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RF Exposure Assessment Report

Regulation

47 CFR FCC Sections 1.1307 and 1.1310

Client

NOKIA SOLUTIONS AND NETWORKS OY

Product Evaluated

**Nokia Drone Networks Electric Drone
with P638893 RF Module and P632592 RF Module**

Report Number

TR2023-0050 FCC MPE

Date Issued

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Revisions

Date	Revision	Section	Change
	0		Initial Release

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The results documented in this report refer exclusively to the product specified, under the conditions and modes of operation as described herein.

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1. ATTESTATION OF TEST RESULTS

Equipment Under Test (EUT)	NDN Electric Drone with P638893 and P632592 RF Modules
Model Name	NDN Electric Drone P591013
FCC ID	2BC99NDNUAV1
Manufacturer	Nokia Solutions and Networks, OY Karakaari 7, FI-02610 Espoo Finland
Applicant:	Nokia of America Corp 3201 Olympus Blvd Dallas, TX 75019
Frequency Bands	P632592 RF Module: 2400-2483.5MHz. P638893 RF Module: 663-3980MHz
GPCL Project Number:	2023-0050
Test Requirement(s)	47 CFR FCC Sections 1.1307 and 1.1310, 15.247, 27.52, 90.223
Other Reference(s)	FCC OET Bulletin 65, KDB 447498 D01
Test Report Number	TR2023-0050 FCC MPE
Test Laboratory	Global Product Compliance Laboratory 600-700 Mountain Avenue Room 5B-108 Murray Hill, New Jersey 07974-0636 USA

The above product has been evaluated and found to be in compliance with the Commission’s Rules and Regulations set forth in the above standards. The data and the descriptions about the test setup, procedures and configuration presented in this report are accurate.

2. SUMMARY OF THE TEST RESULTS

Applied Standard(s): FCC 1.1310		
Configuration	Exposure Environment	Proposed RF Safety Distance (cm)
NDN Electric Drone with two P638893 RF module and one P632592 WiFi module	General Population/Uncontrolled	59
	Occupational/Controlled	27

3. GENERAL INFORMATION

3.1 Product Descriptions

The NDN electric drone P591013 is equipped with two RF modules P638893 and one WiFi module P632592. The P632592 WiFi module supports 2.4GHz DTS (Digital Transmission Systems) with 802.11b/g/n Technologies and Bluetooth with Frequency Hopping Spread Spectrum (FHSS). RF modules P638893 supports both LTE and 5G NR technologies. Two RF modules P638893 will not transmit simultaneously on the same channel.

The module P638893 operates in multiple frequency bands from 663-3980MHz. Each P638893 is equipped with four antennas: a) one external Paddle Antennas P567162 with peak gain +3.0 ~ +5.0dBi and b) three Internal Antennas P601003 617MHz-4400MHz with peak gain -1.7 ~ +3.7dBi.

The wifi module P632592 operates in 2400-2483.5MHz and has an integrated PCB antenna with a maximum antenna gain of 4.54dBi.

Table 3.1.1 Operation Bands of P638893 RF Module in NDN Drone

Bands	Freq Range UL (MHz)	Maxi Conducted Power (W)	Maxi Conducted Power (dBm) ***	EIRP Limit (dBm)	FCC Rule Parts
b2, n2	1850-1910	0.306	24.86	33	Part 24E
b25, n25	1850-1915	0.316	25.00	33	Part 24E
b4	1710-1755	0.315	24.98	30	Part 27
b66, n66	1710-1780	0.313	24.96	30	Part 27
b7, n7	2500 ~ 2570	0.313	24.84	33	Part 27
b12, n12	699 ~ 716	0.308	24.89	36.92	Part 27
b13, n13	777 ~ 787	0.289	24.52	36.92	Part 27
b14, n14	788-798	0.301	24.79	36.92	Part 90R
b17	704-716	0.314	24.97	36.92	Part 27
b26, n26	814-824	0.313	24.96	40.6*	Part 90
b30, n30	2305-2315	0.282	24.50	23.98	Part 27
b38, n38	2570-2620	0.397	25.99	33.0	Part 27
b41, n41	2496 ~ 2690	0.506	27.04	33.0	Part 27
b42	3400 ~ 3600	0.400	26.02	30.0	Part 27
b43	3600 ~ 3800	0.385	25.85	30.0	Part 27
b48, n48**	3550-3700	0.284	24.53	23.0 + 10log(OBW/10MHz)	Part 96
n70	1695 ~ 1710	0.238	23.77	30	Part 27
b71, n71	663 ~ 698	0.315	24.98	36.92	Part 27
n77	3300 ~ 3980	0.355	25.50	30	Part 27
n78	3300-3800	0.385	25.85	30	Part 27

*The maximum ERP limit for 824-849 MHz is 38.45dBm. There is no EIRP limit for 814-824MHz. The 40.6 dBm EIRP is used at 824MHz. ** Maximum EIRP limit for B48/n48 is 29dBm for 40MHz bandwidth. *** These are the maximum conducted power approved for the module. The real output power is lower in b30/n30, b42/b43/b48/n48, n77 and n78 due to the NDN antennas with higher gain.

NDN Electric Drone does not stay in fixed locations and is not close to the public during normal operation. Therefore, the EUT is neither a portable nor a fixed wireless device. The EUT is a mobile device.

For evaluation, the worst case is the case with the highest EIRP and the lowest Tx frequency. Therefore, the following specifications of the EUT are provided below, where the maximum EIRP limit among all operation bands is used for P638893 and P632592:

Table 3.1.2 Product Specifications on NDN Electric Drone

Product	Technologies	Transmitting Frequency (MHz)	Max Output Power EIRP (dBm)
Two P638893	LTE/NR	663-3980	40.6 at 824MHz, 36.92 at other freq
P632592	802.11b/g/n, BT	2400-2483.5	30

3.2 Antenna Information

The maximum allowed antenna gains given on the FCC grant of P638893 as a single module were calculated based on 1) the difference between the maximum rated power for each band plus +2dB tolerance and the EIRP limit for each band plus 3dB for B38/n38, B41/n41, n77 and n78 which support MIMO, and 2) the power level restriction for a minimum safety distance of 20cm, which ever is lower.

Table 3.2.1a Maximum Rated Power of P638893 RF Module and Maximum Antenna Gain Calculated for P638893 SA Module Approval

Bands	Freq Range UL (MHz)	Maxi Rated Power (dBm)	Tolerance (+) ***	MIMO (dB)	P _{max} = Maxi Rated Cond Power +T + MIMO (dBm)	EIRP Limit (dBm)	Maxi Ant Gain Allowed (EIRP _{Lim} - P _{max}) (dBi)	Maxi Ant Gain Allowed on Grant (dBi)
b2, n2	1850-1910	23	2	0	25	33	8	8
b25, n25	1850-1915	23	2	0	25	33	8	8
b4	1710-1755	23	2	0	25	30	5	5
b66, n66	1710-1780	23	2	0	25	30	5	5
b7, n7	2500 ~ 2570	23	2	0	25	33	8	8
b12, n12	699 ~ 716	23	2	0	25	36.92	11.92	8.7*
b13, n13	777 ~ 787	23	2	0	25	36.92	11.92	9.16*
b14, n14	788-798	23	2	0	25	36.92	11.92	9.23*
B17	704-716	23	2	0	25	36.92	11.92	8.74*
b26, n26	814-824	23	2	0	25	40.6	15.6	9.36*
b30, n30	2305-2315	23	2	0	25	23.98	-1.02	-1.02
b38, n38	2570-2620	26	2	3	28	33.0	5	5
b41, n41	2496 ~ 2690	26	2	3	28	33.0	5	5
b42	3400 ~ 3600	26	2	3	28	30.0	2	2
b43	3600 ~ 3800	26	2	3	28	30.0	2	2
b48, n48	3550-3700	23	2	0	25	23.0**	-2	-2
n70	1695 ~ 1710	23	2	0	25	30	5	5
b71, n71	663 ~ 698	23	2	0	25	36.92	11.92	8.48*
n77	3300 ~ 3980	26	2	3	28	30	2	2
n78	3300-3800	26	2	3	28	30	2	2

*Maximum antenna gain allowed was reduced for the FCC grant of P638893 RF Module for a minimum safety distance of 20cm.

