TESTING CERT #3478.01

TEST REPORT

EUT Description	**Wireless Gigabit radio installed in a Hewlett-Packard convertible 2 in 1 laptop**
Brand	**Intel® Tri-Band Wireless-AC 18260**
Model	**Platform Hewlett-Packard HSTNN-I72C/ Intel module 18260NGW**
Serial Number	**Host Laptop: 75812S205C** (see section 4)
FCC/IC ID	**FCC ID: PD918260NG**
Hardware/Software Version	**Test SW: DRTU version 1.8.3-01557** **Driver ver.: 2.1.0.74**
Date of Sample Receipt	**2015-11-19**
Date of start/end of Tests	**Start : 2015-11-23 End: 2016-01-11**
Features	**Module: WiGig + 802.11 a/b/g/n/ac WLAN + BDR/EDR 2.1 + BLE 4.0** **Host: Hewlett-Packard HSTNN-I72C** (see section 5)

Applicant	**Intel Mobile Communications**
Address	**100 Center Point Circle, Suite 200** **Columbia, South Carolina 29210** **USA**
Contact Person	**Steven Hackett**
Telephone/Fax/ Email	**steven.c.hackett@intel.com**

Reference Standards	**FCC CFR Title 47 Part 15.255** (see section 1)

Test Report number	**15112601.TR01**
Revision Control	**Rev. 02**
Date of issue	**2016-02-04**

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Digitally signed by Walid EL HAJJ Date: 2016.02.04 19:06:10 +01'00'	Digitally signed by Nawfal Asrih DN: cn=Nawfal Asrih, o=Intel Mobile Communications, ou=Intel WRF Lab, email=nawfal.asrih@intel.com, c=FR Date: 2016.02.04 19:03:36 +01'00'
Walid EL HAJJ (Test Operator)	Asrih NAWFAL (Laboratory Manager)

Table of Contents

1. Standards, reference documents and applicable test methods

1. FCC 47 CFR part 2 – Subpart C – §15.255 Operation within the band 57-64 GHz.

2. General conditions, competences and guarantees

- ✓ Intel Mobile Communications Wireless RF Lab (Intel WRF Lab) is a testing laboratory accredited by the American Association for Laboratory Accreditation (A2LA).
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3. Environmental Conditions

- ✓ At the site where the measurements were performed the following limits were not exceeded during the tests:

Temperature	24ºC ± 2ºC
Humidity	54% ± 5%

4. Test samples

Sample	Control #	Description	Model	Serial #	Date of reception
#01	15111901.S01	Laptop	Hewlett-Packard HSTNN-I72C	75812S205C	2015-11-19
	15111901.S02	AC/DC Adapter	TPN-CA01	WFCQP2AHH8X1Q9	2015-11-19

5. EUT features

These are the detailed bands and modes supported by the equipment under Test:

WiGig	60GHz (58.320 – 62.640 GHz)
802.11b/g/n	2.4GHz (2400.0 – 2483.5 MHz)
802.11a/n/ac	5.2GHz (5150.0 – 5350.0 MHz) 5.6GHz (5470.0 – 5725.0 MHz) 5.8GHz (5725.0 – 5850.0 MHz)
BDR/EDR v2.1 Bluetooth LE v4.0	2.4GHz (2400.0 – 2483.5 MHz)

6. Remarks and comments

1. This report documents the results of radiated measurements of the EIRP and the resulting power density of a radio device operating in the 60 GHz unlicensed band.

7. Test Verdicts summary

N/A

8. Document Revision History

Revision #	Date	Modified by	Details
Rev. 00	2015-12-04	W. El Hajj	First Issue
Rev. 01	2016-01-19	W. El Hajj	Modifications to address FCC comments
Rev. 02	2016-02-04	W. El Hajj	Modifications to address FCC comments

Annex A. Test & System Description

A.1 Test Conditions

The EUT is an Intel Wireless Gigabit radio model 18260NGW, FCC ID PD918260NG, installed in a Hewlett-Packard HSTNN-I72C convertible 2 in 1 laptop.

The antenna is an integral phased array antenna with a maximum gain of 15.45 dBi.

The DUT was set to transmit at highest radiated power on MCS1 (see Table below) with a nominal 50% duty cycle using proprietary software (Intel DRTU version 1.8.3-01557).

Channel	Maximum EIRP (dBm)
1	15.89
2	16.55
3	14.14

As will be detailed in section B.1, the total (actual measured) duty cycle is the combination (multiplication) of the "Duty Cycle over Burst" with the "Duty Cycle within Burst" as shown by the respective duty cycles plots:
- The Duty Cycle Over Burst Period is 50% (measured: 49.5%).
- The Duty Cycle Within Burst is 98% (measured: 97.5 %)

Therefore total duty cycle is the combination of these so is around 48%

A.2 Measurement system

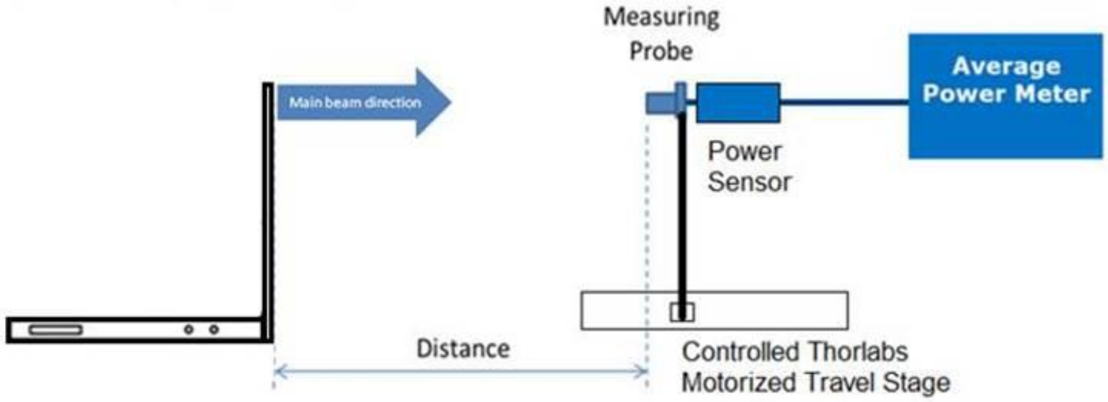
A Thorlabs Motorized Travel Stage controlled by software is used to maintain a consistent and accurate placement of the probe.

Absorber material covering up to 110GHz is placed around the support structures and alignment fixture to reduce reflections, scattering and perturbations.

The Aperture Probe is aligned with the boresight of the EUT antenna. The probe is scanned over X / Y / Polarization to maximize the emissions level.

The DUT's radiated power is measured using the average power meter connected to the power sensor and measuring probe, and recorded for all channels. The Power density and EIRP are then calculated according to the test procedure described in B.2.

The measurement distance is varied from 3 to 19 cm in 1-cm steps and the power and results of subsequent calculations are recorded for each distance. The distance corresponds to the separation between the glass surface of the EUT and the aperture plane of the probe.



A.3 Test Equipment List

ID#	Device	Type/Model	Serial Number	Manufacturer	Cal. Date	Cal. Due Date
0014	Power Sensor (DC -67 GHz)	NRP-Z57	00152266	Rohde & Schwarz	2015-05-06	2017-05-06
0012	Power Meter (Monitoring)	NRP-2	101567	Rohde & Schwarz	Calibration Not Required	
0015	Spectrum analyzer	FSU67	100092	Rohde & Schwarz	2015-07-31	2017-07-31
0016	Signal Generator	SMF100A	102117	Rohde & Schwarz	2014-03-11	2016-03-11
0066	Standard Horn Antenna	FH-SG-075-25	20012	RPG	Calibration Not Required	
0331	Aperture Probe antenna	15EWG1.85	J215060133	A-Info	Characterized Internally	
0063	MULTIPLIER ASSEMBLY 40-220GHz	AFM-40-220	394	RPG	Calibration Not Required	

Note: The Duty cycle is measured using the FSU67 spectrum analyzer and a standard horn antenna. The FSU67 covers (20Hz-67GHz) frequency range, therefore the measurement is performed directly without a need to an external mixer.

A.4 Measurement Uncertainty Evaluation

The Total Measurement Uncertainty is **1.26 dB.** This value is obtained by calculating first the Aperture Probe Gain Measurement Uncertainty (see A.4.1) and then using this value with the other uncertainty sources to deduce the total Uncertainty (see A.4.2).

A.4.1 Aperture Probe Gain Characterization

3 Antennas Gain Method / Probe Characterization

Source of Uncertainty	Value [dB]	Probability Distribution	Divisor	Sensitivity Coefficient	Standard Uncertainty [dB]
Mismatch VSWR SG Block 1.1 - TR 1.5	0.08	U-shaped	1.414	1	0.06
Mismatch VSWR TR 1.5 - PM 1.35	0.26	U-shaped	1.414	1	0.18
Insertion Loss transition	0.40	rectangular	1.732	1	0.23
Mismatch VSWR SG Block 1.1 - Antenna Block 1.1	0.02	U-shaped	1.414	1	0.01
Mismatch VSWR Antenna Block 1.1 - TR 2	0.14	U-shaped	1.414	1	0.10
Mismatch VSWR TR 2 - PM 1.35	0.44	U-shaped	1.414	1	0.31
Position of the phase centre (Receiving Ant.)	0.13	rectangular	1.732	1	0.08
Linearity (included in Repeatability)	0.000	rectangular	1.732	1	0.00
Zero Offset	0.211	rectangular	1.732	1	0.12
Repeatability (Relative Power Meas.)	0.01	rectangular	1.732	1	0.01
Meas Noise	0.043	rectangular	1.732	1	0.02
				Combined Standard Uncertainty	0.47
				Expanded Uncertainty (k=2)*	**0.93**

A.4.2 EUT Measurement.

Source of Uncertainty	Value [dB]	Probability Distribution	Divisor	Sensitivity Coefficient	Standard Uncertainty [dB]
Meas. Antenna Gain Rx Aperture Probe	0.93	Normal k=2	2	1	0.47
Mismatch VSWR Block Antenna 2 - PM 1.35	0.44	U-shaped	1.414	1	0.31
Power Meter Accuracy	0.25	rectangular	1.732	1	0.14
Range Length (near/far field condition)	0.00	rectangular	1.732	1	0.00
Position of the phase center (Receiving Ant.)	0.13	rectangular	1.732	1	0.08
Ambient temperature impact	0.10	normal	1	1	0.10
Repeatability	0.20	normal	1	1	0.20
Zero Offset	0.144	rectangular	1.732	1	0.08
Meas Noise	0.019	rectangular	1.732	1	0.01
				Combined Standard Uncertainty	0.63
				Expanded Uncertainty (k=2)*	***1.26***

SG : Signal Generator TR : Transition PM : Power Meter

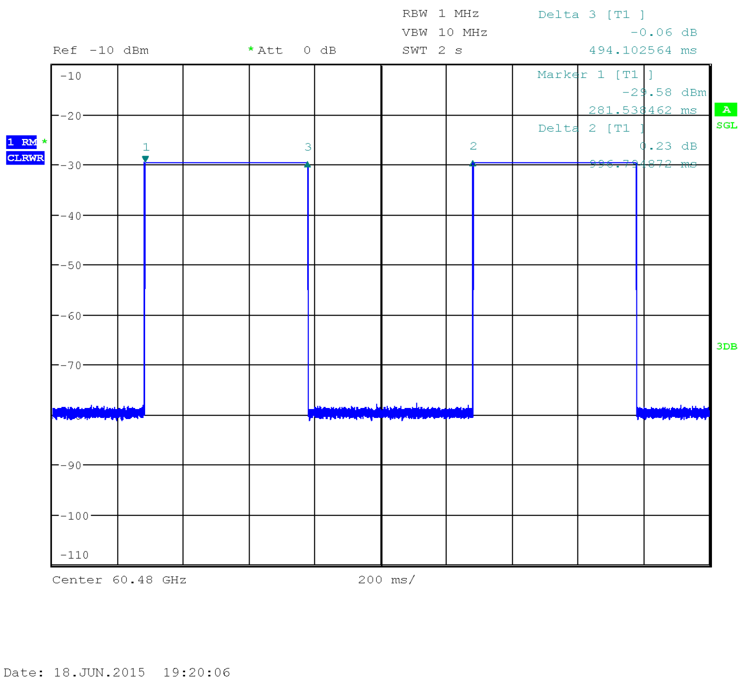
* The expanded Measurement Uncertainty with coverage factor (k=2) corresponds to a confidence level of 95%.

A.5 Power Sensor Consideration and Pulse Response

The averaging settings of the power meter / power sensor combination must be adjusted to respond properly to the modulation bursts and burst period.

The power sensor is connected to the microwave signal generator. The output frequency of the generator is set to 60.48 GHz corresponding to EUT channel 2. The generator is adjusted for pulse modulation using the nominal timing values for the Duty cycle across the Burst Period (500 msec ON, 1000 msec Period). The Duty cycle is verified by measurement (see figure below) using the FSU67 spectrum analyzer.

Description	ON Time (ms)	Period (ms)	Duty Cycle Linear	Duty Cycle Correction (dB)
Nominal Duty Cycle over Burst Period	500	1000	0.5	3
Measured Nominal Duty Cycle over Burst Period	494.102564	996.794872	0.4957	3.0479



The power meter averaging number is then adjusted to provide a stable measurement (after the published settling time has elapsed).
Pulse modulation is then turned off, the delta between Modulation OFF and ON is measured, and compared to the expected measured value of 10 * Log (Measured Nominal duty cycle across Burst period) = 3.0479 dB.

An averaging number of 64000 provided measurements stable to within approximately 0.018 dB (3.0479-3.03dB) for the EUT's nominal pulse characteristics documented above. The power sensor showed a measured difference of 3.03 dB, between CW and modulated.

Description	Pulse Modulation OFF	Pulse Modulation ON	Measured Difference (dB)
Average Power (dBm)	-29.63	-32.66	3.03

Note: The output average level of the mm-Wave generator is adjusted to be similar to the lowest power value obtained during the EIRP measurement. This confirms the measurement averaging stability at the measured power levels.

Annex B. Test Results

B.1 Duty Cycle

Test procedure

Duty cycle is calculated as *[(ON Time)/Period].*

The Duty cycle within the Burst is multiplied by the Duty cycle over the Burst Period to derive the Duty Cycle.

The duty cycle of the EUT modulation is measured, and used to provide the duty cycle correction factor.

*Duty Cycle Correction Factor = 10*Log(Duty Cycle)*

Where:
Duty Cycle Correction Factor is (dB)
Duty Cycle is (Linear)

The Duty cycle is measured using the FSU67 spectrum analyzer and a standard horn antenna. The FSU67 covers (20Hz-67GHz) frequency range. Therefore the measurement is performed directly without a need to an external mixer.

Results tables

Channel 1

Description	ON Time (ms)	Period (ms)	Duty Cycle Linear
Duty Cycle Within Burst	1.991506	2.060417	0.967
Duty Cycle over Burst period	496.564103	1002.974	0.495
Duty Cycle			0.47853

Duty Cycle Correction (dB)	3.2009

Channel 2

Description	ON Time (ms)	Period (ms)	Duty Cycle Linear
Duty Cycle Within Burst	1.998397	2.046635	0.976
Duty Cycle over Burst period	493.358974	999.769231	0.493
Duty Cycle			0.48184

Duty Cycle Correction (dB)	3.1710

Channel 3

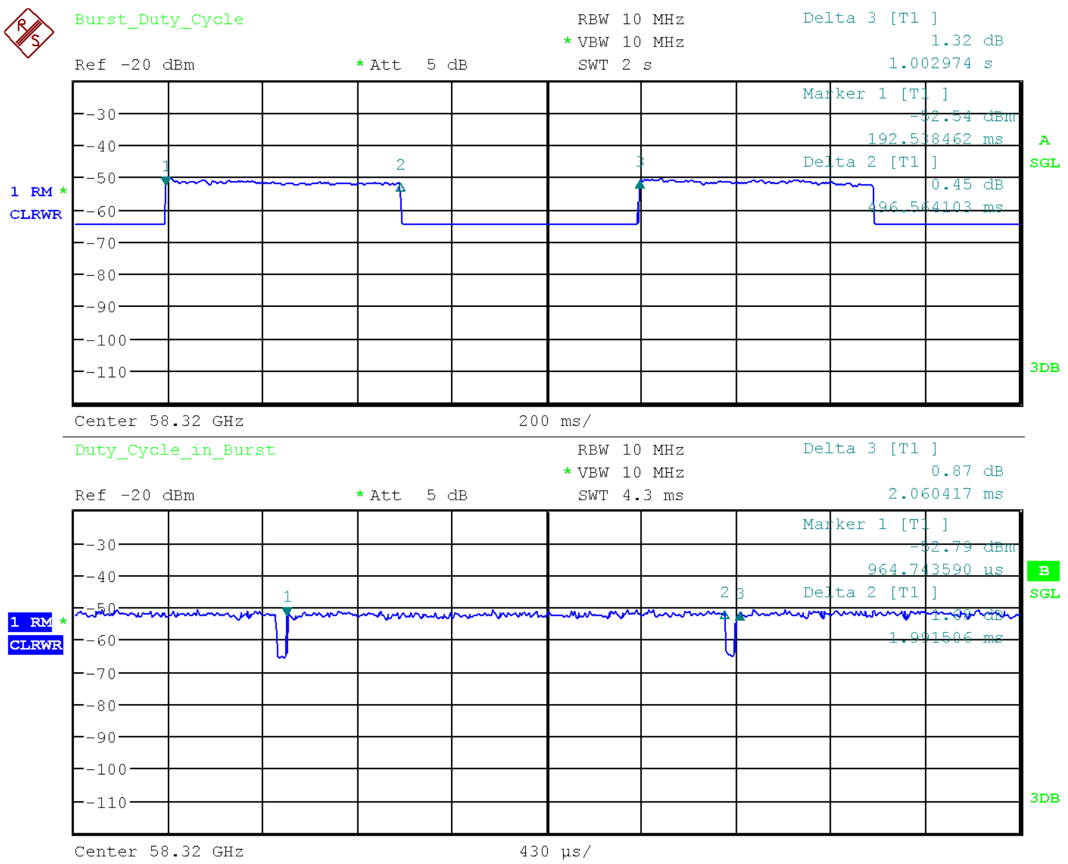
Description	ON Time (ms)	Period (ms)	Duty Cycle Linear
Duty Cycle Within Burst	1.998397	2.046635	0.976
Duty Cycle over Burst period	496.794872	1003.215	0.495
Duty Cycle			0.48354

Duty Cycle Correction (dB)	3.1557

Results screenshot

Duty Cycle

Channel 1



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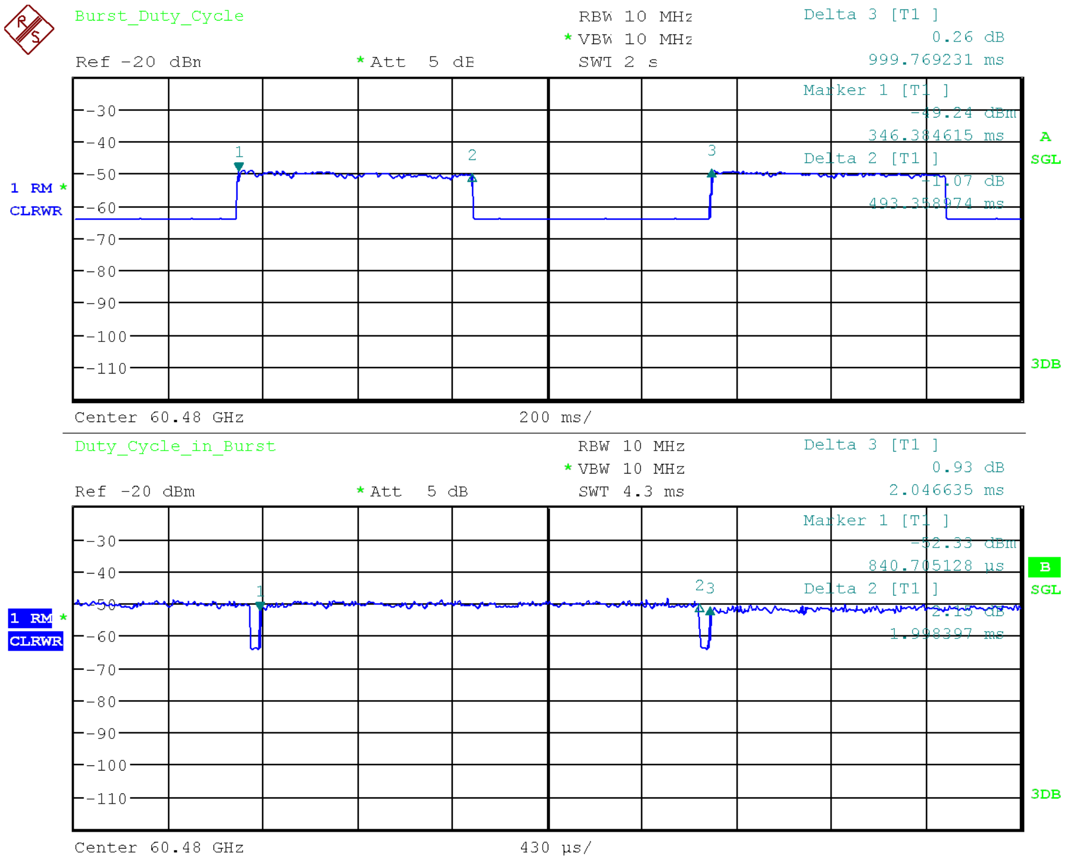
Channel 2



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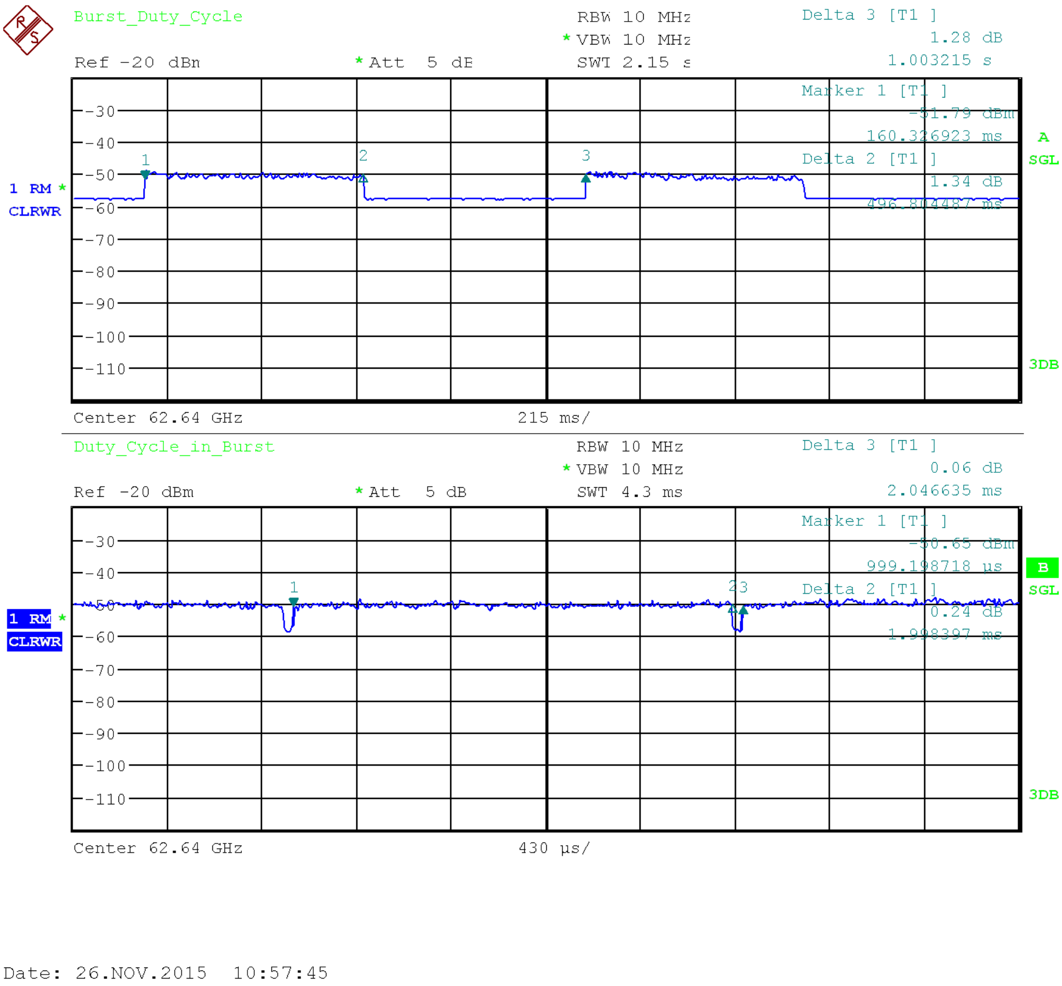
Channel 3


Burst_Duty_Cycle
RBW 10 MHz
* VBW 10 MHz
SWT 2.15 s
Ref -20 dBm
* Att 5 dB
Delta 3 [T1]
1.28 dB
1.003215 s
Delta 2 [T1]
1.34 dB
Center 62.64 GHz
215 ms/
Duty_Cycle_in_Burst
RBW 10 MHz
* VBW 10 MHz
SWT 4.3 ms
Ref -20 dBm
* Att 5 dB
Delta 3 [T1]
0.06 dB
2.046635 ms
Delta 2 [T1]
0.24 dB
Center 62.64 GHz
430 µs/
Date: 26.NOV.2015 10:57:45

B.2 EIRP & Power Density

Test procedure

The radiated emission level is measured with the aperture probe antenna connected to a power sensor.

Using the far-field Friis equation:

$$\frac{P_R}{P_T} = G_T \; G_R \left(\frac{\lambda}{4\pi D}\right)^2$$

the measured power P_R is converted to P_T*G_T using the same equation in logarithmic domain:

$$(P_T*G_T) = P_R - G_R + \mathit{Free\ Space\ Attenuation\ (dB)}$$

Where the:

$$\mathit{Free\ space\ Attenuation\ (dB)} = 20Log\left(\frac{4\pi D}{\lambda}\right)$$

and:

(P_T*G_T) is (dBm) (P_T is the transmitted power and G_T the emission antenna Gain)
D is in (m)
P_R is in (dBm)
G_R is the small aperture probe antenna Gain in (dBi)
λ is the wavelength in (m)

P_T*G_T is converted to power density using:

$$\mathit{Power\ Density} = \frac{P_T\ G_T}{4\pi D^2}$$

Where:
Power Density is in (mW/cm²)
P_T*G_T is in (mW)
D is in (cm)

P_T*G_T is also converted to EIRP during the ON time of the burst using:

$$EIRP = (P_T*G_T) + \mathit{Duty\ Cycle\ Correction\ Factor}$$

Where:
EIRP is in (dBm)
P_T*G_T is in (dBm)
Duty Cycle Correction Factor is in (dB)

Results tables

Channel 1

EUT antenna gain = 15.30dBi

Freq (GHz)	Meas. Distance (cm)	Small Aperture Probe Gain G_R(dBi)	Free Space Attenuation (dB)	Meas Avg Power P_R (dBm)	P_T*G_T (dBm)	P_T*G_T (mW)	Power Density (mW/cm^2)	Duty Cycle Correction (dB)	EIRP (dBm)	Cond[1] Pow (dBm)
58.32	3	5.37	37.30	-21.44	10.49	11.20	0.09899	3.2009	13.69	-1.61
58.32	4	5.37	39.80	-22.92	11.51	14.16	0.07040	3.2009	14.71	-0.59
58.32	5	5.37	41.74	-24.44	11.93	15.59	0.04961	3.2009	15.13	-0.17
58.32	6	5.37	43.32	-26.00	11.95	15.67	0.03464	3.2009	15.15	-0.15
58.32	7	5.37	44.66	-27.13	12.16	16.44	0.02671	3.2009	15.36	0.06
58.32	8	5.37	45.82	-28.32	12.13	16.33	0.02030	3.2009	15.33	0.03
58.32	9	5.37	46.84	-29.25	12.22	16.68	0.01639	3.2009	15.42	0.12
58.32	10	5.37	47.76	-30.12	12.27	16.86	0.01342	3.2009	15.47	0.17
58.32	11	5.37	48.59	-30.81	12.41	17.40	0.01144	3.2009	15.61	0.31
58.32	12	5.37	49.34	-31.42	12.55	18.00	0.00994	3.2009	15.75	0.45
58.32	13	5.37	50.04	-32.33	12.34	17.13	0.00806	3.2009	15.54	0.24
58.32	14	5.37	50.68	-32.86	12.45	17.58	0.00714	3.2009	15.65	0.35
58.32	15	5.37	51.28	-33.28	12.63	18.32	0.00648	3.2009	15.83	0.53
58.32	16	5.37	51.84	-33.87	12.60	18.20	0.00566	3.2009	15.80	0.50
58.32	17	5.37	52.37	-34.39	12.61	18.23	0.00502	3.2009	15.81	0.51
58.32	18	5.37	52.86	-34.99	12.50	17.80	0.00437	3.2009	15.70	0.40
58.32	19	5.37	53.33	-35.27	12.69	18.59	0.00410	3.2009	15.89	0.59

[1] *The conducted power appears to vary over distance and frequency relative to the specified conducted power: the power is slightly dynamic due to potential coupling with the measuring device or other near objects.*

Channel 2

EUT antenna gain = 15.45dBi

Freq (GHz)	Meas. Distance (cm)	Small Aperture Probe Gain G_R(dBi)	Free Space Attenuation (dB)	Meas Avg Power P_R (dBm)	P_T*G_T (dBm)	P_T*G_T (mW)	Power Density (mW/cm^2)	Duty Cycle Correction (dB)	EIRP (dBm)	Cond Pow (dBm)
60.48	3	5.86	37.62	-21.19	10.57	11.39	0.10074	3.1710	13.74	-1.71
60.48	4	5.86	40.12	-22.45	11.81	15.15	0.07537	3.1710	14.98	-0.47
60.48	5	5.86	42.05	-23.67	12.52	17.88	0.05691	3.1710	15.69	0.24
60.48	6	5.86	43.64	-24.9	12.88	19.40	0.04287	3.1710	16.05	0.60
60.48	7	5.86	44.98	-26.01	13.11	20.45	0.03320	3.1710	16.28	0.83
60.48	8	5.86	46.14	-27.14	13.14	20.59	0.02560	3.1710	16.31	0.86
60.48	9	5.86	47.16	-28.14	13.16	20.70	0.02033	3.1710	16.33	0.88
60.48	10	5.86	48.07	-29.10	13.11	20.48	0.01630	3.1710	16.29	0.84
60.48	11	5.86	48.90	-30.01	13.03	20.10	0.01322	3.1710	16.20	0.75
60.48	12	5.86	49.66	-30.61	13.19	20.83	0.01151	3.1710	16.36	0.91
60.48	13	5.86	50.35	-31.27	13.22	21.00	0.00989	3.1710	16.39	0.94
60.48	14	5.86	51.00	-31.91	13.23	21.02	0.00853	3.1710	16.40	0.95
60.48	15	5.86	51.60	-32.50	13.24	21.07	0.00745	3.1710	16.41	0.96
60.48	16	5.86	52.16	-33.26	13.04	20.12	0.00625	3.1710	16.21	0.76
60.48	17	5.86	52.68	-33.49	13.33	21.54	0.00593	3.1710	16.50	1.05
60.48	18	5.86	53.18	-33.94	13.38	21.77	0.00535	3.1710	16.55	1.10
60.48	19	5.86	53.65	-34.44	13.35	21.62	0.00477	3.1710	16.52	1.07

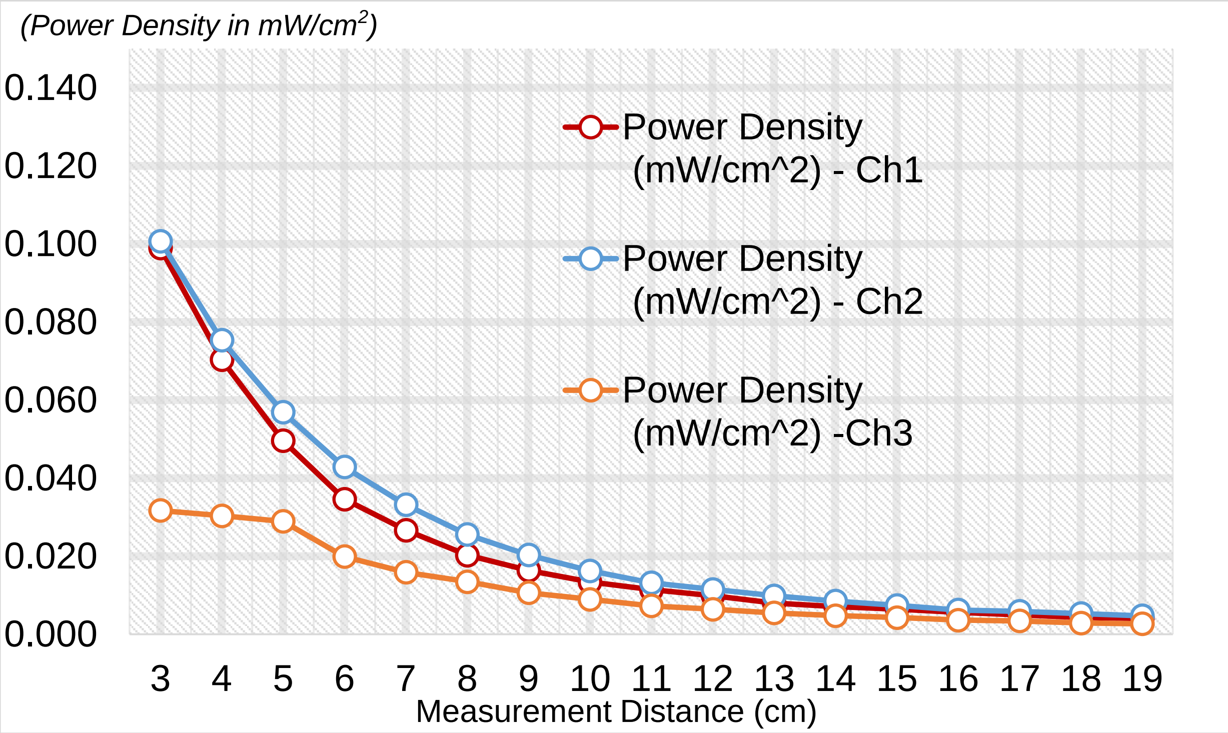
Channel 3

EUT antenna gain = 15.00dBi

Freq (GHz)	Meas. Distance (cm)	Small Aperture Probe Gain G_R(dBi)	Free Space Attenuation (dB)	Meas Avg Power P_R (dBm)	P_T*G_T (dBm)	P_T*G_T (mW)	Power Density (mW/cm^2)	Duty Cycle Correction (dB)	EIRP (dBm)	Cond Pow (dBm)
62.64	3	7.56	37.92	-24.81	5.55	3.59	0.03174	3.1557	8.71	-6.29
62.64	4	7.56	40.42	-25.00	7.86	6.11	0.03039	3.1557	11.02	-3.98
62.64	5	7.56	42.36	-25.21	9.59	9.10	0.02895	3.1557	12.74	-2.26
62.64	6	7.56	43.94	-26.83	9.55	9.02	0.01994	3.1557	12.71	-2.29
62.64	7	7.56	45.28	-27.81	9.91	9.80	0.01591	3.1557	13.07	-1.93
62.64	8	7.56	46.44	-28.52	10.36	10.87	0.01351	3.1557	13.52	-1.48
62.64	9	7.56	47.46	-29.55	10.35	10.85	0.01066	3.1557	13.51	-1.49
62.64	10	7.56	48.38	-30.29	10.53	11.29	0.00899	3.1557	13.68	-1.32
62.64	11	7.56	49.21	-31.19	10.46	11.11	0.00731	3.1557	13.61	-1.39
62.64	12	7.56	49.96	-31.74	10.66	11.65	0.00644	3.1557	13.82	-1.18
62.64	13	7.56	50.66	-32.42	10.68	11.69	0.00550	3.1557	13.83	-1.17
62.64	14	7.56	51.30	-33.02	10.72	11.81	0.00479	3.1557	13.88	-1.12
62.64	15	7.56	51.90	-33.48	10.86	12.19	0.00431	3.1557	14.02	-0.98
62.64	16	7.56	52.46	-34.19	10.71	11.78	0.00366	3.1557	13.87	-1.13
62.64	17	7.56	52.99	-34.44	10.99	12.55	0.00346	3.1557	14.14	-0.86
62.64	18	7.56	53.48	-35.17	10.75	11.90	0.00292	3.1557	13.91	-1.09
62.64	19	7.56	53.95	-35.49	10.90	12.31	0.00271	3.1557	14.06	-0.94

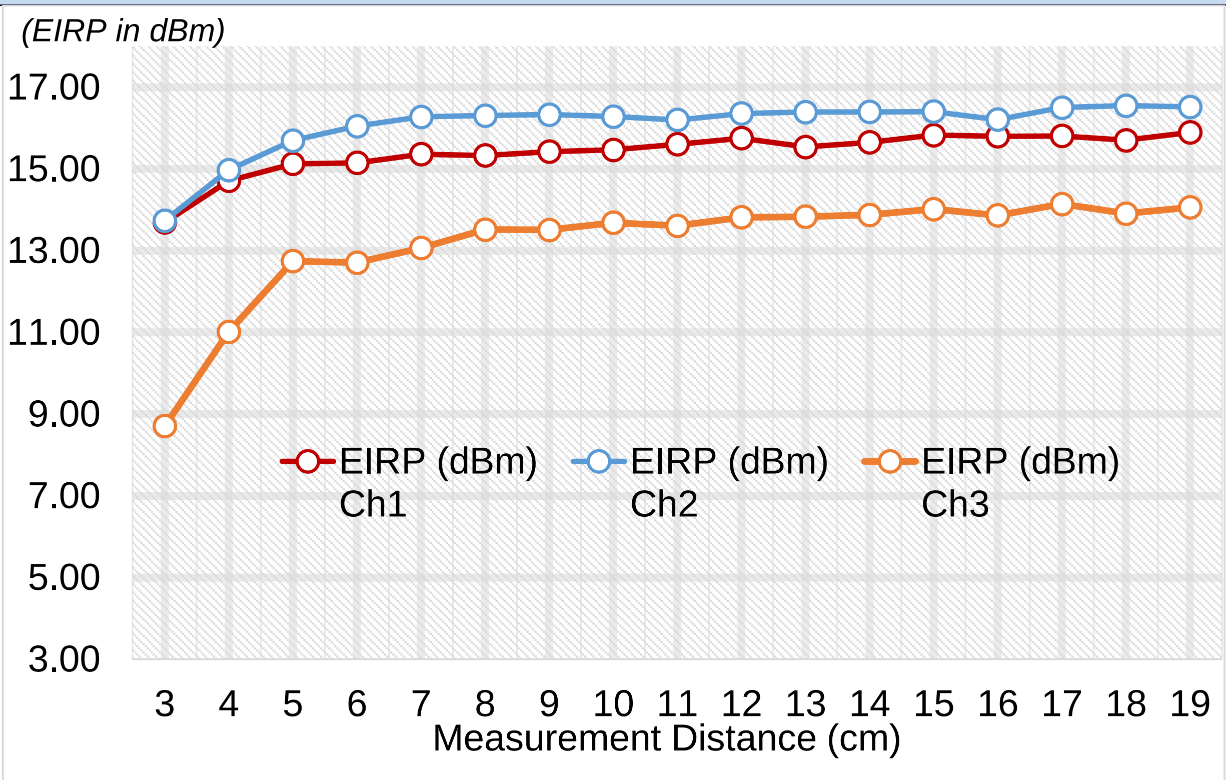
Results graph

Power Density



Power Density calculated from EIRP tests (i.e. with the ~ 48 % duty cycle measured in B.1)
(48% is the combination of the duty cycle over burst and within burst)

EIRP



EIRP normalized for 100% duty cycle (after adding the Duty cycle correction factor measured in B.1

Note: These results are discussed in Annex E.

Annex C. Aperture Probe Antenna Characterization

C.1 Description of the Antenna

The measuring antenna is an open-ended waveguide as specified in IEEE Std C95.3-2002 Clause 5.5.1.1.3 Small apertures. The aperture probe antenna consists of a 19 cm straight section of WR15 rectangular waveguide with a standard UG-385/U flange at one end. The aperture dimensions are (1.88 x 3.76 mm^2).

C.2 Derivation of characterization equations

Indeed, the ratio between the received power and the transmitted power between a pair of antennas is expressed in terms of their gains as follow:

$$G_T\ G_R\ =\ \frac{P_R}{P_T}\left(\frac{4\pi D}{\lambda}\right)^2$$

Converting from linear to logarithmic domain yields:

$$G_T +\ G_R = \ P_R - P_T + 20Log(\frac{4\pi D}{\lambda})$$

Converting from wavelength in meters to frequency in GHz yields:

$$G_T +\ G_R = \ P_R - P_T + 20Log(D) + 20Log(f) + 32.44 \qquad (1)$$

Where:

G_T is the gain of the transmit antenna (dBi)
G_R is the gain of the receive antenna (dBi)
P_R is the power received (dBm)
P_T is the power transmitted (dBm)
D is the distance between the antennas (m)
f is the frequency (GHz)

The individual far-field gain of each of three different antennas can be determined from three path loss measurements made under identical far-field conditions using the three different antennas taken in pairs. Three path loss measurements (P_{R12} - P_T), (P_{R13} - P_T) and (P_{R23} - P_T) are sufficient to simultaneously solve for three unknowns G_1, G_2 and G_3.

The Equation (1) is applied to each of the three path loss measurement as follows applied

$$A =\ G_1 +\ G_2 =\ P_{R12} - P_T + 20Log(D) + 20Log(f) + 32.44 \qquad (2)$$

$$B =\ G_1 +\ G_3 =\ P_{R13} - P_T + 20Log(D) + 20Log(f) + 32.44 \qquad (3)$$

$$C =\ G_2 +\ G_3 =\ P_{R23} - P_T + 20Log(D) + 20Log(f) + 32.44 \qquad (4)$$

Where:

***A*= (*G_1* + *G_2*)** is the sum of the gains of Antennas 1 and 2
***B*= (*G_1* + *G_3*)** is the sum of the gains of Antennas 1 and 3
***C*= (*G_2* + *G_3*)** is the sum of the gains of Antennas 2 and 3
P_{R12} is the power received when measuring Antennas 1 and 2 (dBm)
P_{R13} is the power received when measuring Antennas 1 and 3 (dBm)
P_{R23} is the power received when measuring Antennas 2 and 3 (dBm)
P_T is the transmitted power (dBm)
D is the distance between the antennas (m)
f is the frequency (GHz)

The gain of each individual antenna is calculated as follows:

$$G_1 = 0.5\ (A + B - C) \qquad (5)$$
$$G_2 = 0.5\ (A + C - B) \qquad (6)$$
$$G_3 = 0.5\ (B + C - A) \qquad (7)$$

Where:

G_1 is the gain of Antenna 1 (dBi)
G_2 is the gain of Antenna 2 (dBi)
G_3 is the gain of Antenna 3 (dBi)
A is the result of applying Equation (2)
B is the result of applying Equation (3)
C is the result of applying Equation (4)

C.3 Characterization Procedure

1. Allow the signal source, power sensor and power meter to warm up as specified by the manufacturer of the instruments.

2. