Intel® Model: 18265NGW

FCC ID: PD918265NG

Intel® Model 18265NGW Embedded Inside a notebook brand Dell Model P73G WiGig Subsystem with RFEM 3

Simulations and measurements Comparisons and Compliance Descriptions Report

January 2018

Revision 1.0

Intel

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List of Abbreviations

Table 1 – Abbreviations

Abbreviation	Definition
Ant	Antenna
Az	Azimuth
BB	Base Band
BF	Beam Forming
BT	Bluetooth
BW	Bandwidth
CPU	Central Processing Unit
El	Elevation
EM	Electro-Magnetic

Abbreviation	Definition
GHz	Gigahertz
IF	Intermediate Frequency
MAC	Media Access Control
M.2	M2: Formerly known as Next Generation Form Factor (NGFF); used as specification for connectors of the expansion cards mounted on computer
mmWave	Millimeter Wave
PC	Personal Computer
PCIe	Peripheral Component Interconnect Express; a PCI Special Interest Group standard
R&D	Research and Development
RF	Radio Frequency
RFEM 3	Third-generation Radio Front End Module
RFIC	Radio Frequency Integrated Circuit
RX	Receive
SKU	Stock Keeping Unit, specific product model version
SoC	System-on-Chip
TDM	Time Division Multiplexing
TPC	Transmit Power Control
T/R SW	Transmit/Receive Switch
TX	Transmit
WiGig	Wireless Gigabit Alliance – the alliance that promoted the 60GHz into 802.11ad standard.

Terms and Definitions

- **Subset:** A predefined group of radiating elements that are excited simultaneously with same amplitude and possibly different phases. There are three Subsets, and each one of them includes between 10 to 12 of the 24 elements of RFEM 3. The Subsets are also called Sub-Arrays.
- **Beamforming Code:** A configuration of phase-shifter values for all of the elements in a specific Subset. The Beamforming Code is used in order to direct the antenna to a desired spatial direction.
- **Sector:** A predefined set of Beamforming Codes, used for automatic selection of the Subset to be used.

1 Document Scope

1.1 Introduction

This report is submitted to support the compliance with the FCC rule located in Title 47 of the Code of Federal Regulations (CFR), parts §2.1093 and §15.255(f), of Intel 18265NGW WiGig module (FCC ID: PD918265NG), including an active antenna array, embedded inside the Dell model P73G.

Per the location of the active antenna array (a.k.a. RFEM 3) in the Dell model P73G platform, the distance between the antenna arrays to the body of an end user, at the closest contact point, will be in the near field.

In order to prove that during typical use the energy goes in most cases away from the human body, several tests of beamforming behavior were performed under different use cases conditions. The results are presented in document [3].

These tests are supported by a determination of the near-field power average density performed using an EM simulation supported by a near field measurement. An EM simulation that includes the RFEM 3 transmitter model embedded inside the Dell model P73G is used to determine the worst case configuration and the correspondent near field power density. This worst case power density is considered as a conservative case because the energy is always oriented toward the human body, this latter is also supported by near field measurements.

Due to the range of variations and uncertainty introduced by measurement and simulation, the results can only be applied to supplement each other, in conjunction with the beamforming mitigation results, through qualitative comparison and extrapolation to establish compliance at the device surface.

The simulation method and the simulation results are described in the document [3]. The near field measurement system details are described in the document [2] and the comparison between simulation and measurement are shown in this document.

1.2 Associated Documents

This ‘Simulations and Measurements Comparisons and Compliance Descriptions Report’ and documents called reference [1] and [2] are not confidential; relevant details and explanations that qualify for confidentiality are included separately in the operational description document called reference [1].

[1] "161114-Dell P73G Theory of Operation Report".

[2] "161114 - Dell P73G Near Field Measurement Report".

[3] "161114 - Dell P73G MPE Simulation Report".

2 Near-Field Measurements supporting the RF Exposure Power Density simulations

2.1 Introduction

In this section, the near field power density measurement performed using the worst case antenna phases found by simulation is presented. This near field measurement supports the simulation presented in [3]. Indeed, because the measurement results are unavailable at distances closer than 2 mm, the comparison between simulation and measurement is performed at 5 mm from the evaluation plane.

A near-field RF exposure system from SPEAG is used to perform these measurements.

2.2 Probe Characteristics

The probe consist of two dipoles (0.8 mm length) optimally arranged with different angles (γ1 and γ2) to obtain pseudo-vector information, printed on glass substrate protected by high density foam that allows low perturbation of the measured field.

Three or more measurements are taken for different probe rotational angles, deriving the amplitude and polarization information.

The probe's characteristics are illustrated in Table 2

Table 2 – Near Field probe Characteristics

Frequency Range	**750 MHz – 110 GHz**[1]
Length	320 mm
Probe tip external diameter	8 mm
Probe's two dipoles length	0.9mm – Diode loaded
Probe's substrate	Quartz 0.9 x 20 x 0.18mm (εr=3.8)
Distance between diode sensors and probe's tip	1.5 mm
Axial Isotropy	±0.6 dB
Maximum operating E-field	3000 V/m
Lower E-field detection threshold	5 V/m @ 60 GHz
Minimum Mechanical separation between probe tip and a Surface	0.5mm
Calibration reference point	Diode Sensor

More details about the measurement system are found in reference [2].

[1] *The probe calibration range is 750 MHz – 90 GHz*

2.3 Total Field and Power Flux Density Reconstruction

Computation of the power density in general requires knowledge of the electric (E-) and magnetic (H-) field amplitudes and phases in the plane of incidence. Reconstruction of these quantities from pseudo-vector E-field measurements is feasible, as they are constrained by Maxwell's equations.

The reconstruction algorithm developed by the system manufacturer, together with the ability of the probe to measure extremely close to the source without perturbing the field, permits reconstruction of the E- and H-fields as well as of the power density on measurement plans located as near as 0.5mm away in the frequency band of 60 GHz.

The average of the reconstructed power density is evaluated over a circular area in each measurement plane. The area of the circle is defined by the user; the default is 1 cm^2.

2.4 Measurement configurations

The near field measurement is performed on the four highest maximum spatially averaged power density found among the eighteen calculated worst cases (3 channels x 3 subsets x 2 first worst-cases) showed in reference [3] - Table 11. The test configurations are summarized in Table 3.

Table 3 – Test Configurations

Measurement Configuration						
EUT	Dell Model P73G					
Measured cases	Four highest worst cases* found in simulation:					
		Subset	**Channel**	**Worst-case**	**Distance [mm]**	**Phase Config.***
	Case 1#	1	1	1	5	Ph #1
	Case 2#	1	2	1	5	Ph #2
	Case 3#	1	3	1	5	Ph #3
	Case 4#	1	1	2	5	Ph #10
	Case 5#	3	1	1	5	Ph #7
	Case 6#	3	2	1	5	Ph #8
Measurement Distances / Resolution	1.29 mm					
Scan Plan	4.23 x 4.23 cm^2					

* See Table 8 and Table 9 in reference [3]

2.5 Measurement results

Tables 4 to 9 show the comparison between simulation and measurement for the four measured worst-cases at 5 mm distances from the evaluation plane. Simulation and measurement are both peak phasors. All results are calculated at 100 % duty cycle.

Table 4 – Case 1#: Simulation Vs. test results @ 5 mm.

	Measurement Distance (mm)	Simulated	Measured	Max. Deviation (dB)
E-field (V/m)	5 mm	87.112	71.1753	1.755
H-field (A/m)	5 mm	0.252	0.204	1.835
Single-point PD (mW/cm^2)	5 mm	1.264	0.664	2.796
Average PD (mW/cm^2)	5 mm	0.445	0.3925	0.545

Table 5 – Case 2#: Simulation Vs. test results @ 5 mm.

	Measurement Distance (mm)	Simulated	Measured	Max. Deviation (dB)
E-field (V/m)	5 mm	91.506	78.3291	1.351
H-field (A/m)	5 mm	0.273	0.2632	0.318
Single-point PD (mW/cm^2)	5 mm	1.386	0.763	2.592
Average PD (mW/cm^2)	5 mm	0.442	0.3756	0.707

Table 6 – Case 3#: Simulation Vs. test results @ 5 mm.

	Measurement Distance (mm)	Simulated	Measured	Max. Deviation (dB)
E-field (V/m)	5 mm	86.99	75.2339	1.261
H-field (A/m)	5 mm	0.26	0.186	2.909
Single-point PD (mW/cm^2)	5 mm	1.354	0.69	2.928
Average PD (mW/cm^2)	5 mm	0.359	0.2907	0.916

Table 7 – Case 4#: Simulation Vs. test results @ 5 mm.

	Measurement Distance (mm)	Simulated	Measured	Max. Deviation (dB)
E-field (V/m)	5 mm	73.289	70.7634	0.305
H-field (A/m)	5 mm	0.213	0.2206	0.305
Single-point PD (mW/cm^2)	5 mm	0.823	0.7075	0.657
Average PD (mW/cm^2)	5 mm	0.339	0.2946	0.610

Table 8 – Case 5#: Simulation Vs. test results @ 5 mm.

	Measurement Distance (mm)	Simulated	Measured	Max. Deviation (dB)
E-field (V/m)	5 mm	87.811	83.0713	0.482
H-field (A/m)	5 mm	0.233	0.1984	1.396
Single-point PD (mW/cm^2)	5 mm	1.180	0.8084	1.643
Average PD (mW/cm^2)	5 mm	0.407	0.2370	2.348

Table 9 - Case 6#: Simulation Vs. test results @ 5 mm.

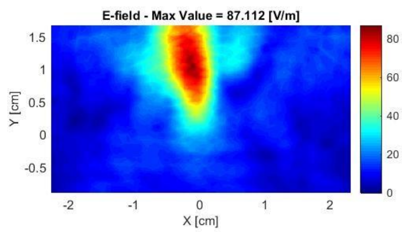
	Measurement Distance (mm)	Simulated	Measured	Max. Deviation (dB)
E-field (V/m)	5 mm	90.201	76.9413	1.381
H-field (A/m)	5 mm	0.244	0.2441	0.004
Single-point PD (mW/cm^2)	5 mm	1.113	0.8233	1.309
Average PD (mW/cm^2)	5 mm	0.400	0.3132	1.062

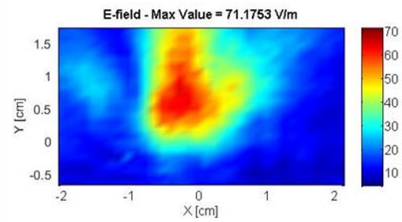
Figures below show the comparison at 5 mm from the evaluation plane, between the simulation and the near field measurement in terms of E-Field, H-Field, Single-point Power Density and Spatially Averaged Power Density at 100 % duty cycle for the six highest worst cases.

Note that the fields results presented in the figures below consider a peak phasor for electromagnetic fields **for both simulation and measurement.**

