Radio Test Report

According to

FCC part 15C,

RSS-247, RSS-Gen

DUT Name:	Haltian EH Locator
Model No.:	SLF
Customer:	Haltian Oy
Address:	Yrttipellontie 1 D, 90230, Oulu FINLAND
Summary	IN COMPLIANCE
Date of Reception:	16.02.2023
Date(s) of Test(s):	07.03.2023 – 29.04.2023

Tested by Test Engineer

Pekka Pulkkinen

Approved by Technical Manager

Jukka Rauma

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Document Version History	Date of issue	Comments	Approved by
v0.1	15.6.2023	Initial version	
v1.0	22.6.2023	Approved version. Test setup pictures updated.	Jukka Rauma
v2.0	8.8.2023	Test sample HW versions corrected to SLF_04S	Jukka Rauma
v3.0	25.9.2023	Test software information added. EIRP results added to table in page 17.	Jukka Rauma
v4.0	5.10.2023	EUT test configuration software added to chapter 3	Jukka Rauma

1. General Information

Test Engineers: Pekka Pulkkinen, Arto Kuosmanen

Location:

Test Firm Name	Eurofins Electric & Electronics Finland Oy (EEEF)
Test Site	Yrttipellontie, Peltola
Address of Test Site	Yrttipellontie 6, 90230 Oulu, Finland
FCC Designation number	FI0008
FCC site registration number	771880
ISED number	29576
CAB Identifier	T290

Customer: Haltian Oy
Juha Pikkarainen
Yrttipellontie 1 D, 90230 Oulu, Finland
tel: +358505501675
e-mail: juha.pikkarainen@haltian.com

Climate Conditions: Temperature: 15 - 35 °C
Air pressure: 860 - 1060 hPa
Humidity: 30-60 rH%
These limits were not exceeded during testing.

2. Test Samples

General description: Haltian EH Locator is Anchor device for Wirepass network. Device has solar panel, USB-C supply and battery. Device can be operated under indoor light.

Test sample (Conducted RF):

Sample number	Serial number	Manufacturer	Model	HW version	SW version
3670ER001	D7C46487A897	Haltian Oy	SLF	SLF_04S	Thigsee_positioning_anchor_wp51_2023.02.16.3

Test sample (Radiated and Conducted Emissions):

Sample number	Serial number	Manufacturer	Model	HW version	SW version
3670ER002	SF16820269	Haltian Oy	SLF	SLF_04S	Thigsee_positioning_anchor_wp51_2023.02.16.3

Auxiliary equipment:

Sample number	Serial number	Manufacturer	DUT Type	Model	Comment
3670ER008	-	goobay	USB-A to USB-C cable	59132	Cable for the power source
3670ER006	-	Sunny Computer Technology Europe, s.r.o.	USB charger	SYS1561-1105 USB inlet	Power source

Additional model	None		
Brand Names(s)	Haltian		
PMN	Haltian EH Locator		
HVIN	SLF		
FVIN	Thingsee_positioning_anchor_wp51_2023.02.16.3		
HMN	N/A		
FCC ID	2AEU3HAEHLO		
IC ID	20236-HAEHLO		
Equipment type	End product		
Radio type	Transceiver		
- operating frequency range:	2400.0 MHz – 2483.5 MHz		
- Nominal Channel Bandwidth:	1 MHz		
Radio technology / type of equipment	Bluetooth LE 5.2		
Modulation:	GFSK		
Bluetooth Specification	LE 1Mbps PHY		Yes
	LE 2Mbps PHY		No
	LE Coced PHY S=2 (500 kbit)		No
	LE Coced PHY S=8 (125 kbit)		No
	Stable Modulation Index - Transmitter		No
	Stable Modulation Index - Reer		No
Antenna	Type	PET foil patch antenna	
	Model	-	
	Manufacturer	Haltian	
	Gain	2.7 dBi	
Supply voltage	120V/60 Hz		
Type of Power source	AC/DC switching adapter		
Operating Temperature	TNom = 20°C TMin = 0°C TMax = 60°C		

3. Configuration and Operation Modes

Conducted RF test:

Test modes / description
Continuous modulated carrier at 2402 MHz, 2442 MHz and 2480 MHz, power level setting + 4dBm, 1 Mbps

Conducted and radiated emission test:

Test modes / description
EUT AC powered, continuous modulated carrier at 2402 MHz, 2440 MHz and 2480 MHz, + 4dBm, 1 Mbps
EUT AC powered, continuous reception at 2440 MHz

Test/configuration software

Manufacturer	Name	Version
Haltian Oy	HEAT Takki	2022.01.27.2

4. Test equipment

Conducted RF tests

R&S TS8997 Test System equipment list:

Equipment	Certification-No.	Calibration Date	Next calibration
SMW200A	1035089-D-K-15195-01-00-2022-03	31.03.2022	30.06.2023
SMB100A	1041326-D-K-15195-01-00-2022-03	31.03.2022	30.06.2023
OSP-B157WX+OSP220	300642762-D-K-15195-01-00-2022-03	31.03.2022	30.06.2023
OSP-B157W8plus+OSP150	300639878-D-K-15195-01-00-2022-03	31.03.2022	30.06.2023
ESW	1039208-D-K-15195-01-00-2022-03	31.03.2022	30.06.2023
CMW500	300693633-D-K-15195-01-00-2023-04	25.04.2023	25.04.2024
CMW-Z800A	20-1040958-C	31.03.2022	30.06.2023

Radiated emission

New ID	Manufacturer	Equipment type	Description	Serial	Calibration information	Next calibration
G4C217	Rohde & Schwarz	HF907	Double-Ridged Waveguide Horn Antenna 800MHz-18GHz	100164	4.11.2020	4.11.2023
G4C264	Rohde & Schwarz	CMW500	Wideband radio communication tester	126426	18.11.2022	18.11.2023
G4C265	Rohde & Schwarz	ESW26	EMI test receiver	101324	25.8.2022	25.8.2023
G4C273	Frankonia	ALX-4000E	Broadband Antenna, 25MHz-4GHz with 6dB (50-A-MFN-06) att.	00816+1531	11.11.2020	11.11.2023
G4C503	Rohde & Schwarz	ESIB26	EMI Test Receiver 20Hz...26.5GHz	100263	9.7.2021	9.7.2023
G4C560	Bruel & Kjaer	Nexus 2690	Conditioning Amplifier	2340586	24.5.2018	N/A
G4C292	Rohde & Schwarz	TS-LNA 1840	RF Preamplifier 18 to 40 GHz	100841	9.6.2022	9.6.2024
G4C469	Rohde & Schwarz	TS_PRE2	RF Preamplifier	101541	9.6.2022	9.6.2024
G4C294	Rohde & Schwarz	TC-HORN40	Horn Antenna -> 40GHz	101057	4.11.2022	4.11.2025

Conducted emission

New ID	Manufacturer	Equipment type	Description	Serial	Calibration information	Next calibration
G4C265	Rohde & Schwarz	ESW26	EMI test receiver	101324	25.8.2022	25.8.2023
G4C515	Rohde & Schwarz	ENV216	Two-line V-Network LISN	101472	11.8.2022	11.8.2023

Test software

Description	Manufacturer	Name	Version
EMC Software	Rohde & Schwarz	EMC32	10.60.20
RF Software	Rohde & Schwarz	WMS32	11.60.00

5. Uncertainties

Description	Expanded Uncertainty (k=2)
RF Output Power	0,99
Peak Power	0,80
Power Spectral Density	0,99
Accumulated Transmit Time	0,01%
Minimum Frequency Occupation Time	0,01%
Hopping Frequency Separation	0,60%
Occupied Channel Bandwidth	2,08 %
Out-of-band emissions	0,89
Transmitter unwanted emissions in the spurious domain	1,76
AC conducted emission	2,24
Radiated emission ≤ 1 GHz	4,62
Radiated emission > 1 GHz	5,72

6. Sample emission level calculation

The following is a description of term and a sample calculation, as appears in the radiated emissions data table. The numbers used in the calculation are for example only. There is no direct correlation to the specific data taken for the product described in this document:

Reading:
This is the reading obtained on the spectrum analyzer in dBuV.

A.F.:
This is the antenna factor for the receiving antenna. It is a conversion factor, which converts electric fields strength to voltages, which can be measured directly on the spectrum analyzer. It is treated as a loss in dB. RF path losses, including RF cables and preamplifiers, have been included with the A.F to simplify the calculations. The antenna factor is used in calculations as follows:

Reading on Analyzer (dBuV) + A.F. (dB/m) = Net field strength (dBuV/m)

Net:
This is the net field strength measurement (as shown above).

Limit:
This is the FCC Class B radiated emission limit (in units of dBuV/m). The FCC limits are given in units of uV/m. The following formula is used to convert the units of uV/m to dbuV/m:

Limit (dBuV/m) = 20*log(uV/m)

Margin :
This is the margin of compliance below the FCC limit. The units are given in dB. A negative margin indicates the emission was below the limit. A positive margin indicates that the emission exceeds the limit.

Example only:

Reading + AF	= Net Reading :	Net reading – FCC limit	= Margin
+ 21.5 dBuV + 26 dB/m	= 47.5 dBuV/m :	47.5 dBuV/m – 57.0 dBuV/m	= -9.5 dB

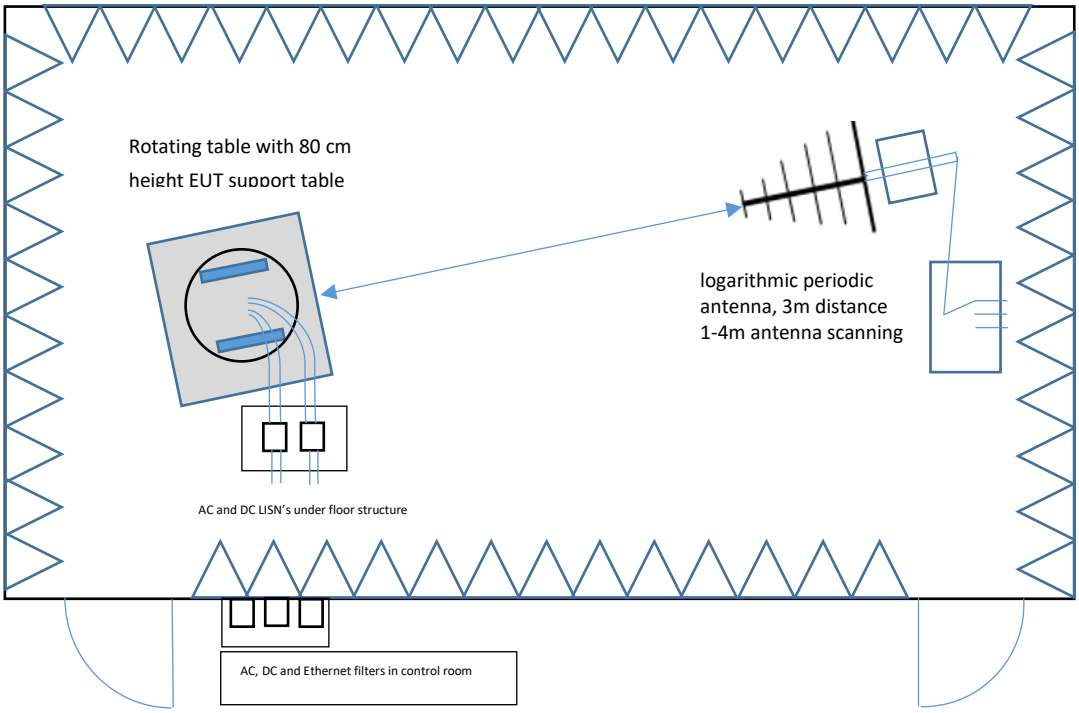
7. Test conditions

All radiated tests were performed in a semi-anechoic chamber, where the measurement antenna (Bilog antenna for the range between 30 MHz to 1000 MHz, 1 GHz-18 GHz Double-ridged horn antenna and 18 GHz-40 GHz horn antenna) is located ted at a distance of 3 m.

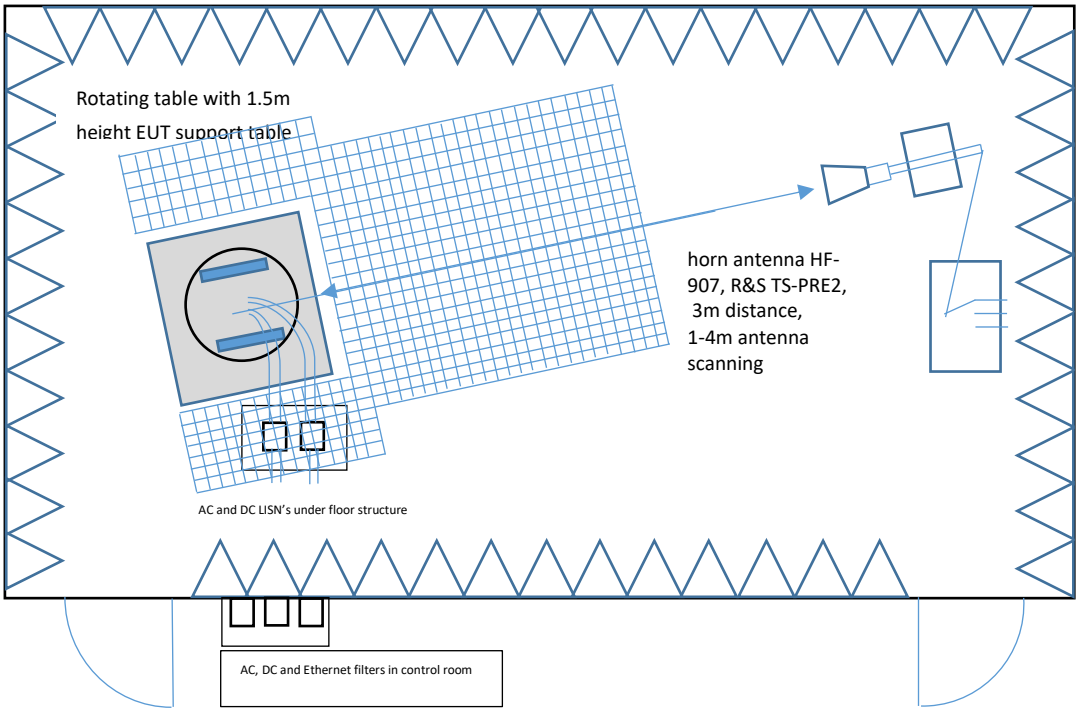
The equipment under test was set up on a non-conductive platform above the ground plane and the situation and orientation was varied to find the maximum radiated emission. It was also rotated 360º and the antenna height (all antennas) was varied from 1 to 4 meters to find the maximum radiated emission.

Measurements were made in both horizontal and vertical planes of polarization.
A resolution bandwidth / video bandwidth of 100 kHz / 300 kHz was used for frequencies below 1 GHz and 1 MHz / 3 MHz for frequencies above 1 GHz.

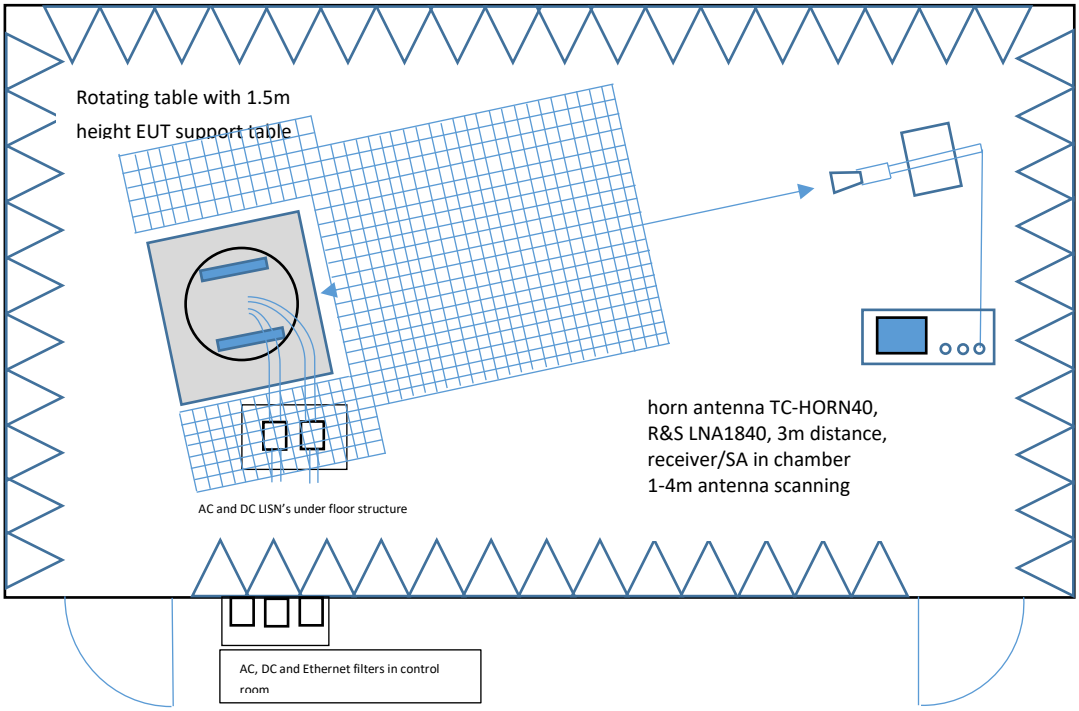
Radiated measurements setup from 30 MHz to 1 GHz:



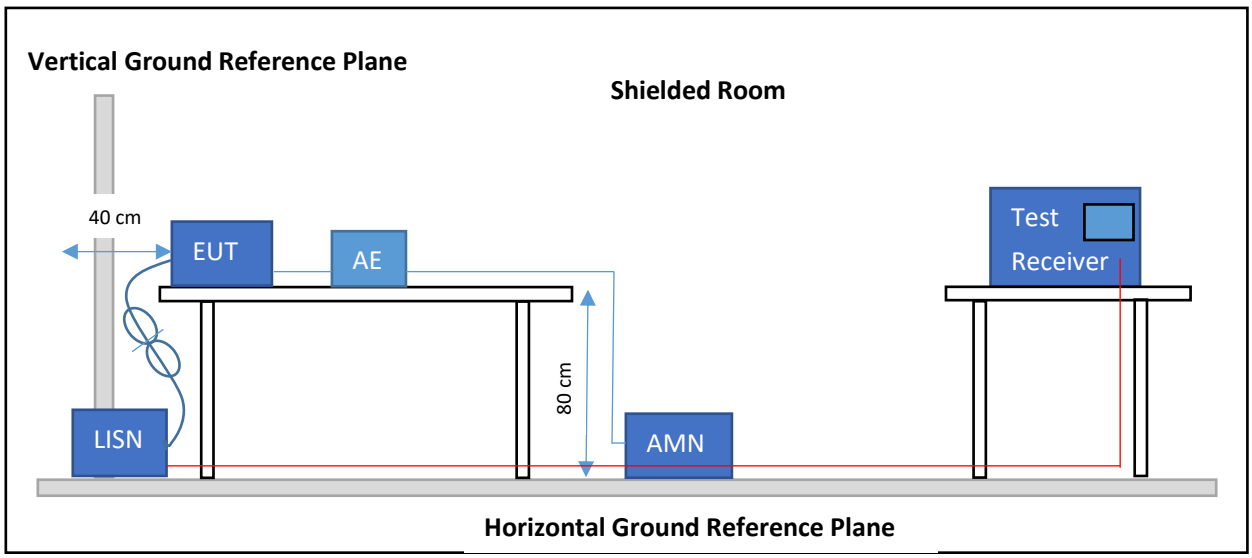
Radiated measurements setup from 1 GHz to 18 GHz:



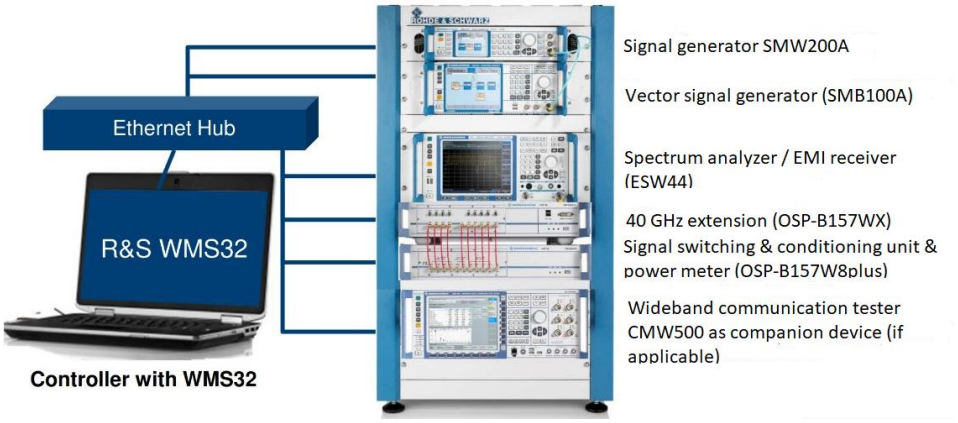
Radiated measurements setup from 18 GHz to 26 / 40 GHz:



Conducted emission setup



Conducted RF measument system:



8. Summary

FCC/ISED Requirement (15.247 / RSS-247)		Reference method	Result	Remark
Occupied Bandwidth	ISED RSS-Gen,Issue 5 A2 (section 6.7)	ANSI C63.10-2013	N/R	Informational only
6 dB Bandwidth	FCC § 15.247(a)(2) / RSS-247, Issue 2 (section	ANSI C63.10-2013	PASS	
Maximum peak conducted power	FCC § 15.247(b) / RSS-247, Issue 2 (section 5.4 (d))	ANSI C63.10-2013	PASS	
Power spectral density	FCC § 15.247(e) / RSS-247, Issue 2 (section 5.2	ANSI C63.10-2013	PASS	
AC power line conducted emissions	FCC § 15.207 / RSS-247, Issue 2 (section 3.1)	ANSI C63.10-2013	PASS	
Band edge compliance	FCC § 15.247(d) / RSS-247, Issue 2 (section 5.5)	ANSI C63.10-2013	PASS	
Conducted spurious emissions	FCC § 15.247(d) / RSS-247, Issue 2 (section 5.5)	ANSI C63.10-2013	PASS	
Transmitter radiated spurious emissions	FCC § 15.247(d), FCC § 15.209 / RSS-Gen,Issue 5 A2 (section 6.13)	ANSI C63.10-2013	PASS	
Receiver radiated spurious emissions	ISED RSS-247, Issue 2 (section 3.1)	ANSI C63.4-2014	PASS	
Possible test case verdicts: PASS = Tested device meets the requirements FAIL = Tested device does not meet the requirements N/A = Test requirement not applicable for tested device N/T = Test requirement applicable for tested device, but not tested				
Applicable FCC KDB(s): KDB 558074 DO1: DTS measurement guidance v 0502 (Apr 2, 2019)				

9. Occupied Bandwidth

Reference: ISED RSS-Gen, Issue 5 A2 (section 6.7)

Test method: ANSI C63.10 (6.9.3)

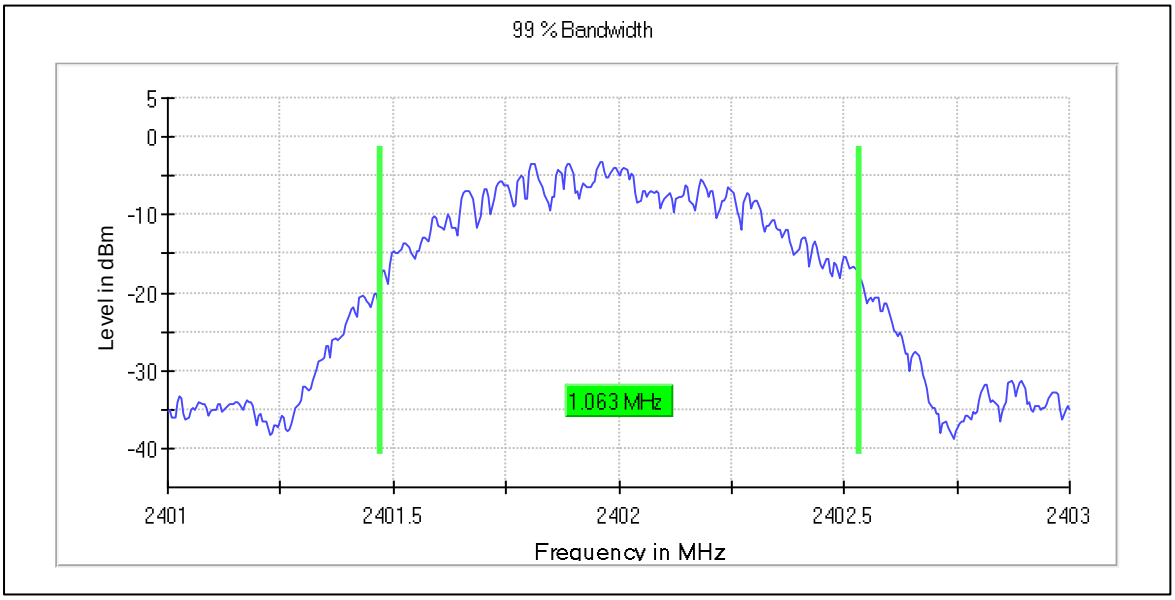
Limits
None (Informational only)

Procedure
1. EUT transmitter is activated in test mode under normal conditions 2. Spectrum analyzer is set to peak detection and maximum hold with a span twice the emission spectrum 3. The resolution bandwidth is set to the range of 1% to 5% of the occupied bandwidth 4. The occupied bandwidth is measured with the build-in analyzer function

