C | | | | |
| 2402 | -4.60 | 7.60 | 20.0 | 12.4 |
| 2440 | -4.81 | 7.39 | 20.0 | 12.6 |
| 2480 | -5.30 | 6.90 | 20.0 | 13.1 |
| Measured at **85**˚C | | | | |
| 2402 | -5.13 | 7.07 | 20.0 | 12.9 |
| 2440 | -5.22 | 6.98 | 20.0 | 13.0 |
| 2480 | -5.58 | 6.62 | 20.0 | 13.4 |

Test Date: November 8, 2018

Signature: *Afzal Fazal* Tested By: Afzal Fazal

### 5.3.2 Duty Cycle, TX-Sequence, TX-Gap (Clause 4.3.2.4)

These requirements do not apply for equipment with a maximum declared RF Output power of less than 10 dBm EIRP or for equipment when operating in a mode where the RF Output power is less than 10 dBm EIRP. In this case the EUT is declared to operate at less than 10 dBm. Therefore this test was not performed.

### 5.3.3 Power Spectral Density (Clause 4.3.2.3)

The EUT employs frequency hopping therefore the Power Spectral Density measurement is not applicable.

### 5.3.4 Accumulated Transmit Time, Minimum Frequency Occupation and Hopping Sequence (Clause 4.3.1.4)

These requirements do not apply for equipment with a maximum declared RF Output power of less than 10 dBm EIRP or for equipment when operating in a mode where the RF Output power is less than 10 dBm EIRP. In this case the EUT is declared to operate at less than 10 dBm. Therefore this test was not performed.

### 5.3.5 Hopping Frequency Separation (Clause 4.3.1.5)

The EUT employs frequency hopping; therefore the Hopping Frequency Separation was measured per the procedures of ETSI EN 300 328 section 4.3.1.5. The analyser was centred in two adjacent hopping frequencies, and the span was set wide enough to captures the power envelope of those two hopping channels. The RBW was ~ 1% of the Span and the VBW was 3*RBW. The trace was set to max hold with the sweep time on Auto.

The Hopping Frequency Separation is the separation of two adjacent hopping frequencies. The minimum Separation is required to be equal to the Occupied Channel Bandwidth of a single hop, with a minimum of 100 kHz. A marker-delta measurement was taken, see figure below.

Environmental Conditions:
Ambient Temperature: 20 ˚C
Relative Humidity: 40 %

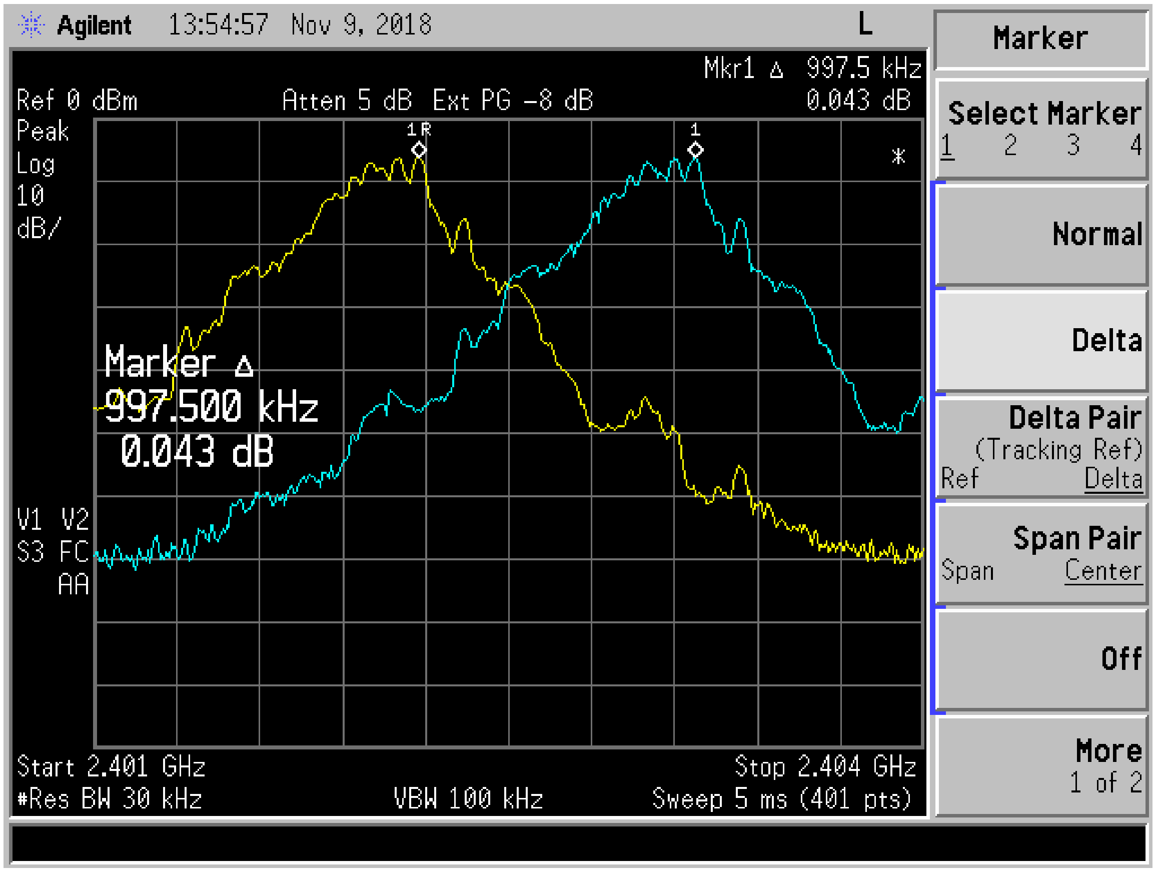



**Figure 1. Hopping Frequency Separation**

| | | |
|---|---|---|
| Frequency separation | 997.50 | kHz |
| Limit | 100.00 | kHz |
| Margin | 887.50 | kHz |

### 5.3.6 Adaptivity (Clause 4.3.2.6)

These requirements do not apply for equipment with a maximum declared RF Output power of less than 10 dBm EIRP or for equipment when operating in a mode where the RF Output power is less than 10 dBm EIRP. In this case the EUT is declared to operate at less than 10 dBm. Therefore this test was not performed.

### 5.3.7 Occupied Channel Bandwidth (Clause 4.3.2.7)

The Occupied Channel Bandwidth is the bandwidth that contains 99% of the signal. In accordance with ETSI EN 300 328 section 4.3.2.7, the Occupied Bandwidth for each hopping frequency shall fall completely within the given frequency band.

The Occupied Channel Bandwidth was measured per the procedures of ETSI EN 300 328 section 5.3.8. The center frequency was set to either the highest or lowest frequency within the allowed frequency band under test and the span was 2x the Occupied Channel bandwidth. The RBW was ~ 1 % of the span and VBW was 3x VBW. The RMS detector mode was used and the trace was set to Max Hold to allow the trace to complete. The 99 % bandwidth function of the spectrum analyser was used to measure the occupied bandwidth.

Environmental Conditions:
Ambient Temperature: 25 ˚C
Relative Humidity: 55 %

Test Date: November 8, 2018

Signature: Afzal Fazal Tested By: Afzal Fazal

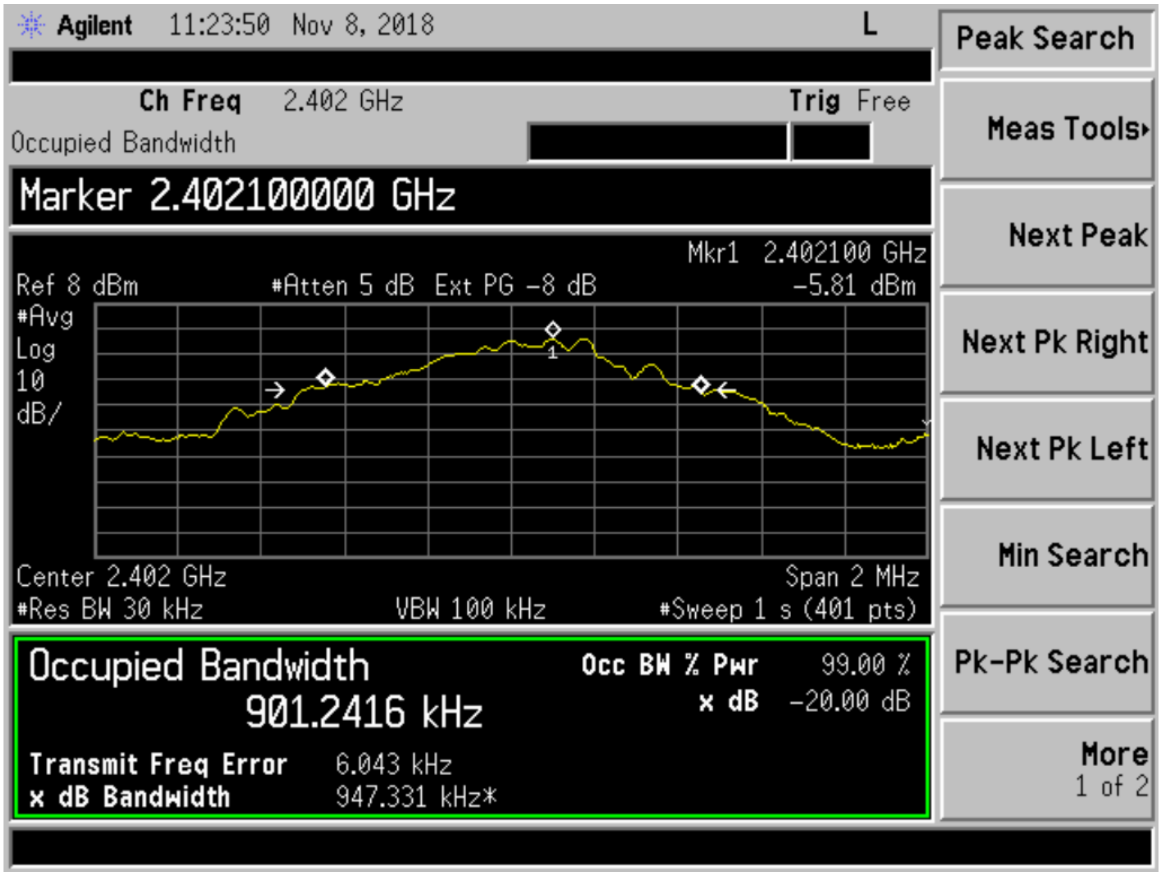



**Figure 2. 2402 MHz Low Channel Occupied Bandwidth**

| | | |
|---|---|---|
| Occupied BW= | 0.9012 | MHz |
| Center frequency | 2402 | MHz |
| Low Band-edge | 2401.549 | MHz |

Low band-edge contained within 2400 MHz.

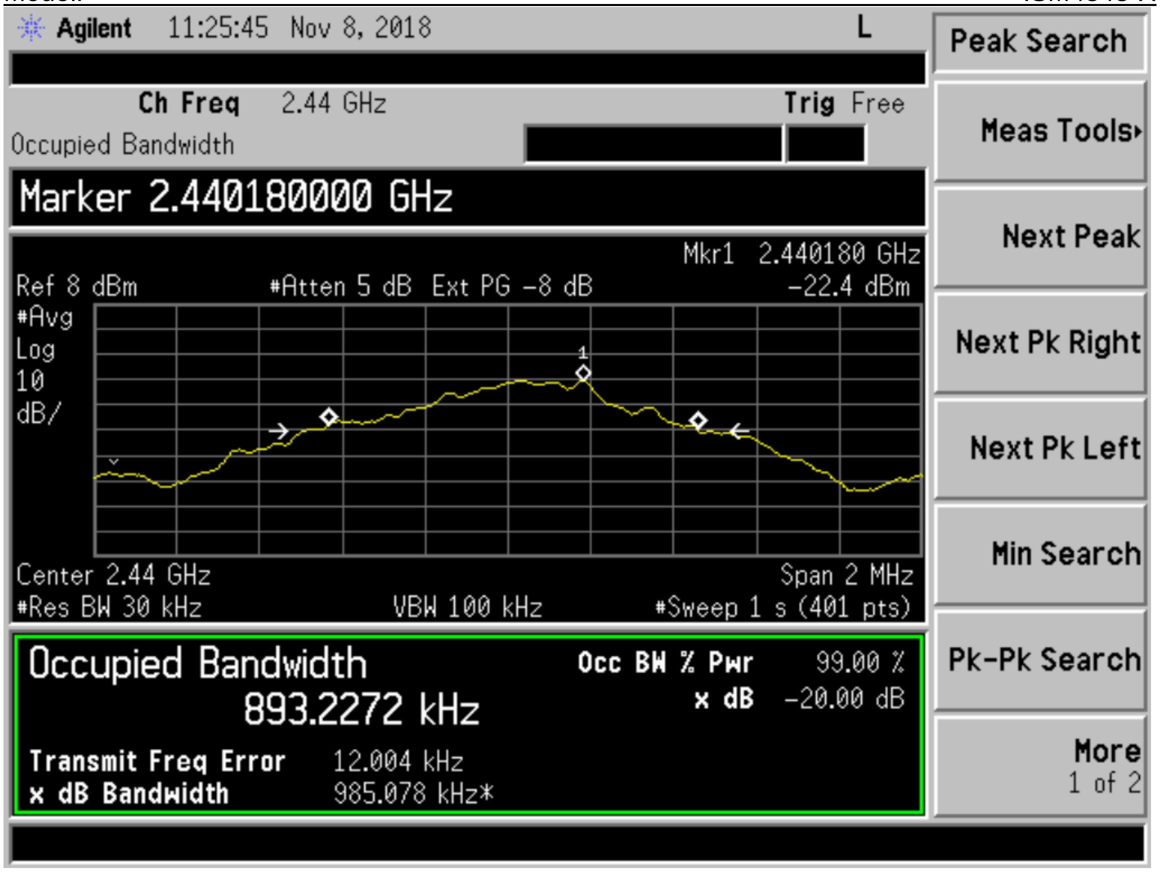



**Figure 3. 2440 MHz Mid Channel Occupied Bandwidth**

| | | |
|---|---|---|
| Occupied BW= | 0.8932 | MHz |
| Center frequency | 2440 | MHz |
| High Band-edge | 2439.107 | MHz |

Mid band-edge contained between 2400 and 2483.5 MHz.

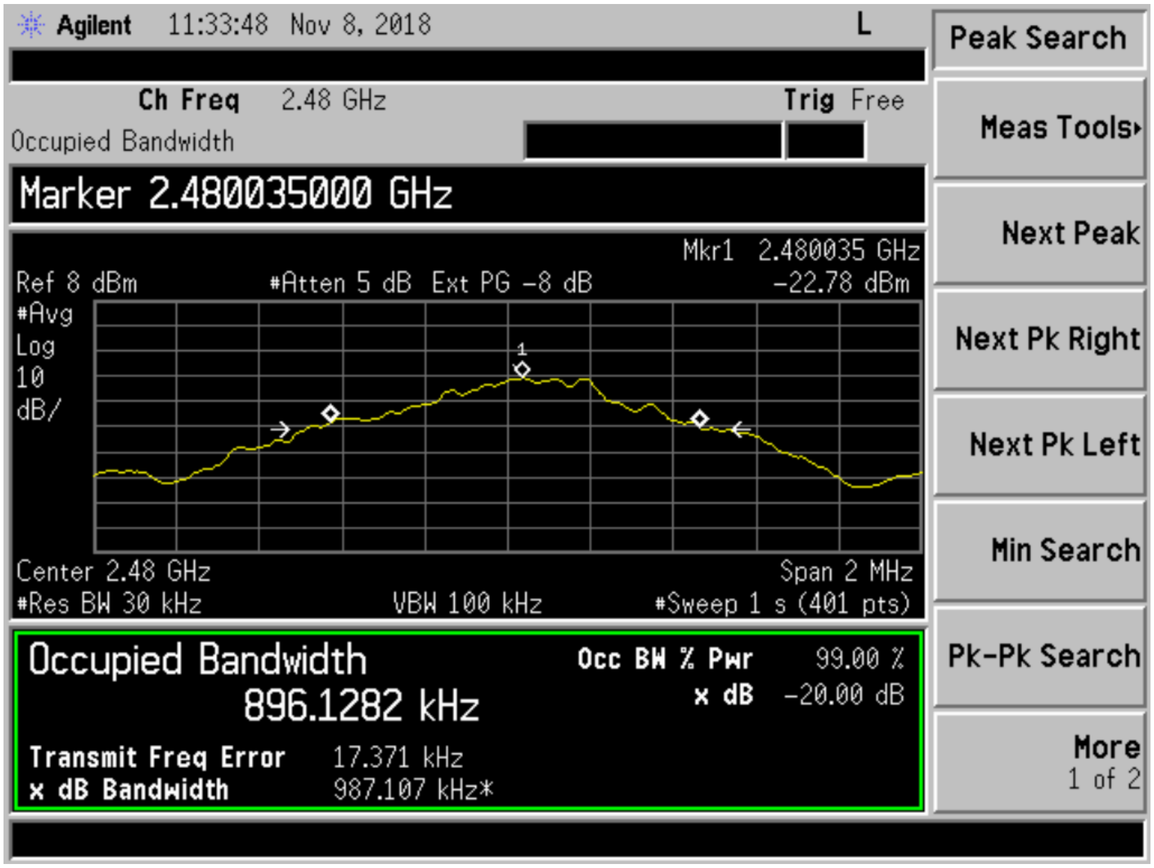



**Figure 4. 2480 MHz High Channel Occupied Bandwidth**

| | | |
|---|---|---|
| Occupied BW= | 0.8962 | MHz |
| Center frequency | 2480 | MHz |
| High Band-edge | 24789.104 | MHz |

High band-edge contained within 2483.5 MHz.

### 5.3.8 Transmitter Unwanted Emissions in the Out-Of-Band Domain (Clause 4.3.2.8)

The 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. In accordance with ETSI EN 300 328 section 4.3.2.8.3, the transmitter unwanted emissions in the out-of-band domain but outside the allocated band, shall not exceed the values provided by the mask in the figure below. Within the band specified, the Out-of-band emissions are fulfilled by compliance with the Occupied Channel Bandwidth requirement in clause 4.3.2.7.

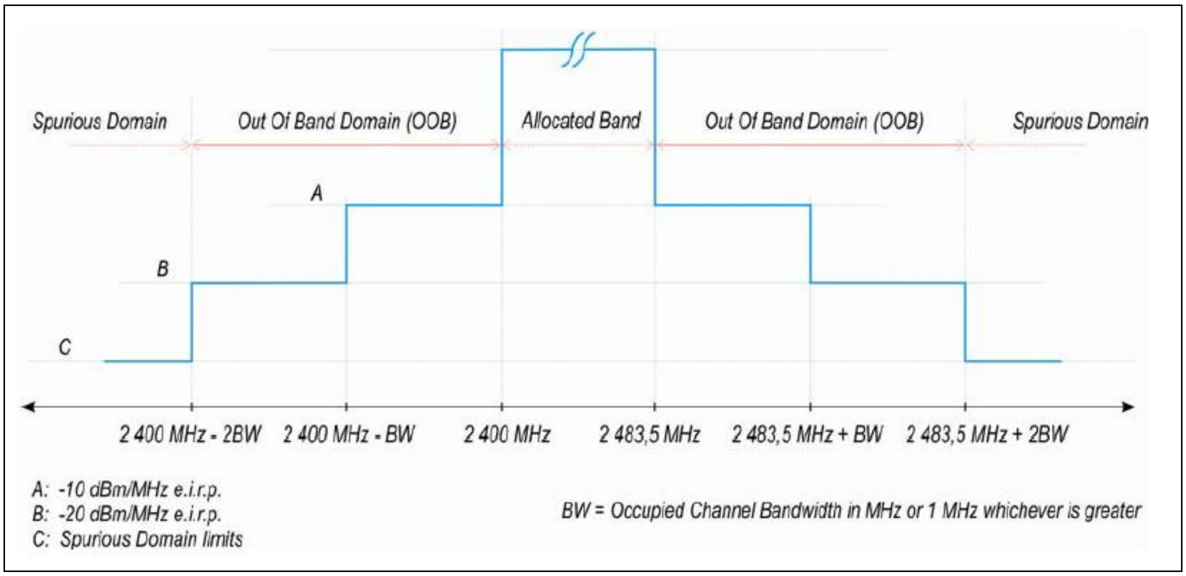



**Figure 5. Transmitter Unwanted Emissions in the Out-of-Band Domain Limits**

The EUT was tested at normal and extreme temperatures. Only the lowest and highest channels were evaluated for each operational mode. The Occupied Bandwidth used was 20 MHz since this is the maximum allowed bandwidth for this type of transmitter. The RF port of the EUT was directly connected to the Spectrum Analyzer. The resolution bandwidth used was 1 MHz with a video bandwidth of 3 MHz. The Peak detector was used and only the worst case emission was recorded below.

Testing performed by:
Test Date: November 8, 2018
Signature: Afzal Fazal Tested By: Afzal Fazal

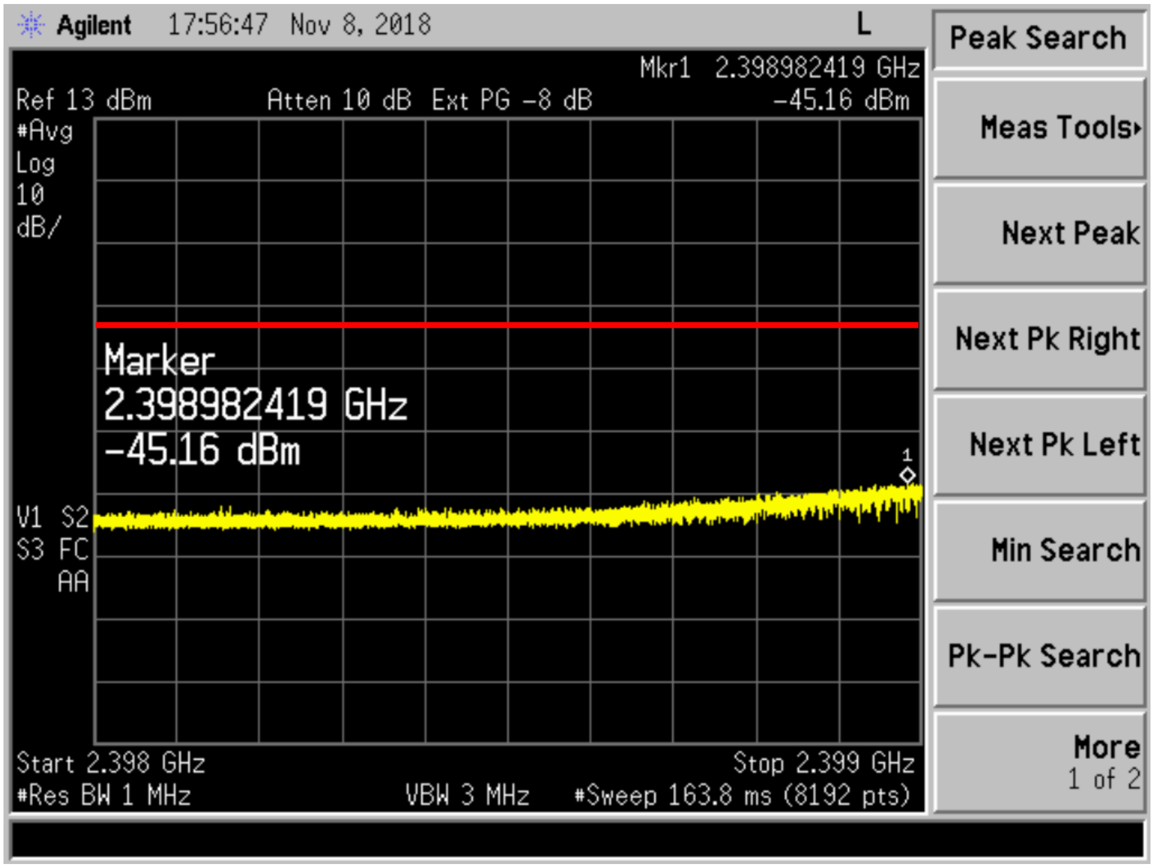



**Figure 6. 2402 MHz, Low Channel TX OOB (2BW-BW)**

**RED= Limit at -20 dBm**

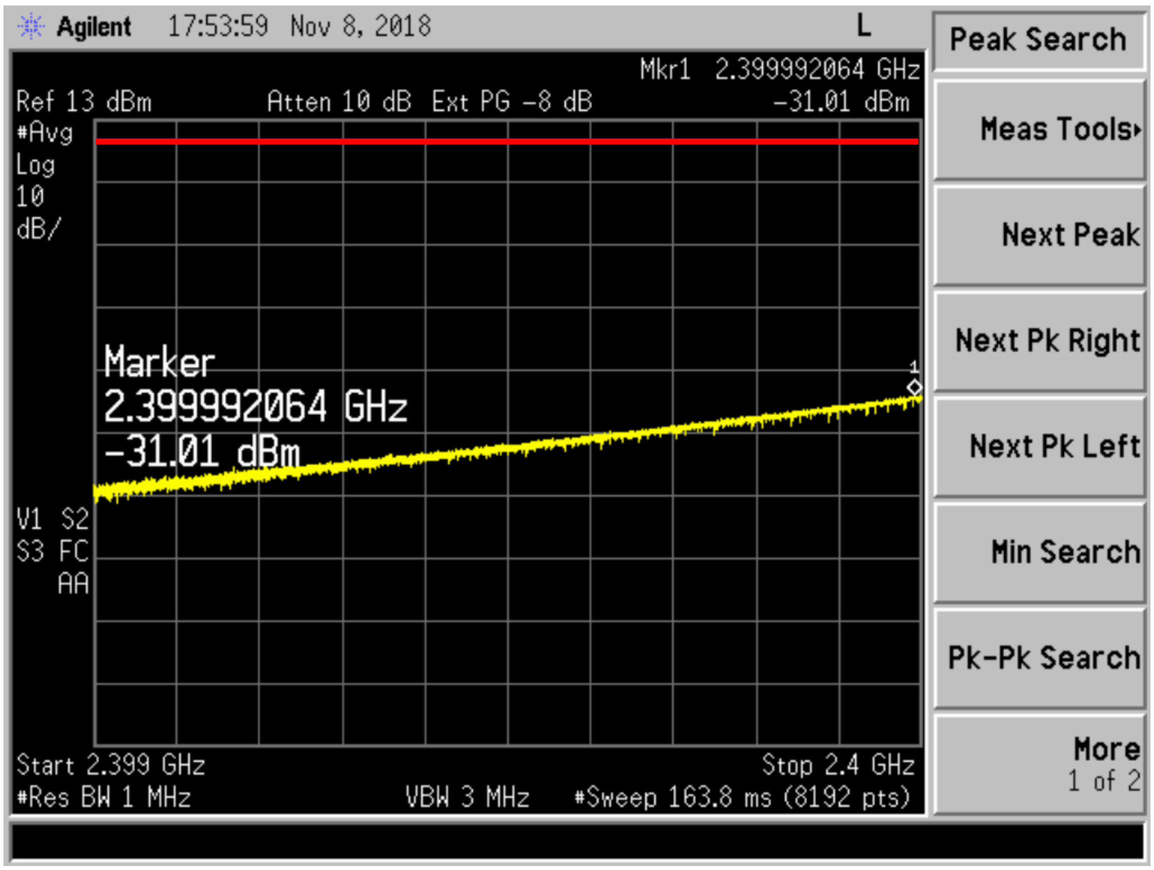



**Figure 7. 2402 MHz, Low Channel TX OOB (BW-BE)**

**RED= Limit at -10 dBm**

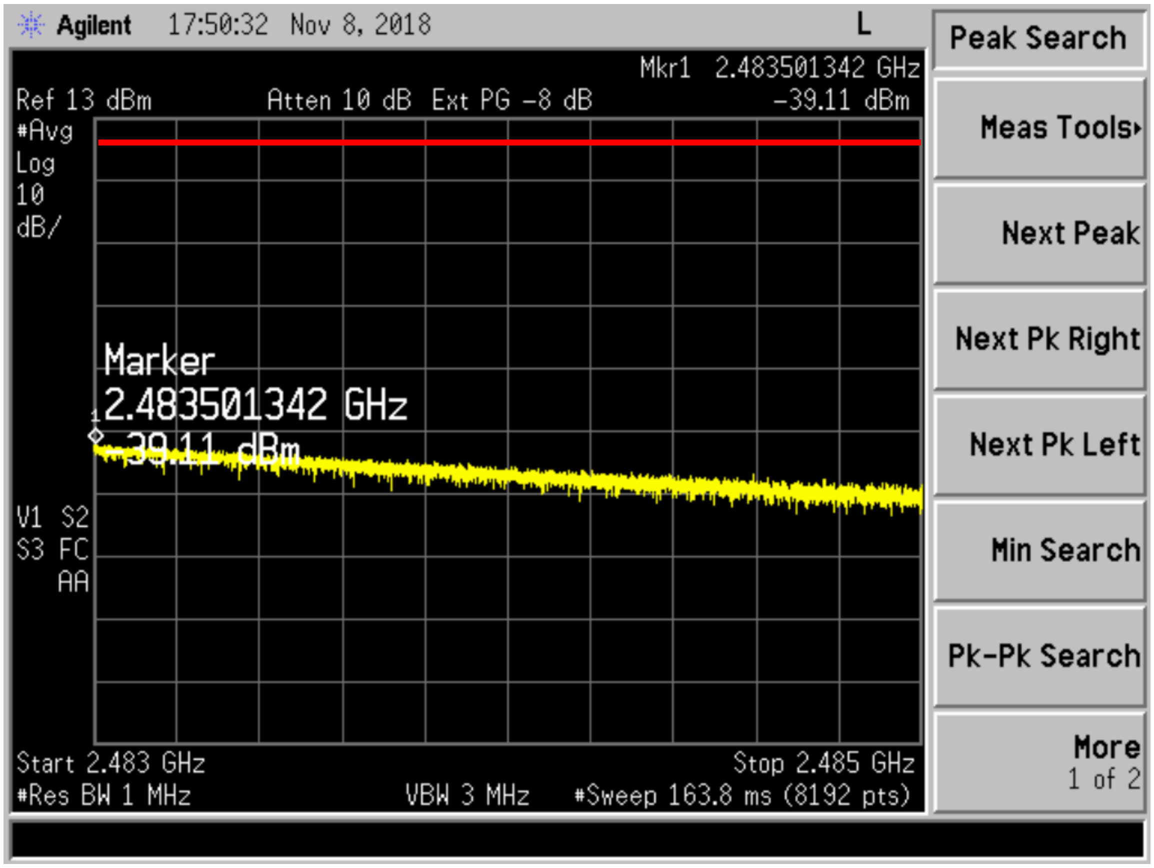



**Figure 8. 2480 MHz, High Channel TX OOB (BE+BW)**

**RED= Limit at -10 dBm**

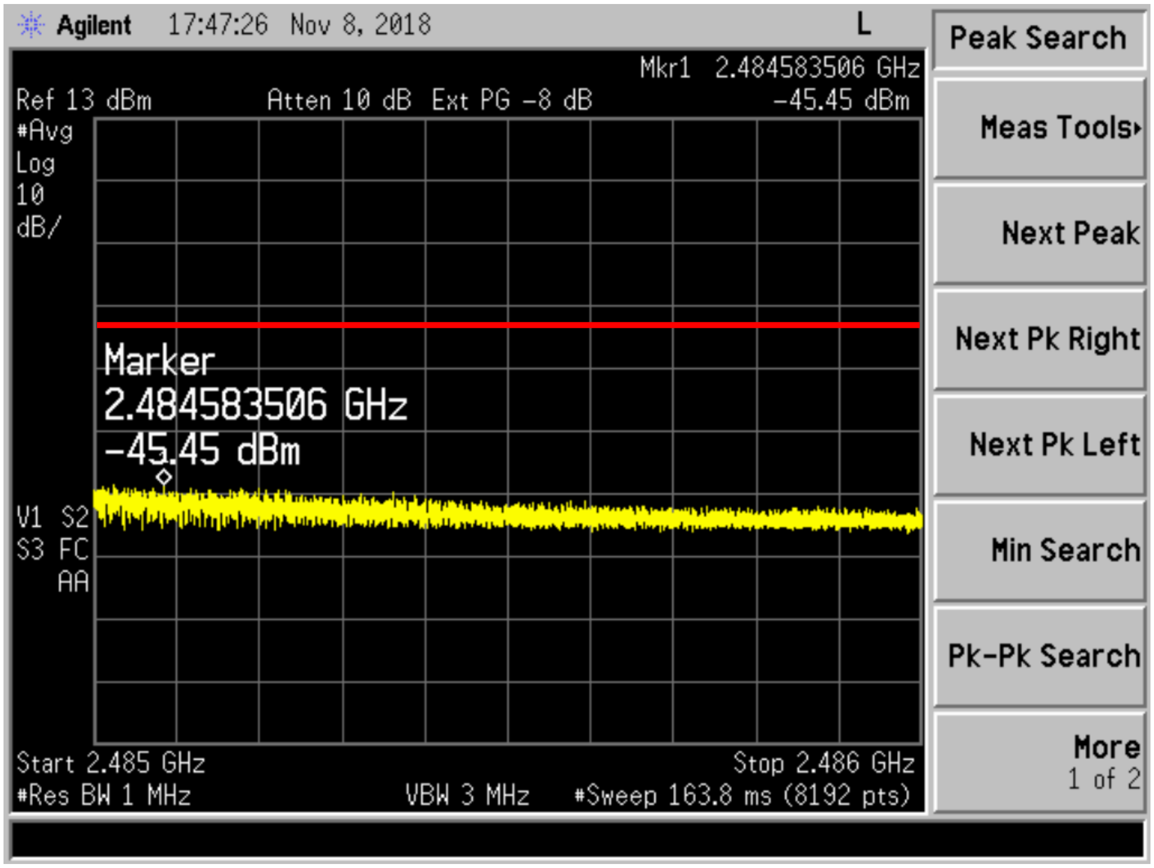



**Figure 9. 2480 MHz, High Channel TX OOB (BW+2BW)**

**RED= Limit at -20 dBm**

### 5.3.9 Transmitter Unwanted Emissions in the Spurious Domain (Clause 4.3.2.9)

Transmitter unwanted emissions in the spurious domain are emissions outside the allocated band and the Out-Of-Band domain when the equipment is in transmit mode, in accordance ETSI EN 300 328 section 4.3.2.9, the spurious emissions cannot be greater than the limits in the Tables following.

**Table 5. Transmitter Unwanted Emission Limits**

| 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 862 MHz | -54 dBm | 100 kHz |
| 862 MHz to 1 GHz | -36 dBm | 100 kHz |
| 1 GHz to 12.75 GHz | -30 dBm | 1 MHz |

The transmitter unwanted emissions in the spurious domain were measured at normal test conditions and with the equipment operating at its worst case scenario with respect to spurious emissions. Measurements were performed at the lowest and highest channels the EUT can operate on.

A pre-scan was performed per ETSI EN 300 328 section 4.3.2. The individual unwanted emissions were then measured per ETSI EN 300 328 section 4.3.2.9 and compared to the spurious limits above. The results are presented below.

Environmental Conditions:
Ambient Temperature: 20 ˚C
Relative Humidity: 40 %

**Table 6. Transmitter Spurious Emissions External Trace Antenna (u.fl)**

| Freq. (MHz) | Maximum RX Reading (dBuV) | Recreated Reading (dBuV) | Difference Column A – B (dB) | TX Gain (dBi) | TX Gain Relative to Dipole (dB) | RF Power into TX Antenna | RF Power into Substitution TX Antenna Corrected By TX Gain Relative to Dipole and TX Cable (dBm) | Limit (dBm) | Margin (dB) | Antenna factor/ Cable loss |
|---|---|---|---|---|---|---|---|---|---|---|
| 2402.000 | 63.24 | 62.35 | 0.89 | 8.8 | 6.7 | -10.0 | -4.32 | 20 | 24.32 | -1.91 |
| 2440.000 | 74.17 | 73.86 | 0.31 | 8.8 | 6.7 | 0.0 | 5.02 | 20 | 14.98 | -1.99 |
| 2480.000 | 75.11 | 73.96 | 1.15 | 8.8 | 6.7 | 0.0 | 5.86 | 20 | 14.14 | -1.99 |
| **No other emissions seen 6 dB above the noise floor.** | | | | | | | | | | |

Note 1) RF Power (dBm) into substitution antenna from signal generator corrected with cable loss and other attenuators factors.
Note 2) Radiated RF power (dBm) was calculated by summing the antenna factor/cable loss, Input RF Power, and the difference in column D.

Sample calculation for 2402.00 MHz:

| | | |
|---|---|---|
| Maximum RX Reading (column 2) | 63.24 | (dBuV/m) |
| Less Recreated Reading (column 3) | 62.35 | (dBuV/m) |
| TX Gain Relative to Dipole (column 6) | 6.7 | (dB) |
| RF Power into TX Antenna (column 7) | -10.00 | (dBm) |
| Antenna factor/Cable loss from spreadsheet factors | -1.91 | (dBm) |
| Corrected RF Power (column 8) | -4.32 | (dBm) |

Testing performed by:
Test Date: November 8, 2018
Signature: Afzal Fazal Tested By: Afzal Fazal

**Table 7. Transmitter Spurious Emissions Onboard Chip Antenna**

| Freq. (MHz) | Maximum RX Reading (dBuV) | Recreated Reading (dBuV) | Difference Column A – B (dB) | TX Gain (dBi) | TX Gain Relative to Dipole (dB) | RF Power into TX Antenna | RF Power into Substitution TX Antenna Corrected By TX Gain Relative to Dipole and TX Cable (dBm) | Limit (dBm) | Margin (dB) | Antenna factor/ Cable loss |
|---|---|---|---|---|---|---|---|---|---|---|
| 2402.00 | 59.16 | 58.44 | 0.72 | 8.8 | 6.7 | -17.0 | -11.46 | 20 | 31.46 | -1.88 |
| 2440.00 | 65.86 | 65.50 | 0.36 | 8.8 | 6.7 | -10.0 | -4.89 | 20 | 24.89 | -1.95 |
| 2480.00 | 71.98 | 69.89 | 2.09 | 8.8 | 6.7 | -3.0 | 3.84 | 20 | 16.16 | -1.95 |
| **No other emissions seen 6 dB above the noise floor.** | | | | | | | | | | |

Note 1) RF Power (dBm) into substitution antenna from signal generator corrected with cable loss and other attenuators factors.
Note 2) Radiated RF power (dBm) was calculated by summing the antenna factor/cable loss, Input RF Power, and the difference in column D.

Sample calculation for 2402.00 MHz:

| | | |
|---|---|---|
| Maximum RX Reading (column 2) | 59.16 | (dBuV/m) |
| Less Recreated Reading (column 3) | 58.44 | (dBuV/m) |
| TX Gain Relative to Dipole (column 6) | 6.70 | (dB) |
| RF Power into TX Antenna (column 7) | -17.00 | (dBm) |
| Antenna factor/Cable loss from spreadsheet factors | -1.88 | (dBm) |
| Corrected RF Power (column 8) | -11.46 | (dBm) |

Test Date: November 8, 2018

Testing performed by:
Signature: Afzal Fazal Tested By: Afzal Fazal

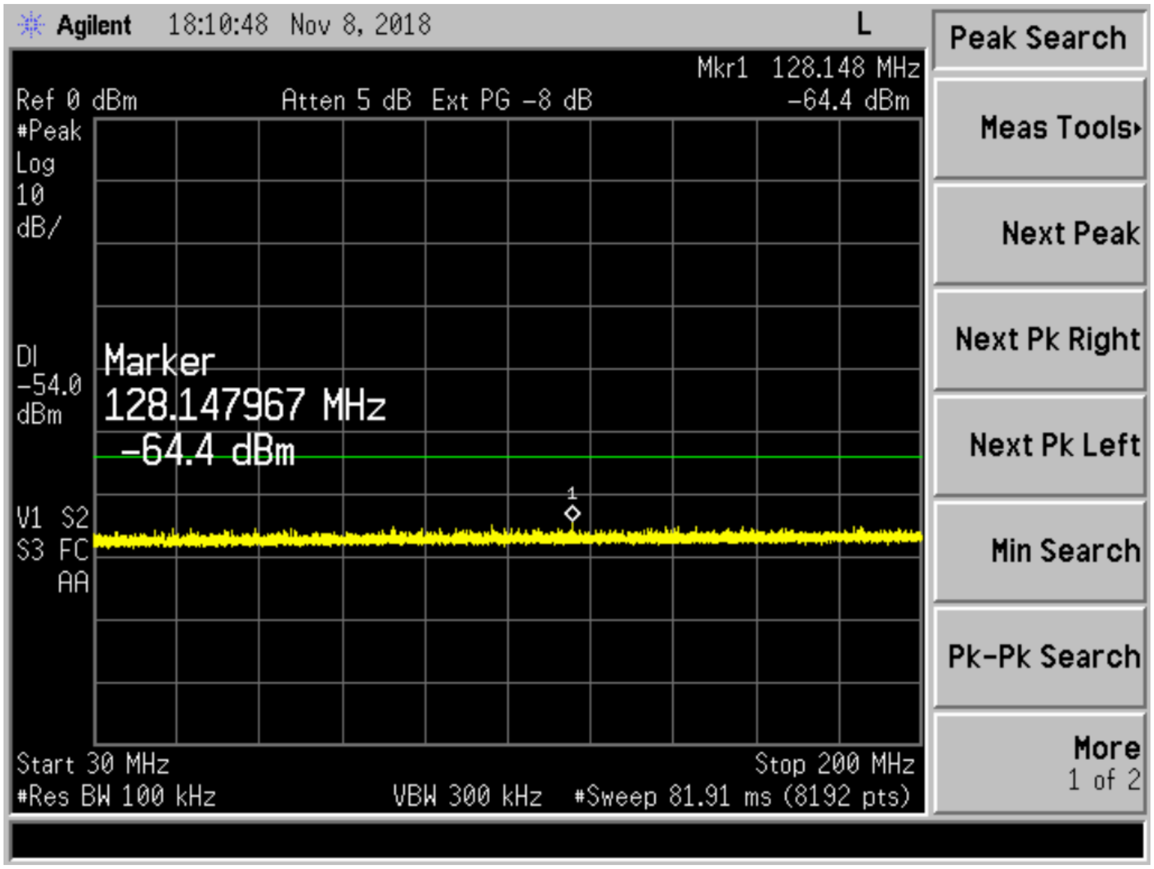



**Figure 10. Conducted Spurious Emissions 2402 MHz Low Channel 30 MHz to 200 MHz**

| | | |
|---|---|---|
| Limit | -54.00 | dBm |
| Measured Emissions (per Figure 19) | -64.40 | dBm |
| Margin | 10.40 | dB |

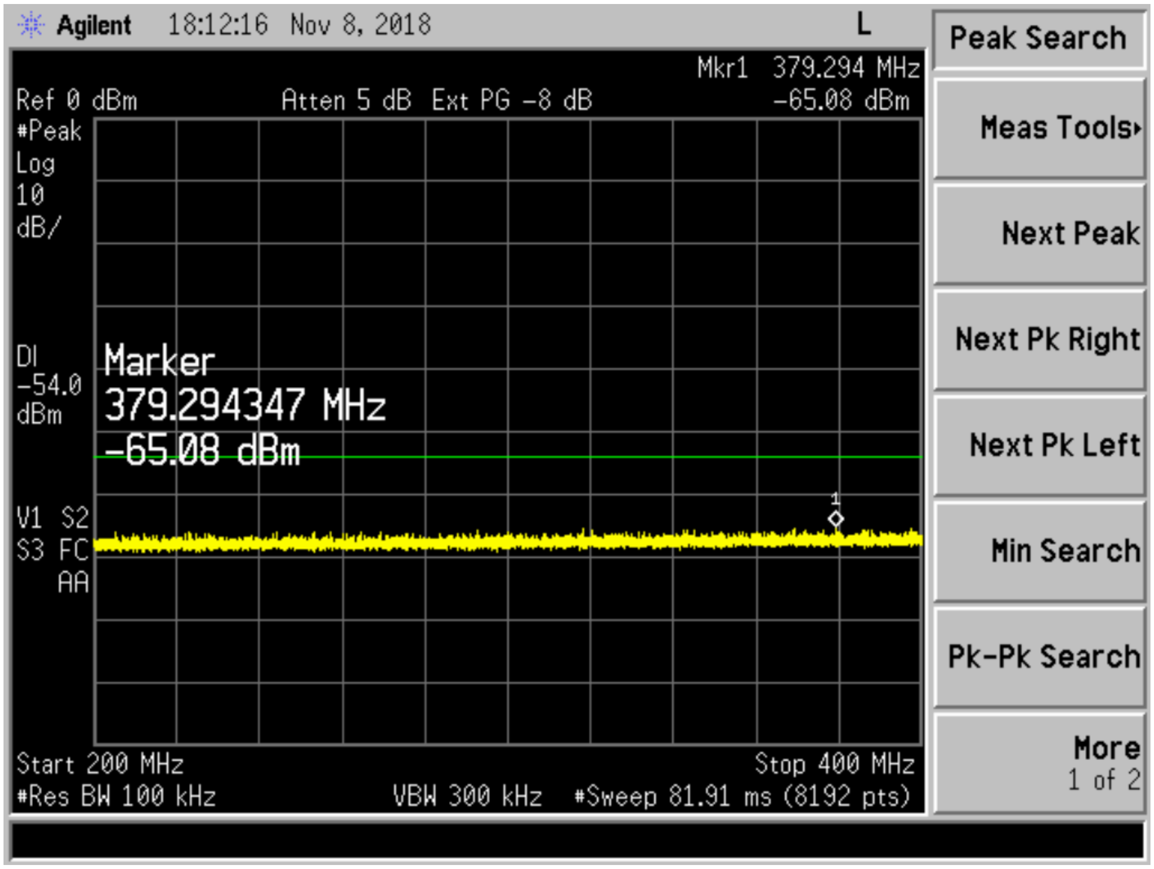



**Figure 11. Conducted Spurious Emissions 2402 MHz Low Channel 200 MHz to 400 MHz**

| | |
|---|---|
| Limit | -54.00 dBm |
| Measured Emissions (per Figure 20) | -65.08 dBm |
| Margin | 11.08 dB |

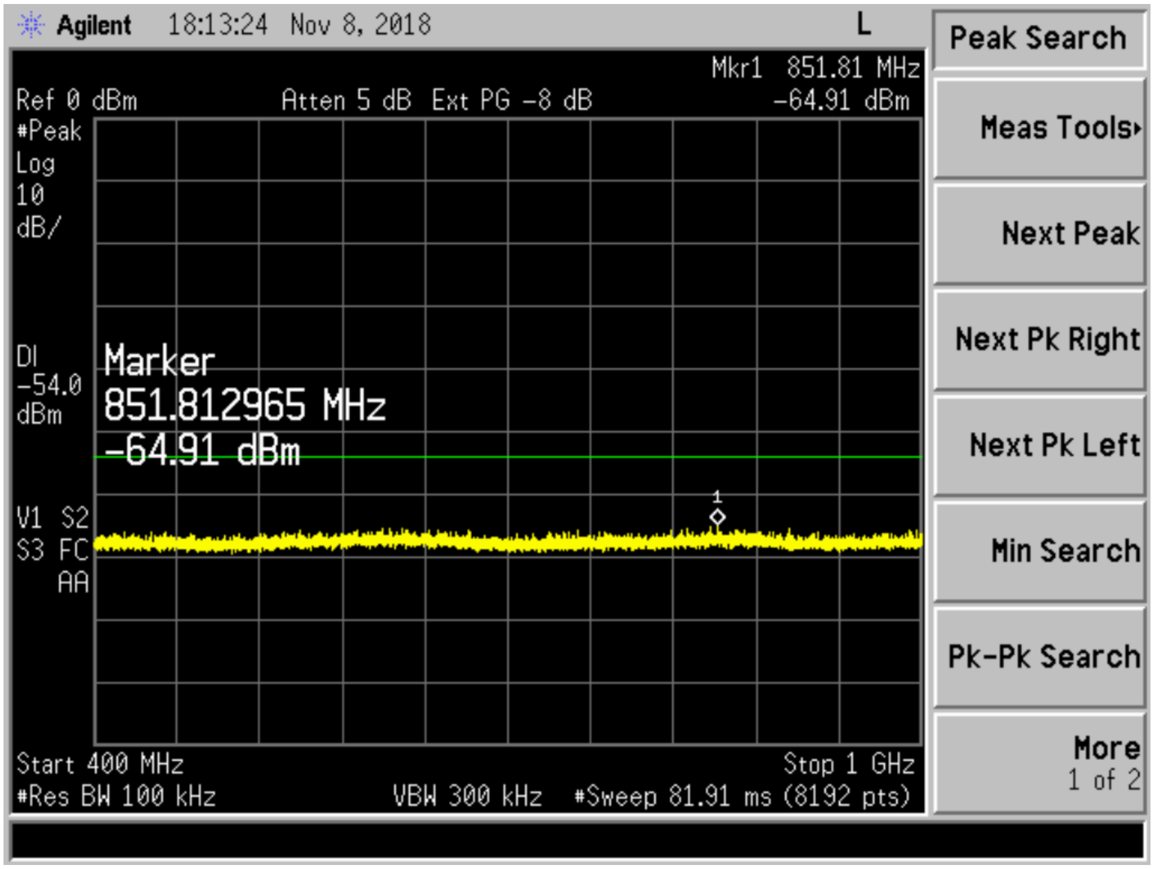



**Figure 12. Conducted Spurious Emissions 2402 MHz Low Channel 400 MHz to 1000 MHz**

| | |
|---|---|
| Limit | -54.00 dBm |
| Measured Emissions (per Figure 21) | -64.91 dBm |
| Margin | 10.91 dB |

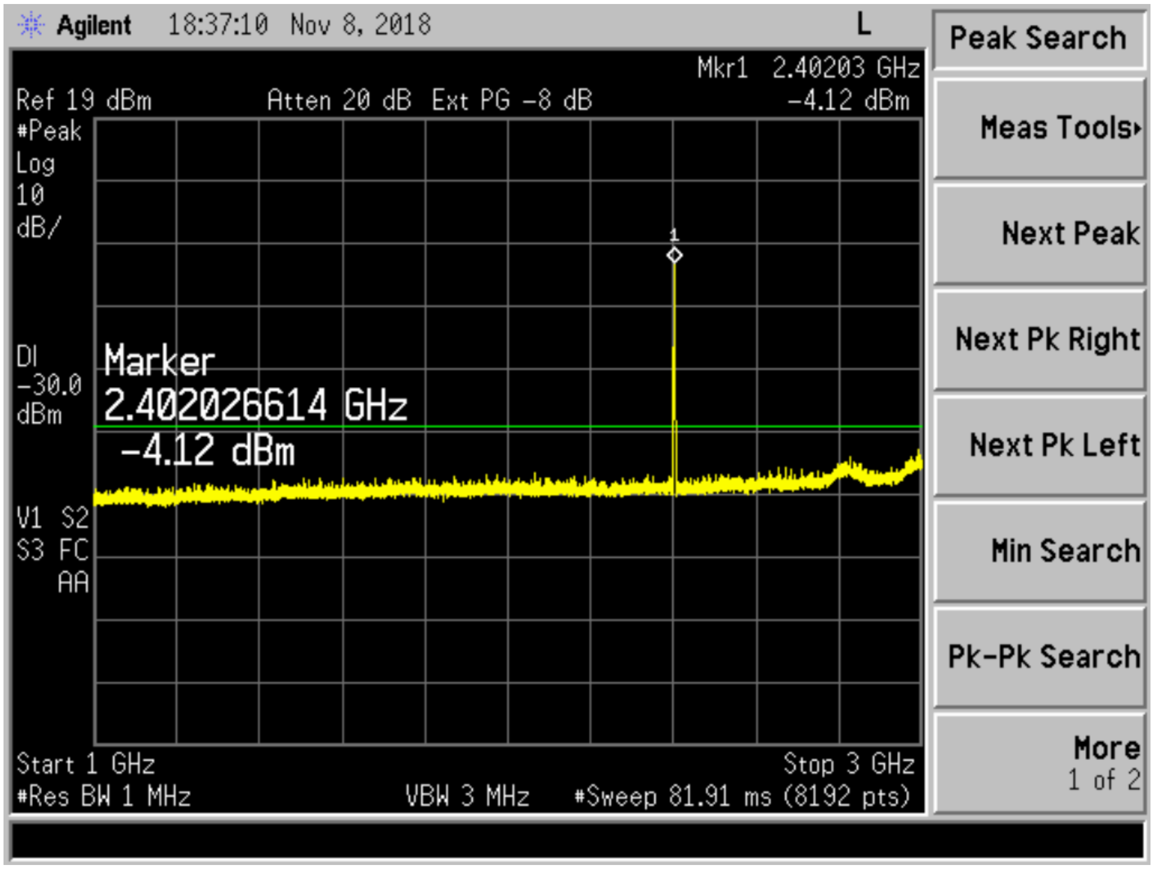



**Figure 13. Conducted Spurious Emissions 2402 MHz High Channel 1 GHz to 3 GHz**

| | |
|---|---|
| Limit | 10.00 dBm |
| Measured Emissions (per Figure 22) | -4.12 dBm |
| Margin | 14.12 dB |

*Note: All other emissions are below the 30 dBm limit as indicated by the plot above.

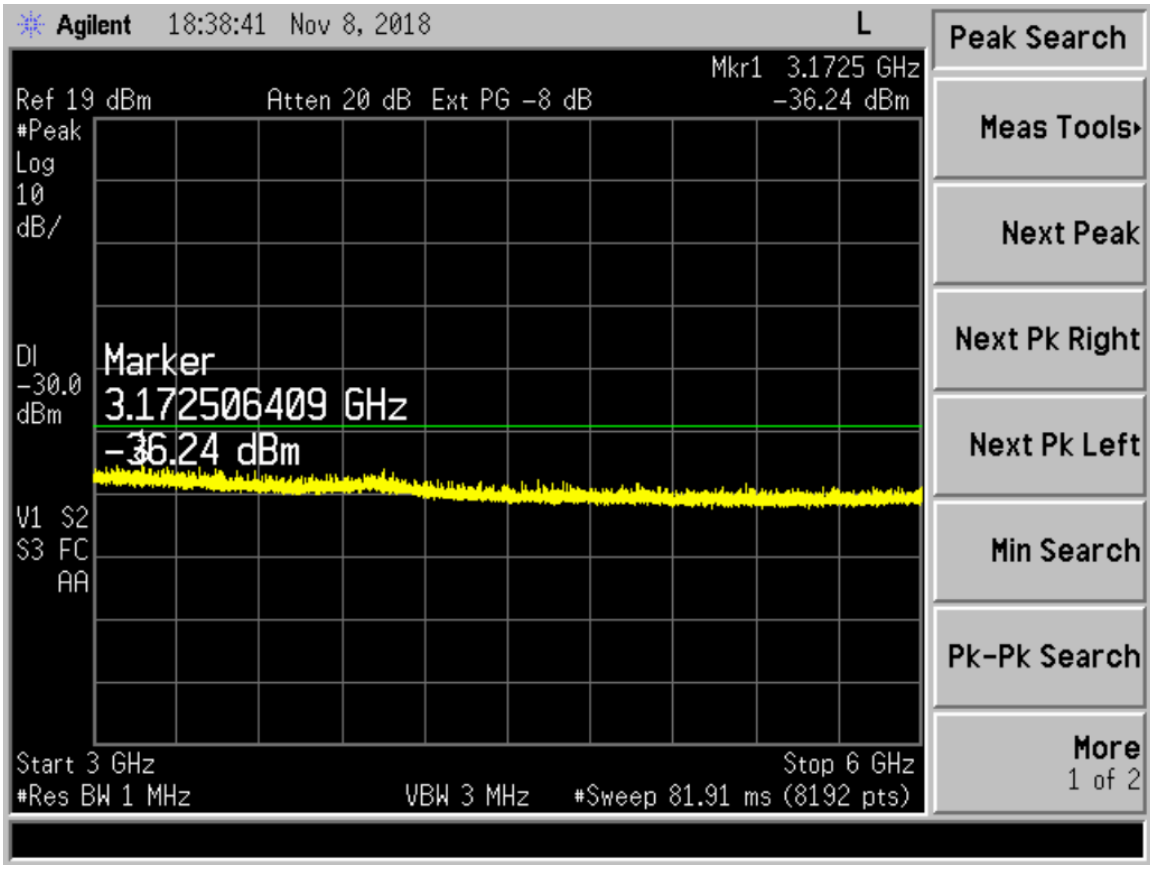



**Figure 14. Conducted Spurious Emissions 2402 MHz High Channel 3 GHz to 6 GHz**

| | | |
|---|---|---|
| Limit | -30.00 | dBm |
| Measured Emissions (per Figure 23) | -36.24 | dBm |
| Margin | 6.24 | dB |

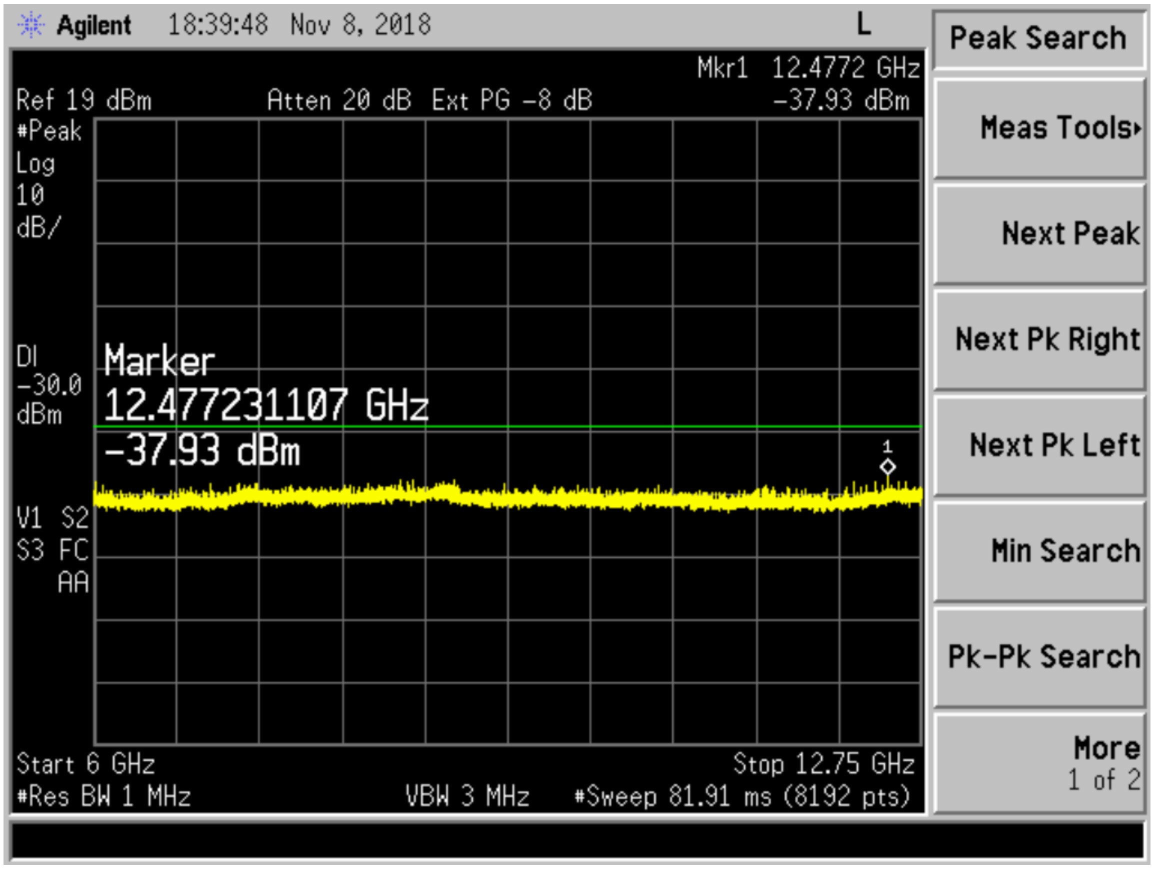



**Figure 15. Conducted Spurious Emissions 2402 MHz High Channel 6 GHz to 12.75 GHz**

| | |
|---|---|
| Limit | -30.00 dBm |
| Measured Emissions (per Figure 24) | -37.93 dBm |
| Margin | 7.93 dB |

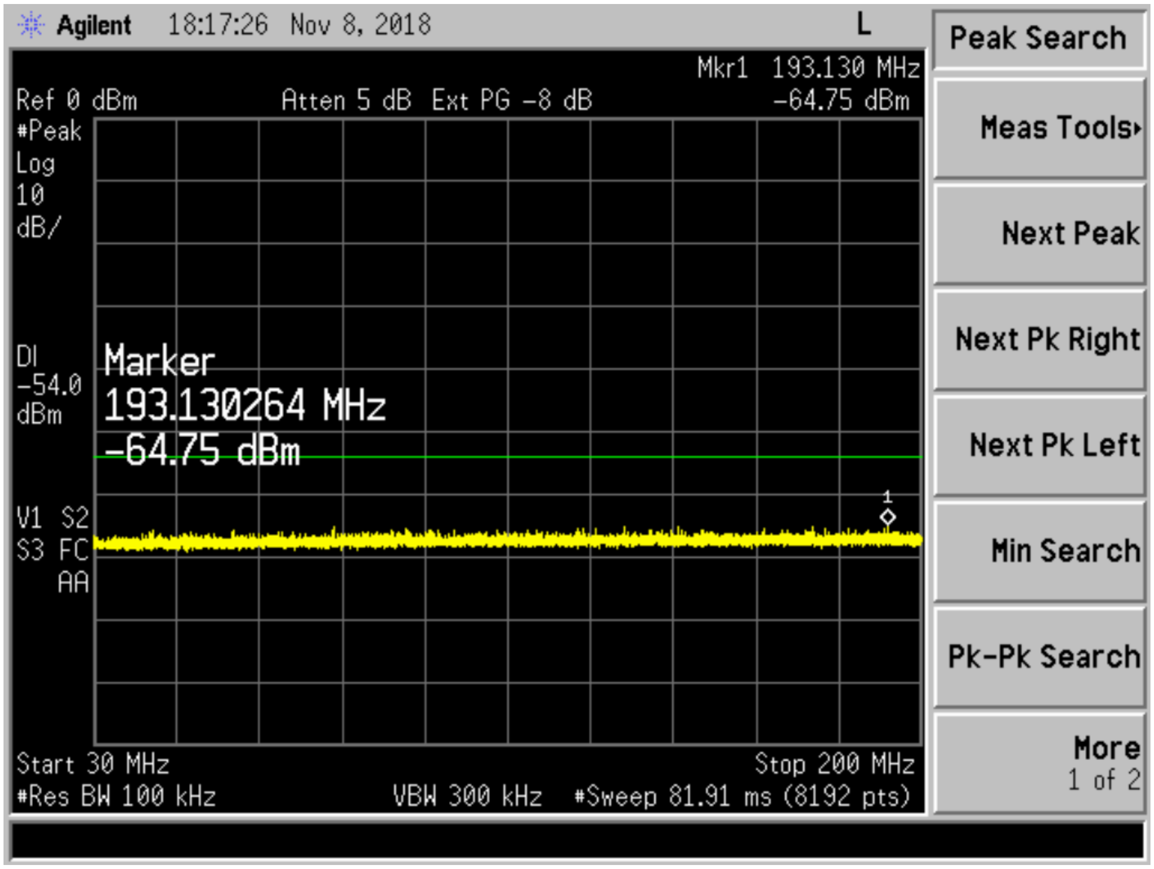



**Figure 16. Conducted Spurious Emissions 2480 MHz Low Channel 30 MHz to 200 MHz**

| | |
|---|---|
| Limit | -54.00 dBm |
| Measured Emissions (per Figure 25) | -64.75 dBm |
| Margin | 10.75 dB |

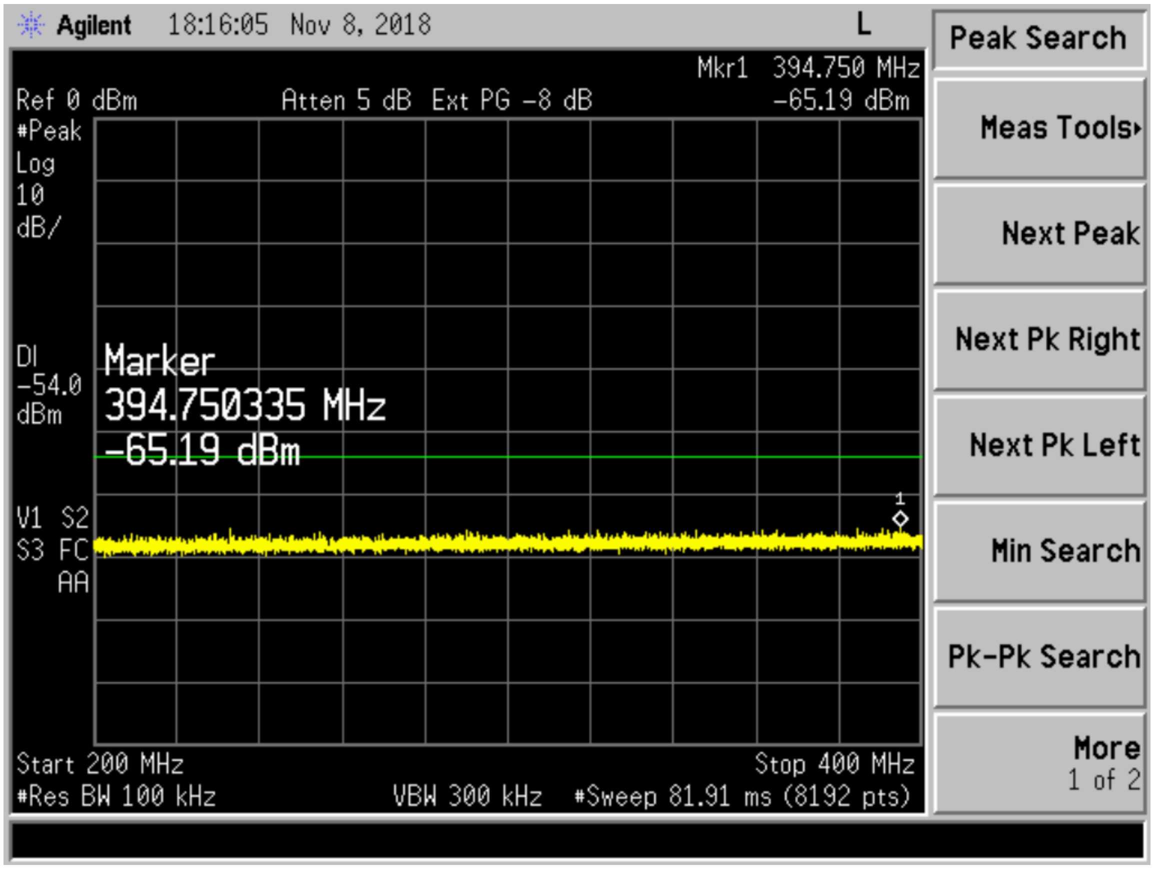



**Figure 17. Conducted Spurious Emissions 2480 MHz Low Channel 200 MHz to 400 MHz**

| | |
|---|---|
| Limit | -54.00 dBm |
| Measured Emissions (per Figure 26) | -65.19 dBm |
| Margin | 11.19 dB |

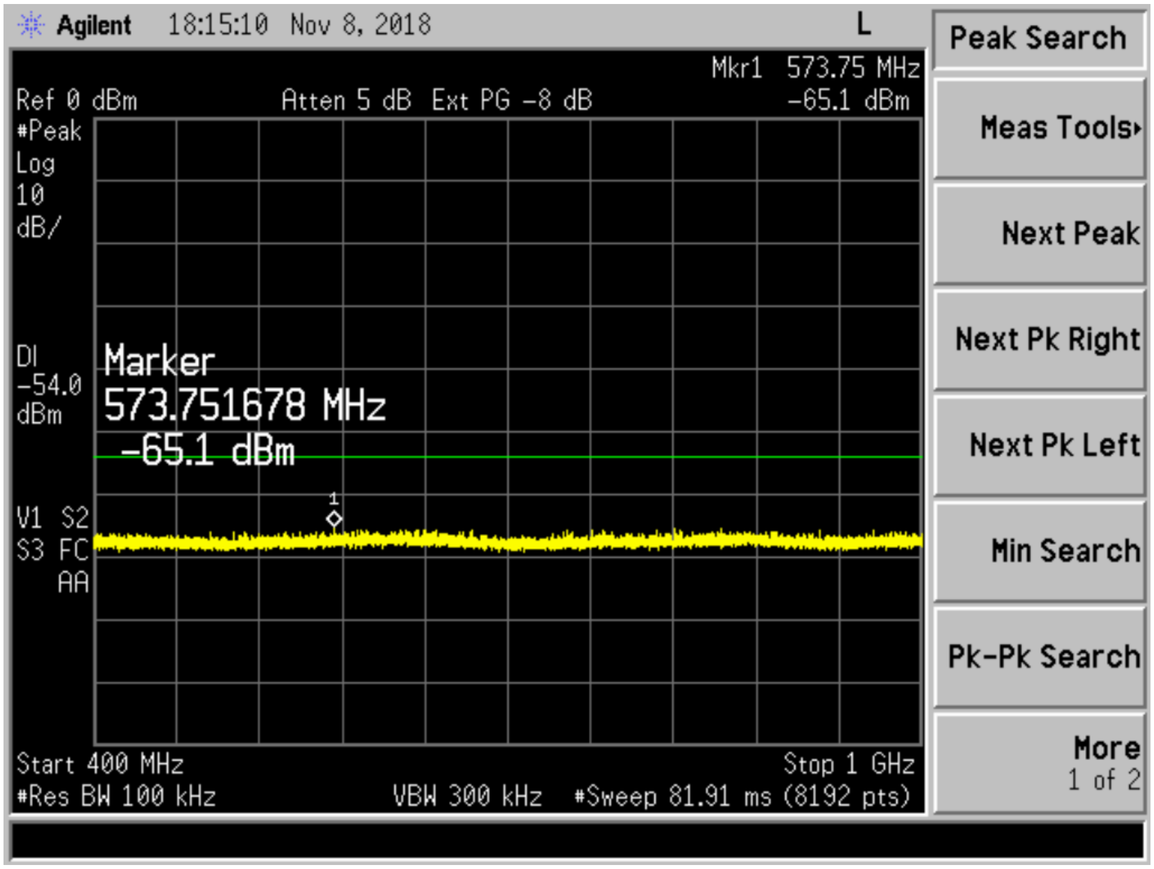



**Figure 18. Conducted Spurious Emissions 2480 MHz Low Channel 400 MHz to 1000 MHz**

| | |
|---|---|
| Limit | -54.00 dBm |
| Measured Emissions (per Figure 27) | -65.10 dBm |
| Margin | 11.10 dB |

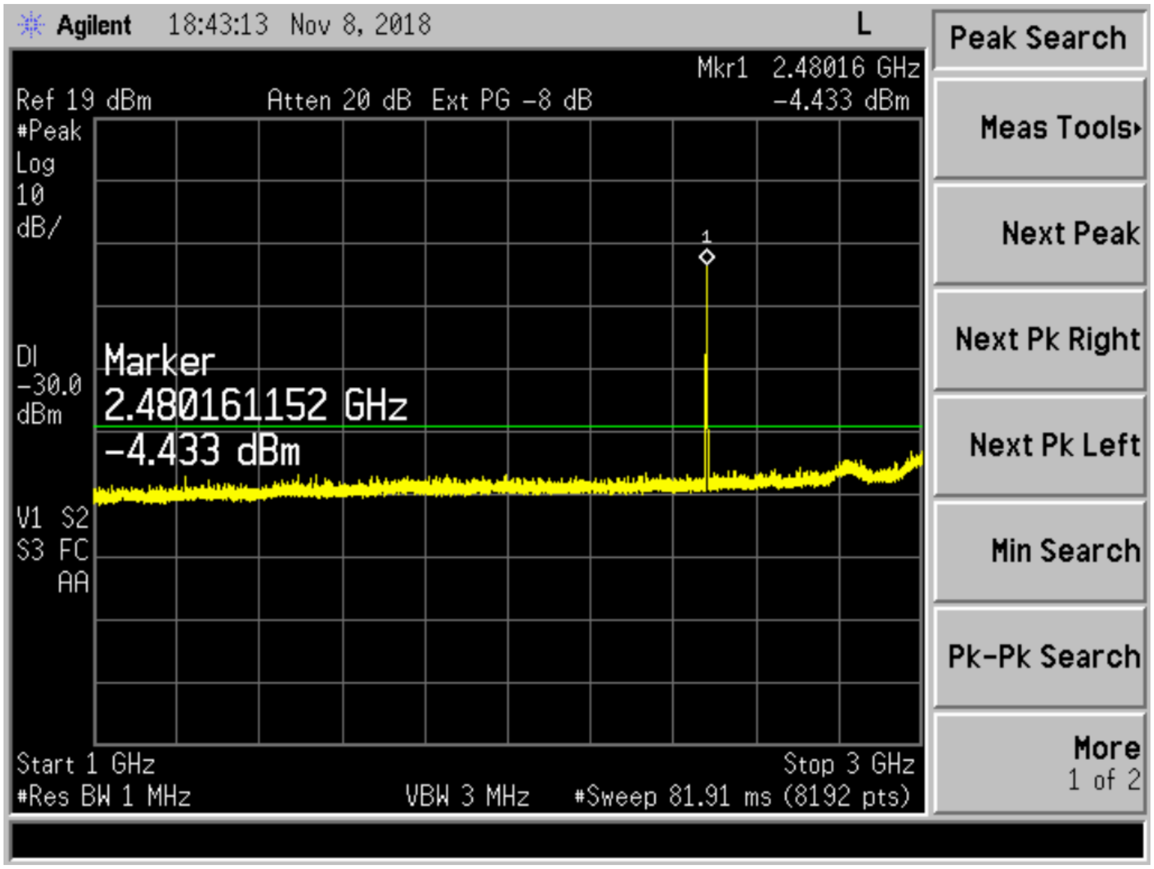



**Figure 19. Conducted Spurious Emissions 2480 MHz High Channel 1 GHz to 3 GHz**

| | |
|---|---|
| Limit | 10.00 dBm |
| Measured Emissions (per Figure 28) | -4.43 dBm |
| Margin | 14.43 dB |

*Note: All other emissions are below the 30 dBm limit as indicated by the plot above.

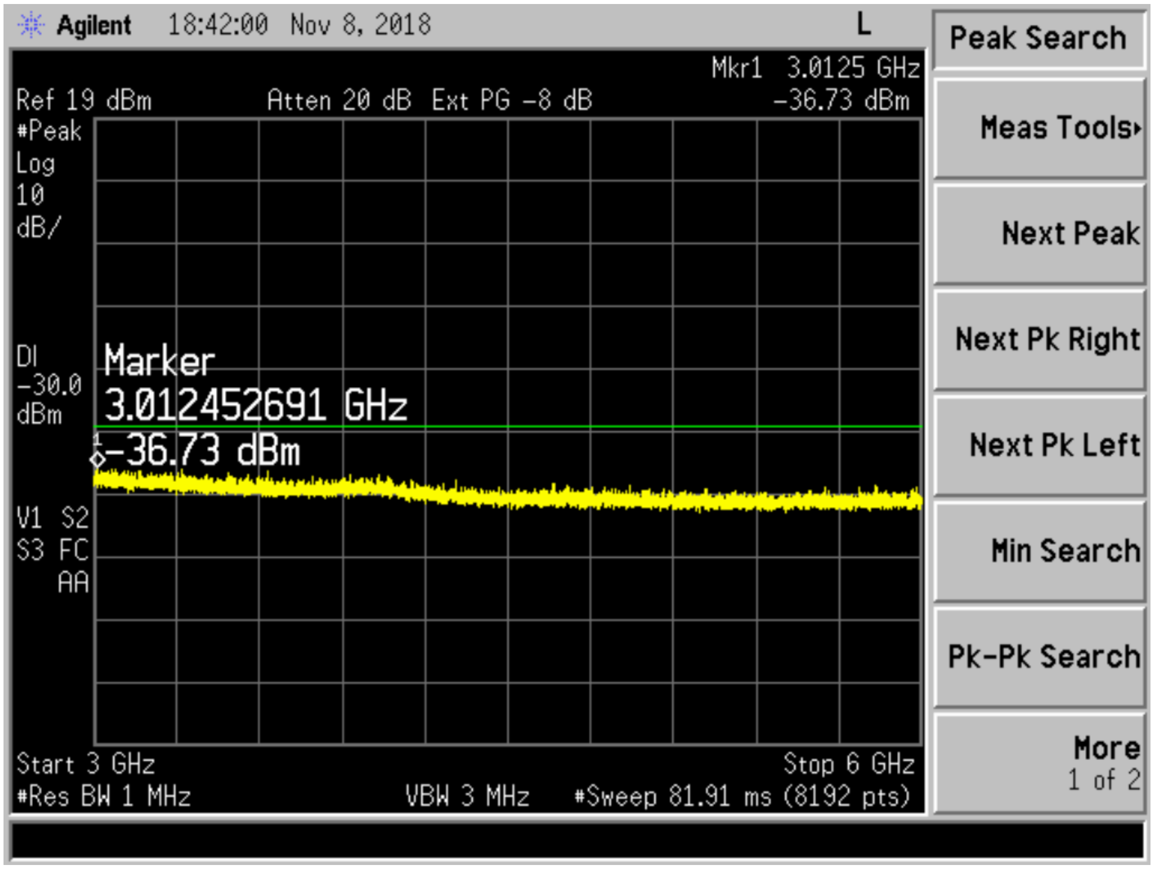



**Figure 20. Conducted Spurious Emissions 2480 MHz High Channel 3 GHz to 6 GHz**

| | |
|---|---|
| Limit | -30.00 dBm |
| Measured Emissions (per Figure 29) | -36.73 dBm |
| Margin | 6.73 dB |

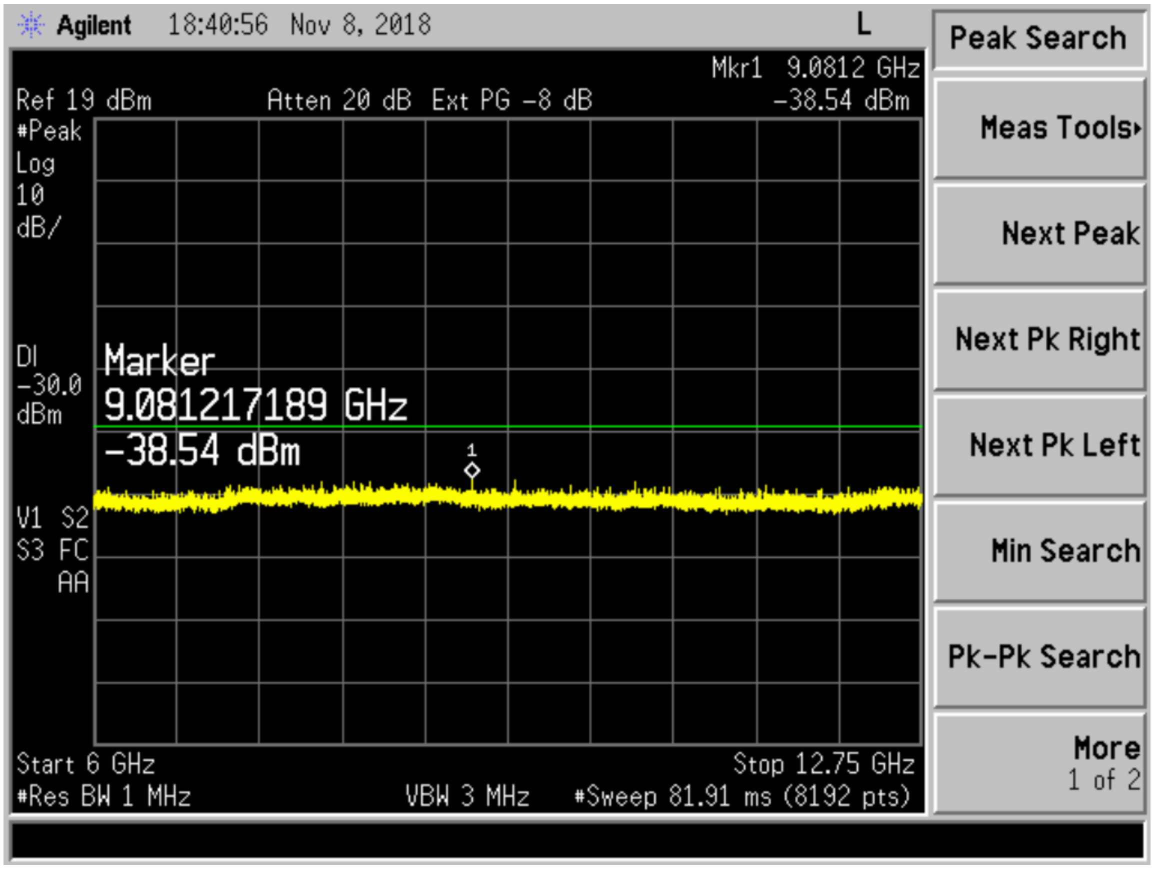



**Figure 21. Conducted Spurious Emissions 2480 MHz High Channel 6 GHz to 12.75 GHz**

| | |
|---|---|
| Limit | -30.00 dBm |
| Measured Emissions (per Figure 30) | -38.54 dBm |
| Margin | 8.54 dB |

### 5.3.10 Receiver Unwanted Emissions in the Spurious (Clause 5.4.10)

Receiver spurious emissions are the emissions at any frequency when the equipment is in receive mode. In accordance ETSI EN 300 328 section 4.3.2.11, the spurious emissions cannot be greater than the limits in the Tables following

**Table 8. Spurious Emissions Limits for Receivers**

| Frequency Range | Maximum Power | Bandwidth |
|---|---|---|
| 30 MHz to 1 GHz | -57 dBm | 100 kHz |
| 1 GHz to 12.75 GHz | -47 dBm | 1 MHz |

The receiver unwanted emissions in the spurious domain were measured at normal test conditions and with the equipment operating at its worst case scenario with respect to spurious emissions.

**Table 9. Receiver/Idle mode Spurious Emissions**

| Freq. (MHz) | Maximum RX Reading (dBuV) | Recreated Reading (dBuV) | Difference Column A – B (dB) | TX Gain (dBi) | TX Gain Relative to Dipole (dB) | RF Power into TX Antenna | RF Power into Substitution TX Antenna Corrected By TX Gain Relative to Dipole and TX Cable (dBm) | Limit (dBm) | Margin (dB) | Antenna factor/ Cable loss |
|---|---|---|---|---|---|---|---|---|---|---|
| **No other emissions seen 6 dB above the noise floor.** | | | | | | | | | | |

Note 1) RF Power (dBm) into substitution antenna from signal generator corrected with cable loss and other attenuators factors.
Note 2) Radiated RF power (dBm) was calculated by summing the antenna factor/cable loss, Input RF Power, and the difference in column D.

Sample calculation: N/A

Date: November 9, 2018

Signature: Afzal Fazal By: Afzal Fazal

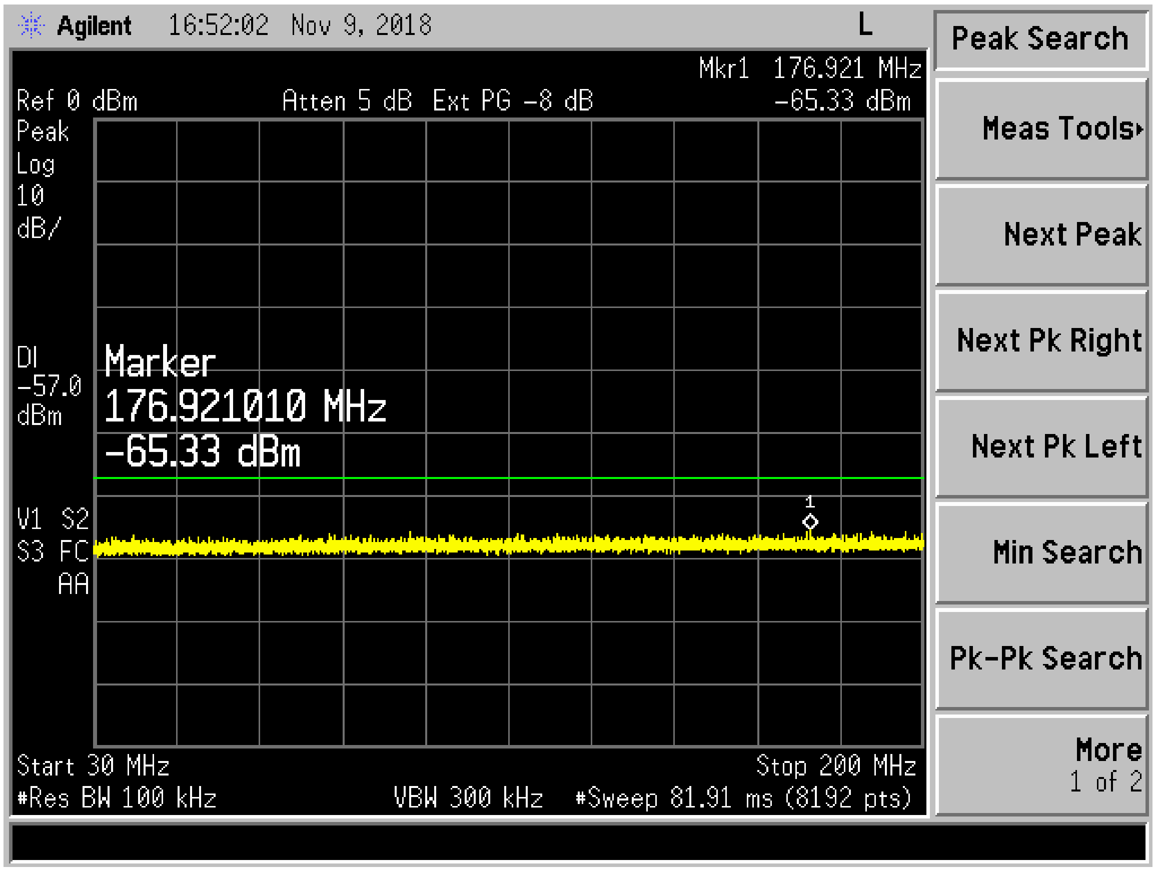



**Figure 22. Receiver Conducted Spurious Emissions 30 MHz to 200 MHz**

| | |
|---|---|
| Limit | -57.00 dBm |
| Measured Emissions ( Figure 41) | -65.33 dBm |
| Margin | 8.33 dB |

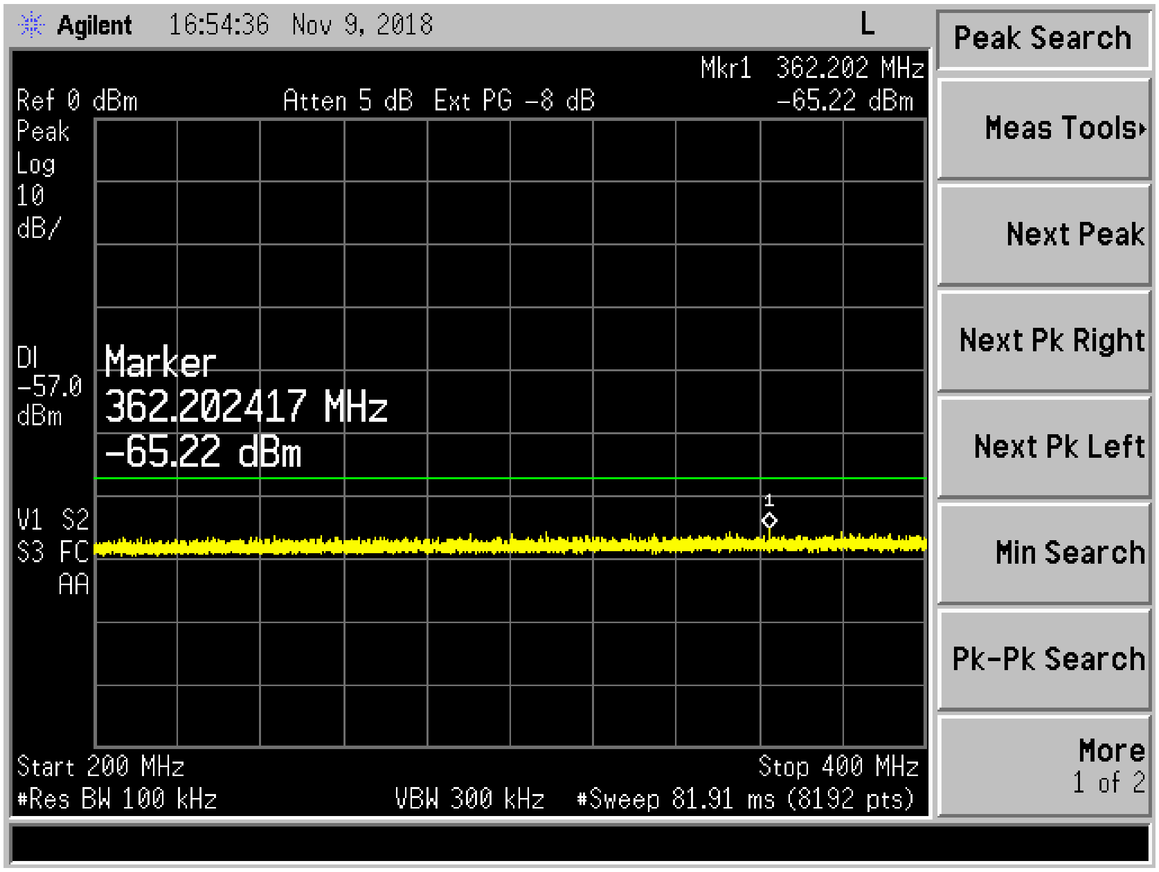



**Figure 23. Receiver Conducted Spurious Emissions 200 MHz to 400 MHz**

| | |
|---|---|
| Limit | -57.00 dBm |
| Measured Emissions ( Figure 41) | -65.22 dBm |
| Margin | 8.22 dB |

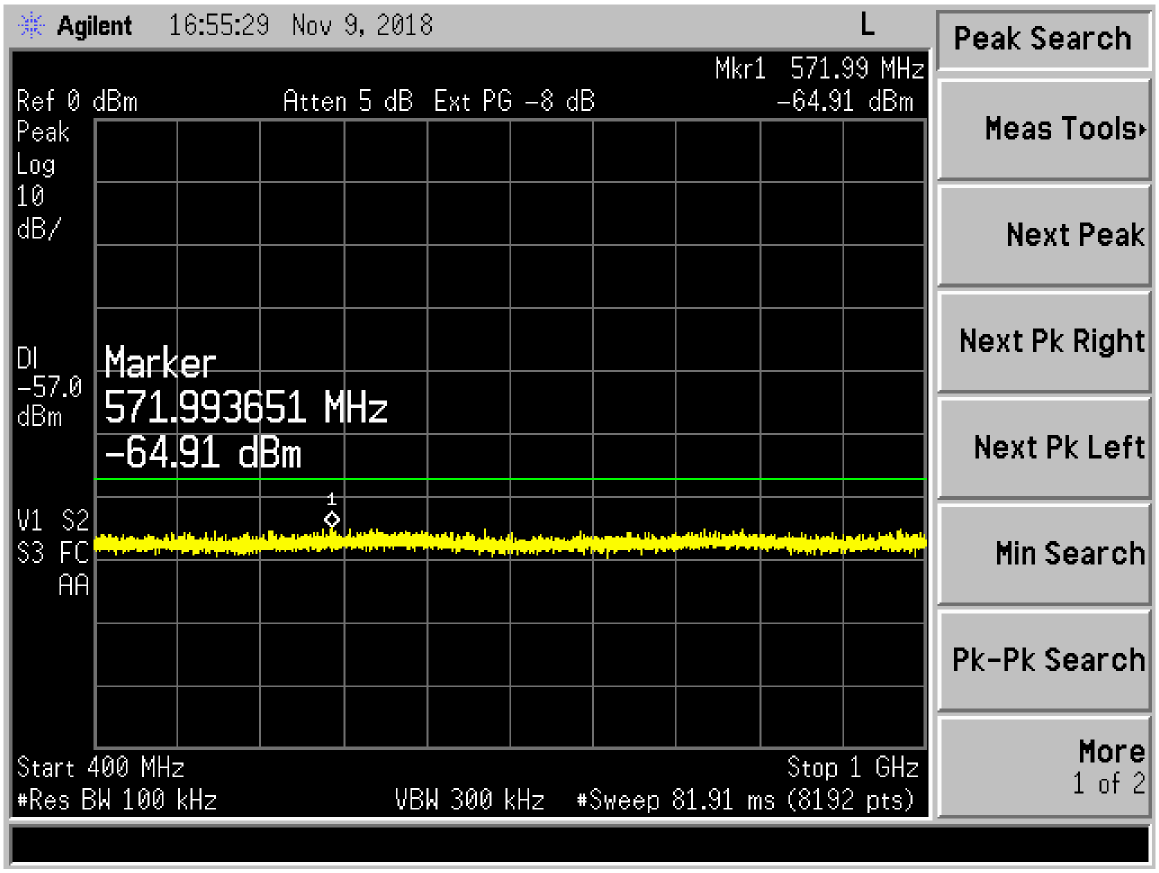



**Figure 24. Receiver Conducted Spurious Emissions 400 MHz to 1000 MHz**

| | |
|---|---|
| Limit | -57.00 dBm |
| Measured Emissions ( Figure 41) | -64.91 dBm |
| Margin | 7.91 dB |

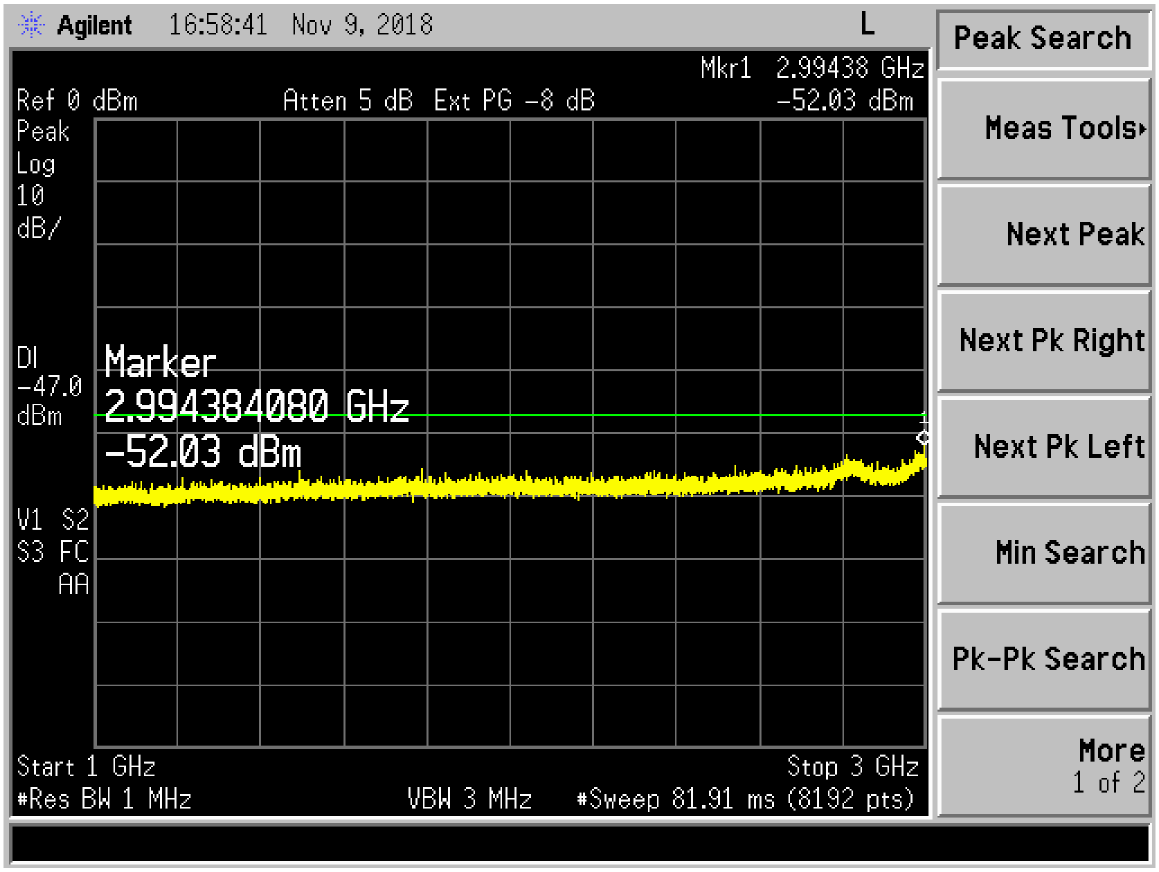



**Figure 25. Receiver Conducted Spurious Emissions 1 GHz to 3 GHz**

| | |
|---|---|
| Limit | -47.00 dBm |
| Measured Emissions ( Figure 41) | -52.03 dBm |
| Margin | 5.03 dB |

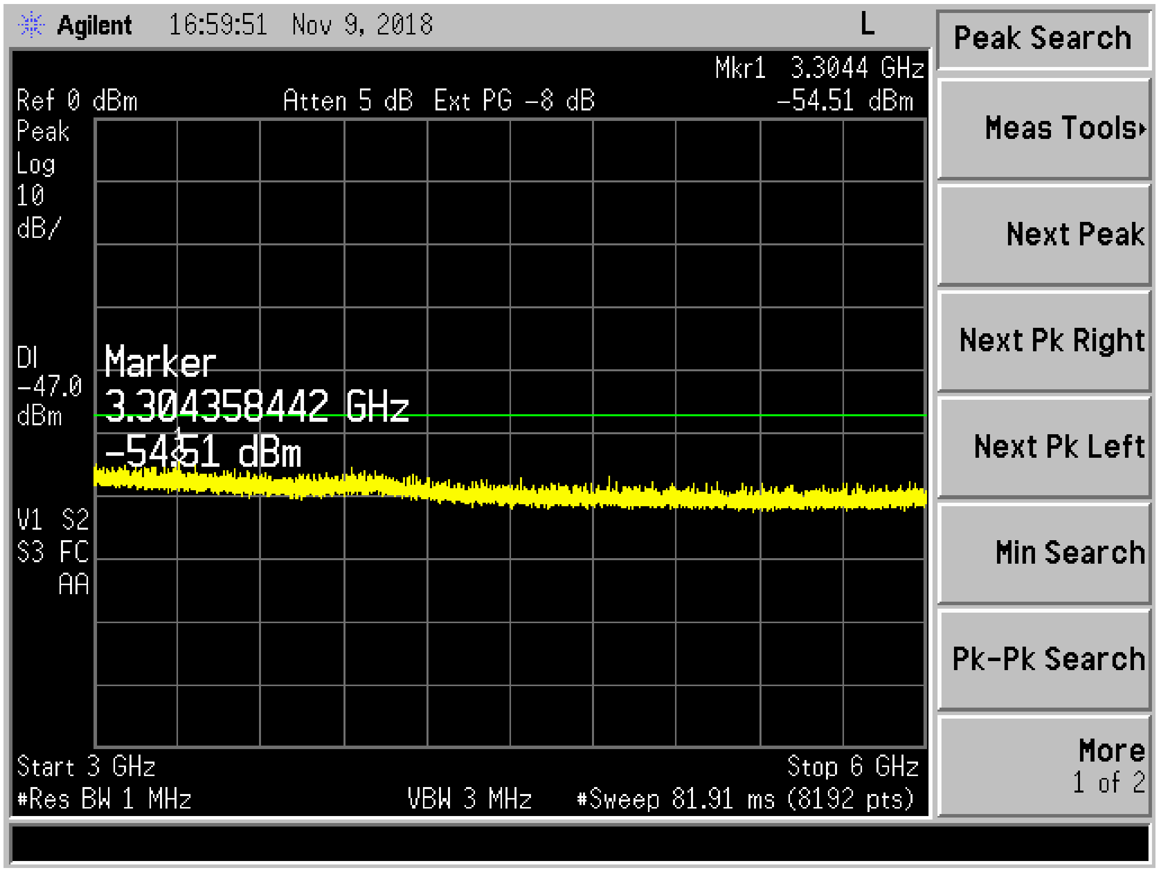



**Figure 26. Receiver Conducted Spurious Emissions 3 GHz to 6 GHz**

| | |
|---|---|
| Limit | -47.00 dBm |
| Measured Emissions ( Figure 41) | -54.51 dBm |
| Margin | 7.52 dB |

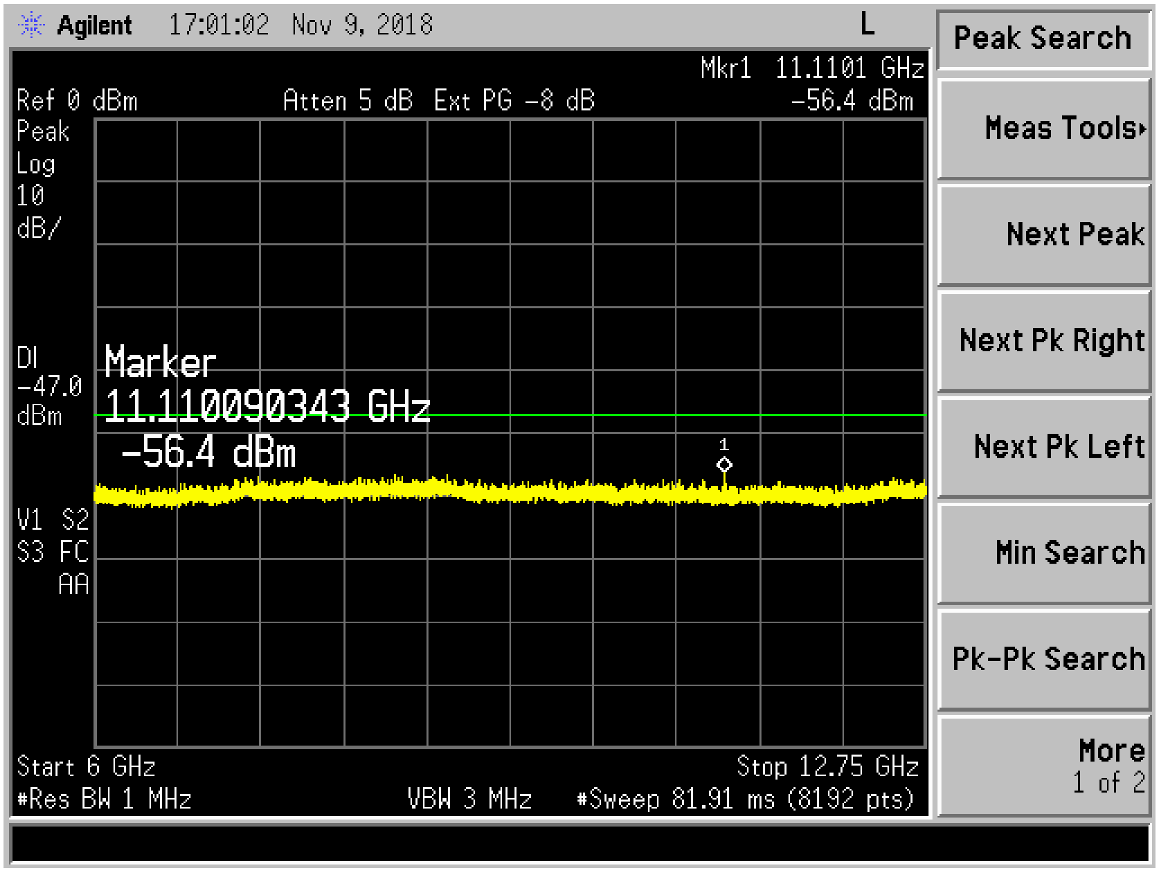



**Figure 27. Receiver Conducted Spurious Emissions 6 GHz to 12.75 GHz**

| | |
|---|---|
| Limit | -47.00 dBm |
| Measured Emissions ( Figure 41) | -56.40 dBm |
| Margin | 9.40 dB |

### 5.3.11 Receiver Blocking (Clause 5.4.11)

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. In accordance with ETSI EN 300 328 section 4.3.2.11.

The EUT is categorized as Receiver Category 1 equipment.

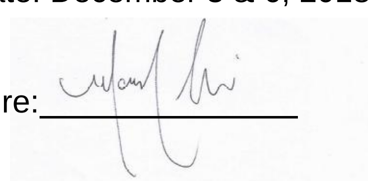
**Table 10. Receiver Blocking Parameters for Receiver Category 1 Equipment**

| Wanted signal mean power from companion device (dBm) | Blocking signal frequency (MHz) | Blocking signal power (dBm) (see note 2) | Type of blocking signal |
|---|---|---|---|
| $P_{min}$ + 6 dB | 2 380<br>2 503,5 | -53 | CW |
| $P_{min}$ + 6 dB | 2 300<br>2 330<br>2 360 | -47 | CW |
| $P_{min}$ + 6 dB | 2 523,5<br>2 553,5<br>2 583,5<br>2 613,5<br>2 643,5<br>2 673,5 | -47 | CW |

NOTE 1: $P_{min}$ is the minimum level of the wanted signal (in dBm) required to meet the minimum performance criteria as defined in clause 4.3.2.11.3 in the absence of any blocking signal.

NOTE 2: The levels specified are levels in front of the UUT antenna. In case of conducted measurements, the levels have to be corrected by the actual antenna assembly gain.

Test Date: December 3 & 6, 2018

Signature: 

Tested By: Mark Afroozi

The measurements were performed at normal test conditions. The EUT uses wide band modulation other than frequency hopping Spread Spectrum (FHSS) modulation. The EUT was tested first while receiving on the lowest channel and then again while receiving on the highest channel. The system has only one receiver chain. The procedures in clause 5.4.11.2.1 were followed for this test. The test results are provided below.

Antenna Gain: +3.2 dBi
$P_{min}$ = Threshold level of RX and TX communication link.
FHSS: YES, the EUT was programmed to receive first on the lowest channel then on the highest channel.

**Table 11. Blocking Signal Test Results**

| Wanted Signal Mean Power | Blocking Signal Frequency (MHz) | Blocking Signal Power Limit (dBm) | Actual Blocking Signal Power (dBm) |
|---|---|---|---|
| Pmin + 6 dBm (-15.55 + 6 dBm) | 2380 | -53 + max antenna gain | > -30 dBm |
| Pmin + 6 dBm | 2503.5 | | > -30 dBm |
| Pmin + 6 dBm | 2300 | -47 + max antenna gain | > -30 dB |
| Pmin + 6 dBm | 2330 | | > -30 dBm |
| Pmin + 6 dBm | 2360 | | > -30 dBm |
| Pmin + 6 dBm | 2523.5 | -47 + max antenna gain | > -30 dBm |
| Pmin + 6 dBm | 2553.5 | | > -30 dBm |
| Pmin + 6 dBm (-16.49 + 6 dBm) | 2583.5 | | > -30 dBm |
| Pmin + 6 dBm | 2613.5 | | > -30 dBm |
| Pmin + 6 dBm | 2643.5 | | > -30 dBm |
| Pmin + 6 dBm | 2673.5 | | > -30 dBm |

**Test Results:** The actual blocking signal power is greater than the required minimum level per the standard. The EUT meets these requirements.

## 5.4 RF Exposure

### EN 50385:2002 MPE Compliance:

The maximum exposure level to the public from the RF power of the EUT shall not exceed a power density, S, of 1 $mW/cm^2$ at a distance, d, of 20 cm from the EUT.

Therefore for:

Measured maximum output power: 8.0 dBm (EIRP)
Highest Gain Antenna (Type of Antenna): 3.2 dBm

Peak Power (Watts) = 0.006 (max output power)
Gain of Transmit Antenna = 3.2 dBi = 2.09 numeric
D = distance = 2- cm = 0.2 m

$S = (PG/4\pi d^2) = EIRP/4A = (0.006*2.09)/4\pi*0.2*0.2$
$= .01254/.5027 = 0.0249\ W/m^2$
$= (W/m^2)\ (1\ m^2/W)(0.1mW/cm^2)$
$= 0.00249$

Which is << less than 1.0 $mW/cm^2$

The radio meets the requirements.