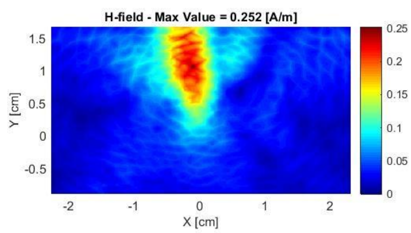
Case #1 - DISTANCE = 5 mm

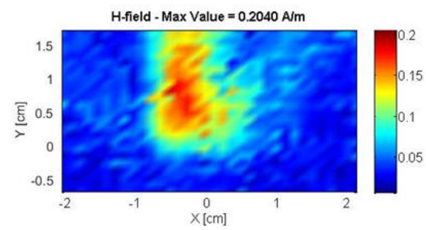
Simulated | **Measured**



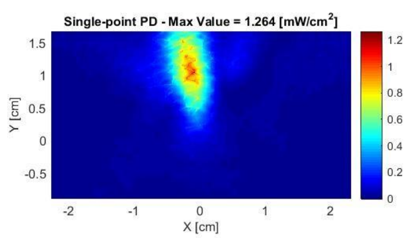


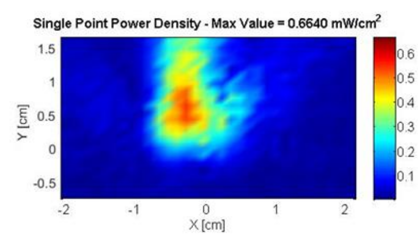
E-field (V/m) @ 5 mm – Deviation of Max Value: 1.755 dB



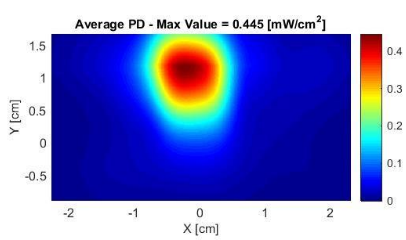


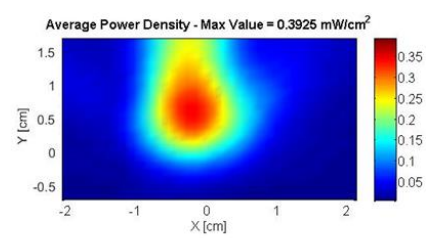
H-field (V/m) @ 5 mm – Deviation of Max Value: 1.835 dB





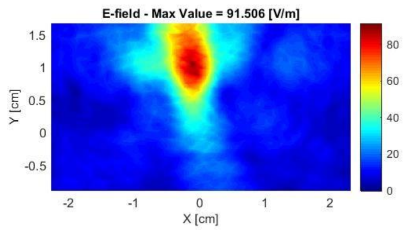
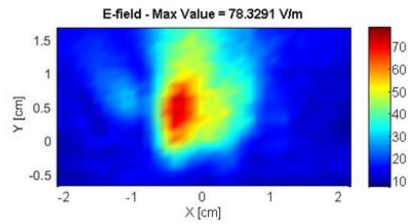
Localized free space PD (mW/cm2) @ 5 mm – Deviation of Max Value: 2.796 dB



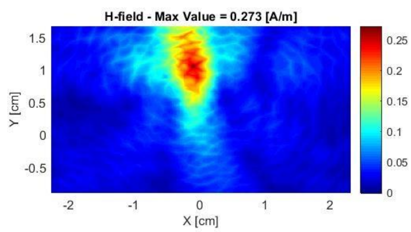
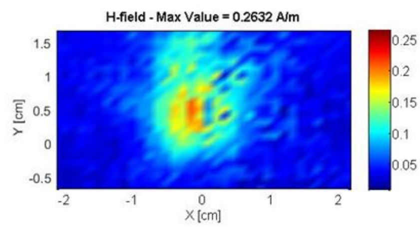


Spatially Averaged PD (mW/cm2) @ 5 mm – Deviation of Max Value: 0.545 dB

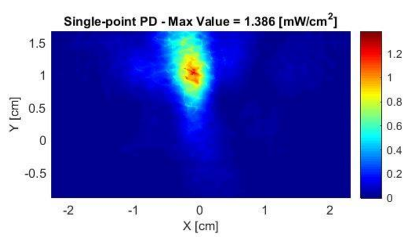
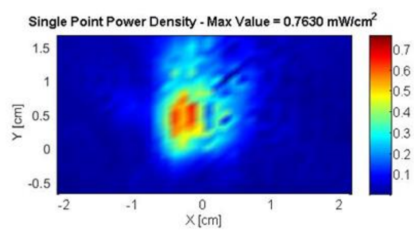
Case #2 - DISTANCE = 5 mm

Simulated	Measured
	

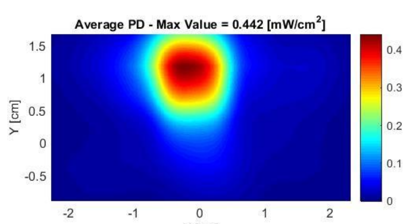
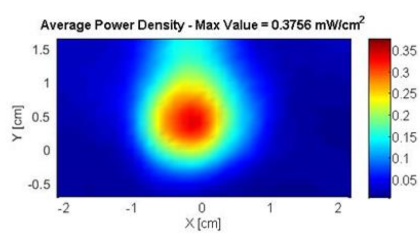
E-field (V/m) @ 5 mm – Deviation of Max Value: 1.351 dB

Simulated	Measured
	

H-field (V/m) @ 5 mm – Deviation of Max Value: 0.318 dB

Simulated	Measured
	

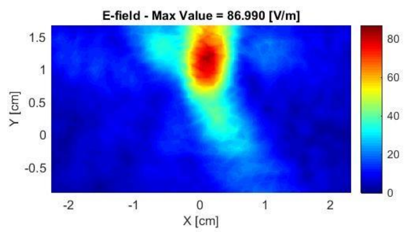
Localized free space PD (mW/cm2) @ 5 mm – Deviation of Max Value: 2.592 dB

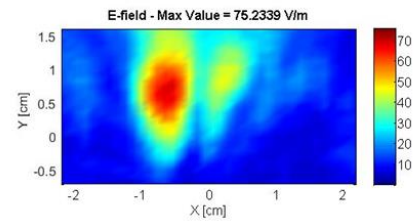
Simulated	Measured
	

Spatially Averaged PD (mW/cm2) @ 5 mm – Deviation of Max Value: 0.707 dB

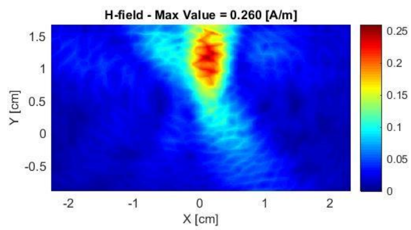
Case #3 - DISTANCE = 5 mm

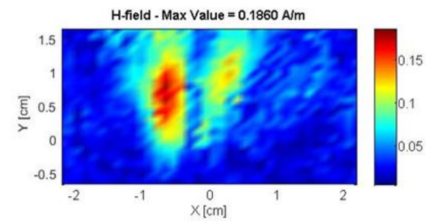
Simulated	Measured



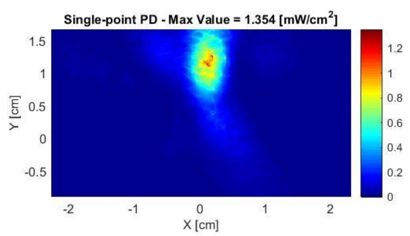


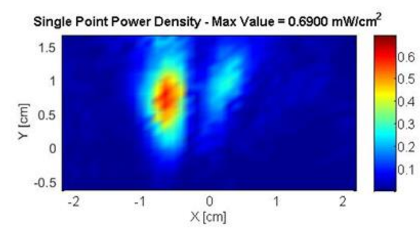
E-field (V/m) @ 5 mm – Deviation of Max Value: 1.261 dB



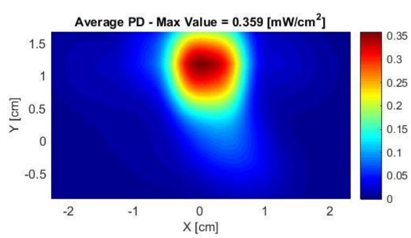


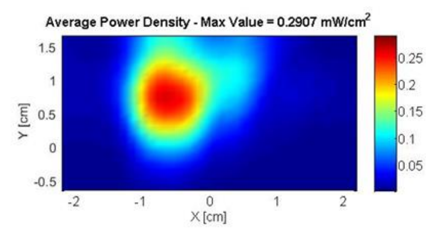
H-field (V/m) @ 5 mm – Deviation of Max Value: 2.909 dB





