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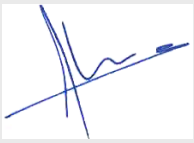
Test report No:
NIE: 58741RAN.002

Assessment report
RF EXPOSURE REPORT ACCORDING TO
FCC 47 CFR Part 2.1091
ISED RSS-102 Issue 5:2015

Identification of item tested	IOT Module
Trademark	nRF91
Model and /or type reference	nRF9160
Other identification of the product	IMEI TAC: 35265610 FCC ID: 2ANPO00NRF9160 IC: 24529-NRF9160 HW Version: DEV2.1.6 SW Version: mfw-m1_nRF9160_0.6.7.31
Features	LTE Cat-M1, LTE-NB1, GPS
Manufacturer	NORDIC SEMICONDUCTOR ASA P.O. Box 436, 0213 Oslo, Norway
Test method requested, standard	FCC 47 CFR Part 2.1091 Radiofrequency radiation exposure evaluation: mobile devices. ISED RSS-102 Issue 5 (2015-03) – Radio Frequency Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands)
Summary	IN COMPLIANCE
Approved by (name / position & signature)	Miguel Lacave Antennas Lab Manager  MIGUEL LACAVE GARCÍA 2018.11.28 13:00:57 +01'00'
Date of issue	2018-11-28
Report template No	FAN36_00

Index

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Identification of the client

NORDIC SEMICONDUCTOR ASA

P.O. Box 436, 0213 Oslo, Norway

General description of the device under evaluation

The device under evaluation consists of an IOT Module that has Application CPU, LTE Cat-M1 Radio and GPS Receiver.

The device under evaluation consists of a module which will be installed into host devices that will be used at a distance greater than 20 cm from the user. In order to perform the assessment a conservative separation distance of 20 cm has been used for the calculations.

The maximum output power declared by the manufacturer for each supported band is:

Band (MHz)	Technology	Band	Max. RF output power (dBm)	Tune-up tolerance (dB)	Max. output power, including tune-up (dBm)
1700	LTE Cat-M1	4	23.0	+1/-3	24.0
750	LTE Cat-M1	13	23.0	+1/-3	24.0

Table 1: Equipment specifications

Assessment summary

Radiofrequency radiation exposure limits				
FCC 47 CFR § 2.1091 & ISED RSS-102 Issue 5 (2015-03)				
Assessment	**Band (MHz)**	**Technology**	**Band**	**VERDICT (Pass/Fail)**
1	1700	LTE Cat-M1	4	Pass
2	750	LTE Cat-M1	13	Pass

Table 2: Assessment summary

Appendix A: FCC RF Exposure

FCC RF Exposure evaluation for mobile devices

Devices operating in standalone mobile device exposure conditions may contain a single transmitter or multiple transmitters that do not transmit simultaneously. A minimum test separation distance ≥ 20 cm is required between the antenna and radiating structures of the device and nearby persons to apply mobile device exposure limits. The distance must be at least 20 cm and fully supported by the operating and installation configurations of the transmitter and its antenna(s), according to the source-based time-averaged maximum power requirements of § 2.1091(d)(2). In cases where cable losses or other attenuations are applied to determine compliance, the most conservative operating configurations and exposure conditions must be evaluated. The minimum test separation distance required for a device to comply with mobile device exposure conditions must be clearly identified in the installation and operating instructions, for all installation and exposure conditions, to enable users and installers to comply with RF exposure requirements. For mobile devices that have the potential to operate in portable device exposure conditions, similar to the configurations described in § 2.1091(d)(4), a KDB inquiry is required to determine the SAR test requirements for demonstrating compliance.

When a device qualifies for the categorical exclusion provision of § 2.1091(c), the minimum test separation distance may be estimated, when applicable, by simple calculations according to plane-wave equivalent conditions, to ensure the transmitter and its antenna(s) can operate in manners that meet or exceed the estimated distance. The source-based time-averaged maximum radiated power, according to the maximum antenna gain, must be applied to calculate the field strength and power density required to establish the minimum test separation distance. When the estimated test separation distance becomes overly conservative and does not support compliance, MPE measurement or computational modeling may be used to determine the required minimum separation distance.

According to §1.1310 Radiofrequency radiation exposure limits, paragraph (e), the limits for Maximum Permissible Exposure (MPE) to radiofrequency electromagnetic fields are:

TABLE 1—LIMITS FOR MAXIMUM PERMISSIBLE EXPOSURE (MPE)

Frequency range (MHz)	Electric field strength (V/m)	Magnetic field strength (A/m)	Power density (mW/cm^2)	Averaging time (minutes)
(A) Limits for Occupational/Controlled Exposure				
0.3–3.0	614	1.63	*100	6
3.0–30	1842/f	4.89/f	$*900/f^2$	6
30–300	61.4	0.163	1.0	6
300–1,500	.....	.....	f/300	6
1,500–100,000	.....	.....	5	6
(B) Limits for General Population/Uncontrolled Exposure				
0.3–1.34	614	1.63	*100	30
1.34–30	824/f	2.19/f	$*180/f^2$	30
30–300	27.5	0.073	0.2	30
300–1,500	.....	.....	f/1500	30
1,500–100,000	.....	.....	1.0	30

f = frequency in MHz * = Plane-wave equivalent power density

FCC EIRP Limits

Maximum FCC EIRP limits are stated into FCC 47 CFR §22.913, FCC 47 CFR §24.232 and FCC 47 CFR §22.50 (d) standards, these limits are frequency-dependent and are shown in the following table:

Standard	Band (MHz)	EIRP limit (W)	EIRP limit (mW)	EIRP limit (dBm)
FCC 47 CFR §22.50 (d)	700	4.92	4920	36.92
FCC 47 CFR §22.913	850	11.48	11480	40.6
FCC 47 CFR §22.50 (d)	1700	1.0	1000	30.0
FCC 47 CFR §24.232	1900	2.0	2000	33.0

FCC MPE Evaluation Results

Each supported transmission technology will be evaluated to determine if it is in compliance with limits for Maximum Permissible Exposure (MPE) to radiofrequency electromagnetic fields.

In order to perform the assessment, the following equations have been used for the calculations; these equations are accurate in the far-field of an antenna and will over-predict power density in the near field, where they could be used for making a "worst case" or conservative prediction:

Power density: $S[mW/cm^2] = \frac{P_{max}[mW]}{4\Pi R[cm]^2}$

Minimum compliance distance: $R_{min}[cm] = \sqrt{\frac{P_{max}[mW]}{4\Pi S[mW/cm^2]}}$

Maximum gain to meet the MPE limit: $G_{max}[dBi] = (10 * \log[S[mW/cm^2] * 4\Pi R[cm]^2) - P_{max}[dBm]$

S = power density

P_{max} = power input to the antenna

R = distance to the center of radiation of the antenna (evaluation distance)

R_{min} = distance to the center of radiation of the antenna

G_{max} = power gain of the antenna in the direction of interest relative to an isotropic radiator

Assessment 1 - LTE Cat-M1 Band 4

MPE Evaluation

Maximum output power (dBm):	24.0
Maximum output power (mW):	251.2
Minimum use distance (cm):	20.0
Worst Case Frequency (MHz):	1710.0
General population - Power density limit (mW/cm^2):	1.0

Power density at minimum use distance:

Power density (mW/cm^2):	0.05
General population - Power density limit (mW/cm^2):	1.0
Verdict for general population:	PASS

The power density level for this transmission mode is below general population exposure power density limit.

Minimum compliance distance for this technology:

Minimum compliance distance for general population (cm):	4.47
Minimum use distance (cm):	20.0
Verdict for general population:	PASS

The minimum use distance is greater than general population exposure minimum compliance distance.

Maximum gain to meet the §1.1310 Radiofrequency radiation exposure limits:

Maximum antenna gain to meet reference level (dBi):	13.0
Power density using max antenna gain (mW/cm^2):	0.997

The power density level using the maximum antenna gain for this transmission mode will be below power density reference level.

EIRP Evaluation

Maximum output power (dBm):	EIRP limit (dBm)	Maximum antenna gain to meet EIRP level (dBi)
24.0	30.0	6.0

Maximun antenna gain to meet power density reference level / EIRP level

Maximum antenna gain (dBi):	6.0

Assessment 2 - LTE Cat-M1 Band 13

MPE Evaluation

Maximum output power (dBm):	24.0
Maximum output power (mW):	251.2
Minimum use distance (cm):	20.0
Worst Case Frequency (MHz):	777.0
General population - Power density limit (mW/cm^2):	0.518

Power density at minimum use distance:

Power density (mW/cm^2):	0.05
General population - Power density limit (mW/cm^2):	0.518
Verdict for general population:	PASS

The power density level for this transmission mode is below general population exposure power density limit.

Minimum compliance distance for this technology:

Minimum compliance distance for general population (cm):	6.21
Minimum use distance (cm):	20.0
Verdict for general population:	PASS

The minimum use distance is greater than general population exposure minimum compliance distance.

Maximum gain to meet the §1.1310 Radiofrequency radiation exposure limits:

Maximum antenna gain to meet reference level (dBi):	10.1
Power density using max antenna gain (mW/cm^2):	0.511

The power density level using the maximum antenna gain for this transmission mode will be below power density reference level.

EIRP Evaluation

Maximum output power (dBm):	EIRP limit (dBm)	Maximum antenna gain to meet EIRP level (dBi)
24.0	36.92	12.92

Maximun antenna gain to meet power density reference level / EIRP level

Maximum antenna gain (dBi):	10.1

Appendix B: ISED RF Exposure

ISED RF Exposure evaluation for mobile devices

According to RSS-102 Issue 5, Paragraph "4. Exposure Limits", Industry of Canada has adopted the RF field strength limits established in Health Canada's RF exposure guideline, Safety code 6:

Table 4: RF Field Strength Limits for Devices Used by the General Public (Uncontrolled Environment)

Frequency Range (MHz)	Electric Field (V/m rms)	Magnetic Field (A/m rms)	Power Density (W/m^2)	Reference Period (minutes)
0.003-10[21]	83	90	-	Instantaneous*
0.1-10	-	$0.73/f$	-	6**
1.1-10	$87/f^{0.5}$	-	-	6**
10-20	27.46	0.0728	2	6
20-48	$58.07/f^{0.25}$	$0.1540/f^{0.25}$	$8.944/f^{0.5}$	6
48-300	22.06	0.05852	1.291	6
300-6000	$3.142 f^{0.3417}$	$0.008335 f^{0.3417}$	$0.02619 f^{0.6834}$	6
6000-15000	61.4	0.163	10	6
15000-150000	61.4	0.163	10	$616000/f^{1.2}$
150000-300000	$0.158 f^{0.5}$	$4.21 \times 10^{-4} f^{0.5}$	$6.67 \times 10^{-5} f$	$616000/f^{1.2}$

Note: f is frequency in MHz.
*Based on nerve stimulation (NS).
** Based on specific absorption rate (SAR).

ISED EIRP Limits

Maximum FCC EIRP limits are stated into RSS-132 Issue 3, RSS-133 Issue 6 and RSS-139 Issue 2/ SRSP-513 standards, these limits are frequency-dependent and are shown in the following table:

Standard	Band (MHz)	EIRP limit (W)	EIRP limit (mW)
FCC 47 CFR §22.50 (d)	700	4.92	4920
RSS-139 Issue 2/ SRSP-513	850	11.48	11480
FCC 47 CFR §22.50 (d)	1700	1.0	1000
RSS-139 Issue 2/ SRSP-513	1900	2.0	2000

ISED MPE Evaluation Results

Each supported transmission technology will be evaluated to determine if it is in compliance with RSS-102 Issue 5, RF Field Strength Limits for devices used by the General Public.

In order to perform the assessment, the following equations have been used for the calculations; these equations are accurate in the far-field of an antenna and will over-predict power density in the near field, where they could be used for making a "worst case" or conservative prediction:

Power density: $S[W/m^2] = \frac{P_{max}[W]}{4\Pi R[m]^2}$

Minimum compliance distance: $R_{min}[m] = \sqrt{\frac{P_{max}[W]}{4\Pi S[W/m^2]}}$

Maximum gain to meet the RSS -102 limit: $G_{max}[dBi] = (10 * \log[S[W/m^2] * 4\Pi R[m]^2) + 30 - P_{max}[dBm]$

S = power density

P_{max} = power input to the antenna

R = distance to the center of radiation of the antenna (evaluation distance)

R_{min} = distance to the center of radiation of the antenna

G_{max} = power gain of the antenna in the direction of interest relative to an isotropic radiator

Assessment 1 - LTE Cat-M1 Band 4

MPE Evaluation

Maximum output power (dBm):	24.0
Maximum output power (W):	0.25
Minimum use distance (m):	0.2
Worst Case Frequency (MHz):	1710.0
General public - Power density limit (W/m^2):	4.24

Power density at minimum use distance:

Power density (W/m^2):	0.50
General public - Power density limit (W/m^2):	4.24
Verdict for general public:	PASS

The power density level for this transmission mode is below general public power density limit.

Minimum compliance distance for this technology:

Minimum compliance distance for general public (m):	0.069
Minimum use distance (m):	0.2
Verdict for general public:	PASS

The minimum use distance is greater than general public minimum compliance distance.

Maximum gain to meet the RSS -102 limits:

Maximum antenna gain to meet reference level (dBi):	9.2
Power density using max antenna gain (W/m^2):	4.16

The power density level using the maximum antenna gain for this transmission mode will be below power density reference level.

EIRP Evaluation

Maximum output power (dBm):	EIRP limit (dBm)	Maximum antenna gain to meet EIRP level (dBi)
24.0	30.0	6.0

Maximun antenna gain to meet power density reference level / EIRP level

Maximum antenna gain (dBi):	6.0

Assessment 2 - LTE Cat-M1 Band 13

MPE Evaluation

Maximum output power (dBm):	24.0
Maximum output power (W):	0.25
Minimum use distance (m):	0.2
Worst Case Frequency (MHz):	777.0
General public - Power density limit (W/m^2):	2.474

Power density at minimum use distance:

Power density (W/m^2):	0.5
General public - Power density limit (W/m^2):	2.474
Verdict for general public:	PASS

The power density level for this transmission mode is below general public power density limit.

Minimum compliance distance for this technology:

Minimum compliance distance for general public (m):	0.09
Minimum use distance (m):	0.2
Verdict for general public:	PASS

The minimum use distance is greater than general public minimum compliance distance.

Maximum gain to meet the RSS -102 limits:

Maximum antenna gain to meet reference level (dBi):	6.9
Power density using max antenna gain (W/m^2):	2.45

The power density level using the maximum antenna gain for this transmission mode will be below power density reference level.

EIRP Evaluation

Maximum output power (dBm):	EIRP limit (dBm)	Maximum antenna gain to meet EIRP level (dBi)
24.0	36.92	12.92

Maximun antenna gain to meet power density reference level / EIRP level

Maximum antenna gain (dBi):	6.9