Test Date: December 19, 2018

Signature:__________ Tested By: George Yang

## 6 Test Instruments

### Table 12. Test Equipment

| INSTRUMENT | MODEL NUMBER | MANUFACTURER | SERIAL NUMBER | CALIBRATION DUE DATE |
|---|---|---|---|---|
| SPECTRUM ANALYZER | E4407B | AGILENT | US41442935 | 8/17/2020 2 yr. |
| SPECTRUM ANALYZER | N9342CN | AGILENT | SG05310114 | 7/21/2019 2 yr. |
| SIGNAL GENERATOR | 70004A | HEWLETT PACKARD | 70340A | Verified before use |
| SIGNAL GENERATOR | 8648B | HEWLETT PACKARD | 3642U01679 | Verified before use |
| SIGNAL GENERATOR | MG3671B | ANRITSU | M520731M5357 3/M17473 | Verified before use |
| BICONICAL ANTENNA | 3110B | EMCO | 9307-1431 | 10/23/2019 2 yr. |
| BICONICAL ANTENNA | 3110B | EMCO | 9306-1708 | 5/02/2019 2 yr. |
| LOG PERIODIC ANTENNA | 3146 | EMCO | 9110-3236 | 5/01/2019 2 yr. |
| LOG PERIODIC ANTENNA | 3146 | EMCO | 9305-3600 | 12/21/2018 Extended |
| HORN ANTENNA | SAS-571 | A.H. Systems | 605 | 10/18/2019 2 yr. |
| HORN ANTENNA | 3115 | EMCO | 9107-3723 | 12/22/2018 Extended |
| PRE-AMPLIFIER | 8449B | HEWLETT PACKARD | 3008A00480 | 6/04/2019 |
| PRE-AMPLIFIER | 8447D | HEWLETT PACKARD | 1937A02980 | 3/07/2019 |
| RF SPLITTER/COMBINER | ZAPD-21 | MINI-CIRCUITS | N/A | Verified Before Use |
| RF SPLITTER/COMBINER | ZFRSC-42 | MINI-CIRCUITS | N/A | Verified Before Use |
| HIGH PASS FILTER | VHP-16 | MINI-CIRCUITS | N/A | 3/7/2019 |
| COPPER SHIELD BOX | N/A | US TECH | N/A | Not Required |

Note: The calibration interval of the above test instruments are 12 months unless stated otherwise and all calibrations are traceable to NIST/USA.

# 7 Photographs

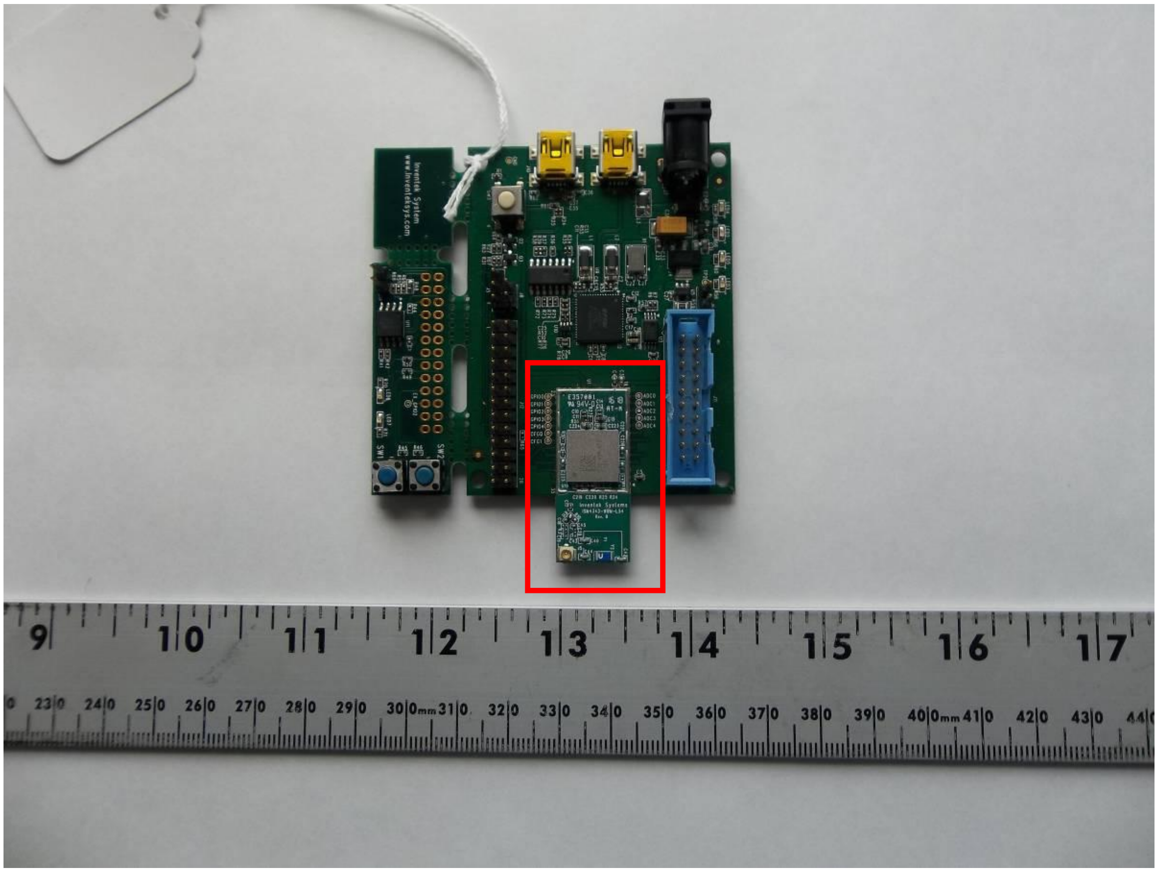


**Figure 28. EUT (circled) on Evaluation Board**


**Figure 29. Radiated Spurious Emissions Below 200 MHz**


**Figure 30. Radiated Spurious Emissions Below 1000 MHz**

**Figure 31. Radiated Spurious Emissions Above 1000 MHz**

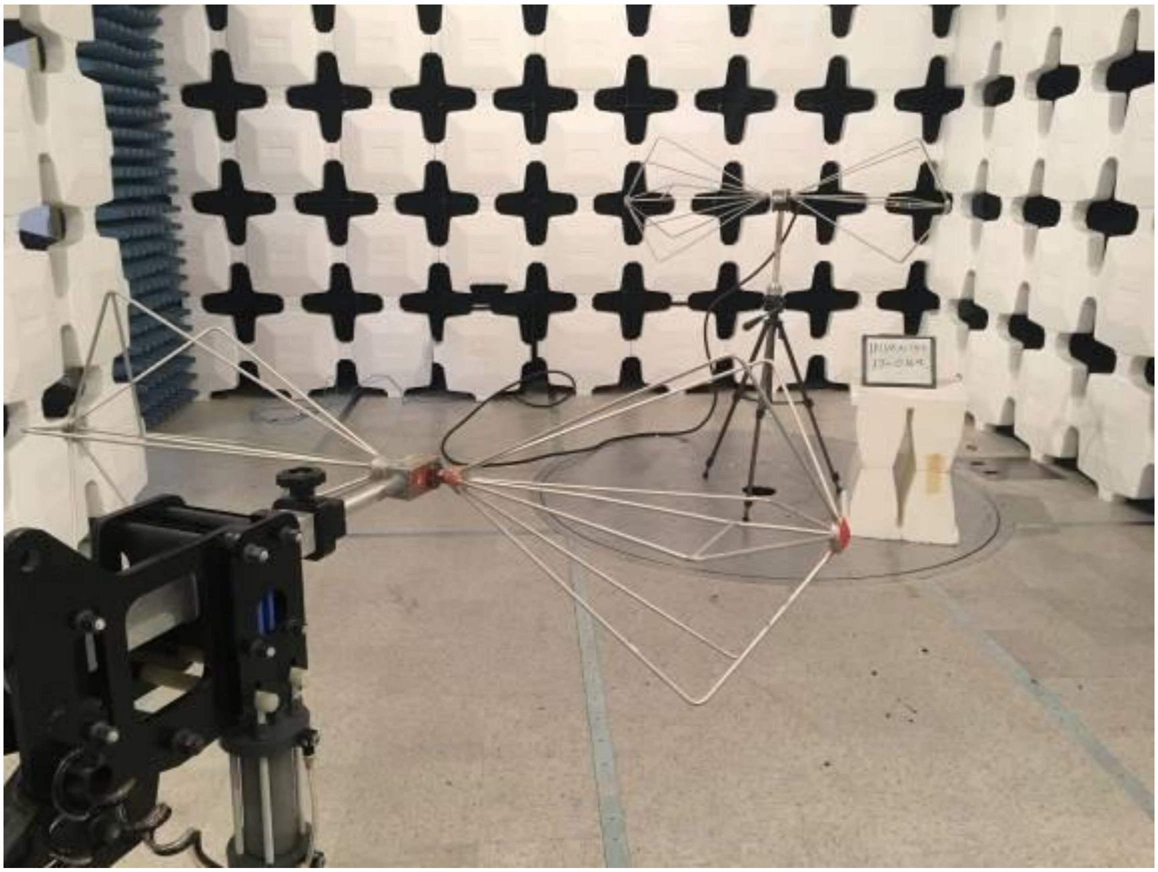


**Figure 32. 30-200 MHz Substitution Test Setup**

**Figure 33. 200-1000 MHz Substitution Testing**

**Figure 34. Above 1 GHz Substitution Testing**


**Figure 35. Extreme Temperature Test Setup**

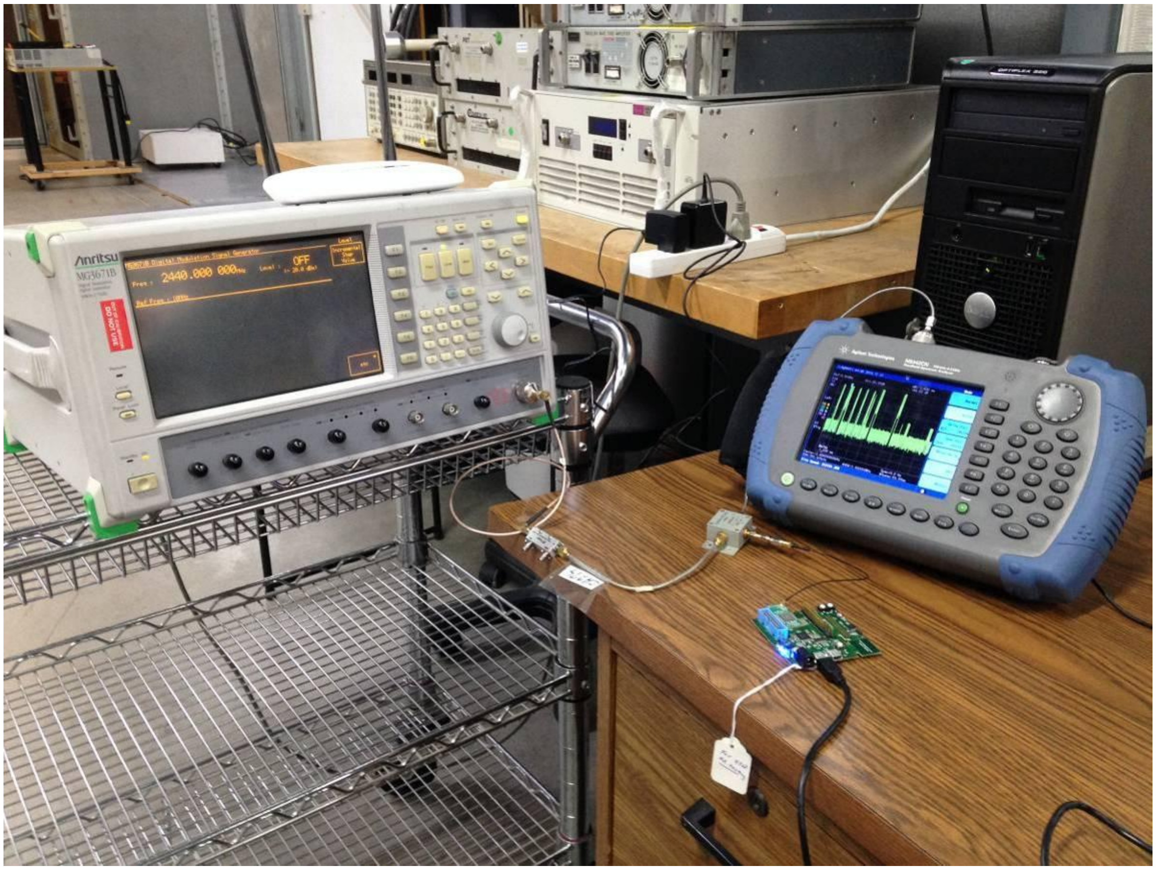


**Figure 36. Adaptivity Test Setup**

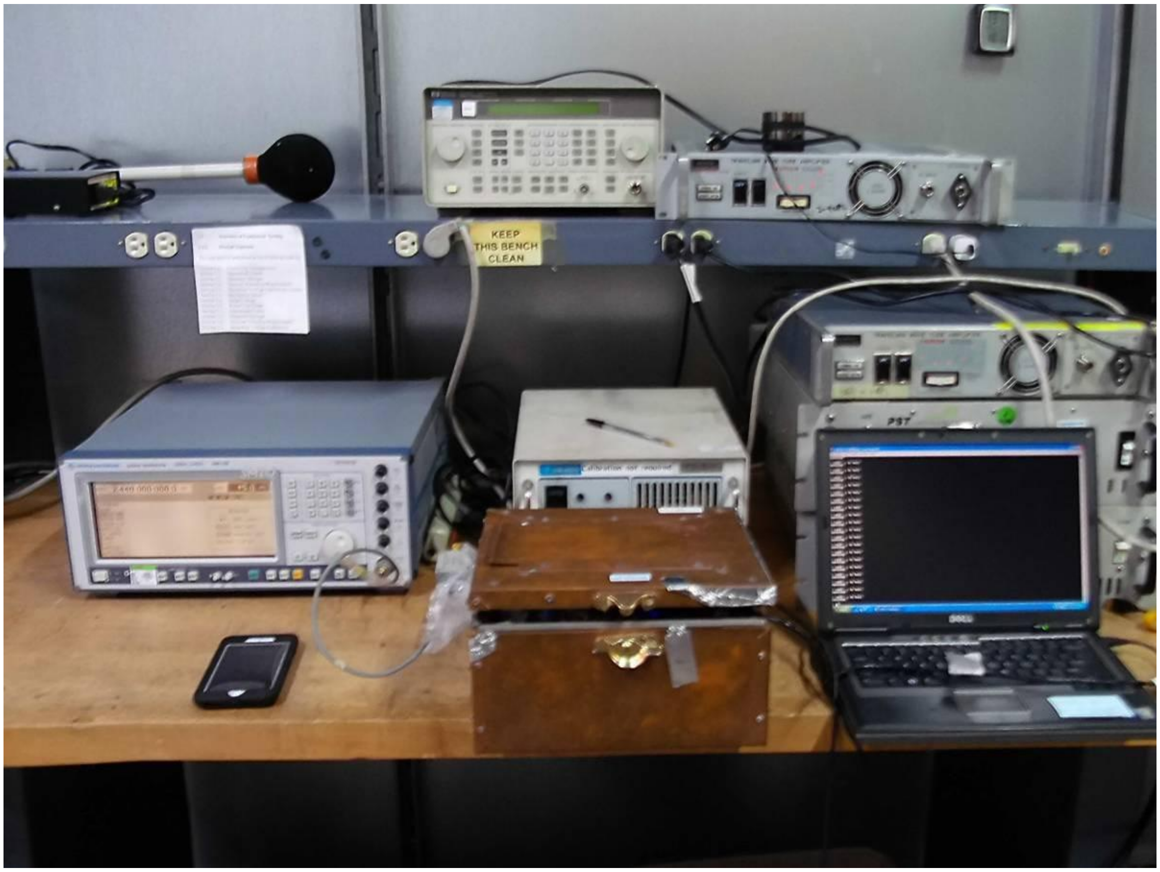



**Figure 37. Receiver Blocking Test Setup**

Note: EUT in receive mode placed inside the Copper Shielded box during testing.