Localized free space PD (mW/cm2) @ 5 mm – Deviation of Max Value: 2.928 dB





Spatially Averaged PD (mW/cm2) @ 5 mm – Deviation of Max Value: 0.916 dB

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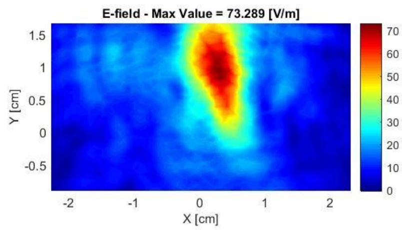
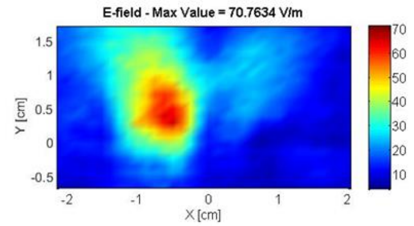
<tr><td>
</td><td>
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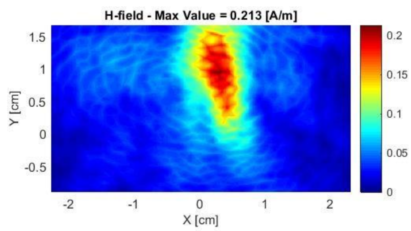
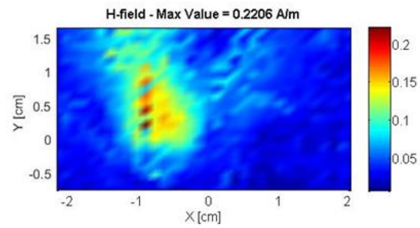
<tr><td>
</td><td>
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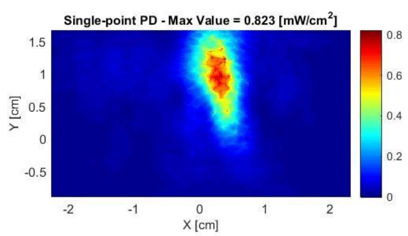
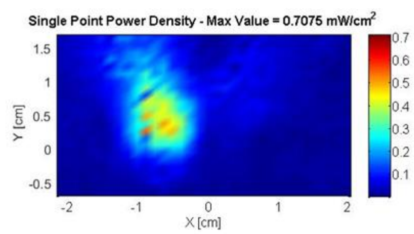
<tr><td>
</td><td>
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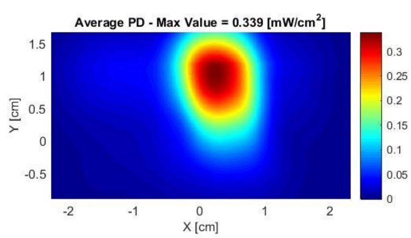
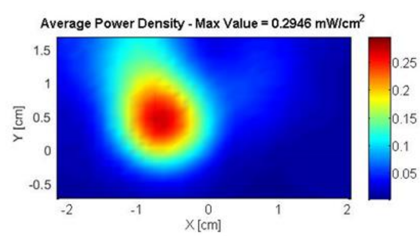
<tr><td>
</td><td>
</td></tr>
<tr><th colspan="2">Spatially Averaged PD (mW/cm2) @ 5 mm – Deviation of Max Value: 0.610 dB</th></tr>
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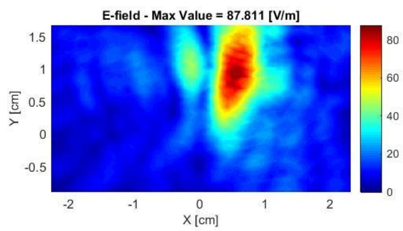
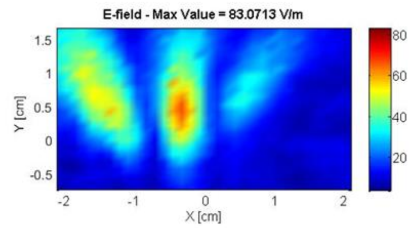
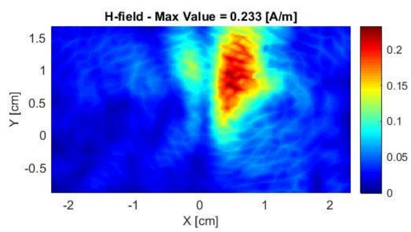
Case #5 - DISTANCE = 5 mm

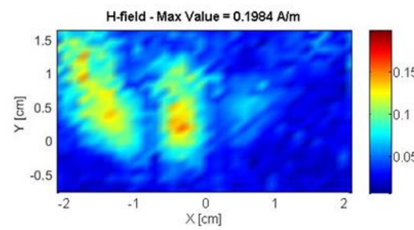
Simulated | **Measured**



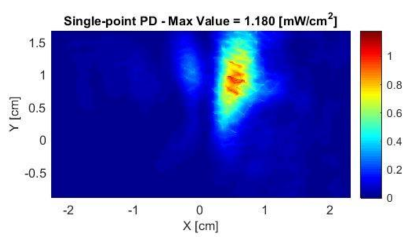


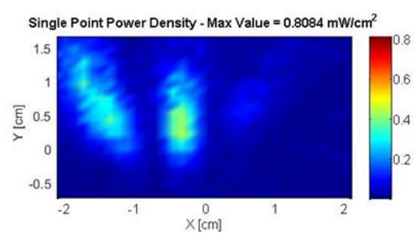
E-field (V/m) @ 5 mm – Deviation of Max Value: 0.482 dB



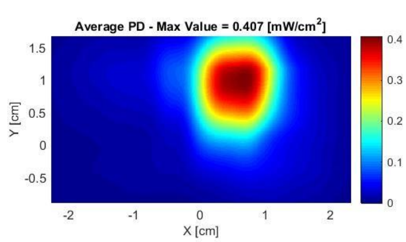


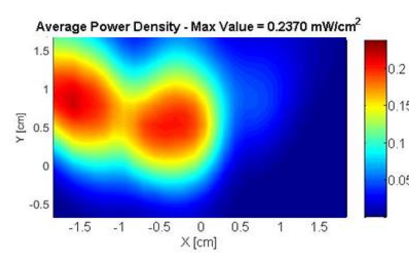
H-field (V/m) @ 5 mm – Deviation of Max Value: 1.396 dB





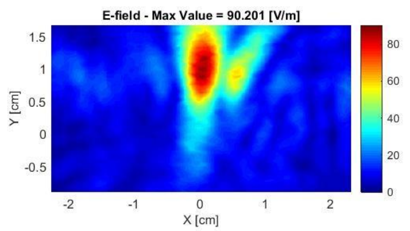
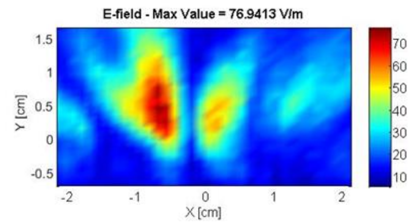
Localized free space PD (mW/cm2) @ 5 mm – Deviation of Max Value: 1.643 dB



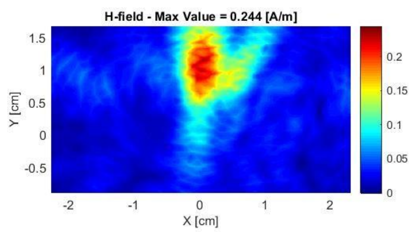
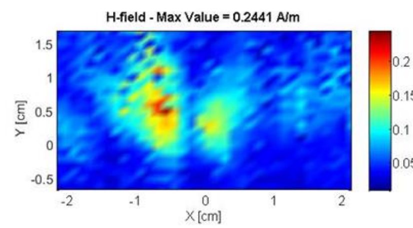


Spatially Averaged PD (mW/cm2) @ 5 mm – Deviation of Max Value: 2.348 dB

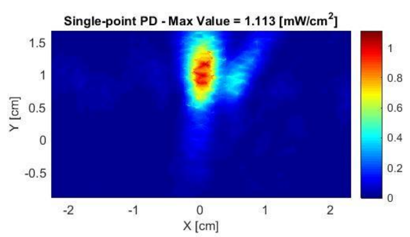
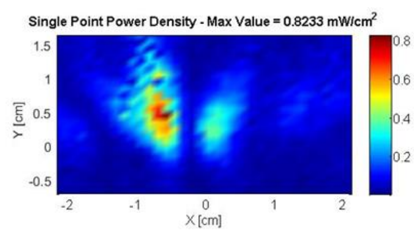
Case #6 - DISTANCE = 5 mm

Simulated	Measured
	

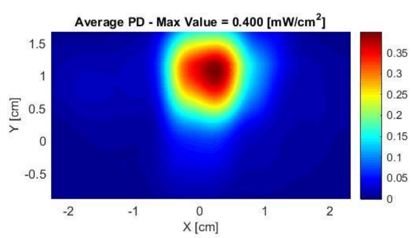
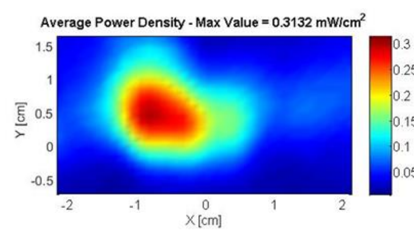
E-field (V/m) @ 5 mm – Deviation of Max Value: 1.381 dB

Simulated	Measured
	

H-field (V/m) @ 5 mm – Deviation of Max Value: 0.004 dB

Simulated	Measured
	

Localized free space PD (mW/cm2) @ 5 mm – Deviation of Max Value: 1.309 dB

Simulated	Measured
	

Spatially Averaged PD (mW/cm2) @ 5 mm – Deviation of Max Value: 1.062 dB

2.6 Conclusion

The near field measurement shows a good correlation with the near field simulation with a maximum deviation below 3 dB for the measured distances.

3 Compliance Assessment

The goal of the beamforming tests presented in chapter 3 of [3] is to determine the likelihood that energy would go towards or away from the human body during typical use.

It was demonstrated that in the vast majority of the cases, over typical usage/height/distances, the chosen subset directs energy away from the body.

As further supplemental compliance supporting information, numerical simulation results in Appendix A of document [3] show that worst case power density is below the RF exposure FCC limit.

The simulation results are supported by near field measurement using a near field probe. Because measurement results are unavailable at distances closer than 2 mm by probe limitation, the comparison between simulation and measurement is performed at 5 mm from the evaluation plane. The results were presented in this document.

Table 10 shows the simulated maximum spatially averaged power density, over 1cm^2 in the evaluation plane of the Intel 18265NGW module, embedded in the Dell model P73G.

Table 10 – Summary of simulation results for RF exposure compliance

Parameter	Value
Total conducted power	5.5 dBm
Maximum spatially averaged power density, over 1cm^2 - Simulation at 100% Duty Cycle	0.811 mW/cm^2
Maximum TX duty-cycle	70%
Maximum spatially averaged power density, over 1cm^2 - Simulation at 70% Duty Cycle	**0.567 mW/cm^2**

Therefore, with 0.567 mW/cm^2 spatially averaged power density value, Intel 18265NGW module, embedded in Dell model P73G, complies with FCC rule located in Title 47 of the Code of Federal Regulations (CFR) parts §2.1093 and §15.255(f).