

RF Exposure Exhibit

EUT Name: Wi-Fi Module

Model No.: NVG5X8AC

CFR Part 1.1310 and RSS 102

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1 Test Methodology

In this document, we evaluate the RF Exposure to human body due the intentional transmission from the transmitter (EUT). The limit for Maximum Permissible Exposure (MPE) specified in FCC 1.1310 is followed. Through the Friis transmission formula and the maximum gain of the antenna, we can calculate the distance, away from the product, where the limit of MPE is reached.

Although the Friis transmission formula is a far field assumption, the calculated result of that is an over-prediction for near field power density. We will take that as the worst case to specify the safety range.

1.1 RF Exposure Limit

According to FCC 1.1310 table 1: The criteria listed in the following table shall be used to evaluate the environmental impact of human exposure to radio-frequency (RF) radiation as specified in 1.1307(b)

LIMITS FOR MAXIMUM PERMISSIBLE EXPOSURE (MPE)

Frequency Range (MHz)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (mW/cm ²)	Average Time (minutes)
(A)Limits For Occupational / Control Exposures				
0.3-1.34	614	1.63	*(100)	6
1.34-30	1842/f	4.89/f	*(900/f ²)	6
30-300	61.4	0.163	1.0	6
30-1500	...	...	F/300	6
1500-100000	...	...	1.0	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
30-1500	...	...	F(MHz)/1500MHz	30
1500-100000	...	...	1.0	30

F = Frequency in MHz

*=Plane wave equivalent density

According to RSS-102 Issue 5: The criteria listed in the following table shall be used to evaluate the environmental impact of human exposure to radio-frequency (RF) radiation

**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/m²)	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 x 10 ⁻⁴ $f^{0.5}$	6.67 x 10 ⁻⁵ f	616000/ $f^{1.2}$
Note: f is frequency in MHz. *Based on nerve stimulation (NS). ** Based on specific absorption rate (SAR).				

1.2 EUT Operating Condition

The Model NVG5X8AC, is a Wi-Fi Module for the home capable of operating in the 2.4 GHz and 5 GHz frequency bands over 20 MHz, 40 MHz and 80 MHz channels.

1.3 MPE calculation

1.3.1 Antenna Gain

The antennas used are:

1. Wifi 2.4 GHz PCB Antenna peak gain: +3.8 dBi
2. Wifi 5.15-5.25 GHz PCB Antenna peak gain: +4.8 dBi; Total directional gain: 8.2 dBi
3. Wifi 5.725-5.850 GHz PCB Antenna peak gain: +4.6 dBi; Total directional gain: 8.8 dBi

1.3.2 Conducted Output Power

1. Wifi 2.4 GHz Band, TUV Test Report 31962242.001:
1x4 mode max power: 25.99 dBm (397.19 mW) at 2.437 GHz
4x4 mode total power: 28.39 dBm (690.24 mW) at 2.412 GHz
2. FCC Wifi 5 GHz Band (UNII-1), TUV Test Report 31962243.001:
1x4 mode max power: 23.96 dBm (248.89 mW) at 5.24 GHz
4x4 mode total power: 26.01 dBm (399.02 mW) at 5.23 GHz
3. ISED Wifi 5 GHz Band (UNII-1), TUV Test Report 31962243.001:
1x4 mode max power: 18.16 dBm (65.46 mW) at 5.19 GHz
4x4 mode total power: 14.78 dBm (30.06 mW) at 5.21 GHz
4. Wifi, 5 GHz Band (UNII-3), TUV Test Report 31962244.001:
1x4 mode max power: 25.80 dBm (380.19 mW) at 5.765 GHz
4x4 mode total power: 27.15 dBm (518.80 mW) at 5.755 GHz

1.3.3 Output Power into Antenna & RF Exposure value (Non-Beamforming Mode)

Calculations are based on highest power measurement and its antenna gain, therefore 2.437 GHz. Result below is Non-Beamforming Mode (1x4).

FCC:

Corrected (including cal factors) Measurement:	25.99	dBm	
The Gain of the antenna:	3.80	dBi	
Type of Measurement:	Conducted		Direct measurement at Antenna Port
Impedance:	50.00	Ω	
Measuring Distance:	0.00	m	
Time weighted Duty Cycle:	100.00	%	

The Power Out would be: 0.397191549 Watts
or: 397.19155 mW
or: 397191.55 μ W
or: 25.99 dBm

Frequency range from 10 MHz to 40 GHz:

Frequency: 2.437 GHz

Power output with DC and antenna Gain (EIRP):

Power (dBm):	29.79
Power (mW):	952.796
Power (W):	0.952796

R = distance in 20 cm

FCC:

Controlled Exposures - Limit =	5	mW/cm ²
Uncontrolled Exposures - Limit =	1	mW/cm ²
Pd =	0.1895528	mW/cm ²
Controlled Margin to Limit =	4.8104	mW/cm ²
Uncontrolled Margin to Limit =	0.8104	mW/cm ²

ISED:

Corrected (including cal factors) Measurement:	25.99	dBm	
The Gain of the antenna:	3.80	dBi	
Type of Measurement:	Conducted		Direct measurement at Antenna Port
Impedance:	50.00	Ω	
Measuring Distance:	0.00	m	
Time weighted Duty Cycle:	100.00	%	

The Power Out would be: 0.397191549 Watts
or: 397.19155 mW
or: 397191.55 μ W
or: 25.99 dBm

Frequency range from 10 MHz to 40 GHz:

Frequency:	2.437	GHz
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Power output with DC and antenna Gain (EiRP):

Power (dBm):	29.79
Power (mW):	952.796
Power (W):	0.952796

R = distance in	20	cm
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IC:

Controlled Exposures to Limit =	31.86574021	W/m ²
Uncontrolled Exposures Limit =	5.403965492	W/m ²
Pd =	1.895528	W/m ²
Controlled Margin to Limit =	29.9702	W/m ²
Uncontrolled Margin to Limit =	3.5084	W/m ²

Calculations are based on highest power measurement, then summed 4 chains and its antenna gain, therefore 2.437 GHz. Result below is Non-Beamforming Mode (4x4).

FCC:

Corrected (including cal factors) Measurement:	28.39	dBm
The Gain of the antenna:	3.80	dBi
Type of Measurement:	Conducted	Direct measurement at Antenna Port
Impedance:	50.00	Ω
Measuring Distance:	0.00	m
Time weighted Duty Cycle:	100.00	%

The Power Out would be: 0.690239804 Watts
 or: 690.23980 mW
 or: 690239.80 μ W
 or: 28.39 dBm

Frequency range from 10 MHz to 40 GHz:

Frequency:	2.412	GHz
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Power output with DC and antenna Gain (EIRP):

Power (dBm):	32.19
Power (mW):	1655.770
Power (W):	1.655770

R = distance in	20	cm
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FCC:

Controlled Exposures - Limit =	5	mW/cm ²
Uncontrolled Exposures - Limit =	1	mW/cm ²
Pd =	0.3294050	mW/cm ²
Controlled Margin to Limit =	4.6706	mW/cm ²
Uncontrolled Margin to Limit =	0.6706	mW/cm ²

ISED:

Corrected (including cal factors) Measurement:	28.39	dBm	
The Gain of the antenna:	3.80	dBi	
Type of Measurement:	Conducted		Direct measurement at Antenna Port
Impedance:	50.00	Ω	
Measuring Distance:	0.00	m	
Time weighted Duty Cycle:	100.00	%	

The Power Out would be: 0.690239804 Watts
or: 690.23980 mW
or: 690239.80 μ W
or: 28.39 dBm

Frequency range from 10 MHz to 40 GHz:

Frequency:	2.412	GHz
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Power output with DC and antenna Gain (EIRP):

Power (dBm):	32.19
Power (mW):	1655.770
Power (W):	1.655770

R = distance in	20	cm
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IC:

Controlled Exposures to Limit =	31.70187129	W/m ²
Uncontrolled Exposures Limit =	5.366018278	W/m ²
Pd =	3.294050	W/m ²
Controlled Margin to Limit =	28.4078	W/m ²
Uncontrolled Margin to Limit =	2.0720	W/m ²

Calculations are based on highest power measurement and its antenna gain, therefore 5.24 GHz. Result below is Non-Beamforming Mode (1x4).