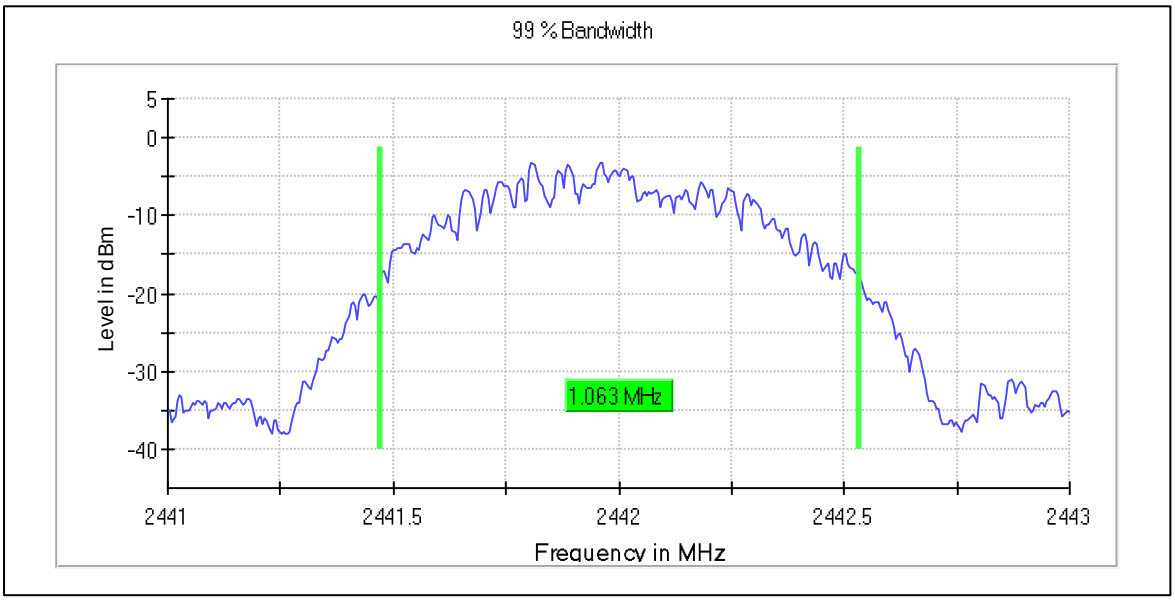
Summary:

Summary		
Mode / modulation	Frequency (MHz)	Bandwidth (MHz)
Bluetooth LE, 1 Mbps	2402	1.062657
Bluetooth LE, 1 Mbps	2442	1.062657
Bluetooth LE, 1 Mbps	2480	1.072682

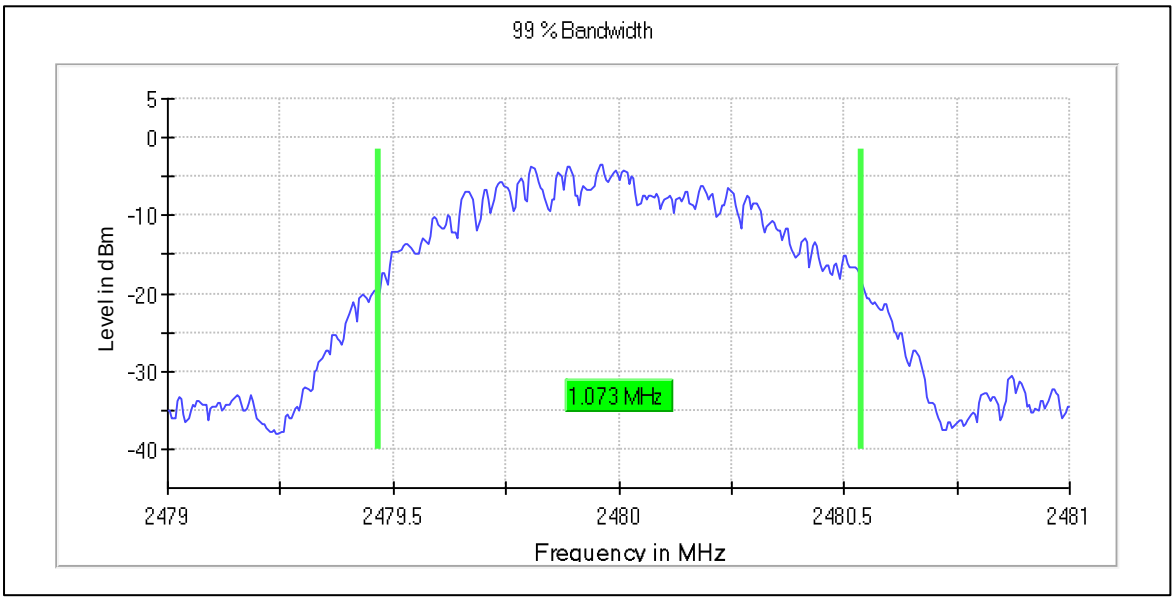
Occupied bandwidth, low channel



Occupied bandwidth, middle channel



Occupied bandwidth, high channel



10. 6 dB bandwidth

Reference: FCC title 47 part 15 §15.247(a), ISED RSS-247, Issue 2 (section 5.2)

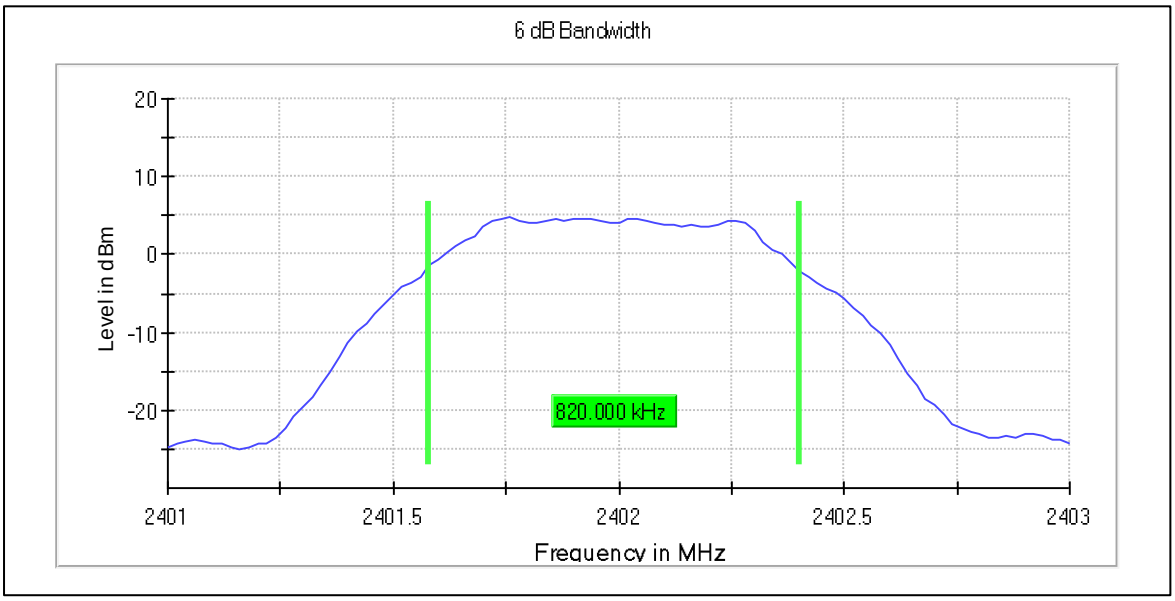
Test method: KDB 558074 D01 DTS Meas Guidance v05r02 and ANSI C63.10-2013 (11.8.1)

Limits
The minimum 6 dB bandwidth shall be at least 500 kHz.

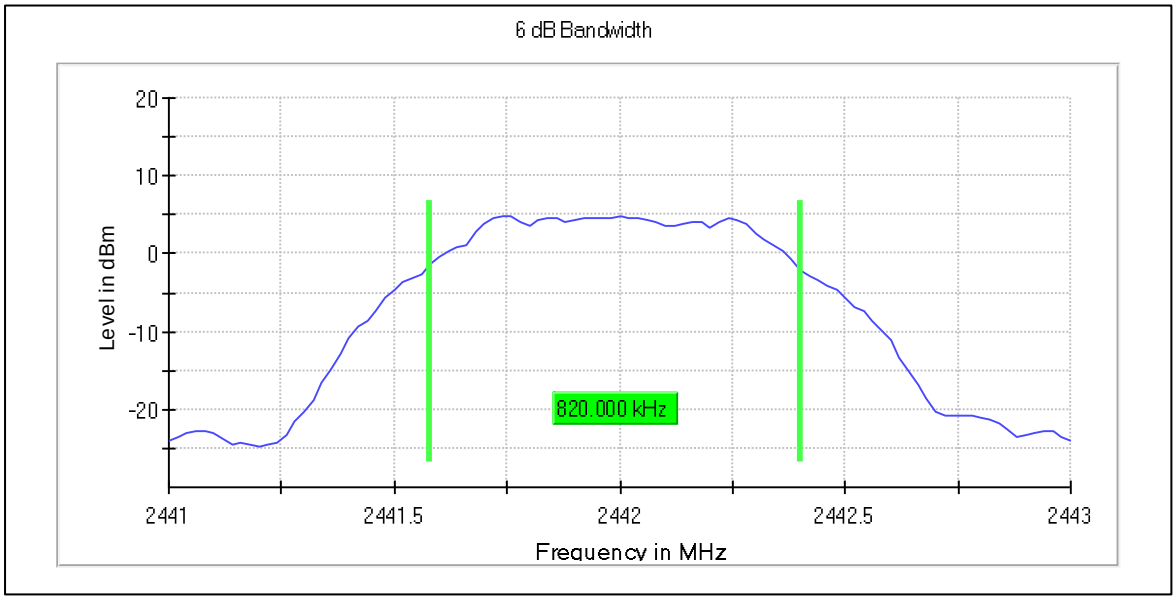
Test procedure
1. EUT set to test mode
2. Span set to at least twice the emission spectrum
3. Detector set to peak and max hold and BW is set to 100 kHz
4. Envelope peak value of emission spectrum is selected
5. Marker on envelope of spectrum is set to level of -6 dB to the left of the peak
6. Marker on envelope of spectrum is set to level of -6 dB to the right of the peak
7. 6 dB bandwidth is determined by marker frequency separation

Mode / modulation	DUT Frequency (MHz)	Bandwidth (MHz)	Limit Min (MHz)	Limit Max (MHz)	Band Edge Left (MHz)	Band Edge Right (MHz)	Result
Bluetooth LE, 1 Mbps	2402.000000	0.820000	0.500000	---	2401.580000	2402.400000	PASS
Bluetooth LE, 1 Mbps	2442.000000	0.820000	0.500000	---	2441.580000	2442.400000	PASS
Bluetooth LE, 1 Mbps	2480.000000	0.800000	0.500000	---	2479.600000	2480.400000	PASS

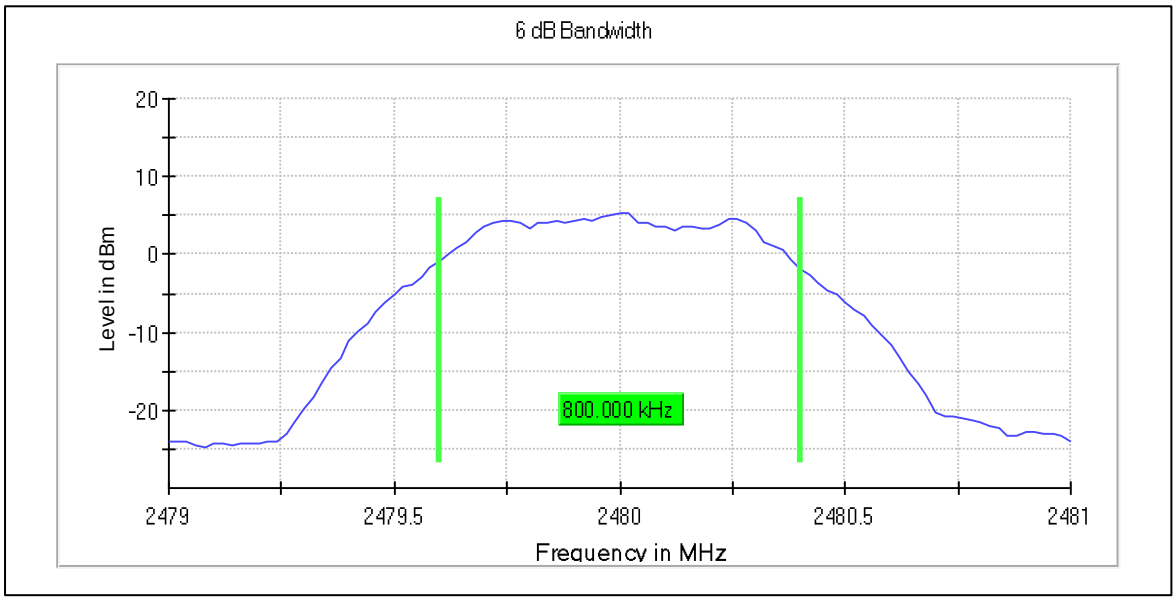
6 dB Bandwidth, low channel:



6 dB Bandwidth, middle channel:



6 dB Bandwidth, high channel:



11. Peak conducted output power

Reference: FCC part 15 §15.247(b), ISED RSS-247, Issue 2 (section 5.4)

Test method: KDB 558074 D01 DTS Meas Guidance v05r02 and ANSI C63.10-2013 (11.9.1.1)

Limits
For systems using digital modulation in the 2400-2483.5 MHz band: 1 watt (30 dBm). The e.i.r.p. shall not exceed 4 W (36 dBm) (Canada).
The conducted output power limit specified above is based on the use of antennas with directional gains that do not exceed 6 dBi. If transmitting antennas of directional gain greater than 6 dBi are used, the conducted output power from the intentional radiator shall be reduced below the stated values in the table, as appropriate, by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

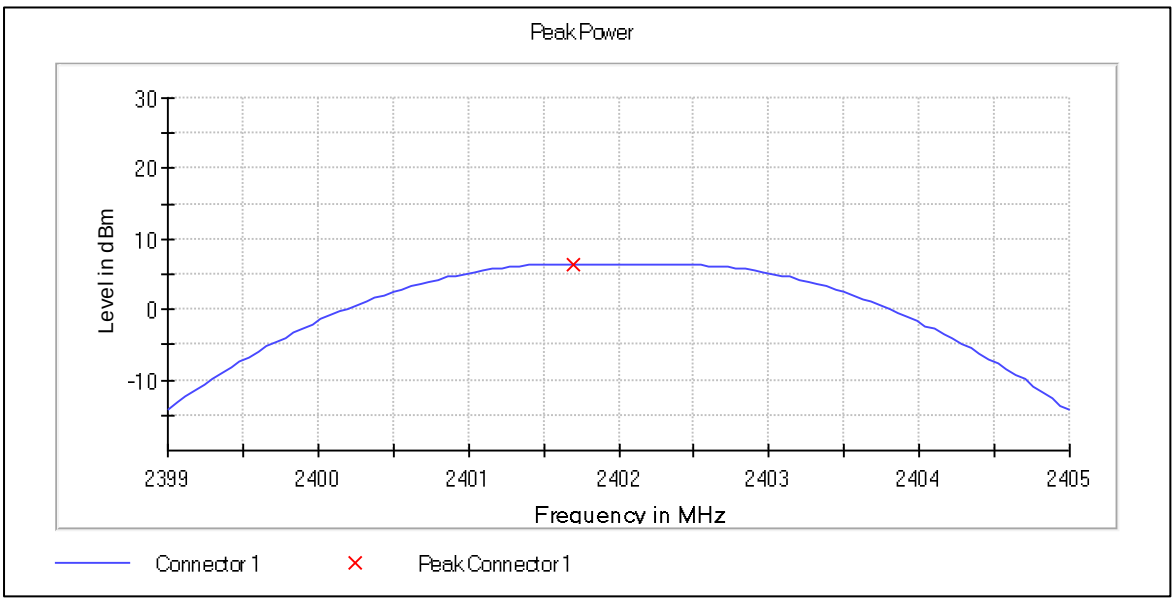
Test procedure
1. EUT set to test mode (communication tested is used if needed)
2. Analyzer resolution bandwidth is set ≥ DTS bandwidth
3. Detector set to peak and max hold
4. Sweep time is set to auto
5. After trace has stabilized a marker is set to peak envelope

The EIRP power (dBm) is calculated by adding the declared maximum antenna gain to the measured conducted power.

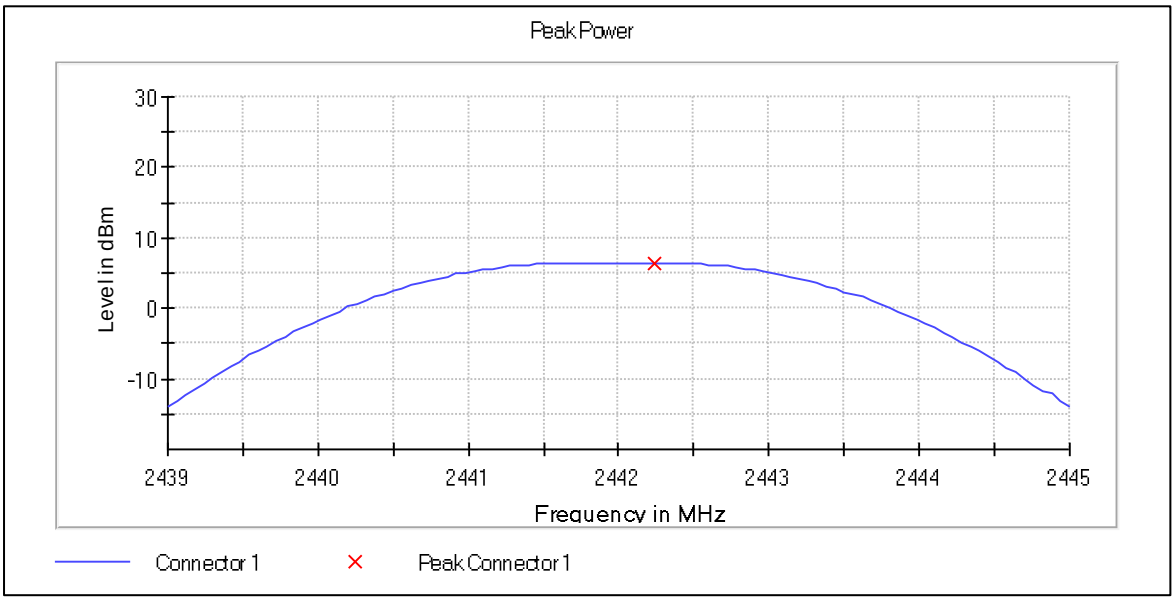
Maximum Declared Antenna Gain: +2.7 dBi

Mode / modulation	DUT Frequency (MHz)	Peak Power (dBm)	EIRP Power (dBm)	Result
Bluetooth LE, 1 Mbps	2402.000000	6.5	9.2	PASS
Bluetooth LE, 1 Mbps	2442.000000	6.4	9.1	PASS
Bluetooth LE, 1 Mbps	2480.000000	6.2	8.9	PASS

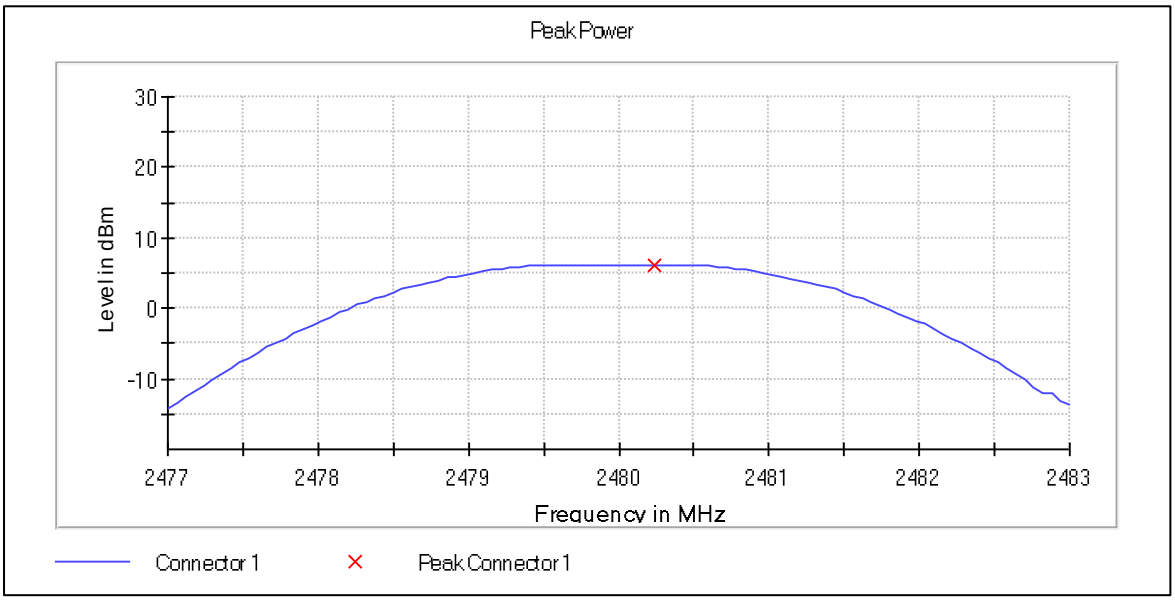
Peak power, low channel



Peak power, middle channel



Peak power, high channel



12. Peak Power Spectral Density

Reference: FCC §15.247(a),(e), ISED RSS-247, Issue 2 (section 5.2)
Test method: KDB 558074 D01 DTS Meas Guidance v05r02 and ANSI C63.10-2013 (11.10.2, 14.3.2)

Specification: For digitally modulated systems, the power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

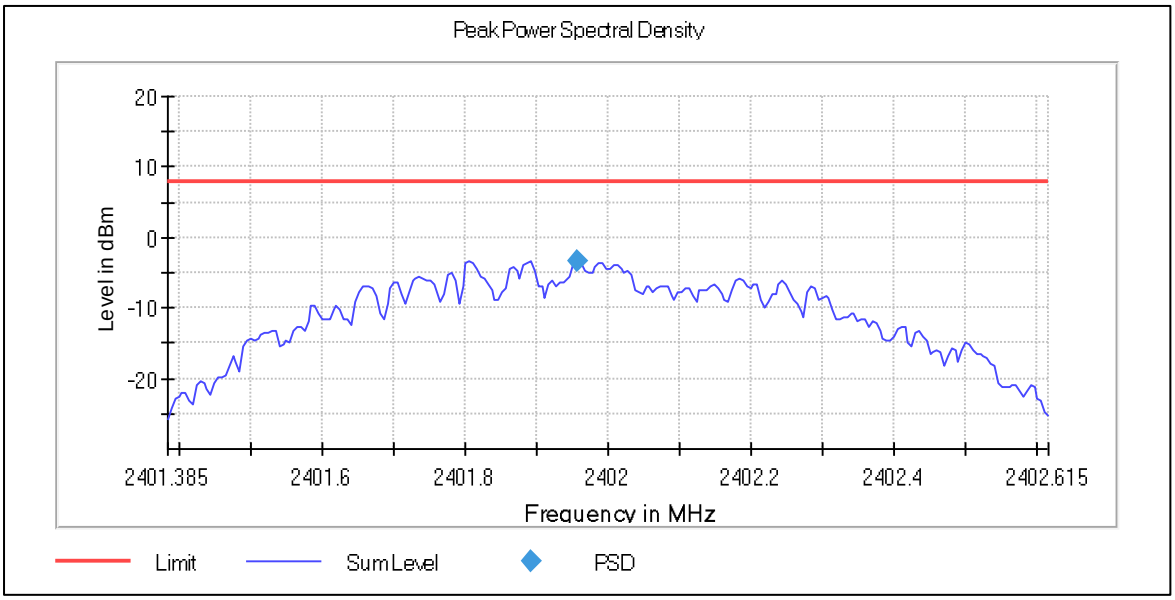
Limits
≤ 8 dBm / 3 kHz

Test procedure
1. EUT set to test mode
2. The analyser is set to DTS channel center frequency with a span of 1.5 times the DTS bandwidth
3. The analyzer is set to 100 kHz with VBW ≥ RBW and the detector is set to peak with max hold
4. After trace has stabilized a marker is set to the envelope maximum
5. If the power spectral density is above the limit the RBW is reduces (not lower than 3 kHz) and the measurement is repeated
6. If the EUT has more than one transmit chain the procedure is repeated for each chain

