

ISED CABid: ES1909
Lab. Company Number: 4621A

Test Report No:
77535RRF.001

Test Report

USA FCC Part 22

CANADA RSS-132

(*) Identification of item tested	nRF91
(*) Trademark	nRF91
(*) Model and/or type reference	nRF9151
Other identification of the product	FCC ID: 2ANPO00nRF9151 IC: 24529-NRF9151
(*) Features	LTE Cat-M1, LTE NB1&NB2 HW version: nRF9151 LACA AA SW version: mfw_nrf91x1_2.0.0
Applicant	NORDIC SEMICONDUCTOR ASA Otto Nielsens Veg 12, 7052 Trondheim, Norway
Test method requested, standard	USA FCC Part 22 (10-1-22 Edition). CANADA RSS-132 Issue 4, Jan. 2023. ANSI C63.26-2015. KDB 971168 D01 Power Meas License Digital Systems v03r01, April. 2018.
Summary	IN COMPLIANCE
Approved by (name / position & signature)	José Manuel Gómez Galván EMC Consumer & RF Lab. Manager
Date of issue	2024-03-21
Report template No	FDT08_24 (*) "Data provided by the client"

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Competences and guarantees

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DEKRA Testing and Certification is an FCC-recognized accredited testing laboratory with appropriate scope of accreditation that covers the performed tests in this report.

DEKRA Testing and Certification is an ISED-recognized accredited testing laboratory, CABid: ES1909, Company Number: 4621A, with the appropriate scope of accreditation that covers the performed tests in this report.

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Uncertainty

Uncertainty (factor $k=2$) was calculated according to the DEKRA Testing and Certification S.A.U. internal document PODT000.

Data provided by the client

The following data has been provided by the client:

1. Information relating to the description of the sample ("Identification of the item tested", "Trademark", "Model and/or type reference tested").
2. The sample model nRF9151 DK is a Development Kit that has nRF9151 IOT Module and GPS. The nRF9151 is capable of LTE Cat-M1, Cat-NB1&NB2 and GPS. The Development kit contains antennas for cellular and GPS.

DEKRA Testing and Certification S.A.U. declines any responsibility with respect to the information provided by the client and that may affect the validity of results.

Usage of samples

Samples undergoing test have been selected by: The client.

Id	Control Number	Description	Model	HW Version	Serial N°	Date Reception	of	Application
S/01	77535C/025_.1	nRF91	nRF9151	nRF9151 LACA CB0	1051231716	2024-01-08		Element Under Test
S/01	77535C/022_.1	SMA Cable	-	-	-	2024-01-08		Auxiliary Element
S/01	77535C/013_.1	USB Cable	-	-	-	2024-01-08		Auxiliary Element
S/02	77535C/026_.1	nRF91	nRF9151	nRF9151 LACA CB0	1051261483	2024-01-08		Element Under Test
S/02	77535C/012_.1	USB Cable	-	-	-	2023-12-15		Auxiliary Element
S/03	77535C/027_.1	nRF91	nRF9151	nRF9151 LACA CB0	1051275581	2024-01-08		Element Under Test
S/03	77535C/023_.1	SMA Cable	-	-	-	2024-01-08		Auxiliary Element
S/03	77535C/015_.1	USB Cable	-	-	-	2024-01-08		Auxiliary Element

Notes referenced to samples during the project:

Id	Type
S/01	Conducted tests.
S/03	Conducted tests: but the RF Output Power tests.
S/02	Radiated tests.

Test sample description

Ports.....:	Port name and description	Cable					
		Specified max length [m]	Attached during test	Shielded	Coupled to patient ⁽³⁾		
		LTE RF	☒	☒	☐		
		GPS	☐	☐	☐		
Supplementary information to the ports.....:	-						
Rated power supply	Voltage and Frequency		Reference poles				
			L1	L2	L3	N	PE
	☐	AC:	☐	☐	☐	☐	☐
	☐	AC:	☐	☐	☐	☐	☐
	☒	DC: 3.0-5.5V, nominal 3.8V					
☐	DC:						
Rated Power.....:	1W						
Clock frequencies.....:	32kHz, 32MHz						

Other parameters	Temperature range: -40C..+85C		
Software version.....	mfw_nrf91x1_2.0.0		
Hardware version	nRF9151 LACA AA		
Dimensions in cm (W x H x D) ...	155x64x9mm		
Mounting position	☒	Table top equipment	
	☐	Wall/Ceiling mounted equipment	
	☐	Floor standing equipment	
	☐	Hand-held equipment	
	☐	Other:	
Modules/parts.....	Module/parts of test item	Type	Manufacturer
	-	-	-
Accessories (not part of the test item)	Description	Type	Manufacturer
	-	-	-
Documents as provided by the applicant	Description	File name	Issue date
	-	-	-

⁽³⁾ Only for Medical Equipment

Identification of the client

NORDIC SEMICONDUCTOR ASA
Otto Nielsens Veg 12, 7052 Trondheim, Norway

Testing period and place

Test Location	DEKRA Testing and Certification S.A.U.
Date (start)	2024-01-08
Date (finish)	2024-02-22

Document history

Report number	Date	Description
77535RRF.001	2024-03-21	First release.

Environmental conditions

In the control chamber, the following limits were not exceeded during the test:

Temperature	Min. = 15 °C Max. = 35 °C
Relative humidity	Min. = 20 % Max. = 75 %

In the semi-anechoic chamber, the following limits were not exceeded during the test:

Temperature	Min. = 15 °C Max. = 35 °C
Relative humidity	Min. = 20 % Max. = 75 %

In the chamber for conducted measurements, the following limits were not exceeded during the test:

Temperature	Min. = 15 °C Max. = 35 °C
Relative humidity	Min. = 20 % Max. = 75 %

Remarks and comments

The tests have been performed by the technical personnel: Ireneo Bibang, Pablo Redondo, Carmen Vázquez, Valentín Andarias, Rafael Fernández.

Used instrumentation:

Control No.	Equipment	Model	Manufacturer	Next Calibration
7760	Digital Multimeter	175	FLUKE	2024-11
6157	Signal and Spectrum Analyzer 10 Hz - 40 GHz	FSV40	ROHDE AND SCHWARZ	2025-01
9227	Wideband Radio Communication Tester	CMW500	ROHDE AND SCHWARZ	2024-07
6254	Attenuator 6 dB 2W DC-26.5 GHz	TWSMAG2	TECHNIWAVE	2024-03
2215	Power Divider DC-25 GHz	5333-104	PICOSECOND PULSE LABS	2024-07
6794	Shielded Room	S101	ETS LINDGREN	N/A
6791	SEMIANECHOIC ABSORBER LINED	FACT 3 200 STP	ETS LINDGREN	N/A
6792	SHIELDED ROOM	S101	ETS LINDGREN	N/A
6666	EMI TEST RECEIVER 2Hz-44GHz	ESW44	ROHDE AND SCHWARZ	2024-03
3541	Hybrid Bilog Antenna 30MHz-6GHz	JB6	SUNOL SCIENCES CORPORATION	2024-11
6021	Attenuator 3 dB, 2W, DC-6GHz	50HN-03	JFW	2025-02
3783	PRE-AMPLIFIER G>30dB 1GHz-18GHz	BLMA 0118-3A	BONN ELEKTRONIK	2025-02
6496	HORN ANTENNA 1-18GHz	BBHA 9120 D	SCHWARZBECK	2026-12
6143	Biconical/Log Antenna 30 MHz - 6 GHz	3142E	ETS LINDGREN	2027-01
4848	SOFTWARE FOR EMC/RF TESTING	EMC32	ROHDE AND SCHWARZ	N/A

Testing verdicts

Not applicable:	N/A
Pass:	P
Fail:	F
Not measured:	N/M

Summary

Appendix A: LTE Cat-M1 Bands 5, 26.

FCC PART 22 / RSS-132 PARAGRAPH		
Requirement – Test case	Verdict	Remark
FCC 22.913 / RSS-132 5.4: RF Output Power	P	
FCC 2.1047 / RSS-132 5.2: Modulation Characteristics	P	
FCC 22.355 / RSS-132 5.3: Frequency Stability	P	
FCC 2.1049: Occupied Bandwidth	P	
FCC 22.917 / RSS-132 5.5: Spurious Emissions at Antenna Terminals	P	
FCC 22.917 / RSS-132 5.5: Spurious Emissions at Antenna Terminals at Block Edges	P	
FCC 22.917 / RSS-132 5.5: Radiated Emissions	P	
<u>Supplementary information and remarks:</u> None.		

Appendix B: LTE Cat NB1 Bands 5, 26.

FCC PART 22 / RSS-132 PARAGRAPH		
Requirement – Test case	Verdict	Remark
FCC 22.913 / RSS-132 5.4: RF Output Power	P	
FCC 2.1047 / RSS-132 5.2: Modulation Characteristics	P	
FCC 22.355 / RSS-132 5.3: Frequency Stability	P	
FCC 2.1049: Occupied Bandwidth	P	
FCC 22.917 / RSS-132 5.5: Spurious Emissions at Antenna Terminals	P	
FCC 22.917 / RSS-132 5.5: Spurious Emissions at Antenna Terminals at Block Edges	P	
FCC 22.917 / RSS-132 5.5: Radiated Emissions	P	
<u>Supplementary information and remarks:</u> None.		

Appendix A: Test results for FCC 22 / RSS-132: LTE Cat-M1 Bands 5, 26

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TEST CONDITIONS

(*): Declared by the Applicant.

POWER SUPPLY (*):

Vnormal: 3.8 Vdc.
Vminimum: 3 Vdc
Vmaximum: 5.5 Vdc
Type of Power Supply: Internal DC.

ANTENNA (*):

Bands	Gain (dBi)	Type of Antenna
LTE Cat-M1 5	+2.7	SMD
LTE Cat-M1 26	+2.7	SMD

TEST FREQUENCIES:

LTE Cat-M1 Band 5. QPSK and 16QAM:

Channel (Frequency MHz)			
BW=1.4 MHz	BW=3 MHz	BW=5 MHz	BW=10 MHz
20407 (824.70)	20415 (825.50)	20425 (826.50)	20450 (829.00)
20525 (836.50)	20525 (836.50)	20525 (836.50)	20525 (836.50)
20643 (848.30)	20635 (847.50)	20625 (846.50)	20600 (844.00)

NOTE: The 824-849 MHz band of the LTE Cat-M1 Band 5 is completely included in the LTE Cat-M1 Band 26, so the LTE Cat-M1 Band 26 channels were tested to give conformity to the assigned block.

LTE Cat-M1 Band 26 sub-band 824-849 MHz. QPSK and 16QAM:

	Channel (Frequency MHz)				
	BW=1.4 MHz	BW=3 MHz	BW=5 MHz	BW=10 MHz	BW=15 MHz
Low	26797 (824.70)	26805 (825.50)	26815 (826.50)	26840 (829.00)	26865 (831.50)
Middle	26915 (836.50)	26915 (836.50)	26915 (836.50)	26915 (836.50)	26915 (836.50)
High	27033 (848.30)	27025 (847.50)	27015 (846.50)	26990 (844.00)	26965 (841.50)

RF Output Power

Limits

* FCC §2.1046 and FCC §22.913. The Effective Radiated Power (E.R.P) of mobile transmitter and auxiliary test transmitter must not exceed 7 Watts (38.45 dBm E.R.P.).

* RSS-132 Issue 4. Clause 5.4. The transmitter output power shall be measured in terms of average power. The equivalent radiated power (e.r.p.) shall not exceed 7 watts for mobile equipment and 3 watts for portable equipment.

The effective isotropic radiated power (e.i.r.p.) shall not exceed the limits specified in SRSP-503 for base station equipment.

In addition, the peak-to-average power ratio (PAPR) of the transmitter shall not exceed 13 dB for more than 0.1% of the time using a signal corresponding to the highest PAPR during periods of continuous transmission.

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 peak-to-average power ratio (PAPR) is measured using an attenuator, power splitter and spectrum analyser with a Complementary Cumulative Distribution Function implemented.

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:

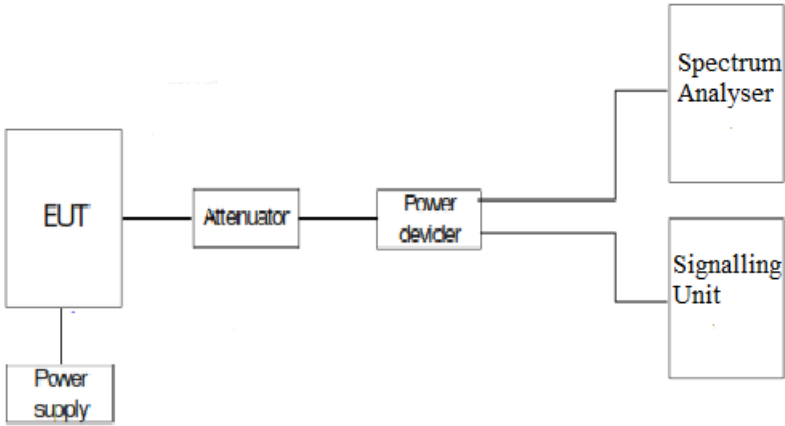
$$E.R.P. = E.I.R.P. - 2.15 \text{ dB}$$

Test Setup

1. CONDUCTED AVERAGE POWER:



2. PEAK-TO-AVERAGE POWER RATIO (PAPR) and Conducted Average power:



Results

1. CONDUCTED AVERAGE POWER:

LTE Cat-M1 Band 26:

Preliminary measurements determined the worst case of RF Power is BW=3 MHz, Middle Channel, QPSK, RB Size=1, RB Offset=0, Narrowband=0.

BANDWIDTH (MHz)	CHANNEL	FREQUENCY (MHz)	MODULATION	RB SIZE	RB OFFSET	AVERAGE POWER (dBm)
3	Low 26805	825.5	QPSK	1	0	22.07
				1	2	22.08
				1	5	22.07
				3	0	21.36
				3	1	21.36
				3	3	21.36
				6	0	20.29
			16QAM	1	0	21.1
				1	2	21.14
				1	5	21.13
				3	0	20.25
				3	1	20.27
				3	3	20.3
				5	0	20.09
	Middle 26865	831.5	QPSK	1	0	22.52
				1	2	22.44
				1	5	22.46
				3	0	21.5
				3	1	21.5
				3	3	21.51
				6	0	20.46
			16QAM	1	0	21.52
				1	2	21.53
				1	5	21.52
				3	0	20.69
				3	1	20.69
				3	3	20.71
				5	0	20.45
	High 27025	847.5	QPSK	1	0	22.22
				1	2	22.29
				1	5	22.29
				3	0	21.29
				3	1	21.3
				3	3	21.27
				6	0	20.24
			16QAM	1	0	21.43
				1	2	21.37
				1	5	21.35
				3	0	20.5
				3	1	20.5
				3	3	20.51
				5	0	20.28

BW=3 MHz. QPSK:

MAX POWER	QPSK COND. POWER AVG (dBm)	ANTENNA GAIN (dBi)	RAD. POWER AVG EIRP (dBm)	RAD. POWER AVG ERP (dBm)
LOW	22.08	2.7	24.78	22.63
MIDDLE	22.52	2.7	25.22	23.07
HIGH	22.29	2.7	24.99	22.84
MAX:	22.52		25.22	23.07

BW=3 MHz. 16QAM:

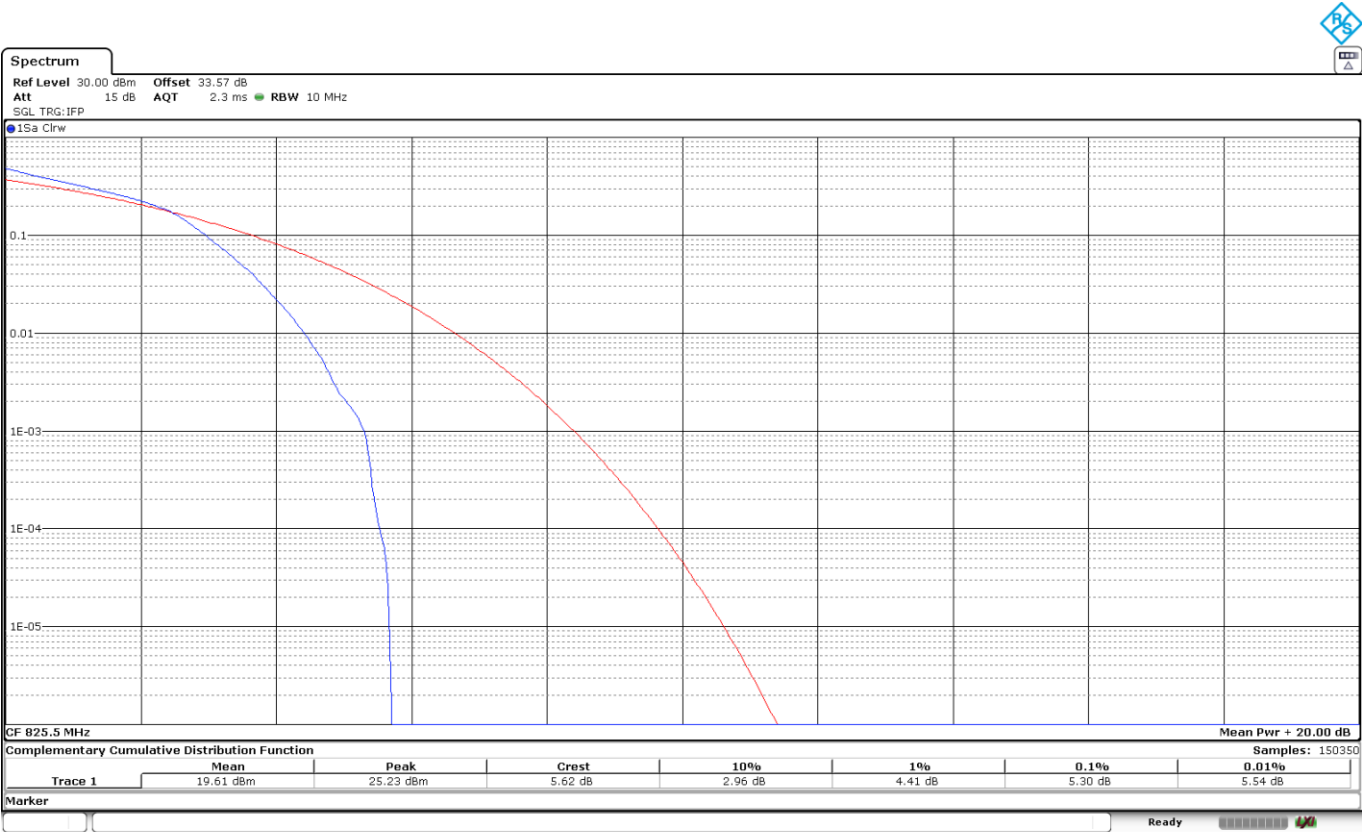
MAX POWER	16QAM COND. POWER AVG (dBm)	ANTENNA GAIN (dBi)	RAD. POWER AVG EIRP (dBm)	RAD. POWER AVG ERP (dBm)
LOW	21.14	2.7	23.84	21.69
MIDDLE	21.53	2.7	24.23	22.08
HIGH	21.43	2.7	24.13	21.98
MAX:	21.53		24.23	22.08

2. PEAK-TO-AVERAGE POWER RATIO (PAPR)

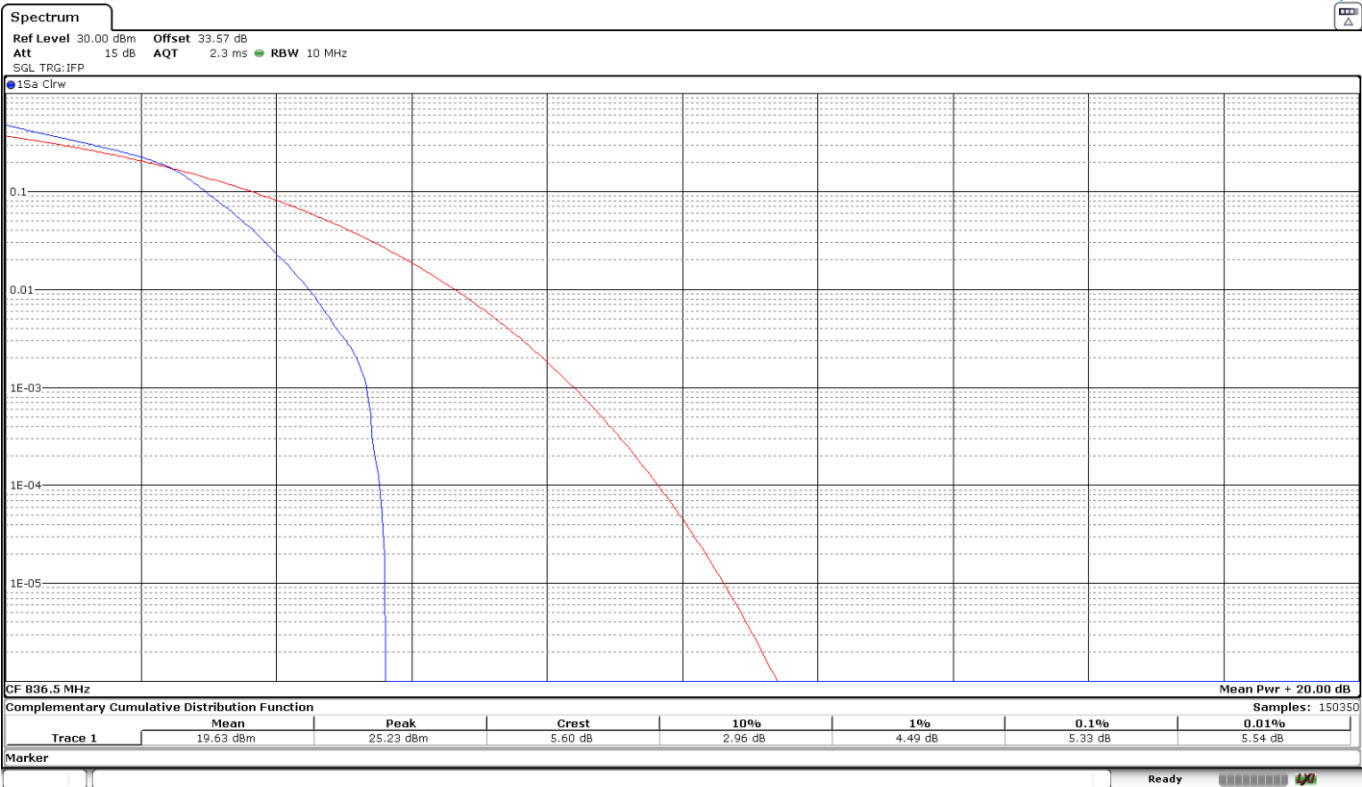
LTE Cat-M1 Band 26:

Preliminary measurements determined the worst-case of PAPR is BW=3 MHz, Middle Channel, 16QAM, RB Size=5, RB Offset=0, Narrowband=0.

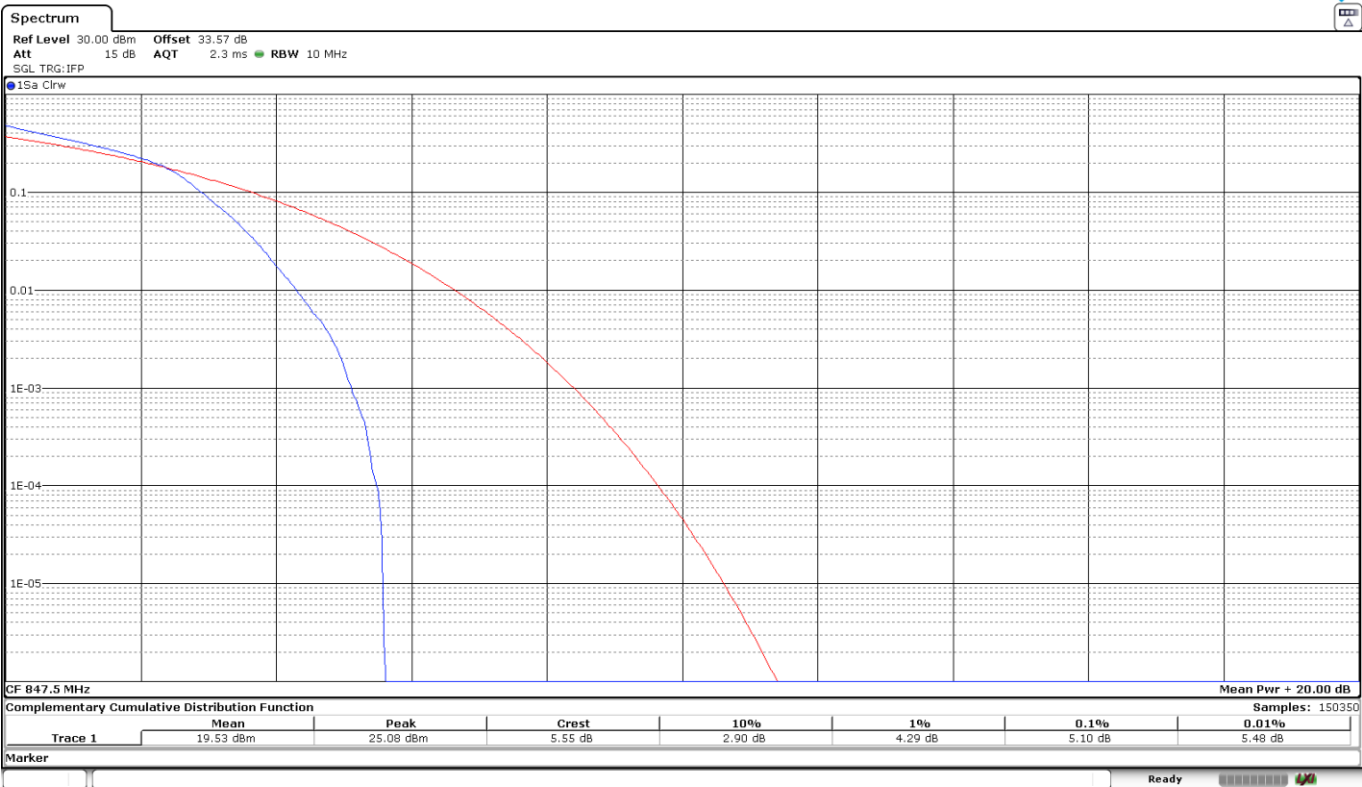
Low Channel:



Middle Channel:



High Channel:



16QAM	Low	Middle	High
PAPR (dB)	5.3	5.33	5.1

Measurement uncertainty (dB) <±1.11

Verdict

Pass

Frequency Stability

Limits

- * FCC §2.1055 and §22.355. ± 2.5 ppm for mobile stations operating in the range 821 to 896 MHz.
- * RSS-132 Issue 4. Clause 5.3. The frequency stability shall be sufficient to ensure that the occupied bandwidth stays within each of the sub-bands when tested at 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 -40°C to $+85^{\circ}\text{C}$. The EUT was placed inside a climatic chamber and the temperature was raised hourly in 10°C steps from -40°C up to $+85^{\circ}\text{C}$.

The supply voltage was varied between 85% and 115% of nominal voltage.

Temperature and voltage range of testing has been extended to the maximum and minimum values declared by customer.

The EUT was set in "Radio Resource Control (RRC) mode" on 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.

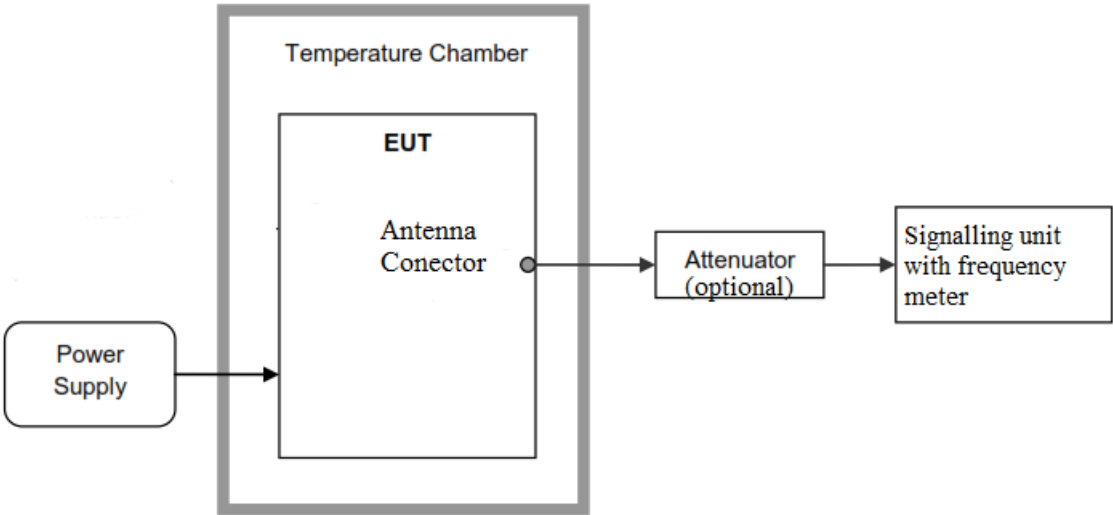
The worst-case LTE mode for conducted power was used for the test.

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 LOW and HIGH channels 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.

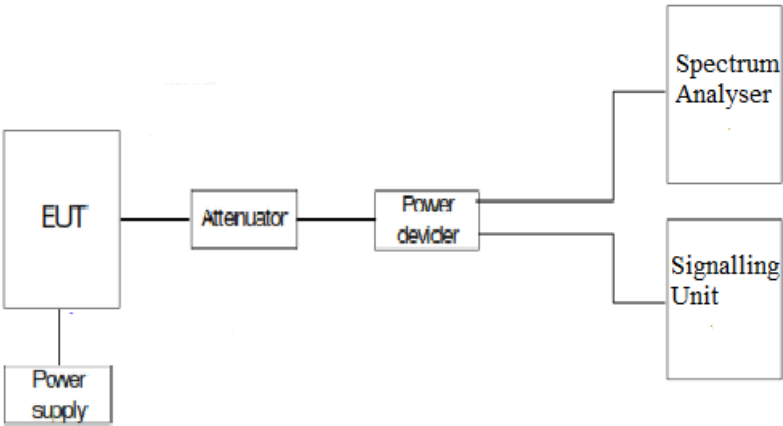
The reference point measurements were made at the RF output terminals of the EUT using an attenuator, power splitter and spectrum analyser. The EUT was controlled via the Universal Radio Communication tester R&S CMW500 selecting maximum transmission power of the EUT and different modes of modulation.

Test Setup

Frequency tolerance:



Reference points f_L and f_H :



Results

LTE Cat-M1 Band 26:

The worst case modulation in terms of Frequency Stability is BW=1.4 MHz, QPSK.

1. Frequency Tolerance:

- Frequency Stability over Temperature Variations:

Temperature (°C)	Frequency Error (Hz)	Frequency Error (ppm)
+85	3.55	0.004243873
+80	1.96	0.002343096
+70	-5.91	-0.007065152
+60	-2.35	-0.002809325
+50	-2.06	-0.002462642
+40	0.23	0.000274955
+30	1.47	0.001757322
+20	-0.82	-0.000980275
+10	1.36	0.001625822
0	0.63	0.000753138
-10	2.65	0.003167962
-20	-4.45	-0.005319785
-30	-7.83	-0.00936043
-40	0.67	0.000800956

- Frequency Stability over Voltage Variations.

Supply voltage	Voltage (V)	Frequency Error (Hz)	Frequency Error (ppm)
Vmax	5.5	-2.1	-0.00251046
Vmin	3	6.28	0.007507472

2. Reference Frequency Points fL and fH:

The worst-case frequency offsets added or subtracted per band and bandwidth:

fL (MHz)	824.0086
fH (MHz)	848.4632

The reference frequency points fL and fH stay within the authorized blocks for the band above.

Measurement uncertainty (Hz) <± 249.55

Verdict

Pass

Modulation Characteristics

Limits

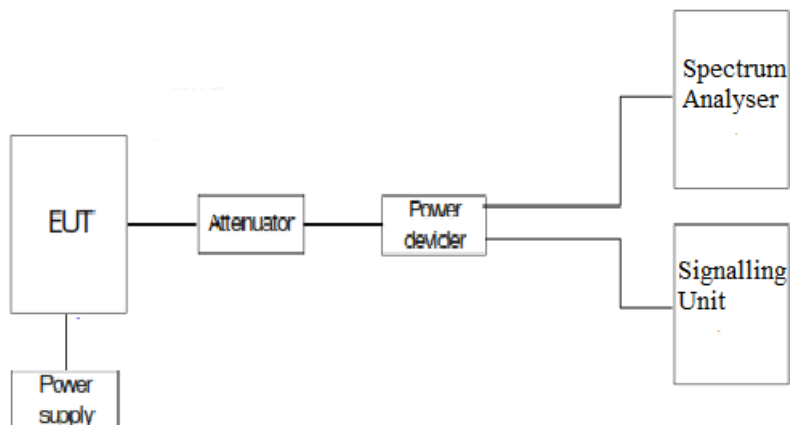
FCC §2.1047.

RSS-132. Clause 5.2: Equipment certified under this standard shall use digital modulation.

Method

For LTE the EUT operates with QPSK and 16QAM modes in which the information is digitized and coded into a bit stream. The RF transmission is multiplexed using *Orthogonal Frequency Division Multiplexing (OFDM)* using different possible arrangement of subcarriers (Resource Blocks RB).

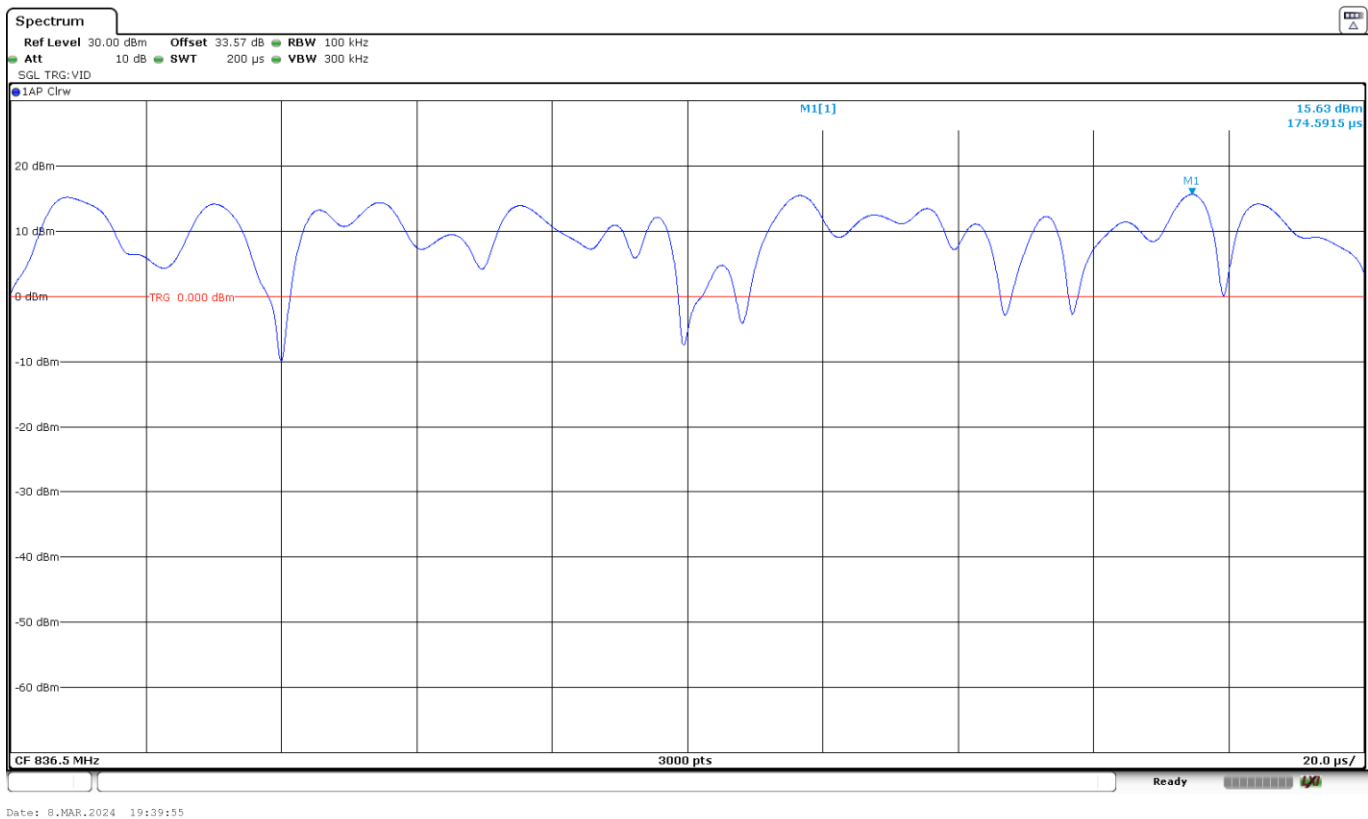
Test Setup



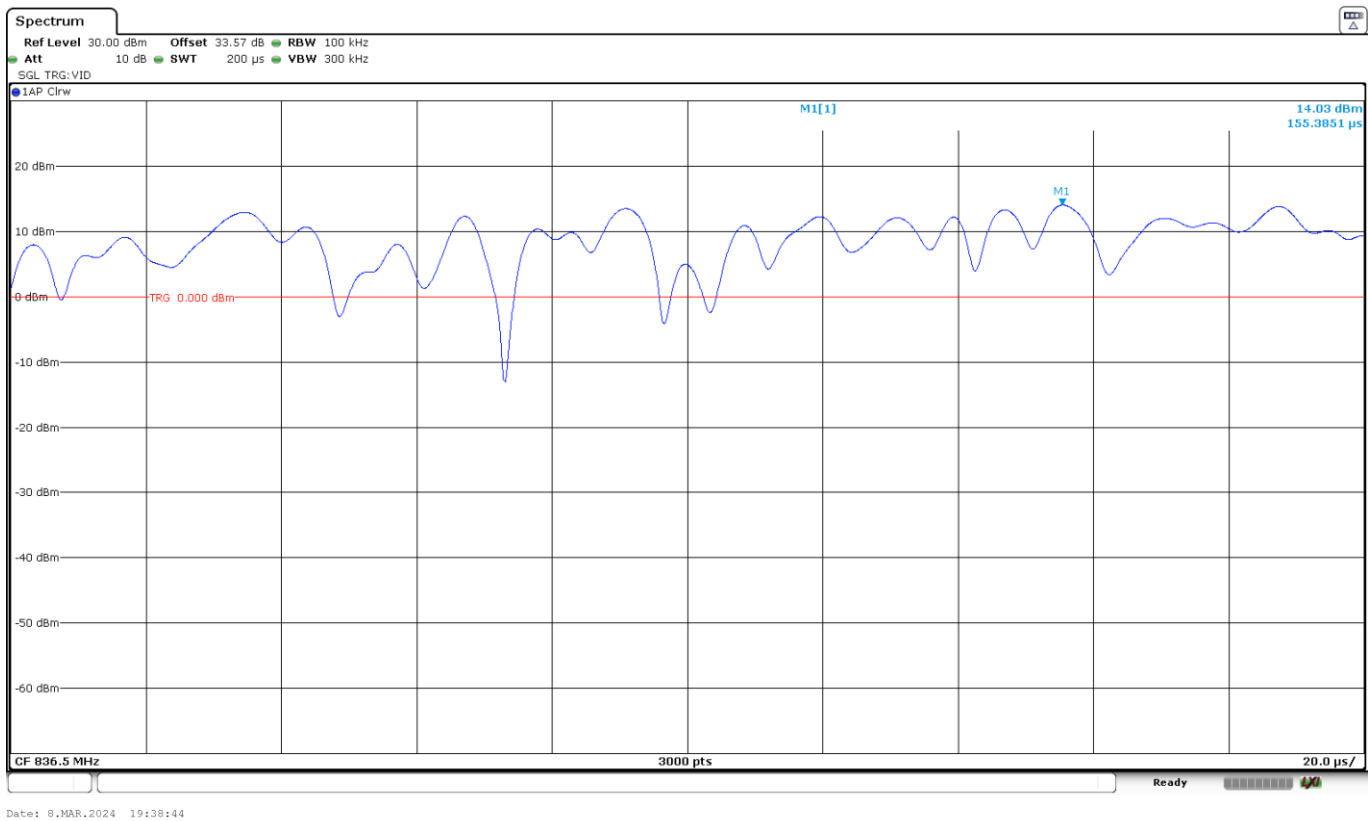
Results

The following plots show the modulation schemes in the EUT.

LTE Cat-M1 Band 26: BW = 1.4 MHz. QPSK. RB Size=1. RB Offset=0.



LTE Cat-M1 Band 26: BW = 1.4 MHz. 16QAM. RB Size=1. RB Offset=0.



Occupied Bandwidth

Limits

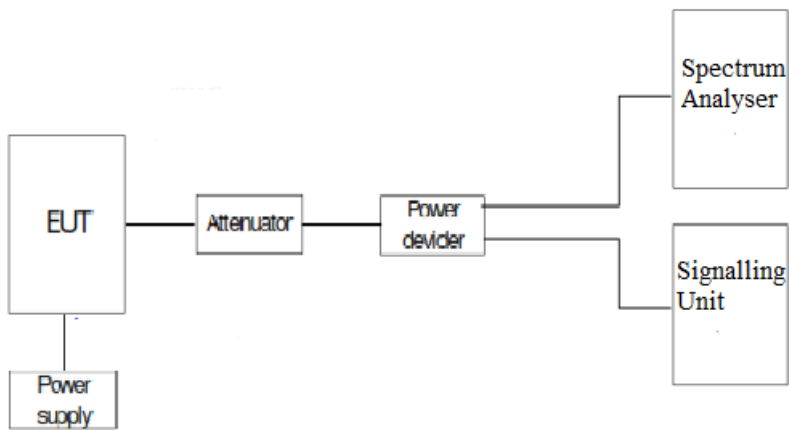
FCC §2.1049. Measurements required: Occupied bandwidth.

RSS-Gen, Clause 6.7.

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

The worst case of occupied bandwidth corresponds to all Resource Blocks (RB) offset 0 regardless either the Narrowband position or the nominal bandwidth selected.

LTE Cat-M1 Band 26:

LTE Cat-M1 Band 26. BW=1.4 MHz. QPSK. RB Size=6. RB Offset=0. Narrowband=0.

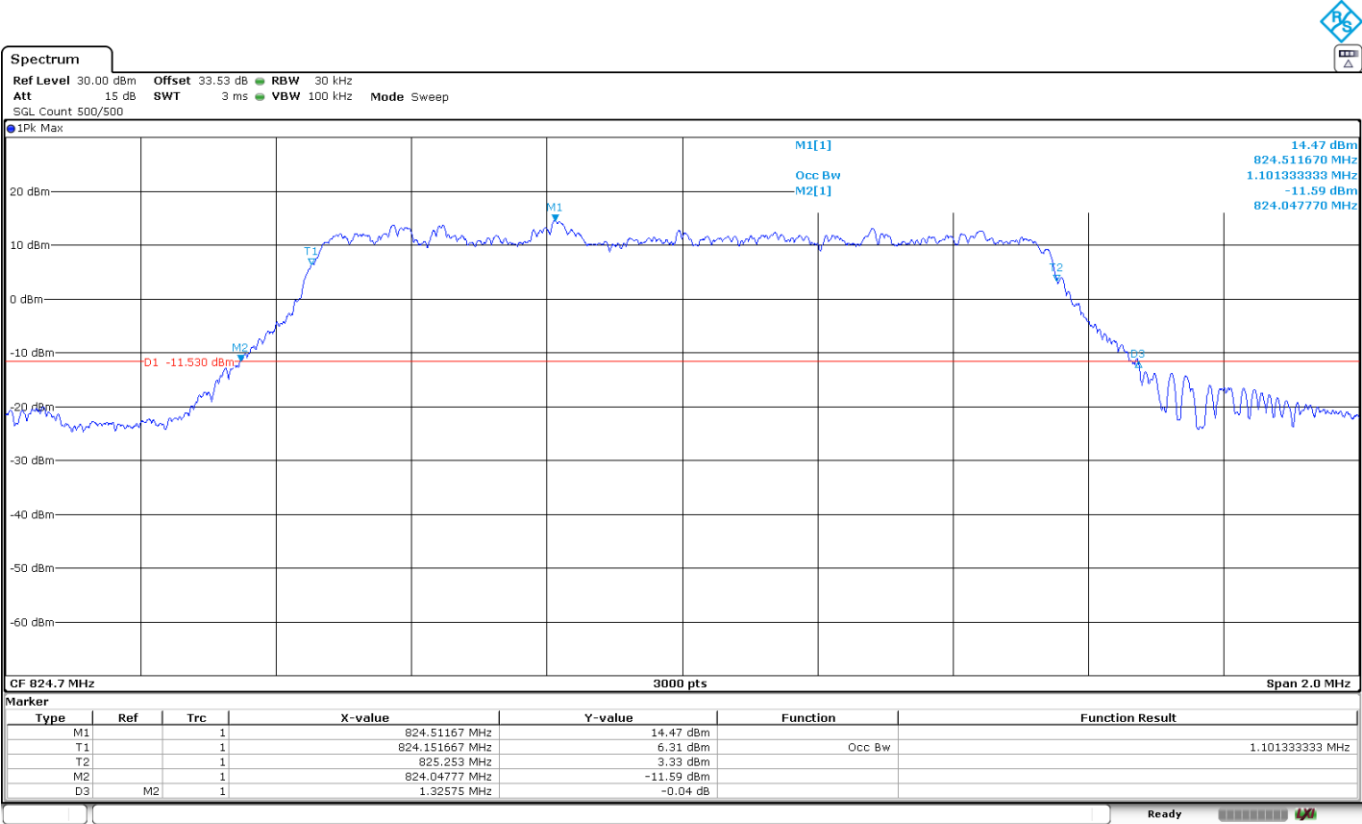
	Low Channel	Middle Channel	High Channel
99% Occupied Bandwidth (MHz)	1.10133	1.10200	1.10333
-26 dBc Bandwidth (MHz)	1.32575	1.32340	1.38540
Measurement uncertainty (kHz)	<±3.75		

LTE Cat-M1 Band 26. BW=1.4 MHz. 16QAM. RB Size=5. RB Offset=0. Narrowband=0.

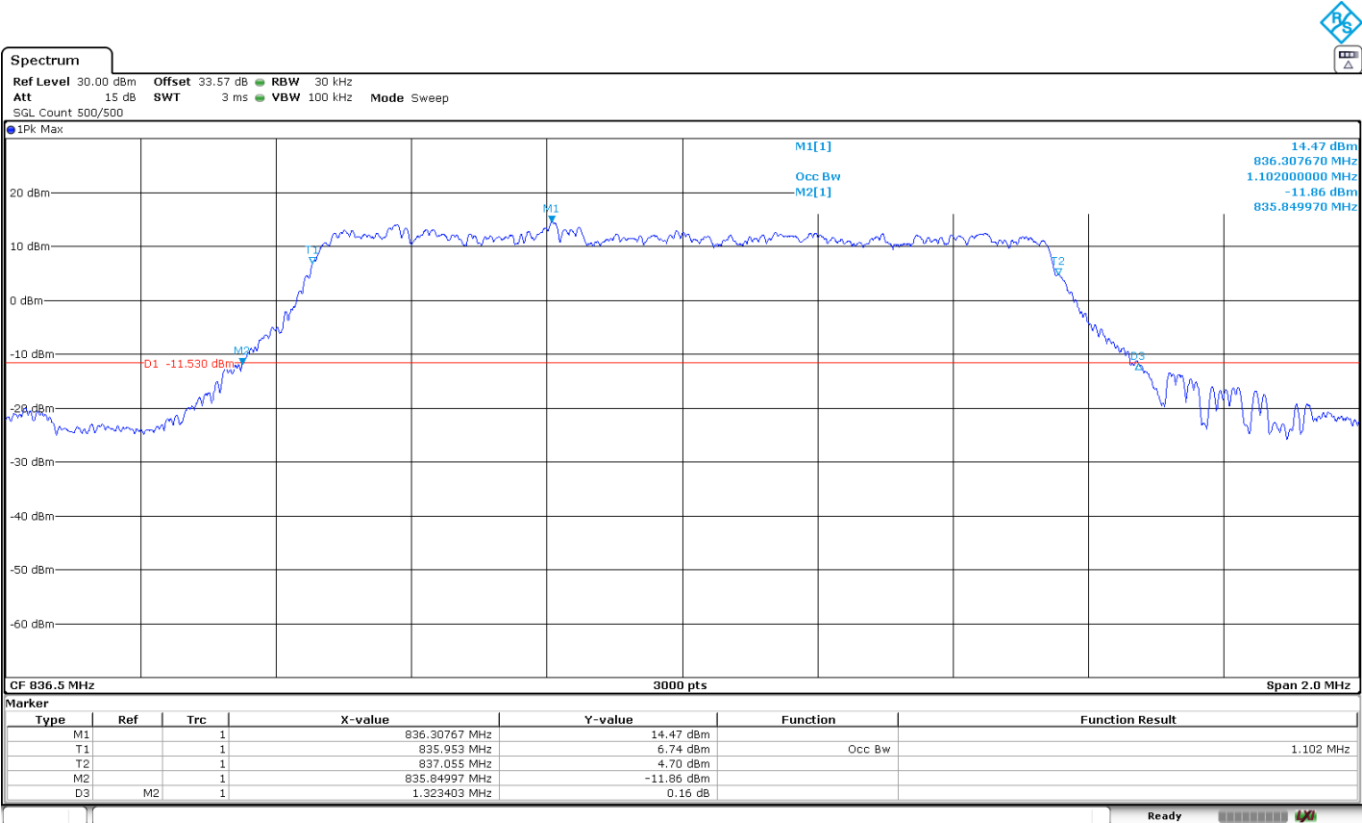
	Low Channel	Middle Channel	High Channel
99% Occupied Bandwidth (MHz)	0.95000	0.93867	0.94600
-26 dBc Bandwidth (MHz)	1.28118	1.28925	1.28848
Measurement uncertainty (kHz)	<±3.75		

LTE Cat-M1 Band 26. BW=1.4 MHz. QPSK. RB Size 6. Offset 0. Narrowband 0.

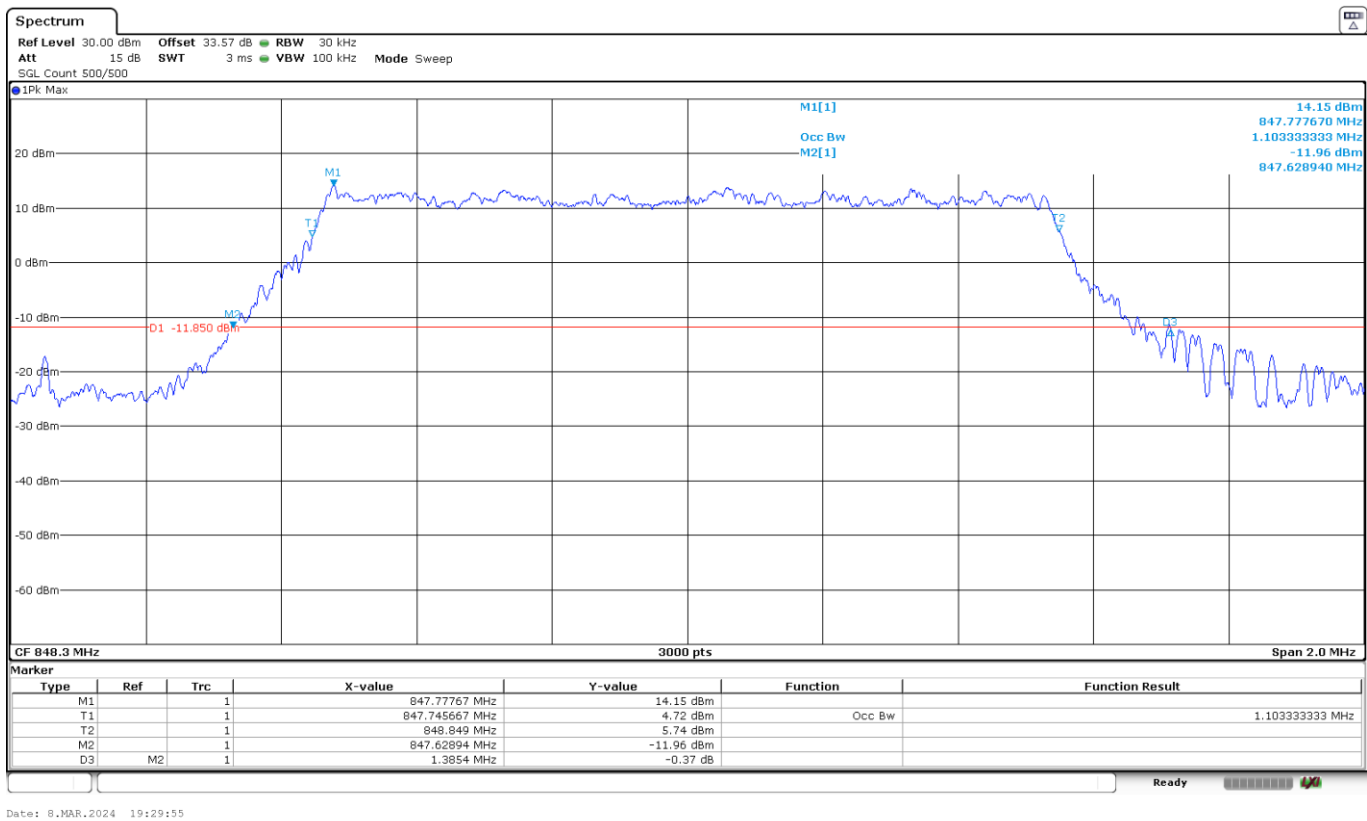
Low Channel:



Middle Channel:

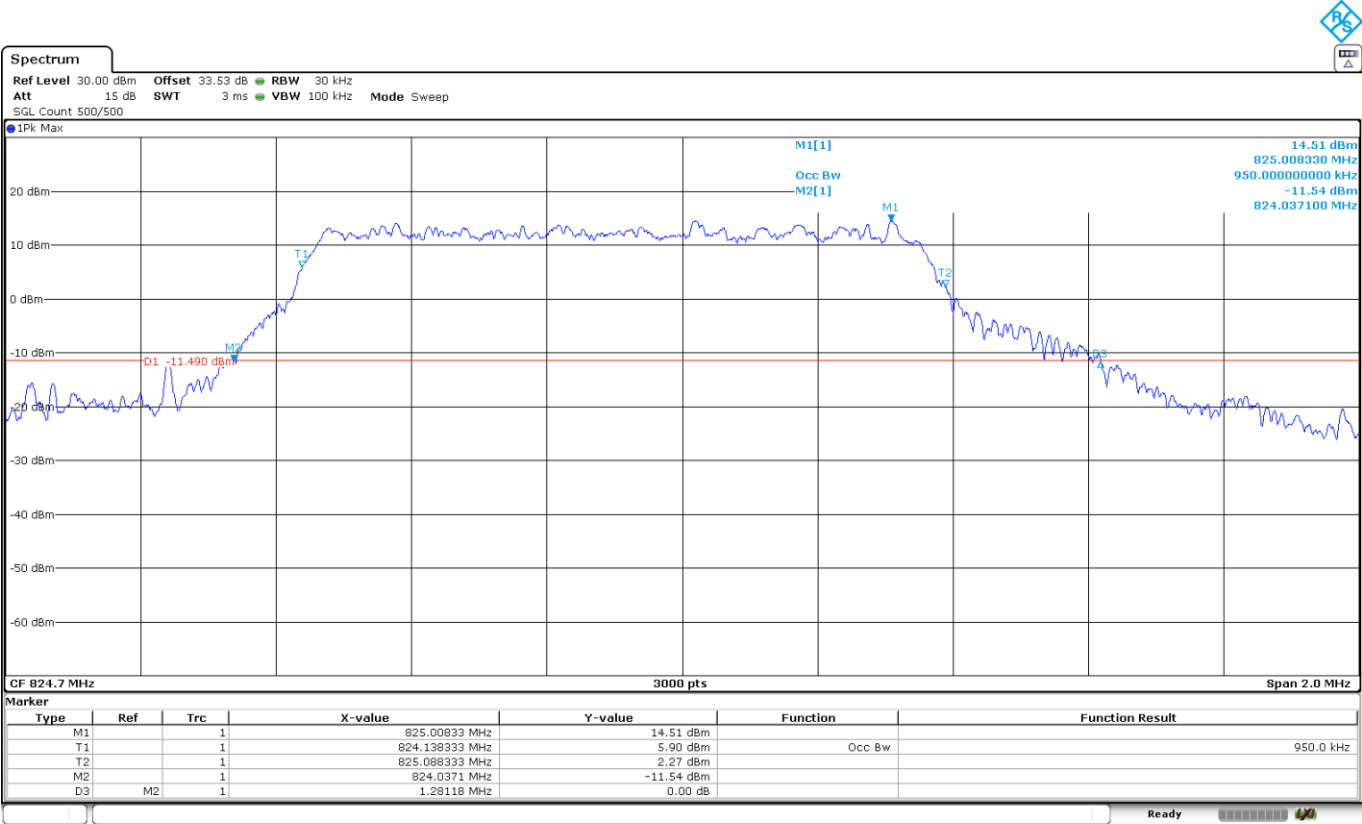


High Channel:

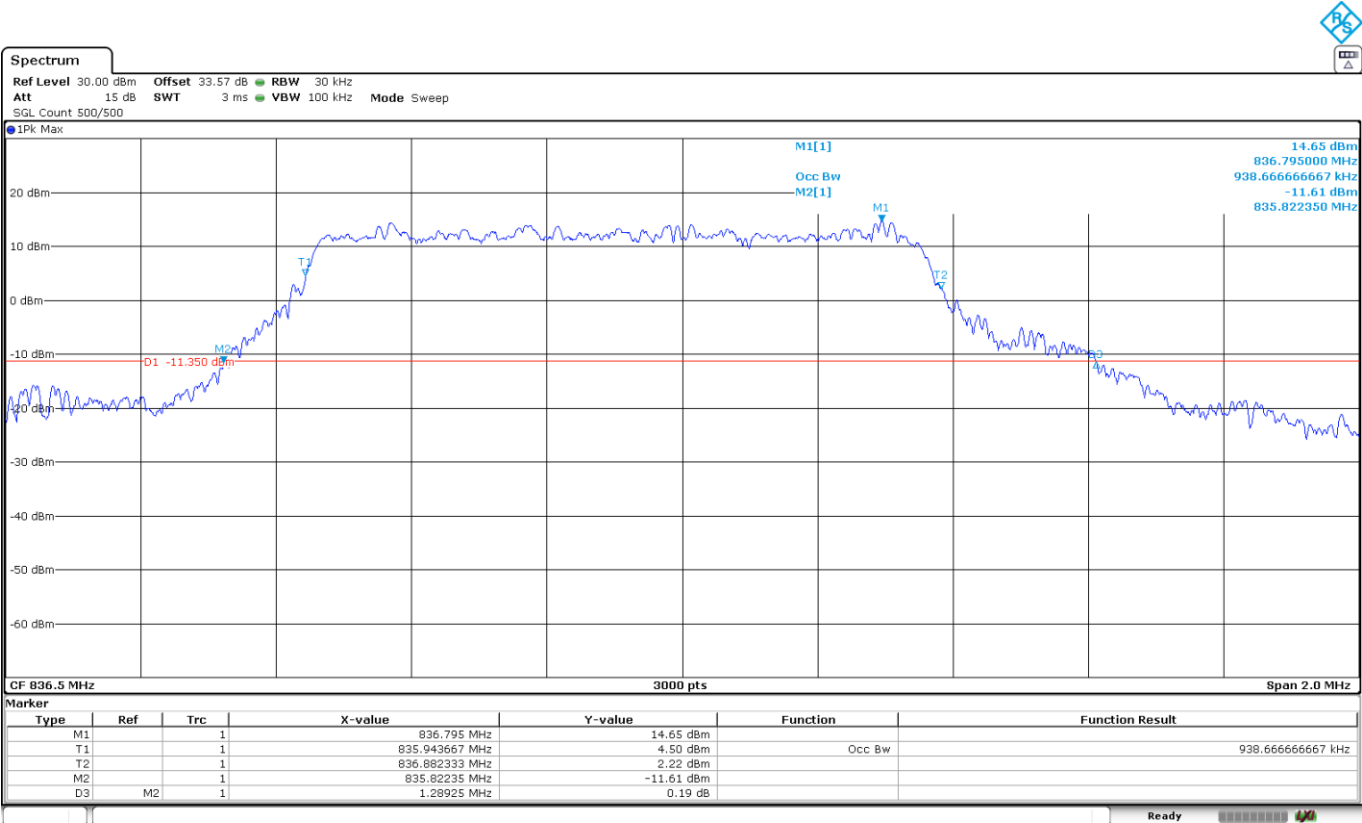


LTE Cat-M1 Band 26. BW=1.4 MHz. 16QAM. RB Size 5. Offset 0. Narrowband 0.

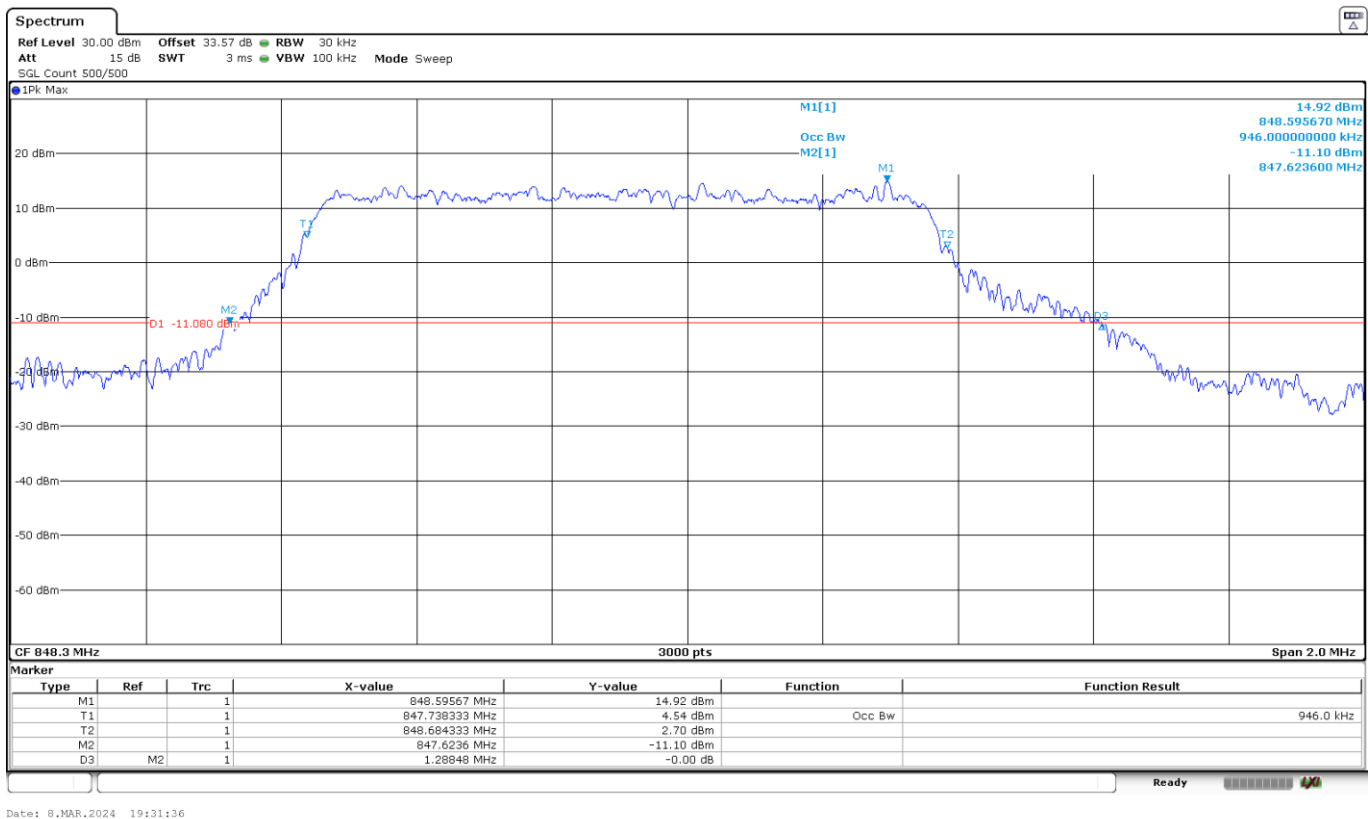
Low Channel:



Middle Channel:



High Channel:



Spurious Emissions at Antenna Terminals

Limits

FCC §2.1051 and §22.917. RSS-132 Clause 5.5.

The power of emissions shall be attenuated below the transmitter power (P) by a factor of at least $43 + 10 \log (P)$ dB. P in watts.

In the spectrum below 1 GHz, instrumentation should employ a reference bandwidth of 100 kHz or greater.
In the spectrum above 1 GHz, instrumentation should employ a reference bandwidth of 1 MHz.

At P_o transmitting power, the specified minimum attenuation becomes $43 + 10 \log (P_o)$, and the level in dBm relative to P_o becomes:

$$P_o \text{ (dBm)} - [43 + 10 \log (P_o \text{ in mW}) - 30] = -13 \text{ dBm}$$

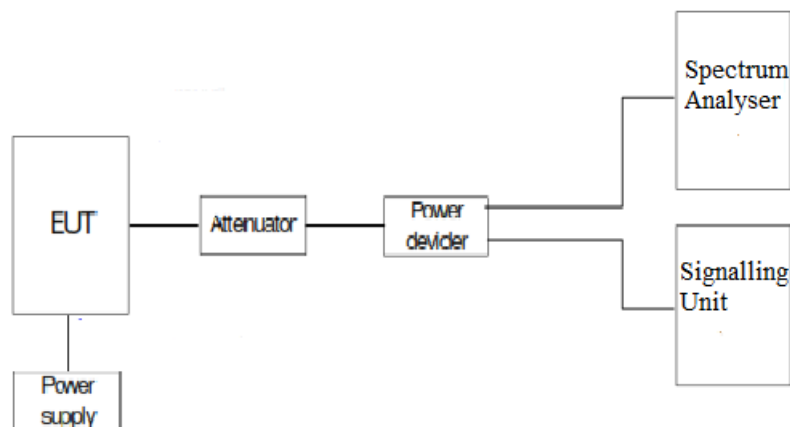
Method

The EUT RF output connector was connected to a spectrum analyser and to the Universal Radio Communication tester R&S CMW500 (selecting maximum transmission power of the EUT and different modes of modulation) using a 50-Ohm attenuator and a power divider.

The reading of the spectrum analyser is corrected with the attenuation loss of connection between output terminal of EUT and input of the spectrum analyser.

The configuration of Resource Blocks and modulation which is the worst case for conducted power was used.

Test Setup



Results

LTE Cat-M1 Band 26:

A preliminary scan determined the worst-case:

BW=3 MHz. QPSK. RB Size=1. RB Offset=0. Narrowband=0.

The next results are for this worst-case configuration.

Frequency range 9 KHz - 10 GHz:

- Low Channel: No spurious frequencies at less than 20 dB below the limit.
- Middle Channel: No spurious frequencies at less than 20 dB below the limit.
- High Channel: Spurious frequencies at less than 20 dB below the limit:

Frequency (MHz)	Emission limitations conducted (dBm)
1692.4375	-34.9

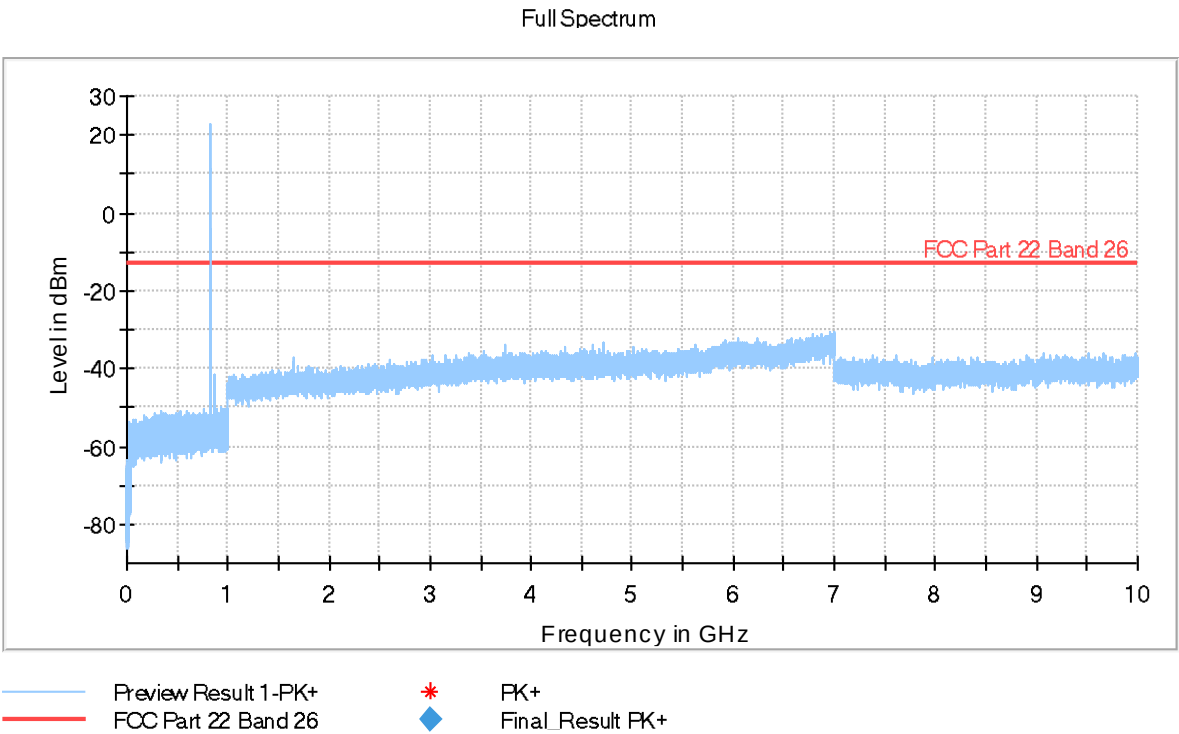
Measurement uncertainty (dB): <±2.76

Verdict: PASS

Subrange	Step Size	Detectors	Bandwidth	Sweep Time	Preamp
Receiver: [FSV 40]					
9 kHz - 150 kHz	14,1 Hz	PK+	300 Hz	Coupled	0 dB
150 kHz - 30 MHz	932,812 Hz	PK+	10 kHz	Coupled	0 dB
30 MHz - 1 GHz	30,312 kHz	PK+	100 kHz	Coupled	0 dB
1 GHz - 10 GHz	281,25 kHz	PK+	1 MHz	Coupled	0 dB

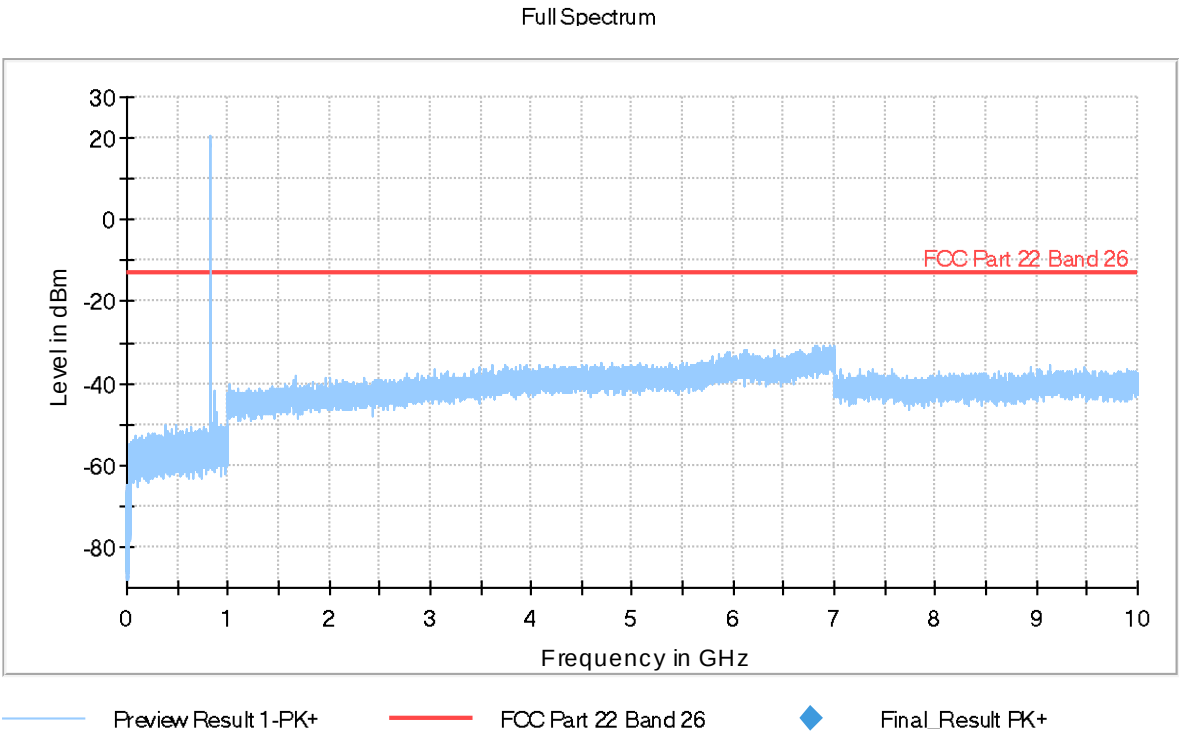
LTE Cat-M1 Band 26: BW=3 MHz. QPSK. RB Size=1. RB Offset=0. Narrowband=0.

Low Channel:



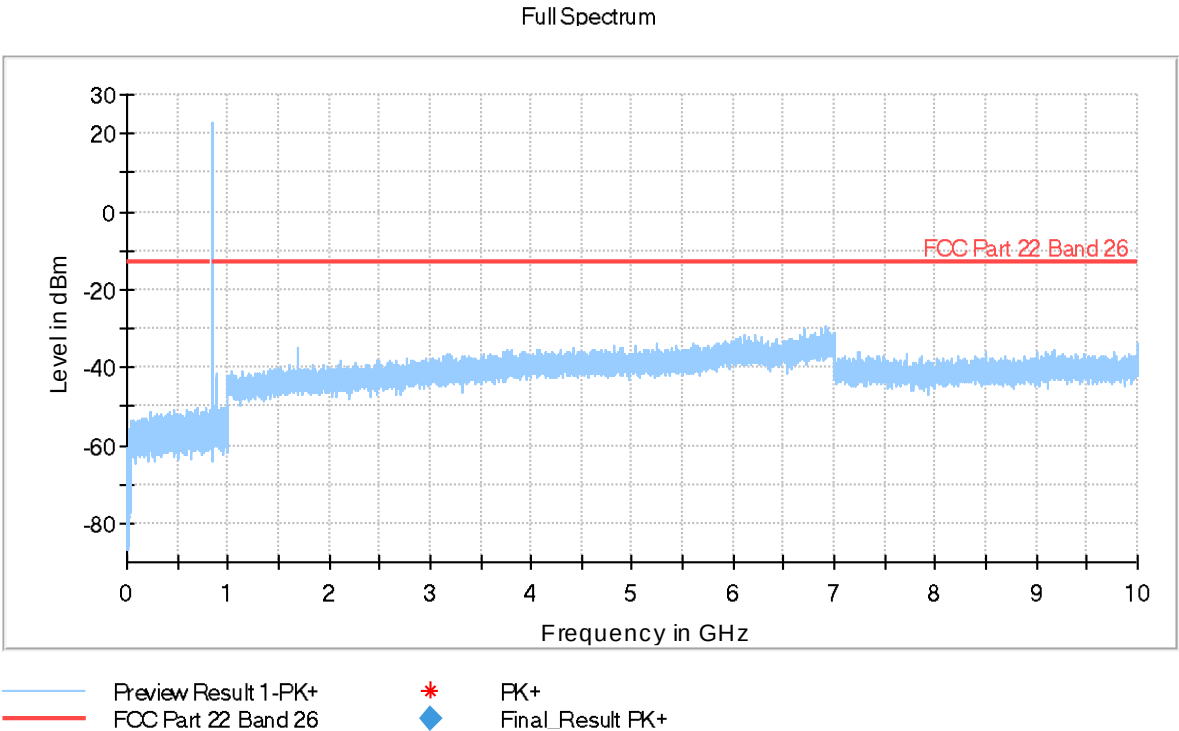
The peak above the limit is the carrier frequency.

Middle Channel:



The peak above the limit is the carrier frequency.

High Channel:



The peak above the limit is the carrier frequency.

Spurious Emissions at Antenna Terminals at Block Edges

Limits

FCC § 2.1051 and § 22.917:

The power of any emission outside of the authorized operating frequency ranges must be attenuated below the transmitting power (P) by a factor of at least $43 + 10 \log(P)$ dB.

Compliance with these rules is based on the use of measurement instrumentation employing a reference bandwidth as follows:

In the spectrum below 1 GHz, instrumentation should employ a reference bandwidth of 100 kHz or greater. In the 1 MHz bands immediately outside and adjacent to the frequency block, a resolution bandwidth of at least one percent of the emission bandwidth of the fundamental emission of the transmitter may be employed.

RSS-132. Clause 5.5:

Mobile and base station equipment shall comply with the limits below.

In the first 1.0 MHz band immediately outside and adjacent to each of the sub-bands, the power of emissions per any 1% of the occupied bandwidth shall be attenuated (in dB) below the transmitter output power P (dBW) by at least $43 + 10 \log 10 p$ (watts).

Method

The EUT RF output connector was connected to a spectrum analyzer and to the Universal Radio Communication tester R&S CMW500 (selecting maximum transmission power of the EUT and different modes of modulation) using a 50-Ohm attenuator and a power splitter.

The reading of the spectrum analyser is corrected with the path loss of the connection between the output terminal of the EUT and the input of the spectrum analyzer.

The configuration of modulation which is the worst case for conducted power was used.

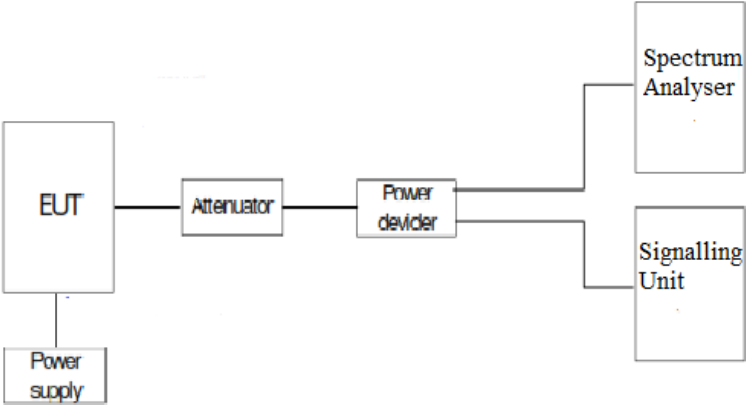
As stated in FCC part 22.917 / RSS-132 Clause 5.5, in the 1 MHz bands immediately outside and adjacent to the frequency block or band a resolution bandwidth of at least one percent of the emission bandwidth of the fundamental emission of the transmitter may be employed.

Measurement Limit:

At P_o transmitting power, the specified minimum attenuation $43 + 10 \log_{10} p$ (watts) becomes:

$$P_o \text{ (dBm)} - [43 + 10 \log (P_o \text{ in mwatts}) - 30] = -13 \text{ dBm}$$

Test Setup



Results

LTE Cat-M1 Band 26:

Preliminary measurements determined QPSK, BW=1.4 MHz as the worst-case modulation in terms of band edge results. The next results are for this worst-case configuration.

LTE Cat-M1 Band 26. QPSK.	Narrowband=0 RB=1. Offset=0. BW=1.4 MHz	Narrowband=0 RB=1. Offset=0. BW = 3 MHz	Narrowband=0 RB=1. Offset =0. BW=5 MHz	Narrowband=0 RB=1. Offset =0. BW=10 MHz	Narrowband=0 RB=1. Offset =0. BW=15 MHz
Maximum measured level at <u>Low Block Edge</u> at antenna port (dBm)	-14.17	-20.79	-19.53	-29.44	-33.56

LTE Cat-M1 Band 26. QPSK.	Narrowband=0 RB=6. Offset=0. BW=1.4 MHz	Narrowband=0 RB=6. Offset=0. BW = 3 MHz	Narrowband=0 RB=6. Offset=0. BW=5 MHz	Narrowband=0 RB=6. Offset=0. BW=10 MHz	Narrowband=0 RB=6. Offset=0. BW=15 MHz
Maximum measured level at <u>Low Block Edge</u> at antenna port (dBm)	-15.14	-17.84	-14.67	-19.39	-21.51

LTE Cat-M1 Band 26. QPSK.	Narrowband=0 RB=1. Offset=Max. BW=1.4 MHz	Narrowband=1 RB=1. Offset =Max. BW = 3 MHz	Narrowband=3 RB=1. Offset =Max. BW=5 MHz	Narrowband=7 RB=1. Offset =Max. BW=10 MHz	Narrowband=11 RB=1. Offset =Max. BW=15 MHz
Maximum measured level at <u>High Block Edge</u> at antenna port (dBm)	-14.75	-21.42	-17.78	-19.95	-25.09

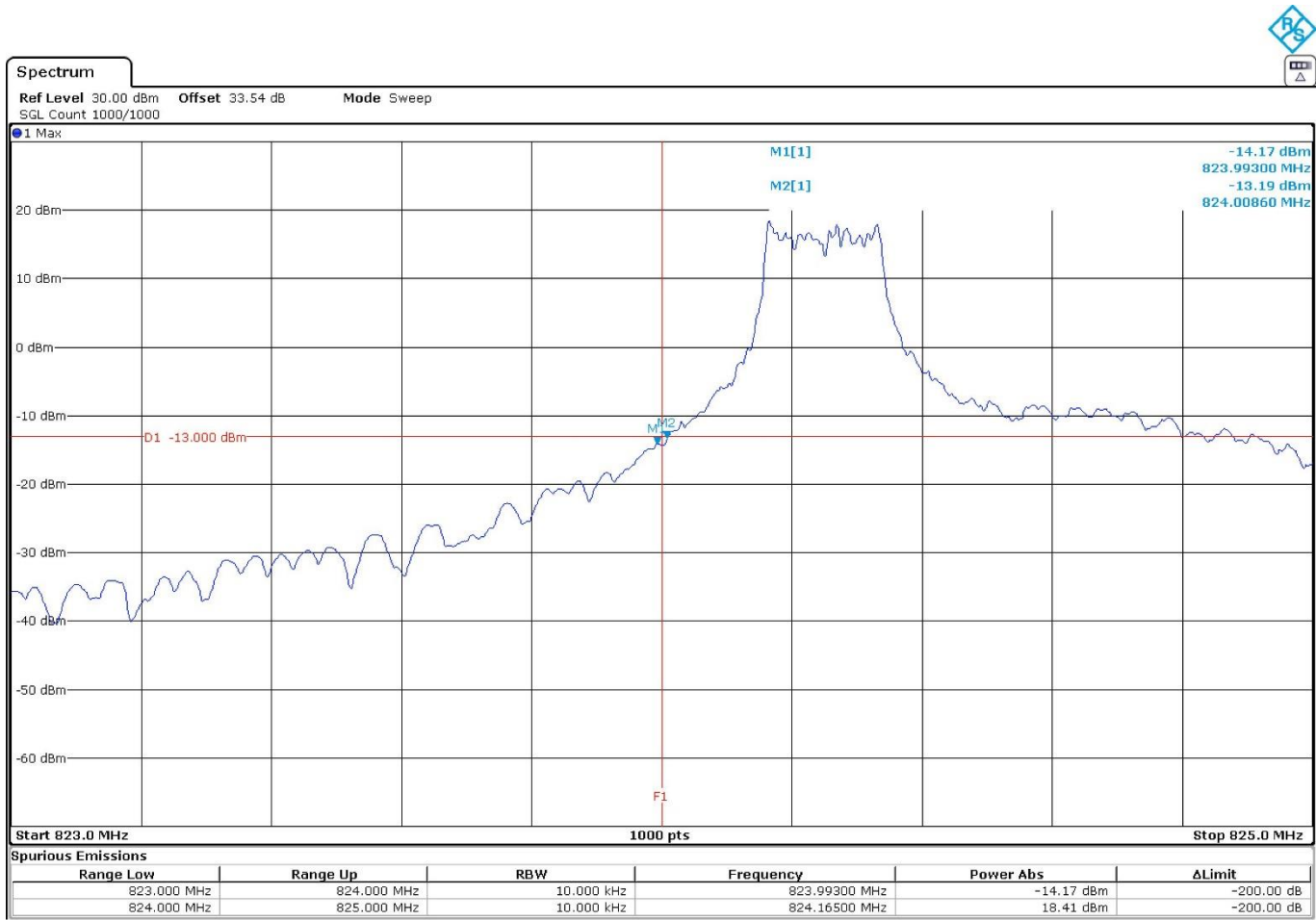
LTE Cat-M1 Band 26. QPSK.	Narrowband=0 RB=6. Offset=1. BW=1.4 MHz	Narrowband=1 RB=6. Offset=1. BW = 3 MHz	Narrowband=3 RB=6. Offset=1. BW=5 MHz	Narrowband=7 RB=6. Offset=1. BW=10 MHz	Narrowband=11 RB=6. Offset=1. BW=15 MHz
Maximum measured level at <u>High Block Edge</u> at antenna port (dBm)	-14.27	-16.89	-14.31	-20.97	-19.68

Measurement uncertainty (dB): <±2.76

Verdict

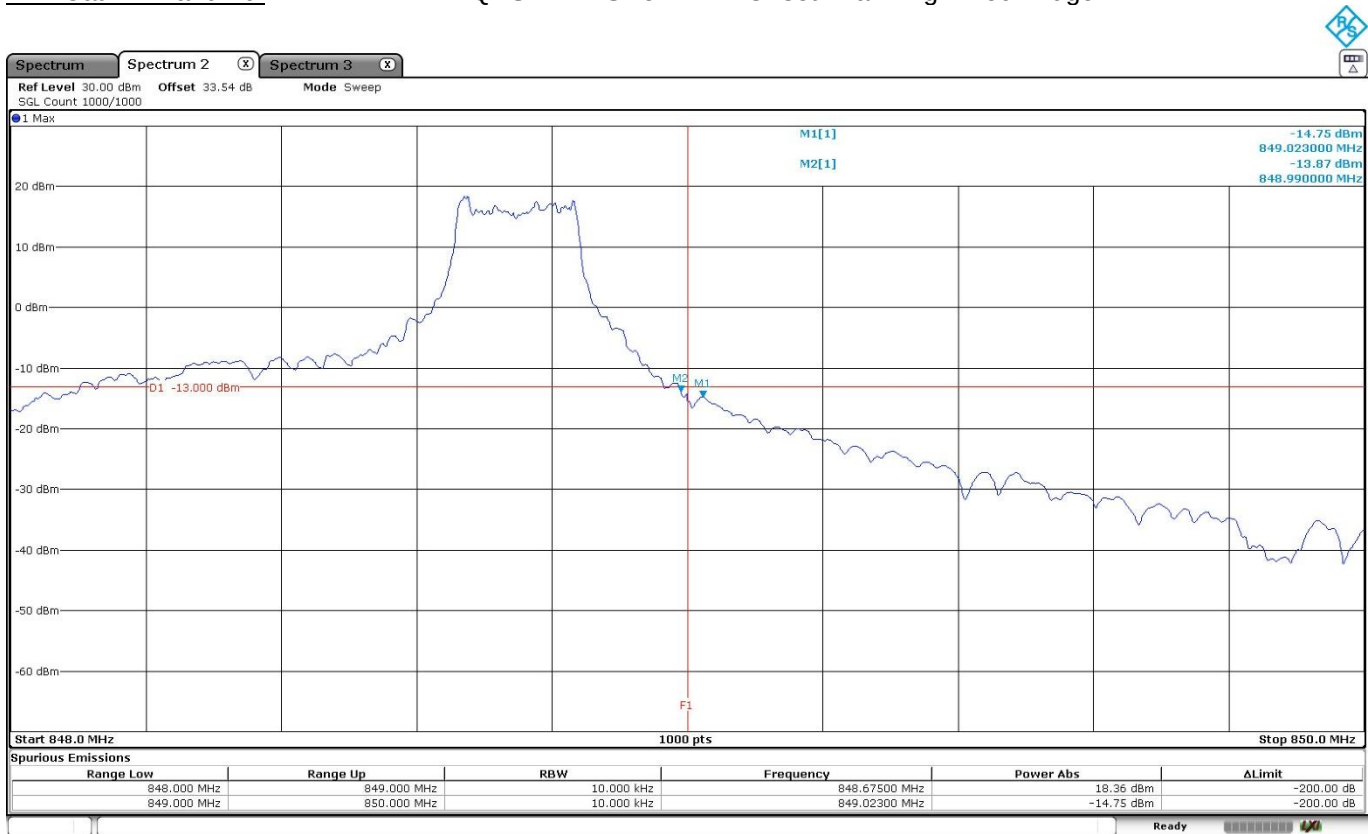
Pass

LTE Cat-M1 Band 26. BW=1.4 MHz. QPSK. RB Size=1. RB Offset=0. Low Block Edge:



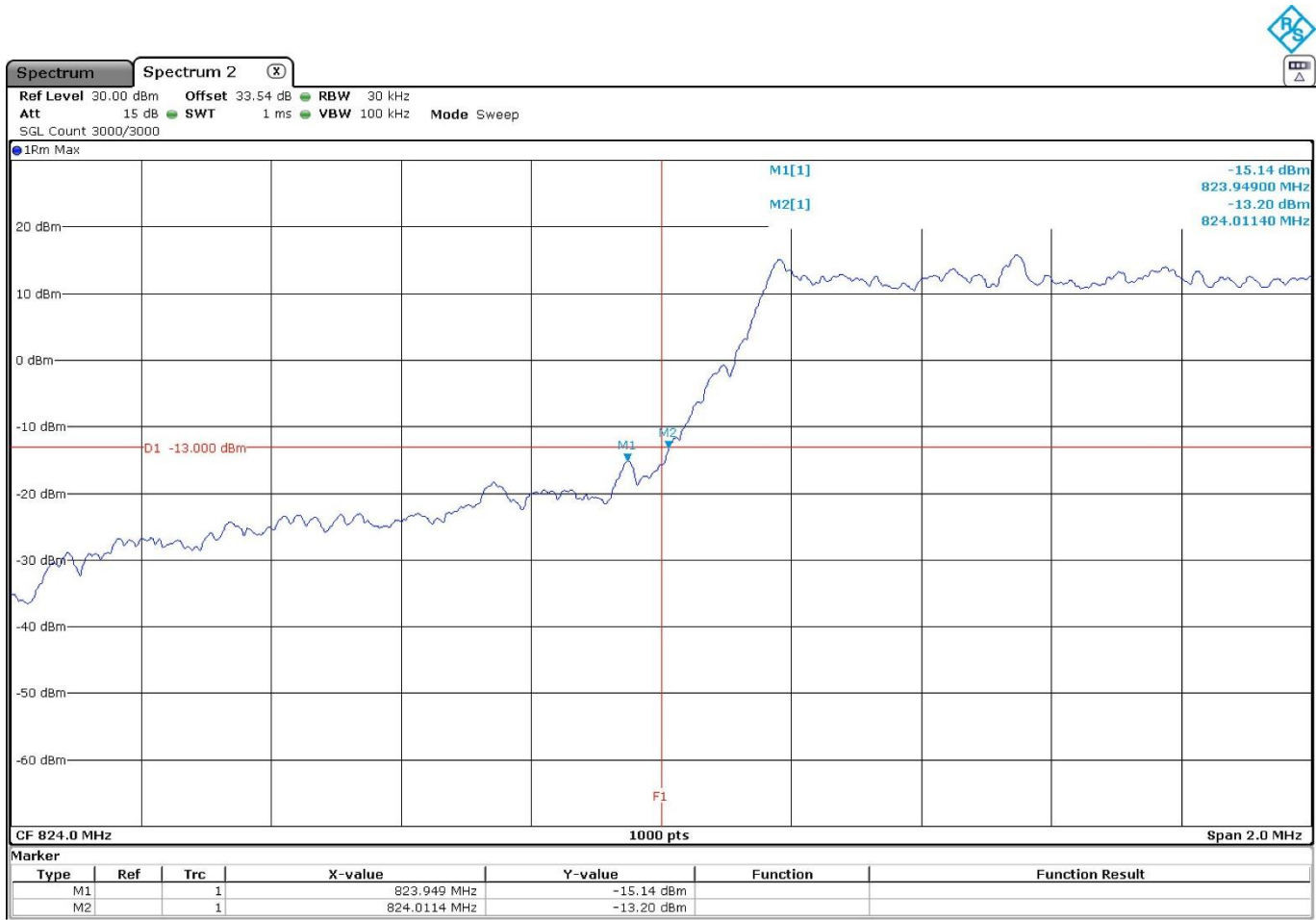
The equipment transmits at the maximum output power.

LTE Cat-M1 Band 26. BW=1.4 MHz. QPSK. RB Size=1. RB Offset=Max. High Block Edge:



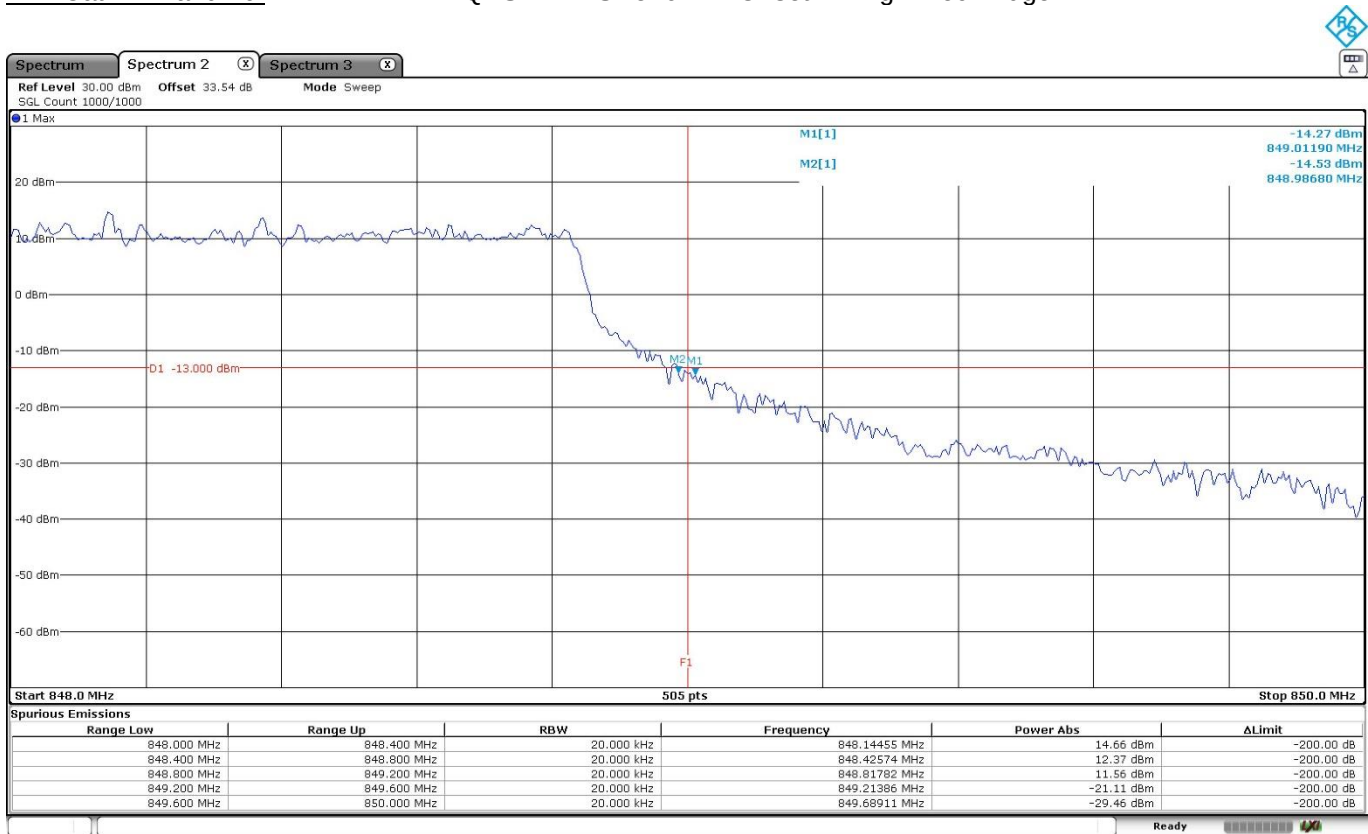
The equipment transmits at the maximum output power.

LTE Cat-M1 Band 26. BW=1.4 MHz. QPSK. RB Size=6. RB Offset=0. Low Block Edge:



The equipment transmits at the maximum output power.

LTE Cat-M1 Band 26. BW=1.4 MHz. QPSK. RB Size=6. RB Offset=1. High Block Edge:



The equipment transmits at the maximum output power.

Verdict: PASS

Radiated Emissions

Limits

* FCC §2.1051 and §22.917: The power of any emission outside of the authorized operating frequency ranges must be attenuated below the transmitting power (P) by a factor of at least $43 + 10 \log(P)$ dB.

- * RSS-132. 5.5: Mobile and base station equipment shall comply with the limits in (i) and (ii) below.
- i. In the first 1.0 MHz band immediately outside and adjacent to each of the sub-bands specified in Section 5.1, the power of emissions per any 1% of the occupied bandwidth shall be attenuated (in dB) below the transmitter output power P (dBW) by at least $43 + 10 \log_{10} P$ (watts).
 - ii. After the first 1.0 MHz immediately outside and adjacent to each of the sub-bands, the power of emissions in any 100 kHz bandwidth shall be attenuated (in dB) below the transmitter output power P (dBW) by at least $43 + 10 \log_{10} P$ (watts). If the measurement is performed using 1% of the occupied bandwidth, power integration over 100 kHz is required.

Method

The measurement was performed with the EUT inside an anechoic chamber. The spectrum was scanned from 30 MHz to at least the 10th harmonic of the HIGH frequency generated within the equipment.

The EUT was placed on a 1 meter high non-conductive stand at a 3 meter distance from the measuring antenna. Detected emissions were maximized at each frequency by rotating the EUT and adjusting the height and polarization of the measuring antenna. The maximum meter reading was recorded.

Measurement Limit:

According to specification, the power of emissions shall be attenuated below the transmitter power (P) by a factor of at least $43 + 10 \log (P)$ dB, P in watts.

At P_o transmitting power, the specified minimum attenuation becomes $43+10\log (P_o)$, and the level in dBm relative P_o becomes:

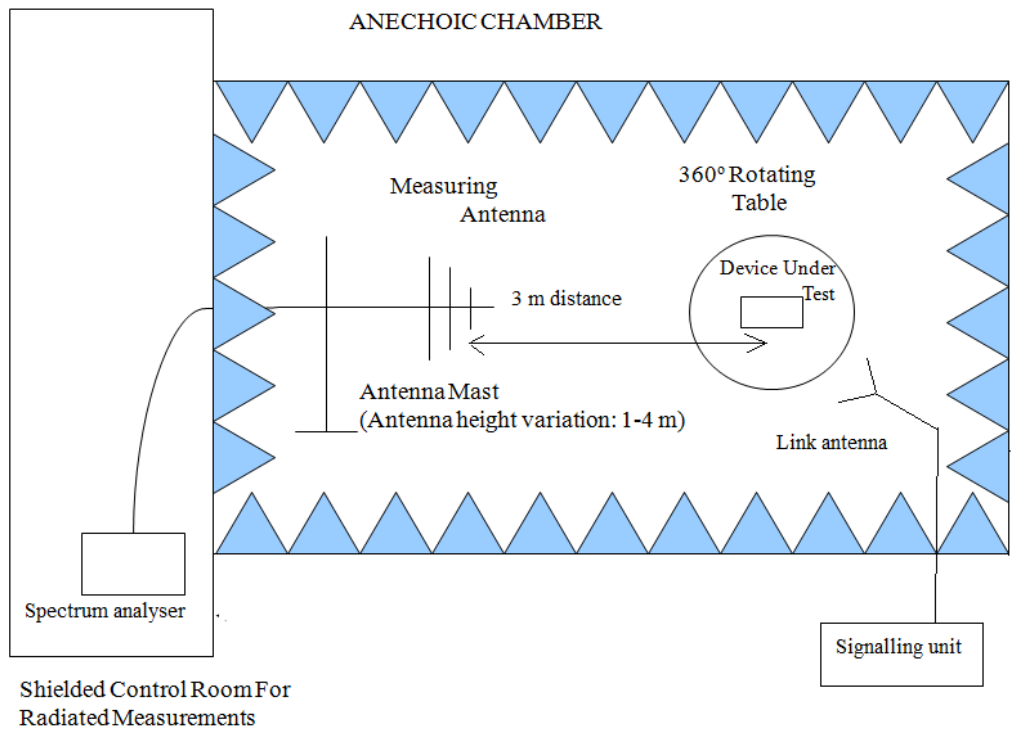
$$P_o \text{ (dBm)} - [43 + 10 \log (P_o \text{ in mwatts}) - 30] = - 13 \text{ dBm}$$

The maximum field strength (dB μ V/m) of each detected emission at less than 20 dB respect to the limit is converted to an equivalent EIRP level (dBm) according to ANSI C63.26 with the formula:

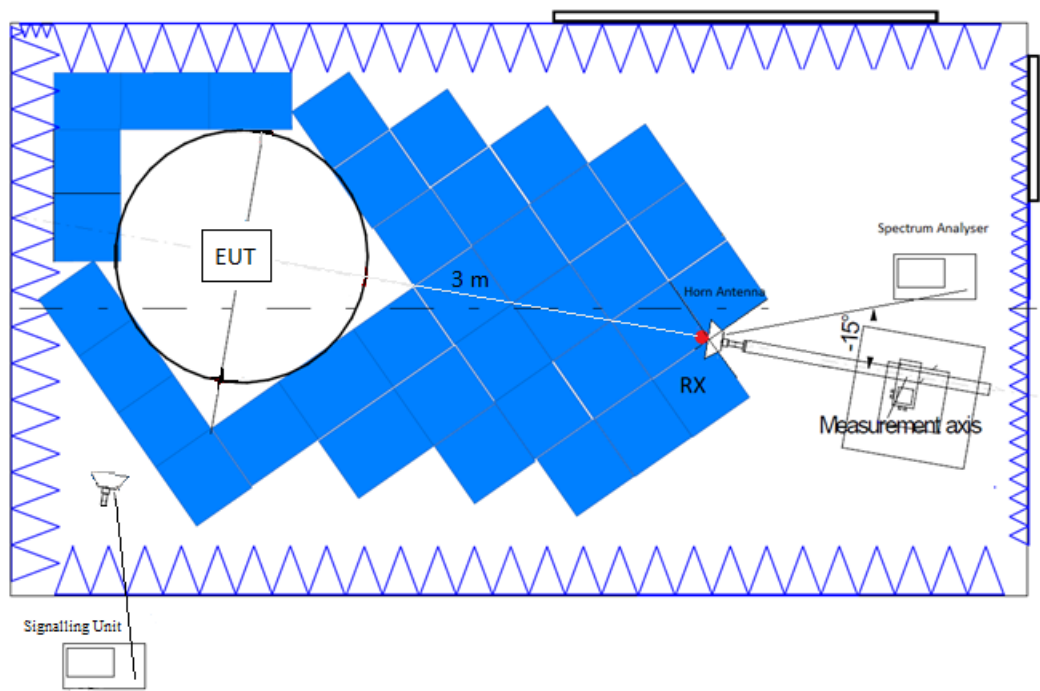
$EIRP \text{ (dBm)} = E \text{ (dB}\mu\text{V/m)} + 20 \log(D) - 104.8$; where D is the measurement distance (in the far field region) in m. $D = 3 \text{ m}$

Test Setup

Radiated measurements below 1 GHz:



Radiated measurements above 1 GHz:



Results

LTE Cat-M1 Band 26:

A preliminary scan determined the BW=3 MHz, QPSK, RB Size=1, RB Offset=0, Narrowband=0 as the worst case. The following results are for this worst-case configuration.

- LOW CHANNEL:

Frequency range 30 MHz - 1 GHz:

No spurious frequencies at less than 20 dB below the limit.

Frequency range 1 - 8.5 GHz:

No spurious frequencies at less than 20 dB below the limit.

- MIDDLE CHANNEL:

Frequency range 30 MHz - 1 GHz:

No spurious frequencies at less than 20 dB below the limit.

Frequency range 1 - 8.5 GHz:

No spurious frequencies at less than 20 dB below the limit.

- HIGH CHANNEL:

Frequency range 30 MHz - 1 GHz:

No spurious frequencies at less than 20 dB below the limit.

Frequency range 1 - 8.5 GHz:

No spurious frequencies at less than 20 dB below the limit.

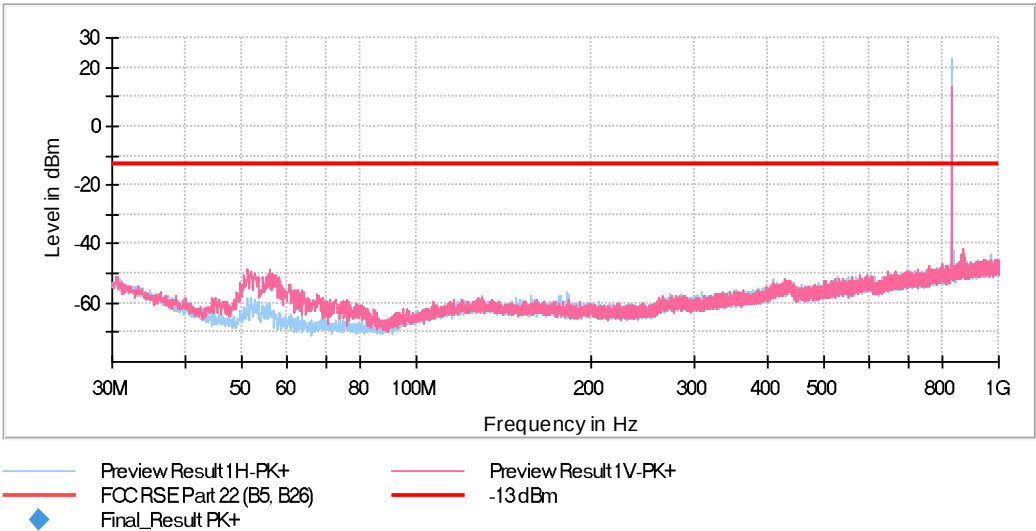
Measurement uncertainty (dB): $<\pm 5.03$ for $f \geq 30$ MHz up to 1 GHz
 $<\pm 4.32$ for $f \geq 1$ GHz up to 8.5 GHz

Verdict: PASS

Subrange	Step Size	Detectors	Bandwidth	Sweep Time	Preamp
30 MHz - 1 GHz	30.312 kHz	PK+	100 kHz	Coupled	0 dB
1 GHz - 8.5 GHz	234.375 kHz	PK+	100 kHz	1 s	0 dB

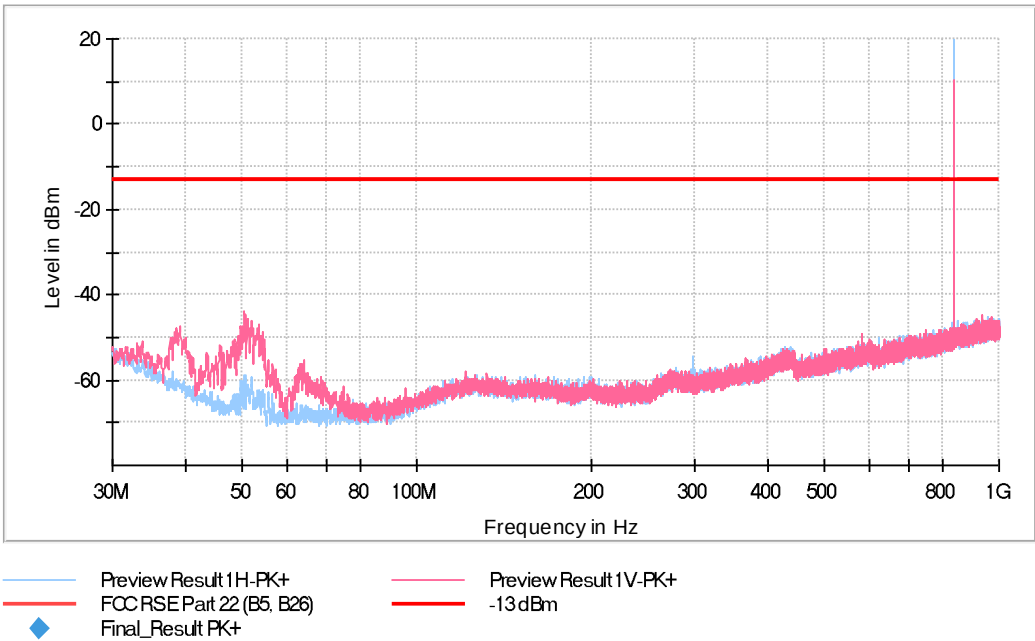
FREQUENCY RANGE 30 MHz - 1 GHz:

- LOW CHANNEL:



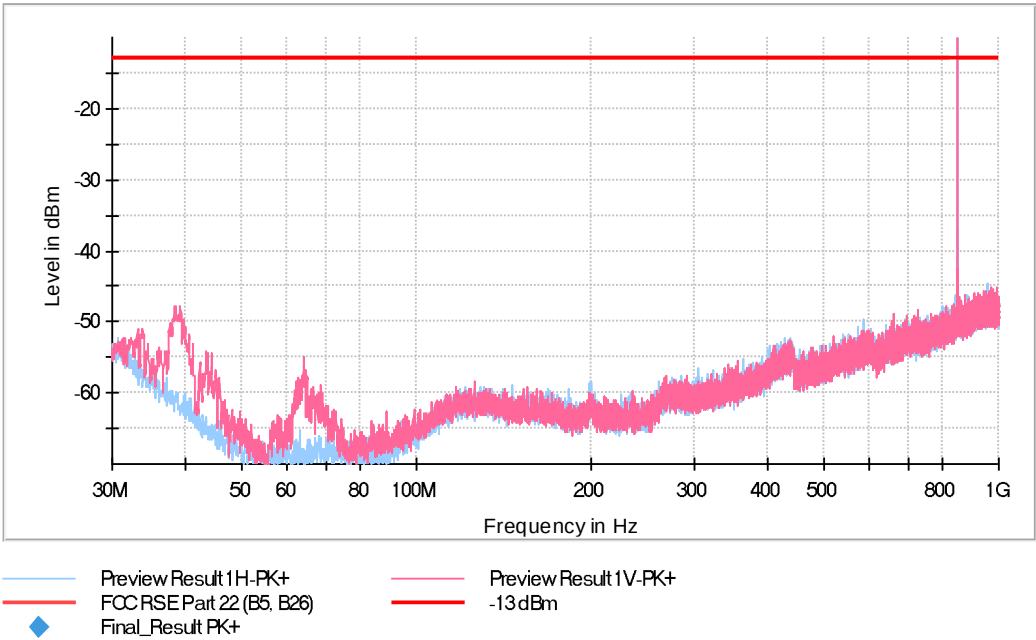
The peak above the limit is the carrier frequency.

- MIDDLE CHANNEL:



The peak above the limit is the carrier frequency.

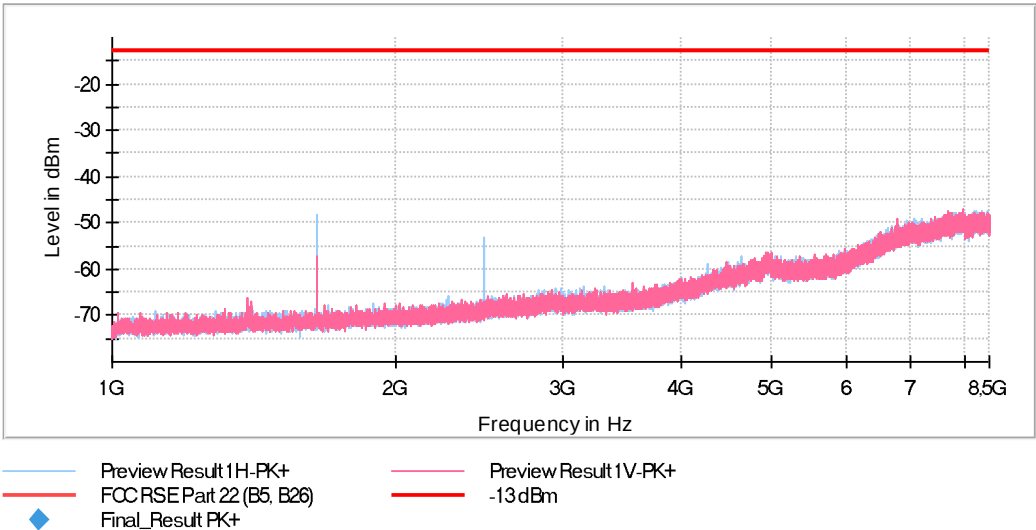
- HIGH CHANNEL:



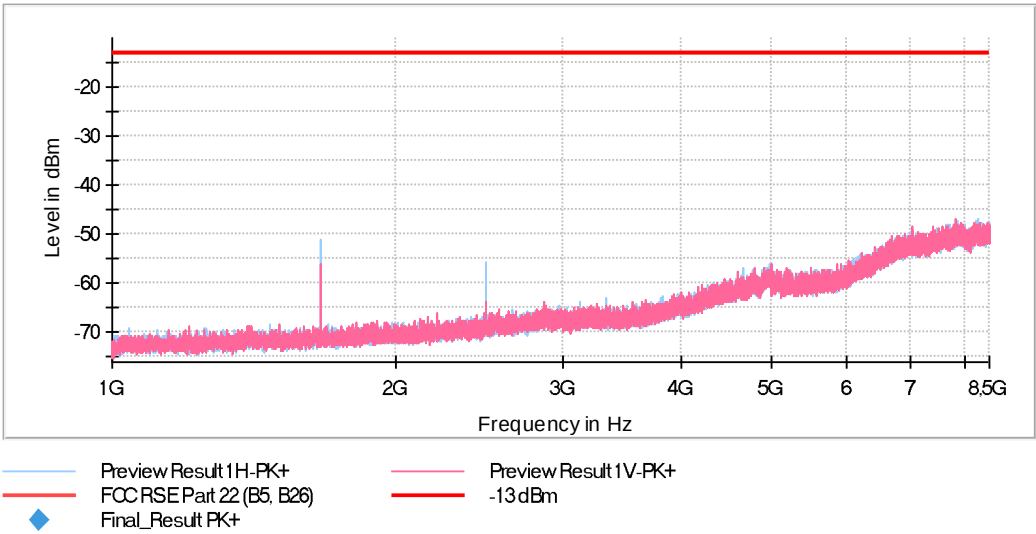
The peak above the limit is the carrier frequency.

FREQUENCY RANGE 1 - 8.5 GHz:

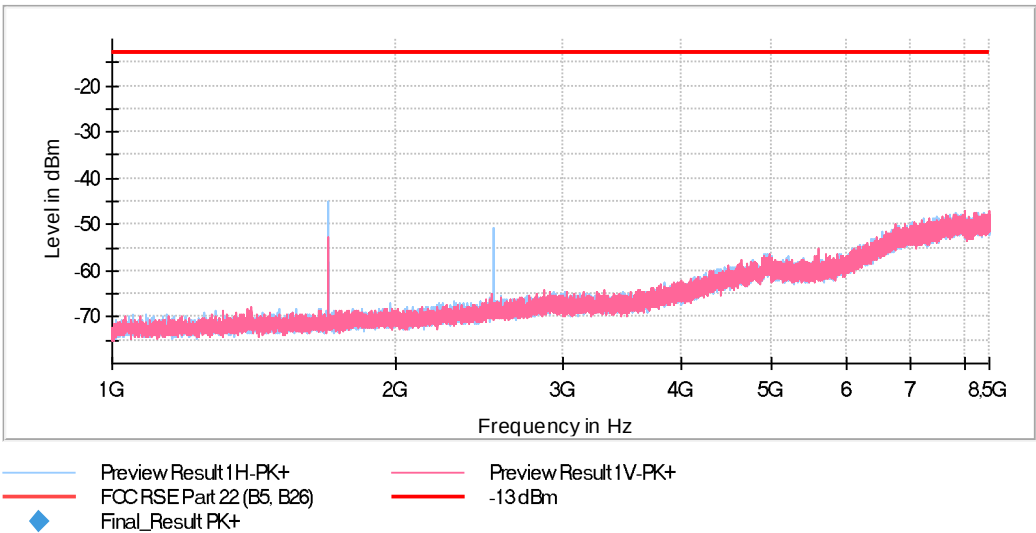
- LOW CHANNEL:



- MIDDLE CHANNEL:



- HIGH CHANNEL:



Appendix B: Test results for FCC 22 / RSS-132: LTE Cat NB1 Bands 5, 26

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TEST CONDITIONS

(*): Data provided by the Applicant.

POWER SUPPLY (*):

Vnormal: 3.8 Vdc.
Vminimum: 3 Vdc
Vmaximum: 5.5 Vdc
Type of Power Supply: Internal DC.

ANTENNA (*):

Bands	Gain (dBi)	Type
LTE Cat NB1 Band 5	+2.7	SMD
LTE Cat NB1 Band 26	+2.7	SMD

TEST FREQUENCIES:

LTE Cat NB1 Band 5. Pi/2-BPSK, Pi/4-QPSK, QPSK modulations:

Channel. Number (Frequency, MHz)		
Low	Middle	High
20402 (824.20)*	20525 (836.50)	20648 (848.80)*
*The outermost channel which is in compliance with Block edge testing.		

NOTE: The 824-849 MHz sub-band of the LTE Cat-NB1 Band 5 is completely included in the LTE Cat-NB1 Band 26, so the LTE Cat-M1 Band 26 channels were tested to give conformity to the assigned block.

LTE Cat NB1 Band 26. Pi/2-BPSK, Pi/4-QPSK, QPSK modulations:

Channel. Number (Frequency, MHz)		
Low	Middle	High
26792 (824.2)*	26915 (836.5)	27038 (848.8)*
*The outermost channel which is in compliance with Block edge testing.		

RF Output Power

Limits

* FCC §2.1046 and FCC §22.913. The Effective Radiated Power (E.R.P) of mobile transmitter and auxiliary test transmitter must not exceed 7 Watts (38.45 dBm E.R.P.).

* RSS-132 Issue 4. Clause 5.4. The transmitter output power shall be measured in terms of average power. The equivalent radiated power (e.r.p.) shall not exceed 7 watts for mobile equipment and 3 watts for portable equipment.

The effective isotropic radiated power (e.i.r.p.) shall not exceed the limits specified in SRSP-503 for base station equipment.

In addition, the peak-to-average power ratio (PAPR) of the transmitter shall not exceed 13 dB for more than 0.1% of the time using a signal corresponding to the highest PAPR during periods of continuous transmission.

In addition, the peak-to-average power ratio (PAPR) of the transmitter shall not exceed 13 dB for more than 0.1% of the time using a signal corresponding to the High PAPR during periods of continuous transmission.

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 peak-to-average power ratio (PAPR) is measured using an attenuator, power splitter and spectrum analyser with a Complementary Cumulative Distribution Function implemented.

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:

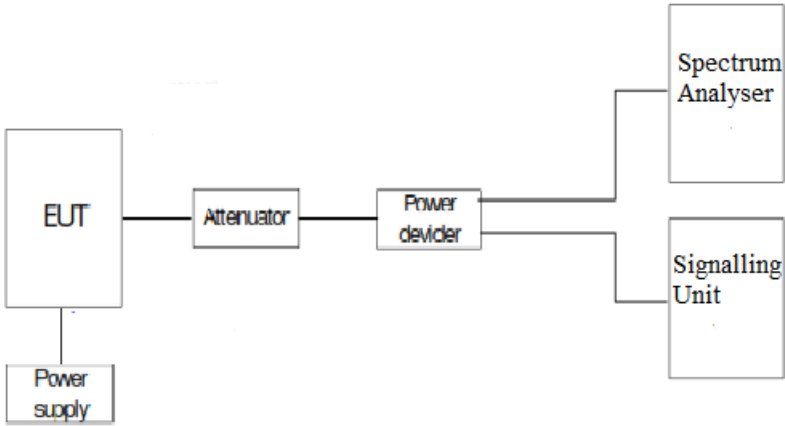
$$\text{E.R.P.} = \text{E.I.R.P.} - 2.15 \text{ dB}$$

Test Setup

1. CONDUCTED AVERAGE POWER:



2. PEAK-TO-AVERAGE POWER RATIO (PAPR) and Conducted Average power:



Results

1. CONDUCTED AVERAGE POWER

LTE Cat NB1 Band 26:

Preliminary measurements determined the worst case of RF Power is Middle Channel, Pi/4-QPSK, BW=15 kHz, Tone Number=1, Tone Offset=0, MSC/TBS=3.

CHANNEL	FREQUENCY (MHz)	MODULATION	BW	Tone Number	Tone Offset (Start SubCarrier)	MCS / TBS	AVERAGE POWER (dBm)
Low 26792	824.2 MHz	Pi/2-BPSK	3.75 kHz	1	0	0	22.3
				1	47	0	22.34
			15 kHz	1	0	0	22.33
				1	11	0	22.34
		Pi/4-QPSK	3.75 kHz	1	0	3	22.41
				1	47	3	22.4
			15 kHz	1	0	3	22.4
				1	11	3	22.38
		QPSK	15 kHz	3	0	5	22.28
				3	6	5	22.34
				6	0	5	21.51
				6	6	5	21.43
Middle 26915	836.50 MHz	Pi/2-BPSK	3.75 kHz	1	0	0	22.35
				1	47	0	22.32
			15 kHz	1	0	0	22.39
				1	11	0	22.41
		Pi/4-QPSK	3.75 kHz	1	0	3	22.39
				1	47	3	22.43
			15 kHz	1	0	3	22.44
				1	11	3	22.43
		QPSK	15 kHz	3	0	5	22.3
				3	6	5	22.32
				6	0	5	22.41
				6	6	5	21.47
High 27038	848.8 MHz	Pi/2-BPSK	3.75 kHz	1	0	0	22.39
				1	47	0	22.32
			15 kHz	1	0	0	22.41
				1	11	0	22.42
		Pi/4-QPSK	3.75 kHz	1	0	3	22.41
				1	47	3	22.31
			15 kHz	1	0	3	22.39
				1	11	3	22.4
		QPSK	15 kHz	3	0	5	22.28
				3	6	5	22.42
				6	0	5	21.5
				6	6	5	21.44
				12	0	5	20.38

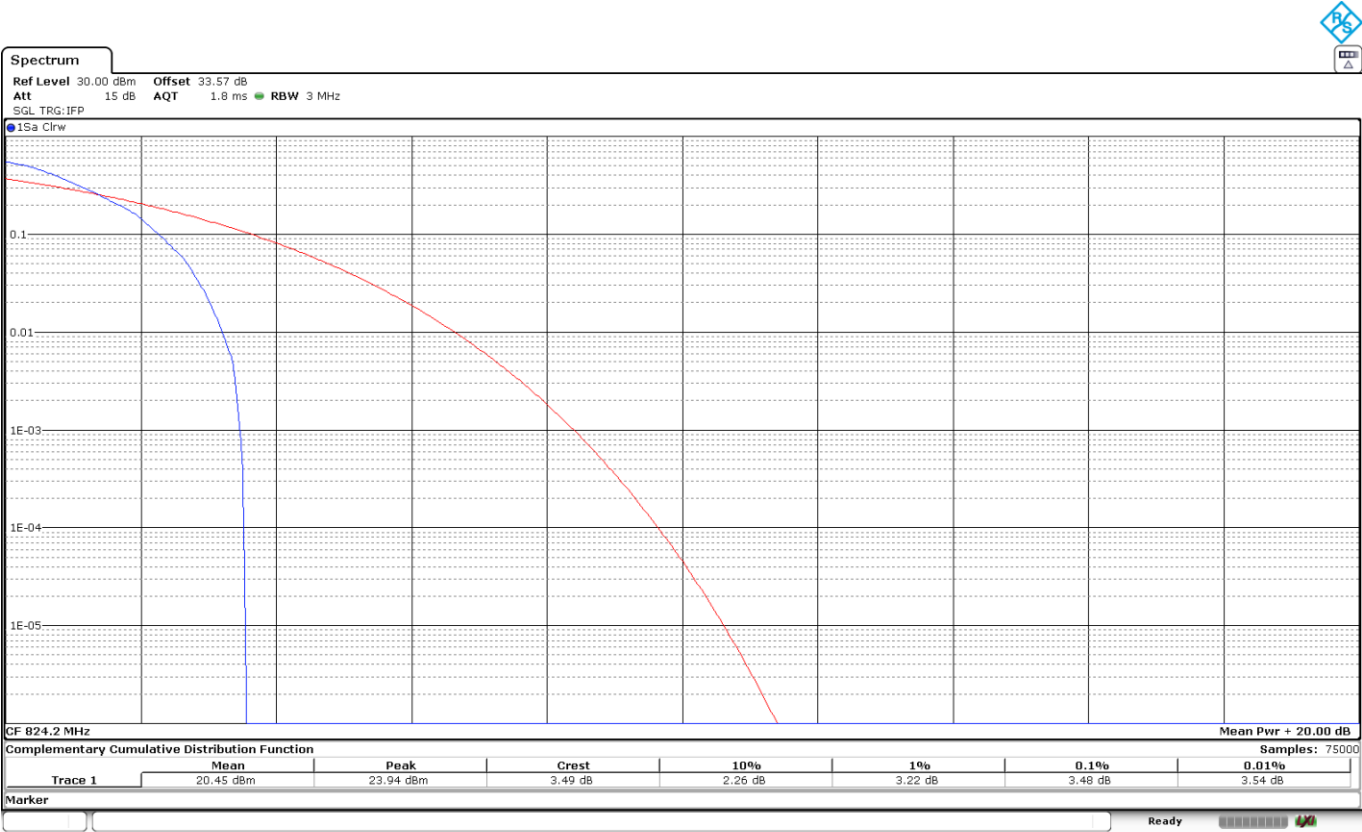
MAX POWER	COND. POWER AVG (dBm)	ANTENNA GAIN (dBi)	RAD. POWER AVG EIRP (dBm)	RAD. POWER AVG ERP (dBm)
LOW	22.41	2.7	25.11	22.96
MIDDLE	22.44	2.7	25.14	22.99
HIGH	22.42	2.7	25.12	22.97
MAX:	22.44		25.14	22.99

2. PEAK-TO-AVERAGE POWER RATIO (PAPR)

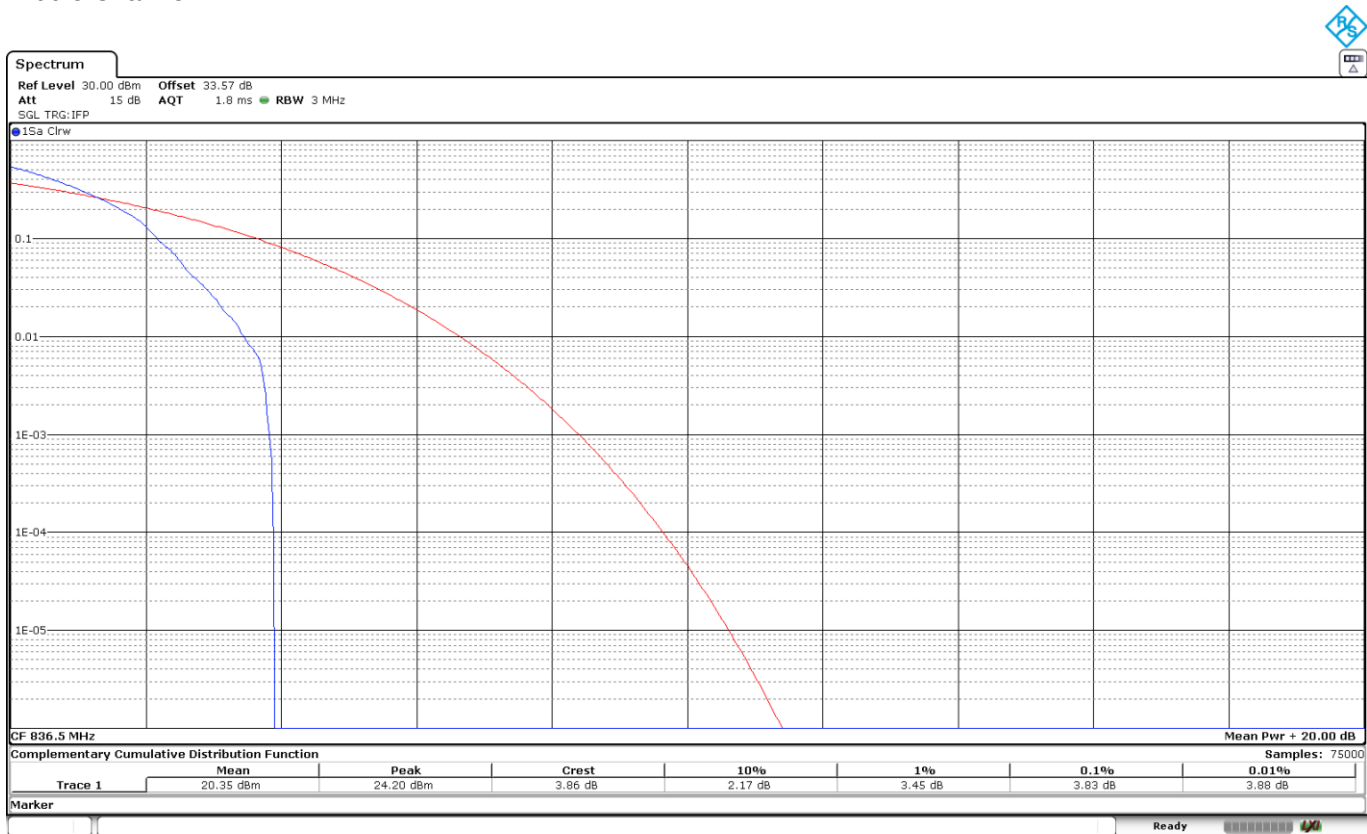
LTE Cat NB1 Band 26:

Preliminary measurements determined the worst-case of PAPR is High Channel, QPSK, BW=15 kHz, Tone Number=12, Tone Offset=0, MSC/TBS=5.

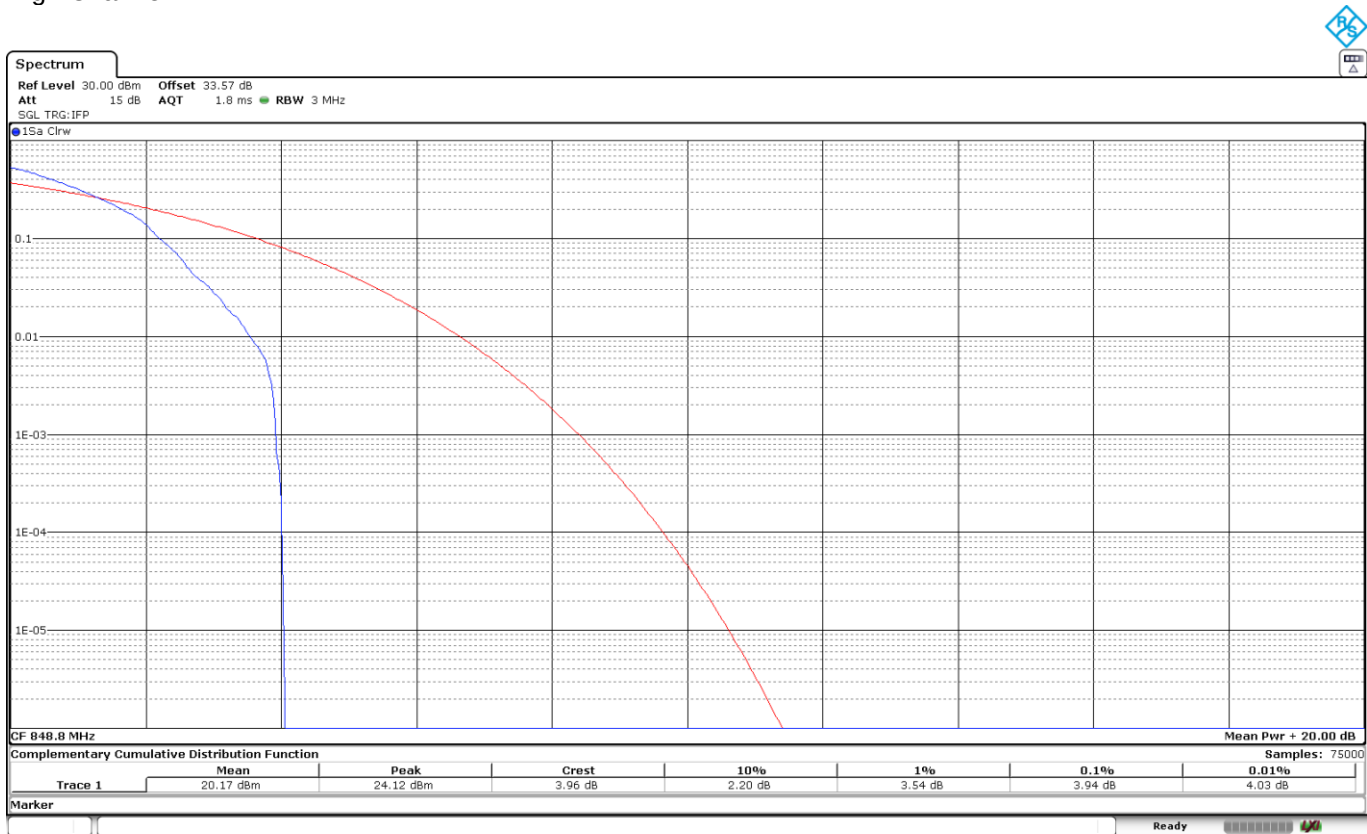
Low Channel:



Middle Channel:



High Channel:



16QAM	Low	Middle	High
PAPR (dB)	3.48	3.83	3.94

Measurement uncertainty (dB) <±1.11

Verdict

Pass

Frequency Stability

Limits

- * FCC §2.1055 and §22.355. ± 2.5 ppm for mobile stations operating in the range 821 to 896 MHz.
- * RSS-132 Issue 4. Clause 5.3. The frequency stability shall be sufficient to ensure that the occupied bandwidth stays within each of the sub-bands when tested at 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 -40°C to $+85^{\circ}\text{C}$. The EUT was placed inside a climatic chamber and the temperature was raised hourly in 10°C steps from -40°C up to $+85^{\circ}\text{C}$.

The supply voltage was varied between 85% and 115% of nominal voltage.

Temperature and voltage range of testing has been extended to the maximum and minimum values declared by customer.

The EUT was set in "Radio Resource Control (RRC) mode" on 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.

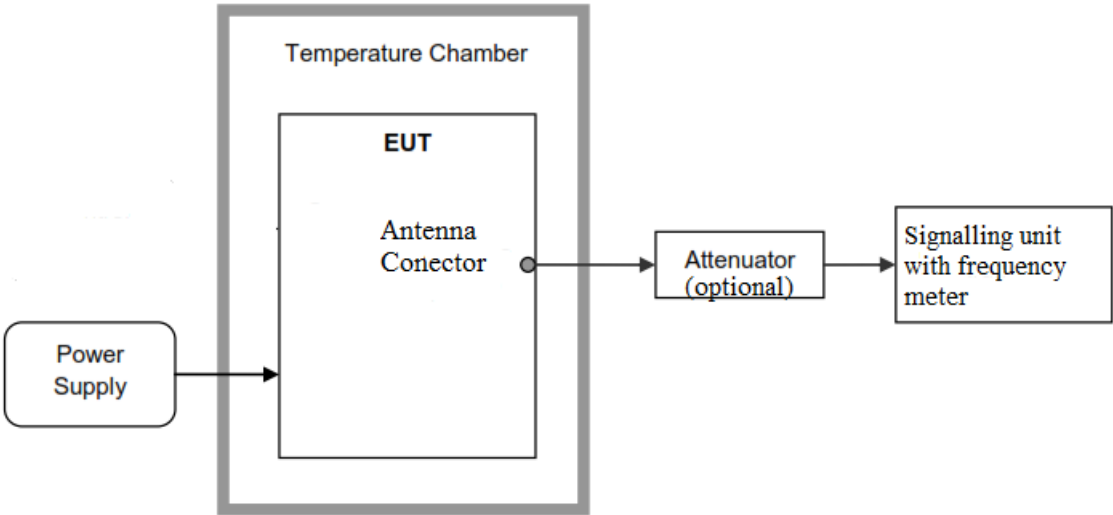
The worst-case LTE mode for conducted power was used for the test.

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 Low and High channels 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.

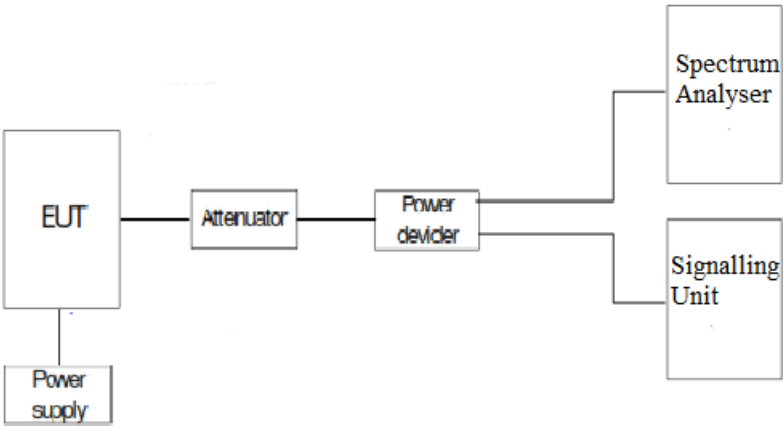
The reference point measurements were made at the RF output terminals of the EUT using an attenuator, power splitter and spectrum analyser. The EUT was controlled via the Universal Radio Communication tester R&S CMW500 selecting maximum transmission power of the EUT and different modes of modulation.

Test Setup

Frequency tolerance:



Reference points f_L and f_H :



Results

LTE Cat NB1 Band 26:

The worst case modulation in terms of Frequency Stability is QPSK, BW=15 kHz, Tone Number=3, Tone Offset=6, MSC/TBS=5.

1. Frequency Tolerance:

- Frequency Stability over Temperature Variations:

Temperature (°C)	Frequency Error (Hz)	Frequency Error (ppm)
+85	-10.81	-0.012922893
+80	-1.77	-0.002115959
+70	0.93	0.001111775
+60	18.01	0.021530185
+50	-18.64	-0.022283323
+40	-8.88	-0.01061566
+30	-20.53	-0.024542738
+20	-10.04	-0.012002391
+10	-6.44	-0.007698745
0	-14.39	-0.01720263
-10	-7.55	-0.009025702
-20	1.87	0.002235505
-30	-8.75	-0.010460251
-40	24.65	0.029468022

- Frequency Stability over Voltage Variations.

Supply voltage	Voltage (V)	Frequency Error (Hz)	Frequency Error (ppm)
Vmax	5.5	-7.32	-0.008750747
Vmin	3.0	-6.88	-0.008224746

2. Reference Frequency Points f_L and f_H:

The worst-case frequency offsets added or subtracted per band and bandwidth:

f _L (MHz)	824.0214
f _H (MHz)	848.9375

The reference frequency points f_L and f_H stay within the authorized blocks for the band above.

Measurement uncertainty (Hz) <± 249.55

Verdict: PASS

Modulation Characteristics

Limits

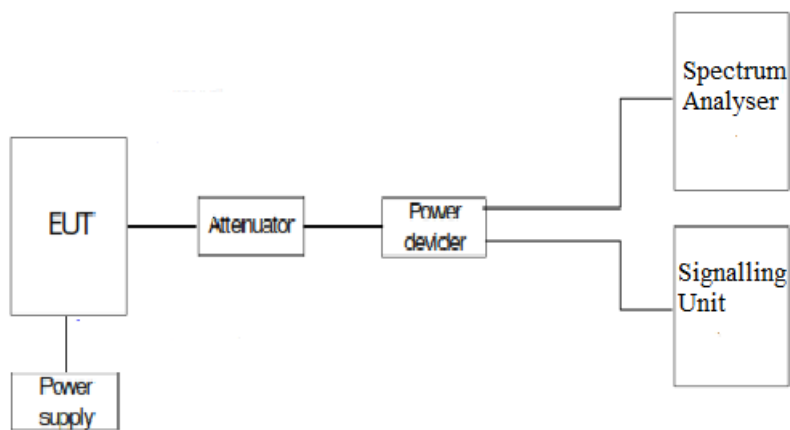
FCC §2.1047.

RSS-132. Clause 5.2: Equipment certified under this standard shall use digital modulation.

Method

For LTE NB1 the EUT operates with $\pi/2$ -BPSK, $\pi/4$ -QPSK, QPSK modulations in which the information is digitized and coded into a bit stream.

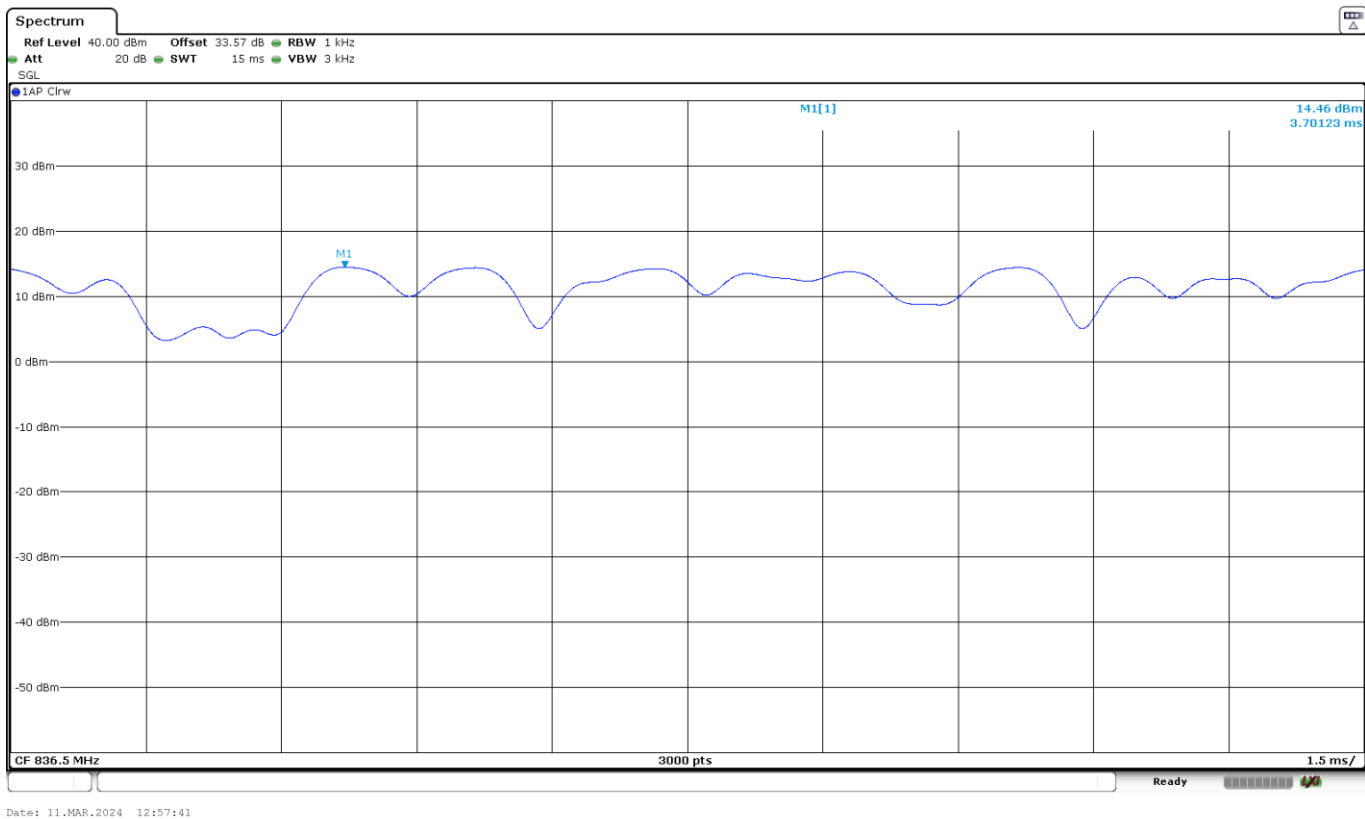
Test Setup



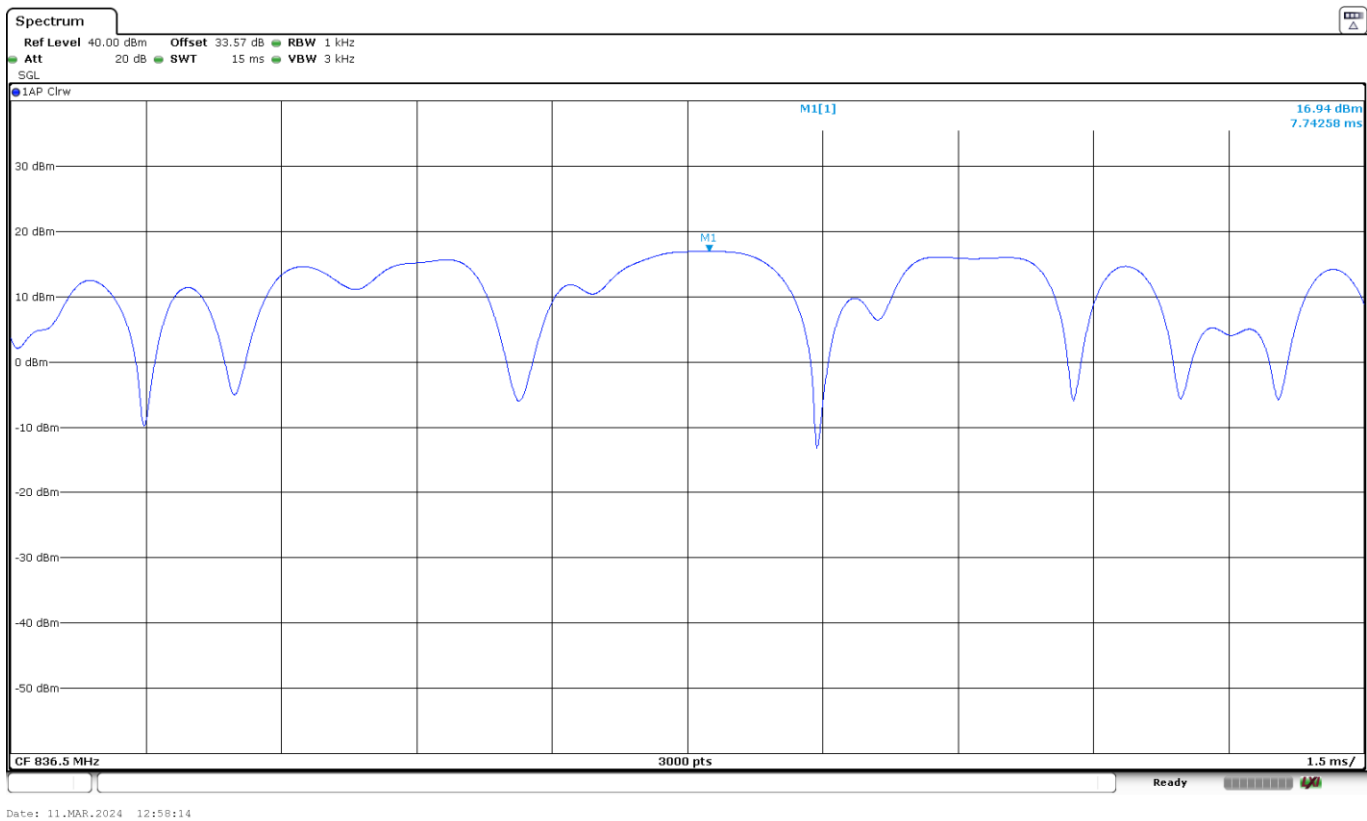
Results

The following plots show the modulation schemes in the EUT.

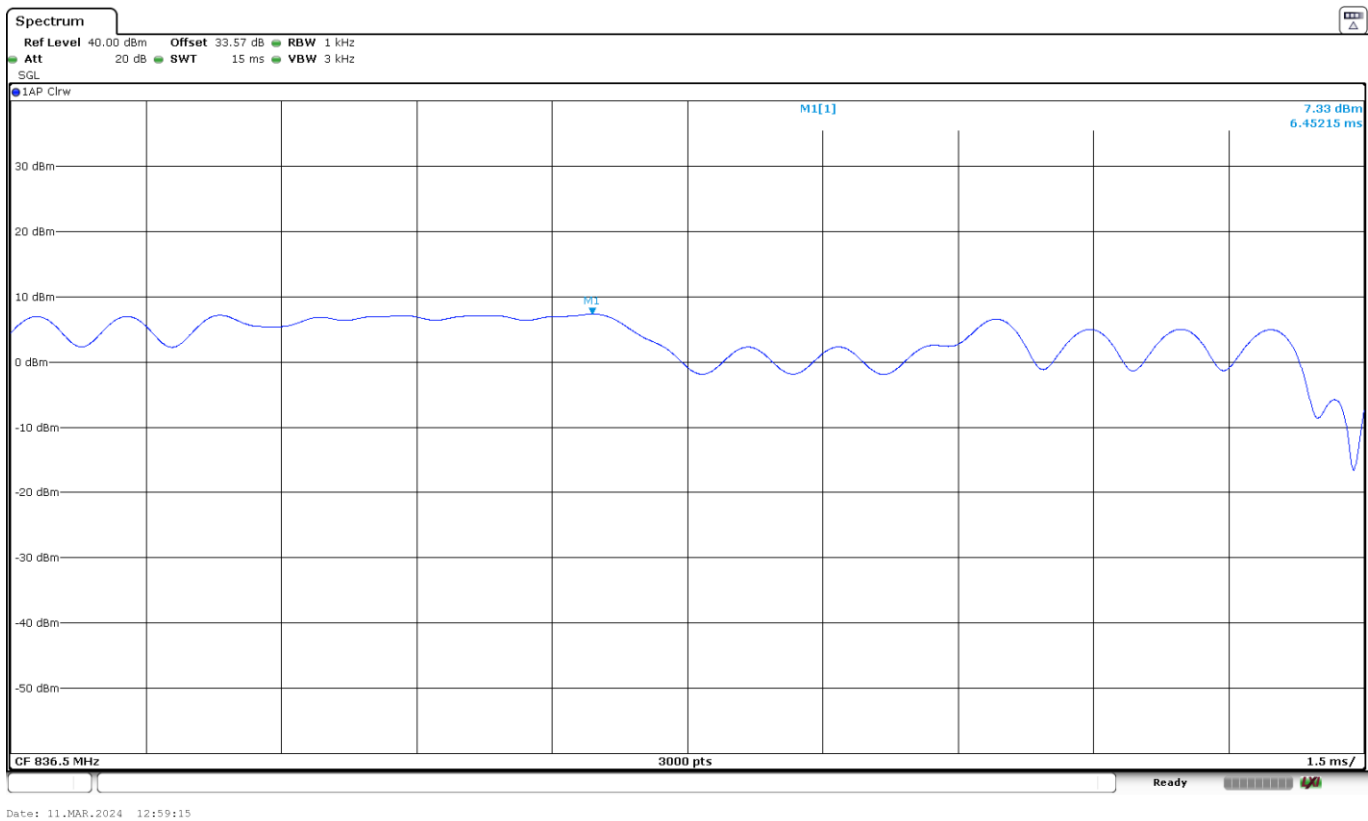
LTE Cat NB1 Band 26: Pi/2-BPSK. Middle Channel. BW=3.75 kHz. Tone Number=1. Tone Offset=0. MSC/TBS=0.



LTE Cat NB1 Band 26: Pi/4-QPSK. Middle Channel. BW=3.75 kHz. Tone Number=1. Tone Offset=0. MSC/TBS=3.



LTE Cat NB1 Band 26: QPSK. Middle Channel. BW=15 kHz. Tone Number=3. Tone Offset=0. MSC/TBS=5.



Occupied Bandwidth

Limits

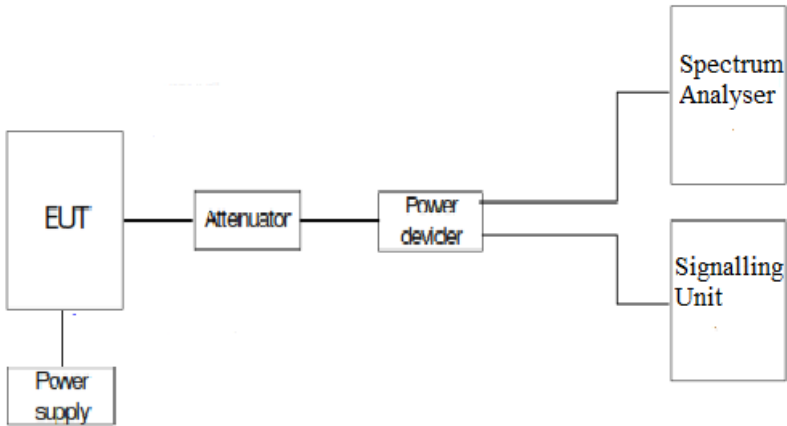
FCC §2.1049. Measurements required: Occupied bandwidth.

RSS-Gen, Clause 6.7.

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

The worst case per modulation is:

LTE Cat NB1 Band 26:

LTE Cat NB1 Band 26. Pi/2-BPSK. BW=3.75 kHz. Tone Number=1. Tone Offset=23. MSC/TBS=0.

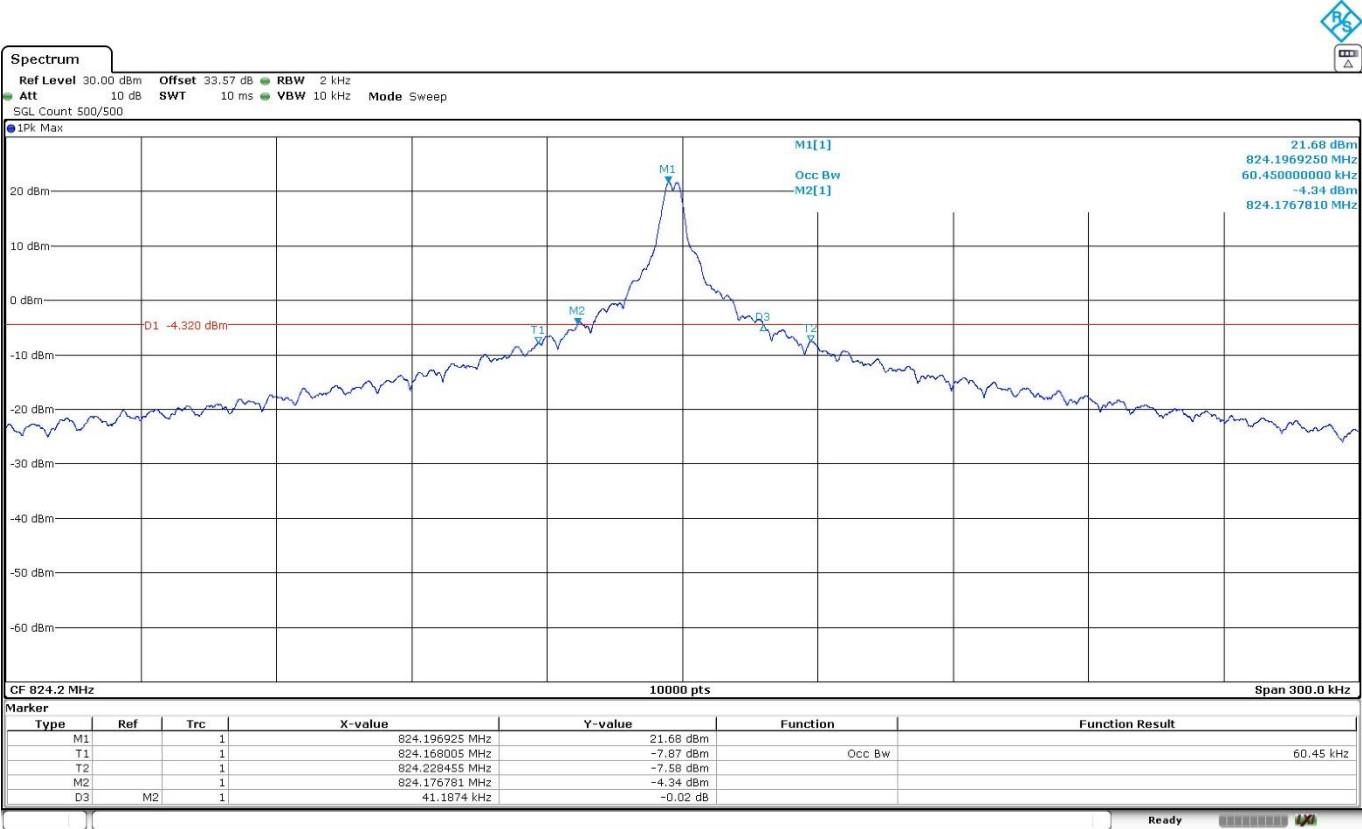
	Low Channel	Middle Channel	High Channel
99% Occupied Bandwidth (kHz)	60.45000	60.39000	61.02000
-26 dBc Bandwidth (kHz)	41.18740	41.06450	41.08730
Measurement uncertainty (kHz)	<±3.75		

LTE Cat NB1 Band 26. Pi/4-QPSK. BW=3.75 kHz. Tone Number=1. Tone Offset=23. MSC/TBS=3.

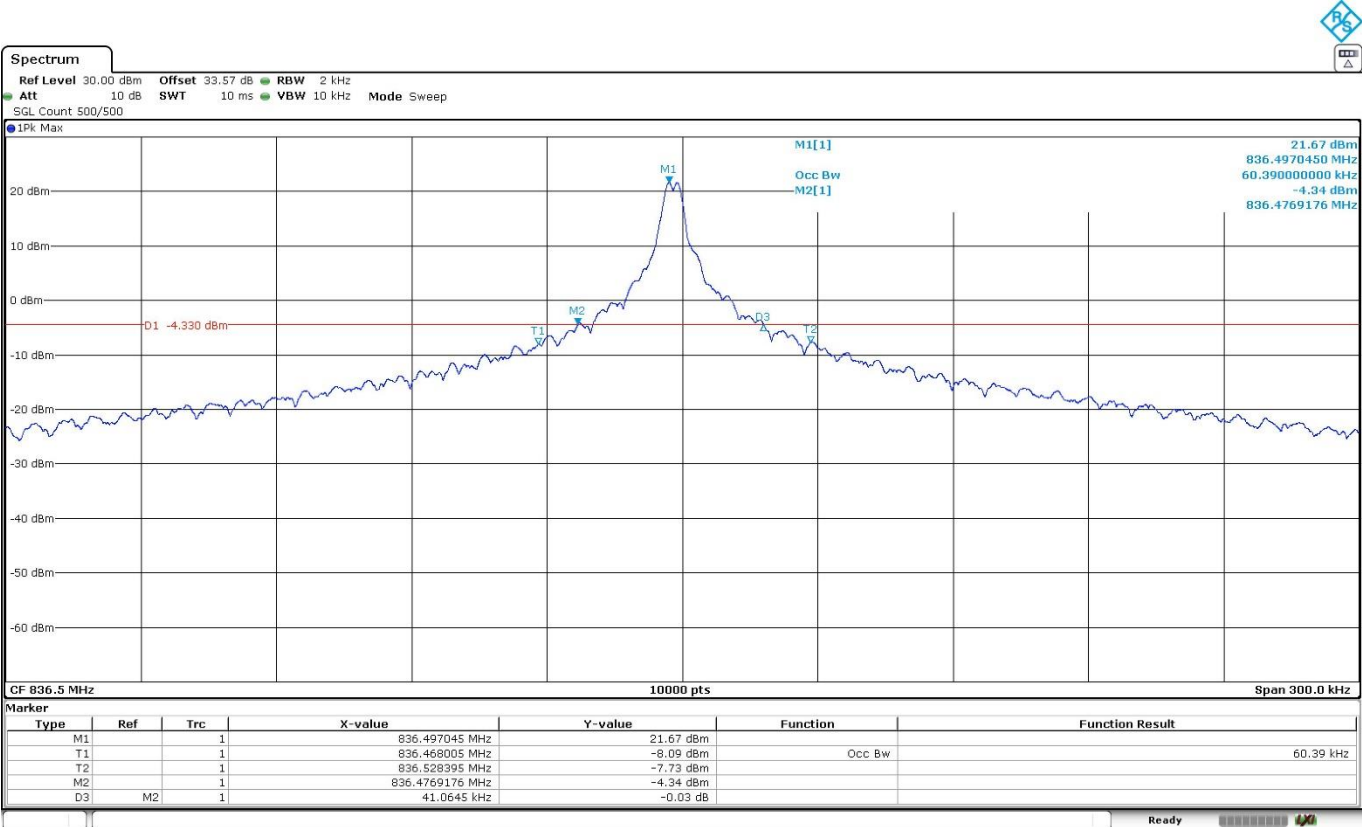
	Low Channel	Middle Channel	High Channel
99% Occupied Bandwidth (kHz)	64.68000	64.20000	65.13000
-26 dBc Bandwidth (kHz)	41.78700	41.92510	41.92730
Measurement uncertainty (kHz)	<±3.75		

LTE Cat NB1 Band 26. Pi/2-BPSK. BW=3.75 kHz. Tone Number=1. Tone Offset=23. MSC/TBS=0.

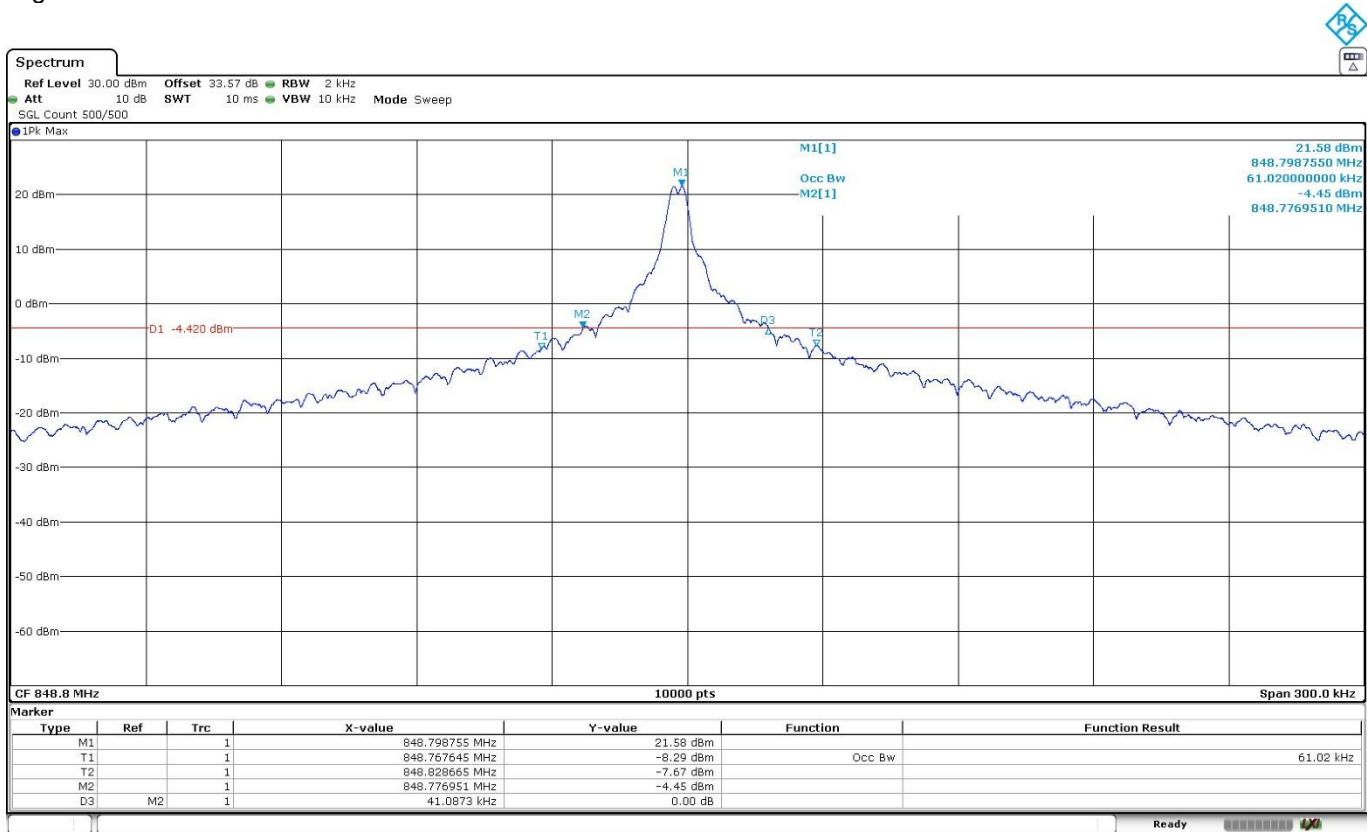
Low Channel:



Middle Channel:

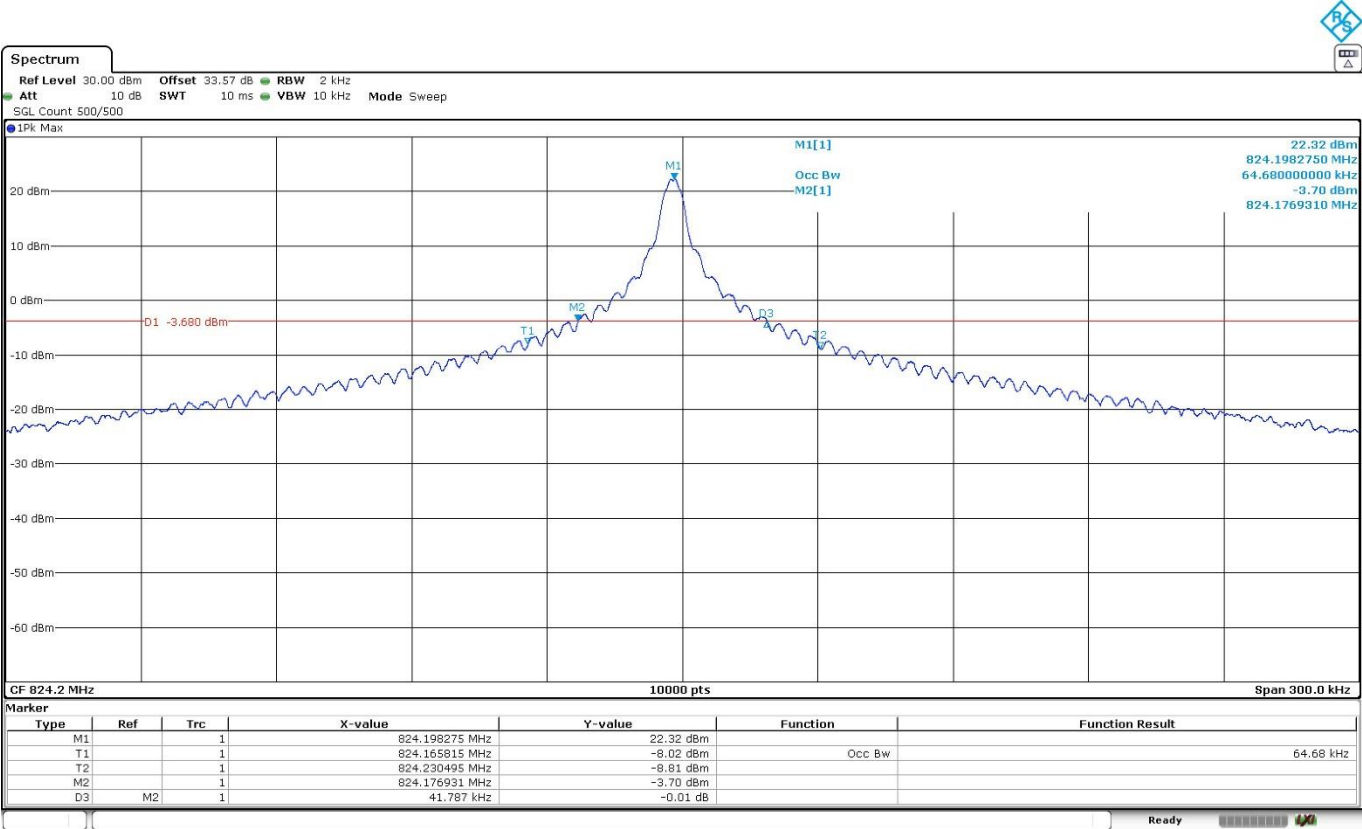


High Channel:

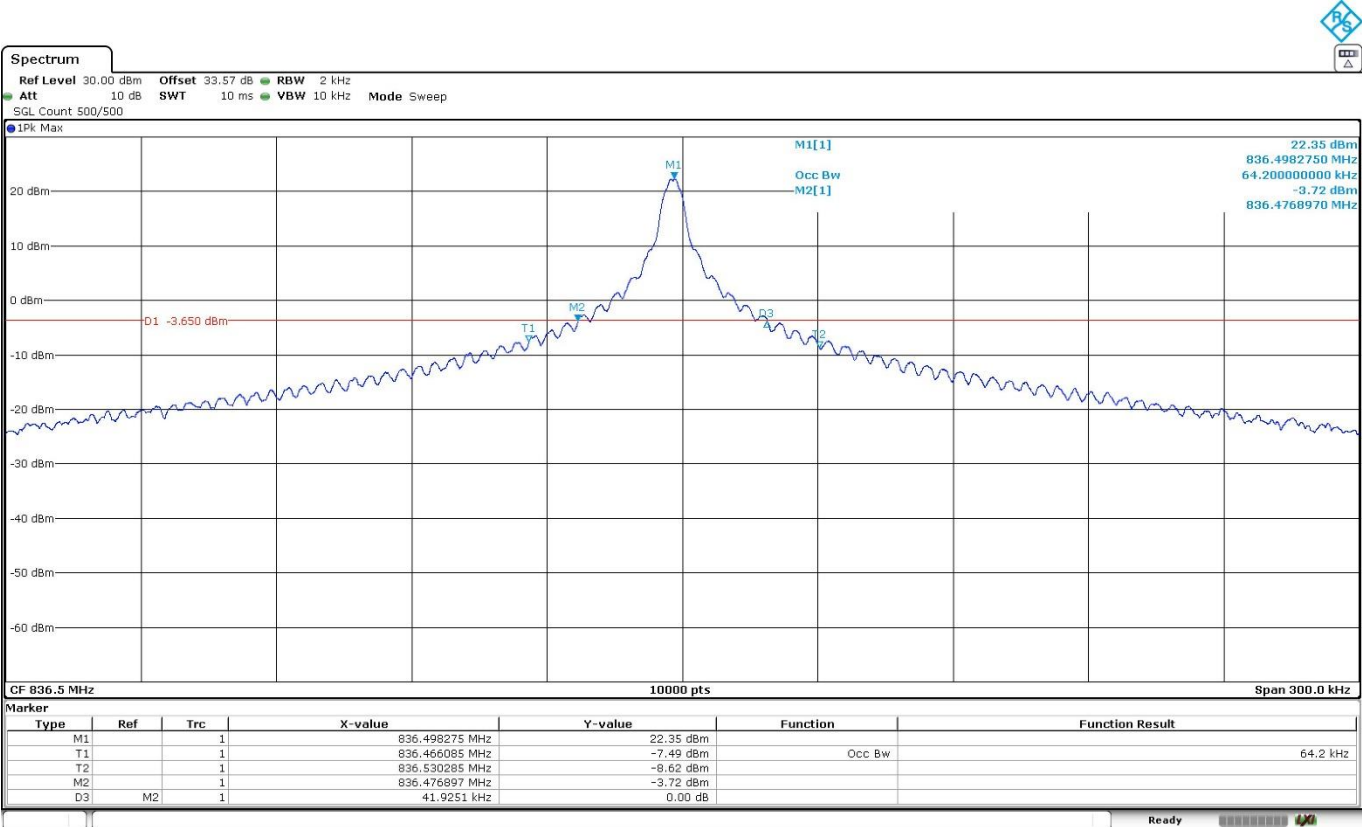


LTE Cat NB1 Band 26. Pi/4-QPSK. BW=3.75 kHz. Tone Number=1. Tone Offset=23. MSC/TBS=3.

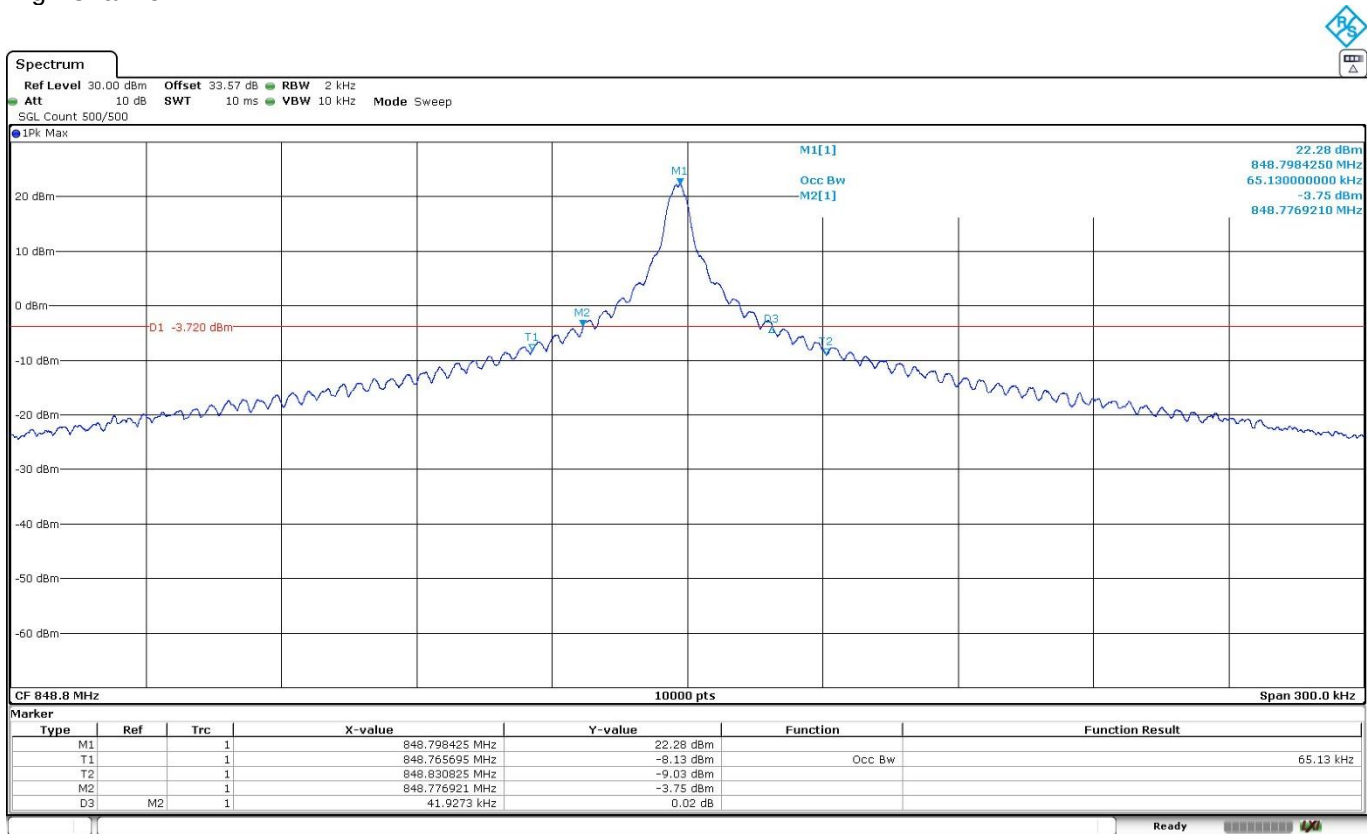
Low Channel:



Middle Channel:



High Channel:



LTE Cat NB1 Band 26. Pi/2-BPSK. BW=15 kHz. Tone Number=1. Tone Offset=5. MSC/TBS=0.

	Low Channel	Middle Channel	High Channel
99% Occupied Bandwidth (kHz)	126.00000	125.61000	124.71000
-26 dBc Bandwidth (kHz)	126.70230	120.12840	126.75670
Measurement uncertainty (kHz)	<±3.75		

LTE Cat NB1 Band 26. Pi/4-QPSK. BW=15 kHz. Tone Number=1. Tone Offset=5. MSC/TBS=3.

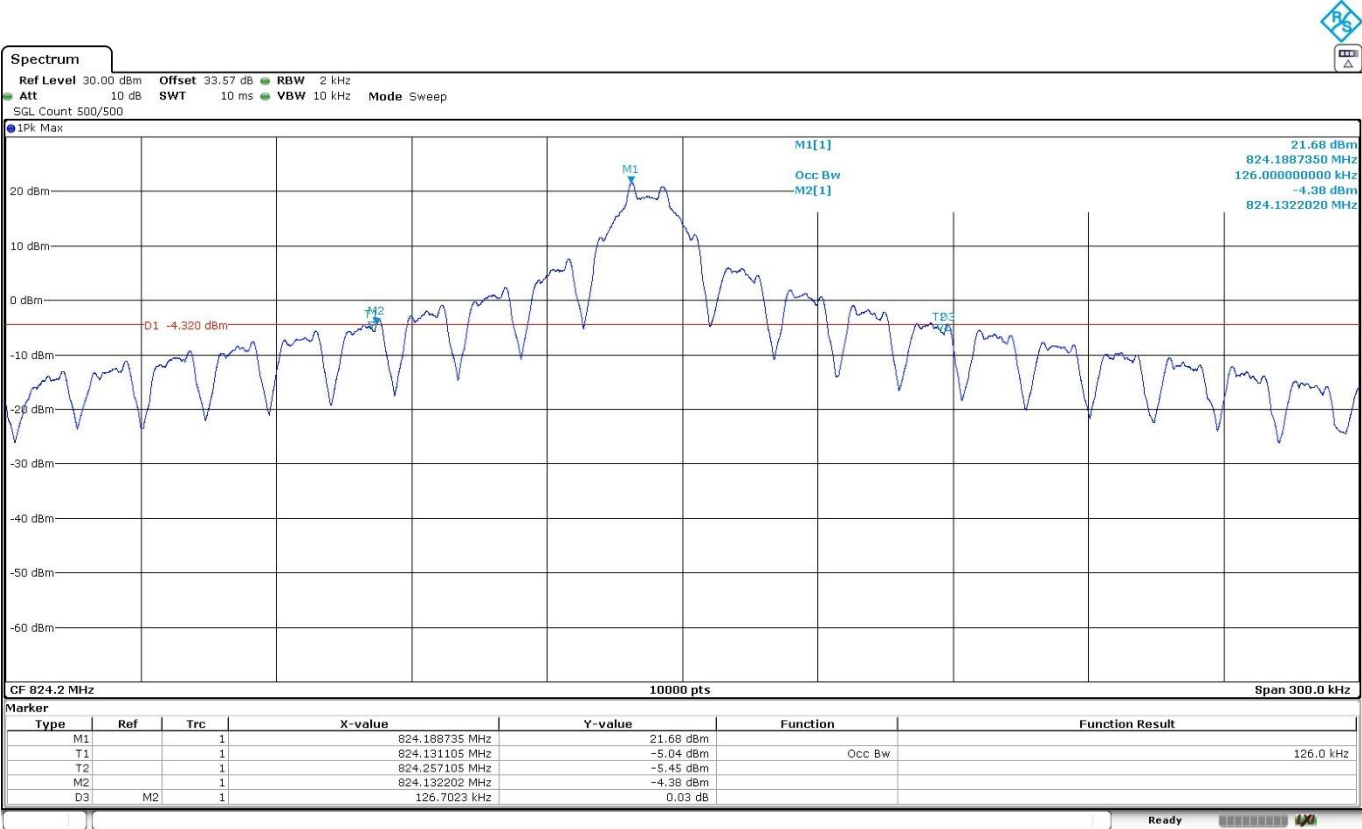
	Low Channel	Middle Channel	High Channel
99% Occupied Bandwidth (kHz)	126.48000	126.90000	125.97000
-26 dBc Bandwidth (kHz)	155.12170	145.11300	130.50670
Measurement uncertainty (kHz)	<±3.75		

LTE Cat NB1 Band 26. QPSK. BW=15 kHz. Tone Number=12. Tone Offset=0. MSC/TBS=5.

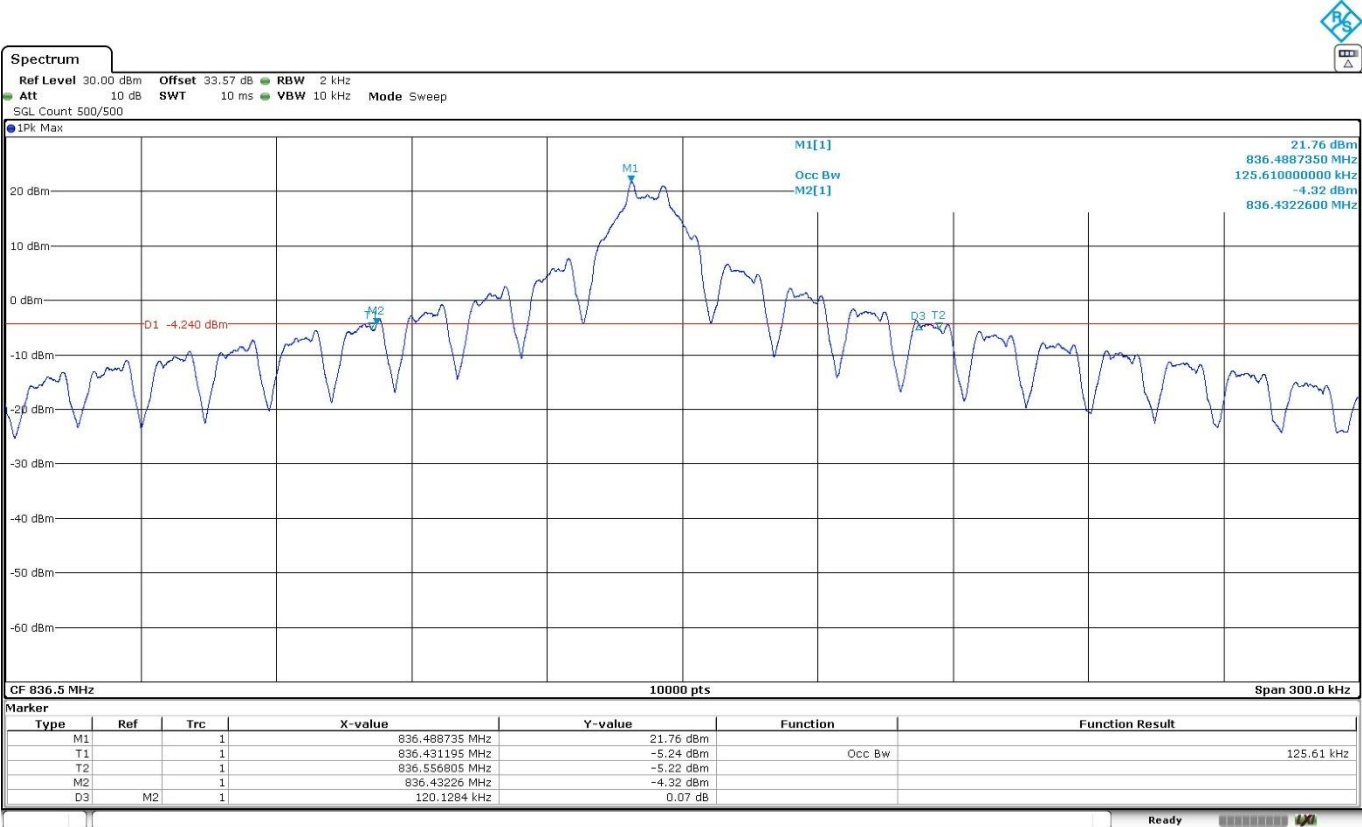
	Low Channel	Middle Channel	High Channel
99% Occupied Bandwidth (kHz)	188.30000	187.20000	188.60000
-26 dBc Bandwidth (kHz)	308.38320	290.87140	289.78600
Measurement uncertainty (kHz)	<±3.75		

LTE Cat NB1 Band 26. Pi/2-BPSK. BW=15 kHz. Tone Number=1. Tone Offset=5. MSC/TBS=0.

Low Channel:



Middle Channel:



High Channel:

