

Limit

According to section 15.209(a),

Except as provided elsewhere in this subpart, the emissions from an intentional radiator shall not exceed the field strength levels specified in the following table:

Frequency (MHz)	Field strength ($\mu\text{V}/\text{m}$)	Measurement distance (m)
0.009 - 0.490	2 400/F(kHz)	300
0.490 - 1.705	24 000/F(kHz)	30
1.705 - 30	30	30
30 - 88	100**	3
88 - 216	150**	3
216 - 960	200**	3
Above 960	500	3

**Except as provided in paragraph (g), fundamental emissions from intentional radiators operating under this section shall not be located in the frequency bands 54–72 MHz, 76–88 MHz, 174–216 MHz or 470–806 MHz. However, operation within these frequency bands is permitted under other sections of this part, e.g., Section 15.231 and 15.241.

According to section 15.205(a) and (b),

Only spurious emissions are permitted in any of the frequency bands listed below:

MHz	MHz	MHz	GHz
0.009 - 0.110	16.42 - 16.423	399.9 - 410	4.5 - 5.15
0.495 - 0.505	16.694 75 - 16.695 25	608 - 614	5.35 - 5.46
2.173 5 - 2.190 5	16.804 25 - 16.804 75	960 - 1 240	7.25 - 7.75
4.125 - 4.128	25.5 - 25.67	1 300 - 1 427	8.025 - 8.5
4.177 25 - 4.177 75	37.5 - 38.25	1 435 - 1 626.5	9.0 - 9.2
4.207 25 - 4.207 75	73 - 74.6	1 645.5 - 1 646.5	9.3 - 9.5
6.215 - 6.218	74.8 - 75.2	1 660 - 1 710	10.6 - 12.7
6.267 75 - 6.268 25	108 - 121.94	1 718.8 - 1 722.2	13.25 - 13.4
6.311 75 - 6.312 25	123 - 138	2 200 - 2 300	14.47 - 14.5
8.291 - 8.294	149.9 - 150.05	2 310 - 2 390	15.35 - 16.2
8.362 - 8.366	156.524 75 - 156.525	2 483.5 - 2 500	17.7 - 21.4
8.376 25 - 8.386 75	25	2 690 - 2 900	22.01 - 23.12
8.414 25 - 8.414 75	156.7 - 156.9	3 260 - 3 267	23.6 - 24.0
12.29 - 12.293	162.012 5 - 167.17	3 332 - 3 339	31.2 - 31.8
12.519 75 - 12.520 25	167.72 - 173.2	3 345.8 - 3 358	36.43 - 36.5
12.576 75 - 12.577 25	240 - 285	3 600 - 4 400	Above 38.6
13.36 - 13.41	322 - 335.4		

The field strength of emissions appearing within these frequency bands shall not exceed the limits shown in section 15.209. At frequencies equal to or less than 1 000 MHz, compliance with the limits in section 15.209 shall be demonstrated using measurement instrumentation employing a CISPR quasi-peak detector. Above 1 000 MHz, compliance with the emission limits in section 15.209 shall be demonstrated based on the average value of the measured emissions. The provisions in section 15.35 apply to these measurements.

Test procedure

ANSI C63.10-2013

Test settings

Peak field strength measurements

1. Analyzer center frequency was set to the frequency of the radiated spurious emission of interest
2. RBW = as specified in table
3. VBW $\geq$ (3 $\times$ RBW)
4. Detector = peak
5. Sweep time = auto
6. Trace mode = max hold
7. Allow sweeps to continue until the trace stabilizes

Table. RBW as a function of frequency

Frequency	RBW
9 kHz to 150 kHz	200 Hz to 300 Hz
0.15 MHz to 30 MHz	9 kHz to 10 kHz
30 MHz to 1 000 MHz	100 kHz to 120 kHz
> 1 000 MHz	1 MHz

Average field strength measurements

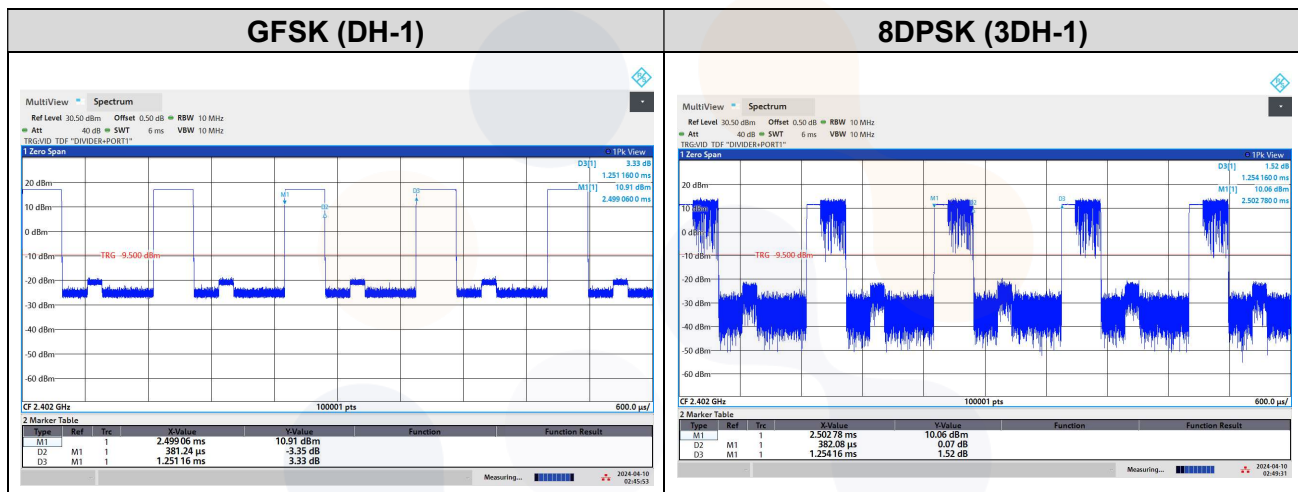
1. Analyzer center frequency was set to the frequency of the radiated spurious emission of interest
2. RBW = 1 MHz
3. VBW = $1/T \geq 1$ Hz
4. Averaging type was set to RMS to ensure that video filtering was applied in the power domain
5. Detector = peak
6. Sweep time = auto
7. Trace mode = max hold
8. Trace was allowed to run for at least 50 times(1/duty cycle) traces

Notes:

- The resolution bandwidth and video bandwidth of test receiver/spectrum analyzer is 1 MHz for Peak detection and frequency above 1 GHz. The resolution bandwidth of test receiver/spectrum analyzer is 1 MHz and the video bandwidth is 3 kHz ($\geq 1/T$) for Average detection (AV) at frequency above 1 GHz.

According to ANSI C63.10-2013, for average measurement during radiation test, Reduced VBW shall be greater than $[1/(\text{minimum transmitter on time})]$ and no less than 1 Hz.

Test mode	Period (ms)	On time (ms)	Reduced VBW (Hz)
GFSK	1.251 16	0.381 24	2 623.02
8DPSK	1.254 16	0.382 08	2 617.25



- $f < 30$ MHz, extrapolation factor of 40 dB/decade of distance. $F_d = 40 \log(D_m/D_s)$
 $f \geq 30$ MHz, extrapolation factor of 20 dB/decade of distance. $F_d = 20 \log(D_m/D_s)$

Where:

F_d = Distance factor in dB

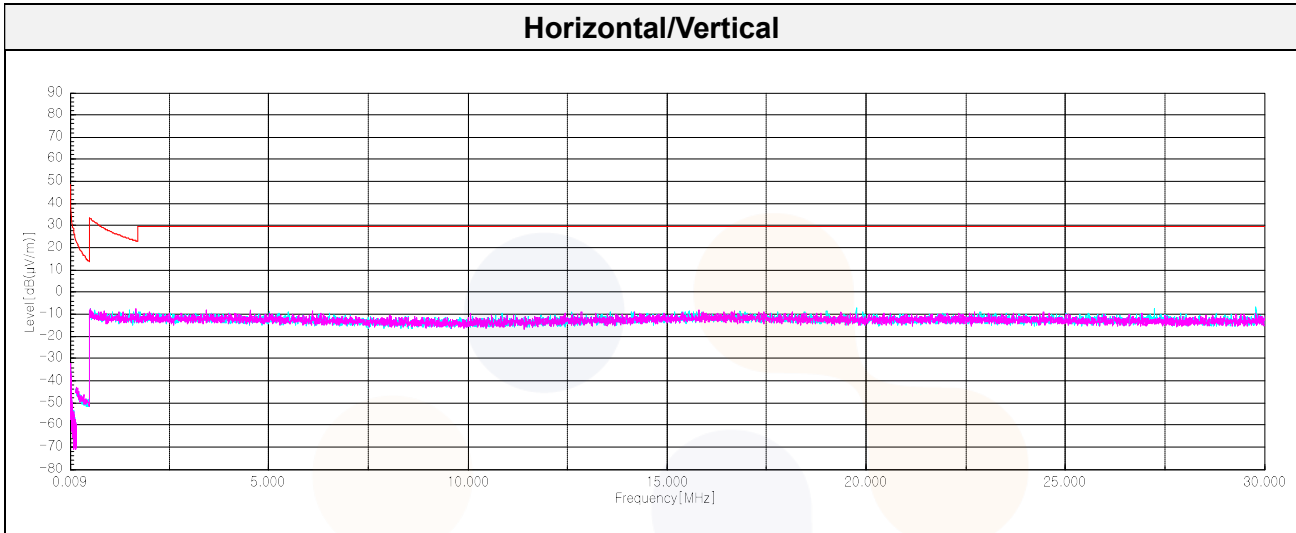
D_m = Measurement distance in meters

D_s = Specification distance in meters

- Factors(dB) = Antenna factor(dB/m) + Cable loss(dB) + or Amp. gain(dB) + or F_d (dB)
- The worst-case emissions are reported however emissions whose levels were not within 20 dB of respective limits were not reported.
- Average test would be performed if the peak result were greater than the average limit.
- ¹⁾ means restricted band.
- Above 1 GHz the worst results between two antenna polarizations (H and V) were documented in the test report.
- Below 30 MHz frequency range, In order to search for the worst result, all orientations about parallel, perpendicular, and ground-parallel were investigated then reported. when the emission level was higher than 20 dB of the limit, then the following statement shall be made: "No spurious emissions were detected within 20 dB of the limit."