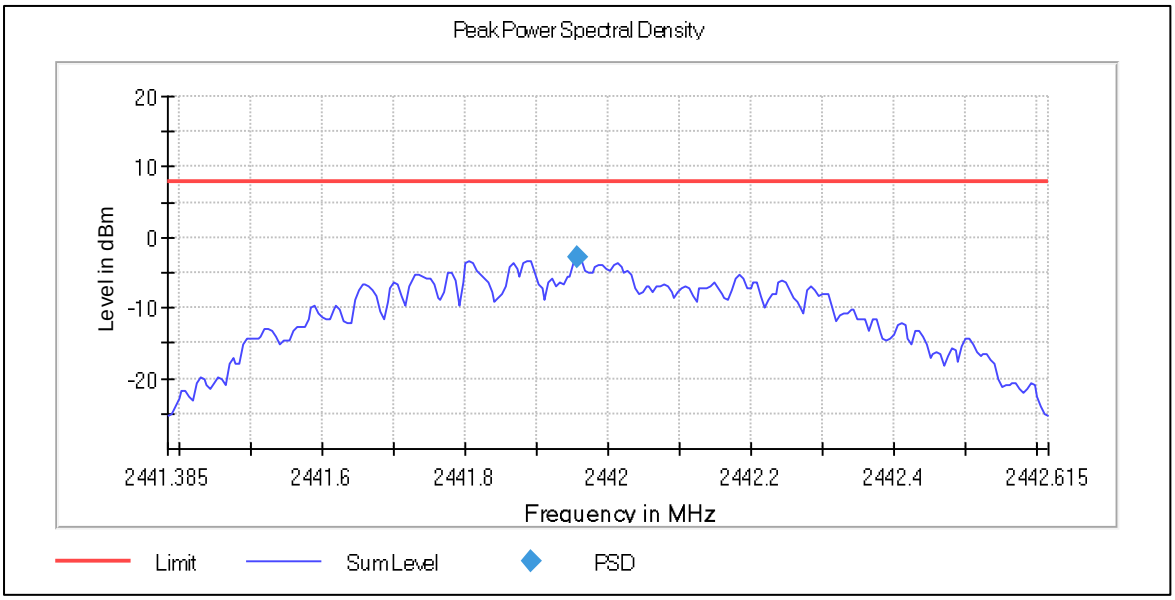
Summary

Mode / modulation	DUT Frequency (MHz)	Frequency (MHz)	PSD (dBm)	Limit Max (dBm)	Result
Bluetooth LE, 1 Mbps	2402.000000	2401.957327	-3.271	8.0	PASS
Bluetooth LE, 1 Mbps	2442.000000	2441.957327	-2.912	8.0	PASS
Bluetooth LE, 1 Mbps	2480.000000	2479.806695	-3.422	8.0	PASS

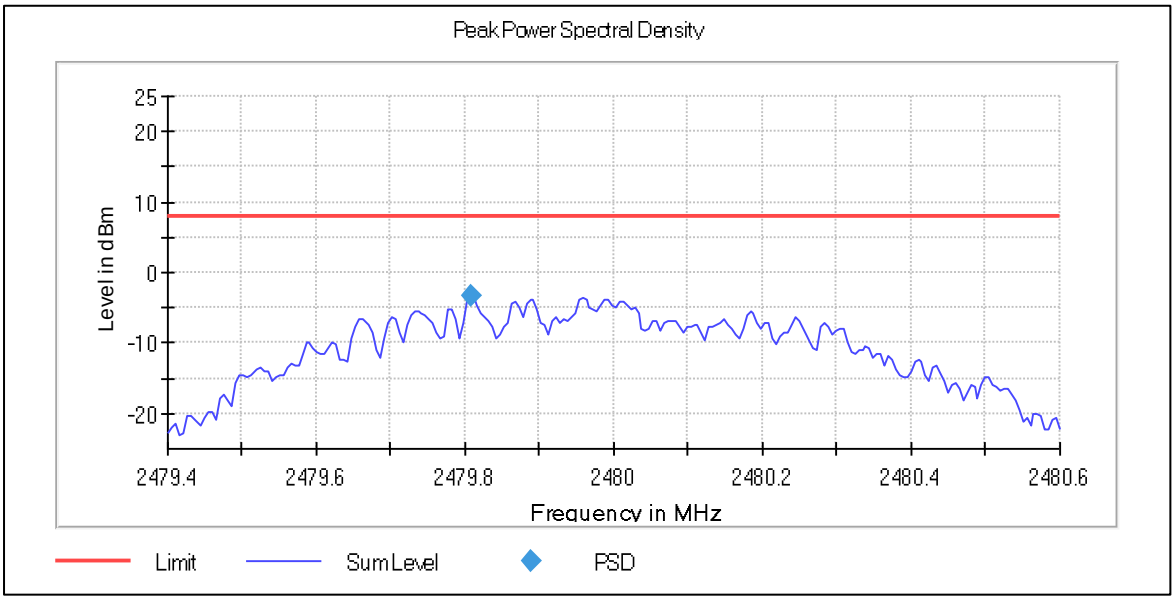
Peak power spectral density, low channel



Peak power spectral density, middle channel



Peak power spectral density, high channel:



13. AC power line conducted emissions

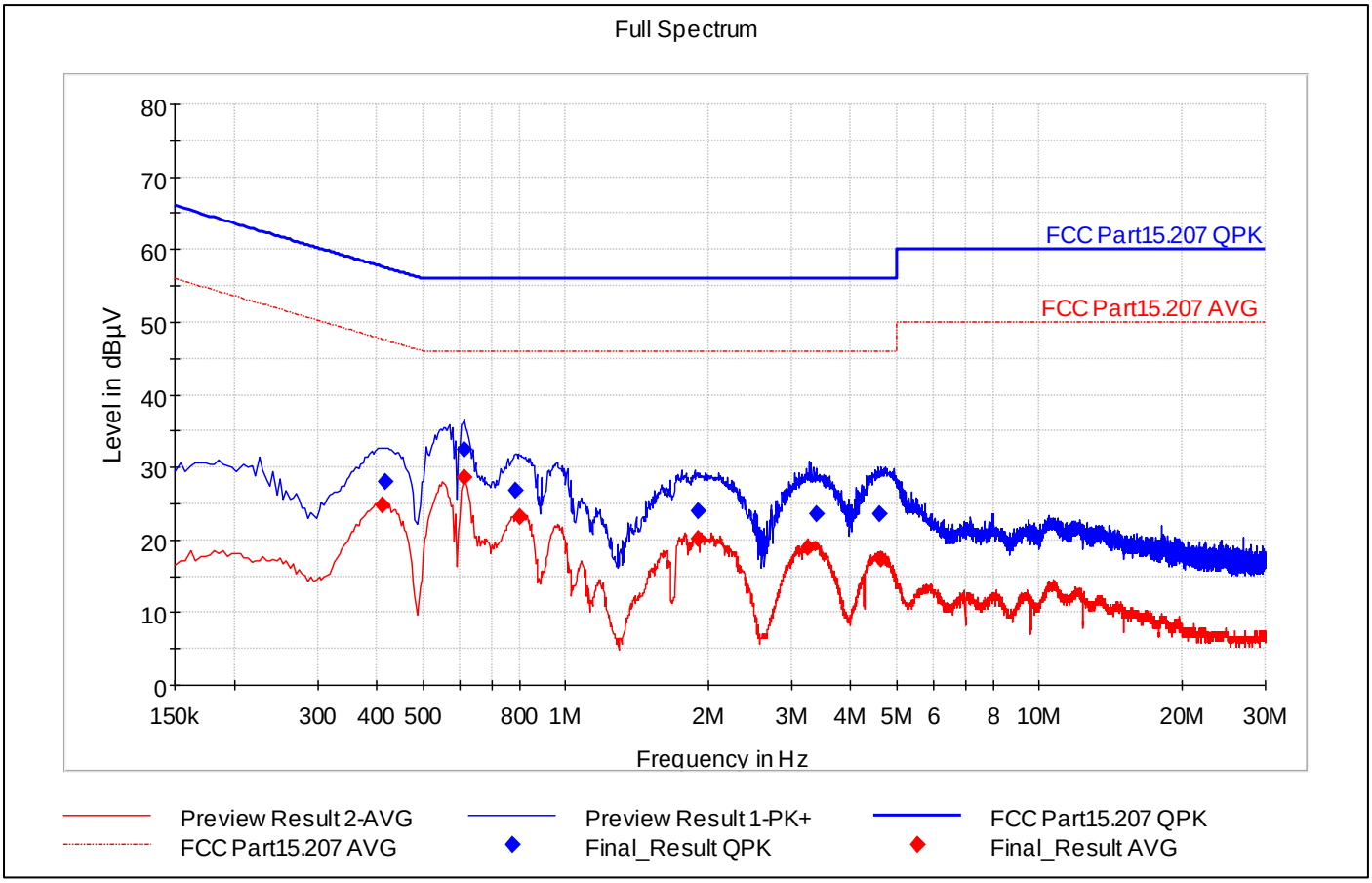
Reference: FCC §15.207, ISED RSS-247, Issue 2 (section 3.1)
Test method: ANSI C63.10-2013 (6.2)

Limits		
Frequency (MHz)	Quasi-Peak (dBuV)	Average (dBuV)
0.15 – 0.5	66 -56*	56 – 46*
0.5 – 5	56	46
5 - 30	60	50
*Limit decreases linearly with the logarithm of the frequency		

Operation mode(s)	Configuration	Test Verdict
Bluetooth LE TX, 1 Mbps	Low channel, 2402 MHz	PASS
Bluetooth LE TX, 1 Mbps	Mid channel, 2440 MHz	PASS
Bluetooth LE TX, 1 Mbps	High channel, 2480 MHz	PASS

Conducted emission at the mains power port according to 47 CFR Part 15.207, BLE 2402 MHz

Graph and final results

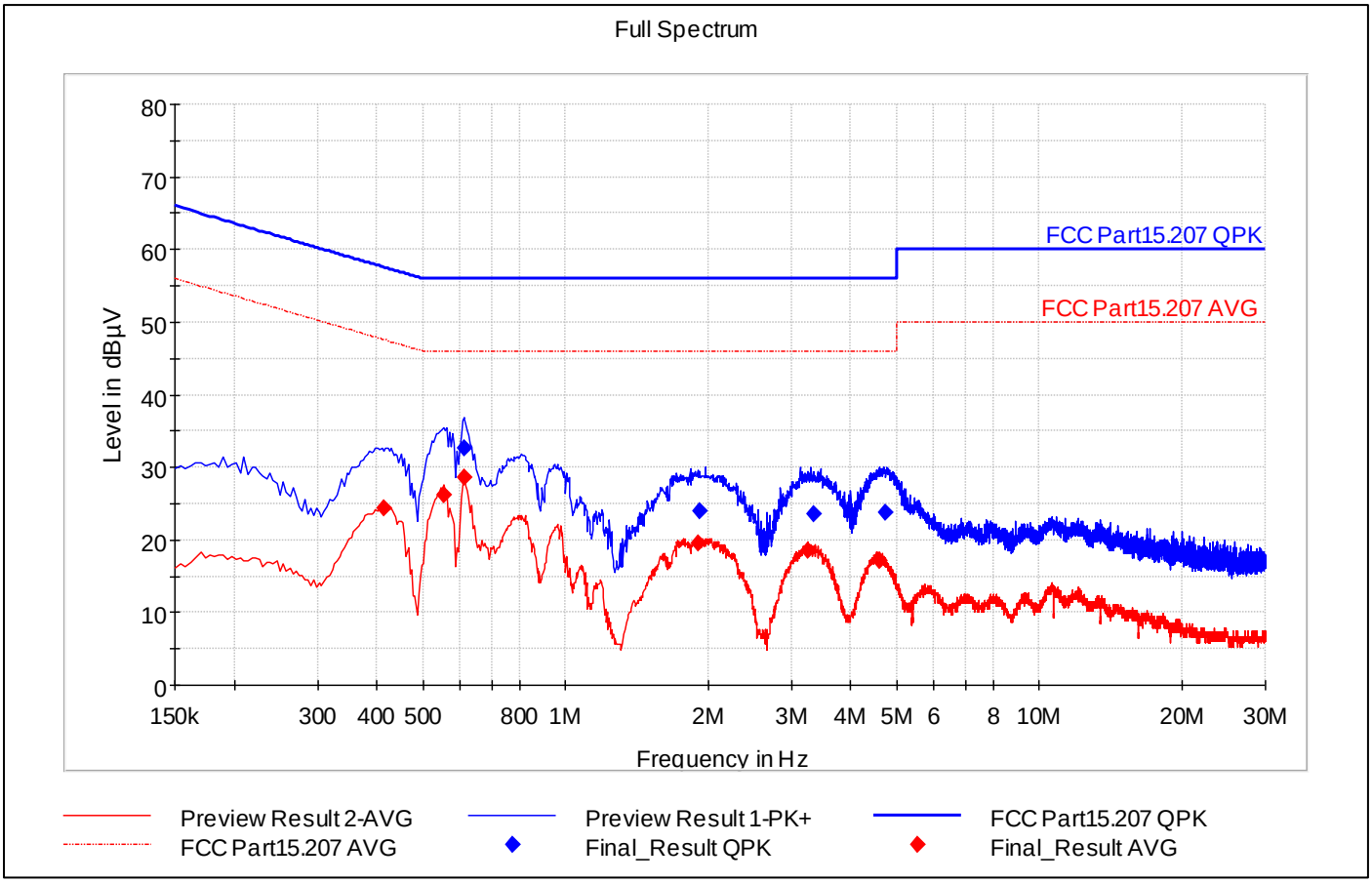


Final_Result

Frequency (MHz)	QuasiPeak (dBµV)	Average (dBµV)	Limit (dBµV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	Filter	Corr. (dB)	Comment
0.410000	---	24.73	47.65	22.92	15000.0	9.000	N	ON	9.6	PASS
0.418000	27.99	---	57.49	29.50	15000.0	9.000	N	ON	9.6	PASS
0.610000	---	28.65	46.00	17.35	15000.0	9.000	N	ON	9.6	PASS
0.610000	32.53	---	56.00	23.47	15000.0	9.000	N	ON	9.6	PASS
0.786000	26.74	---	56.00	29.26	15000.0	9.000	N	ON	9.6	PASS
0.802000	---	23.09	46.00	22.91	15000.0	9.000	N	ON	9.6	PASS
1.902000	24.01	---	56.00	31.99	15000.0	9.000	N	ON	9.7	PASS
1.902000	---	20.12	46.00	25.88	15000.0	9.000	N	ON	9.7	PASS
3.254000	---	18.88	46.00	27.12	15000.0	9.000	N	ON	9.7	PASS
3.378000	23.48	---	56.00	32.52	15000.0	9.000	N	ON	9.7	PASS
4.610000	23.66	---	56.00	32.34	15000.0	9.000	L1	ON	9.7	PASS
4.638000	---	17.30	46.00	28.70	15000.0	9.000	N	ON	9.7	PASS

Conducted emission at the mains power port according to 47 CFR Part 15.207, , BLE 2440 MHz

Graph and final results

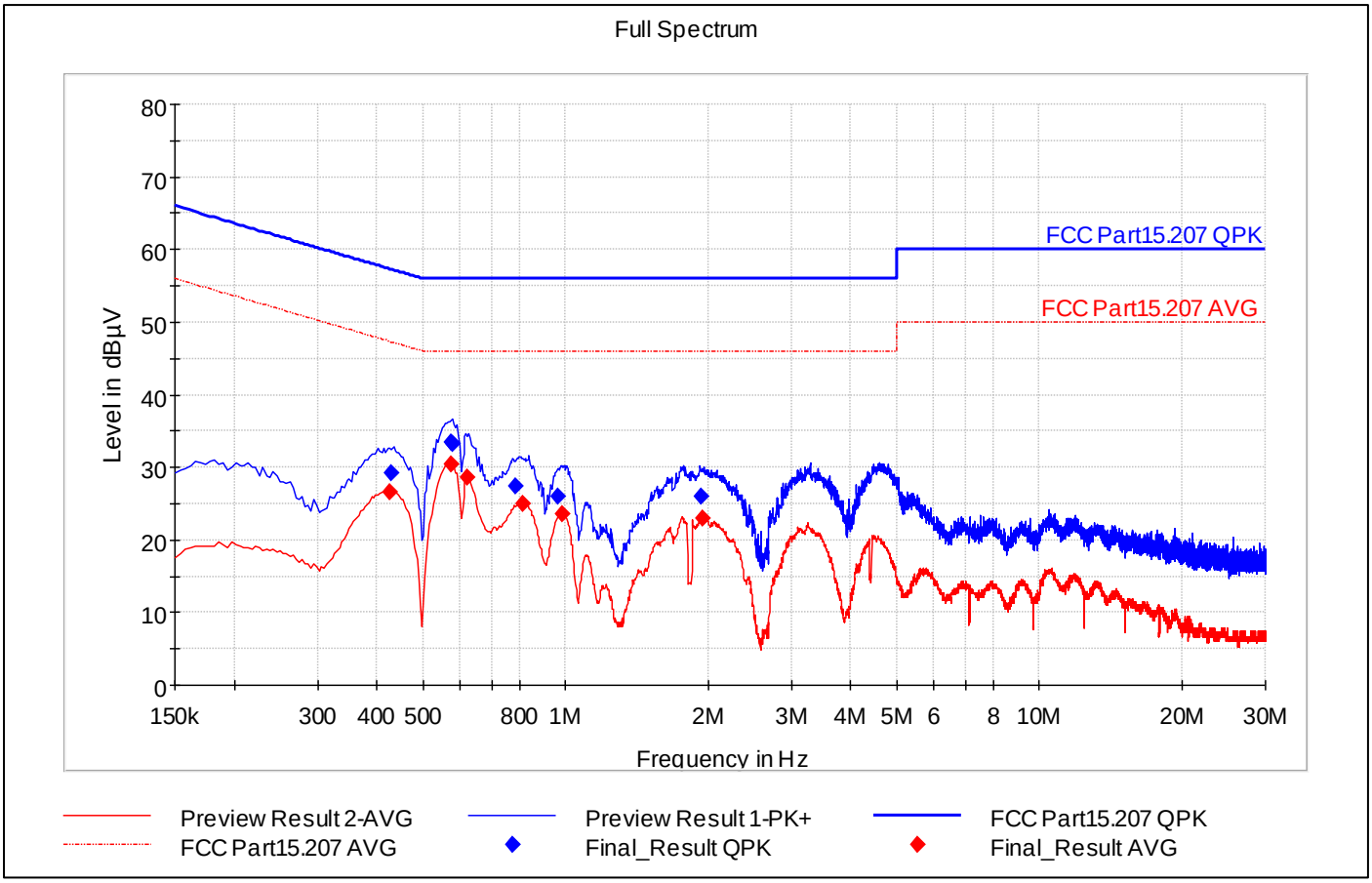


Final_Result

Frequency (MHz)	QuasiPeak (dBµV)	Average (dBµV)	Limit (dBµV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	Filter	Corr. (dB)	Comment
0.414000	---	24.28	47.57	23.28	15000.0	9.000	N	ON	9.6	PASS
0.554000	---	26.30	46.00	19.70	15000.0	9.000	N	ON	9.6	PASS
0.610000	32.72	---	56.00	23.28	15000.0	9.000	N	ON	9.6	PASS
0.610000	---	28.54	46.00	17.46	15000.0	9.000	N	ON	9.6	PASS
1.902000	---	19.54	46.00	26.46	15000.0	9.000	N	ON	9.7	PASS
1.922000	23.92	---	56.00	32.08	15000.0	9.000	N	ON	9.7	PASS
3.238000	---	18.46	46.00	27.54	15000.0	9.000	N	ON	9.7	PASS
3.350000	23.48	---	56.00	32.52	15000.0	9.000	N	ON	9.7	PASS
4.614000	---	17.03	46.00	28.97	15000.0	9.000	N	ON	9.7	PASS
4.726000	23.84	---	56.00	32.16	15000.0	9.000	L1	ON	9.7	PASS

Conducted emission at the mains power port according to 47 CFR Part 15.207, BLE 2480 MHz

Graph and critical frequencies



Final_Result

Frequency (MHz)	QuasiPeak (dBµV)	Average (dBµV)	Limit (dBµV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	Filter	Corr. (dB)	Comment
0.426000	---	26.67	47.33	20.66	15000.0	9.000	N	ON	9.6	PASS
0.430000	29.22	---	57.25	28.03	15000.0	9.000	N	ON	9.6	PASS
0.574000	---	30.47	46.00	15.53	15000.0	9.000	N	ON	9.6	PASS
0.574000	33.37	---	56.00	22.63	15000.0	9.000	N	ON	9.6	PASS
0.578000	33.31	---	56.00	22.69	15000.0	9.000	N	ON	9.6	PASS
0.622000	---	28.54	46.00	17.46	15000.0	9.000	N	ON	9.6	PASS
0.786000	27.41	---	56.00	28.59	15000.0	9.000	N	ON	9.6	PASS
0.814000	---	24.95	46.00	21.05	15000.0	9.000	N	ON	9.6	PASS
0.966000	26.08	---	56.00	29.92	15000.0	9.000	N	ON	9.6	PASS
0.982000	---	23.62	46.00	22.38	15000.0	9.000	N	ON	9.6	PASS
1.934000	26.04	---	56.00	29.96	15000.0	9.000	N	ON	9.7	PASS
1.942000	---	22.97	46.00	23.03	15000.0	9.000	N	ON	9.7	PASS

14. Band edge emissions compliance (transmitter)

Reference: FCC §15.247(d), ISED RSS-247, Issue 2 (section 5.5)

Test method: KDB 558074 D01 DTS Meas Guidance v05r02 8.7 and ANSI C63.10-2013 (11.13)

Specification: In any 100 kHz bandwidths outside the frequency band in which the intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, the attenuation required under this paragraph shall be 30 dB instead of 20 dB.

Limits	
Power measurement	Out-of-band attenuation (dB)
Peak	20
RMS	30

Procedure
1. EUT set to test mode (communication tester is used if needed)
2. Span set around lower band edge and detector is set to peak and max hold
3. Resolution bandwidth is set to 100 kHz
4. Peak emission level(s) within frequency band and outside frequency band is measured
5. Band edge attenuation is determined from level difference

Summary

Mode / modulation	DUT Frequency (MHz)	Result
Bluetooth LE, 1 Mbps	2402.000000	PASS
Bluetooth LE, 1 Mbps	2480.000000	PASS

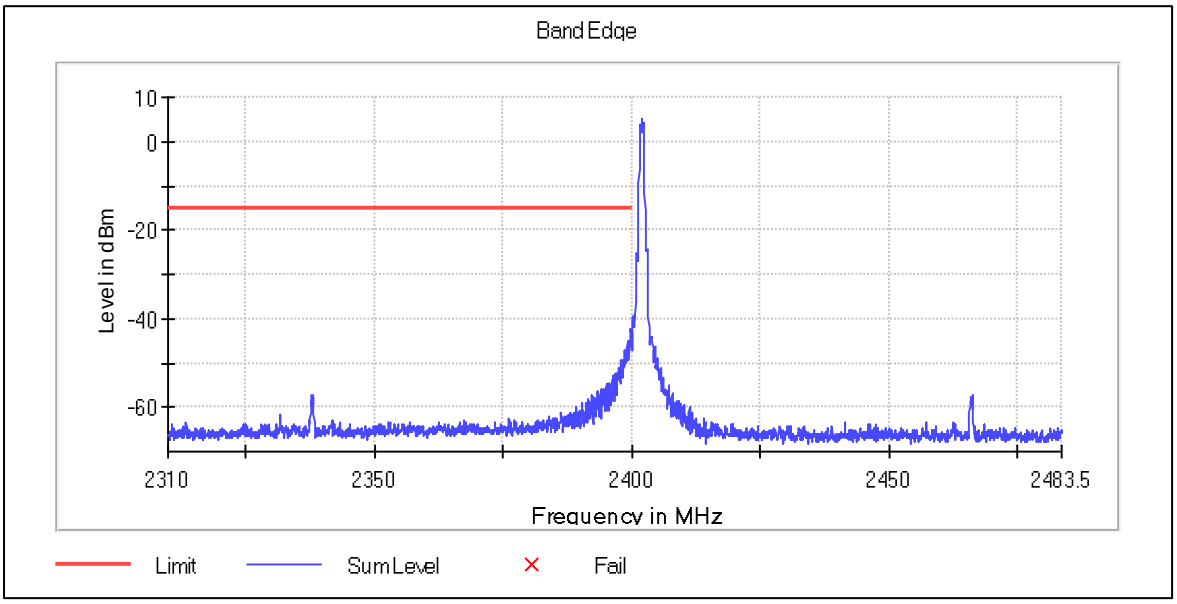
Measurements, band edge low

Frequency (MHz)	Level (dBm)	Margin (dB)	Limit (dBm)	Result
2399.799889	-42.2	27.2	-15.0	PASS
2399.849917	-42.2	27.2	-15.0	PASS
2399.699833	-42.2	27.2	-15.0	PASS
2399.749861	-42.2	27.2	-15.0	PASS
2399.899944	-42.8	27.8	-15.0	PASS
2399.949972	-43.4	28.4	-15.0	PASS
2399.649805	-43.5	28.5	-15.0	PASS
2399.249583	-45.0	30.0	-15.0	PASS
2399.199555	-45.2	30.2	-15.0	PASS
2399.299611	-45.7	30.7	-15.0	PASS
2399.599778	-46.0	31.0	-15.0	PASS
2399.149528	-46.6	31.6	-15.0	PASS
2399.349639	-46.6	31.6	-15.0	PASS
2399.099500	-46.7	31.7	-15.0	PASS
2399.399666	-46.8	31.8	-15.0	PASS

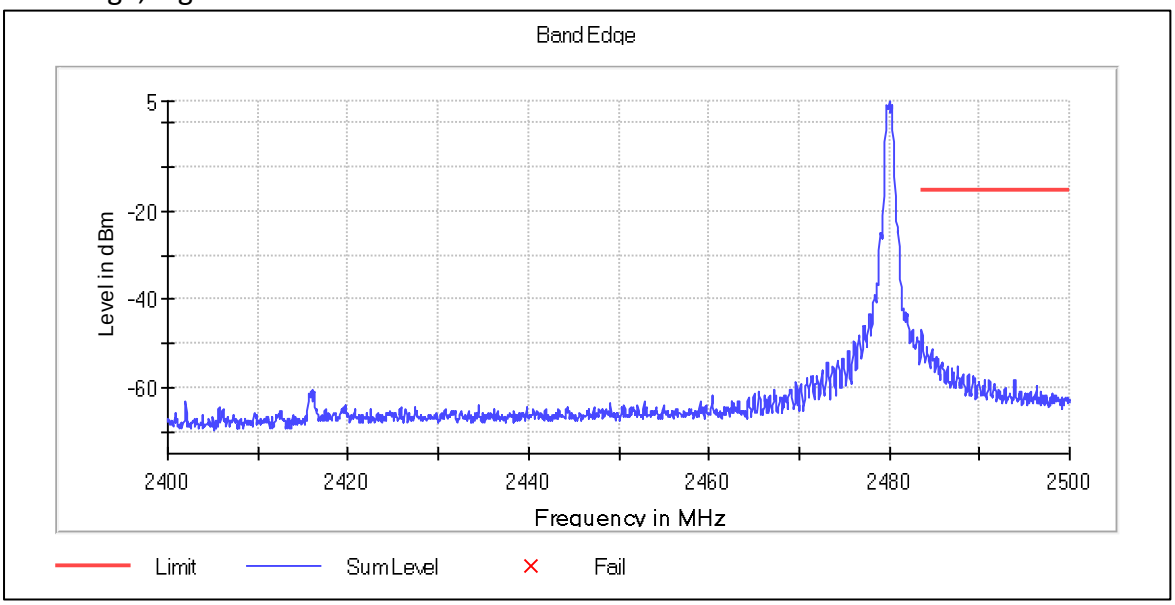
Measurements, band edge high

Frequency (MHz)	Level (dBm)	Margin (dB)	Limit (dBm)	Result
2483.600304	-47.1	32.1	-15.0	PASS
2483.550152	-47.1	32.1	-15.0	PASS
2483.650456	-48.4	33.4	-15.0	PASS
2483.700608	-48.6	33.5	-15.0	PASS
2484.151976	-50.7	35.7	-15.0	PASS
2483.750760	-50.7	35.7	-15.0	PASS
2484.101824	-50.9	35.9	-15.0	PASS
2484.703647	-51.2	36.2	-15.0	PASS
2484.753799	-51.3	36.2	-15.0	PASS
2484.202128	-51.4	36.4	-15.0	PASS
2483.800912	-51.7	36.6	-15.0	PASS
2484.252280	-52.1	37.1	-15.0	PASS
2484.051672	-52.4	37.4	-15.0	PASS
2484.653495	-52.6	37.6	-15.0	PASS
2484.352584	-53.1	38.1	-15.0	PASS

Band edge, low channel



Band edge, high channel



15. Tx spurious emissions, conducted

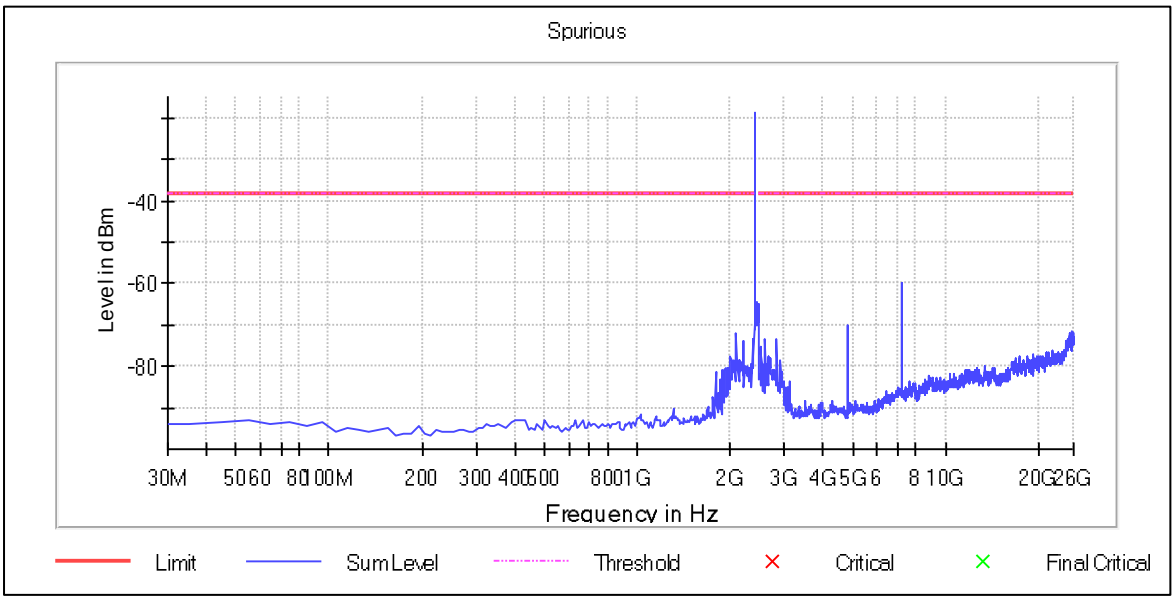
Reference: FCC §15.247(d), ISED RSS-247, Issue 2 (section 5.5)
Test method: KDB 558074 D01 DTS Meas Guidance v05r02 8.5 and ANSI C63.10-2013 (11.11.2 & 11.11.3)

Limits	
Power measurement	Out-of-band attenuation (dB)
Peak	20
RMS	30

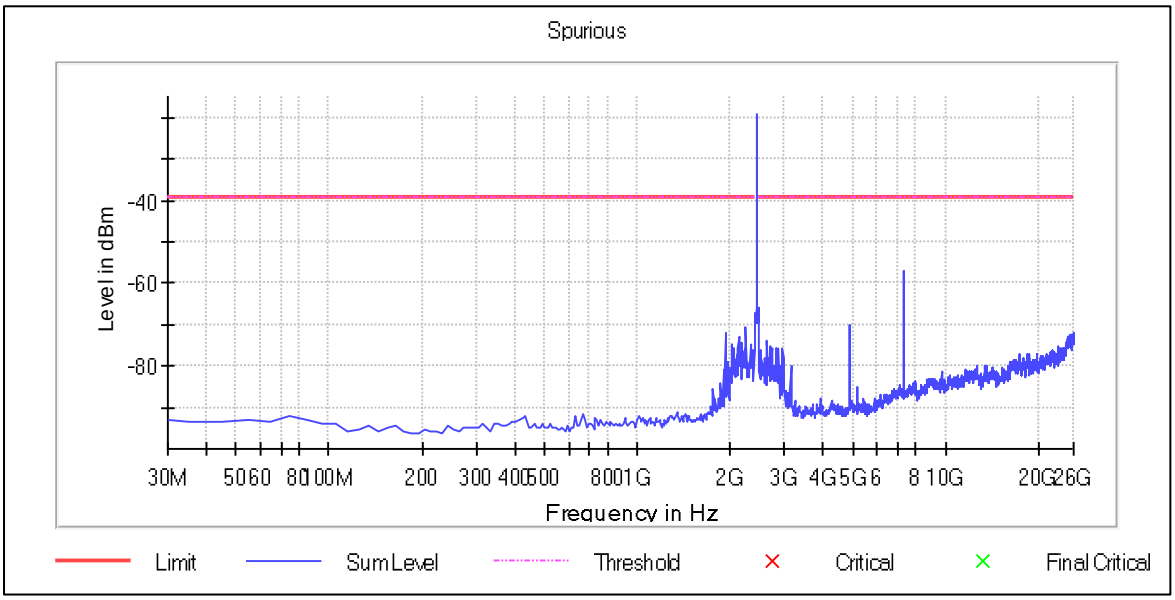
Test procedure
1. EUT set to test mode (communication tester is used if needed)
2. Span set around lower band edge and detector is set to peak and max hold
3. Resolution bandwidth is set to 100 kHz
4. Markers are set to peak emission levels outside frequency band

Mode / modulation	DUT Frequency (MHz)	Result
Bluetooth LE, 1 Mbps	2402.000000	PASS
Bluetooth LE, 1 Mbps	2442.000000	PASS
Bluetooth LE, 1 Mbps	2480.000000	PASS

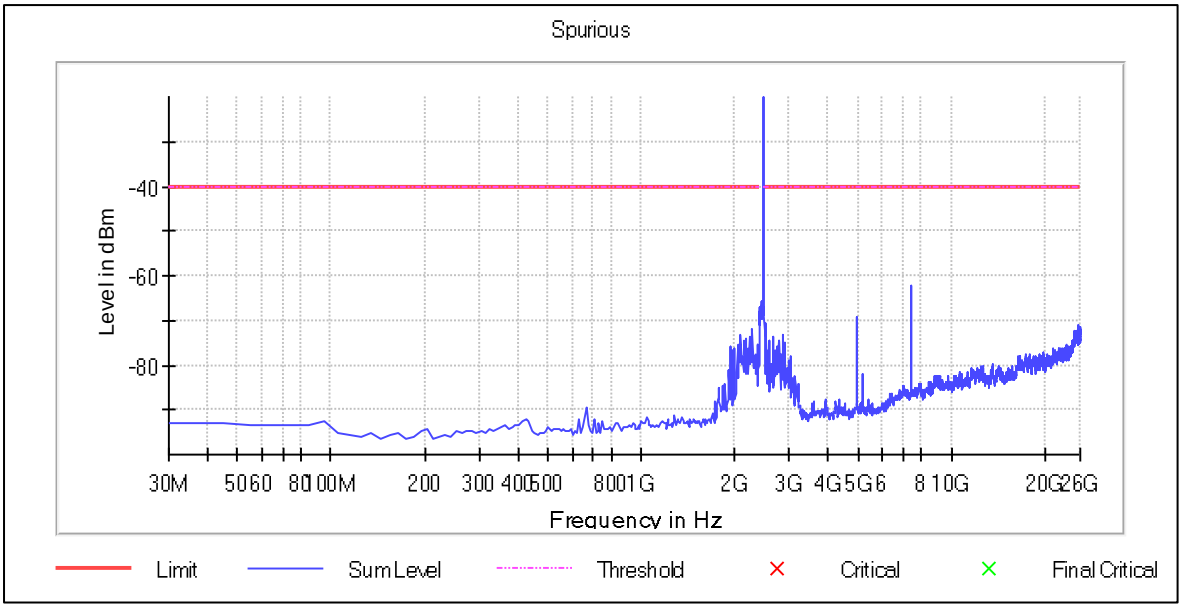
Low channel



Middle channel



High channel



16. Tx spurious emissions, radiated

Reference: FCC §15.247(d), FCC §15.209, ISED RSS-Gen Issue 5 A2 (section 6.13)
Test method: KDB 558074 D01 DTS Meas Guidance v05r02 8.5 and ANSI C63.10-2013 (6.4, 6.5, 6.6 & 11.12)

Specification: Radiated emissions which fall in the restricted bands, as defined in Section 15.205(a), must also comply with the radiated emission limits specified in Section 15.209(a) (see Section 15.205(c)/RSS-Gen):

Limits				
Frequency range (MHz)	Detector	Field strength (uV/m)	Field strength (dBuV/m)	Measurement distance (m)
0.009 – 0.09	Average	2400/F(kHz)	-	300
0.09 – 0.110	Quasi-Peak	2400/F(kHz)	-	300
0.110 – 0.490	Average	2400/F(kHz)	-	300
0.490 – 1.705	Quasi-Peak	24000/F(kHz)	-	30
1.705 – 30.0	Quasi-Peak	30	-	30
30 - 88	Quasi-Peak	100	40	3
88 – 216	Quasi-Peak	150	43.5	3
216 – 960	Quasi-Peak	200	46	3
960 - 1000	Quasi-Peak	500	54	3
>1000	Average	500	54	3

Test procedure 30 MHz -1 GHz
1. EUT is placed on a non conducting support at the center of a turn table 0.8m above the ground 2. EUT set to test mode 3. The receiver is set to peak detection with max hold 4. The EUT is rotated through 360 degrees (orientation varied), measurements were made in both horizontal and vertical planes of polarization 5. Found peak values were further maximized by adjusting turntable position ±22,5 degrees around detected value and scanning the antenna height 1 to 4m 6. For maximized values, final measurement was done with the corresponding final detector.

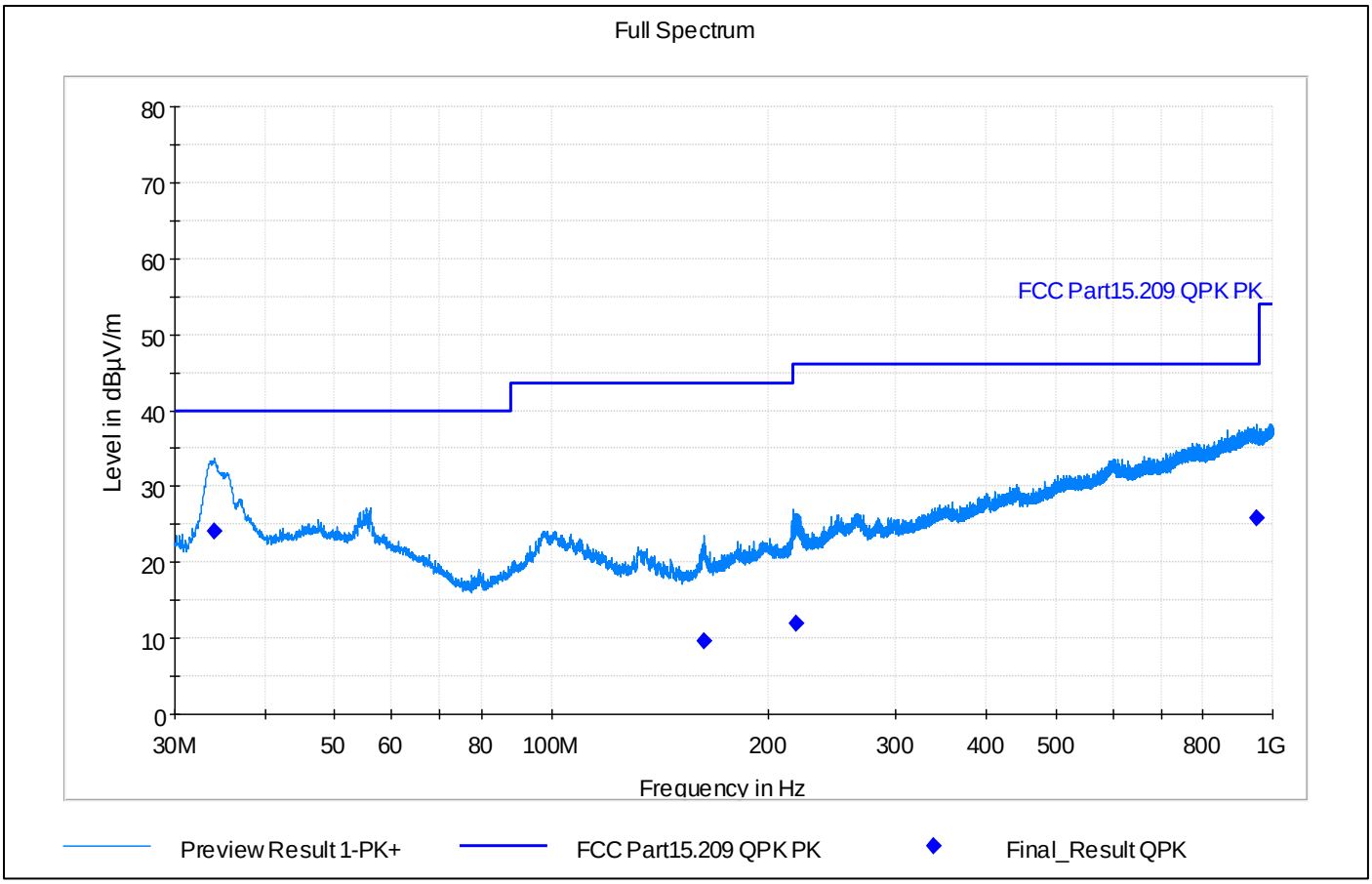
Test procedure > 1 GHz
1. EUT is placed on a non conducting support at the center of a turn table 1.5m above the ground 2. EUT set to test mode 3. The receiver is set to peak detection with max hold 4. The EUT is rotated through 360 degrees (orientation varied), measurements were made in both horizontal and vertical planes of polarization. 5. Found peak values were further maximized by adjusting turntable position ±22,5 degrees around detected value and scanning the antenna height 1 to 4m 6. For maximized values, final measurement was done with the corresponding final detector.

For average radiated emission measurements above 1000 MHz, there is also a limit corresponding to 20 dB above the indicated values in the table is specified when measuring with peak detector function. RSS-247: Attenuation below the general field strength limits specified in RSS-Gen is not required.

The field strength is calculated by adding correction factor to the measured level from the spectrum analyzer. This correction factor includes antenna factor, cable loss and pre-amplifiers gain.

Operation mode(s)	Configuration	Test Verdict
Bluetooth LE TX, 1 Mbps	Low channel, 2402 MHz	PASS
Bluetooth LE TX, 1 Mbps	Mid channel, 2442 MHz	PASS
Bluetooth LE TX, 1 Mbps	High channel, 2480 MHz	PASS

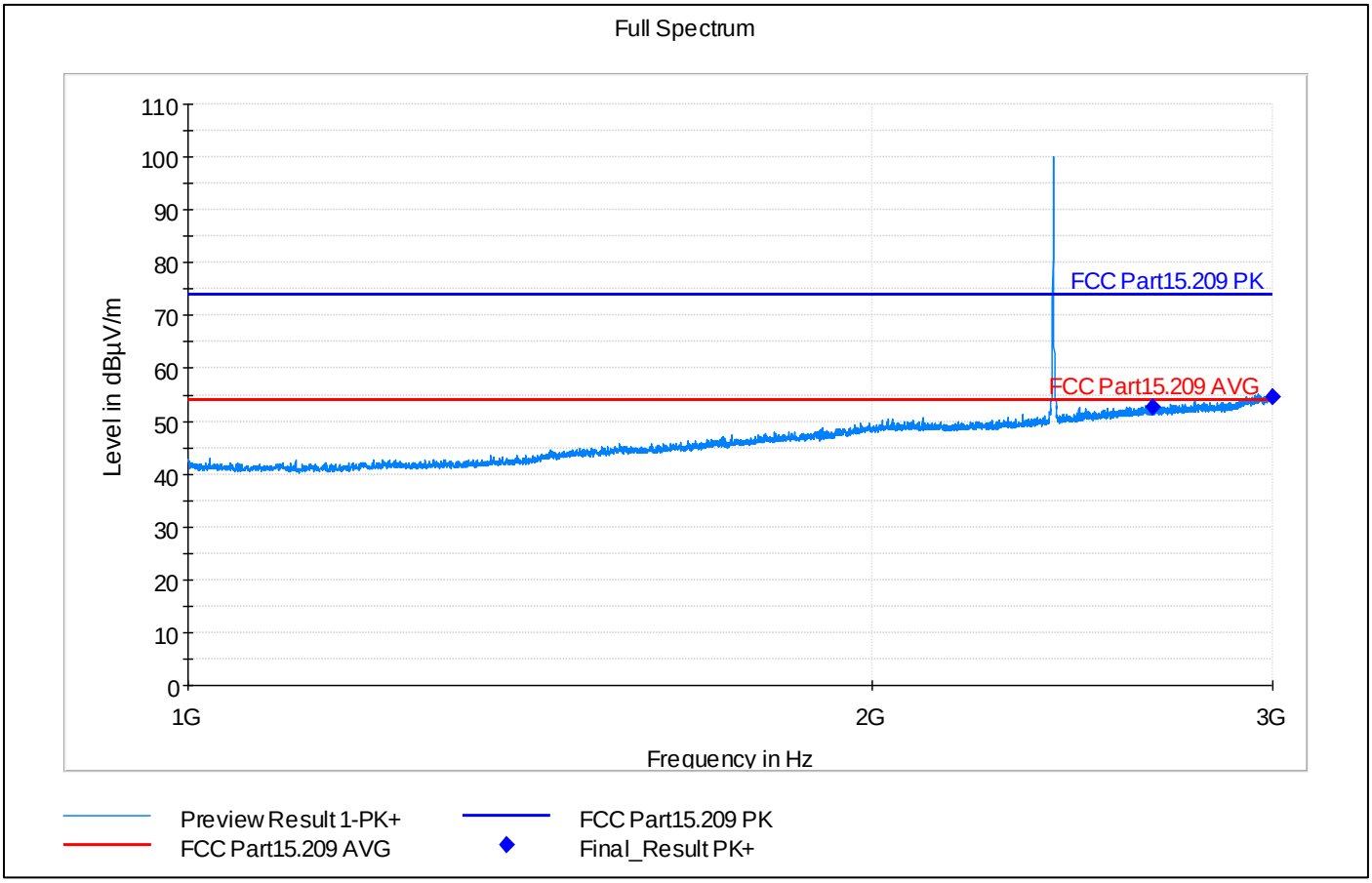
Low channel, 30 MHz – 1 GHz



Final_Result

Frequency	QuasiPeak	CAverage	Limit (dBµV/m	Margin	Meas. Time	Bandwidth	Height	Pol	Azimuth	Elevation	Corr. (dB/m	Comment
34.020000	24.10	---	40.00	15.90	15000.	120.000	98.0	V	337.0	90.0	17.2	PASS
162.93000	9.59	---	43.50	33.91	15000.	120.000	102.0	V	5.0	0.0	16.7	PASS
217.86000	12.02	---	46.00	33.98	15000.	120.000	98.0	V	277.0	0.0	19.7	PASS
950.70000	25.79	---	46.00	20.21	15000.	120.000	410.0	H	61.0	90.0	34.0	PASS

Low channel, 1 – 3 GHz



Note: Frequency 2402,250 MHz is excluded from spurious domain measurements and ignored. See table below.

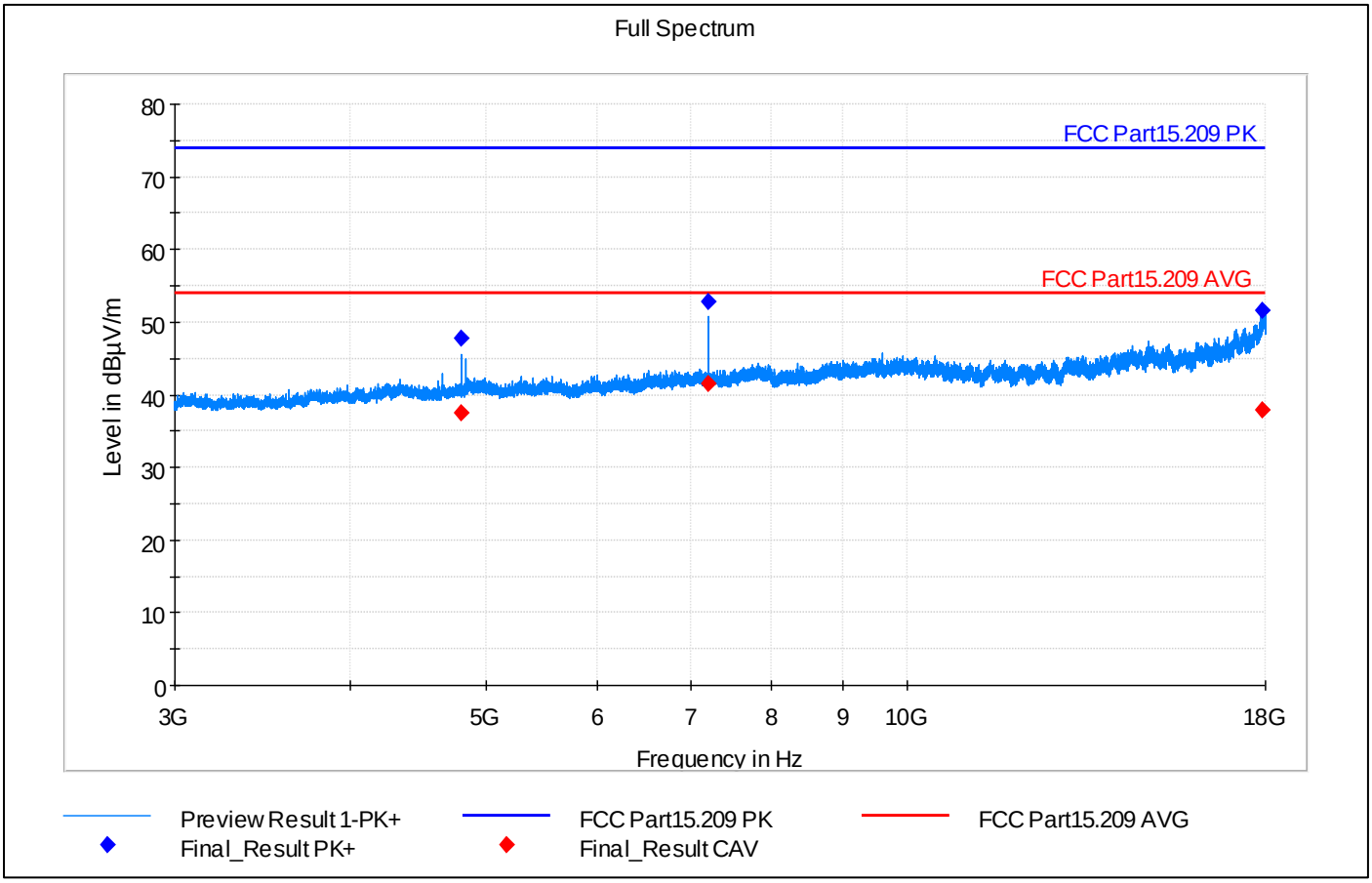
Critical_Freqs

Frequency (MHz)	Comment
2402.250000	EUT BLE Low CH TX signal, IGNORED

Final_Result

Frequency (MHz)	MaxPeak	CAverage	Limit (dBµV/m	Margin	Meas. Time	Bandwidth	Height	Pol	Azimuth	Elevation	Corr. (dB/m	Comment
2658.00000	---	36.20	54.00	17.80	15000.	1000.000	107.0	V	128.0	0.0	39.4	PASS
2658.00000	52.78	---	74.00	21.22	15000.	1000.000	107.0	V	128.0	0.0	39.4	PASS
3000.00000	---	38.92	54.00	15.08	15000.	1000.000	98.0	H	26.0	90.0	41.1	PASS
3000.00000	54.53	---	74.00	19.47	15000.	1000.000	98.0	H	26.0	90.0	41.1	PASS