** for 10MHz

*** ±1dB in RF module P638893 specification.

NDN Electric Drone certainly does not need to maintain a minimum safety distance at 20cm. Therefore, the maximum allowed antenna gain data on the FCC grant of P638893 as a single module are no longer valid. The maximum allowed antenna gain for NDN Drone should be based on the value $(EIRP_{Lim} - P_{max})$, where the maximum rated power, extra tolerance +2dB and MIMO have been taken into consideration.

Table 3.2.1b Maximum Allowed Antenna Gain in Licensed Bands for NDN Drone P591013

Bands	Freq Range UL (MHz)	NDN Maxi Conducted Power (dBm)	NDN Maxi Ant Gain Used (dBi)	EIRP Limit (dBm)	EIRP Limit - NDN Maxi Conducted Pwr (dB)	Maxi Ant Gain Allowed for NDN Drone (dBi)
b2, n2	1850-1910	24.86	4.0	33	8.14	8.0
b25, n25	1850-1915	25.00	4.0	33	8.00	8.0
b4	1710-1755	24.98	4.0	30	5.02	5.0
b66, n66	1710-1780	24.96	4.0	30	5.04	5.0
b7, n7	2500 ~ 2570	24.96	4.0	33	8.04	8.0
b12, n12	699 ~ 716	24.89	3.0	36.92	12.03	11.92
b13, n13	777 ~ 787	24.61	3.0	36.92	12.31	11.92
b14, n14	788-798	24.79	3.0	36.92	12.13	11.92
B17	704-716	24.97	3.0	36.92	11.95	11.92
b26, n26	814-824	24.96	3.0	40.6	15.64	15.6
b30, n30	2305-2315	19.48	4.0	23.98	4.5	4.0
b38, n38	2570-2620	25.99	4.0	33.0	7.01	5.0
b41, n41	2496 ~ 2690	27.04	4.0	33.0	5.96	5.0
b42	3400 ~ 3600	23.02	5.0	30.0	6.98	5.0
b43	3600 ~ 3800	22.85	5.0	30.0	7.15	5.0
b48, n48	3550-3700	17.53	5.0	23.0*	5.47	5.0
n70	1695 ~ 1710	23.77	2.7	30	6.23	5.0
b71, n71	663 ~ 698	24.98	3.0	36.92	11.94	11.92
n77	3300 ~ 3980	23.02	5.0	30	6.98	5
n78	3300-3800	22.85	5.0	30	7.15	5

* for 10MHz

Table 3.2.2 Maximum Allowed Antenna Gain in 2.4G Bands

Modules	Maximum Conducted Power (dBm)	EIRP Limit (dBm)	Maximum Antenna Gain Allowed (dBi)
P632592	18.72	30	11.28

4. REQUIRED EVALUATION AND RESULTS

4.1 Regulatory Requirements

The assessment in this report was performed for the NDN Electric Drone P591013 which is equipped with two RF modules P638893 and one WiFi module P632592.

The regulatory requirements for the RF exposure compliance of RF transceivers were specified in 47 CFR FCC Parts 1, 15.247, 27.52 and 90.223.

The FCC Part 1.1310 sets out the requirements and measurement techniques used to evaluate RF exposure compliance of radiocommunication apparatus.

I. FCC Section 15.247 RF Exposure Requirement

Radio frequency devices operating under the provisions of this part are subject to the radio frequency radiation exposure requirements specified in §§ 1.1307(b), 1.1310, 2.1091, and 2.1093 of this chapter, as appropriate. Applications for equipment authorization of mobile or portable devices operating under this section must contain a statement confirming compliance with these requirements. Technical information showing the basis for this statement must be submitted to the Commission upon request.

II. FCC Section 27.52 and 90.223 RF Exposure Requirements

Licenses and manufacturers shall ensure compliance with the Commission's radio frequency exposure requirements in §§ 1.1307(b), 2.1091, and 2.1093 of this chapter, as appropriate. Applications for equipment authorization of mobile or portable devices operating under this section must contain a statement confirming compliance with these requirements. Technical information showing the basis for this statement must be submitted to the Commission upon request.

III. FCC Section 1.1307(b) Evaluation Environmental Assessment Requirement for Equipment Authorization

Commission actions granting construction permits, licenses to transmit or renewals thereof, equipment authorizations or modifications in existing facilities, require the preparation of an Environmental Assessment (EA) if the particular facility, operation or transmitter would cause human exposure to levels of radiofrequency radiation in excess of the limits in FCC Sections 1.1310 and 2.1093.

IV. FCC Section 1.1310 Radio Frequency Radiation Exposure Limits

At operating frequencies less than or equal to 6 GHz, the limits for maximum permissible exposure (MPE), derived from whole-body SAR limits and listed in Table 1 of Section 1.1310, may be used instead of whole-body SAR limits to evaluate the environmental impact of human exposure to RF radiation as specified in Section 1.1307(b), except for portable devices as defined in § 2.1093 as these evaluations shall be performed according to the SAR provisions in Section 2.1093 of this chapter.

At operating frequencies above 6 GHz, the MPE limits shall be used in all cases to evaluate the environmental impact of human exposure to RF radiation as specified in Section 1.1307(b).

The MPE limits listed in Table 1 of Section 1.1310 are for continuous exposure, that is, for indefinite time periods. Exposure levels higher than the limits are permitted for shorter exposure times, as long as the average exposure over the specified averaging time in Table 1 is less than the limits. Detailed information regarding procedures for evaluating compliance with all of these exposure limits can be found in the FCC's OET Bulletin 65, "Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields," and in supplements to Bulletin 65.

The exposure limits specified for occupational/controlled exposure and general population/uncontrolled exposure, which are tabulated below shall be met.

Table 4.1.1 Limits for Occupational/Controlled Exposure and General Population/Uncontrolled Exposure (FCC Section 1.1310 Table 1(B))

Frequency Range (MHz)	Electric Field Strength (E) (V/m)	Magnetic Field Strength (H) (A/m)	Power Density (S) (mW/cm ²)	Average Time E ² , H ² or S (minutes)
(A) Limits for Occupational/Controlled Exposure				
300 - 1500			f/300	6
1500 - 100,000			5.0	6
(B) Limits for General Population/Uncontrolled Exposure				
300 - 1500			f/1500	30
1500 - 100,000			1.0	30

Note: f = frequency in MHz.

4.2 RF Exposure Assessment

The regulatory requirements and limits were provided in Section 4.1. The product specifications on RF transceivers and antennas were provided in Section 3.

The limits at the operation frequencies of transmitters installed in NDN Electric Drone were calculated and provided in Table 4.2.1.

Table 4.2.1 Power Density Limits for Occupational/Controlled Exposure and General Population/Uncontrolled for NDN Electric Drone with P638893

Environment	Frequency Range (MHz)	Min Power Density (S) (mW/cm ²)
Occupational/Controlled	663	2.21
General Population/Uncontrolled	663	0.442
Occupational/Controlled	824	2.75
General Population/Uncontrolled	824	0.549

Table 4.2.2 Power Density Limits for Occupational/Controlled Exposure and General Population/Uncontrolled for NDN Electric Drone with P632592

Environment	Frequency Range (MHz)	Min Power Density (S) (mW/cm ²)
Occupational/Controlled	2400	5
General Population/Uncontrolled	2400	1

Per IEEE C95.3 Annex B Equation (37) or FCC's OST/OET Bulletin Number 65, the appropriate safety distance can be calculated based on the relationship between power density limit and EIRP (equivalent or effective isotopically radiated power), i.e.,

$$S = \frac{EIRP}{4\pi R^2}, \quad (1)$$

where S is the power density in mW/cm², R is the distance to the center of radiation of the antenna in cm and EIRP is in mW.

When all transmitters or channels operate simultaneously, the EIRP and thus power density from all transmitters gives the worst-case scenario.

The RF exposure assessment was conducted on NDN Electric Drone.

Table 4.2.2(a) Minimum RF Safety Distances for Uncontrolled Exposure

NDN Electric Drone	Max EIRP (dBm)	Max EIRP (mW)	Limit of Pwr Density S (mW/cm ²)	RF Safety Distance (cm)
P638893	36.92	4920	0.442	29.8
P638893	36.92	4920	0.442	29.8
P632592	30	1000	1	8.9
Total	40.35	10,841		43.0

Table 4.2.2(b) Minimum RF Safety Distances for for Controlled Exposure

NDN Electric Drone	Max EIRP (dBm)	Max EIRP (mW)	Limit of Pwr Density S (mW/cm ²)	RF Safety Distance (cm)
P638893	36.92	4920	2.21	13.3
P638893	36.92	4920	2.21	13.3
P632592	30	1000	5	4
Total	40.35	10,841		19.2

Table 4.2.2(c) Minimum RF Safety Distances for Uncontrolled Exposure

NDN Electric Drone	Max EIRP (dBm)	Max EIRP (mW)	Limit of Pwr Density S (mW/cm ²)	RF Safety Distance (cm)
P638893	40.6	11482	0.549	40.8
P638893	40.6	11482	0.549	40.8
P632592	30	1000	1	8.9
Total	43.80	23964		58.4

Table 4.2.2(d) Minimum RF Safety Distances for for Controlled Exposure

NDN Electric Drone	Max EIRP (dBm)	Max EIRP (mW)	Limit of Pwr Density S (mW/cm ²)	RF Safety Distance (cm)
P638893	40.6	11482	2.75	18.2
P638893	40.6	11482	2.75	18.2
P632592	30	1000	5	4
Total	43.80	23964		26.1

Since,

$$\frac{S}{LPD} \leq 1,$$

$$\frac{EIRP}{4\pi R^2 \cdot LPD} \leq 1,$$

then

$$R \geq \sqrt{\frac{EIRP}{4\pi \cdot LPD}} \tag{2}$$

From Equation (2), the minimum distance R = 58.4 cm for uncontrolled exposure and 26.1cm for controlled exposure with the 43.8dBm EIRP, the maximum allowed.

Table 4.2.3(a) Power Density at the Minimum RF Safety Distance for Uncontrolled Exposure

Module	Max EIRP (dBm)	Max EIRP (mW)	RF Safety Distance (cm)	Power Density S (mW/cm ²)	Limit of Power Density S (mW/cm ²)	S/LPD
P638893	40.6	11482	59	0.2625	0.549	0.478
P638893	40.6	11482	59	0.2625	0.549	0.478
P632592	30	1000	59	0.0229	1.0	0.023
Total	43.80	23964	59			0.979

Table 4.2.3(b) Power Density at the Minimum RF Safety Distance for Controlled Exposure

Module	Max EIRP (dBm)	Max EIRP (mW)	RF Safety Distance (cm)	Power Density S (mW/cm ²)	Limit of Power Density S (mW/cm ²)	S/LPD
P638893	40.6	11482	27	1.253	2.747	0.456
P638893	40.6	11482	27	1.253	2.747	0.456
P632592	30	1000	27	0.109	5	0.022
Total	43.80	23964	27			0.934

Therefore,

Table 4.2.4 Proposed RF Safety Distances for NDN Electric Drone

Exposure	RF Safety Distance (cm)
General Population/Uncontrolled	59
Occupational/Controlled	27

Only the general population/uncontrolled exposure environment will be considered for UNII devices.

5. REFERENCES

- [1]. Title 47 Code of Federal Regulations (CFR) Parts 1, 2 and 15.
- [2]. FCC OET Bulletin 65 and Supplements, Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields, August 1997
- [3]. KDB 447498 D01, RF Exposure Procedures and Equipment Authorization Policies for Mobile and Portable Devices, Oct 2015, V06
- [4]. IEEE C95.3, IEEE Recommended Practice for Measurements and Computations of Radio Frequency Electromagnetic Fields with Respect to Human Exposure to Such Fields, 100 kHz–300 GHz, 2002 (R2008).
- [5]. FCC Order and Authorization 20-48, April 19, 2022