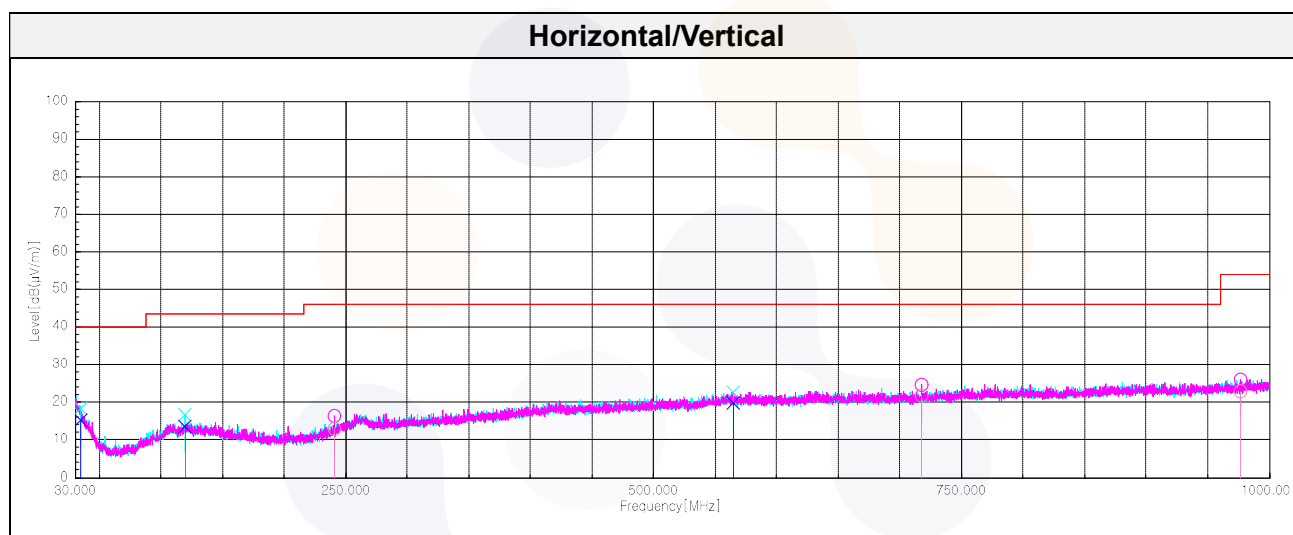
Test results (Below 30 MHz) – Worst case: GFSK 2 480 MHz

Frequency	Pol.	Reading	Ant. Factor	Amp. + Cable	DCCF	Result	Limit	Margin
(MHz)	(V/H)	(dB(μ V))	(dB)	(dB)	(dB)	(dB(μ V/m))	(dB(μ V/m))	(dB)
Quasi peak data								
No spurious emissions were detected within 20 dB of the limit.								



Test results (Below 1 000 MHz) – Worst case: GFSK 2 480 MHz

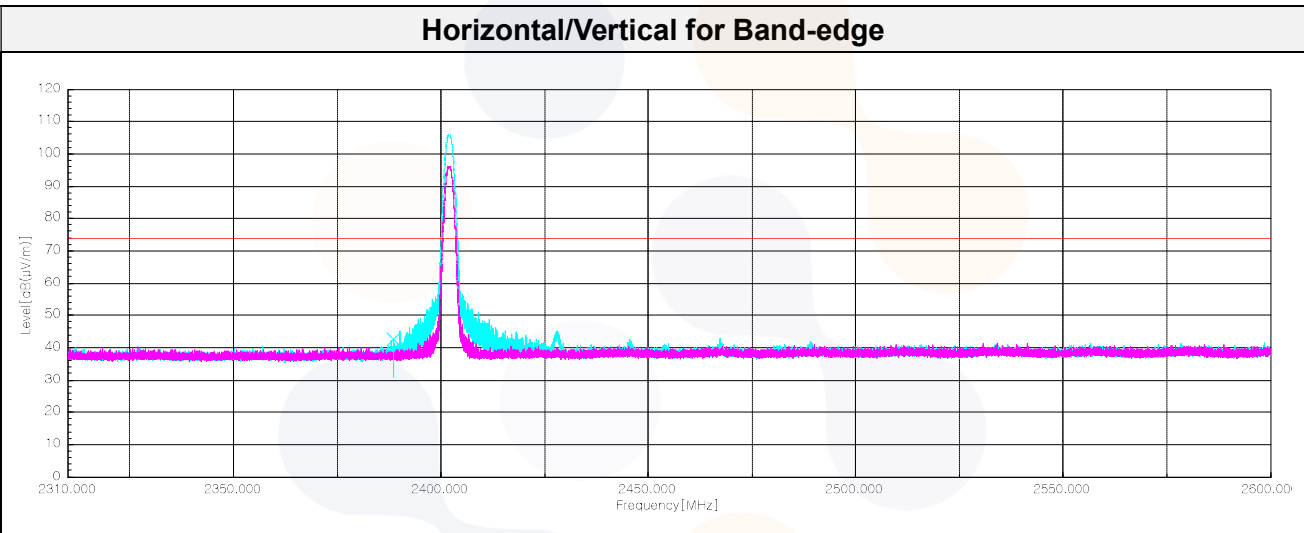
Frequency	Pol.	Reading	Ant. Factor	Amp. + Cable	DCCF	Result	Limit	Margin
(MHz)	(V/H)	(dB(μV))	(dB)	(dB)	(dB)	(dB(μV/m))	(dB(μV/m))	(dB)
Quasi peak data								
34.37	V	24.50	22.42	-31.76	-	15.16	40.00	24.84
119.60 ¹⁾	V	27.20	17.86	-31.44	-	13.62	43.50	29.88
240.85 ¹⁾	H	27.00	17.23	-31.14	-	13.09	46.00	32.91
717.73	H	26.70	24.99	-30.00	-	21.69	46.00	24.31
564.47	V	25.50	24.70	-30.53	-	19.67	46.00	26.33
976.60 ¹⁾	H	24.00	27.03	-27.98	-	23.05	54.00	30.95



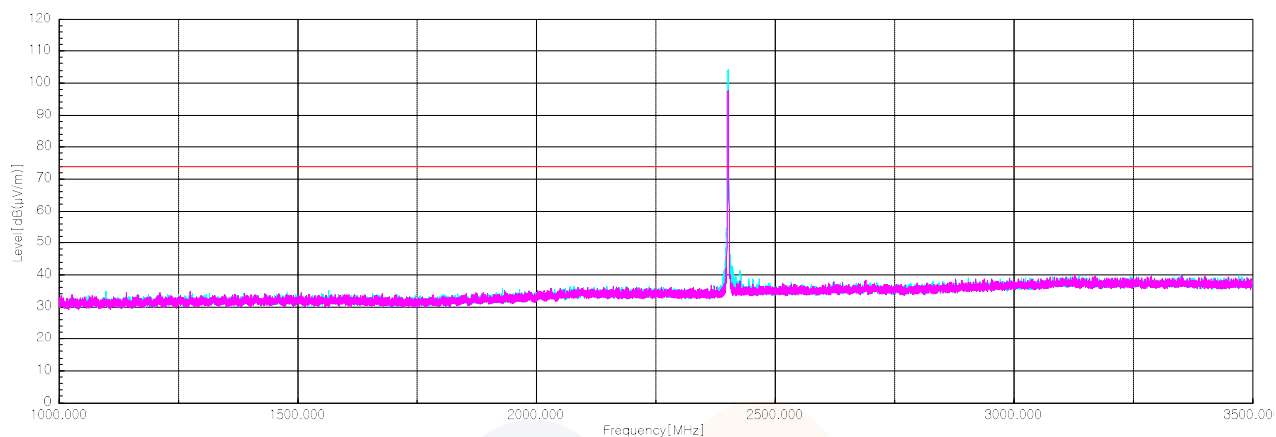
Test results (Above 1 000 MHz)

GFSK_Low Channel

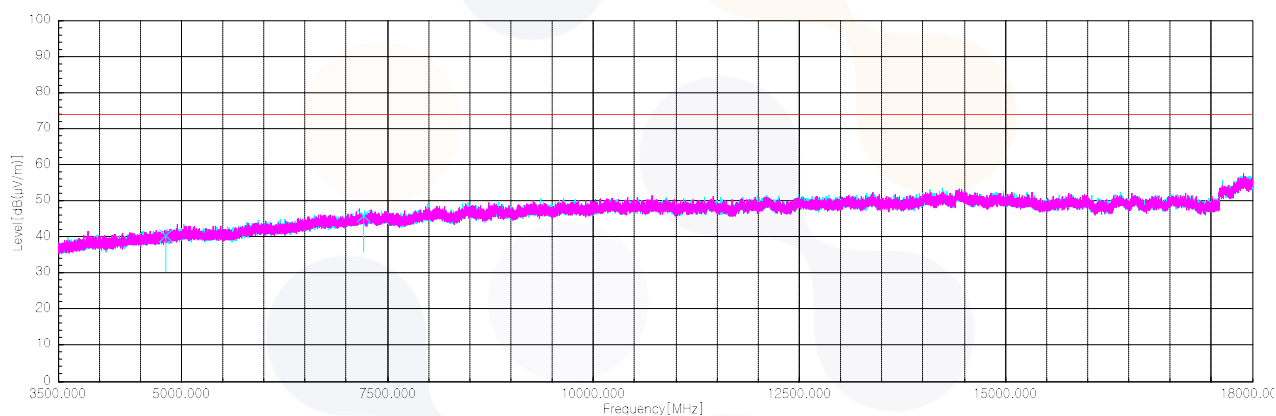
Frequency	Pol.	Reading	Ant. Factor	Amp. + Cable	DCCF	Result	Limit	Margin
(MHz)	(V/H)	(dB(μ V))	(dB)	(dB)	(dB)	(dB(μ V/m))	(dB(μ V/m))	(dB)
Peak data								
2 388.51 ¹⁾	V	46.00	26.99	-30.36	-	42.63	74.00	31.37
4 804.03 ¹⁾	V	51.90	32.22	-43.83	-	40.29	74.00	33.71
7 206.20	V	50.30	36.72	-41.32	-	45.70	74.00	28.30
Average Data								
No spurious emissions were detected within 20 dB of the limit.								