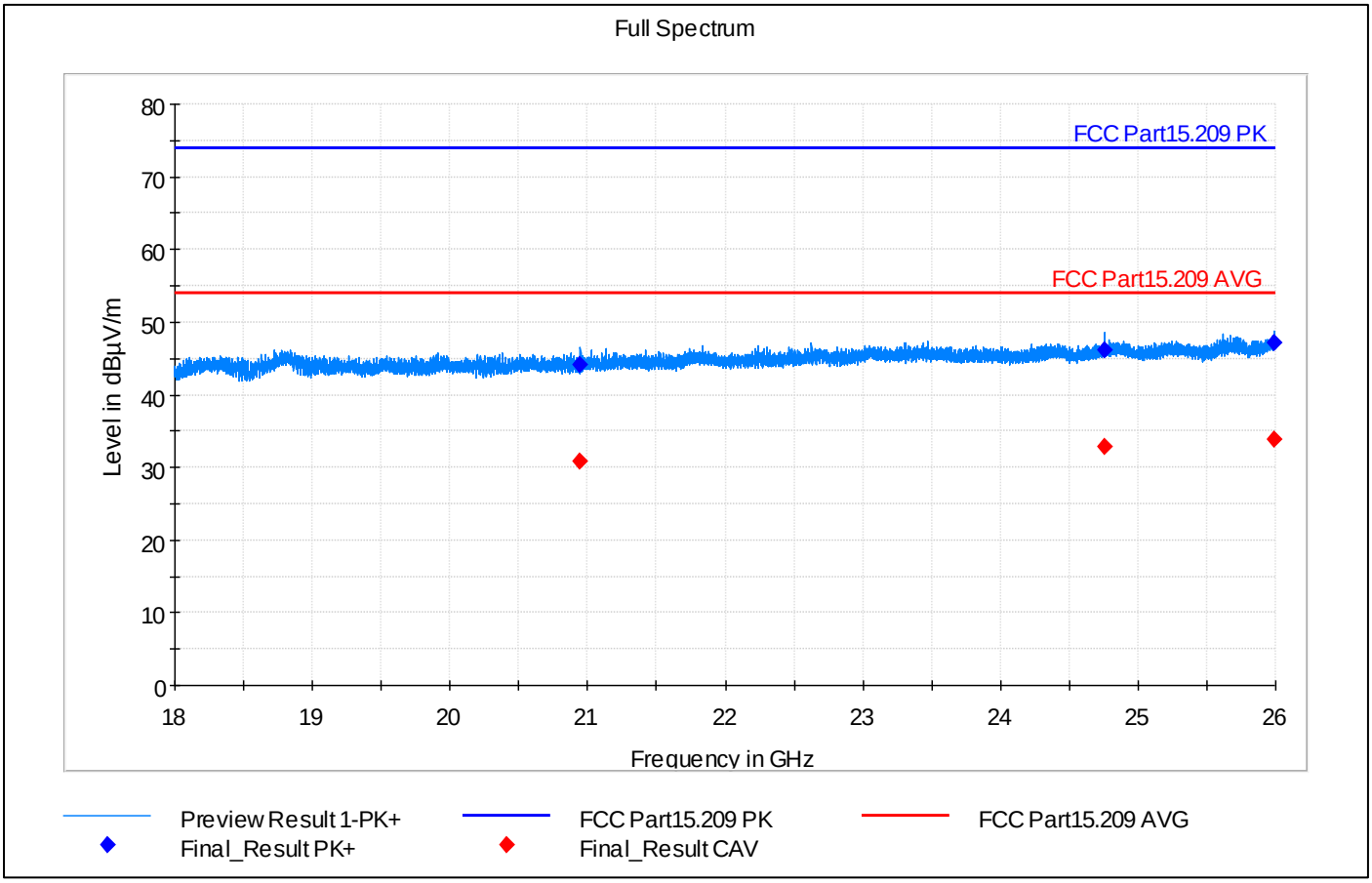
Low channel, 3 – 18 GHz



Final_Result

Frequency (MHz)	MaxPeak	CAverage	Limit (dBµV/	Margin	Meas. Time	Bandwidth	Height	Pol	Azimuth	Elevation	Corr. (dB/m	Comment
4804.000000	---	37.54	54.00	16.46	15000.	1000.000	231.0	H	179.0	90.0	9.0	PASS
4804.000000	47.69	---	74.00	26.31	15000.	1000.000	231.0	H	179.0	90.0	9.0	PASS
7205.250000	---	41.46	54.00	12.54	15000.	1000.000	207.0	H	243.0	90.0	13.5	PASS
7205.250000	52.79	---	74.00	21.21	15000.	1000.000	207.0	H	243.0	90.0	13.5	PASS
17924.25000	51.65	---	74.00	22.35	15000.	1000.000	315.0	H	11.0	0.0	35.1	PASS
17924.25000	---	37.92	54.00	16.08	15000.	1000.000	315.0	H	11.0	0.0	35.1	PASS

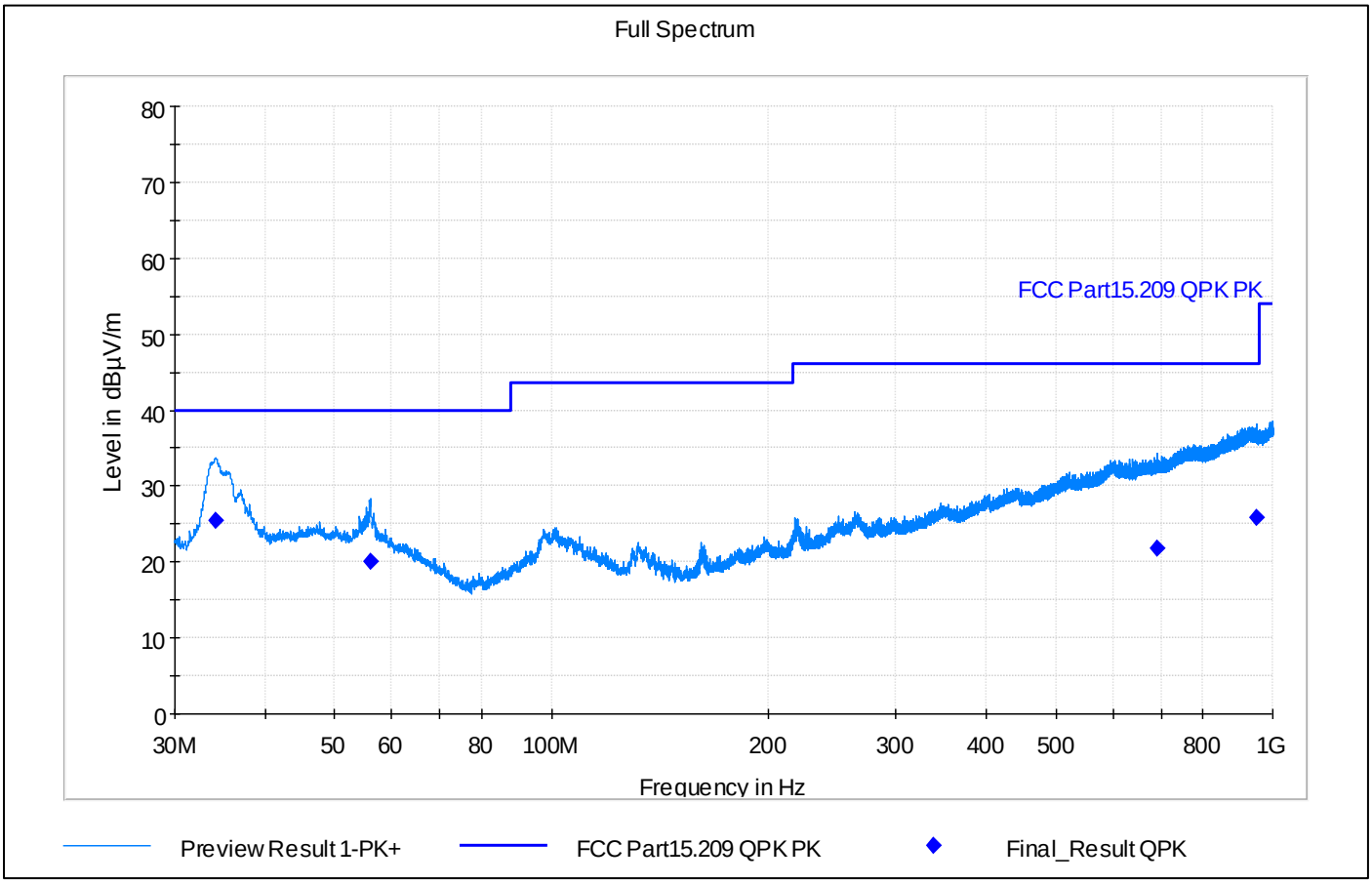
Low channel, 18 – 26 GHz



Final_Result

Frequency (MHz)	MaxPeak	CAverage	Limit (dBµV/m	Margin	Meas. Time	Bandwidth	Height	Pol	Azimuth	Elevation	Corr. (dB/m	Comment
20948.00000	44.08	---	74.00	29.92	3000.	1000.000	327.0	V	202.0	0.0	24.5	PASS
20948.00000	---	30.90	54.00	23.10	3000.	1000.000	327.0	V	202.0	0.0	24.5	PASS
24761.50000	46.09	---	74.00	27.91	3000.	1000.000	183.0	V	189.0	90.0	26.4	PASS
24761.50000	---	32.81	54.00	21.19	3000.	1000.000	183.0	V	189.0	90.0	26.4	PASS
25991.75000	---	33.90	54.00	20.10	3000.	1000.000	238.0	H	250.0	0.0	27.0	PASS
25991.75000	47.14	---	74.00	26.86	3000.	1000.000	238.0	H	250.0	0.0	27.0	PASS

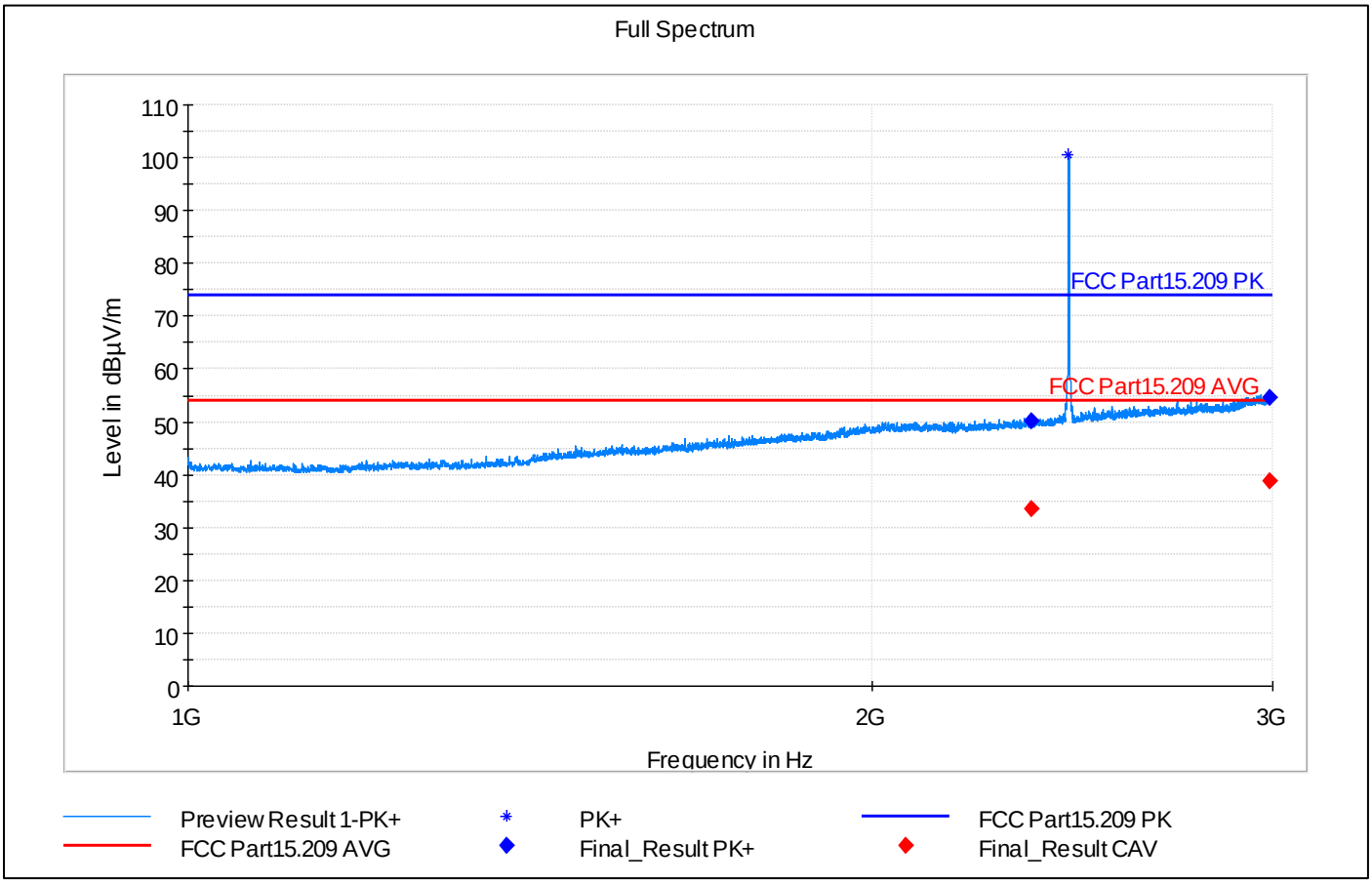
Mid channel, 30 MHz – 1 GHz



Final_Result

Frequency	QuasiPeak	CAverage	Limit (dBµV/m	Margin	Meas. Time	Bandwidth	Height	Pol	Azimuth	Elevation	Corr. (dB/m	Comment
34.140000	25.39	---	40.00	14.61	15000.	120.000	98.0	V	292.0	90.0	17.2	PASS
56.040000	20.13	---	40.00	19.87	15000.	120.000	98.0	V	268.0	0.0	20.6	PASS
693.03000	21.71	---	46.00	24.29	15000.	120.000	398.0	V	191.0	0.0	30.4	PASS
949.14000	25.83	---	46.00	20.17	15000.	120.000	313.0	V	96.0	90.0	34.0	PASS

Mid channel, 1 - 3 GHz



Note: Frequency 2440,000 MHz is excluded from spurious domain measurements and ignored. See table below.

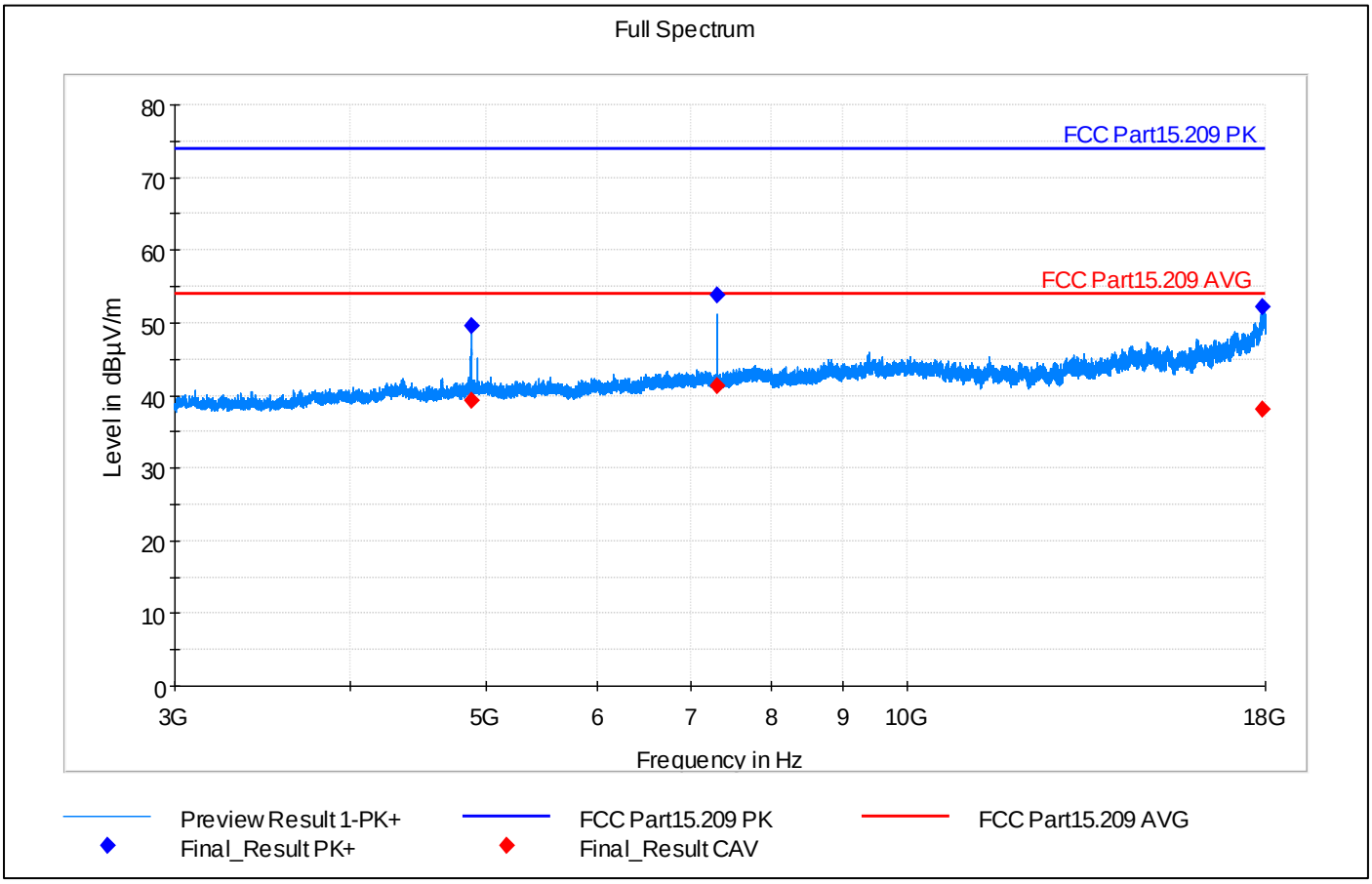
Critical_Freqs

Frequency (MHz)	Comment
2440.000000	EUT BLE Mid Ch TX Signal, IGNORED

Final_Result

Frequency (MHz)	MaxPeak	CAverage	Limit (dBµV/m	Margin	Meas. Time	Bandwidth	Height	Pol	Azimuth	Elevation	Corr. (dB/m	Comment
2348.75000	50.24	---	74.00	23.76	15000.	1000.000	282.0	V	253.0	0.0	37.7	PASS
2348.75000	---	33.59	54.00	20.41	15000.	1000.000	282.0	V	253.0	0.0	37.7	PASS
2990.75000	---	38.93	54.00	15.07	15000.	1000.000	117.0	H	319.0	0.0	40.9	PASS
2990.75000	54.52	---	74.00	19.48	15000.	1000.000	117.0	H	319.0	0.0	40.9	PASS

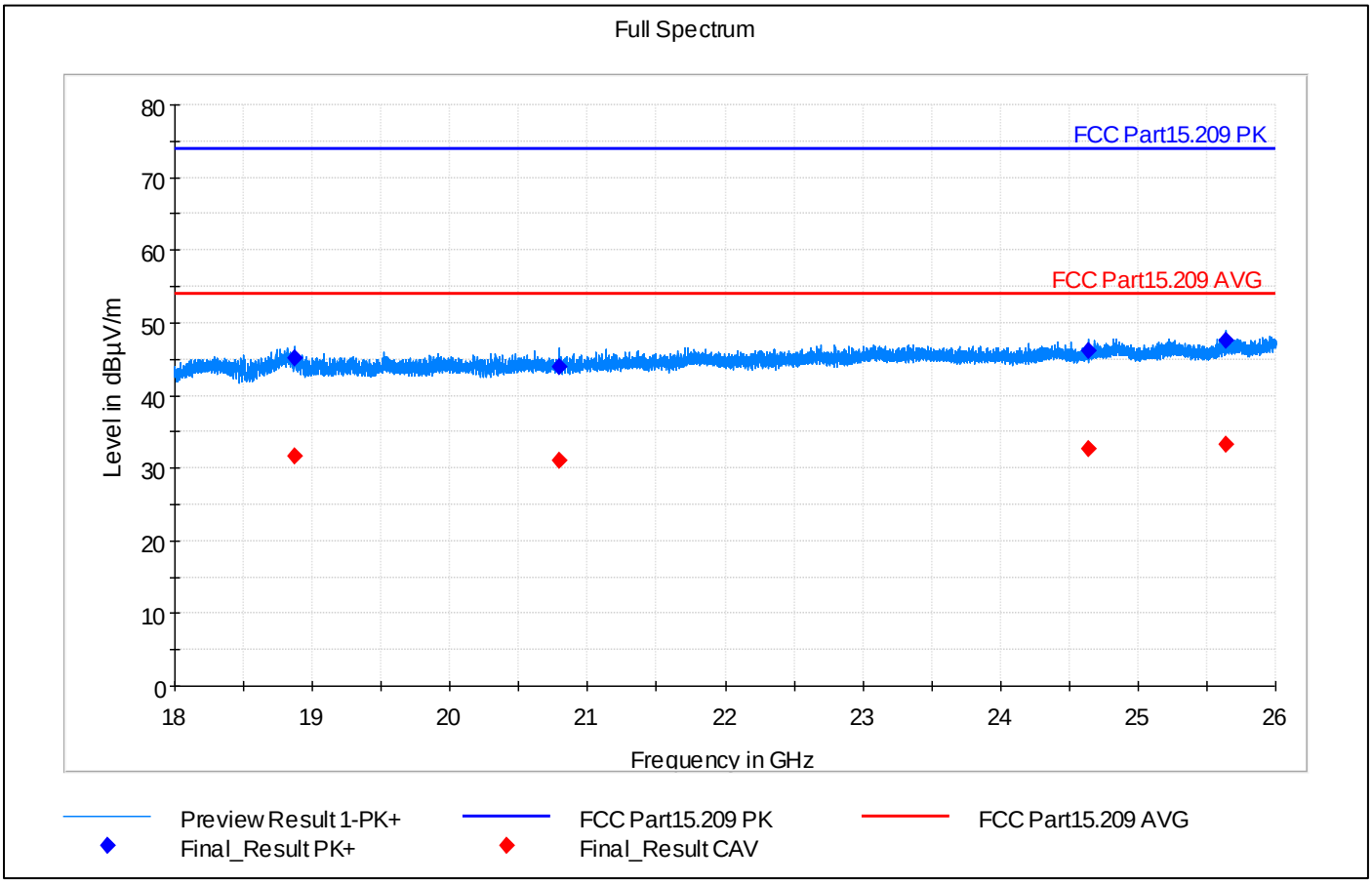
Mid channel, 3-18 GHz



Final_Result

Frequency (MHz)	MaxPeak	CAverage	Limit (dBµV/	Margin	Meas. Time	Bandwidth	Height	Pol	Azimuth	Elevation	Corr. (dB/m	Comment
4880.000000	---	39.32	54.00	14.68	15000.	1000.000	236.0	H	176.0	90.0	9.5	PASS
4880.000000	49.56	---	74.00	24.44	15000.	1000.000	236.0	H	176.0	90.0	9.5	PASS
7320.750000	---	41.24	54.00	12.76	15000.	1000.000	218.0	H	236.0	90.0	13.8	PASS
7320.750000	53.74	---	74.00	20.26	15000.	1000.000	218.0	H	236.0	90.0	13.8	PASS
17924.50000	52.10	---	74.00	21.90	15000.	1000.000	322.0	H	166.0	0.0	35.2	PASS
17924.50000	---	38.14	54.00	15.86	15000.	1000.000	322.0	H	166.0	0.0	35.2	PASS