FCC:

Corrected (including cal factors) Measurement:	23.96	dBm
The Gain of the antenna:	4.80	dBi
Type of Measurement:	Conducted	Direct measurement at Antenna Port
Impedance:	50.00	Ω
Measuring Distance:	0.00	m
Time weighted Duty Cycle:	100.00	%

The Power Out would be: 0.248885732 Watts
or: 248.88573 mW
or: 248885.73 μ W
or: 23.96 dBm

Frequency range from 10 MHz to 40 GHz:

Frequency:	5.24	GHz
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Power output with DC and antenna Gain (EIRP):

Power (dBm):	28.76
Power (mW):	751.623
Power (W):	0.751623

R = distance in	20	cm
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FCC:

Controlled Exposures - Limit =	5	mW/cm ²
Uncontrolled Exposures - Limit =	1	mW/cm ²
Pd =	0.1495306	mW/cm ²
Controlled Margin to Limit =	4.8505	mW/cm ²
Uncontrolled Margin to Limit =	0.8505	mW/cm ²

Calculations are based on highest power measurement and its antenna gain, therefore 5.19 GHz. Result below is Non-Beamforming Mode (1x4).

ISED:

Corrected (including cal factors) Measurement:	18.16	dBm
The Gain of the antenna:	4.80	dBi
Type of Measurement:	Conducted	Direct measurement at Antenna Port
Impedance:	50.00	Ω
Measuring Distance:	0.00	m
Time weighted Duty Cycle:	100.00	%

The Power Out would be: 0.065463617 Watts
or: 65.46362 mW
or: 65463.62 μ W
or: 18.16 dBm

Frequency range from 10 MHz to 40 GHz:

Frequency: 5.19 GHz

Power output with DC and antenna Gain (EIRP):

Power (dBm):	22.96
Power (mW):	197.697
Power (W):	0.197697

R = distance in 20 cm

IC:

Controlled Exposures to Limit =	46.50288806	W/m ²
Uncontrolled Exposures Limit =	9.059012747	W/m ²
Pd =	0.393306	W/m ²
Controlled Margin to Limit =	46.1096	W/m ²
Uncontrolled Margin to Limit =	8.6657	W/m ²

Calculations are based on highest power measurement and its antenna gain, therefore 5.765 GHz. Result below is Non-Beamforming Mode (1x4).

FCC:

Corrected (including cal factors) Measurement:	25.80	dBm
The Gain of the antenna:	4.60	dBi
Type of Measurement:	Conducted	Direct measurement at Antenna Port
Impedance:	50.00	Ω
Measuring Distance:	0.00	m
Time weighted Duty Cycle:	100.00	%

The Power Out would be: 0.380189396 Watts
 or: 380.18940 mW
 or: 380189.40 μ W
 or: 25.80 dBm

Frequency range from 10 MHz to 40 GHz:

Frequency:	5.765	GHz
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Power output with DC and antenna Gain (EIRP):

Power (dBm):	30.40
Power (mW):	1096.478
Power (W):	1.096478

R = distance in	20	cm
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FCC:

Controlled Exposures - Limit =	5	mW/cm ²
Uncontrolled Exposures - Limit =	1	mW/cm ²
Pd =	0.2181374	mW/cm ²
Controlled Margin to Limit =	4.7819	mW/cm ²
Uncontrolled Margin to Limit =	0.7819	mW/cm ²

ISED:

Corrected (including cal factors) Measurement:	25.80	dBm
The Gain of the antenna:	4.60	dBi
Type of Measurement:	Conducted	Direct measurement at Antenna Port
Impedance:	50.00	Ω
Measuring Distance:	0.00	m
Time weighted Duty Cycle:	100.00	%

The Power Out would be: 0.380189396 Watts
 or: 380.18940 mW
 or: 380189.40 μ W
 or: 25.80 dBm

Frequency range from 10 MHz to 40 GHz:

Frequency:	5.765	GHz
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Power output with DC and antenna Gain (EIRP):

Power (dBm):	30.40
Power (mW):	1096.478
Power (W):	1.096478

R = distance in	20	cm
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IC:

Controlled Exposures to Limit =	49.01126392	W/m ²
Uncontrolled Exposures Limit =	9.733426371	W/m ²
Pd =	2.181374	W/m ²
Controlled Margin to Limit =	46.8299	W/m ²
Uncontrolled Margin to Limit =	7.5521	W/m ²

1.3.4 RF Exposure value when 2 radios operating simultaneously (Non-Beamforming Mode)

Non-Beamforming Exposure result (FCC)

Operating Frequency (MHz)	Power Density (mW/cm ²)	
2412	0.33	
* 5765	0.22	
	0.55	Total Power Density (mW/cm²)
	1.00	Uncontrolled Exposure Limit (mW/cm²)
	-0.45	Margin (mW/cm²)
Note: 1. * = worst case in the UNII band 2. Minimum distance from the user must be at 20 cm		

Non-Beamforming Exposure result (ISED)

Operating Frequency (MHz)	Power Density (W/cm ²)	Limit (W/cm ²)	Ratio	
2412	0.61	5.37	0.61	
* 5765	0.22	9.73	0.22	
			0.84	Σ ratio
Note: 1. The MPE calculation for simultaneous transmission is less than 1. 2. * = worst case in the UNII band 3. Minimum distance from the user must be at 20 cm				

1.3.5 Output Power into Antenna & RF Exposure value (Beamforming Mode)

Calculations are based on highest power measurement, then summed 4 chains and total antenna gain, therefore 5.23 GHz. Result below is Beamforming Mode (4x4).

FCC:

Corrected (including cal factors) Measurement:	26.01	dBm
The Gain of the antenna:	8.20	dBi
Type of Measurement:	Conducted	Direct measurement at Antenna Port
Impedance:	50.00	Ω
Measuring Distance:	0.00	m
Time weighted Duty Cycle:	100.00	%

The Power Out would be: 0.399024902 Watts
or: 399.02490 mW
or: 399024.90 μ W
or: 26.01 dBm

Frequency range from 10 MHz to 40 GHz:

Frequency:	5.23	GHz
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Power output with DC and antenna Gain (EIRP):

Power (dBm):	34.21
Power (mW):	2636.331
Power (W):	2.636331

R = distance in	20	cm
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FCC:

Controlled Exposures - Limit =	5	mW/cm ²
Uncontrolled Exposures - Limit =	1	mW/cm ²
Pd =	0.5244815	mW/cm ²
Controlled Margin to Limit =	4.4755	mW/cm ²
Uncontrolled Margin to Limit =	0.4755	mW/cm ²

Calculations are based on highest power measurement, then summed 4 chains and total antenna gain, therefore 5.21 GHz. Result below is Beamforming Mode (4x4).

ISED:

Corrected (including cal factors) Measurement:	14.78	dBm
The Gain of the antenna:	8.20	dBi
Type of Measurement:	Conducted	Direct measurement at Antenna Port
Impedance:	50.00	Ω
Measuring Distance:	0.00	m
Time weighted Duty Cycle:	100.00	%

The Power Out would be: 0.030060763 Watts
or: 30.06076 mW
or: 30060.76 μ W
or: 14.78 dBm

Frequency range from 10 MHz to 40 GHz:

Frequency:	5.21	GHz
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Power output with DC and antenna Gain (EIRP):

Power (dBm):	22.98
Power (mW):	198.609
Power (W):	0.198609

R = distance in	20	cm
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IC:

Controlled Exposures to Limit =	46.59240284	W/m ²
Uncontrolled Exposures Limit =	9.082855364	W/m ²
Pd =	0.395121	W/m ²
Controlled Margin to Limit =	46.1973	W/m ²
Uncontrolled Margin to Limit =	8.6877	W/m ²

Calculations are based on highest power measurement, then summed 4 chains and total antenna gain, therefore 5.755 GHz. Result below is Beamforming Mode (4x4).

FCC:

Corrected (including cal factors) Measurement:	27.15	dBm
The Gain of the antenna:	8.80	dBi
Type of Measurement:	Conducted	Direct measurement at Antenna Port
Impedance:	50.00	Ω
Measuring Distance:	0.00	m
Time weighted Duty Cycle:	100.00	%

The Power Out would be: 0.518800039 Watts

or: 518.80004 mW

or: 518800.04 μ W

or: 27.15 dBm

Frequency range from 10 MHz to 40 GHz:

Frequency:	5.755	GHz
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Power output with DC and antenna Gain (EIRP):

Power (dBm):	35.95
Power (mW):	3935.501
Power (W):	3.935501

R = distance in	20	cm
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FCC:

Controlled Exposures - Limit =	5	mW/cm ²
Uncontrolled Exposures - Limit =	1	mW/cm ²
Pd =	0.7829430	mW/cm ²
Controlled Margin to Limit =	4.2171	mW/cm ²
Uncontrolled Margin to Limit =	0.2171	mW/cm ²

ISED:

Corrected (including cal factors) Measurement:	27.15	dBm	
The Gain of the antenna:	8.80	dBi	
Type of Measurement:	Conducted		Direct measurement at Antenna Port
Impedance:	50.00	Ω	
Measuring Distance:	0.00	m	
Time weighted Duty Cycle:	100.00	%	

The Power Out would be: 0.518800039 Watts
or: 518.80004 mW
or: 518800.04 μ W
or: 27.15 dBm

Frequency range from 10 MHz to 40 GHz:

Frequency:	5.755	GHz
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Power output with DC and antenna Gain (EIRP):

Power (dBm):	35.95
Power (mW):	3935.501
Power (W):	3.935501

R = distance in	20	cm
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IC:

Controlled Exposures to Limit =	48.96873787	W/m ²
Uncontrolled Exposures Limit =	9.721884912	W/m ²
Pd =	7.829430	W/m ²
Controlled Margin to Limit =	41.1393	W/m ²
Uncontrolled Margin to Limit =	1.8925	W/m ²

1.3.6 RF Exposure value when 1 radio operating in the UNII band (Beamforming Mode)

Beamforming Mode Exposure result (FCC)

Frequency (MHz)	Power Density (mW/cm ²)	
* 5755	0.78	
	0.78	Total Power Density (mW/cm²)
	1.00	Uncontrolled Exposure Limit (mW/cm²)
	-0.22	Margin (mW/cm²)
Note: 1. * = worst case in the UNII band 2. Minimum distance from the user must be at 20 cm		

Beamforming Mode Exposure result (ISED)

Operating Frequency (MHz)	Power Density (W/cm ²)	Limit (W/cm ²)	Ratio	
* 5755	7.83	9.72	0.81	
			0.81	Σ ratio
Note: 1. The MPE calculation for simultaneous transmission is less than 1. 2. * = worst case in the UNII band 3. Minimum distance from the user must be at 20 cm				

As originally tested, the EUT was found to be compliant to the requirements of the test standard(s).
 FCC and ISED: Minimum distance from the user must be at 20 cm.

1.3.7 Sample Calculation

The Friss transmission formula: $P_d = (P_{out} * G) / (4 * \pi * R^2)$

Where;

P_d = power density in mW/cm²

P_{out} = output power to antenna in mW

G = gain of antenna in linear scale

$\pi \approx 3.1416$

R = distance between observation point and center of the radiator in cm

Ref. : David K. Cheng, *Field and Wave Electromagnetics*, Second Edition, Page 640, Eq. (11-133).