Horizontal/Vertical for 1 GHz ~ 3.5 GHz



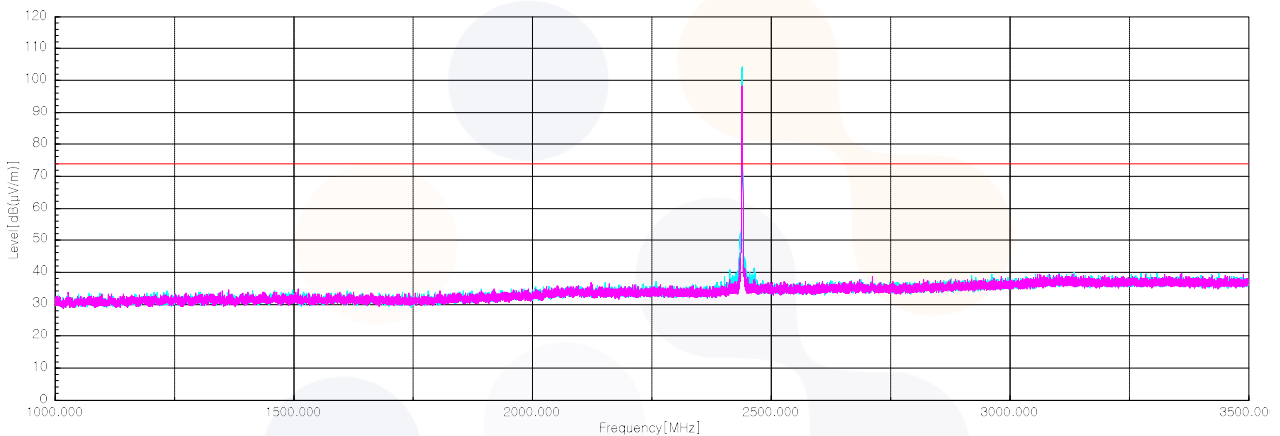
Horizontal/Vertical for 3.5 GHz ~ 18 GHz



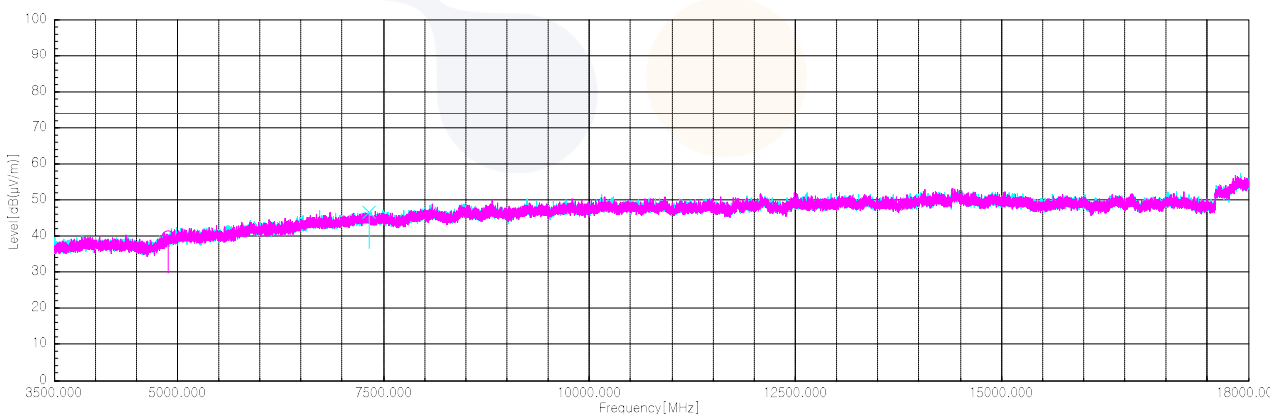
GFSK_Mid Channel

Frequency	Pol.	Reading	Ant. Factor	Amp. + Cable	DCCF	Result	Limit	Margin
(MHz)	(V/H)	(dB(μV))	(dB)	(dB)	(dB)	(dB(μV/m))	(dB(μV/m))	(dB)
Peak data								
4 882.33 ¹⁾	H	50.90	32.53	-43.48	-	39.95	74.00	34.05
7 322.68 ¹⁾	V	51.30	36.65	-41.28	-	46.67	74.00	27.33
Average Data								
No spurious emissions were detected within 20 dB of the limit.								

Horizontal/Vertical for 1 GHz ~ 3.5 GHz

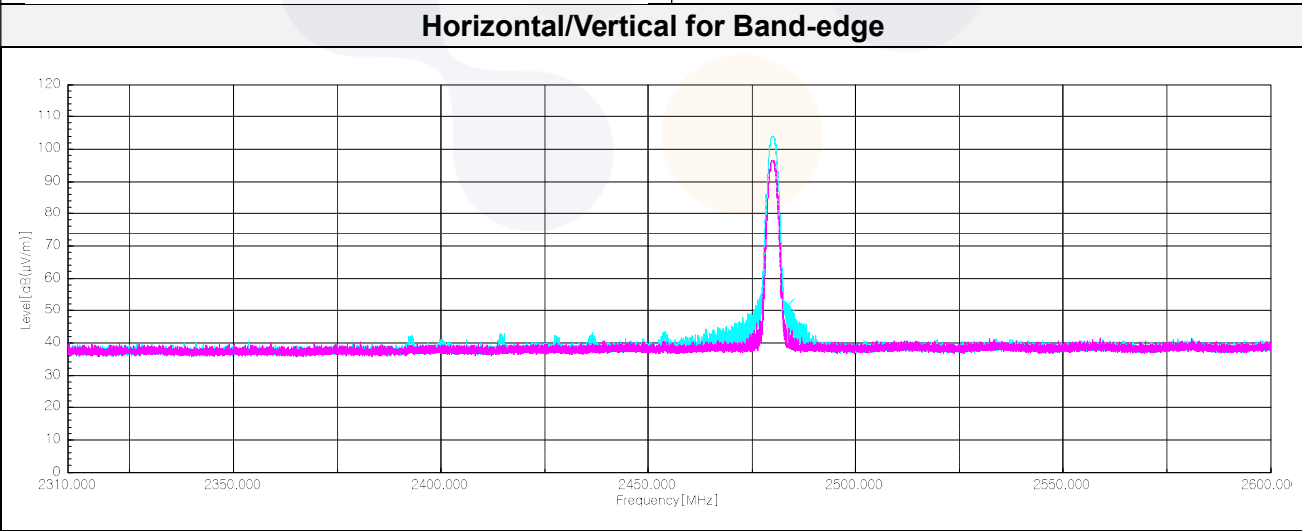
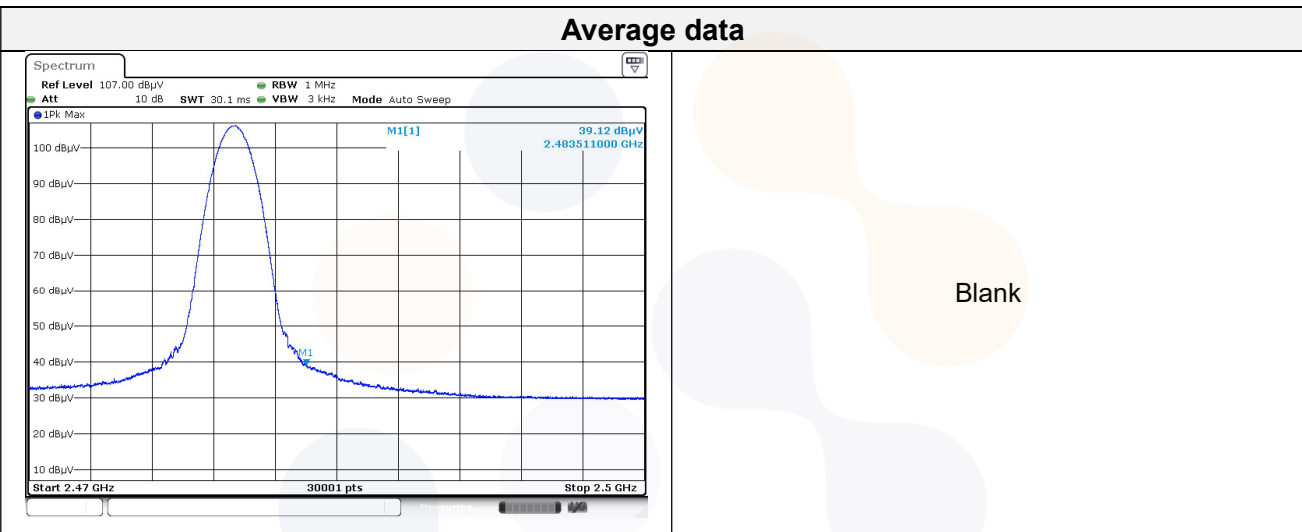


Horizontal/Vertical for 3.5 GHz ~ 18 GHz

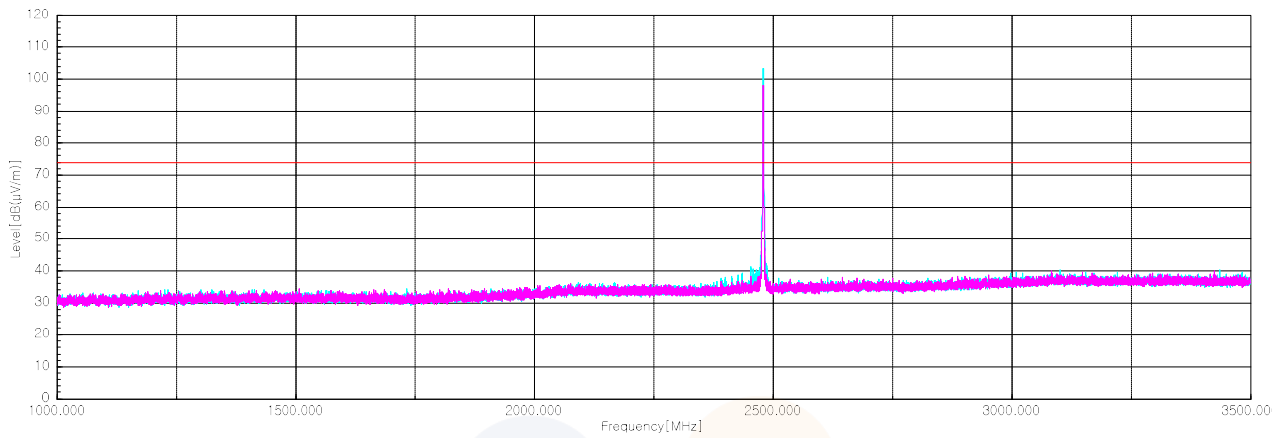


GFSK_High Channel

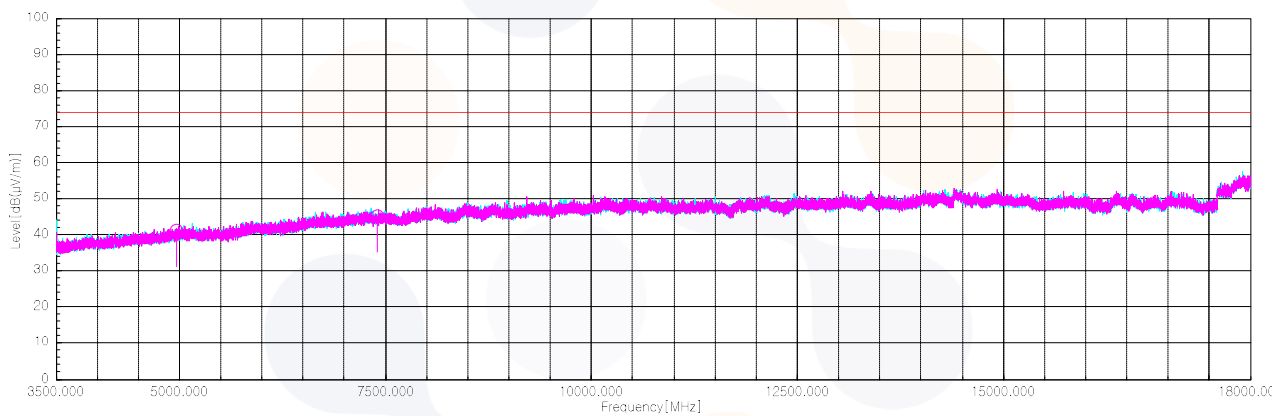
Frequency	Pol.	Reading	Ant. Factor	Amp. + Cable	DCCF	Result	Limit	Margin
(MHz)	(V/H)	(dB(μV))	(dB)	(dB)	(dB)	(dB(μV/m))	(dB(μV/m))	(dB)
Peak data								
2 483.51 ¹⁾	V	54.40	27.50	-30.26	-	51.64	74.00	22.36
4 960.63 ¹⁾	H	51.60	32.64	-43.19	-	41.05	74.00	32.95
7 401.95 ¹⁾	H	50.30	36.40	-41.44	-	45.26	74.00	28.74
Average Data								
2 483.51 ¹⁾	V	39.12	27.50	-30.26	-	36.36	54.00	17.64



Horizontal/Vertical for 1 GHz ~ 3.5 GHz

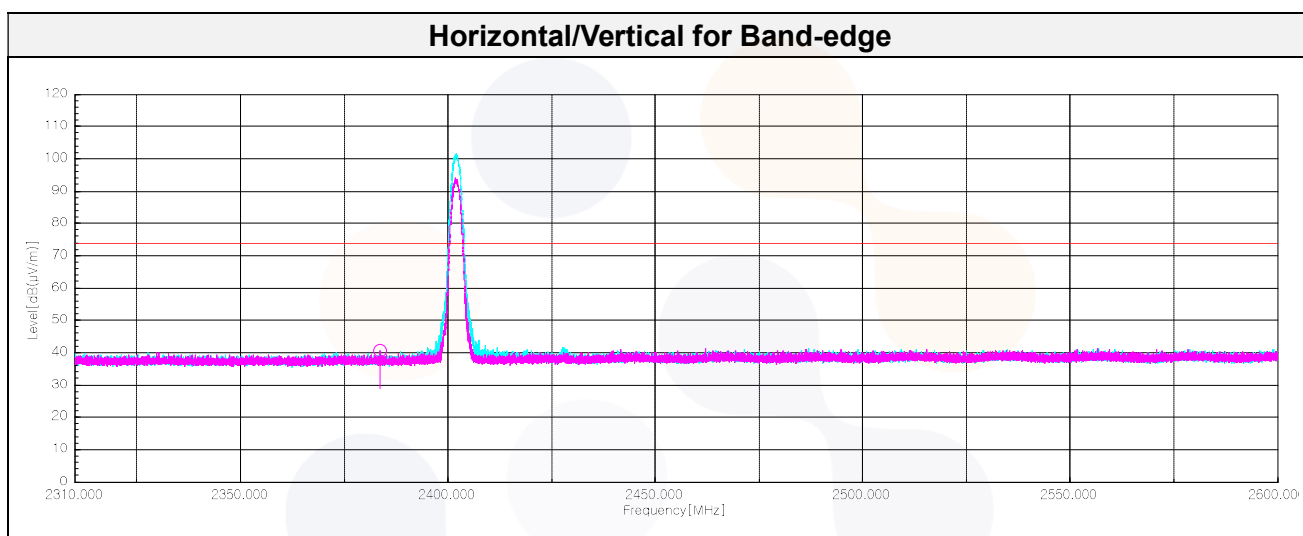


Horizontal/Vertical for 3.5 GHz ~ 18 GHz

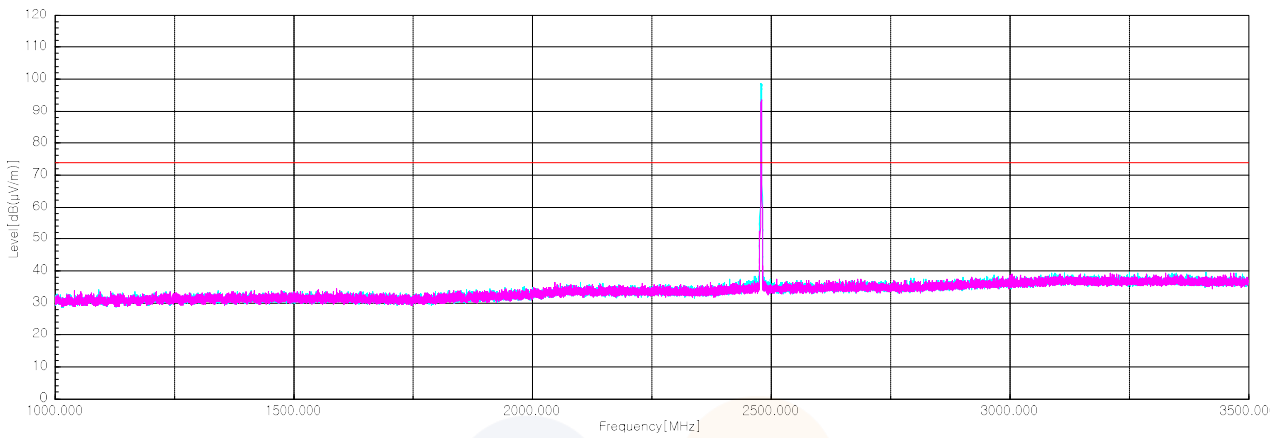


8DPSK_Low Channel

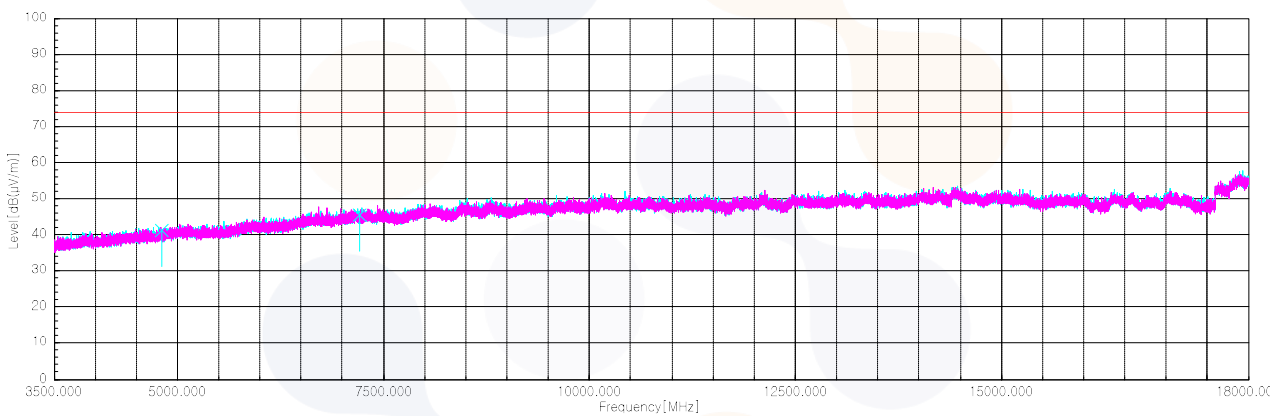
Frequency	Pol.	Reading	Ant. Factor	Amp. + Cable	DCCF	Result	Limit	Margin
(MHz)	(V/H)	(dB(μV))	(dB)	(dB)	(dB)	(dB(μV/m))	(dB(μV/m))	(dB)
Peak data								
2 383.71 ¹⁾	H	43.80	26.94	-30.38	-	40.36	74.00	33.64
4 804.03 ¹⁾	V	52.80	32.22	-43.83	-	41.19	74.00	32.81
7 206.20	V	50.10	36.72	-41.32	-	45.50	74.00	28.50
Average Data								
No spurious emissions were detected within 20 dB of the limit.								



Horizontal/Vertical for 1 GHz ~ 3.5 GHz



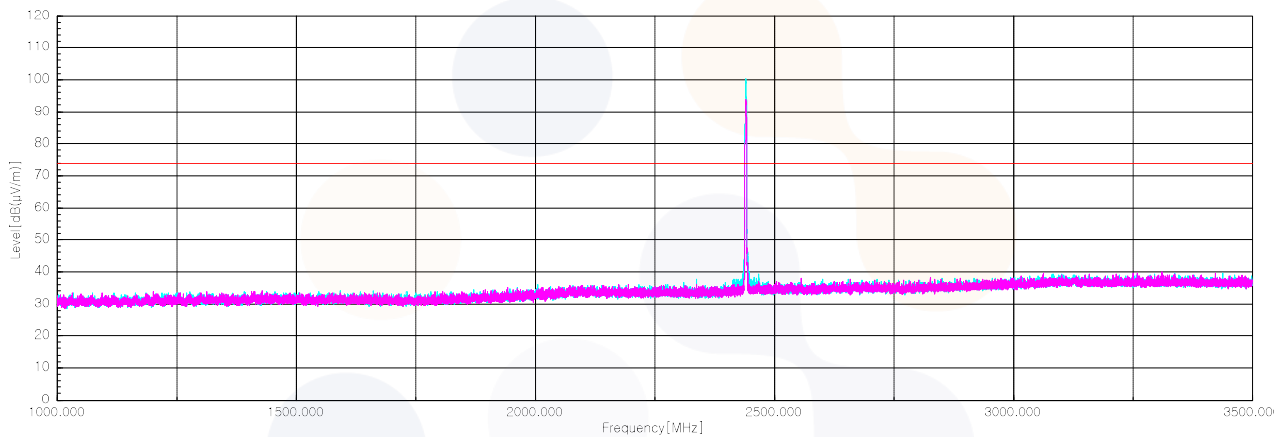
Horizontal/Vertical for 3.5 GHz ~ 18 GHz



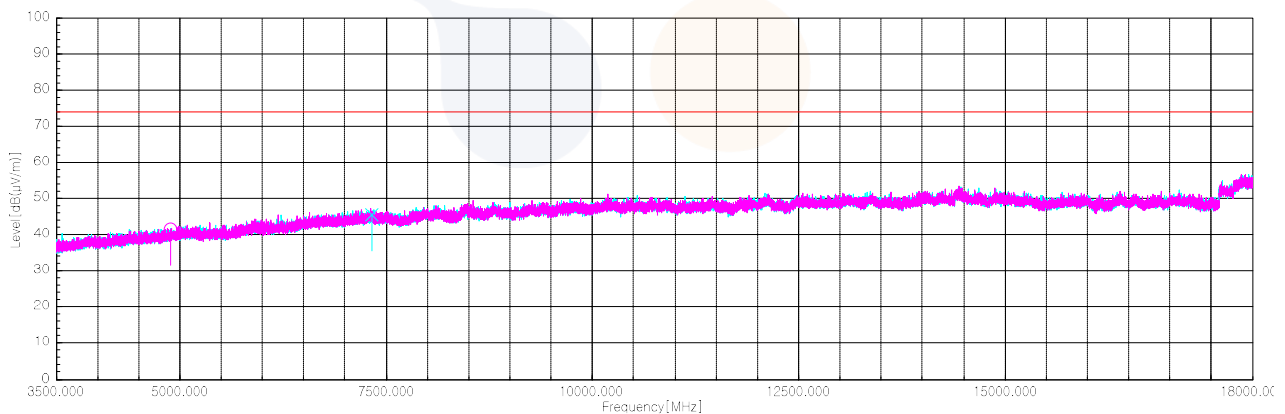
8DPSK_Mid Channel

Frequency	Pol.	Reading	Ant. Factor	Amp. + Cable	DCCF	Result	Limit	Margin
(MHz)	(V/H)	(dB(μ V))	(dB)	(dB)	(dB)	(dB(μ V/m))	(dB(μ V/m))	(dB)
Peak data								
4 881.85 ¹⁾	H	52.70	32.53	-43.48	-	41.75	74.00	32.25
7 323.65 ¹⁾	V	50.20	36.65	-41.28	-	45.57	74.00	28.43
Average Data								
No spurious emissions were detected within 20 dB of the limit.								