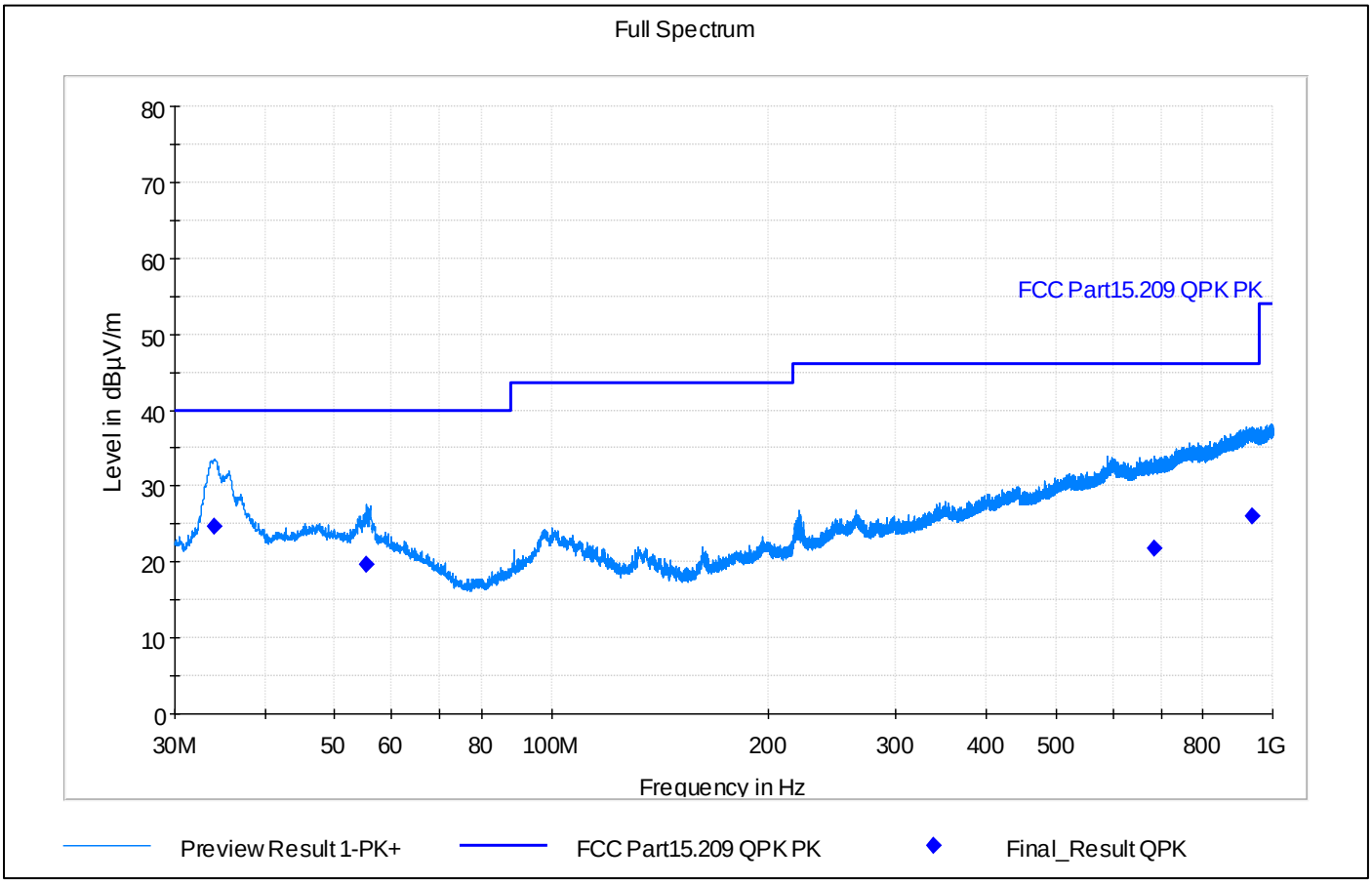
Mid channel, 18 – 26 GHz



Final_Result

Frequency (MHz)	MaxPeak	CAverage	Limit (dBµV/m	Margin	Meas. Time	Bandwidth	Height	Pol	Azimuth	Elevation	Corr. (dB/m	Comment
18872.25000	---	31.63	54.00	22.37	3000.	1000.000	410.0	H	179.0	0.0	23.5	PASS
18872.25000	45.11	---	74.00	28.89	3000.	1000.000	410.0	H	179.0	0.0	23.5	PASS
20795.00000	43.91	---	74.00	30.09	3000.	1000.000	324.0	H	4.0	0.0	24.3	PASS
20795.00000	---	31.05	54.00	22.95	3000.	1000.000	324.0	H	4.0	0.0	24.3	PASS
24643.75000	---	32.70	54.00	21.30	3000.	1000.000	410.0	H	81.0	90.0	26.3	PASS
24643.75000	46.19	---	74.00	27.81	3000.	1000.000	410.0	H	81.0	90.0	26.3	PASS
25640.75000	47.55	---	74.00	26.45	3000.	1000.000	187.0	H	72.0	0.0	26.7	PASS
25640.75000	---	33.26	54.00	20.74	3000.	1000.000	187.0	H	72.0	0.0	26.7	PASS

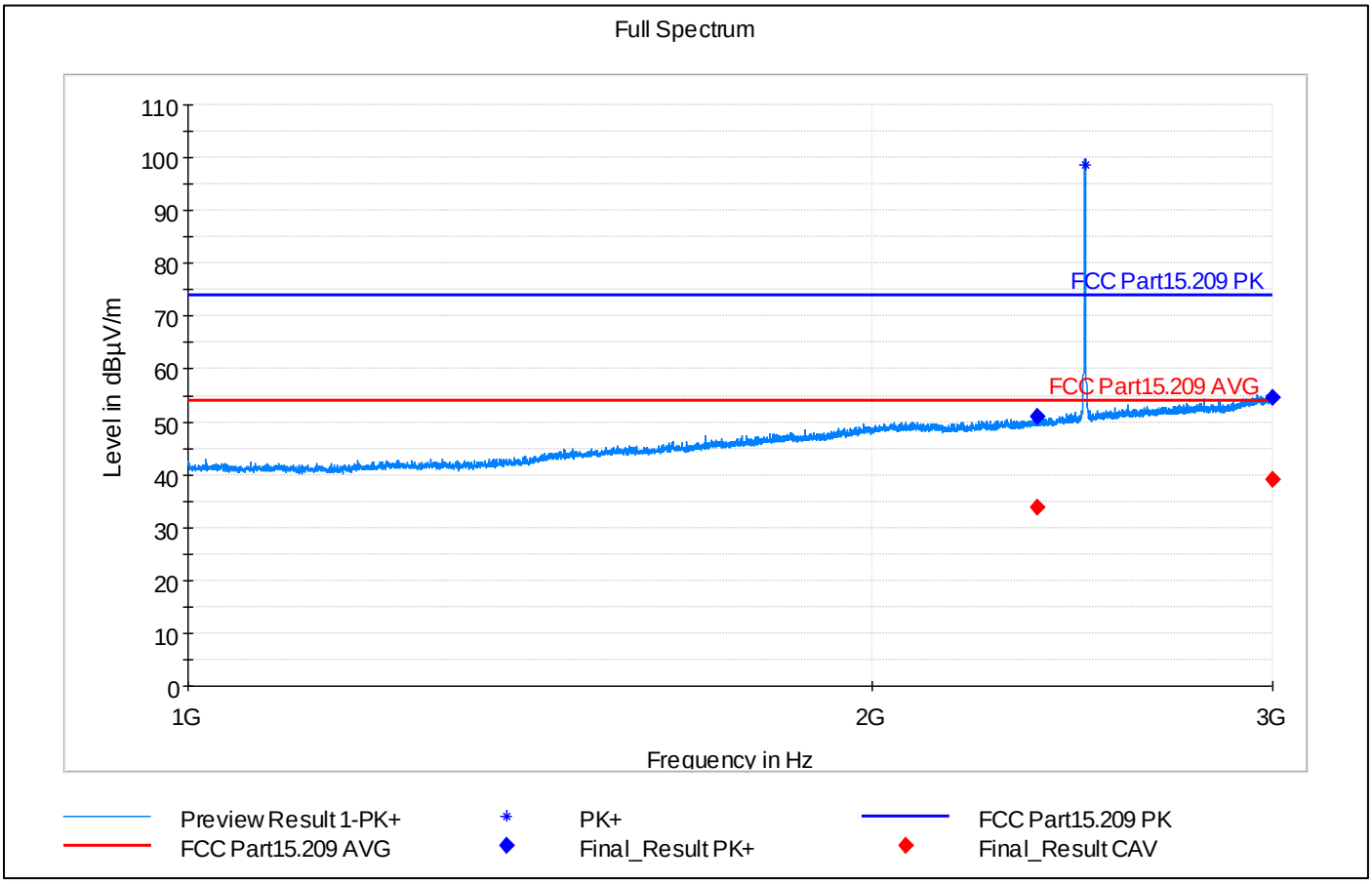
High channel, 30 MHz – 1 GHz



Final_Result

Frequency	QuasiPeak	CAverage	Limit (dBµV/m	Margin	Meas. Time	Bandwidth	Height	Pol	Azimuth	Elevation	Corr. (dB/m	Comment
34.080000	24.64	---	40.00	15.36	15000.	120.000	98.0	V	218.0	90.0	17.2	PASS
684.66000	21.82	---	46.00	24.18	15000.	120.000	247.0	H	202.0	90.0	30.4	PASS
937.68000	26.02	---	46.00	19.98	15000.	120.000	277.0	H	67.0	90.0	34.1	PASS
55.320000	19.75	---	40.00	20.25	15000.	120.000	110.0	V	313.0	90.0	20.7	PASS

High channel, 1 – 3 GHz



Note: Frequency 2480,500 MHz is excluded from spurious domain measurements and ignored. See table below.

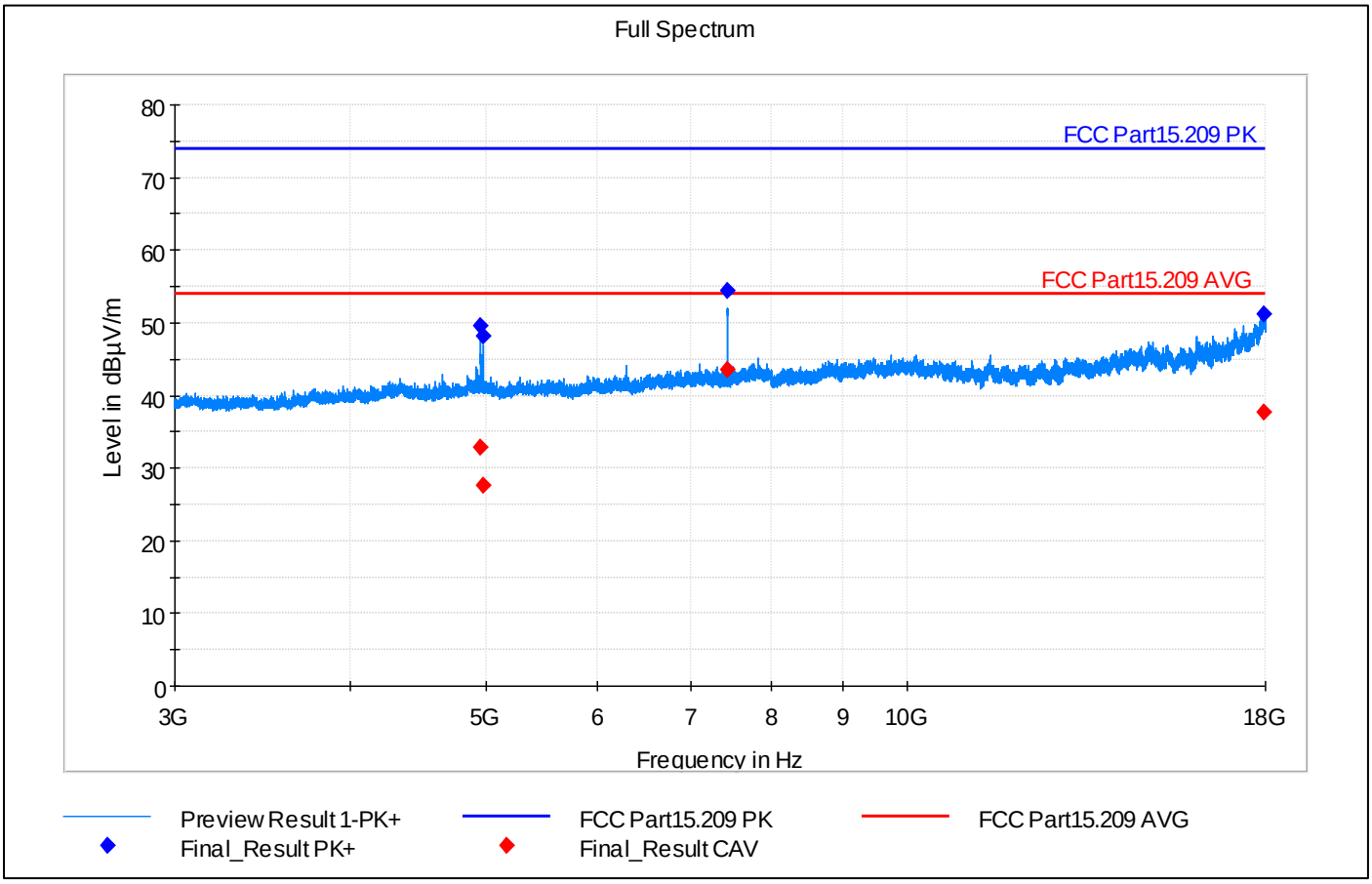
Critical_Freqs

Frequency (MHz)	Comment
2480.500000	EUT BLE High Ch TX Signal, IGNORED

Final_Result

Frequency (MHz)	MaxPeak	CAverage	Limit (dBµV/m	Margin	Meas. Time	Bandwidth	Height	Pol	Azimuth	Elevation	Corr. (dB/m	Comment
2364.00000	51.04	---	74.00	22.96	15000.	1000.000	140.0	H	41.0	90.0	37.9	PASS
2364.00000	---	33.72	54.00	20.28	15000.	1000.000	140.0	H	41.0	90.0	37.9	PASS
2999.50000	---	39.06	54.00	14.94	15000.	1000.000	372.0	H	292.0	90.0	41.1	PASS
2999.50000	54.71	---	74.00	19.29	15000.	1000.000	372.0	H	292.0	90.0	41.1	PASS

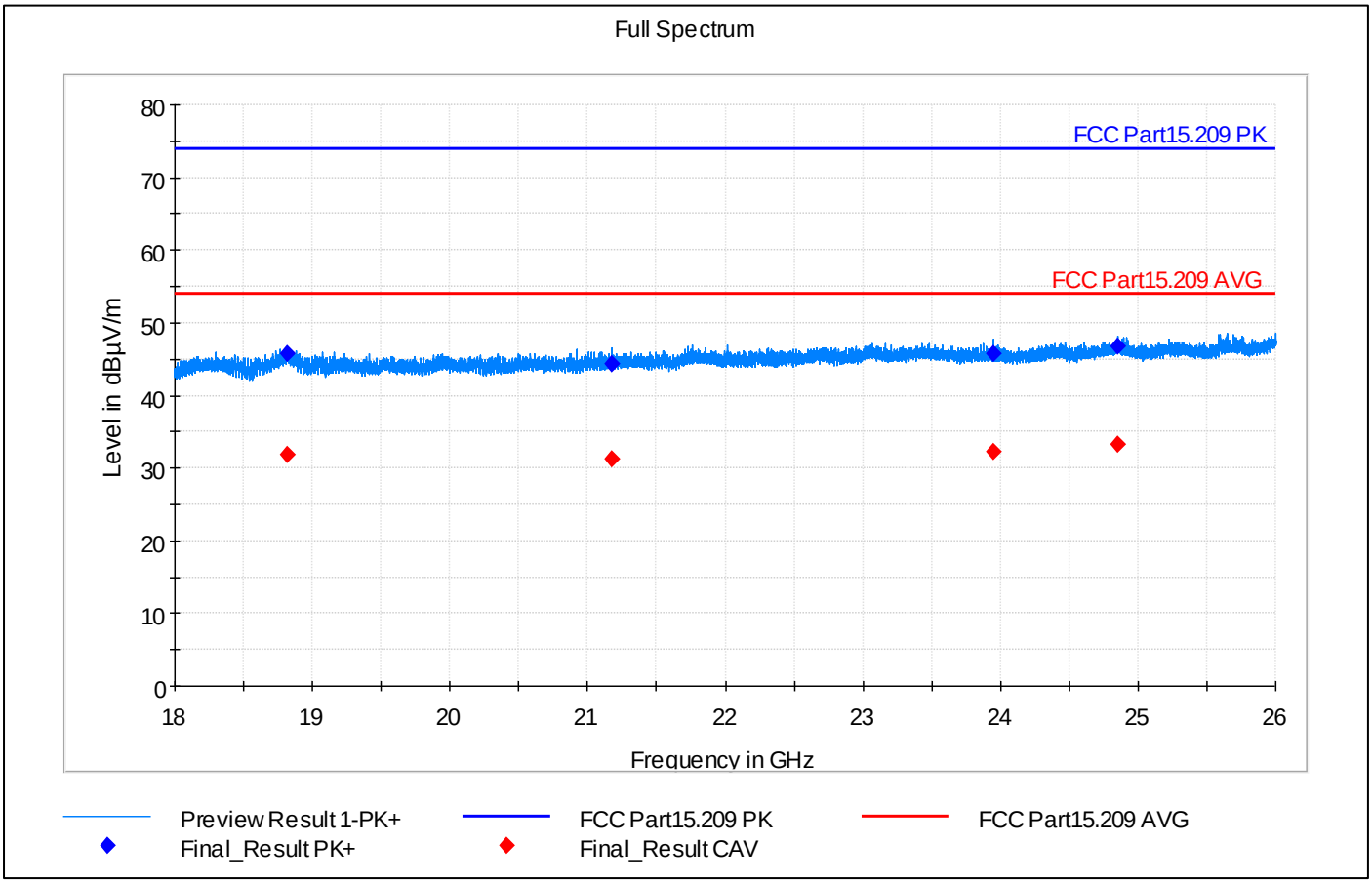
High channel, 3 – 18 GHz



Final_Result

Frequency (MHz)	MaxPeak	CAverage	Limit (dBµV/	Margin	Meas. Time	Bandwidth	Height	Pol	Azimuth	Elevation	Corr. (dB/m	Comment
4960.000000	49.55	---	74.00	24.45	15000.	1000.000	110.0	H	264.0	90.0	9.2	PASS
4960.000000	---	32.93	54.00	21.07	15000.	1000.000	110.0	H	264.0	90.0	9.2	PASS
4983.250000	---	27.69	54.00	26.31	15000.	1000.000	104.0	V	90.0	0.0	9.2	PASS
4983.250000	48.26	---	74.00	25.74	15000.	1000.000	104.0	V	90.0	0.0	9.2	PASS
7439.250000	54.46	---	74.00	19.54	15000.	1000.000	115.0	H	234.0	90.0	13.5	PASS
7439.250000	---	43.48	54.00	10.52	15000.	1000.000	115.0	H	234.0	90.0	13.5	PASS
17940.25000	---	37.76	54.00	16.24	15000.	1000.000	118.0	H	132.0	90.0	34.7	PASS
17940.25000	51.28	---	74.00	22.72	15000.	1000.000	118.0	H	132.0	90.0	34.7	PASS

High channel, 18 – 26 GHz



Final_Result

Frequency (MHz)	MaxPeak	CAverage	Limit (dBµV/m	Margin	Meas. Time	Bandwidth	Height	Pol	Azimuth	Elevation	Corr. (dB/m	Comment
18816.25000	45.84	---	74.00	28.16	3000.	1000.000	165.0	V	292.0	90.0	23.5	PASS
18816.25000	---	31.83	54.00	22.17	3000.	1000.000	165.0	V	292.0	90.0	23.5	PASS
21178.25000	---	31.21	54.00	22.79	3000.	1000.000	142.0	H	282.0	0.0	24.5	PASS
21178.25000	44.37	---	74.00	29.63	3000.	1000.000	142.0	H	282.0	0.0	24.5	PASS
23947.75000	---	32.23	54.00	21.77	3000.	1000.000	255.0	H	79.0	0.0	25.8	PASS
23947.75000	45.77	---	74.00	28.23	3000.	1000.000	255.0	H	79.0	0.0	25.8	PASS
24851.50000	46.66	---	74.00	27.34	3000.	1000.000	104.0	V	171.0	90.0	26.4	PASS
24851.50000	---	33.25	54.00	20.75	3000.	1000.000	104.0	V	171.0	90.0	26.4	PASS

17. Receiver spurious emissions, radiated

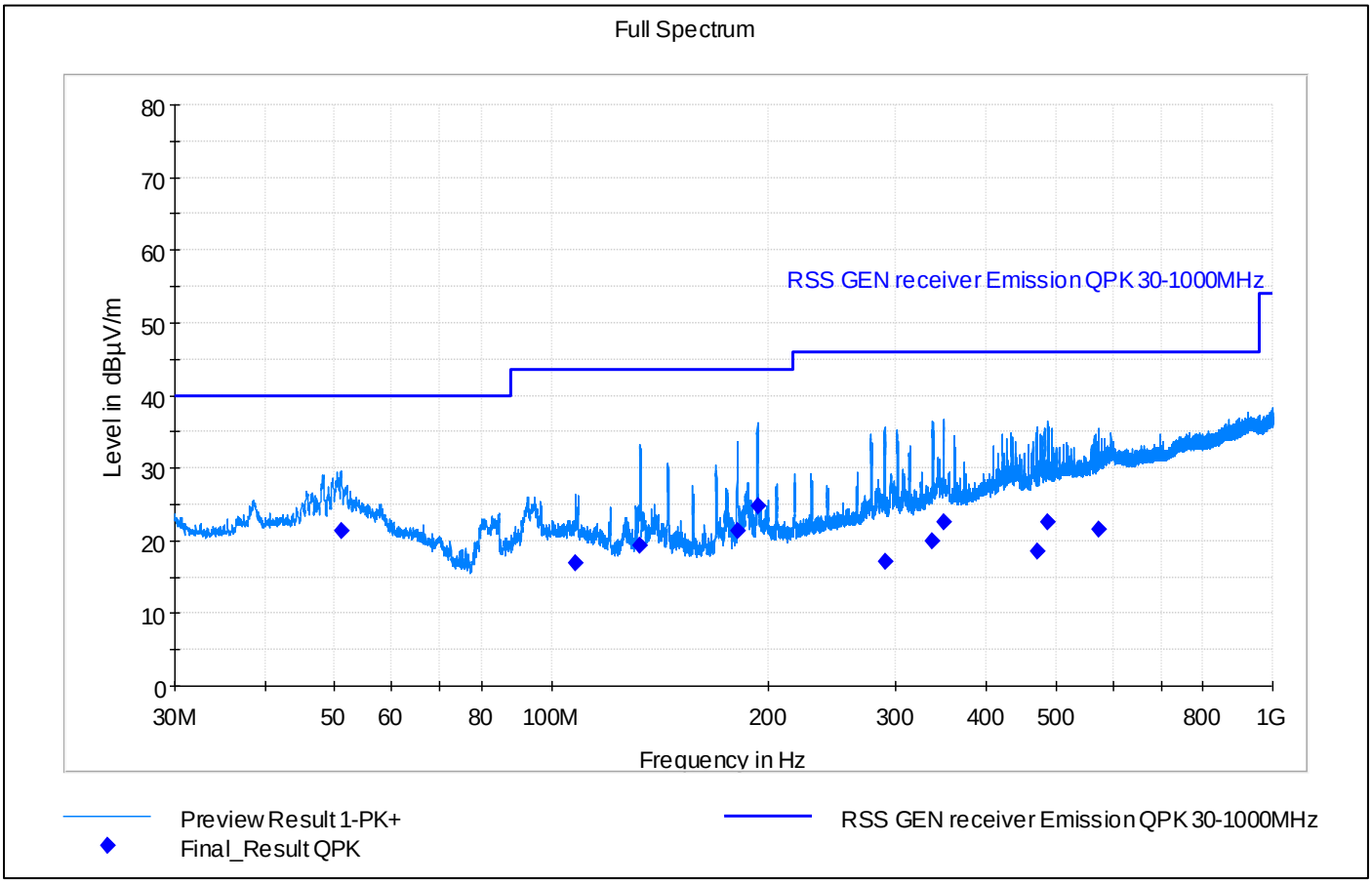
Reference: ISED RSS-247, Issue 2 (section 3.1)
Test method: ANSI C63.4-2014 (8.1 – 8.3)

Limits			
Frequency (MHz)	Detector	Field strength (uV/m)	Measurement distance (m)
30 – 88	Quasi-Peak	100	3
88 - 216	Quasi-Peak	150	3
216 - 960	Quasi-Peak	200	3
960 - 1000	Quasi-Peak	500	3
> 1000	Average	500	3

Test procedure
1. EUT is placed on a non conducting support at the center of a turn table 0.8m above the ground 2. EUT set to test mode 3. The receiver is set to peak detection with max hold 4. The EUT is rotated through 360 degrees (orientation varied), measurements were made in both horizontal and vertical planes of polarization 5. Found peak values were further maximized by adjusting turntable position ±22,5 degrees around detected value and scanning the antenna height 1 to 4m 6. For maximized values, final measurement was done with the corresponding final detector.

Operation mode(s)	Configuration	Test Verdict
Bluetooth LE RX	Mid channel, 2440 MHz	PASS

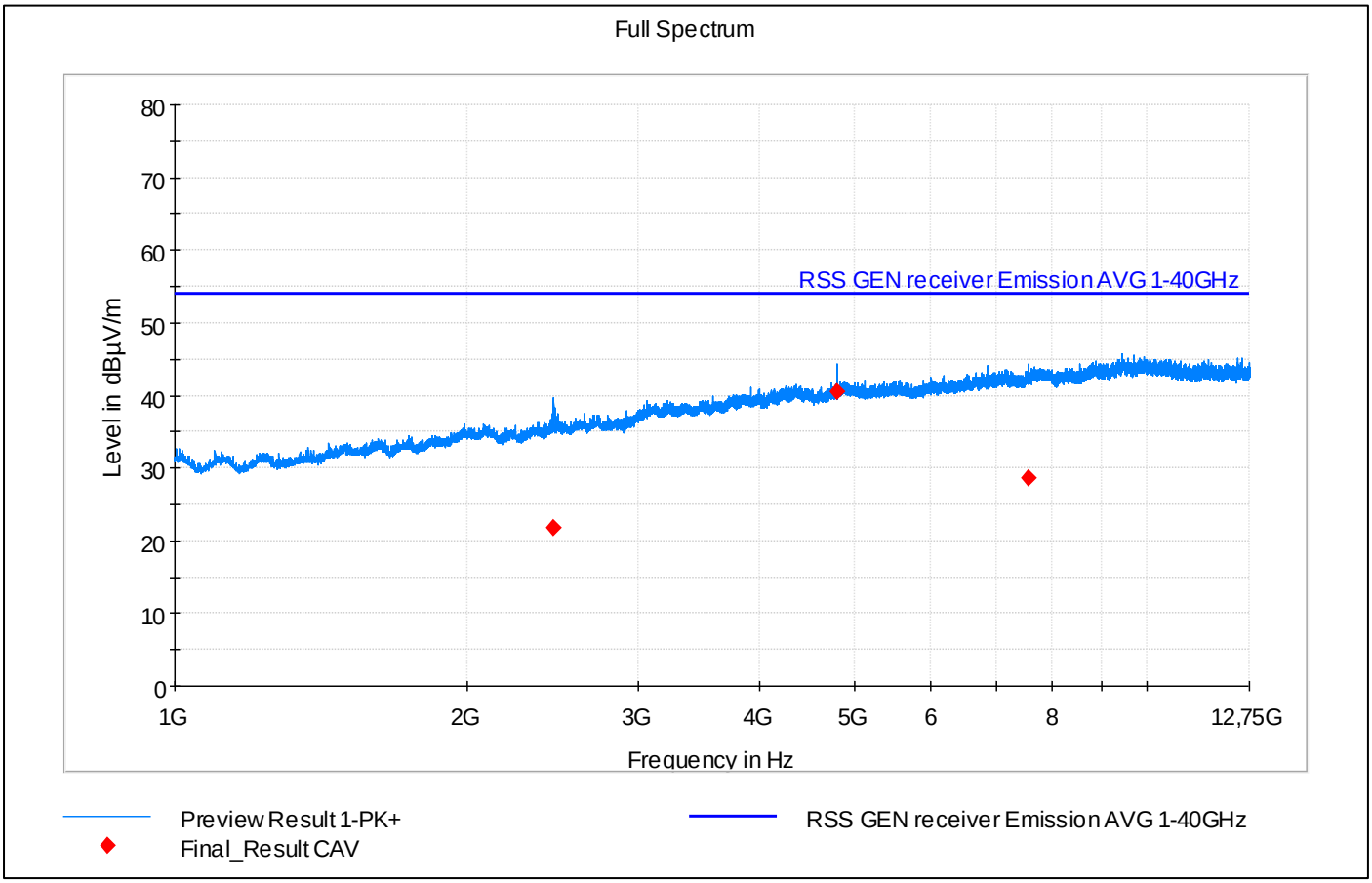
Mid channel, 30 MHz – 1 GHz



Final_Result

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Elevation (deg)	Corr. (dB/m)	Comment
50.970000	21.31	40.00	18.69	15000.0	120.000	112.0	V	19.0	0.0	21.0	PASS
108.000000	16.85	43.50	26.65	15000.0	120.000	162.0	V	38.0	0.0	19.4	PASS
132.660000	19.31	43.50	24.19	15000.0	120.000	106.0	V	313.0	0.0	16.4	PASS
181.200000	21.43	43.50	22.07	15000.0	120.000	101.0	V	280.0	0.0	17.8	PASS
192.870000	24.71	43.50	18.79	15000.0	120.000	105.0	V	313.0	0.0	19.4	PASS
289.500000	17.05	46.00	28.95	15000.0	120.000	129.0	H	83.0	0.0	22.1	PASS
337.680000	19.89	46.00	26.11	15000.0	120.000	112.0	H	157.0	0.0	23.8	PASS
349.590000	22.63	46.00	23.37	15000.0	120.000	101.0	H	183.0	90.0	24.4	PASS
470.550000	18.59	46.00	27.41	15000.0	120.000	133.0	H	213.0	0.0	26.3	PASS
488.310000	22.57	46.00	23.43	15000.0	120.000	150.0	H	137.0	0.0	26.9	PASS
573.120000	21.63	46.00	24.37	15000.0	120.000	133.0	H	257.0	0.0	28.6	PASS

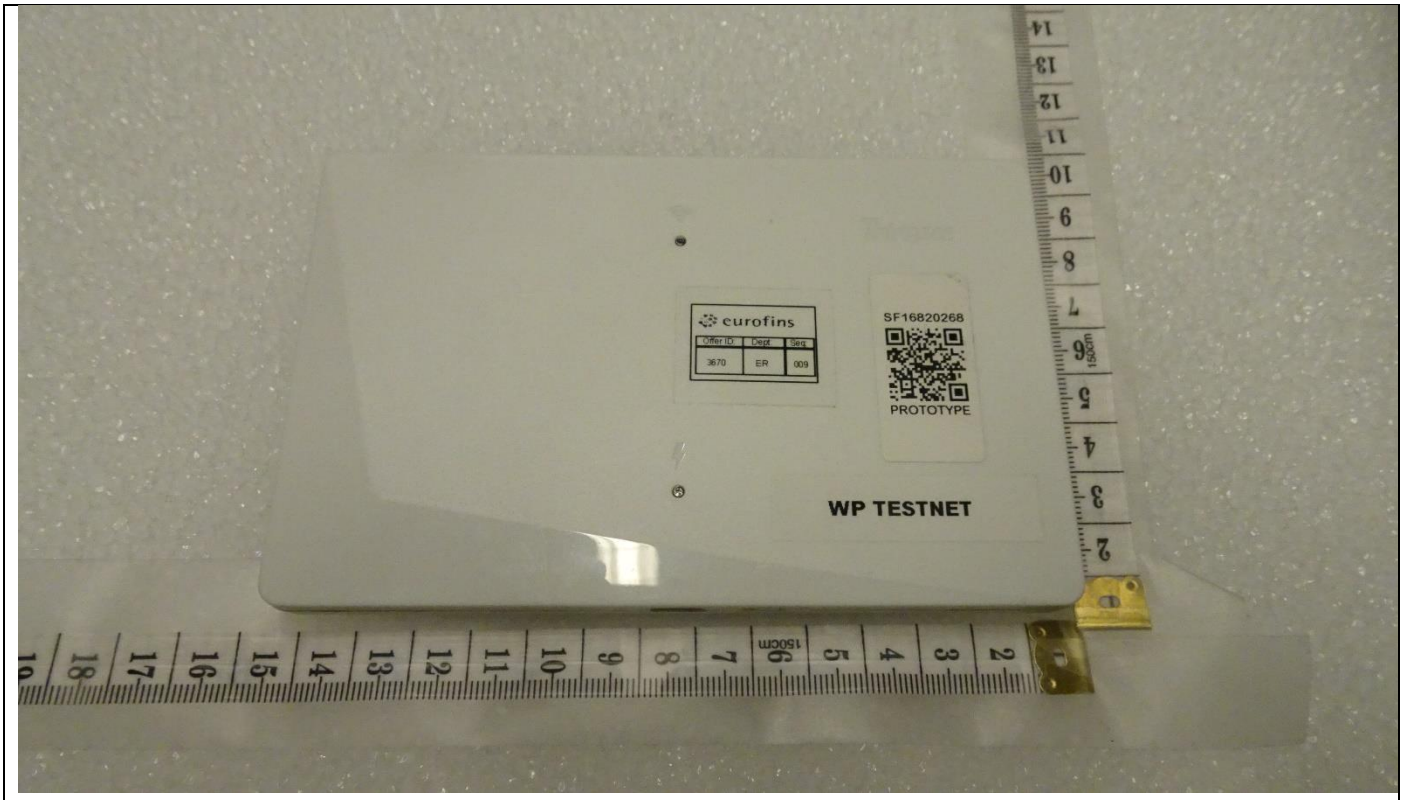
High channel, 1 GHz – 12,75 GHz



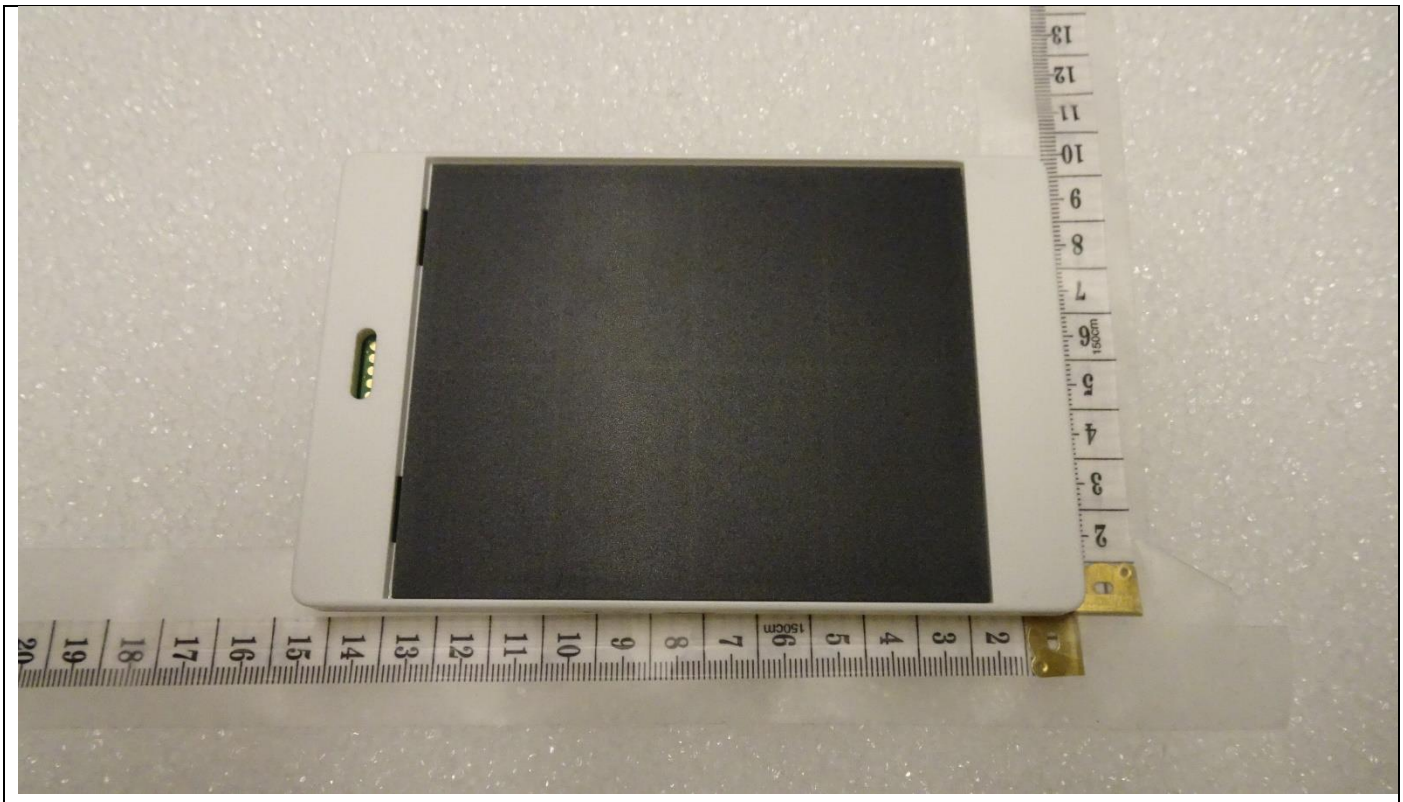
Final_Result

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)	Comment
2454.750000	---	21.72	54.00	32.28	500.0	1000.000	209.0	H	198.0	-0.2	PASS
4802.000000	---	40.54	54.00	13.46	500.0	1000.000	100.0	V	67.0	8.2	PASS
7558.000000	---	28.68	54.00	25.32	500.0	1000.000	232.0	V	292.0	13.5	PASS

18. Photographs – Equipment External

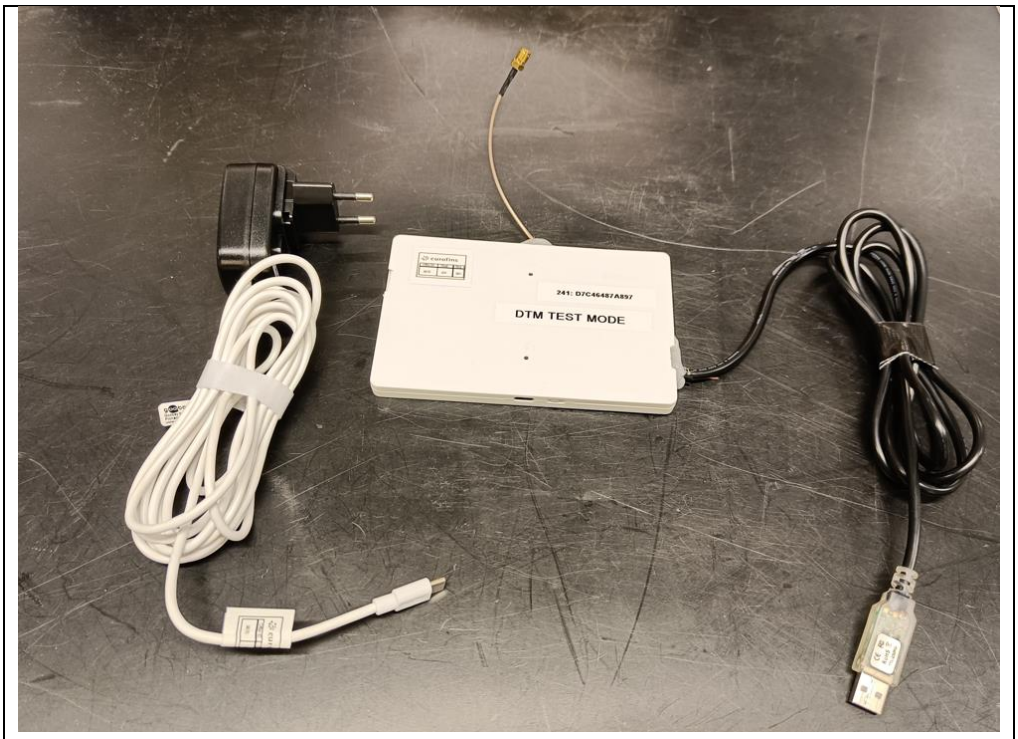


Picture 1, EUT Top view

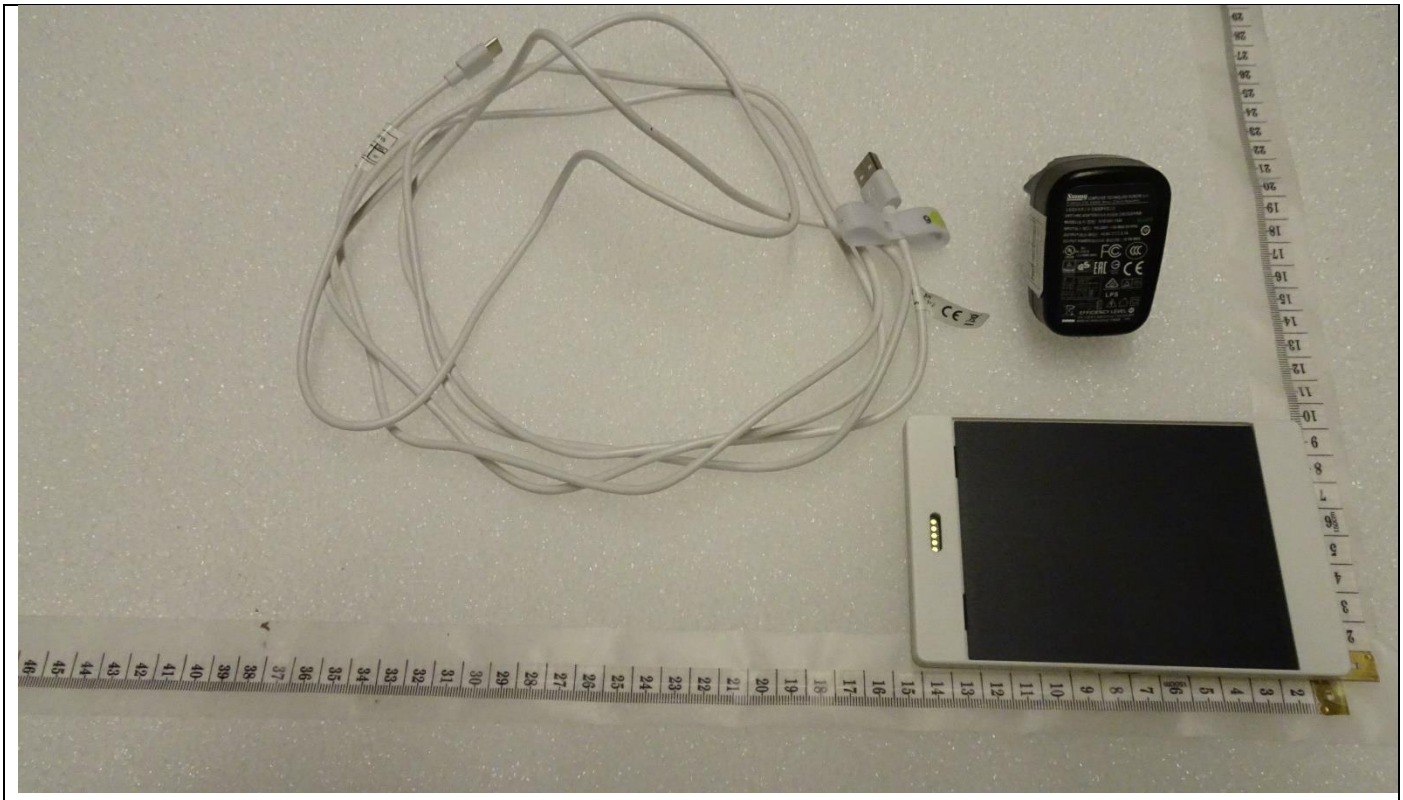


Picture 2, EUT Bottom view

Picture 3, EUT USB port

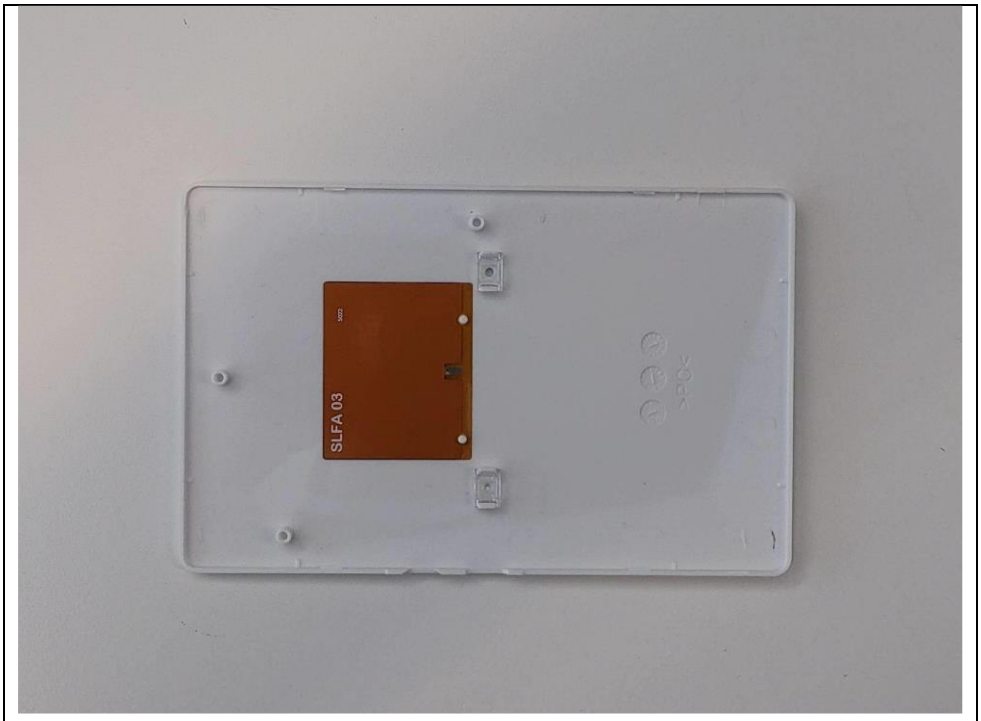


Picture 4, Conducted RF EUT with auxiliary equipment

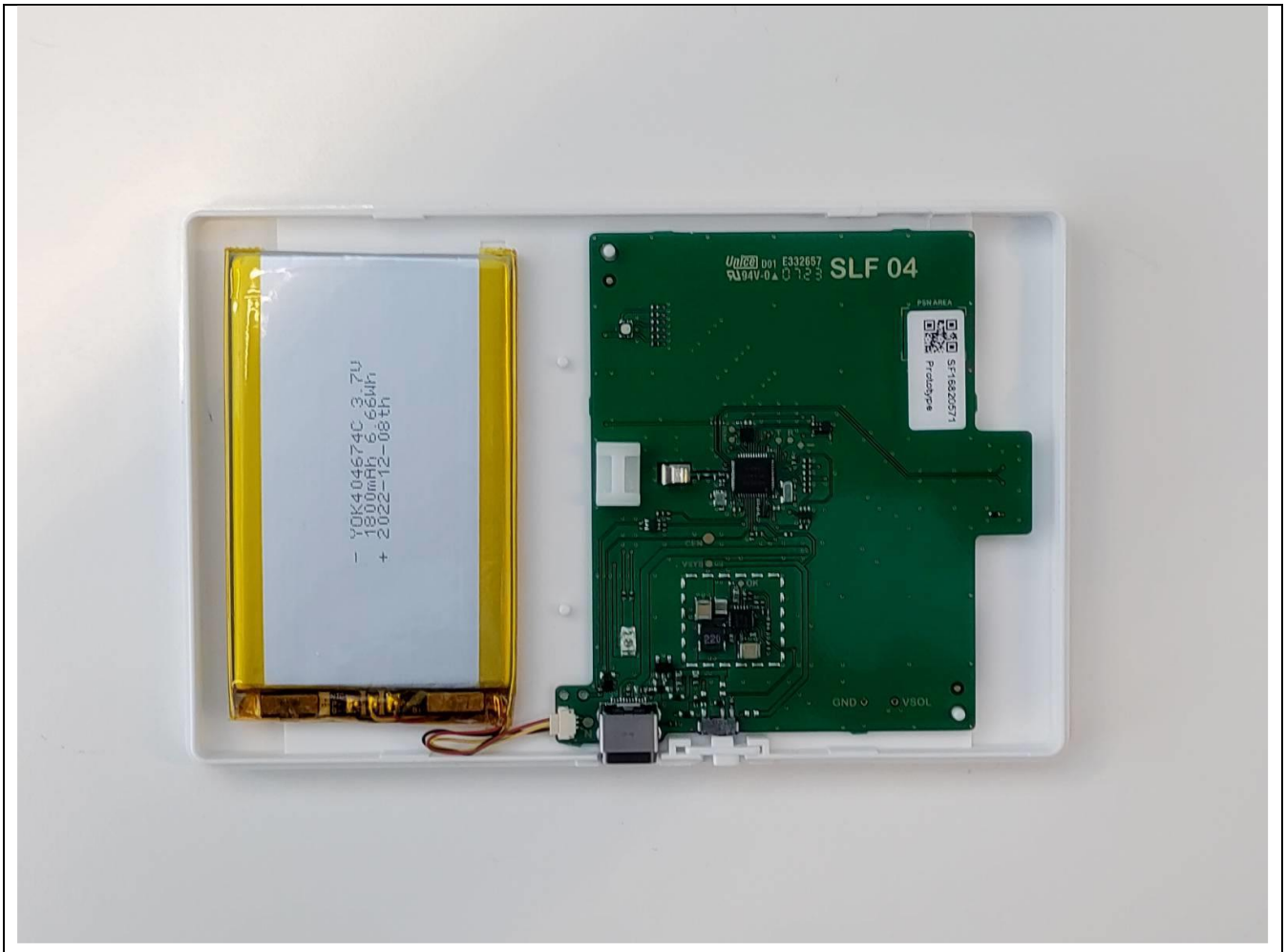


Picture 5, EUT with auxiliary equipment

19. Photographs – Equipment Internal (provided by customer)

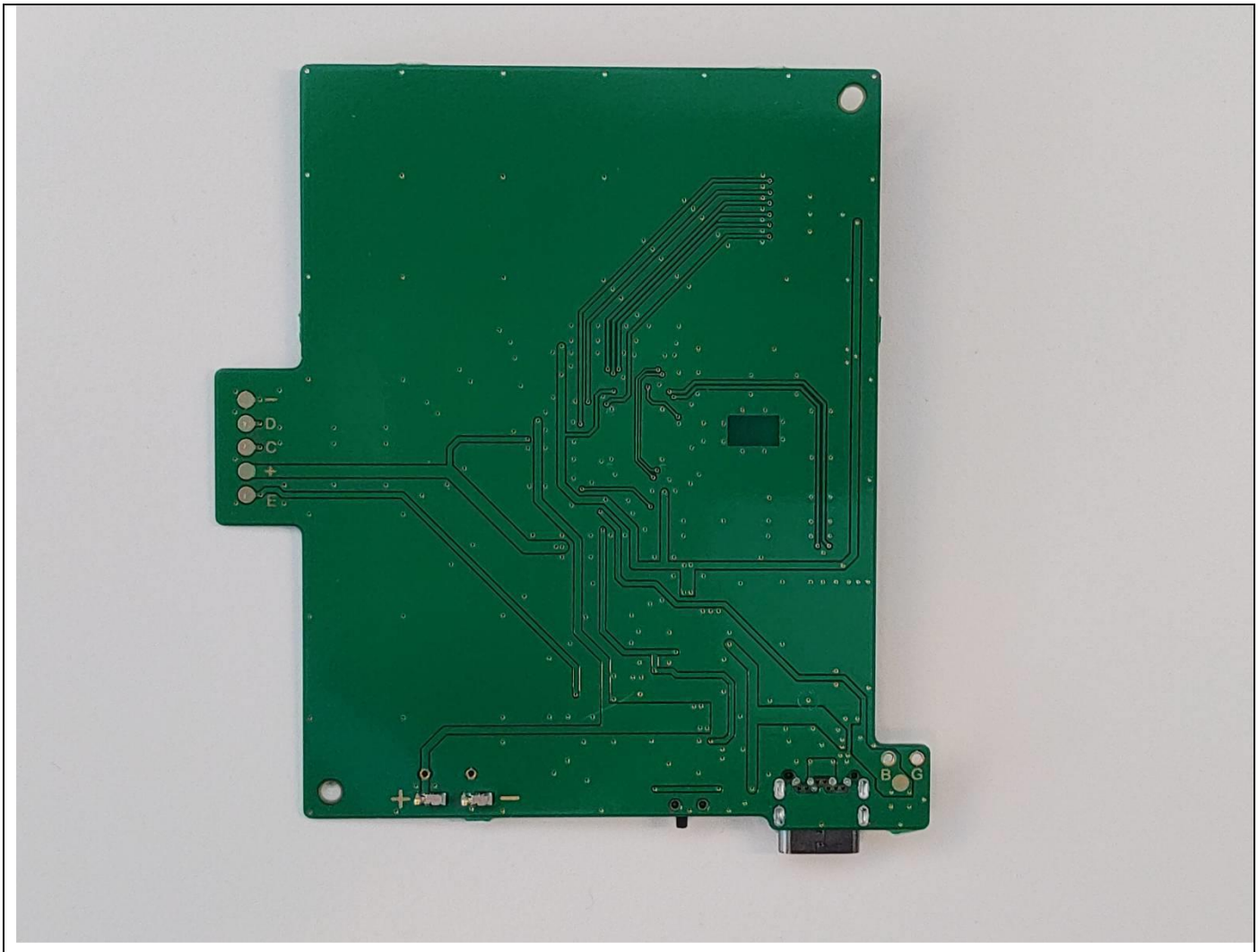


Picture 6, EUT a cover inside with antenna



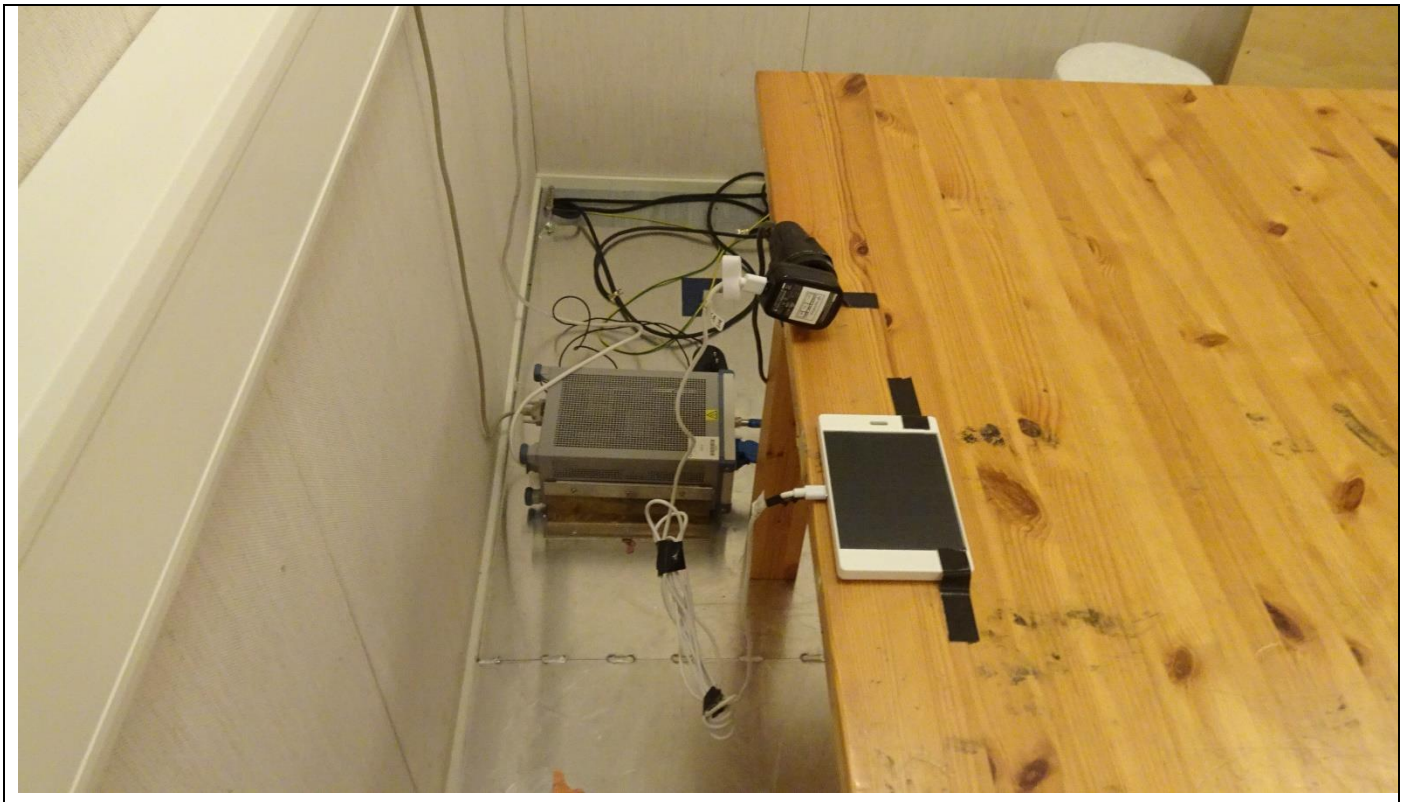
Picture 7, EUT PCB and battery inside B cover

Picture 8, EUT PCB top

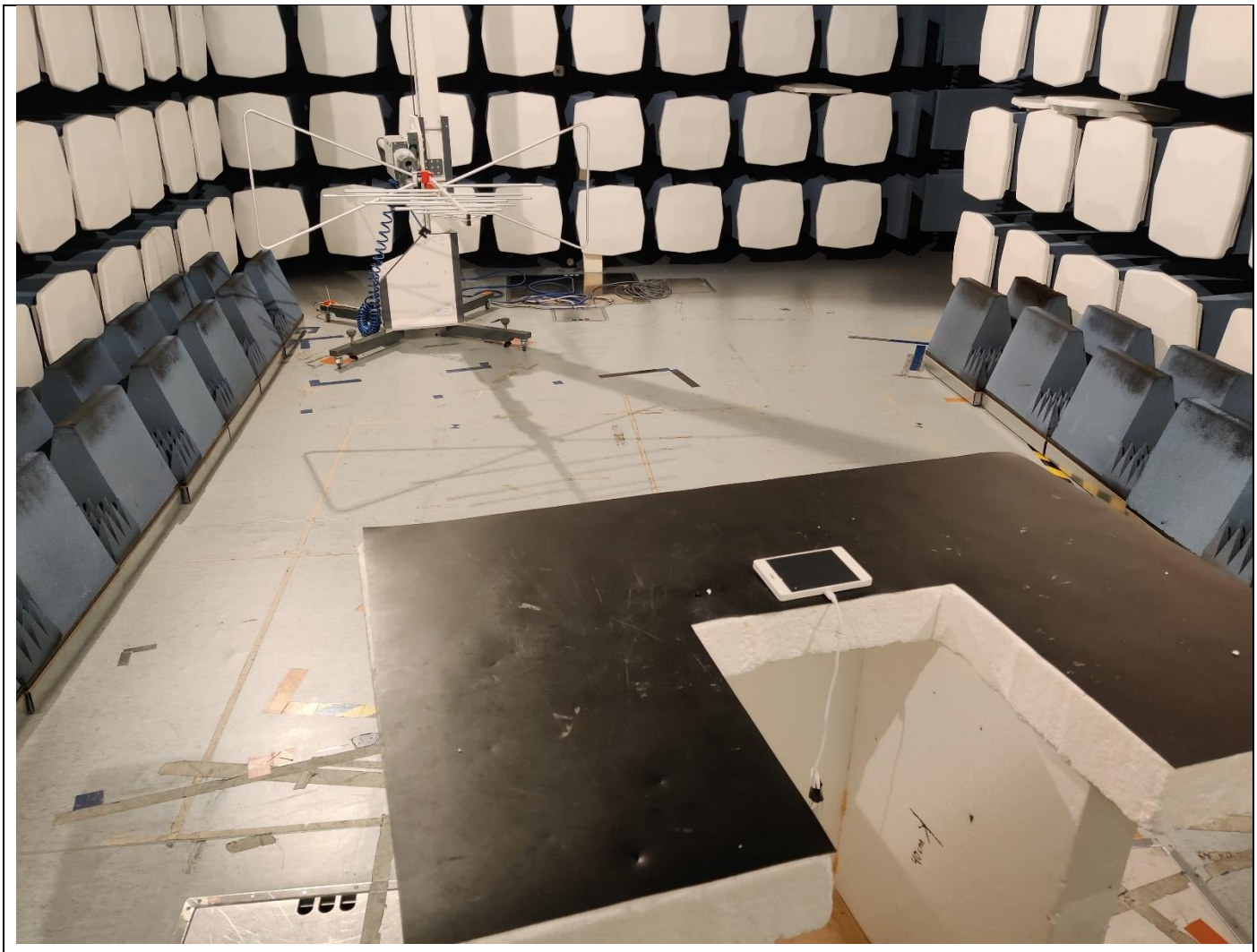


Picture 9, PCB bottom

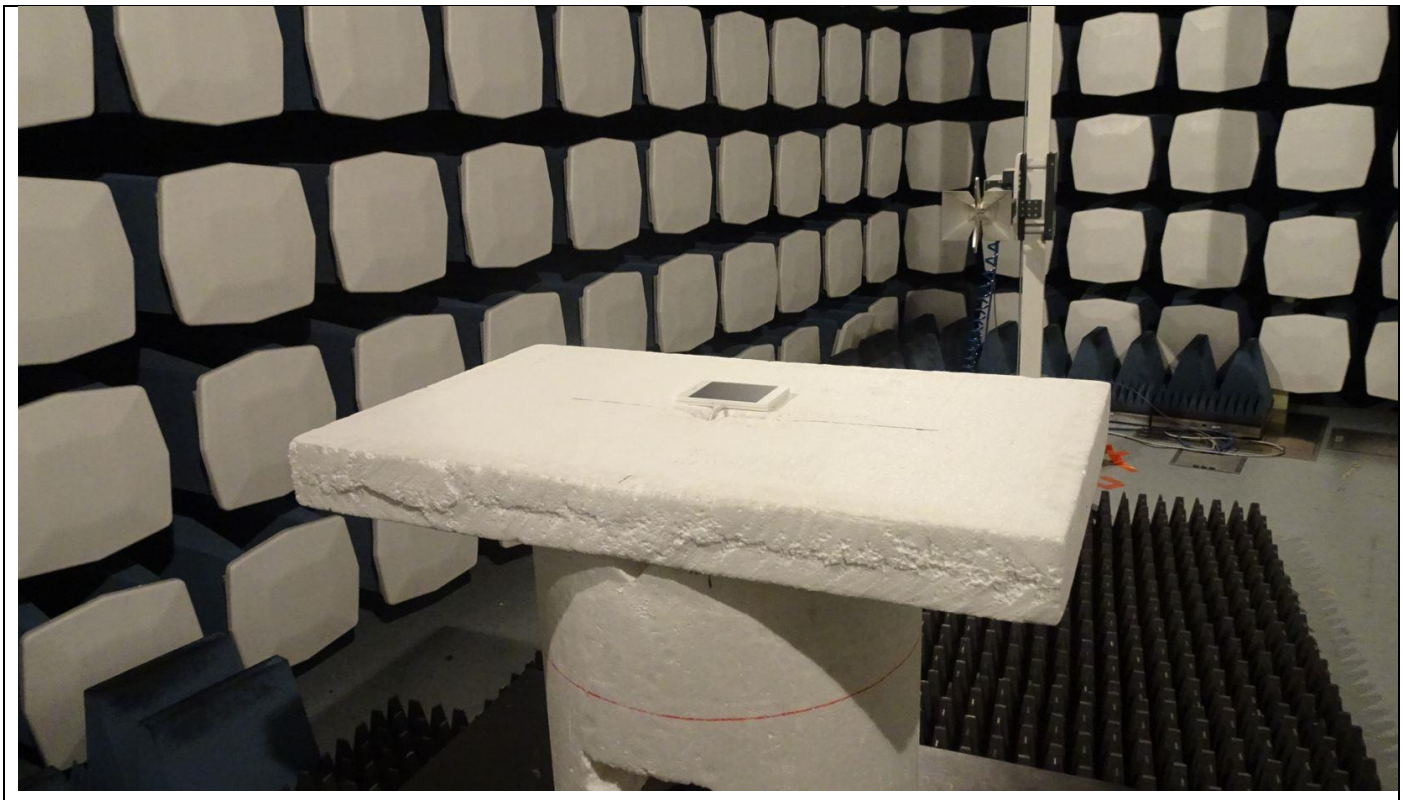
20. Photographs – Test Setups



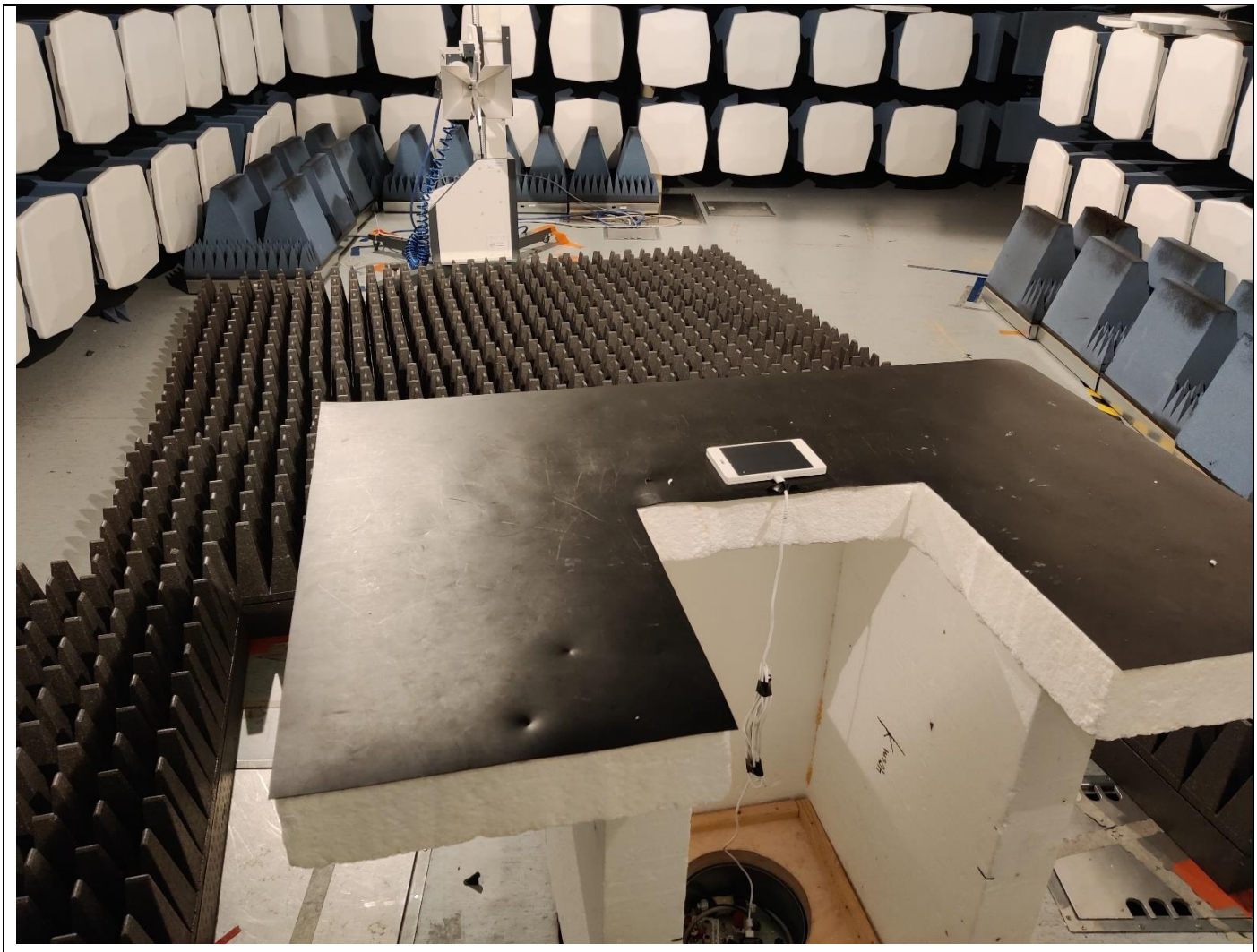
Picture 10, AC Power Line Conducted Emissions



Picture 11, Radiated Spurious Emissions, common setup, TX and RX 30 - 1000 MHz

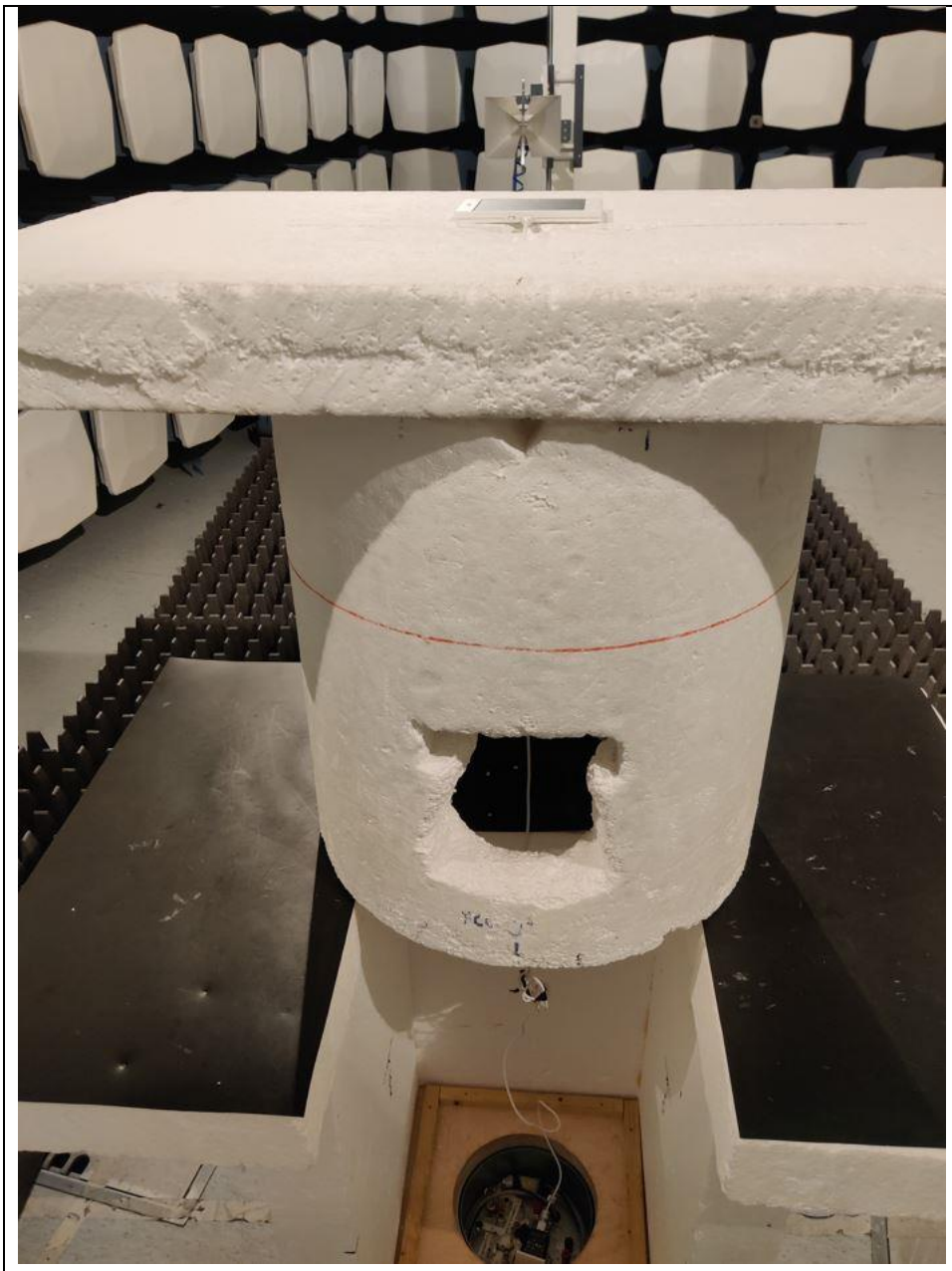


Picture 12, Radiated Spurious Emissions, common setup, TX, 1 – 26 GHz

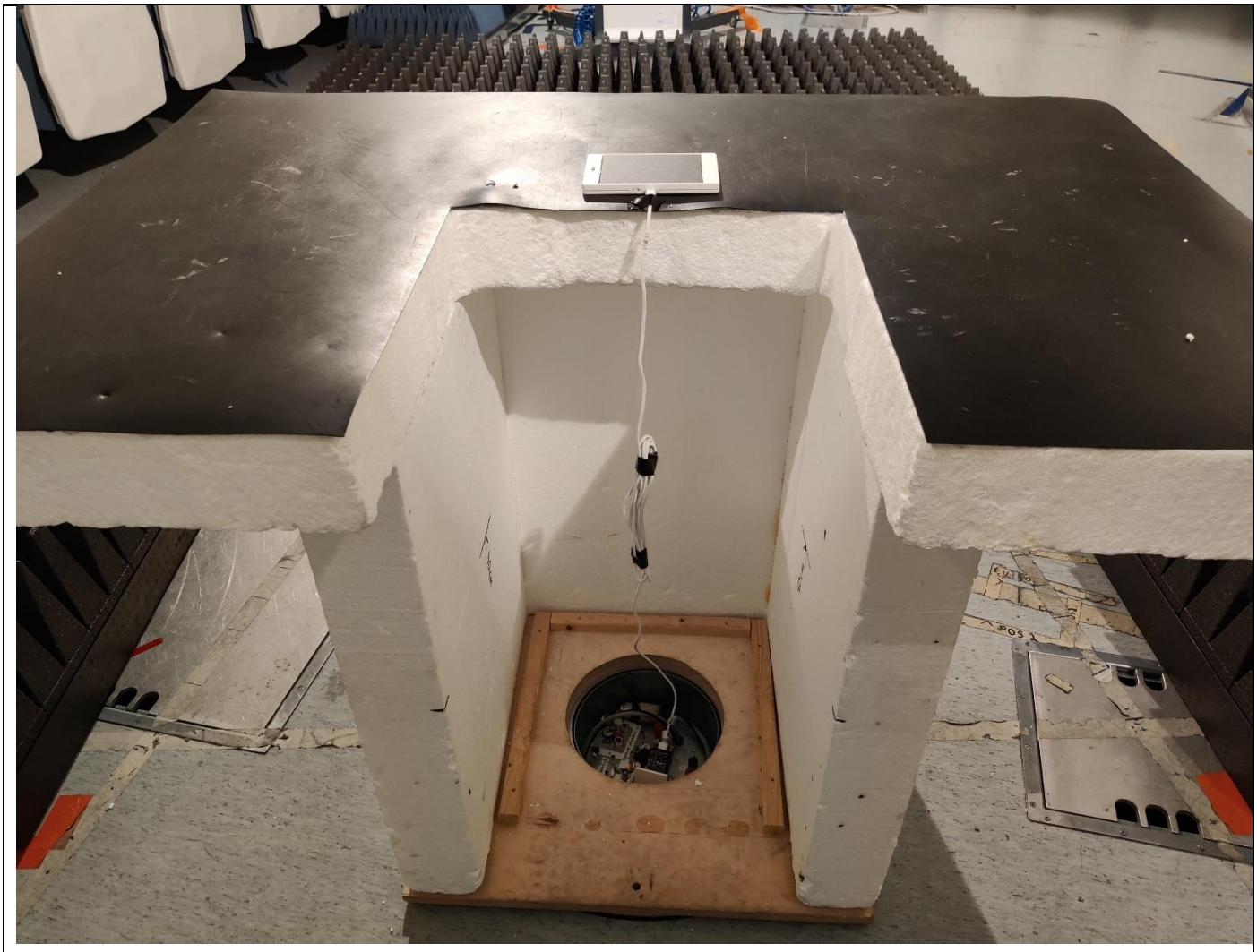


Picture 13, Radiated Spurious Emissions, common setup, RX, 1 – 12,75 MHz

Picture 14, Radiated Spurious Emissions, EUT setup, TX and RX 30 – 1000 MHz



Picture 15, Radiated Spurious Emissions, EUT setup, TX 1 – 26 GHz



Picture 16, Radiated Spurious Emissions, EUT setup, RX 1 – 12,75 GHz