Appendix C: Test results for FCC Part 27 / RSS-139 / RSS-130

INDEX

TEST CONDITIONS

Power supply (V):

Vnominal = 3.8 Vdc

Type of power supply = DC Voltage from external power supply

Type of antenna = external antenna.

Declared Gain for antenna = +2.15dBi for all bands.

TEST FREQUENCIES:

NBIoT. π/2 - BPSK AND π/4 - QPSK MODULATION (BAND 4)

Channel (Frequency. MHz)		
Lowest	Middle	Highest
19952 (1710.2)	20175 (1732.5)	20398 (1754.8)

NOTE: Band 4 is completely included in band 66. so the channels of band 66 were tested to give conformity to the assigned block

NBIoT. π/2 - BPSK AND π/4 - QPSK MODULATION (BAND 12)

Channel (Frequency. MHz)		
Lowest	Middle	Highest
23012 (699.2)	23095 (707.5)	23178 (715.8)

NBIoT. π/2 - BPSK AND π/4 - QPSK MODULATION (BAND 13)

Channel (Frequency. MHz)		
Lowest	Middle	Highest
23182 (777.2)	23230 (782)	23278 (786.8)

NBIoT. π/2 - BPSK AND π/4 - QPSK MODULATION (BAND 66)

Channel (Frequency. MHz)		
Lowest	Middle	Highest
131974 (1710.2)	132322 (1745)	132670 (1779.8)

NBIoT. π/2 - BPSK AND π/4 - QPSK MODULATION (BAND 85)

Channel (Frequency. MHz)		
Lowest	Middle	Highest
134004 (698.2)	134092 (707)	134180 (715.8)

RF Output Power

SPECIFICATION

FCC §27.50 (c) (10).
Portable stations (hand-held devices) in the 600 MHz uplink band and the 698-746 MHz band. and fixed and mobile stations in the 600 MHz uplink band are limited to 3 watts ERP.

FCC §27.50 (b) (10).

Portable stations (hand-held devices) transmitting in the 746-757 MHz. 776-788 MHz. and 805-806 MHz bands are limited to 3 watts ERP.

RSS-130 Clause 4.4.
The e.i.r.p. shall not exceed 50 watts (46.99 dBm) for mobile equipment or for outdoor fixed subscriber equipment nor shall it exceed 5 watts (36.99 dBm) for portable equipment or for indoor fixed subscriber equipment.

FCC §27.50 (d) (4). RSS-139 Clause 6.5.
Fixed. mobile. and portable (hand-held) stations operating in the 1710-1755 MHz band are limited to 1 watt EIRP (30 dBm). Fixed stations operating in the 1710-1755 MHz band are limited to a maximum antenna height of 10 meters above ground. Mobile and portable stations operating in these bands must employ a means for limiting power to the minimum necessary for successful communications.

METHOD

The conducted RF output power measurements were made at the RF output terminals of the EUT using the power meter of the Universal Radio Communication tester R&S CMW500. selecting maximum transmission power of the EUT and different modes of modulation.

The maximum equivalent isotropically radiated power (e.i.r.p.) is calculated by adding the declared maximum antenna gain (dBi).

The maximum effective radiated power e.r.p. is calculated from the maximum equivalent isotropically radiated power (e.i.r.p.) by subtracting 2.15 dB:

$$E.R.P. = E.I.R.P. – 2.15\ dB$$

The EUT was controlled via the Universal Radio Communication tester R&S CMW500 selecting maximum transmission power of the EUT and different modes of modulation.

TEST SETUP

Conducted average power.

RESULTS

MAXIMUM OUTPUT POWER (CONDUCTED).

NBIoT. BAND 4.

Ch	Freq. (MHz)	Modulation	BW (kHz)	Num. tone	Offset Tone	Average Power (dBm)	PAPR (dB)
19950	1710.2	π/2 - BPSK	3.75	1	0	22.31	(*)
				1	47	22.54	(*)
			15	1	0	22.48	(*)
				1	11	22.38	(*)
		π/4 - QPSK	3.75	1	0	22.38	(*)
				1	47	22.3	(*)
			15	1	0	22.39	(*)
				1	11	22.36	(*)
				3	0	21.86	4.9
				3	6	22.19	4.49
				6	0	21.34	5.99
				6	6	21.37	6.08
				12	0	20.68	6.83
20175	1732.5	π/2 - BPSK	3.75	1	0	22.31	(*)
				1	47	22.54	(*)
			15	1	0	22.48	(*)
				1	11	22.38	(*)
		π/4 - QPSK	3.75	1	0	22.38	(*)
				1	47	22.3	(*)
			15	1	0	22.39	(*)
				1	11	22.36	(*)
				3	0	21.86	4.49
				3	6	22.19	4.47
				6	0	21.34	6.17
				6	6	21.37	6.23
				12	0	20.68	6.65
20398	1754.2	π/2 - BPSK	3.75	1	0	22.31	(*)
				1	47	22.54	(*)
			15	1	0	22.48	(*)
				1	11	22.38	(*)
		π/4 - QPSK	3.75	1	0	22.38	(*)
				1	47	22.3	(*)
			15	1	0	22.39	(*)
				1	11	22.36	(*)
				3	0	21.86	4.42
				3	6	22.19	4.45
				6	0	21.34	6.19
				6	6	21.37	5.96
				12	0	20.68	6.63

(*): Preliminary measurements determined that 3. 6 or 12 tones of 15kHz as the worst case. The results in the next tables shows the results for this configuration.

NBIoT. BAND 12.

Ch	Freq. (MHz)	Modulation	BW (kHz)	Num. tone	Offset Tone	Average Power (dBm)	PAPR (dB)
23012	699.2	π/2 - BPSK	3.75	1	0	22.43	(*)
				1	47	22.42	(*)
			15	1	0	22	(*)
				1	11	22.6	(*)
		π/4 - QPSK	3.75	1	0	22.48	(*)
				1	47	22.57	(*)
			15	1	0	22.85	(*)
				1	11	22.22	(*)
				3	0	22.52	3.73
				3	6	23.27	3.65
				6	0	21.78	5.27
				6	6	21.78	5.3
				12	0	20.83	5.69
23095	707.5	π/2 - BPSK	3.75	1	0	22.8	(*)
				1	47	22.85	(*)
			15	1	0	23.12	(*)
				1	11	23.11	(*)
		π/4 - QPSK	3.75	1	0	22.88	(*)
				1	47	22.91	(*)
			15	1	0	23.2	(*)
				1	11	23.14	(*)
				3	0	22.64	4.1
				3	6	23.21	3.87
				6	0	21.86	5.48
				6	6	21.91	5.4
				12	0	20.88	6.06
23178	715.8	π/2 - BPSK	3.75	1	0	22.78	(*)
				1	47	22.79	(*)
			15	1	0	22.91	(*)
				1	11	22.84	(*)
		π/4 - QPSK	3.75	1	0	22.83	(*)
				1	47	22.83	(*)
			15	1	0	22.8	(*)
				1	11	22.78	(*)
				3	0	22.28	4.09
				3	6	23.1	4.08
				6	0	21.6	5.67
				6	6	21.61	5.66
				12	0	20.64	6.22

(*): Preliminary measurements determined that 3. 6 or 12 tones of 15kHz as the worst case. The results in the next tables shows the results for this configuration.

NBIoT. BAND 13.

Ch	Freq. (MHz)	Modulation	BW (kHz)	Num. tone	Offset Tone	Average Power (dBm)	PAPR (dB)
23182	777.20	π/2 - BPSK	3.75	1	0	22.78	(*)
				1	47	22.74	(*)
			15	1	0	22.77	(*)
				1	11	22.73	(*)
		π/4 - QPSK	3.75	1	0	22.79	(*)
				1	47	22.81	(*)
			15	1	0	22.88 (***) 22.83 (**)	(*)
				1	11	22.65	(*)
				3	0	22.05	4.54
				3	6	22.51	4.58
				6	0	21.51	6.36
				6	6	21.51	6.3
				12	0	20.54	6.68
23230	782	π/2 - BPSK	3.75	1	0	22.67	(*)
				1	47	22.66	(*)
			15	1	0	22.73	(*)
				1	11	22.75	(*)
		π/4 - QPSK	3.75	1	0	22.65	(*)
				1	47	22.67	(*)
			15	1	0	22.77	(*)
				1	11	22.71	(*)
				3	0	22.1	4.54
				3	6	22.52	4.56
				6	0	21.54	6.39
				6	6	21.57	6.25
				12	0	20.6	6.67
23278	786.8	π/2 - BPSK	3.75	1	0	22.75	(*)
				1	47	22.74	(*)
			15	1	0	22.62	(*)
				1	11	22.73	(*)
		π/4 - QPSK	3.75	1	0	22.8	(*)
				1	47	22.79	(*)
			15	1	0	22.8	(*)
				1	11	22.64	(*)
				3	0	22.04	4.45
				3	6	22.47	4.58
				6	0	21.52	6.33
				6	6	21.53	6.31
				12	0	20.52	6.59

(*): Preliminary measurements determined that 3. 6 or 12 tones of 15kHz as the worst case. The results in the next tables shows the results for this configuration.

(**) Average power measurement in Sample 01.

(***): Average power measurement in Sample 02.

NBIoT. BAND 66.

Ch	Freq. (MHz)	Modulation	BW (kHz)	Num. tone	Offset Tone	Average Power (dBm)	PAPR (dB)
131974	1710.2	π/2 - BPSK	3.75	1	0	23.71	(*)
				1	47	23.72(***) 23.01(**)	(*)
			15	1	0	23.68	(*)
				1	11	23.64	(*)
		π/4 - QPSK	3.75	1	0	23.69	(*)
				1	47	23.68	(*)
			15	1	0	23.68	(*)
				1	11	23.66	(*)
				3	0	23.22	4.37
				3	6	23.57	4.38
				6	0	22.72	6.16
				6	6	22.74	6.07
				12	0	22.04	6.68
132322	1745	π/2 - BPSK	3.75	1	0	23.57	(*)
				1	47	23.58	(*)
			15	1	0	23.44	(*)
				1	11	23.41	(*)
		π/4 - QPSK	3.75	1	0	23.58	(*)
				1	47	23.58	(*)
			15	1	0	23.52	(*)
				1	11	23.47	(*)
				3	0	22.91	4.42
				3	6	23.23	4.49
				6	0	22.31	6.13
				6	6	22.4	6.1
				12	0	21.7	6.44
132670	1779.8	π/2 - BPSK	3.75	1	0	23.53	(*)
				1	47	23.53	(*)
			15	1	0	23.45	(*)
				1	11	23.47	(*)
		π/4 - QPSK	3.75	1	0	23.55	(*)
				1	47	23.53	(*)
			15	1	0	23.47	(*)
				1	11	23.45	(*)
				3	0	23.43	4.5
				3	6	23.32	4.53
				6	0	22.39	6.25
				6	6	22.38	6.22
				12	0	21.76	6.81

(*): Preliminary measurements determined that 3. 6 or 12 tones of 15kHz as the worst case. The results in the next tables shows the results for this configuration.

(**) Average power measurement in Sample 01.

(***): Average power measurement in Sample 02.

NBIoT. BAND 85.

Ch	Freq. (MHz)	Modulation	BW (kHz)	Num. tone	Offset Tone	Average Power (dBm)	PAPR (dB)
134004	698.2	π/2 - BPSK	3.75	1	0	22.36	(*)
				1	47	22.34	(*)
			15	1	0	22.81	(*)
				1	11	22.8	(*)
		π/4 - QPSK	3.75	1	0	22.49	(*)
				1	47	22.48	(*)
			15	1	0	22.78	(*)
				1	11	22.79	(*)
				3	0	22.41	3.61
				3	6	22.94	3.42
				6	0	21.64	4.97
				6	6	21.63	5.03
				12	0	20.66	5.56
134092	707	π/2 - BPSK	3.75	1	0	22.65	(*)
				1	47	22.64	(*)
			15	1	0	22.44	(*)
				1	11	22.75	(*)
		π/4 - QPSK	3.75	1	0	22.95	(*)
				1	47	22.73	(*)
			15	1	0	22.75	(*)
				1	11	22.72	(*)
				3	0	22.24	3.84
				3	6	22.79	3.63
				6	0	21.55	5.19
				6	6	21.57	5.06
				12	0	20.58	5.83
134180	715.8	π/2 - BPSK	3.75	1	0	22,62	(*)
				1	47	22,65	(*)
			15	1	0	22.68	(*)
				1	11	22.69	(*)
		π/4 - QPSK	3.75	1	0	22.75	(*)
				1	47	22.76	(*)
			15	1	0	22.68	(*)
				1	11	22.61	(*)
				3	0	22.11	4.04
				3	6	22.64	3.85
				6	0	21.44	5.4
				6	6	21.47	5.32
				12	0	20.5	6.27

(*): Preliminary measurements determined that 3. 6 or 12 tones of 15kHz as the worst case. The results in the next tables shows the results for this configuration.

NBIoT BAND 4.

Channel	Measured maximum average power (dBm) at antenna port	Maximum declared antenna gain (dBi)	Maximum equivalent isotropically radiated power (E.I.R.P.) (dBm)	Maximum effective radiated power E.R.P. (dBm)
Lowest	22.54	2.15	24.69	22.54
Middle	22.57	2.15	24.72	22.57
Highest	22.37	2.15	24.52	22.37
Measurement uncertainty (dB)	<±0.941			

NBIoT BAND 12.

Channel	Measured maximum average power (dBm) at antenna port	Maximum declared antenna gain (dBi)	Maximum equivalent isotropically radiated power (E.I.R.P.) (dBm)	Maximum effective radiated power E.R.P. (dBm)
Lowest	23.27	2.15	25.42	23.27
Middle	23.21	2.15	25.36	23.21
Highest	23.10	2.15	25.25	23.10
Measurement uncertainty (dB)	<±0.941			

NBIoT BAND 13.

Channel	Measured maximum average power (dBm) at antenna port	Maximum declared antenna gain (dBi)	Maximum equivalent isotropically radiated power (E.I.R.P.) (dBm)	Maximum effective radiated power E.R.P. (dBm)
Lowest	22.88	2.15	25.03	22.88
Middle	22.77	2.15	24.92	22.77
Highest	22.80	2.15	24.95	22.80
Measurement uncertainty (dB)	<±0.941			

NBIoT BAND 66.

Channel	Measured maximum average power (dBm) at antenna port	Maximum declared antenna gain (dBi)	Maximum equivalent isotropically radiated power (E.I.R.P.) (dBm)	Maximum effective radiated power E.R.P. (dBm)
Lowest	23.72	2.15	25.87	23.72
Middle	23.58	2.15	25.73	23.58
Highest	23.55	2.15	25.70	23.55
Measurement uncertainty (dB)	<±0.941			

NBIoT BAND 85.

Channel	Measured maximum average power (dBm) at antenna port	Maximum declared antenna gain (dBi)	Maximum equivalent isotropically radiated power (E.I.R.P.) (dBm)	Maximum effective radiated power E.R.P. (dBm)
Lowest	22.94	2.15	25.09	22.94
Middle	22.95	2.15	25.10	22.95
Highest	22.76	2.15	24.91	22.76
Measurement uncertainty (dB)	<±0.941			

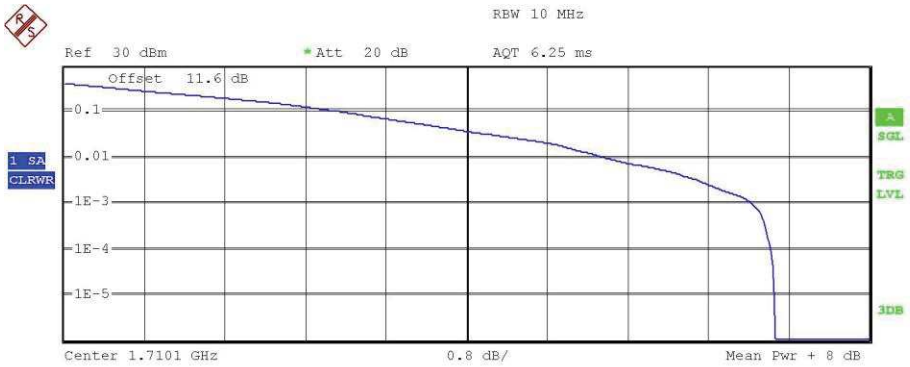
Verdict: PASS

PEAK-TO-AVERAGE POWER RATIO (PAPR).

NBIoT BAND 4.

Preliminary measurements determined that 12 tones of 15kHz as the worst case. The results in the next tables shows the results for this configuration.

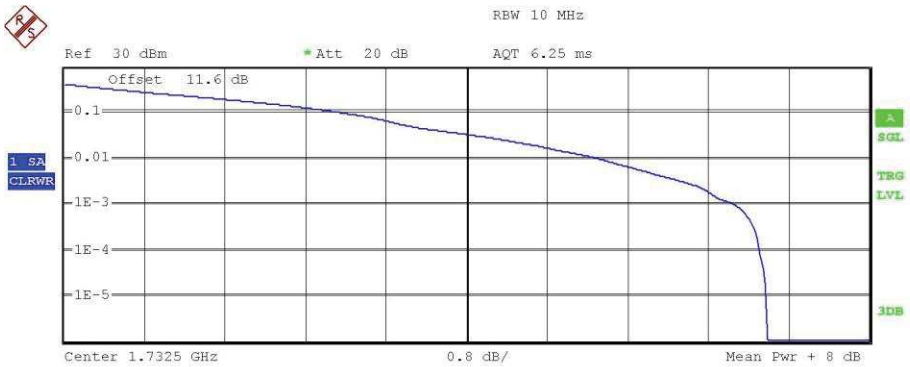
Channel Low:



Complementary Cumulative Distribution Function
NOF samples: 100000, Usable BW: 11.2MHz

	Trace 1
Mean	20.83 dBm
Peak	27.89 dBm
Crest	7.06 dB
10 %	2.78 dB
1 %	5.38 dB
.1 %	6.83 dB
.01 %	7.03 dB

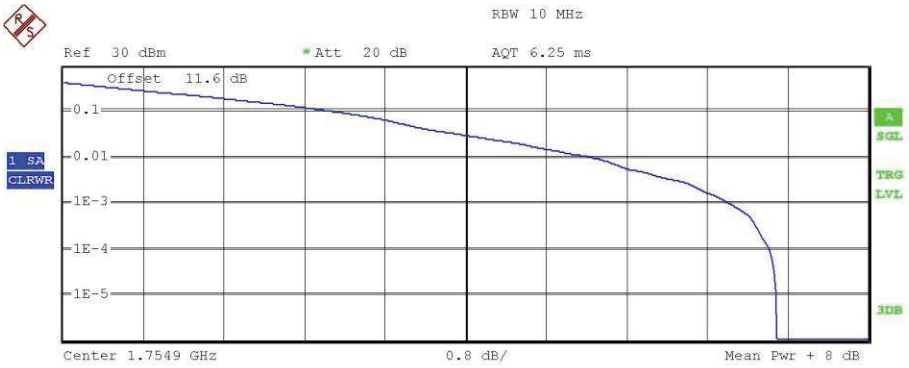
Channel Middle:



Complementary Cumulative Distribution Function
NOF samples: 100000, Usable BW: 11.2MHz

	Trace 1
Mean	20.72 dBm
Peak	27.70 dBm
Crest	6.98 dB
10 %	2.78 dB
1 %	5.31 dB
.1 %	6.65 dB
.01 %	6.91 dB

Channel High:



Complementary Cumulative Distribution Function
NOF samples: 100000, Usable BW: 11.2MHz

	Trace 1
Mean	20.33 dBm
Peak	27.42 dBm
Crest	7.09 dB
10 %	2.73 dB
1 %	5.27 dB
.1 %	6.63 dB
.01 %	7.03 dB

NBIoT BAND 12.

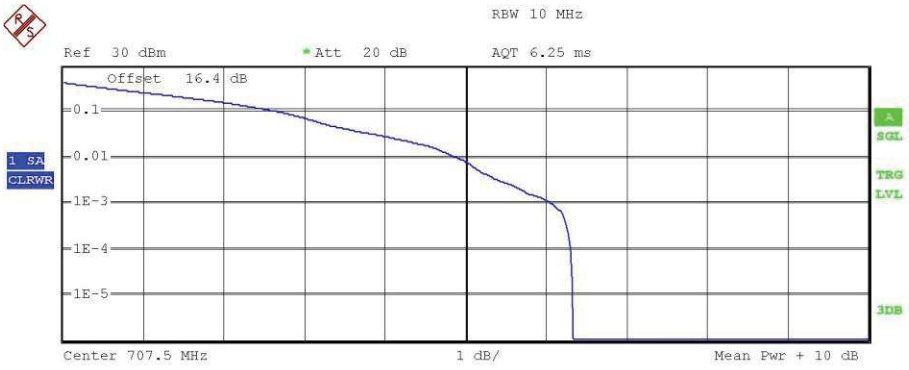
Preliminary measurements determined that 12 tones of 15kHz as the worst case. The results in the next tables shows the results for this configuration.

Channel Low:

Complementary Cumulative Distribution Function
NOF samples: 100000, Usable BW: 11.2MHz

	Trace 1
Mean	20.92 dBm
Peak	27.03 dBm
Crest	6.11 dB
10 %	2.61 dB
1 %	4.68 dB
.1 %	5.69 dB
.01 %	6.06 dB

Channel Middle:



Complementary Cumulative Distribution Function
NOF samples: 100000, Usable BW: 11.2MHz

	Trace 1
Mean	20.85 dBm
Peak	27.17 dBm
Crest	6.33 dB
10 %	2.69 dB
1 %	4.89 dB
.1 %	6.06 dB
.01 %	6.31 dB

Channel High:

Complementary Cumulative Distribution Function
NOF samples: 100000, Usable BW: 11.2MHz

	Trace 1
Mean	20.74 dBm
Peak	27.31 dBm
Crest	6.56 dB
10 %	2.60 dB
1 %	4.95 dB
.1 %	6.22 dB
.01 %	6.55 dB

NBIoT BAND 13.

Preliminary measurements determined that 12 tones of 15kHz as the worst case. The results in the next tables shows the results for this configuration.

Channel Low:

Complementary Cumulative Distribution Function
NOF samples: 100000, Usable BW: 11.2MHz

	Trace 1
Mean	20.62 dBm
Peak	27.81 dBm
Crest	7.19 dB
10 %	2.60 dB
1 %	5.08 dB
.1 %	6.68 dB
.01 %	7.13 dB

Channel Middle:

Complementary Cumulative Distribution Function
NOF samples: 100000, Usable BW: 11.2MHz

	Trace 1
Mean	20.57 dBm
Peak	27.74 dBm
Crest	7.17 dB
10 %	2.60 dB
1 %	5.06 dB
.1 %	6.67 dB
.01 %	7.15 dB

Channel High:

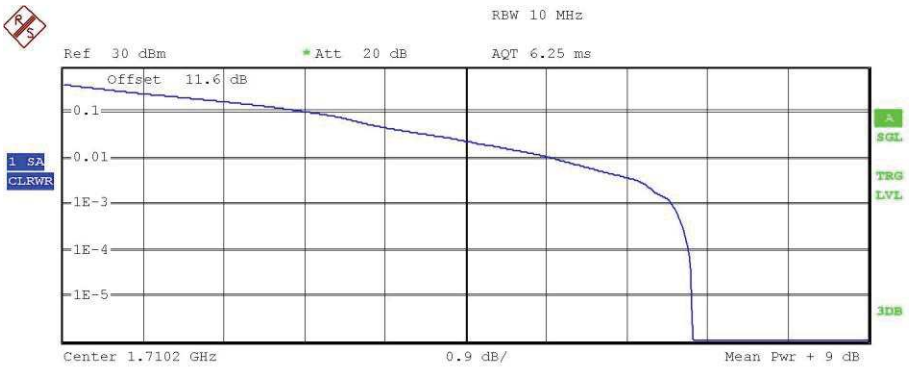
Complementary Cumulative Distribution Function
NOF samples: 100000, Usable BW: 11.2MHz

	Trace 1
Mean	20.58 dBm
Peak	27.82 dBm
Crest	7.24 dB
10 %	2.61 dB
1 %	5.06 dB
.1 %	6.59 dB
.01 %	7.15 dB

NBIoT BAND 66.

Preliminary measurements determined that 12 tones of 15kHz as the worst case. The results in the next tables shows the results for this configuration.

Channel Low:



Complementary Cumulative Distribution Function
NOF samples: 100000, Usable BW: 11.2MHz

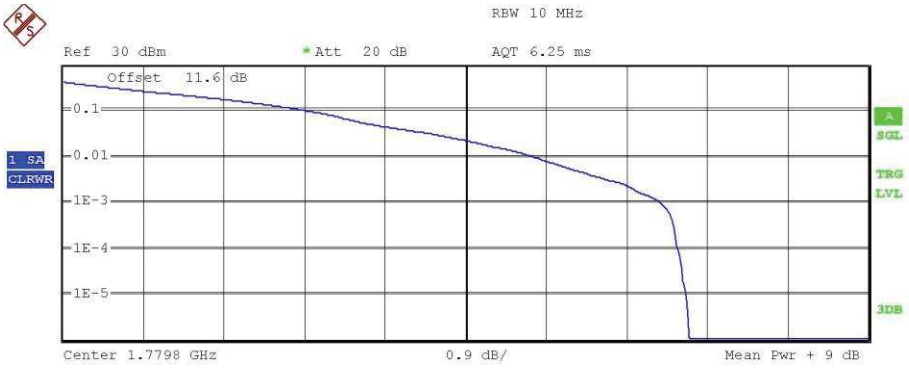
	Trace 1
Mean	20.86 dBm
Peak	27.89 dBm
Crest	7.03 dB
10 %	2.81 dB
1 %	5.50 dB
.1 %	6.81 dB
.01 %	7.00 dB

Channel Middle:

Complementary Cumulative Distribution Function
NOF samples: 100000, Usable BW: 11.2MHz

	Trace 1
Mean	20.58 dBm
Peak	27.48 dBm
Crest	6.90 dB
10 %	2.70 dB
1 %	5.27 dB
.1 %	6.44 dB
.01 %	6.84 dB

Channel High:



Complementary Cumulative Distribution Function
NOF samples: 100000, Usable BW: 11.2MHz

	Trace 1
Mean	20.27 dBm
Peak	27.27 dBm
Crest	7.00 dB
10 %	2.74 dB
1 %	5.26 dB
.1 %	6.68 dB
.01 %	6.88 dB

NBIoT BAND 85.

Preliminary measurements determined that 12 tones of 15kHz as the worst case. The results in the next tables shows the results for this configuration.

Channel Low:

Complementary Cumulative Distribution Function
NOF samples: 100000, Usable BW: 11.2MHz

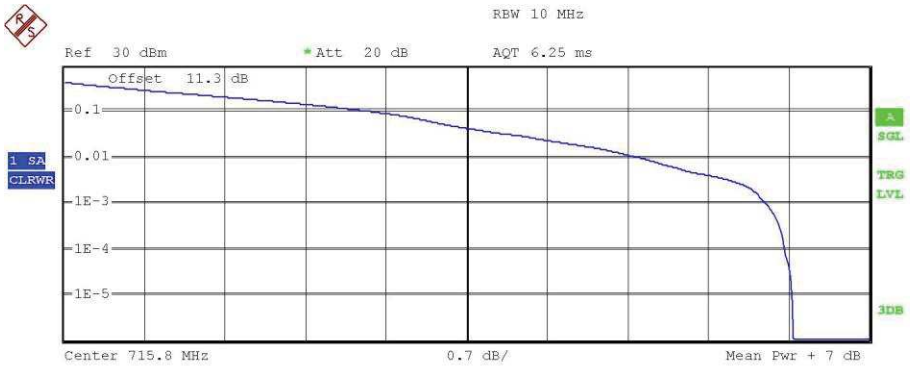
	Trace 1
Mean	20.83 dBm
Peak	26.65 dBm
Crest	5.82 dB
10 %	2.74 dB
1 %	4.61 dB
.1 %	5.56 dB
.01 %	5.77 dB

Channel Middle:

Complementary Cumulative Distribution Function
NOF samples: 100000, Usable BW: 11.2MHz

	Trace 1
Mean	20.79 dBm
Peak	26.87 dBm
Crest	6.08 dB
10 %	2.76 dB
1 %	4.85 dB
.1 %	5.83 dB
.01 %	6.00 dB

Channel High:



Complementary Cumulative Distribution Function
NOF samples: 100000, Usable BW: 11.2MHz

	Trace 1
Mean	20.66 dBm
Peak	27.00 dBm
Crest	6.33 dB
10 %	2.70 dB
1 %	5.00 dB
.1 %	6.10 dB
.01 %	6.27 dB

Frequency Stability

SPECIFICATION

FCC §2.1055 and §27.54.

The frequency stability shall be sufficient to ensure that the fundamental emission stays within the authorized frequency block.

RSS-130. Clause 4.3.

The applicant shall ensure frequency stability by showing that fL minus the frequency offset and fH plus the frequency offset shall be within the frequency range in which the equipment is designed to operate.

RSS-139 Clause 6.4.

The frequency stability shall be sufficient to ensure that the occupied bandwidth stays within the operating frequency block when tested to the temperature and supply voltage variations specified in RSS-Gen.

METHOD

The frequency tolerance measurements over temperature variations were made over the temperature range of –30ºC to +50ºC. The EUT was placed inside a climatic chamber and the temperature was raised hourly in 10ºC steps from –30ºC up to +50ºC.
The supply voltage was varied between 85% and 115% of nominal voltage.

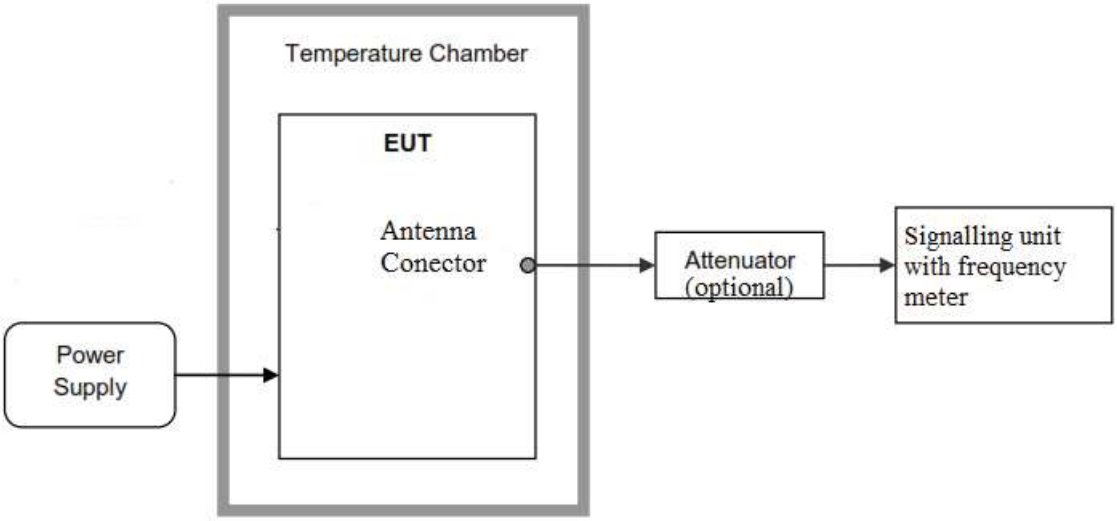
The EUT was set in “Radio Resource Control (RRC) mode” in the middle channel using the Universal Radio Communication tester R&S CMW500 and the maximum frequency error was measured using the built-in calibrated frequency meter.
The worst case NBIoT mode for conducted power was used for the test.

In order to check that the frequency stability is sufficient such that the fundamental emissions stay within the authorized bands of operation. a reference point is established at the applicable unwanted emissions limit using a RBW equal to the RBW required by the unwanted emissions specification of the applicable regulatory standard. These reference points measured using the lowest and highest channel of operation are identified as fL and fH respectively. The worst-case frequency offset determined in the above methods is added or subtracted from the values of fL and fH to check that the resulting frequencies remain within the band.

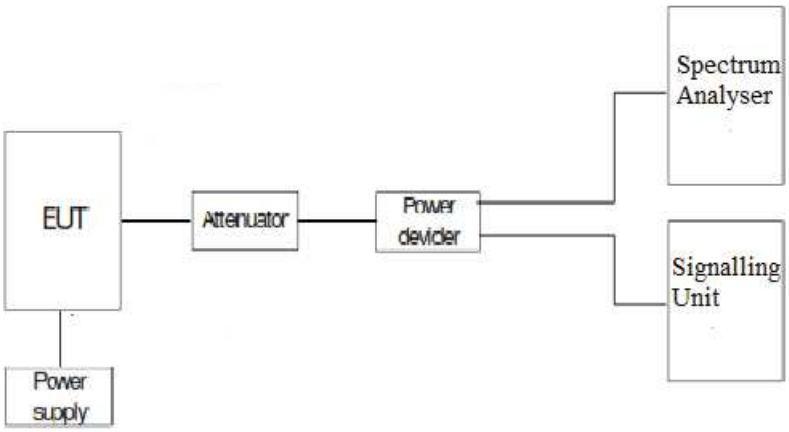
The reference point measurements were made at the RF output terminals of the EUT using an attenuator. power splitter and spectrum analyser. The EUT was controlled via the Universal Radio Communication tester R&S CMW500 selecting maximum transmission power.

TEST SETUP

Frequency tolerance.



Reference points *f*L and *fH.*



RESULTS

Frequency stability over temperature variations.

NBIoT Band 12 - π/4 - QPSK modulation. 1 tone 3.75 kHz. Channel: 707.5 MHz.

Temperature (ºC)	Frequency Error (Hz)	Frequency Error (ppm)
+50	-1.76	-0.002487633
+40	-6.85	-0.009681979
+30	3.02	0.004268551
+20	-2.89	-0.004084806
+10	1.85	0.002614841
0	-9.33	-0.013187279
-10	-4.96	-0.007010601
-20	-6.81	-0.009625442
-30	1.44	0.002035336

Measurement uncertainty (Hz)	<±87

NBIoT Band 13 - π/4 - QPSK modulation. 1 tone 3.75 kHz. Channel: 782 MHz.

Temperature (ºC)	Frequency Error (Hz)	Frequency Error (ppm)
+50	1.65	0.002109974
+40	-1.13	-0.001445013
+30	3.01	0.003849105
+20	-0.76	-0.000971867
+10	0.93	0.001189258
0	2.73	0.003491049
-10	2.13	0.002723785
-20	-5.79	-0.007404092
-30	4.98	0.006368286

Measurement uncertainty (Hz)	<±96

NBIoT Band 66 - π/4 - QPSK modulation. 1 tone 3.75 kHz. Channel: 1745 MHz.

Temperature (ºC)	Frequency Error (Hz)	Frequency Error (ppm)
+50	3.33	0.001908309
+40	-2.9	-0.001661891
+30	-2.88	-0.00165043
+20	-5.24	-0.003002865
+10	6.94	0.003977077
0	6.19	0.003547278
-10	-2.68	-0.001535817
-20	2.33	0.001335244
-30	-6.22	-0.00356447

Measurement uncertainty (Hz)	<±208

NBIoT Band 85 - π/4 - QPSK modulation. 1 tone 3.75 kHz. Channel: 707 MHz.

Temperature (ºC)	**Frequency Error (Hz)**	**Frequency Error (ppm)**
+50	-4.63	-0.006548798
+40	-7.07	-0.01
+30	10.81	0.015289958
+20	0.87	0.001230552
+10	5.69	0.008048091
0	11.77	0.016647808
-10	1.56	0.002206506
-20	-2.46	-0.003479491
-30	2.96	0.004186704

Measurement uncertainty (Hz)	<±87

Frequency stability over voltage variations.

NBIoT Band 12

Battery Supply voltage	**Voltage (V)**	**Frequency Error (Hz)**	**Frequency Error (ppm)**
Vmax	4.2	1.96	0.002770318
Vmin	3.2	-4.05	-0.005724382

NBIoT Band 13

Battery Supply voltage	Voltage (V)	Frequency Error (Hz)	Frequency Error (ppm)
Vmax	4.2	-6.37	-0.00814578
Vmin	3.2	-2.43	-0.003107417

NBIoT Band 66

Battery Supply voltage	Voltage (V)	Frequency Error (Hz)	Frequency Error (ppm)
Vmax	4.2	1.68	0.000962751
Vmin	3.2	8.73	0.005002865

NBIoT Band 85

Battery Supply voltage	Voltage (V)	Frequency Error (Hz)	Frequency Error (ppm)
Vmax	4.2	-6.11	-0.00864215
Vmin	3.2	-2.85	-0.004031117

Reference points established at the applicable unwanted emissions limit (worst case):

	NBIoT Band 12
*f*L (MHz)	698.937670
fH (MHz)	715.963417

	NBIoT Band 13
*f*L (MHz)	777.048700
fH (MHz)	786.952633

	NBIoT Band 66
*f*L (MHz)	1710.05340
fH (MHz)	1779.93900

	NBIoT Band 85
*f*L (MHz)	698.04290
fH (MHz)	715.97494

Reference points *f*L and *fH* with the worst-case frequency offsets added or subtracted:

	NBIoT Band 12
*f*L (MHz)	698.937660
fH (MHz)	715.963420

	NBIoT Band 13
*f*L (MHz)	777.048694
fH (MHz)	786.952637

	NBIoT Band 66
*f*L (MHz)	1710.05324
fH (MHz)	1779.93900

	NBIoT Band 85
*f*L (MHz)	698.042892
fH (MHz)	715.975177

The reference frequency points stay within the authorized blocks.

Verdict: PASS

Modulation Characteristics

SPECIFICATION

FCC §2.1047

RSS-130. Clause 4.1 and RSS-133. Clause 6.2. Equipment certified under this standard shall use digital modulation.

RSS-139 Clause 6.2:

> The devices may employ any type of modulation techniques. The type of modulation used must be reported.

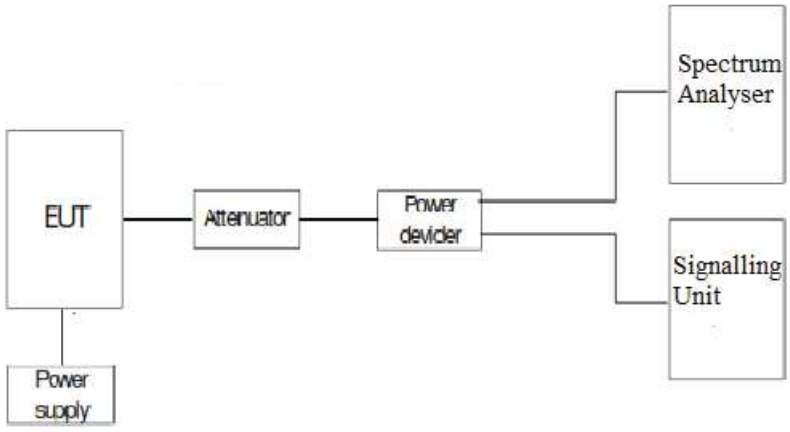
RSS-199 Clause 4.1:

> Equipment certified under this standard shall employ digital modulation.

METHOD

For NBIoT the EUT operates with π/2 - BPSK and π/4 - QPSK modulation modes in which the information is digitised and coded into a bit stream.

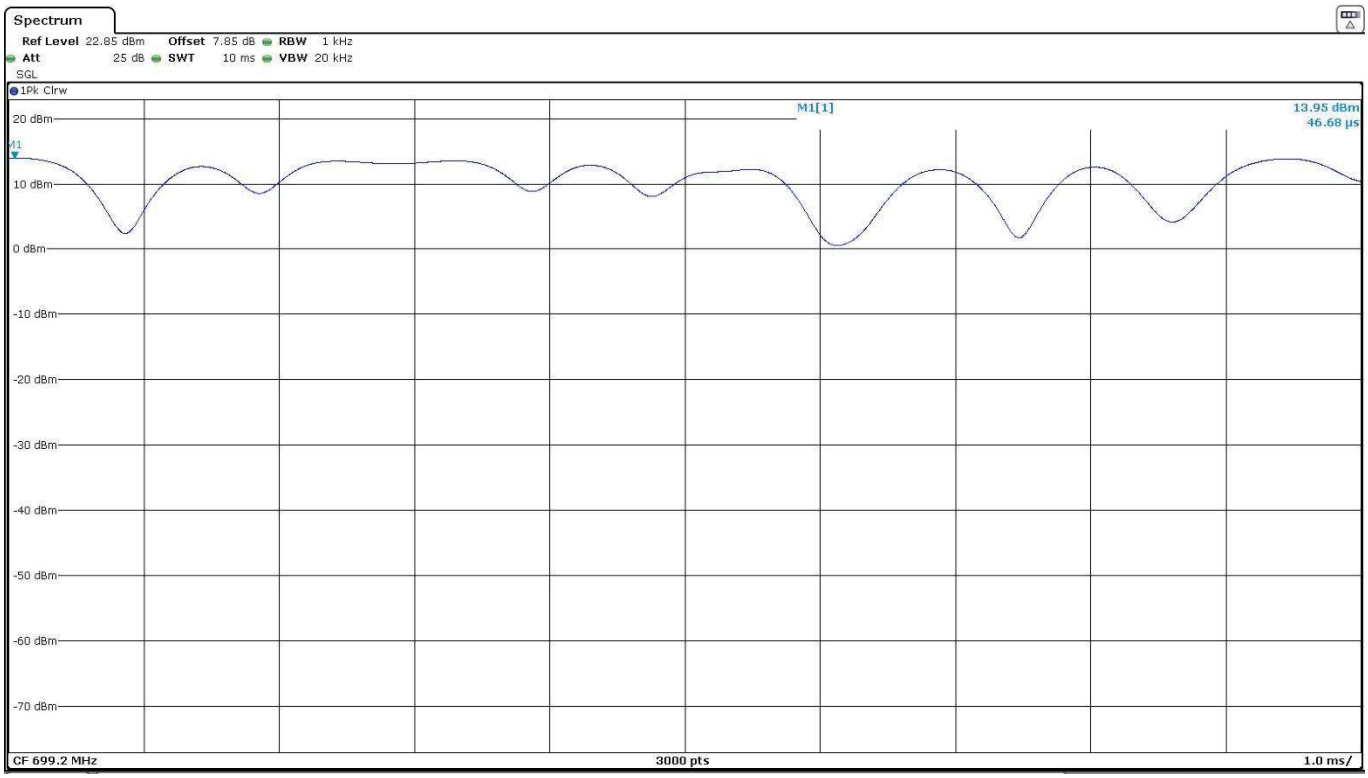
TEST SETUP



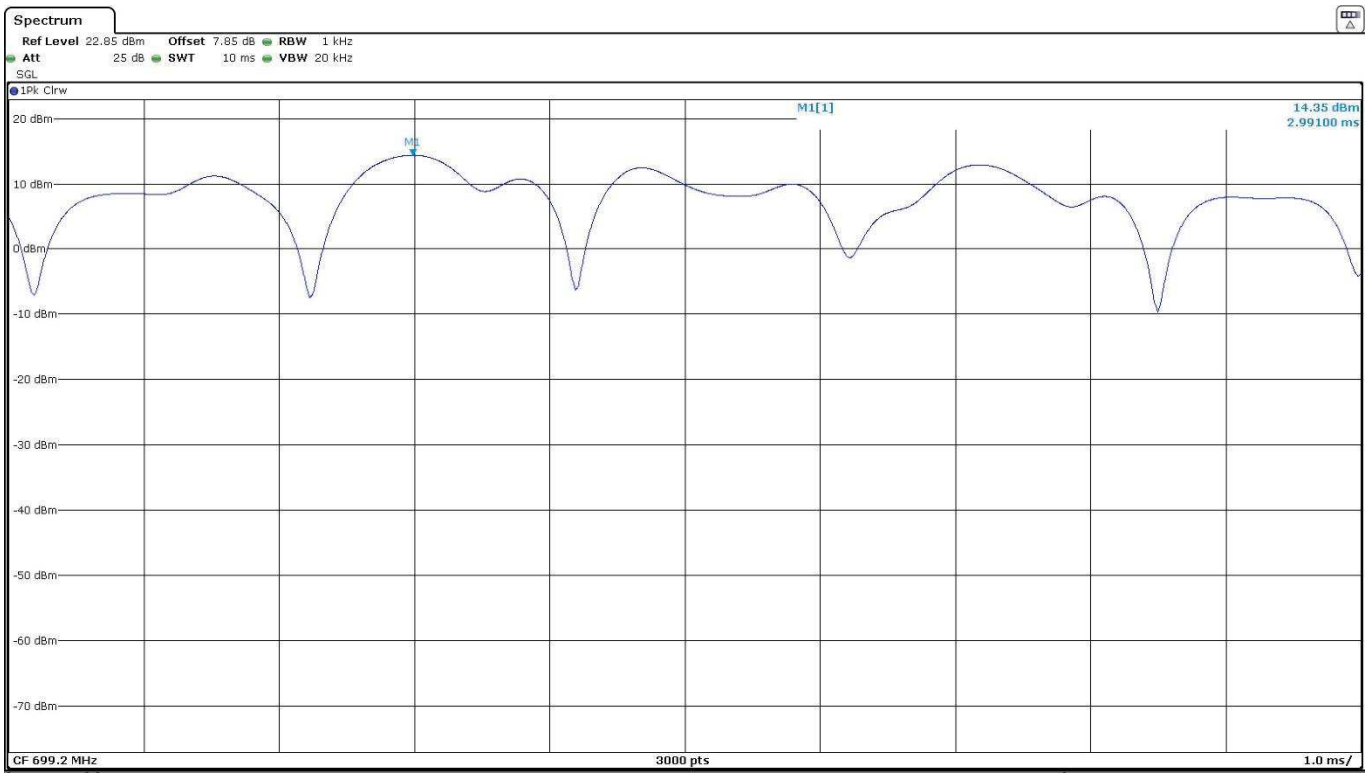
RESULTS

The following plot shows the modulation schemes in the EUT.

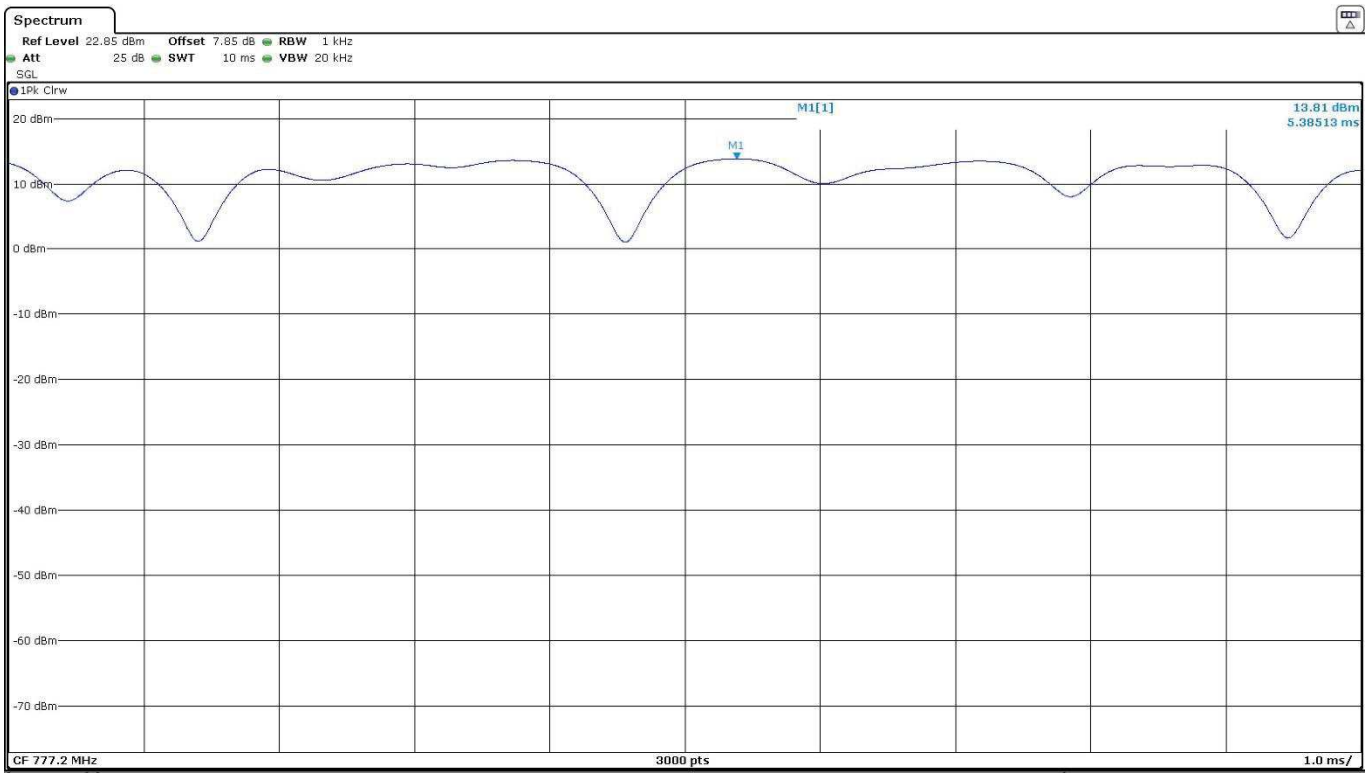
NBIoT MODULATION (Band 12). π/2 - BPSK.



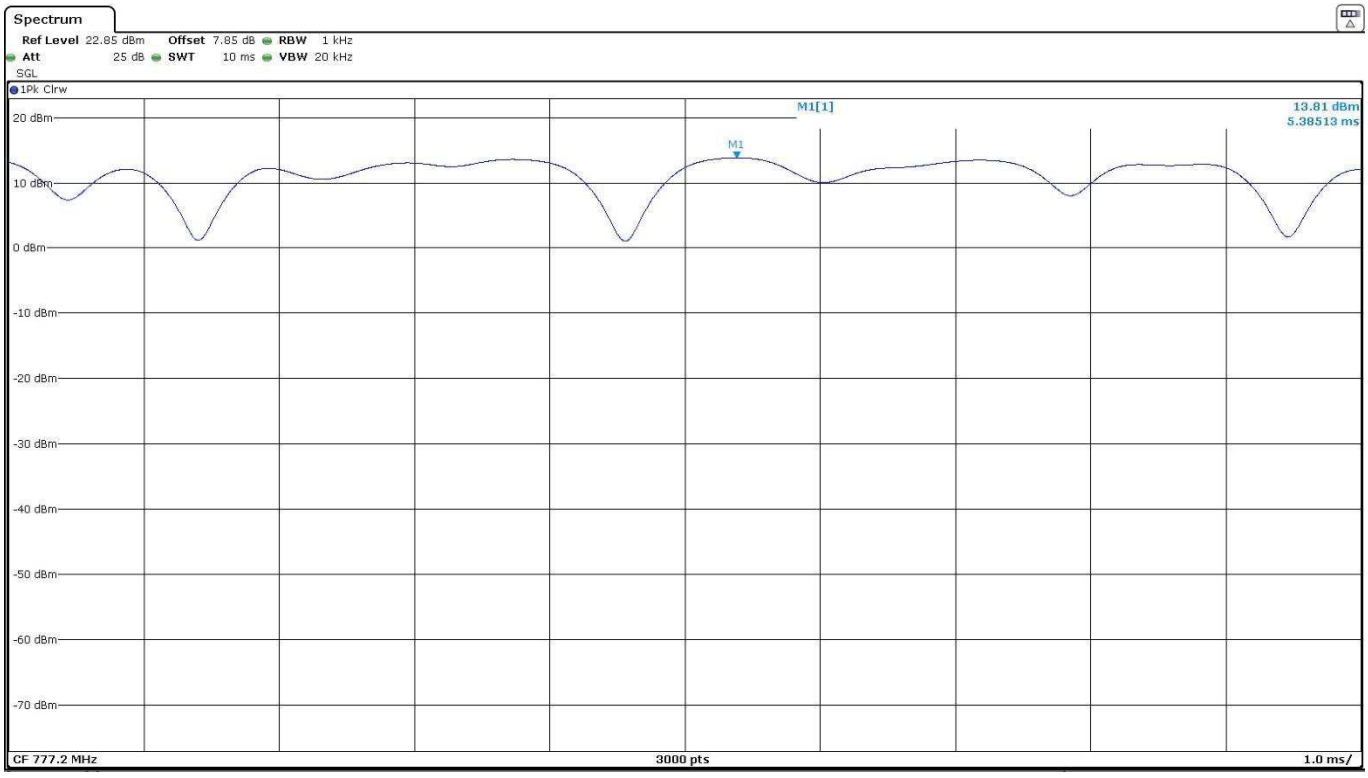
NBIoT MODULATION (Band 12). π/4 - QPSK.



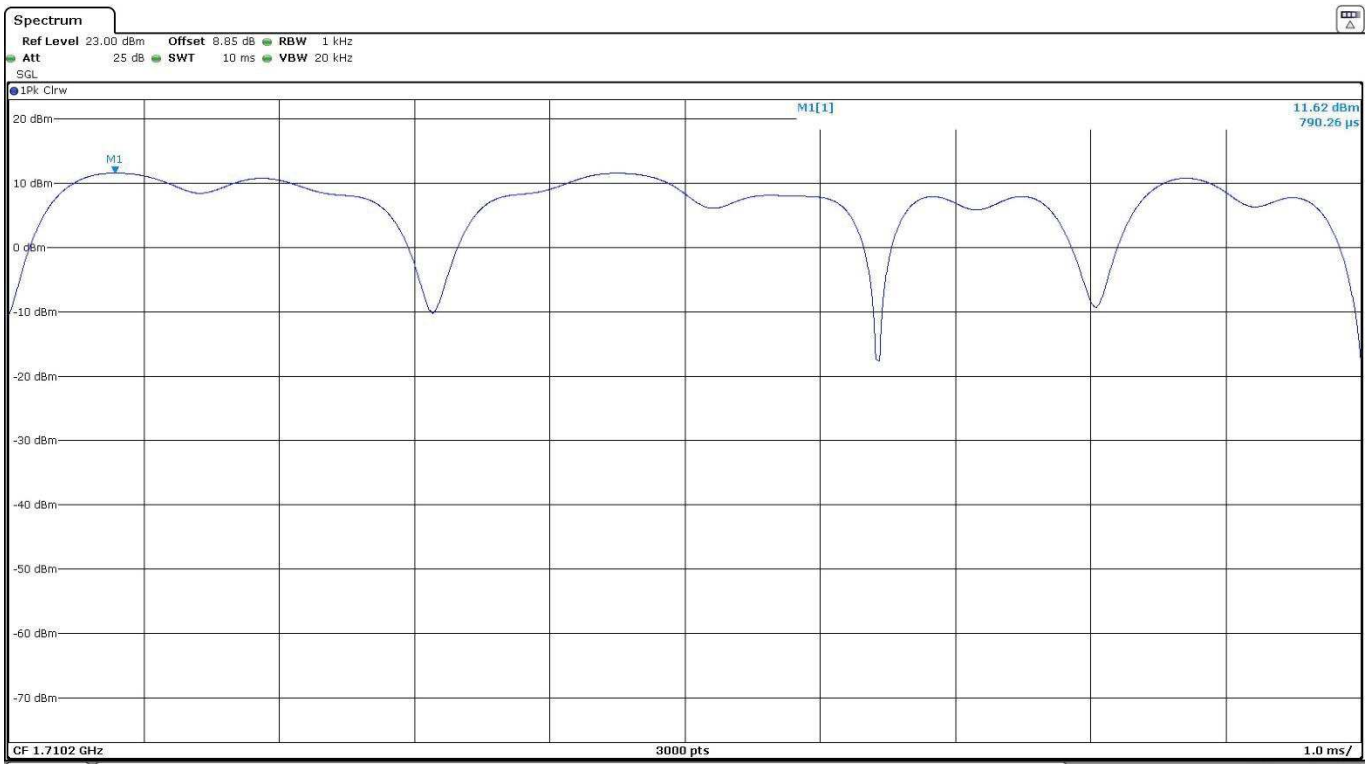
NBIoT MODULATION (Band 13). π/2 - BPSK.



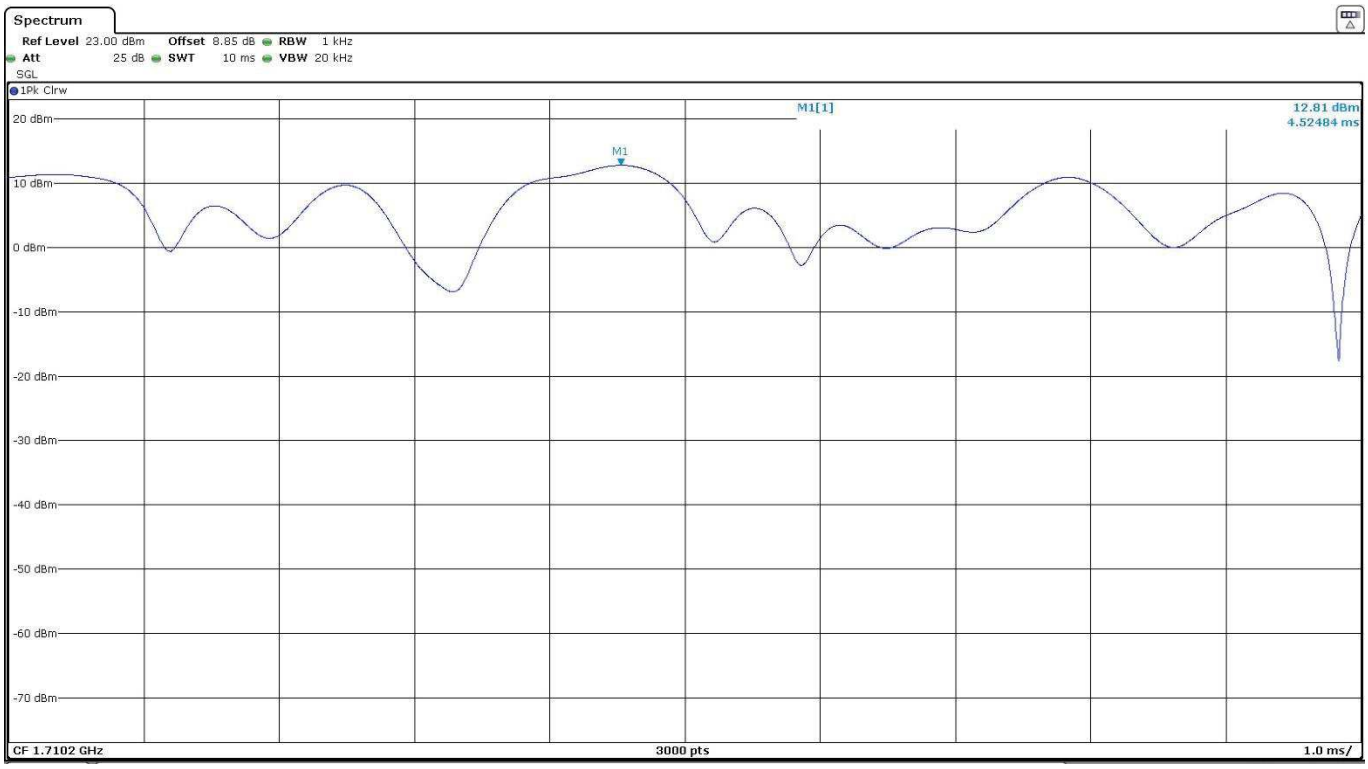
NBIoT MODULATION (Band 13). π/4 - QPSK.



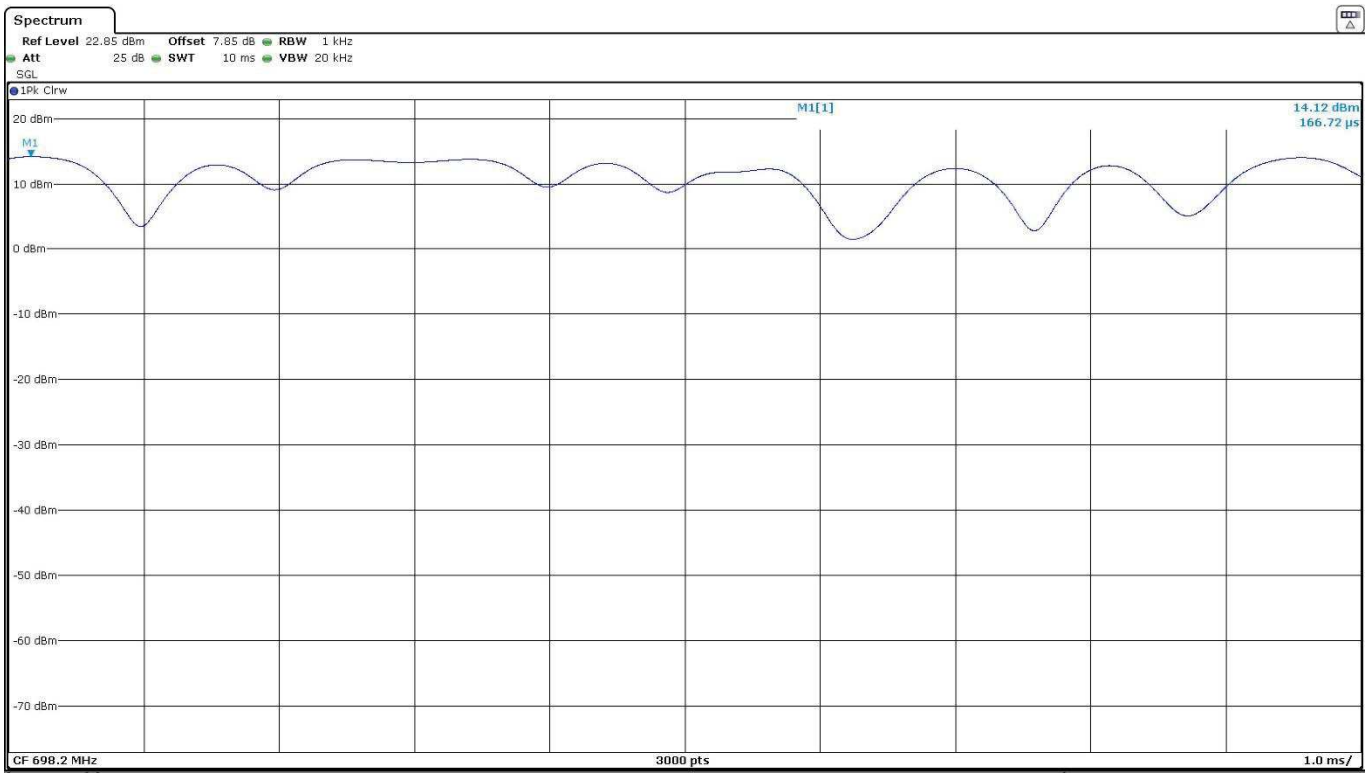
NBIoT MODULATION (Band 66). π/2 - BPSK.



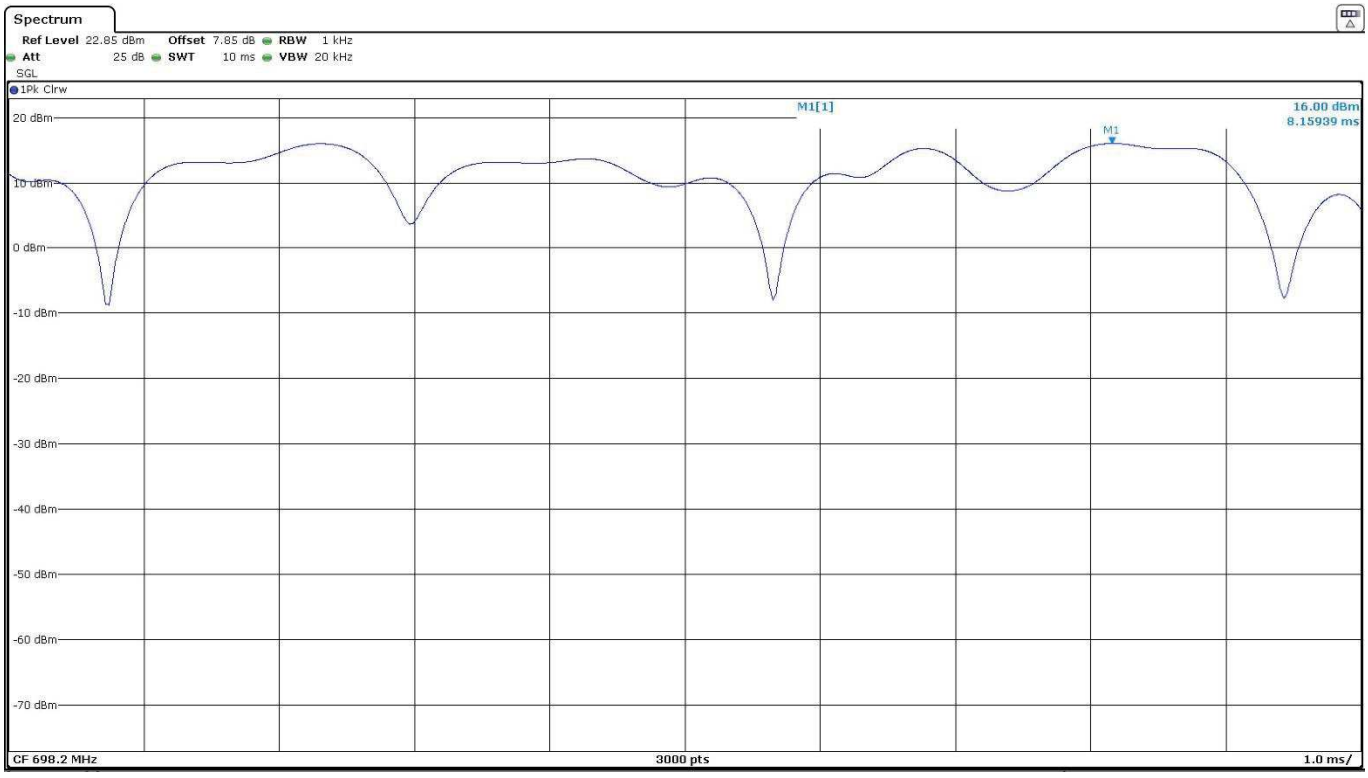
NBIoT MODULATION (Band 66). π/4 - QPSK.



NBIoT MODULATION (Band 85). π/2 - BPSK.



NBIoT MODULATION (Band 85). π/4 - QPSK.



Occupied Bandwidth

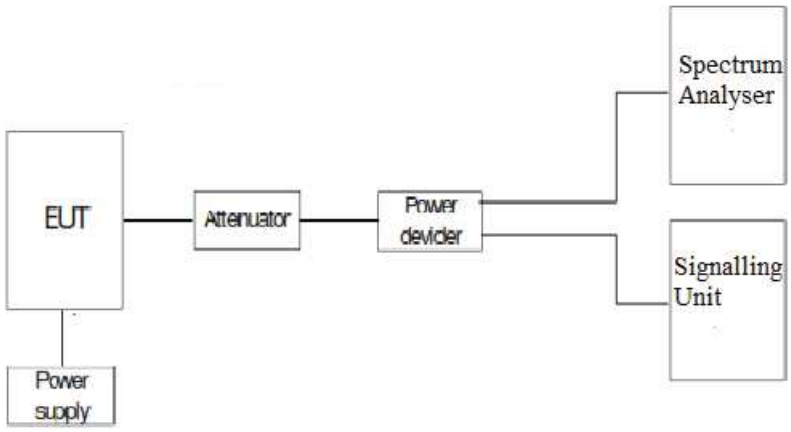
SPECIFICATION

§2.1049

METHOD

The occupied bandwidth measurement was performed at the output terminals of the EUT using an attenuator. power splitter and spectrum analyser. The EUT was controlled via the Universal Radio Communication tester R&S CMW500 selecting maximum transmission power of the EUT and different modes of modulation. The 99% occupied bandwidth and the -26 dBc bandwidth were measured directly using the built-in bandwidth measuring option of spectrum analyser.

TEST SETUP



RESULTS (see next plots)

NBIoT BAND 12.

Tone 3.75 kHz. π/2 - BPSK MODULATION

Channel	Lowest	Middle	Highest
99% Occupied bandwidth (kHz)	37.433	37.600	37.667
-26 dBc bandwidth (kHz)	34.801	34.803	34.868
Measurement uncertainty (kHz)	<±0.13		

Tone 3.75 kHz. π/4 - QPSK MODULATION

Channel	Lowest	Middle	Highest
99% Occupied bandwidth (kHz)	37.967	37.867	38.033
-26 dBc bandwidth (kHz)	36.978	39.277	36.968
Measurement uncertainty (kHz)	<±0.13		

Tone 15 kHz. π/2 - BPSK MODULATION

Channel	Lowest	Middle	Highest
99% Occupied bandwidth (kHz)	73.333	72.933	73.200
-26 dBc bandwidth (kHz)	89.057	88.924	92.168
Measurement uncertainty (kHz)	<±0.27		

12 Tones 15 kHz. π/4 - QPSK MODULATION

Channel	Lowest	Middle	Highest
99% Occupied bandwidth (kHz)	190.133	189.867	190.533
-26 dBc bandwidth (kHz)	254.981	255.119	266.176
Measurement uncertainty (kHz)	<±0.12		

NBIoT BAND 13.

Tone 3.75 kHz. π/2 - BPSK MODULATION

Channel	Lowest	Middle	Highest
99% Occupied bandwidth (kHz)	37.767	37.833	37.533
-26 dBc bandwidth (kHz)	34.868	34.870	34.830
Measurement uncertainty (kHz)	<±0.13		

Tone 3.75 kHz. π/4 - QPSK MODULATION

Channel	Lowest	Middle	Highest
99% Occupied bandwidth (kHz)	38.167	38.100	38.267
-26 dBc bandwidth (kHz)	37.031	36.968	39.297
Measurement uncertainty (kHz)	<±0.13		

Tone 15 kHz. π/2 - BPSK MODULATION

Channel	Lowest	Middle	Highest
99% Occupied bandwidth (kHz)	73.467	73.200	73.467
-26 dBc bandwidth (kHz)	92.368	92.306	92.221
Measurement uncertainty (kHz)	<±0.27		

12 Tones 15 kHz. π/4 - QPSK MODULATION

Channel	Lowest	Middle	Highest
99% Occupied bandwidth (kHz)	191.467	189.333	190.533
-26 dBc bandwidth (kHz)	266.096	267.800	256.016
Measurement uncertainty (kHz)	<±0.65		

NBIoT BAND 66.

Tone 3.75 kHz. π/2 - BPSK MODULATION

Channel	Lowest	Middle	Highest
99% Occupied bandwidth (kHz)	45.600	45.333	45.933
-26 dBc bandwidth (kHz)	40.300	40.933	41.200
Measurement uncertainty (kHz)	<±0.13		

Tone 3.75 kHz. π/4 - QPSK MODULATION

Channel	Lowest	Middle	Highest
99% Occupied bandwidth (kHz)	47.333	47.600	48.000
-26 dBc bandwidth (kHz)	41.700	41.800	41.600
Measurement uncertainty (kHz)	<±0.13		

Tone 15 kHz. π/2 - BPSK MODULATION

Channel	Lowest	Middle	Highest
99% Occupied bandwidth (kHz)	75.083	75.333	75.666
-26 dBc bandwidth (kHz)	92.250	89.333	89.867
Measurement uncertainty (kHz)	<±0.27		

12 Tones 15 kHz. π/4 - QPSK MODULATION

Channel	Lowest	Middle	Highest
99% Occupied bandwidth (kHz)	192.800	192.800	193.067
-26 dBc bandwidth (kHz)	277.050	268.800	268.400
Measurement uncertainty (kHz)	<±0.65		

NBIoT BAND 85.

Tone 3.75 kHz. π/2 - BPSK MODULATION

Channel	Lowest	Middle	Highest
99% Occupied bandwidth (kHz)	37.600	34.233	37.733
-26 dBc bandwidth (kHz)	34.833	37.433	34.800
Measurement uncertainty (kHz)	<±0.13		

Tone 3.75 kHz. π/4 - QPSK MODULATION

Channel	Lowest	Middle	Highest
99% Occupied bandwidth (kHz)	37.900	37.933	38.133
-26 dBc bandwidth (kHz)	36.933	39.233	36.933
Measurement uncertainty (kHz)	<±0.13		

Tone 15 kHz. π/2 - BPSK MODULATION

Channel	Lowest	Middle	Highest
99% Occupied bandwidth (kHz)	73.667	73.667	73.500
-26 dBc bandwidth (kHz)	92.192	92.083	92.000
Measurement uncertainty (kHz)	<±0.27		

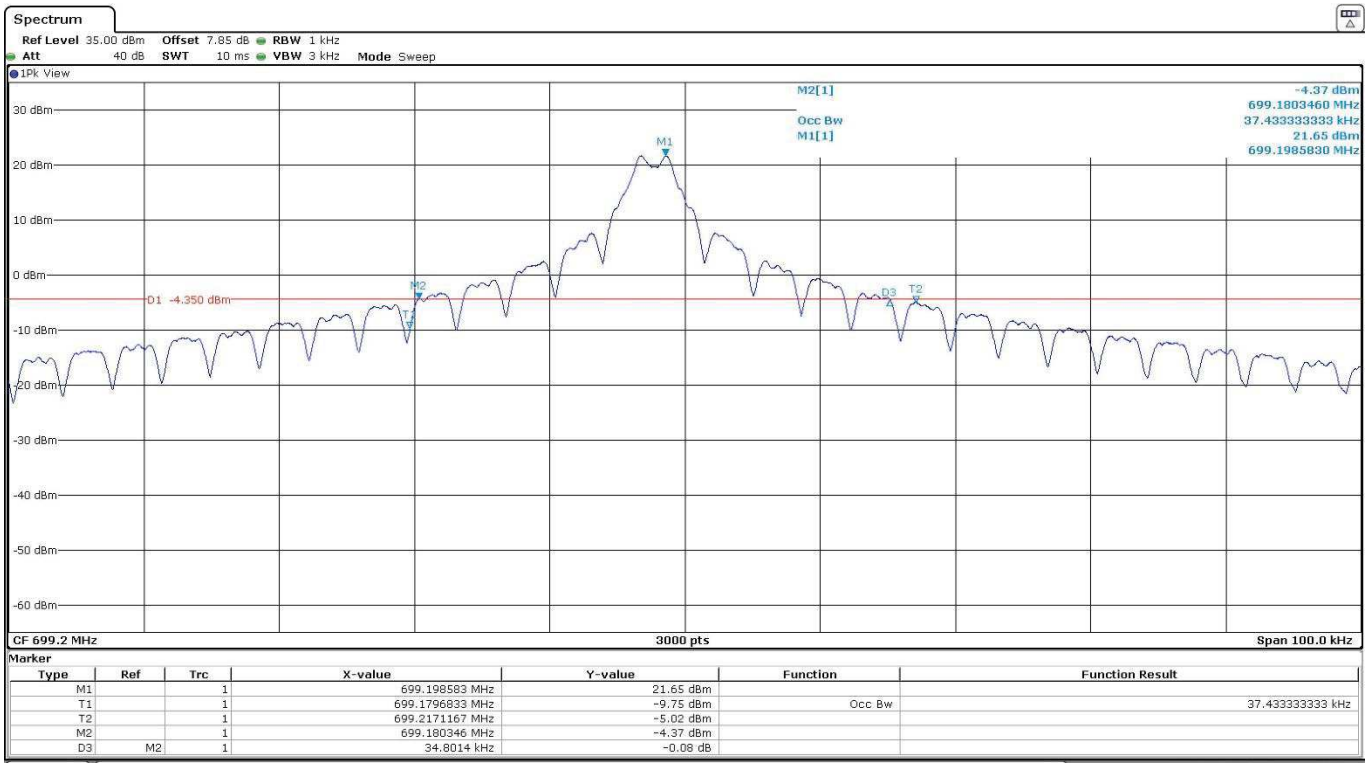
12 Tones 15 kHz. π/4 - QPSK MODULATION

Channel	Lowest	Middle	Highest
99% Occupied bandwidth (kHz)	190.267	189.733	190.133
-26 dBc bandwidth (kHz)	254.800	254.800	254.800
Measurement uncertainty (kHz)	<±0.65		

NBIoT BAND 12.

Tone 3.75 kHz. π/2 - BPSK MODULATION

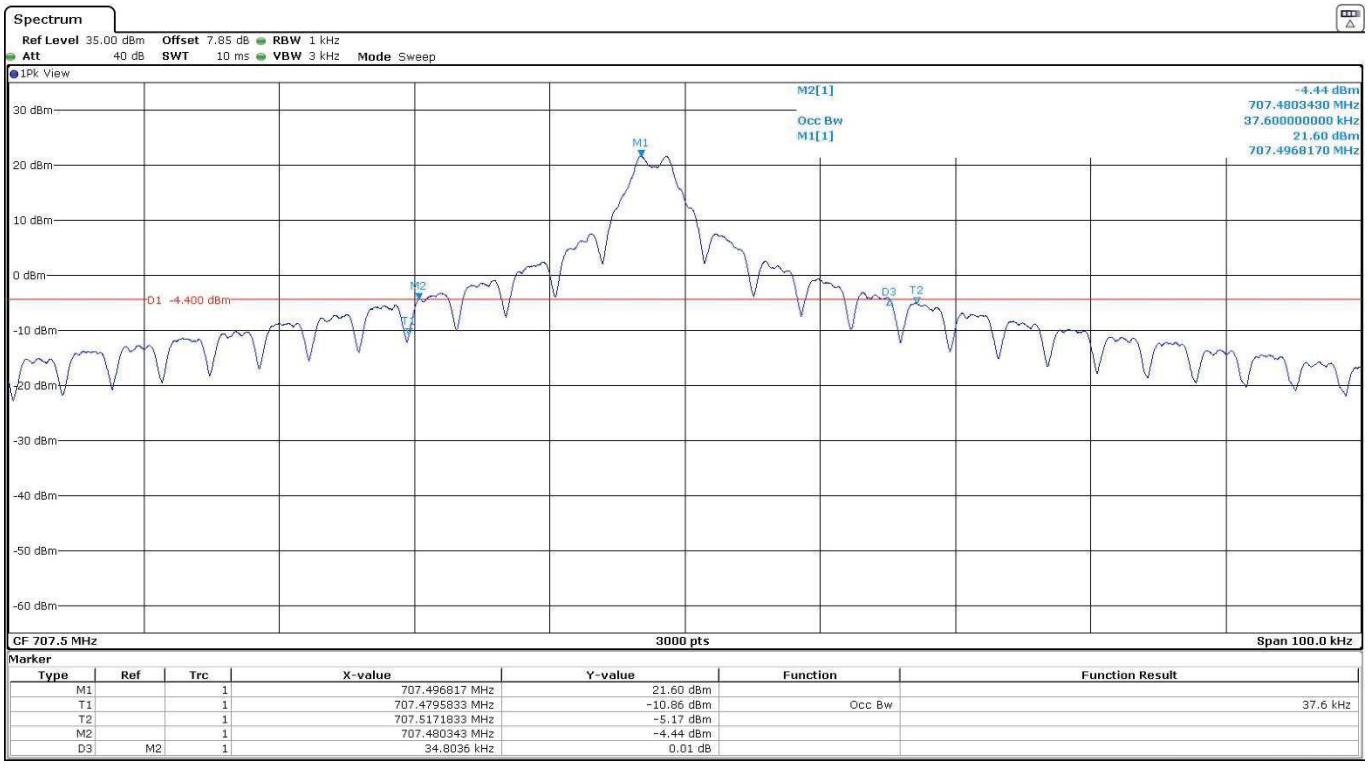
Lowest Channel



Marker

Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1		1	699.198583 MHz	21.65 dBm		
T1		1	699.1796833 MHz	-9.75 dBm	Occ Bw	37.433333333 kHz
T2		1	699.2171167 MHz	-5.02 dBm		
M2		1	699.180346 MHz	-4.37 dBm		
D3	M2	1	34.8014 kHz	-0.08 dB		

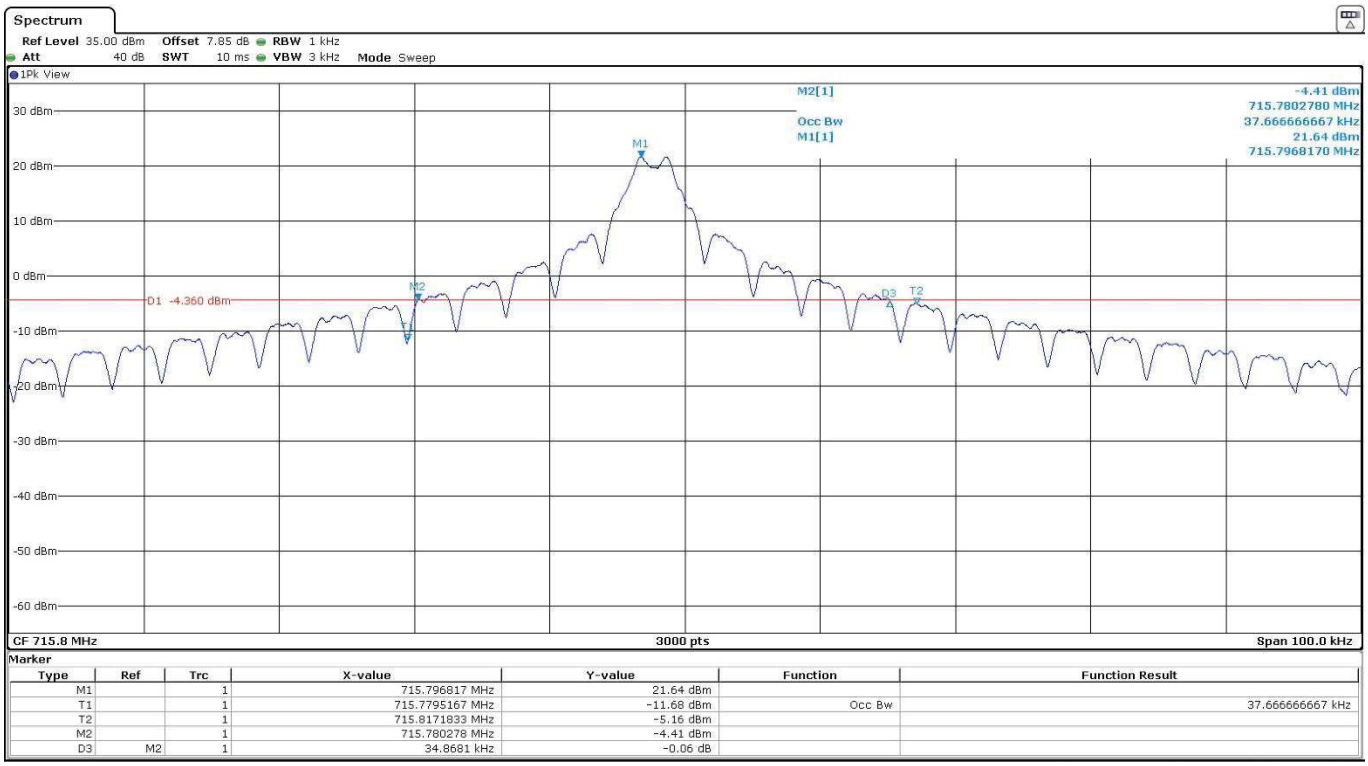
Middle Channel



Marker

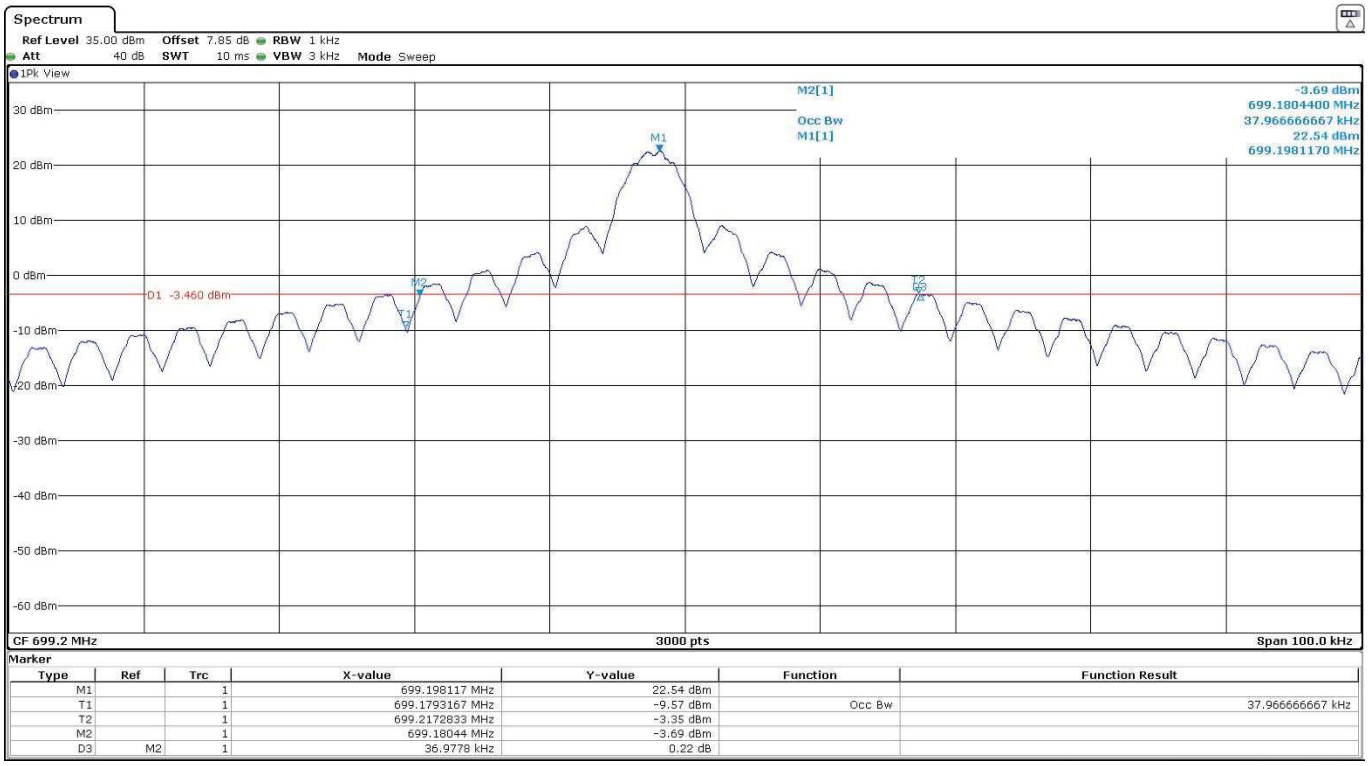
Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1		1	707.496817 MHz	21.60 dBm		
T1		1	707.4795833 MHz	-10.86 dBm	Occ Bw	37.6 kHz
T2		1	707.5171833 MHz	-5.17 dBm		
M2		1	707.480343 MHz	-4.44 dBm		
D3	M2	1	34.8036 kHz	0.01 dB		

Highest Channel

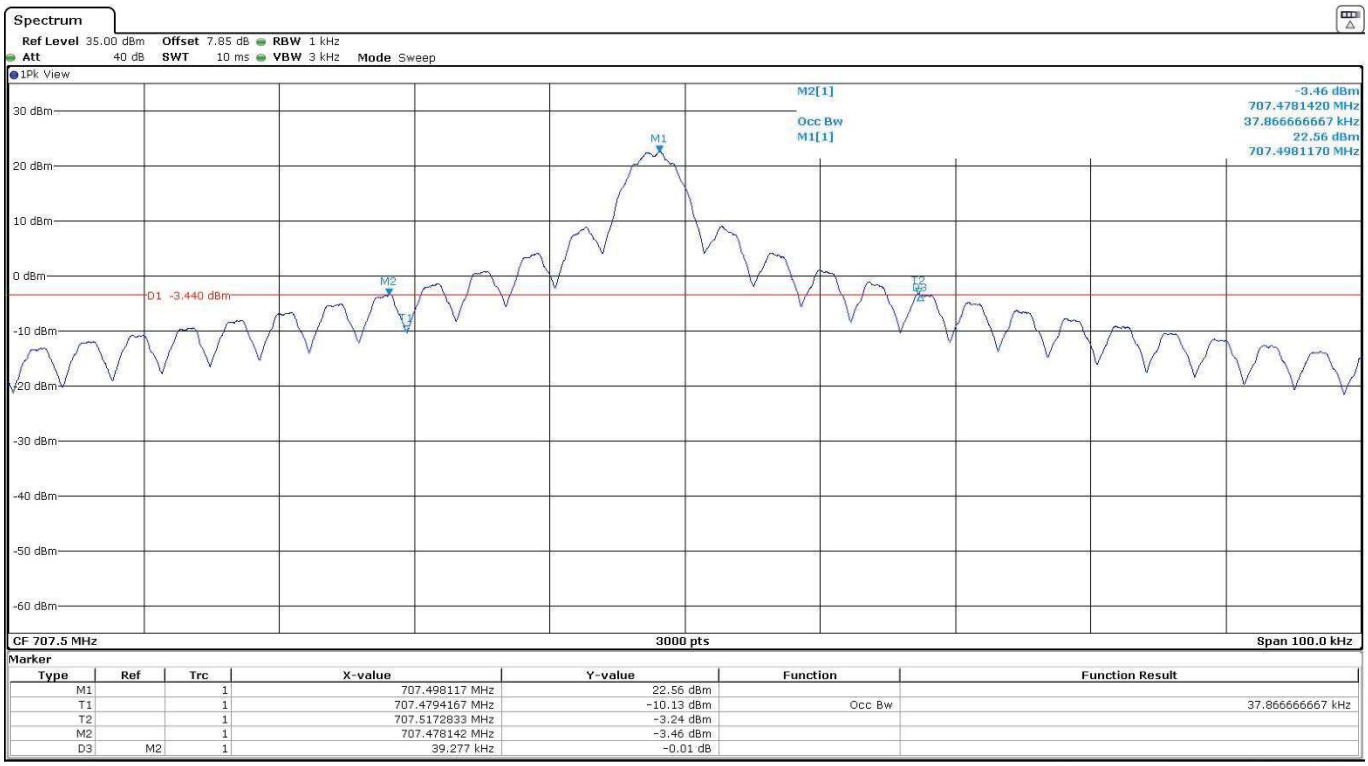


Tone 3.75 kHz. π/4 - QPSK MODULATION

Lowest Channel



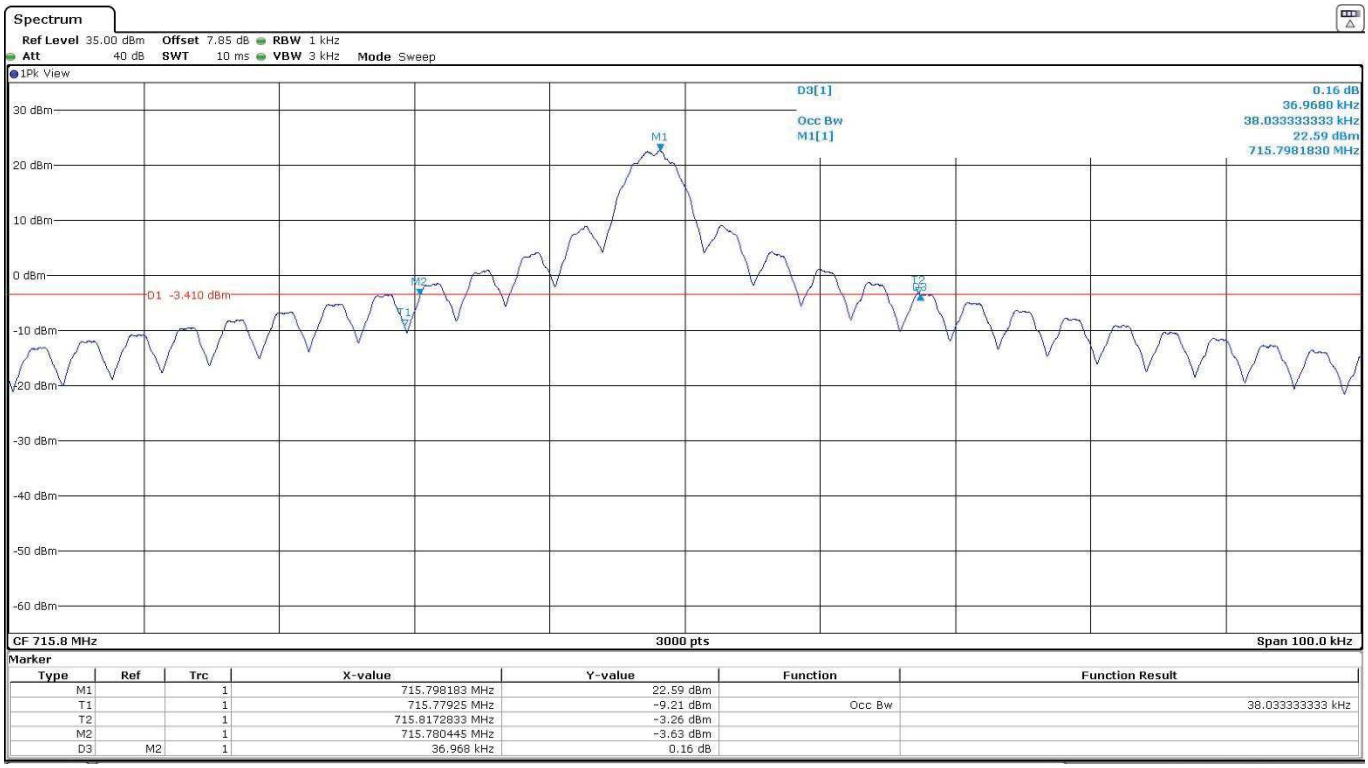
Middle Channel



Marker

Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1		1	707.498117 MHz	22.56 dBm		
T1		1	707.4794167 MHz	-10.13 dBm	Occ Bw	37.866666667 kHz
T2		1	707.5172833 MHz	-3.24 dBm		
M2		1	707.478142 MHz	-3.46 dBm		
D3	M2	1	39.277 kHz	-0.01 dB		

Highest Channel

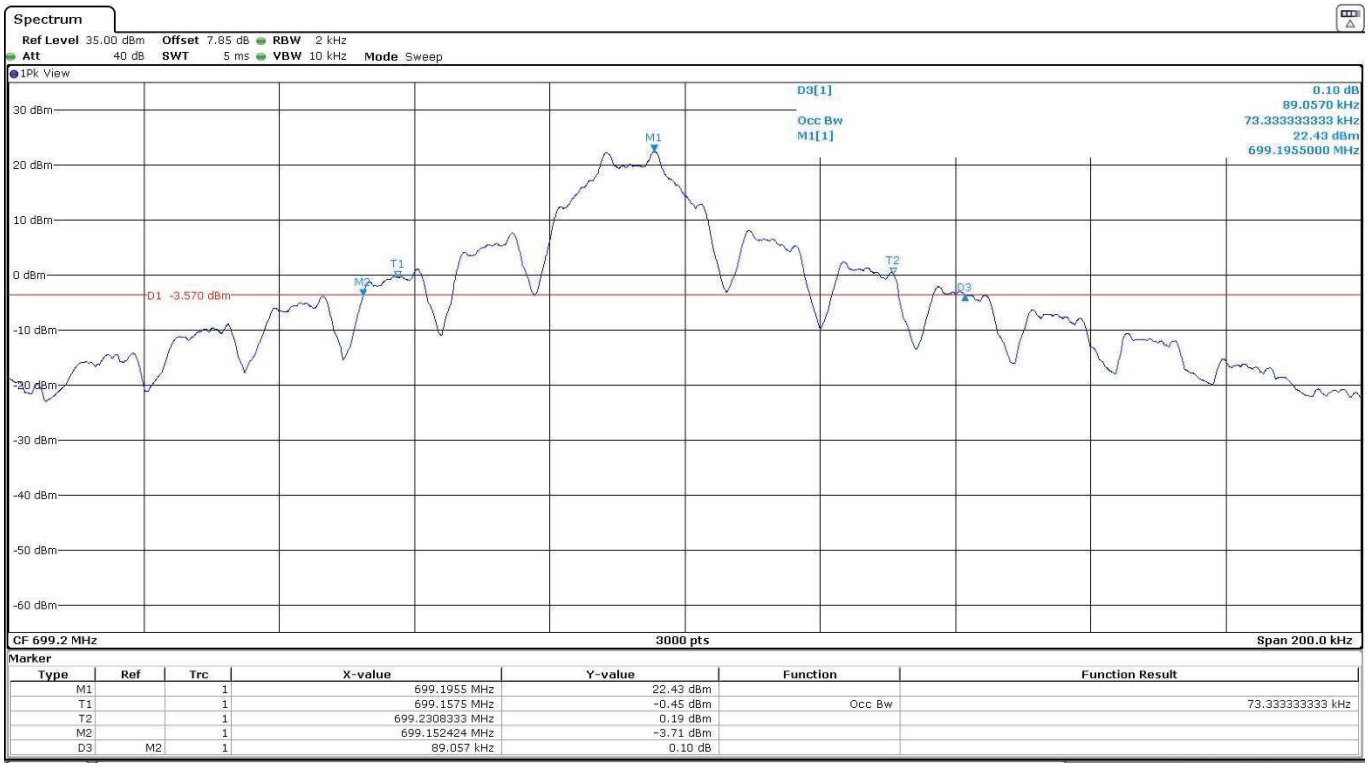


Marker

Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1		1	715.798183 MHz	22.59 dBm		
T1		1	715.77925 MHz	-9.21 dBm	Occ Bw	38.033333333 kHz
T2		1	715.8172833 MHz	-3.26 dBm		
M2		1	715.780445 MHz	-3.63 dBm		
D3	M2	1	36.968 kHz	0.16 dB		

Tone 15 kHz. π/2 - BPSK MODULATION

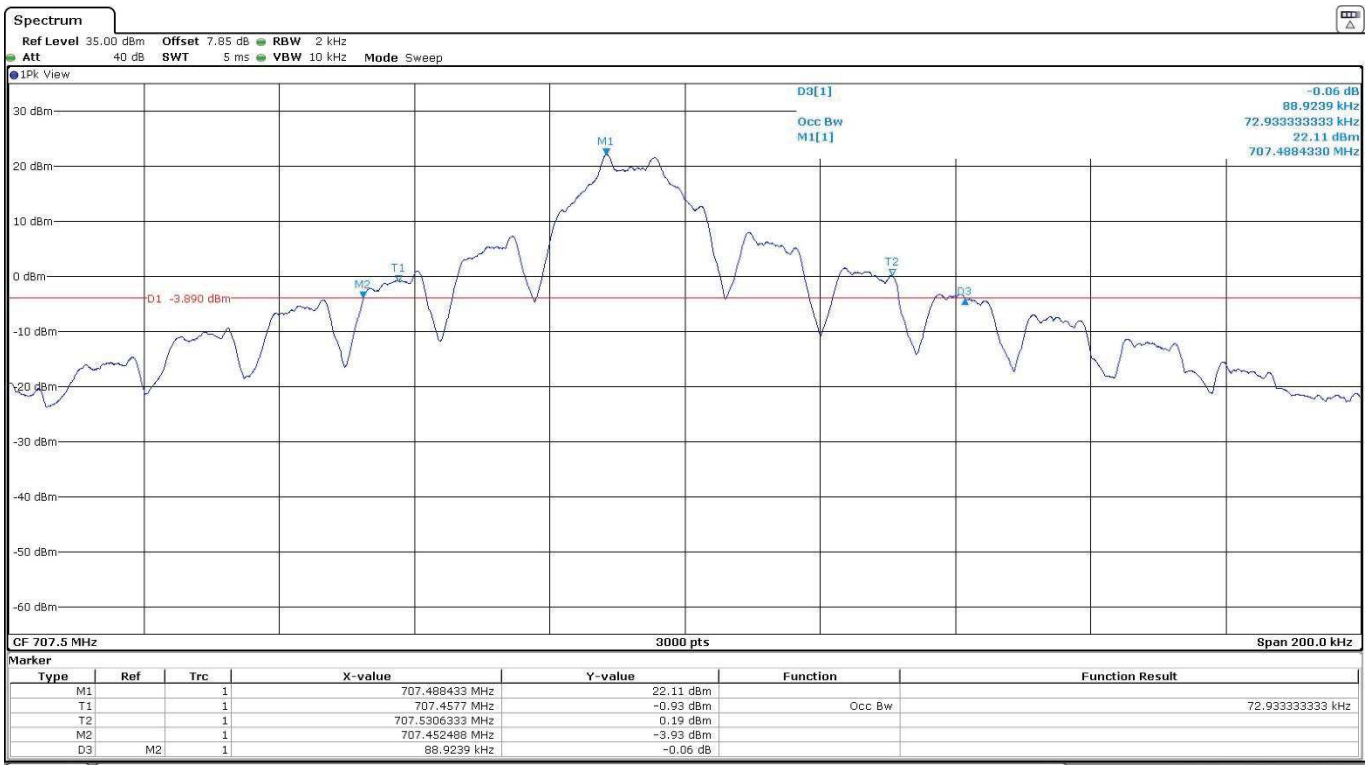
Lowest Channel



Marker

Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1		1	699.1955 MHz	22.43 dBm		
T1		1	699.1575 MHz	-0.45 dBm	Occ Bw	73.333333333 kHz
T2		1	699.2308333 MHz	0.19 dBm		
M2		1	699.152424 MHz	-3.71 dBm		
D3	M2	1	89.057 kHz	0.10 dB		

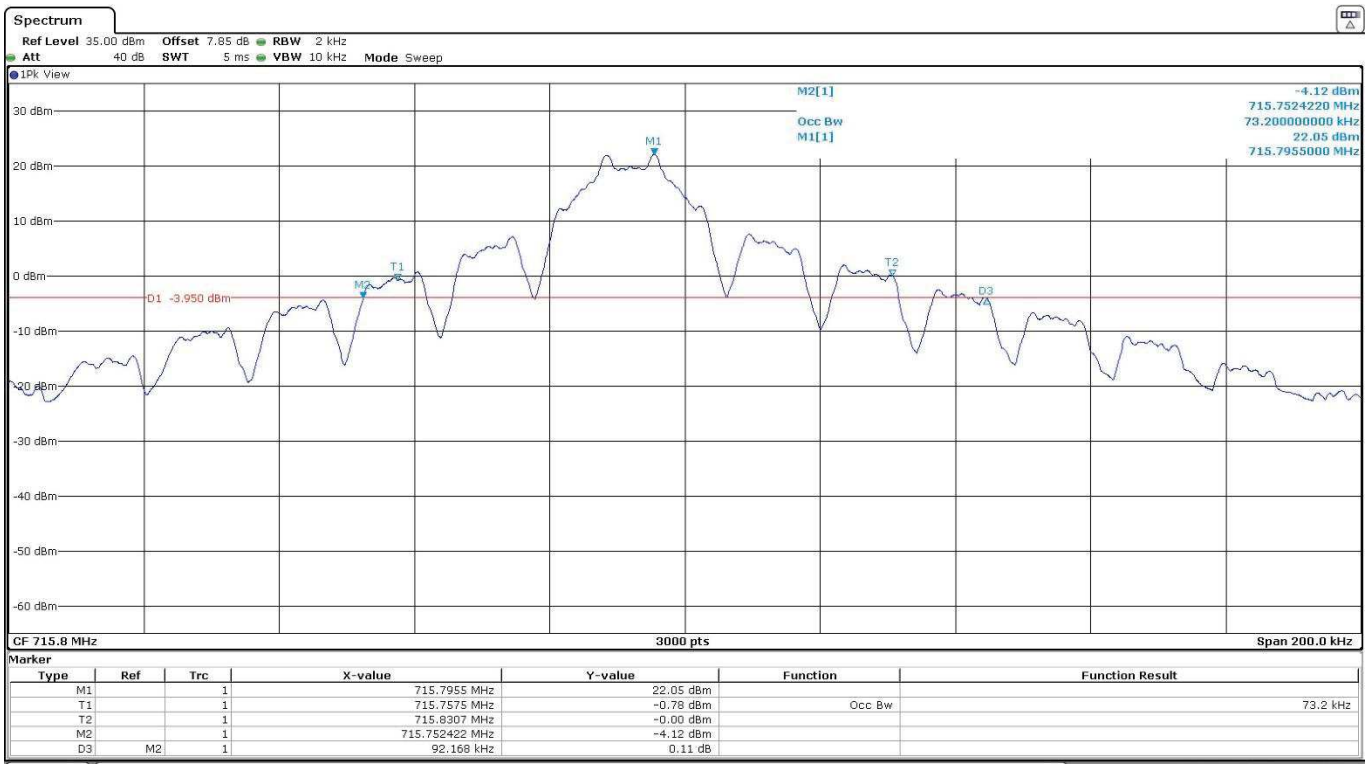
Middle Channel



Marker

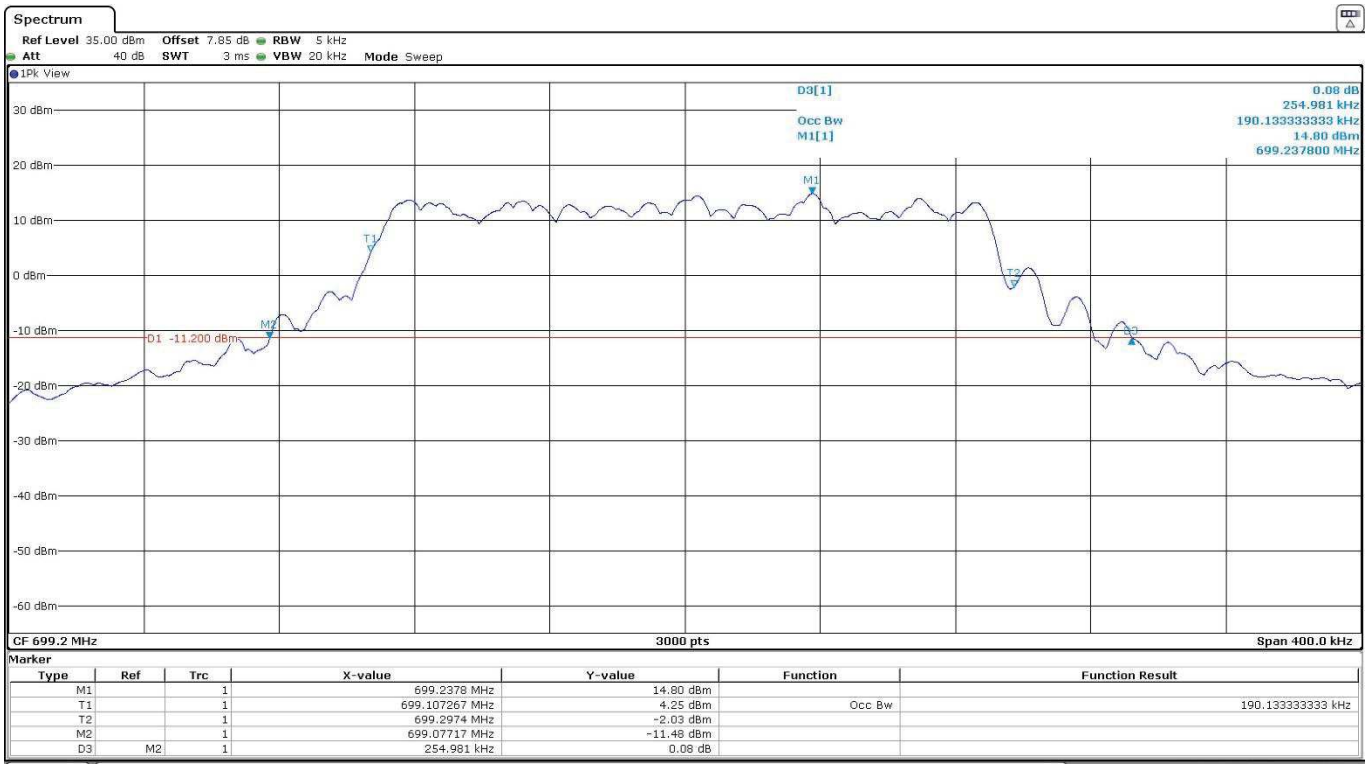
Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1		1	707.488433 MHz	22.11 dBm		
T1		1	707.4577 MHz	-0.93 dBm	Occ Bw	72.933333333 kHz
T2		1	707.5306333 MHz	0.19 dBm		
M2		1	707.452488 MHz	-3.93 dBm		
D3	M2	1	88.9239 kHz	-0.06 dB		

Highest Channel

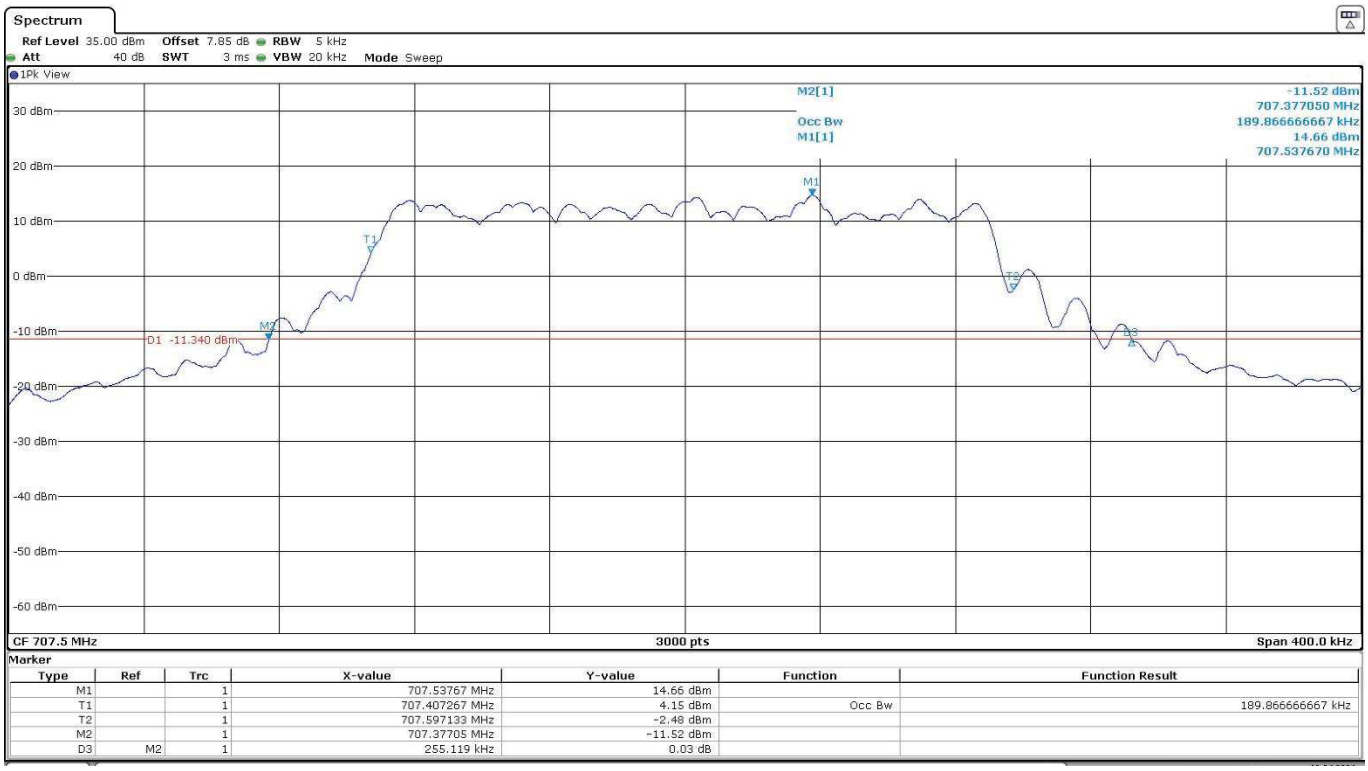


12 Tones 15 kHz. π/4 - QPSK MODULATION

Lowest Channel



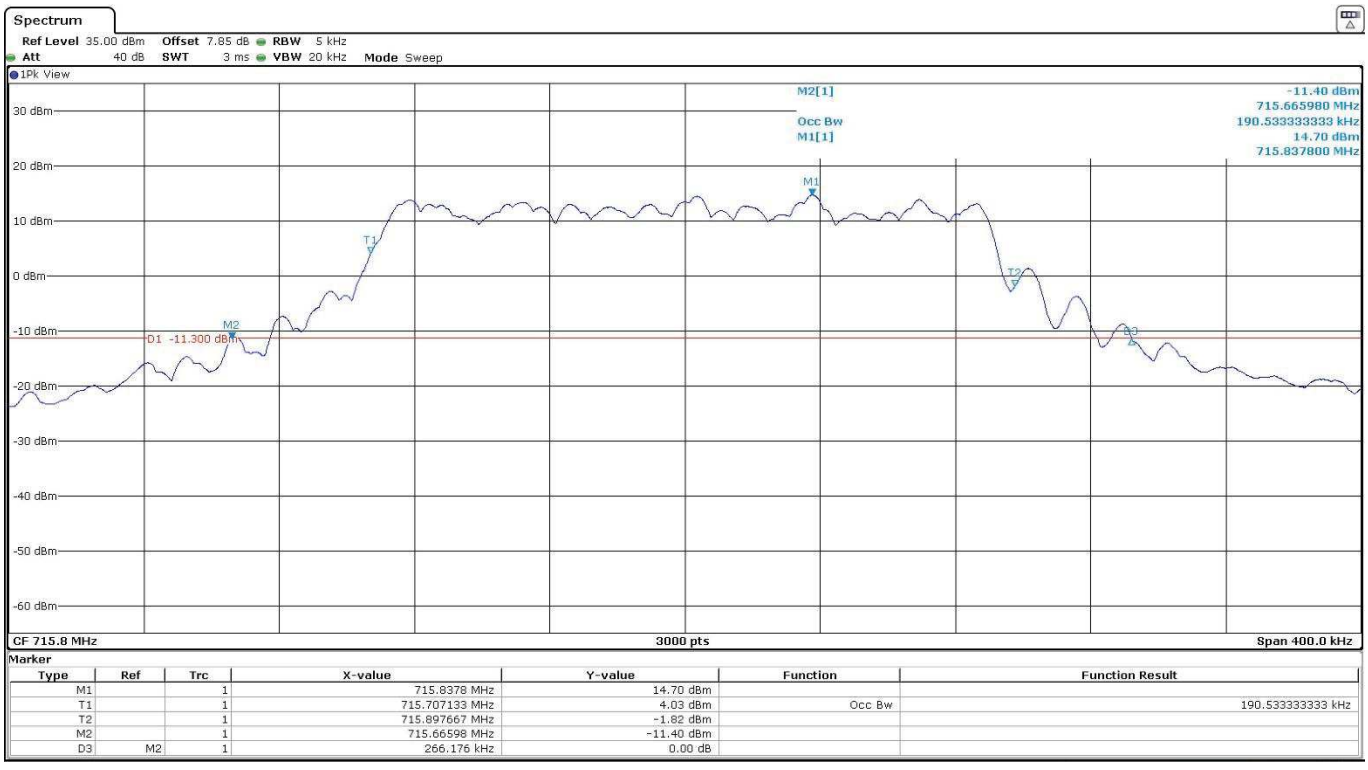
Middle Channel



Marker

Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1		1	707.53767 MHz	14.66 dBm		
T1		1	707.407267 MHz	4.15 dBm	Occ Bw	189.866666667 kHz
T2		1	707.597133 MHz	-2.48 dBm		
M2		1	707.37705 MHz	-11.52 dBm		
D3	M2	1	255.119 kHz	0.03 dB		

Highest Channel



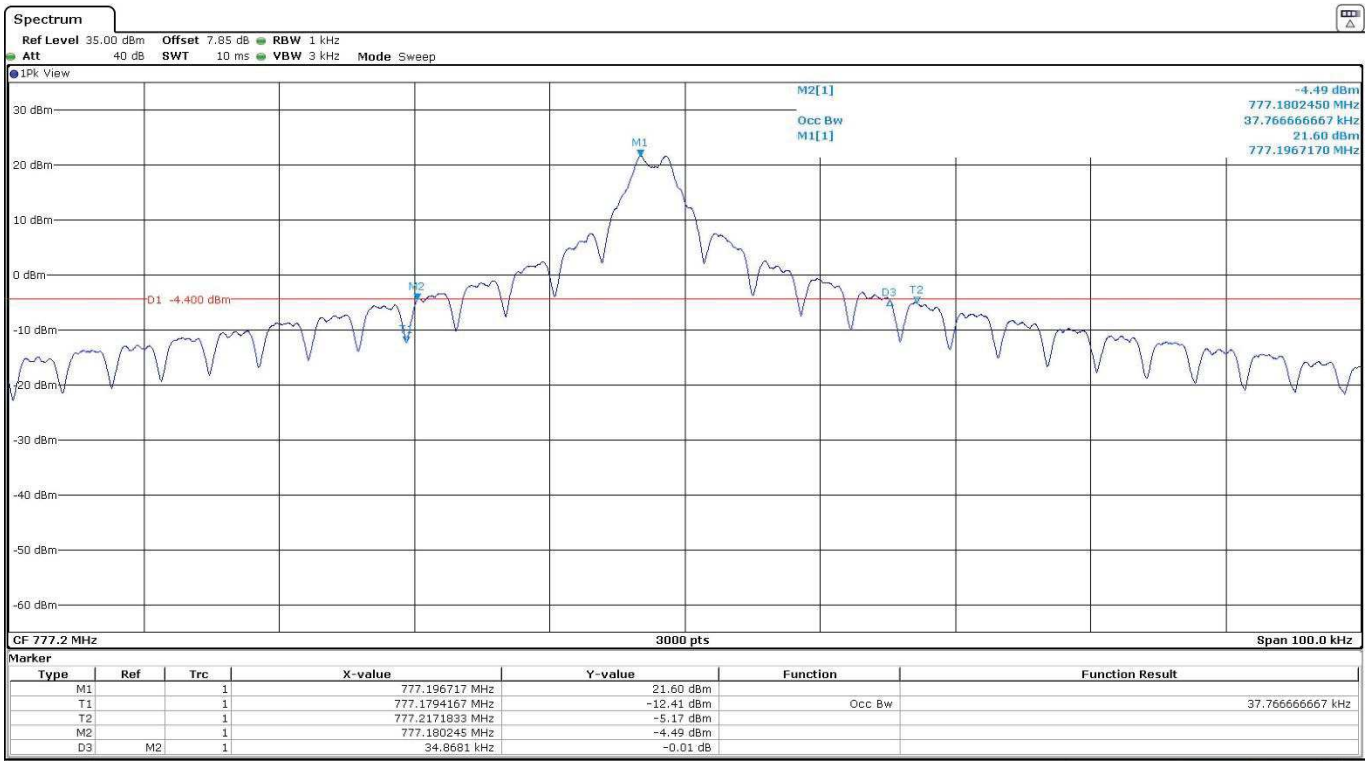
Marker

Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1		1	715.8378 MHz	14.70 dBm		
T1		1	715.707133 MHz	4.03 dBm	Occ Bw	190.533333333 kHz
T2		1	715.897667 MHz	-1.82 dBm		
M2		1	715.66598 MHz	-11.40 dBm		
D3	M2	1	266.176 kHz	0.00 dB		

NBIoT BAND 13.

Tone 3.75 kHz. π/2 - BPSK MODULATION

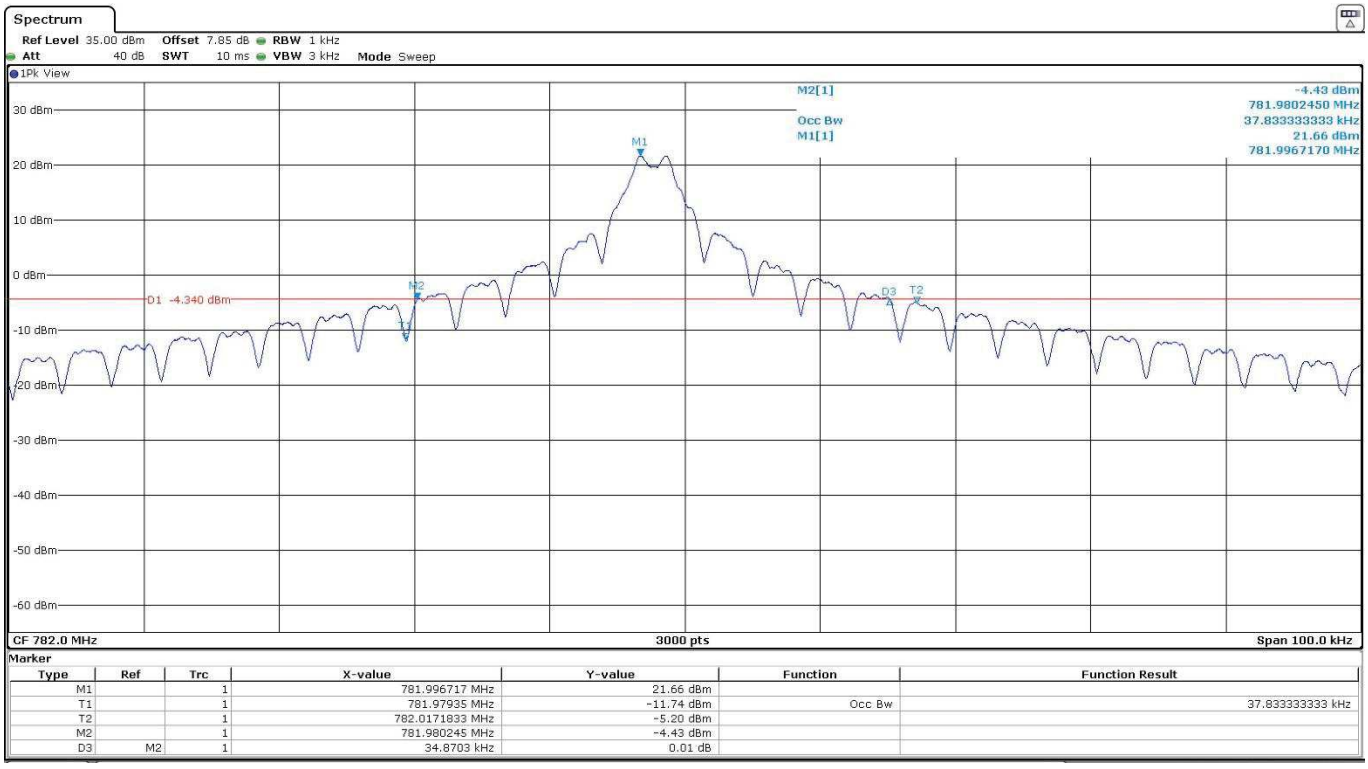
Lowest Channel



Marker

Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1		1	777.196717 MHz	21.60 dBm		
T1		1	777.1794167 MHz	-12.41 dBm	Occ Bw	37.766666667 kHz
T2		1	777.2171833 MHz	-5.17 dBm		
M2		1	777.180245 MHz	-4.49 dBm		
D3	M2	1	34.8681 kHz	-0.01 dB		

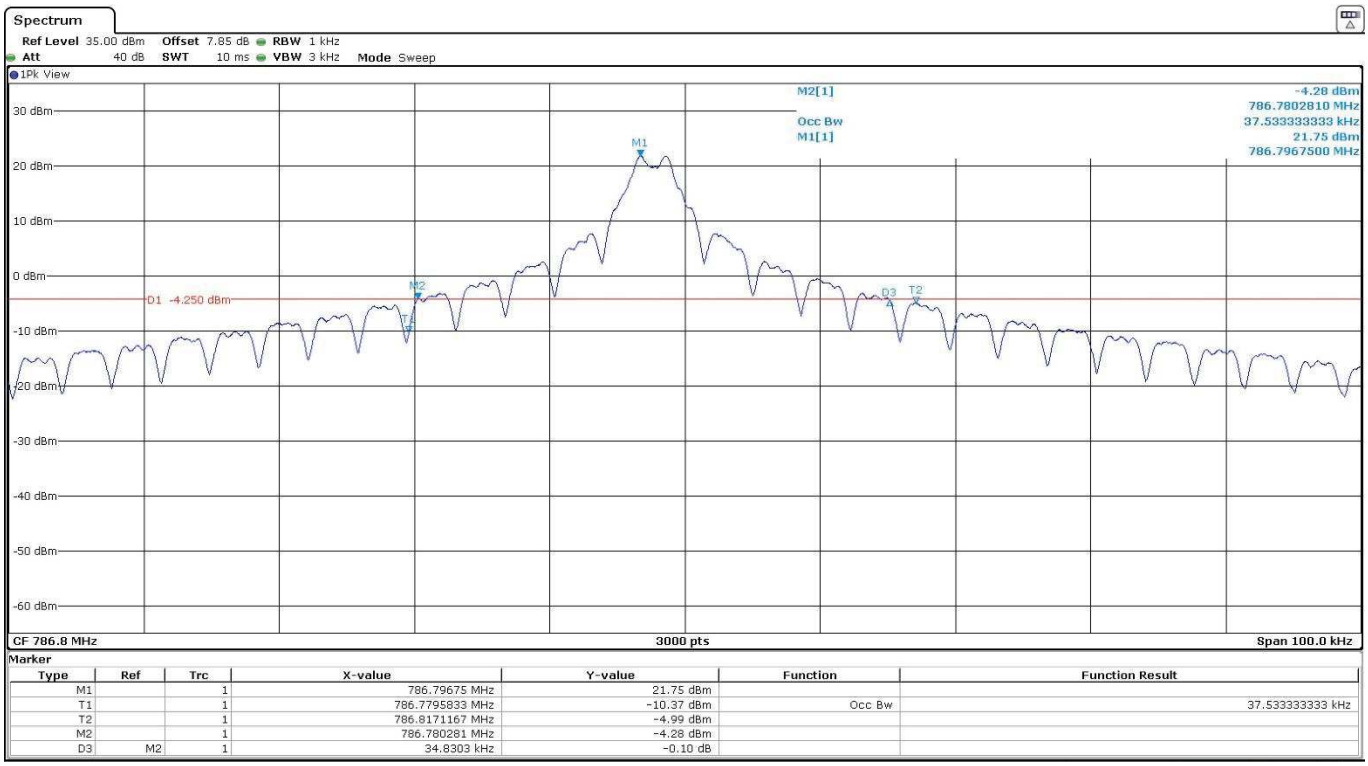
Middle Channel



Marker

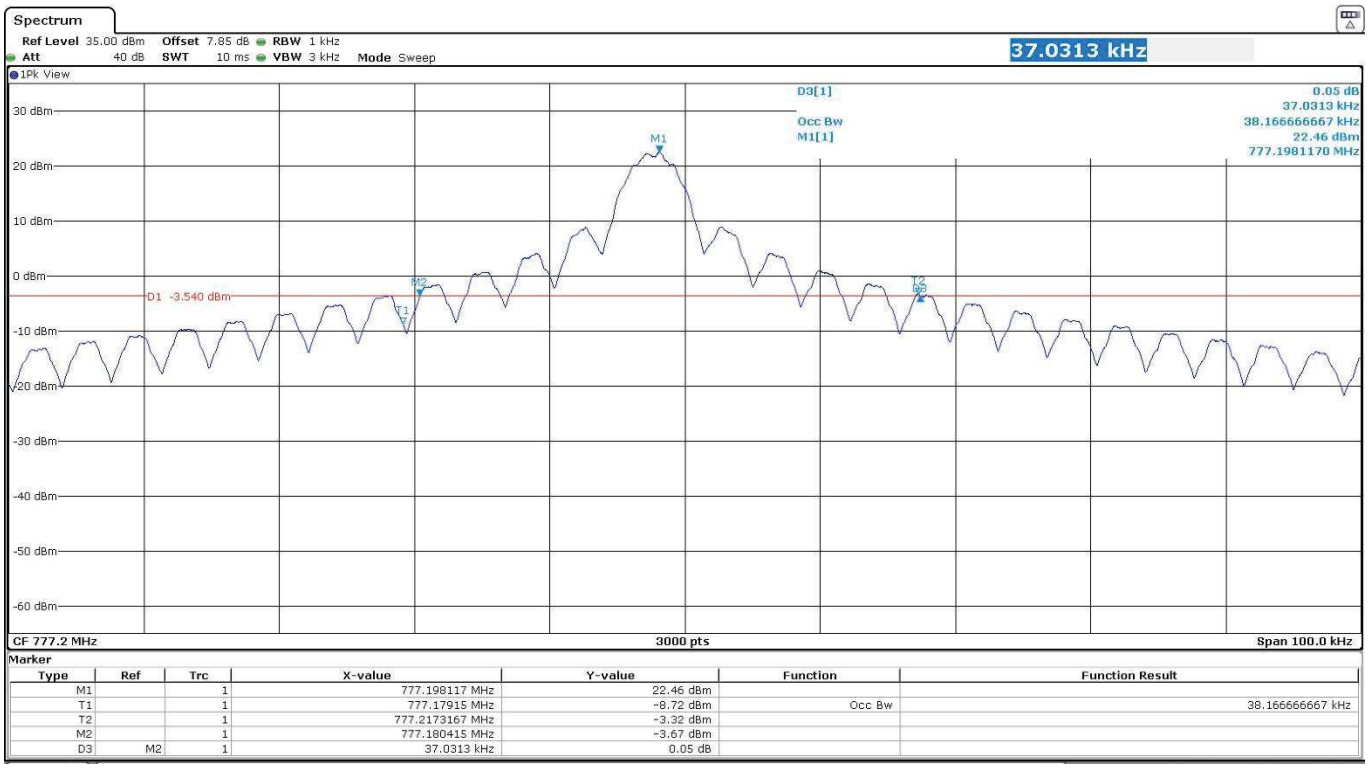
Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1		1	781.996717 MHz	21.66 dBm		
T1		1	781.97935 MHz	-11.74 dBm	Occ Bw	37.833333333 kHz
T2		1	782.0171833 MHz	-5.20 dBm		
M2		1	781.980245 MHz	-4.43 dBm		
D3	M2	1	34.8703 kHz	0.01 dB		

Highest Channel

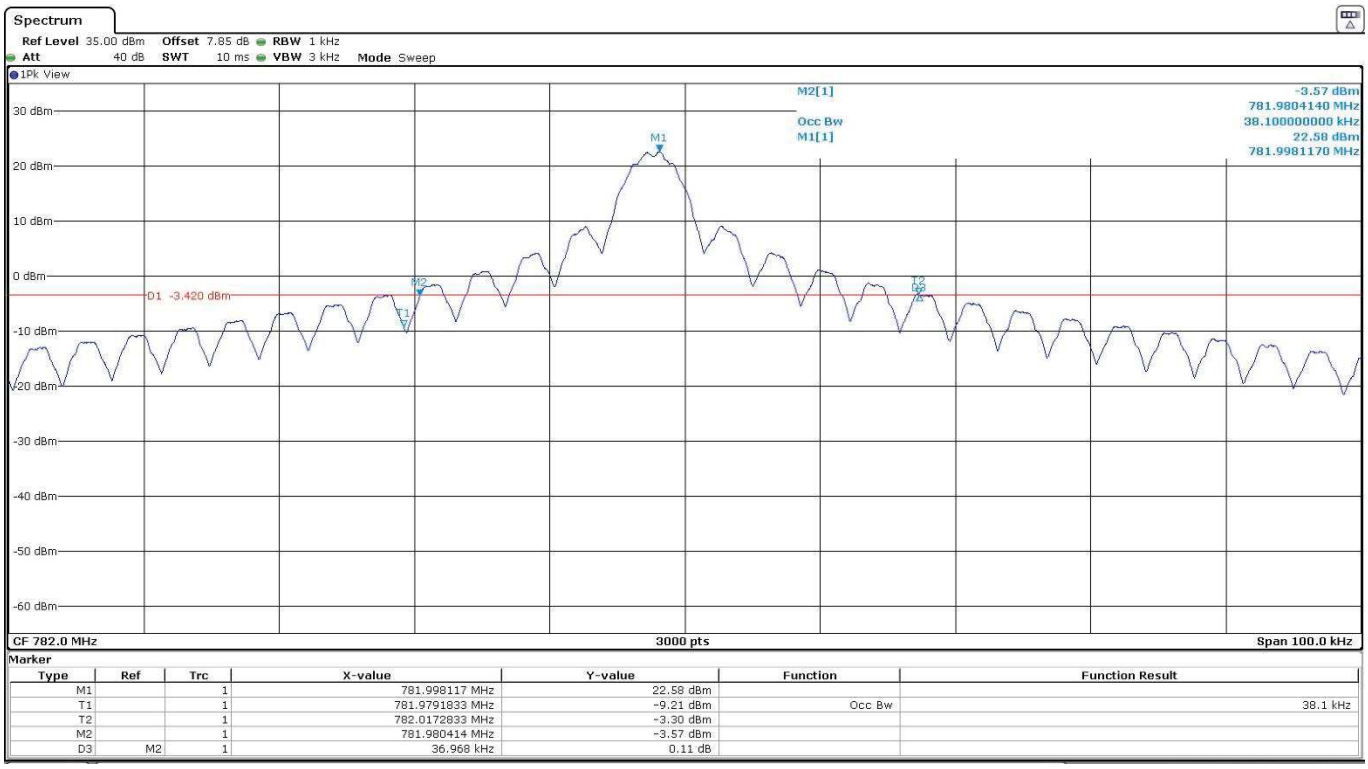


Tone 3.75 kHz. π/4 - QPSK MODULATION

Lowest Channel



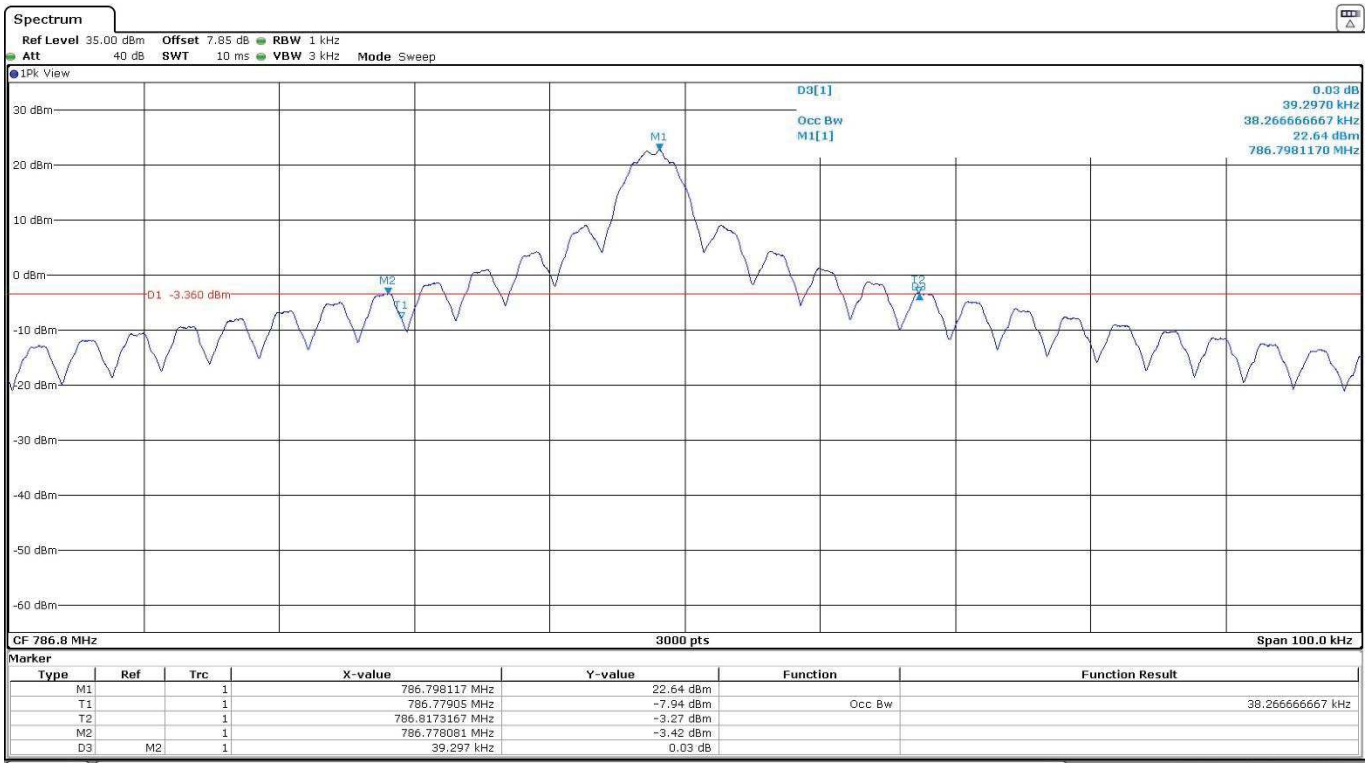
Middle Channel



Marker

Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1		1	781.998117 MHz	22.58 dBm		
T1		1	781.9791833 MHz	-9.21 dBm	Occ Bw	38.1 kHz
T2		1	782.0172833 MHz	-3.30 dBm		
M2		1	781.980414 MHz	-3.57 dBm		
D3	M2	1	36.968 kHz	0.11 dB		

Highest Channel

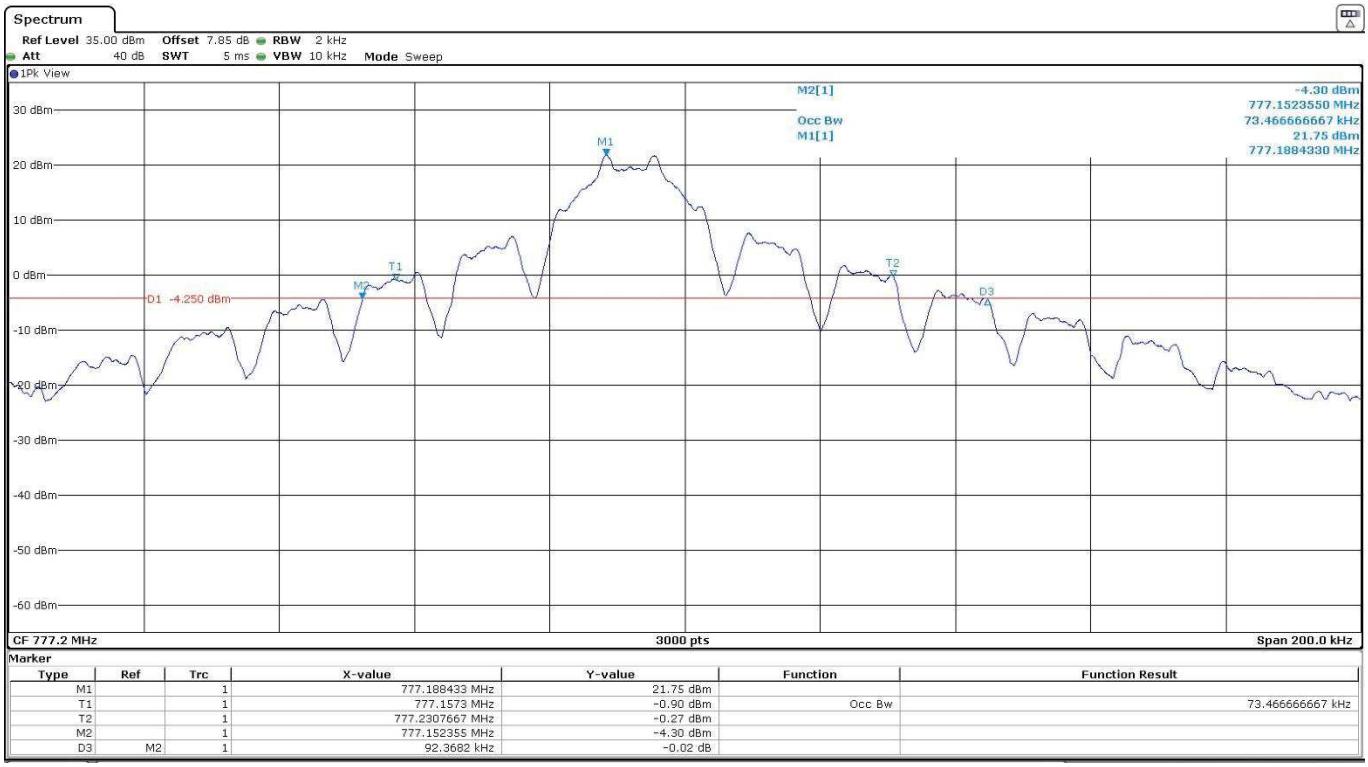


Marker

Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1		1	786.798117 MHz	22.64 dBm		
T1		1	786.77905 MHz	-7.94 dBm	Occ Bw	38.266666667 kHz
T2		1	786.8173167 MHz	-3.27 dBm		
M2		1	786.778081 MHz	-3.42 dBm		
D3	M2	1	39.297 kHz	0.03 dB		

Tone 15 kHz. π/2 - BPSK MODULATION

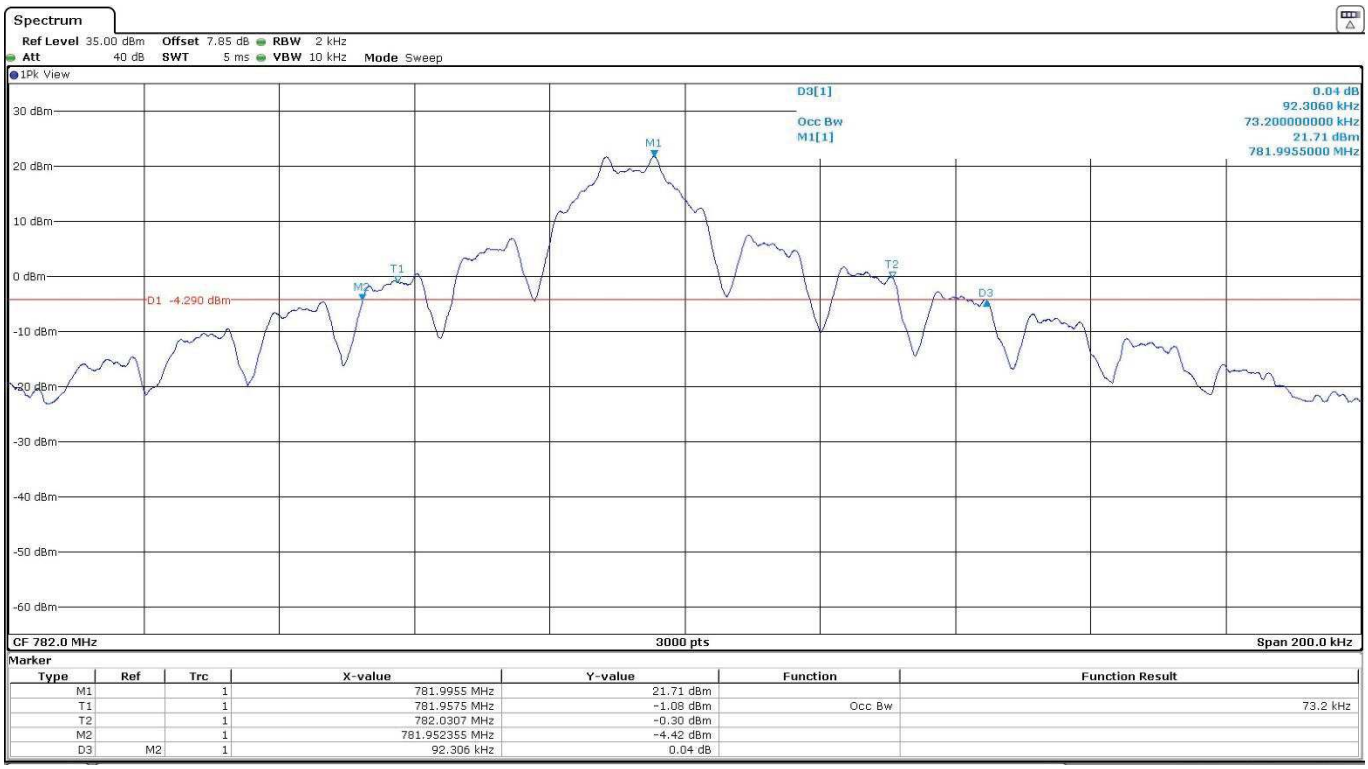
Lowest Channel



Marker

Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1		1	777.188433 MHz	21.75 dBm		
T1		1	777.1573 MHz	-0.90 dBm	Occ Bw	73.466666667 kHz
T2		1	777.2307667 MHz	-0.27 dBm		
M2		1	777.152355 MHz	-4.30 dBm		
D3	M2	1	92.3682 kHz	-0.02 dB		

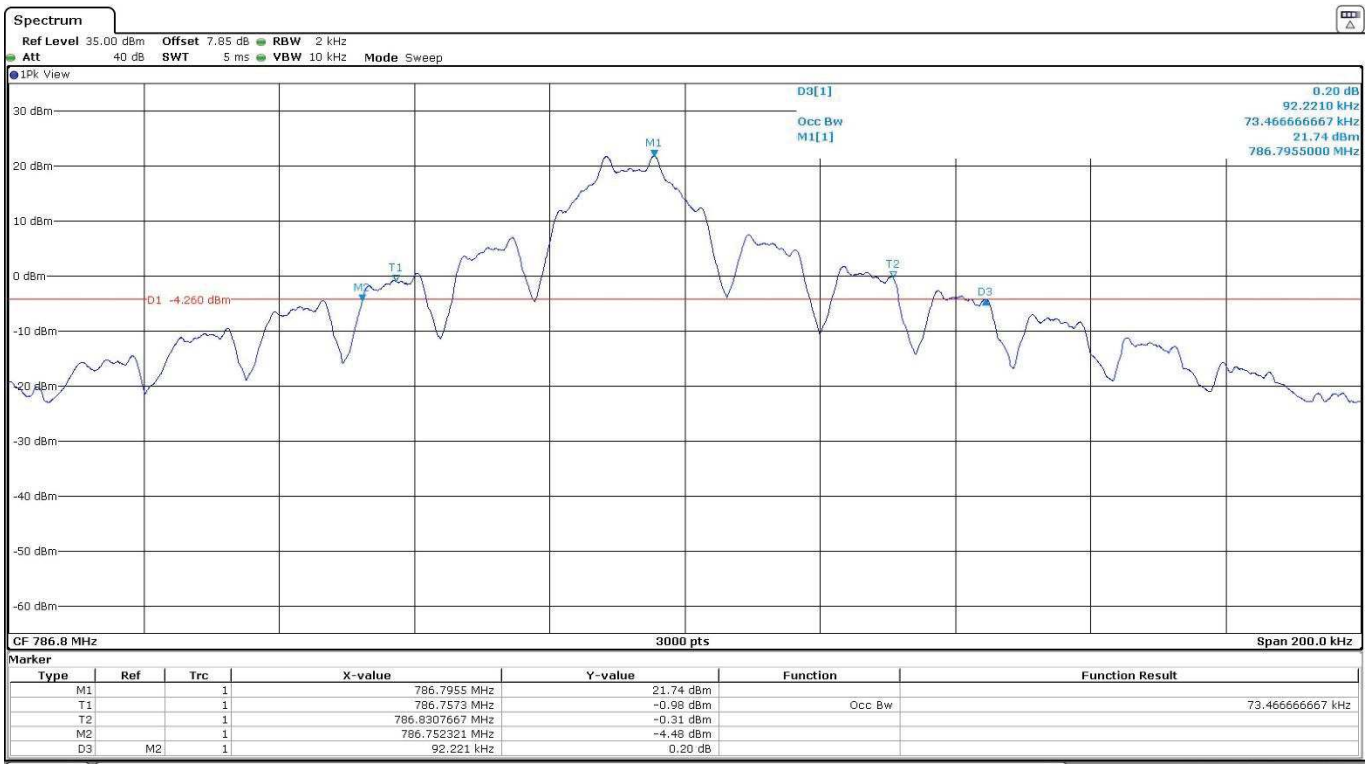
Middle Channel



Marker

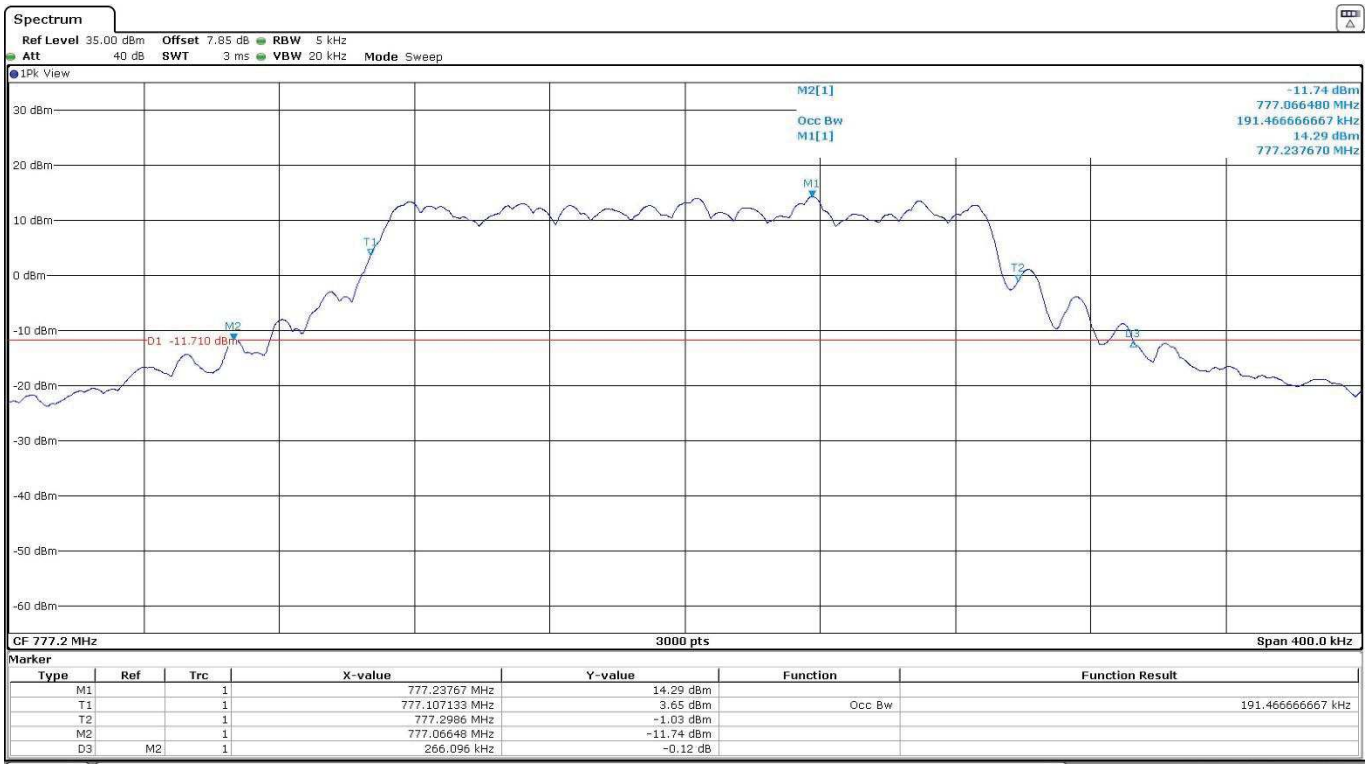
Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1		1	781.9955 MHz	21.71 dBm		
T1		1	781.9575 MHz	-1.08 dBm	Occ Bw	73.2 kHz
T2		1	782.0307 MHz	-0.30 dBm		
M2		1	781.952355 MHz	-4.42 dBm		
D3	M2	1	92.306 kHz	0.04 dB		

Highest Channel

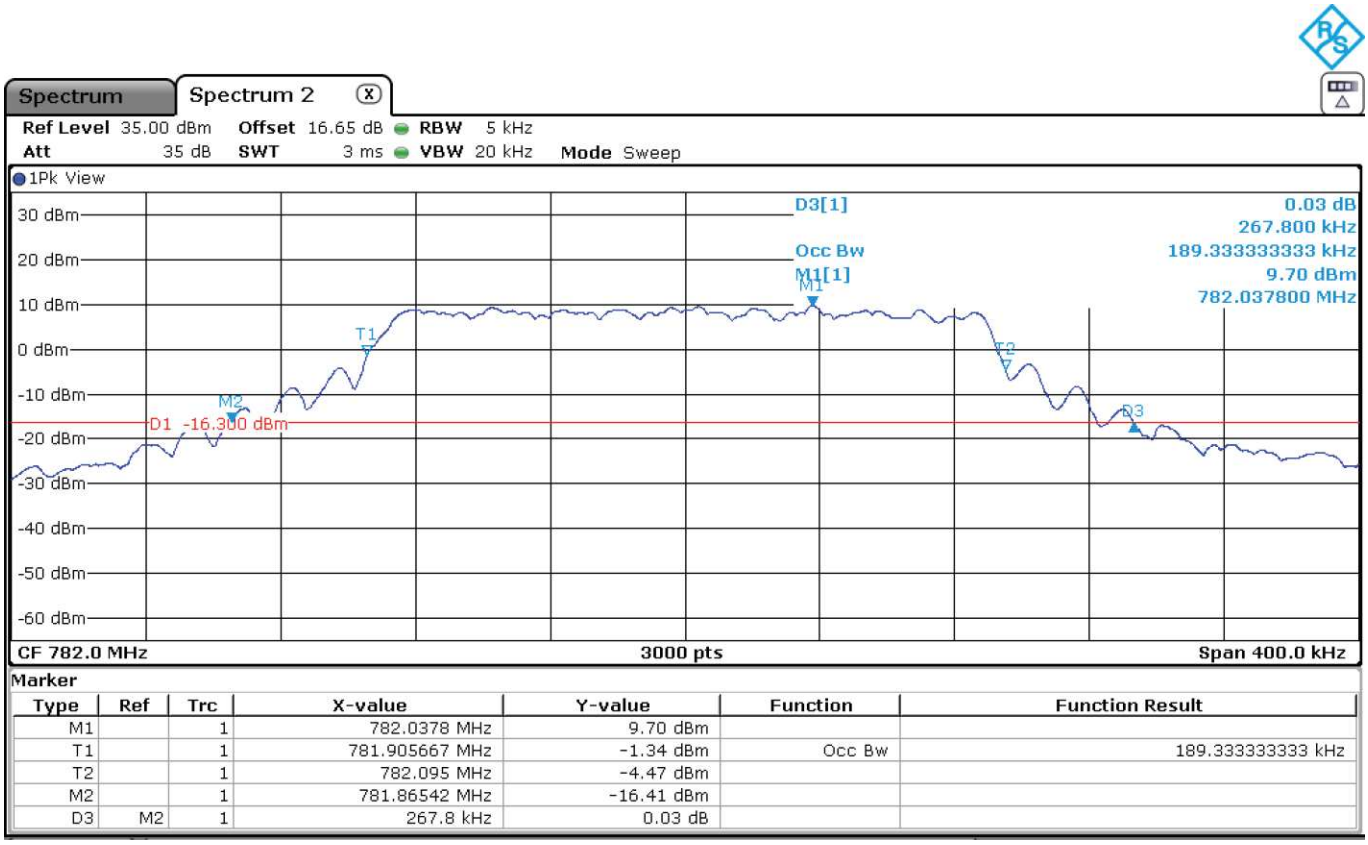


12 Tones 15 kHz. π/4 - QPSK MODULATION

Lowest Channel



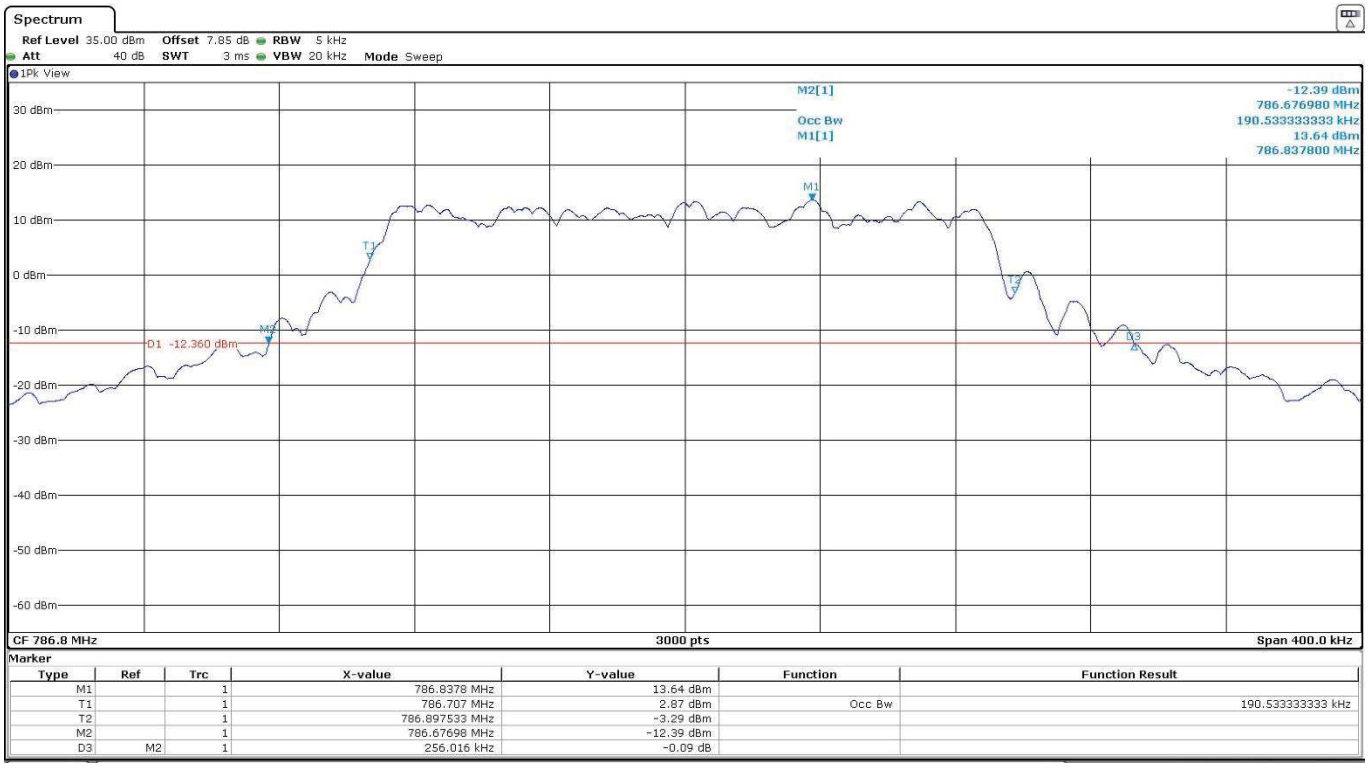
Middle Channel



Marker

Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1		1	782.0378 MHz	9.70 dBm		
T1		1	781.905667 MHz	-1.34 dBm	Occ Bw	189.333333333 kHz
T2		1	782.095 MHz	-4.47 dBm		
M2		1	781.86542 MHz	-16.41 dBm		
D3	M2	1	267.8 kHz	0.03 dB		

Highest Channel



Marker

Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1		1	786.8378 MHz	13.64 dBm		
T1		1	786.707 MHz	2.87 dBm	Occ Bw	190.533333333 kHz
T2		1	786.897533 MHz	-3.29 dBm		
M2		1	786.67698 MHz	-12.39 dBm		
D3	M2	1	256.016 kHz	-0.09 dB		