Horizontal/Vertical for 1 GHz ~ 3.5 GHz

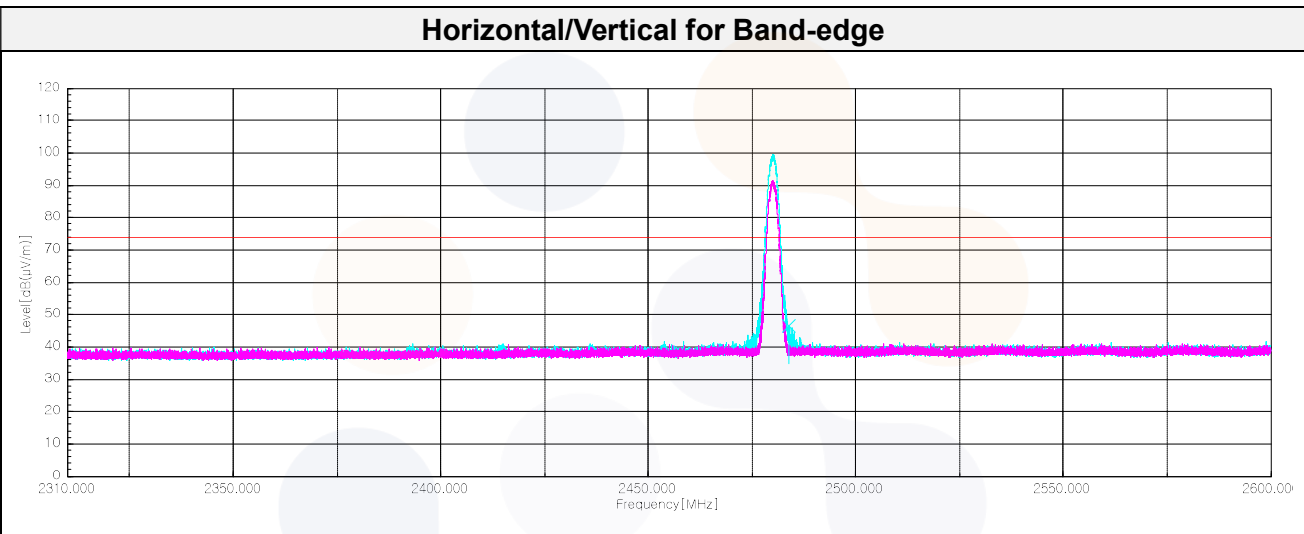


Horizontal/Vertical for 3.5 GHz ~ 18 GHz

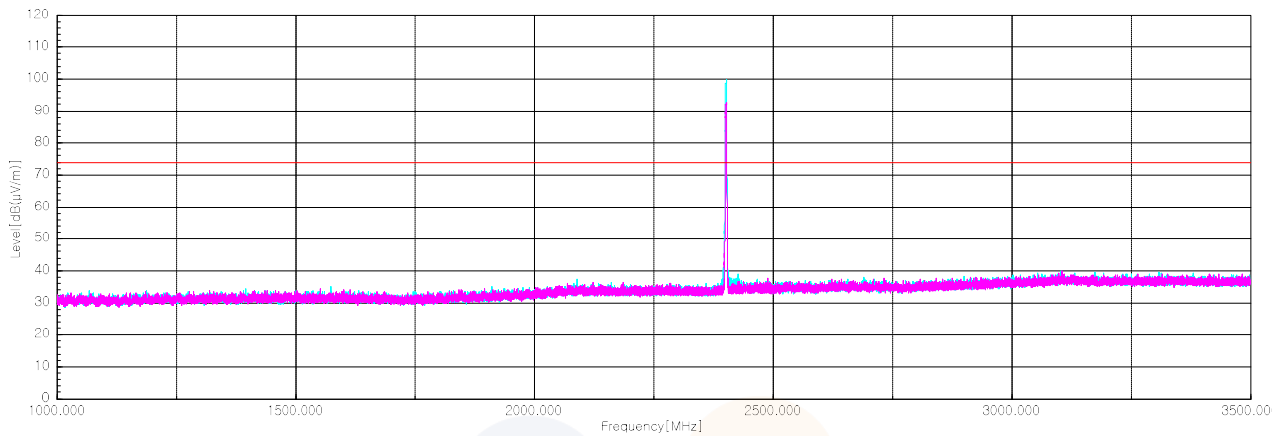


8DPSK_High Channel

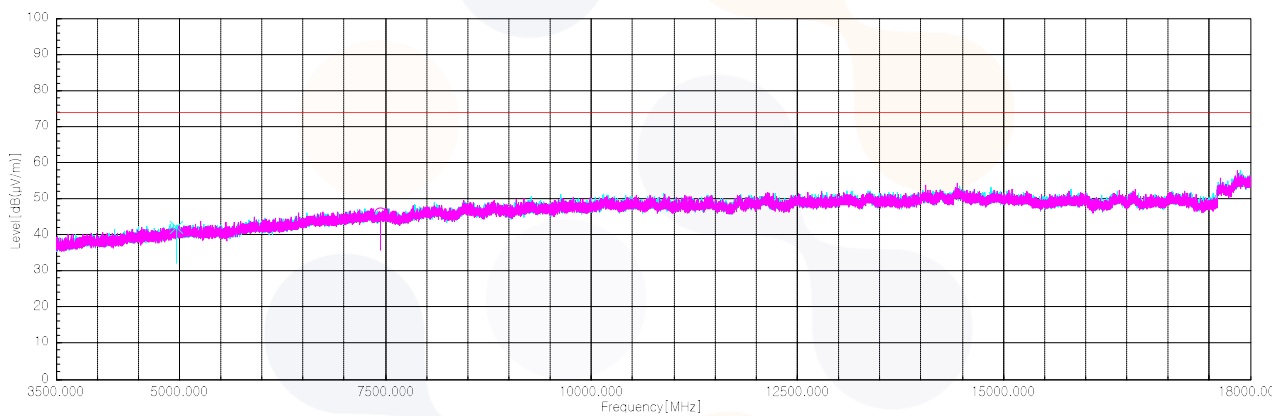
Frequency	Pol.	Reading	Ant. Factor	Amp. + Cable	DCCF	Result	Limit	Margin
(MHz)	(V/H)	(dB(μ V))	(dB)	(dB)	(dB)	(dB(μ V/m))	(dB(μ V/m))	(dB)
Peak data								
2 483.87 ¹⁾	V	49.30	27.50	-30.26	-	46.54	74.00	27.46
4 959.67 ¹⁾	V	52.60	32.64	-43.19	-	42.05	74.00	31.95
7 439.65 ¹⁾	H	50.80	36.32	-41.35	-	45.77	74.00	28.23
Average Data								
No spurious emissions were detected within 20 dB of the limit.								



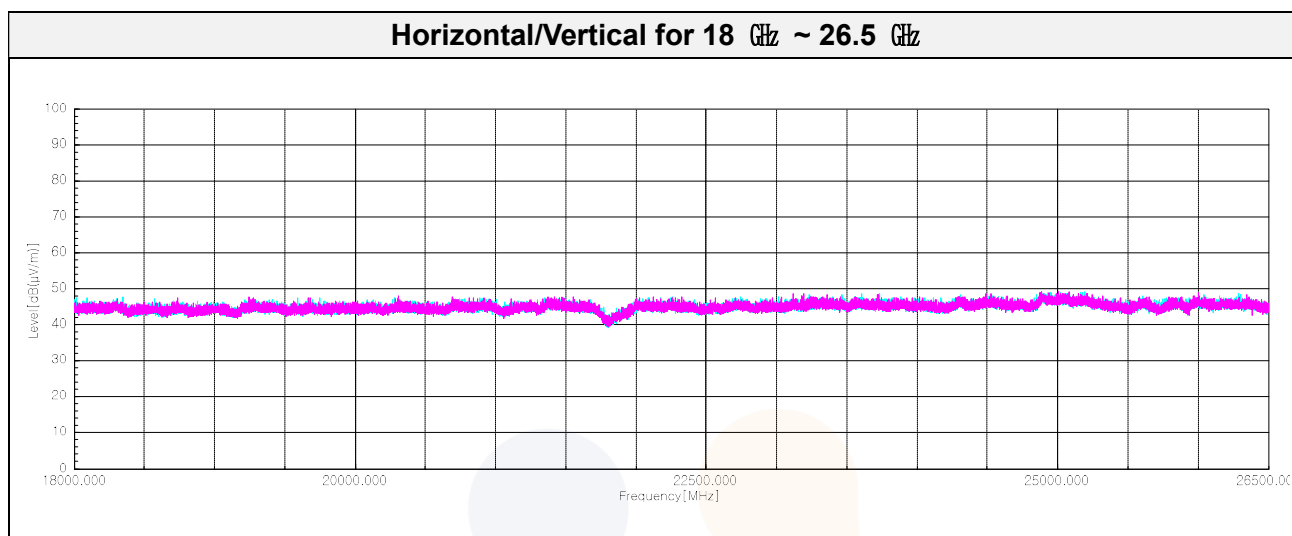
Horizontal/Vertical for 1 GHz ~ 3.5 GHz



Horizontal/Vertical for 3.5 GHz ~ 18 GHz



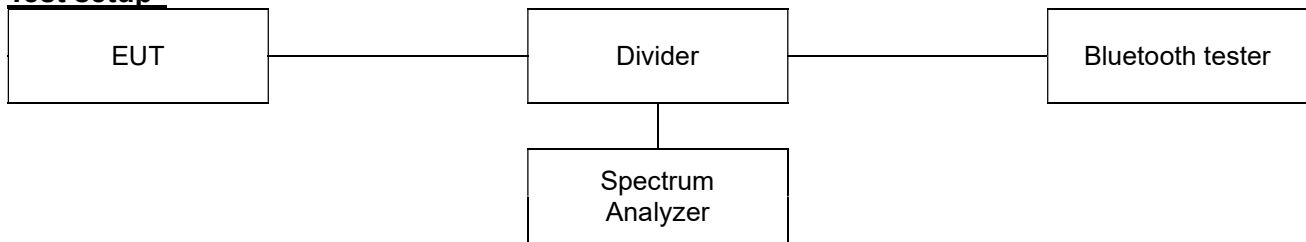
Test results (Above 18 GHz) – Worst case: GFSK 2 441 MHz



Note: The Worst case was based on the lowest margin condition considering Harmonic and Spurious Emission

7.7. Conducted Spurious Emission

Test setup



Limit

According to §15.247(d),

In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operation, 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 averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation specified in §15.209(a) is not required. In addition, radiated emission limits specified in §15.209(a) (see §15.205(c)).

Limit : 20 dBc

Test procedure

ANSI C63.10-2013 - Section 6.10.4, 7.8.8

Test settings

▪ Band-edge

- 1) Span : Wide enough to capture the peak level of the emission operating on the channel closest to the band edge, as well as any modulation products which fall outside of the authorized band of operation
- 2) Reference level : As required to keep the signal from exceeding the maximum instrument input mixer level for linear operation. In general, the peak of the spectral envelope shall be more than $[10 \log(\text{OBW}/\text{RBW})]$ below the reference level.
- 3) Attenuation: Auto (at least 10 dB preferred)
- 4) Sweep time = Coupled
- 5) RBW : 100 kHz
- 6) VBW : 300 kHz
- 7) Detector : Peak
- 8) Trace : Max hold

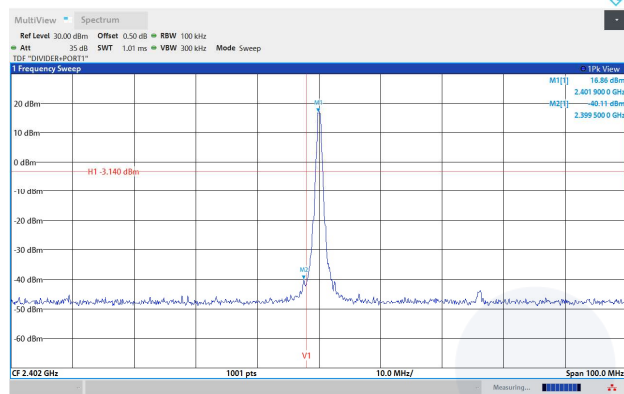
▪ Spurious emissions

- 1) Span : 30 MHz to 10 times the operating frequency in GHz
- 2) RBW : 100 kHz
- 3) VBW : 300 kHz
- 4) Sweep time : Coupled
- 5) Detector : Peak

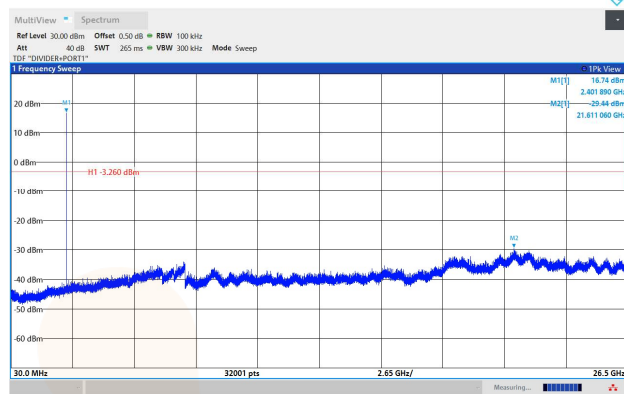
Test results

GFSK

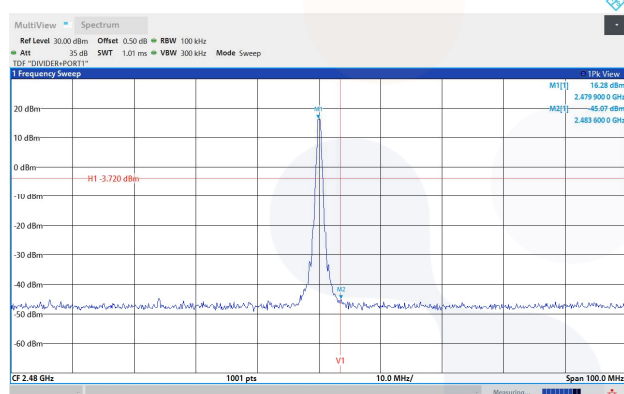
Conducted band-edge / Low ch.



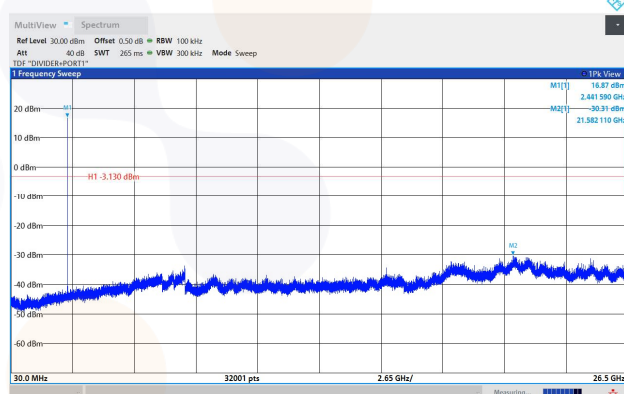
Conducted spurious / Low ch.



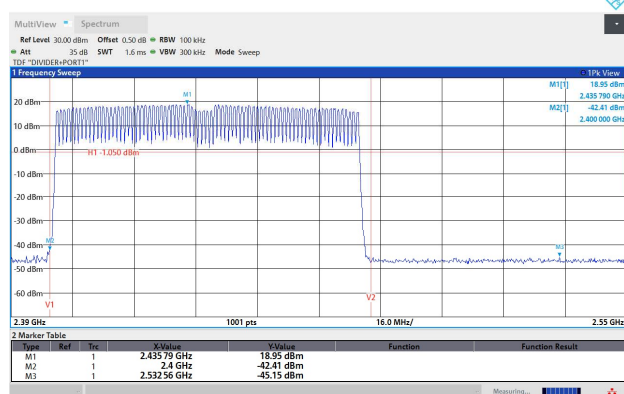
Conducted band-edge / High ch.



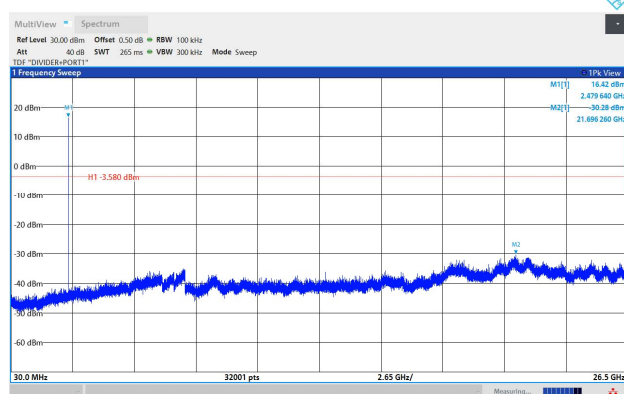
Conducted spurious / Mid ch.



Conducted band-edge / Hopping ch.

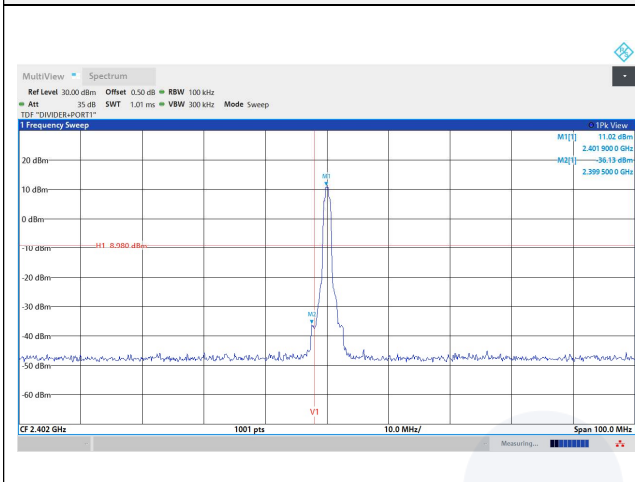


Conducted spurious / High ch.

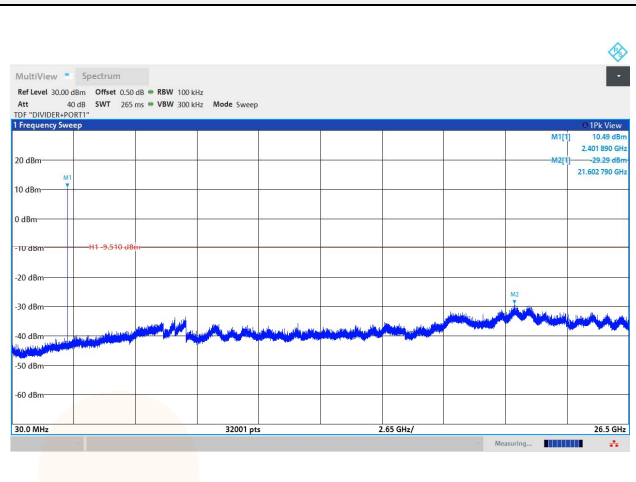


8DPSK

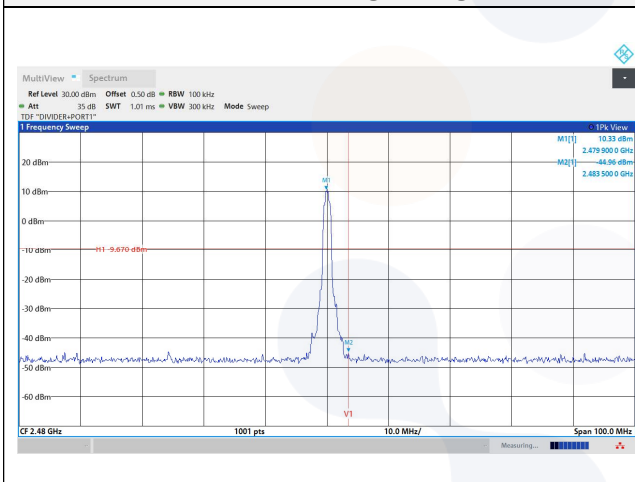
Conducted band-edge / Low ch.



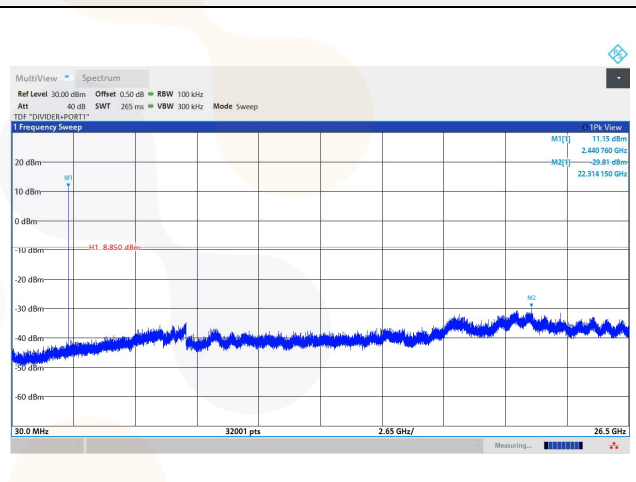
Conducted spurious / Low ch.



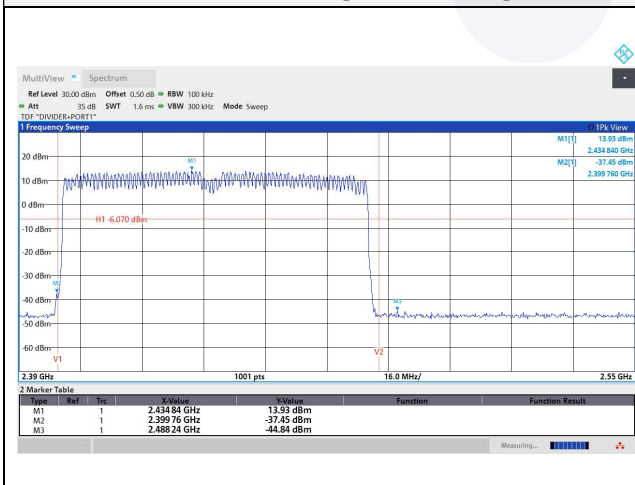
Conducted band-edge / High ch.



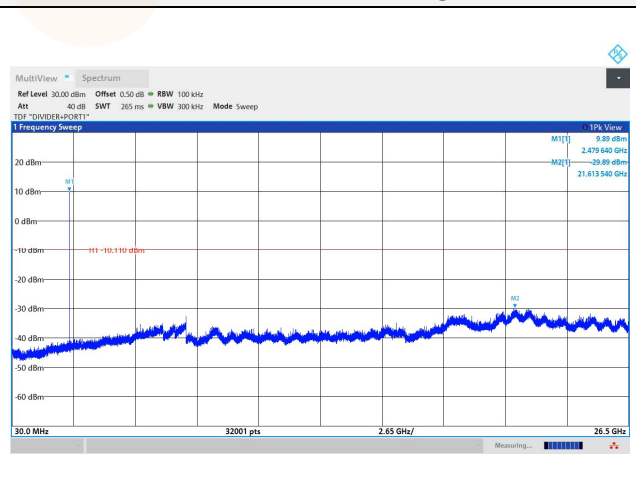
Conducted spurious / Mid ch.



Conducted band-edge / Hopping ch.

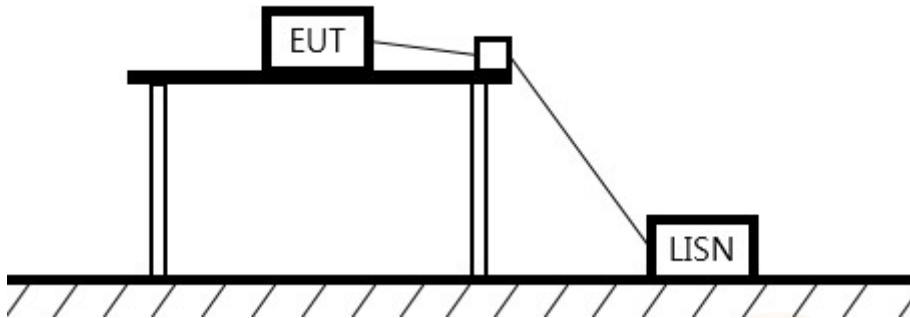


Conducted spurious / High ch.



7.8. AC Conducted emission

Test setup



Limit

According to 15.207(a),

For an intentional radiator that is designed to be connected to the public utility (AC) power line, the radio frequency voltage that is conducted back onto the AC power line on any frequency or frequencies, within the band 150 kHz to 30 MHz, shall not exceed the limits in the following table, as measured using a 50uH/50 ohm line impedance stabilization network (LISN). Compliance with the provision of this paragraph shall on the measurement of the radio frequency voltage between each power line and ground at the power terminal. The lower applies at the boundary between the frequencies ranges.

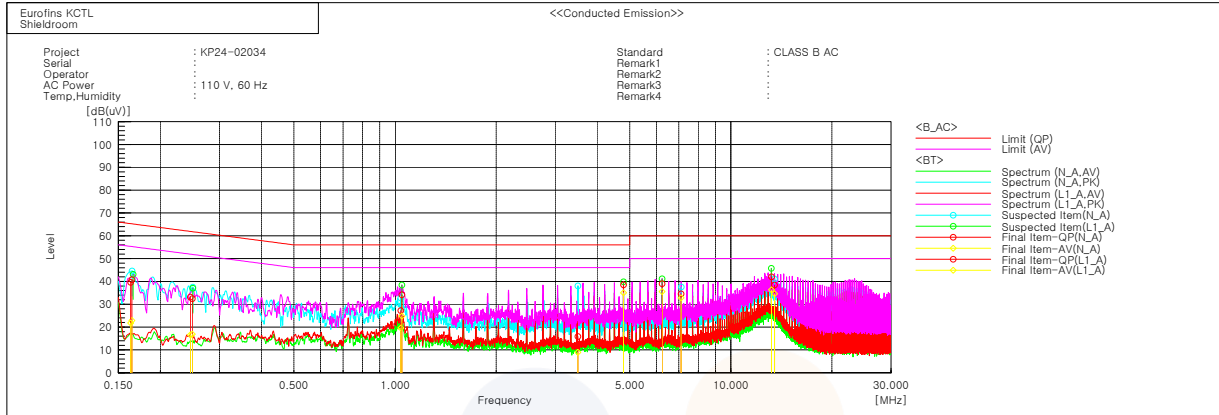
Frequency of Emission (MHz)	Conducted limit (dBμV/m)	
	Quasi-peak	Average
0.15 – 0.50	66 - 56*	56 - 46*
0.50 – 5.00	56	46
5.00 – 30.0	60	50

Measurement procedure

1. The EUT was placed on a wooden table of size, 1 m by 1.5 m, raised 80 cm in which is located 40 cm away from the vertical wall and 1.5m away from the side wall of the shielded room.
2. Each current-carrying conductor of the EUT power cord was individually connected through a 50Ω/50μH LISN, which is an input transducer to a spectrum analyzer or an EMI/Field Intensity Meter, to the input power source.
3. Exploratory measurements were made to identify the frequency of the emission that had the highest amplitude relative to the limit by operating the EUT in a range of typical modes of operation, cable position, and with a typical system equipment configuration and arrangement. Based on the exploratory tests of the EUT, the one EUT cable configuration and arrangement and mode of operation that had produced the emission with the highest amplitude relative to the limit was selected for the final measurement.
4. The final test on all current-carrying conductors of all of the power cords to the equipment that comprises the EUT (but not the cords associated with other non-EUT equipment is the system) was then performed over the frequency range of 0.15 MHz to 30 MHz.
5. The measurements were made with the detector set to peak amplitude within a bandwidth of 10 kHz or to quasi-peak and average within a bandwidth of 9 kHz. The EUT was in transmitting mode during the measurements.

Test results

Worst case: GFSK 2 480 MHz



Final Result

--- N_A Phase ---										
No.	Frequency	Reading QP	Reading CAV	c.f	Result QP	Result CAV	Limit QP	Limit AV	Margin QP	Margin CAV
	[MHz]	[dB(uV)]	[dB(uV)]	[dB]	[dB(uV)]	[dB(uV)]	[dB(uV)]	[dB(uV)]	[dB]	[dB]
1	0.1645	30.4	12.4	10.4	40.8	22.8	65.2	55.2	24.4	32.4
2	0.24559	23.1	6.6	10.0	33.1	16.6	61.9	51.9	28.8	35.3
3	1.04045	17.2	9.6	10.0	27.2	19.6	56.0	46.0	28.8	26.4
4	3.50533	6.0	-1.0	9.9	15.9	8.9	56.0	46.0	40.1	37.1
5	7.11212	24.2	22.5	10.3	34.5	32.8	60.0	50.0	25.5	17.2
6	13.49825	27.6	23.8	10.8	38.4	34.6	60.0	50.0	21.6	15.4

--- L1_A Phase ---										
No.	Frequency	Reading QP	Reading CAV	c.f	Result QP	Result CAV	Limit QP	Limit AV	Margin QP	Margin CAV
	[MHz]	[dB(uV)]	[dB(uV)]	[dB]	[dB(uV)]	[dB(uV)]	[dB(uV)]	[dB(uV)]	[dB]	[dB]
1	0.16311	29.3	11.5	10.3	39.6	21.8	65.3	55.3	25.7	33.5
2	0.24898	22.5	6.9	10.0	32.5	16.9	61.8	51.8	29.3	34.9
3	1.04782	24.1	14.8	10.0	34.1	24.8	56.0	46.0	21.9	21.2
4	4.79022	28.5	25.0	10.0	38.5	35.0	56.0	46.0	17.5	11.0
5	6.24206	28.9	25.4	10.1	39.0	35.5	60.0	50.0	21.0	14.5
6	13.20896	31.2	25.5	10.8	42.0	36.3	60.0	50.0	18.0	13.7

8. Measurement equipment

Equipment Name	Manufacturer	Model No.	Serial No.	Next Cal. Date
Bluetooth Tester	TESCOM	TC-3000B	3000B640056	25.01.19
Spectrum Analyzer	R&S	FSV3040	101427	25.03.28
Signal Generator	R&S	SMB100A	176206	25.01.18
DC Power Supply	AGILENT	E3632A	MY40000265	24.04.27
Power Divider	Marki Microwave, Inc.	PD-0040	D0002	24.07.04
Power Sensor	R&S	NRP-Z81	1137.9009.02-106224-tg	24.09.12
Spectrum Analyzer	R&S	FSV40	100988	24.07.03
Spectrum Analyzer	R&S	FSV40	100988	24.07.03
PSA Spectrum Analyzer	Agilent	E4440A	MY44303500	24.07.04
EMI TEST RECEIVER	R&S	ESC13	101408	24.08.18
TWO-LINE V - NETWORK	R&S	ENV216	101358	24.09.27
Bluetooth Tester	TESCOM	TC-3000C	3000C000270	24.07.04
Broadband PreAmplifier	SCHWARZBECK	BBV9718D	53	25.01.19
Low Noise Amplifier	TESTEK	TK-PA18H	220123-L	24.10.12
Low Noise Amplifier	TESTEK	TK-PA1840H	220234-L	24.10.17
Amplifier	SONOMA INSTRUMENT	310N	421910	24.10.12
Bilog Antenna	Teseq GmbH	CBL 6112D	61521	24.11.17
Loop Antenna	R&S	HFH2-Z2	100355	24.08.10
Horn Antenna	SCHWARZBECK	BBHA9120D	2764	24.10.18
Horn Antenna	SCHWARZBECK	BBHA9170	1266	24.10.16
High Pass Filter	Wainwright Instruments GmbH	WHKX12-2805-3000-18000-40SS	SN59	24.10.16
High Pass Filter	Qotana TECHNOLOGIES	DBHF058004000A	23041800061	24.07.10

End of test report