Intel® Model: 18265NGW

FCC ID: PD918265NG

Intel® Model 18265NGW Embedded Inside a notebook brand Dell Model P29S WiGig Subsystem with RFEM 3

Simulations and measurements Comparisons and Compliance Descriptions Report

July 2018

Revision 1.0

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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

- **Sub-array:** A predefined group of radiating elements that are excited simultaneously with same amplitude and possibly different phases. There are three sub-arrays, and each one of them includes between, 10 to 12 of the 24 elements of RFEM 3.

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(g), of Intel 18265NGW WiGig module (FCC ID: PD918265NG), including an active antenna array, embedded inside the Dell model P29S.

Per the location of the active antenna array (a.k.a. RFEM 3) in the Dell model P29S 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 beam-forming 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 P29S 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 beam-forming 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 [2] and [3] are not confidential; relevant details and explanations that qualify for confidentiality are included separately in the operational description document called reference [1].

[1] "161006-Dell P29S - Theory of Operation Report".

[2] "161006-Dell P29S - Near Field Measurement Report".

[3] "161006-Dell P29S - 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 [2]. 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 0.5 mm 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 six highest maximum spatially averaged power density found among the thirty six calculated worst cases (3 channels x 3 sub-arrays x 2 first worst-cases x 2 evaluation planes) showed in reference [3]. The test configurations are summarized in Table 3.

Table 3 – Test Configurations

<table>
<tr><th colspan="7">Measurement Configuration</th></tr>
<tr><td>EUT</td><td colspan="6">Dell Model P29S</td></tr>
<tr><td rowspan="8">Measured cases</td><td colspan="6">Six highest worst cases* found in simulation:</td></tr>
<tr><td></td><td>Evaluation Plane</td><td>Sub-array</td><td>Channel</td><td>Worst-case</td><td>Phase Config.*</td></tr>
<tr><td>Case 1#</td><td>Edge</td><td>1</td><td>2</td><td>1</td><td>Ph1 #2</td></tr>
<tr><td>Case 2#</td><td>Edge</td><td>1</td><td>2</td><td>2</td><td>Ph1 #11</td></tr>
<tr><td>Case 3#</td><td>Base</td><td>3</td><td>2</td><td>1</td><td>Ph2 #8</td></tr>
<tr><td>Case 4#</td><td>Edge</td><td>3</td><td>2</td><td>1</td><td>Ph1 #8</td></tr>
<tr><td>Case 5#</td><td>Base</td><td>3</td><td>2</td><td>2</td><td>Ph2 #17</td></tr>
<tr><td>Case 6#</td><td>Base</td><td>1</td><td>2</td><td>1</td><td>Ph2 #2</td></tr>
<tr><td>Measurement Distances / Resolution</td><td colspan="6">5 mm / 1.24 mm</td></tr>
<tr><td>Scan Plan</td><td colspan="6">4.34 x 4.34 cm^2</td></tr>
</table>

* See Table 7, Table 8, Table 13 and Table 14 in reference [3]

2.5 Measurement results

Tables 4 to 9 show the comparison between simulation and measurement for the six 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	87.667	79.689	0.829
H-field (A/m)	5 mm	0.239	0.242	0.107
Single-point PD (mW/cm^2)	5 mm	1.177	0.698	2.267
Average PD (mW/cm^2)	5 mm	0.373	0.419	0.500

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

	Measurement Distance (mm)	Simulated	Measured	Max. Deviation (dB)
E-field (V/m)	5 mm	87.277	69.504	1.978
H-field (A/m)	5 mm	0.246	0.227	0.687
Single-point PD (mW/cm^2)	5 mm	1.143	0.582	2.936
Average PD (mW/cm^2)	5 mm	0.323	0.324	0.013

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

	Measurement Distance (mm)	Simulated	Measured	Max. Deviation (dB)
E-field (V/m)	5 mm	101.043	105.916	0.409
H-field (A/m)	5 mm	0.302	0.221	2.708
Single-point PD (mW/cm^2)	5 mm	1.703	1.105	1.878
Average PD (mW/cm^2)	5 mm	0.515	0.302	2.309

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

	Measurement Distance (mm)	Simulated	Measured	Max. Deviation (dB)
E-field (V/m)	5 mm	61.123	66.295	0.705
H-field (A/m)	5 mm	0.172	0.173	0.048
Single-point PD (mW/cm^2)	5 mm	0.591	0.531	0.470
Average PD (mW/cm^2)	5 mm	0.217	0.231	0.271

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

	Measurement Distance (mm)	Simulated	Measured	Max. Deviation (dB)
E-field (V/m)	5 mm	97.845	93.564	0.389
H-field (A/m)	5 mm	0.291	0.222	2.364
Single-point PD (mW/cm^2)	5 mm	1.458	1.034	1.491
Average PD (mW/cm^2)	5 mm	0.446	0.288	1.898

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

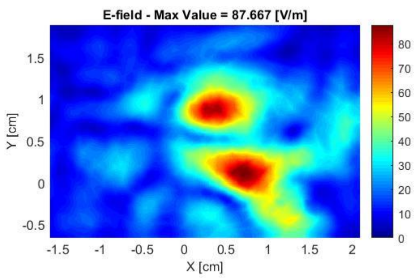
	Measurement Distance (mm)	Simulated	Measured	Max. Deviation (dB)
E-field (V/m)	5 mm	91.853	77.309	1.497
H-field (A/m)	5 mm	0.254	0.201	2.057
Single-point PD (mW/cm^2)	5 mm	1.291	0.766	2.265
Average PD (mW/cm^2)	5 mm	0.398	0.225	2.468

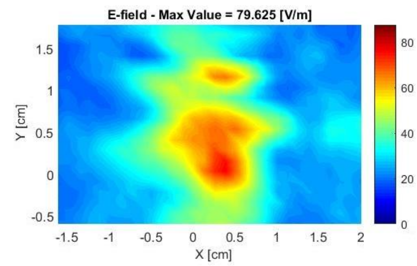
Figures below show the comparison at 5 mm from the evaluation plane, between the simulation and the near field measurement in terms of E-Field, H-Field, Single-point Power Density and Spatially Averaged Power Density at 100 % duty cycle for the six highest worst cases.

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

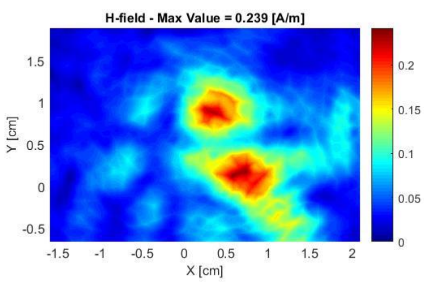
Case #1 - DISTANCE = 5 mm

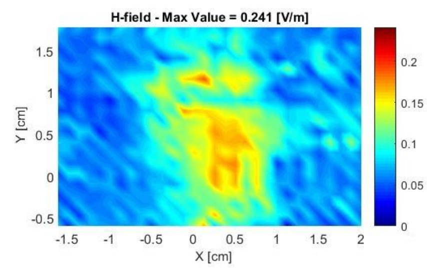
Simulated | **Measured**



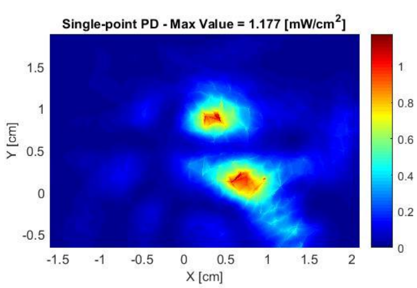


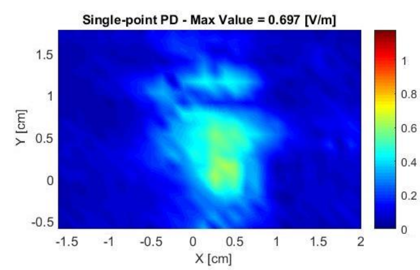
E-field (V/m) @ 5 mm – Deviation of Max Value: 0.829 dB



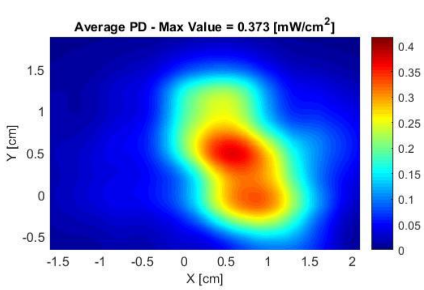


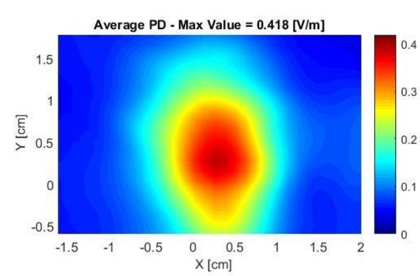
H-field (V/m) @5 mm – Deviation of Max Value: 0.107 dB





Localized free space PD (mW/cm2) @ 5 mm – Deviation of Max Value: 2.267 dB

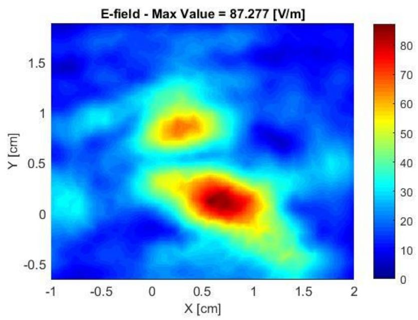


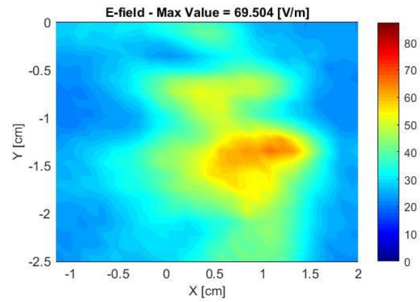


Spatially Averaged PD (mW/cm2) @ 5 mm – Deviation of Max Value: 0.500 dB

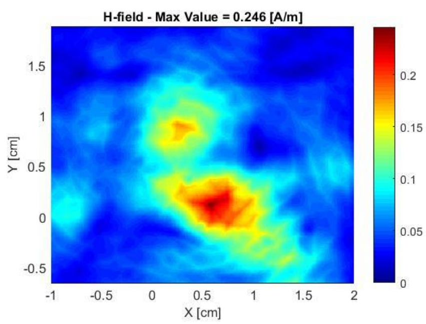
Case #2 - DISTANCE = 5 mm

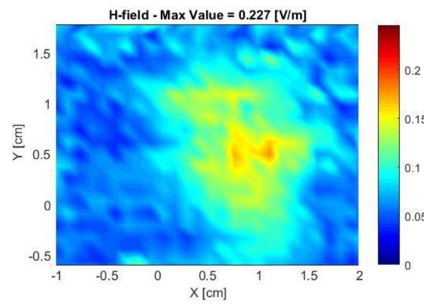
Simulated	Measured



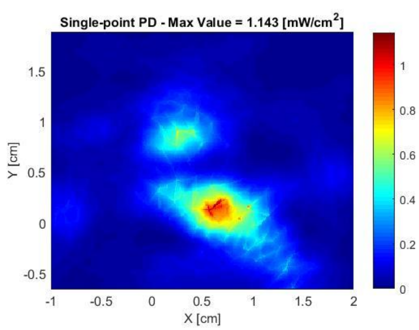


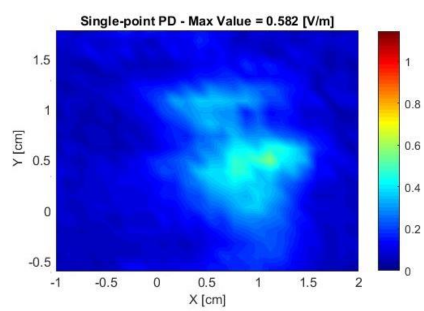
E-field (V/m) @ 5 mm – Deviation of Max Value: 1.978 dB



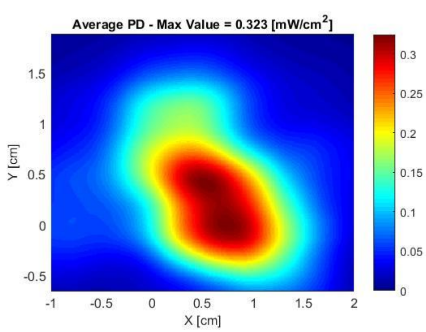


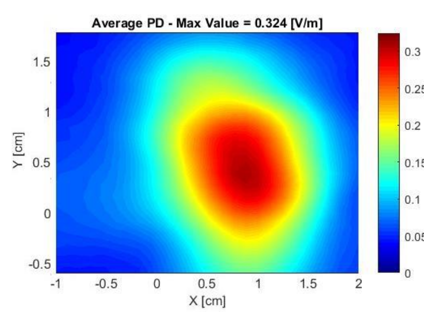
H-field (V/m) @5 mm – Deviation of Max Value: 0.687 dB





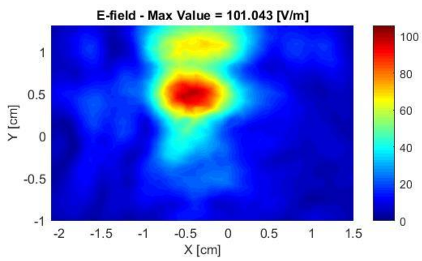
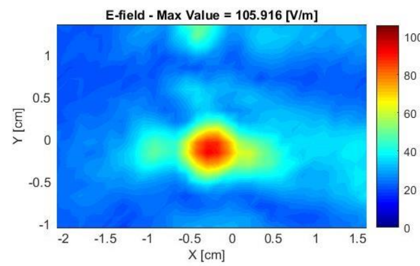
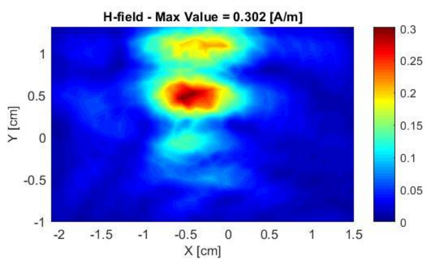
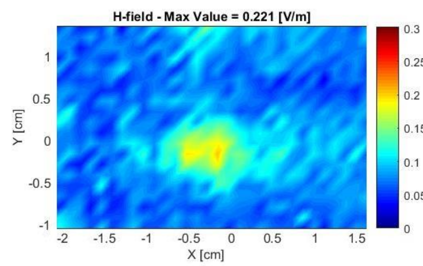
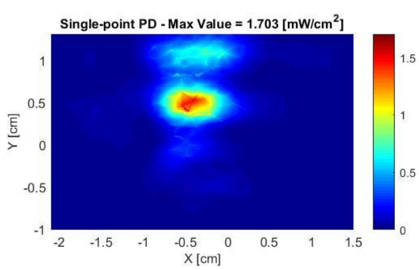
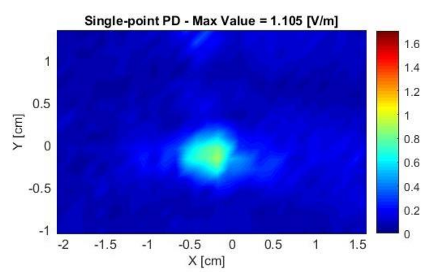
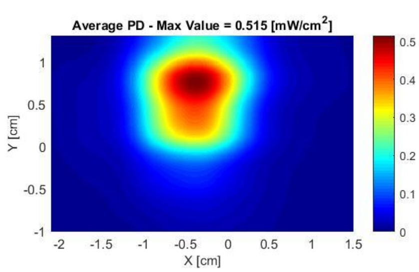
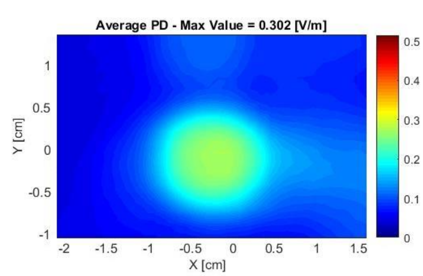
Localized free space PD (mW/cm2) @ 5 mm – Deviation of Max Value: 2.936 dB





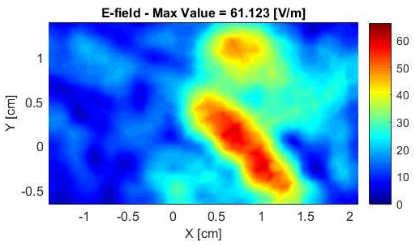
Spatially Averaged PD (mW/cm2) @ 5 mm – Deviation of Max Value: 0.013 dB

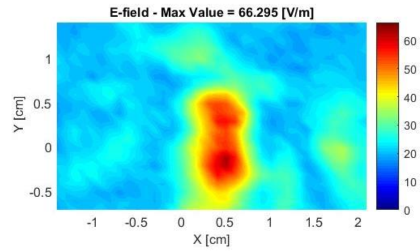
Case #3 - DISTANCE = 5 mm

Simulated	Measured
	
E-field (V/m) @ 5 mm – Deviation of Max Value: 0.409 dB	
	
H-field (V/m) @5 mm – Deviation of Max Value: 2.708 dB	
	
Localized free space PD (mW/cm2) @ 5 mm – Deviation of Max Value: 1.878 dB	
	
Spatially Averaged PD (mW/cm2) @ 5 mm – Deviation of Max Value: 2.309 dB	

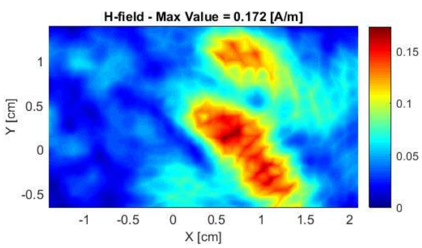
Case #4 - DISTANCE = 5 mm

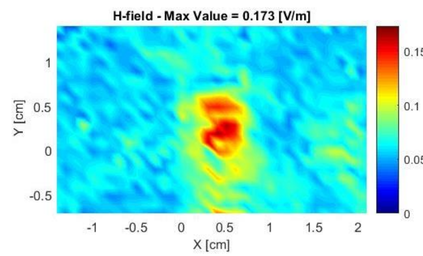
Simulated | **Measured**



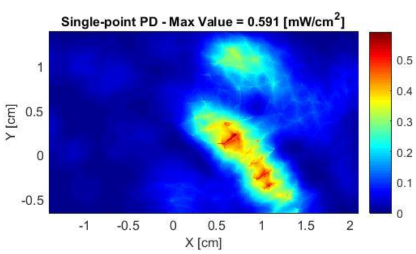


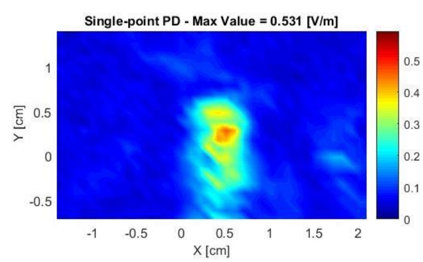
E-field (V/m) @ 5 mm – Deviation of Max Value: 0.705 dB



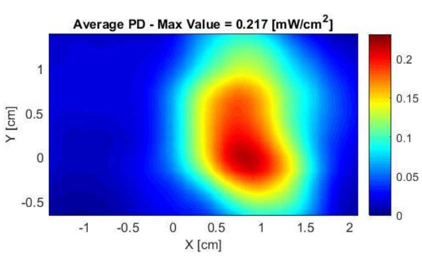


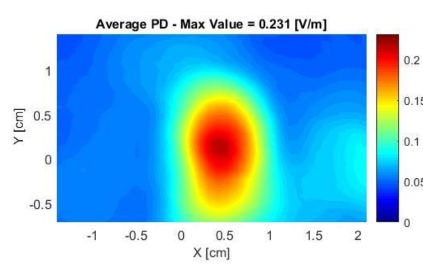
H-field (V/m) @5 mm – Deviation of Max Value: 0.048 dB



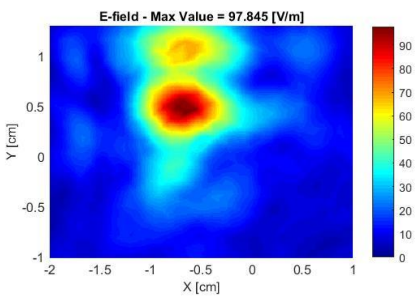
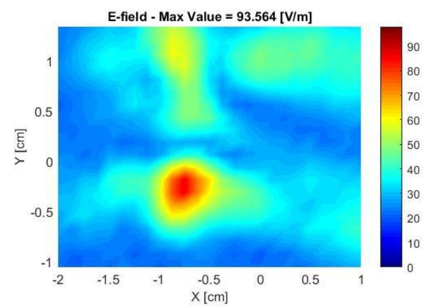


Localized free space PD (mW/cm2) @ 5 mm – Deviation of Max Value: 0.470 dB





Spatially Averaged PD (mW/cm2) @ 5 mm – Deviation of Max Value: 0.271 dB

<table>
<tr><th colspan="2">Case #5 - DISTANCE = 5 mm</th></tr>
<tr><th>Simulated</th><th>Measured</th></tr>
<tr><td>
</td><td>
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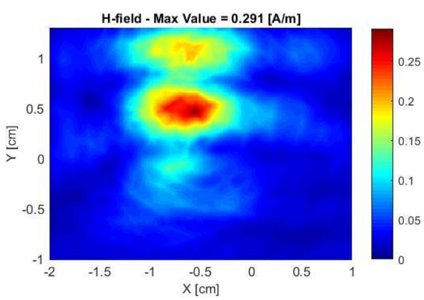
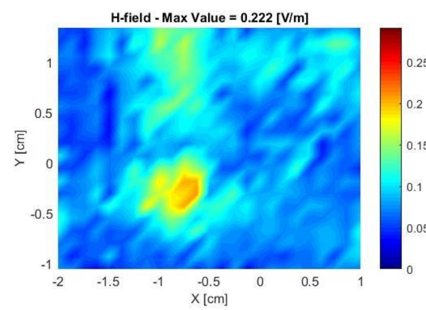
<tr><td colspan="2">E-field (V/m) @ 5 mm – Deviation of Max Value: 0.389 dB</td></tr>
<tr><td>
</td><td>
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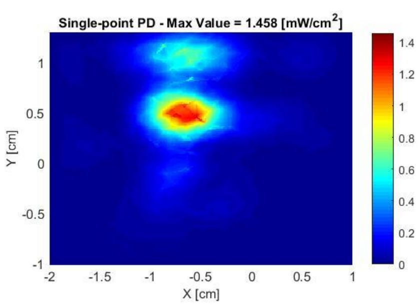
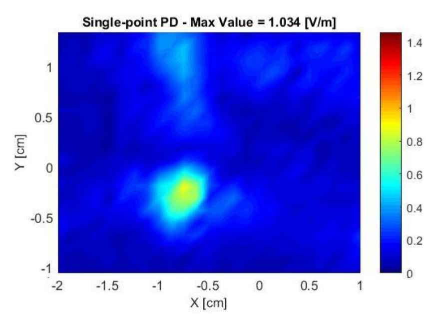
<tr><td colspan="2">H-field (V/m) @5 mm – Deviation of Max Value: 2.364 dB</td></tr>
<tr><td>
</td><td>
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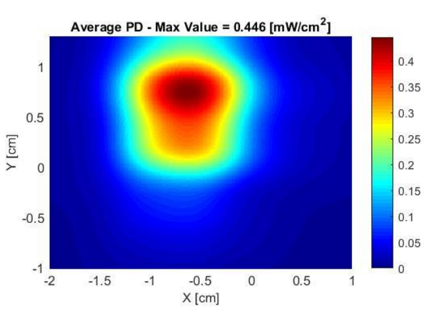
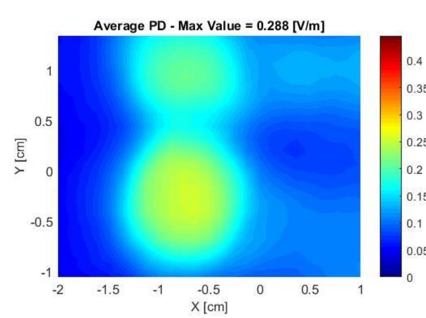
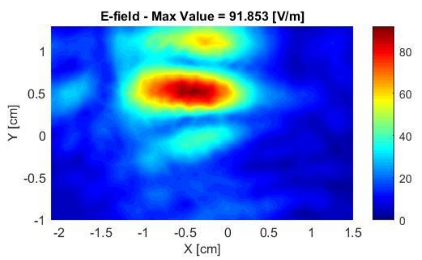
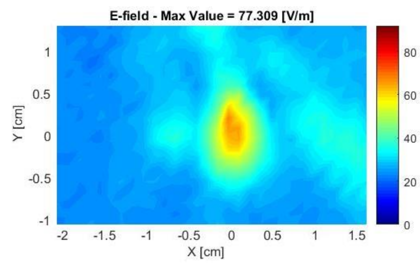
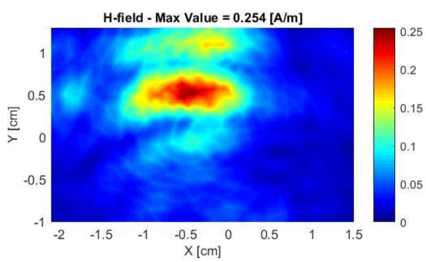
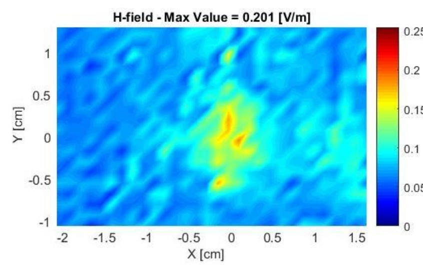
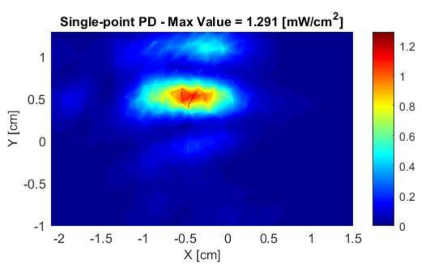
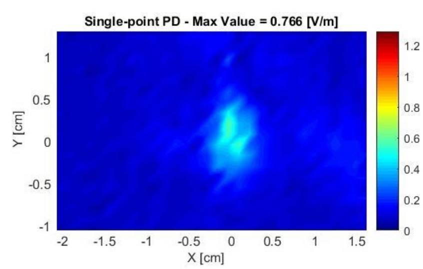
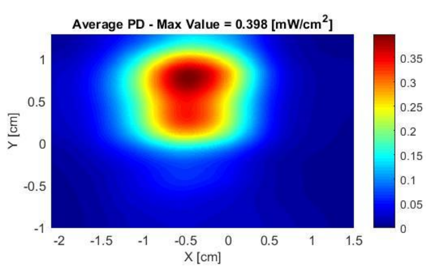
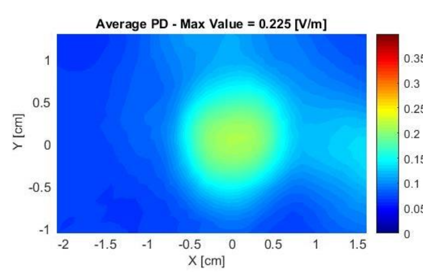
<tr><td colspan="2">Localized free space PD (mW/cm2) @ 5 mm – Deviation of Max Value: 1.491 dB</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td colspan="2">Spatially Averaged PD (mW/cm2) @ 5 mm – Deviation of Max Value: 1.898 dB</td></tr>
</table>

Case #6 - DISTANCE = 5 mm	
Simulated	**Measured**
	
E-field (V/m) @ 5 mm – Deviation of Max Value: 1.497 dB	
	
H-field (V/m) @5 mm – Deviation of Max Value: 2.057 dB	
	
Localized free space PD (mW/cm2) @ 5 mm – Deviation of Max Value: 2.265 dB	
	
Spatially Averaged PD (mW/cm2) @ 5 mm – Deviation of Max Value: 2.468 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 beam-forming 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 sub-array 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 P29S.

Table 10 – Summary of simulation results for RF exposure compliance

Parameter	Value
Total conducted power	6.0 dBm
Maximum spatially averaged power density, over 1cm^2 - Simulation at 100% Duty Cycle	0.794 mW/cm^2
Maximum TX duty-cycle	70%
Maximum spatially averaged power density, over 1cm^2 - Simulation at 70% Duty Cycle	**0.556 mW/cm^2**

Therefore, with 0.556 mW/cm^2 spatially averaged power density value, Intel 18265NGW module, embedded in Dell model P29S, complies with FCC rule located in Title 47 of the Code of Federal Regulations (CFR) parts §2.1093 and §15.255(g).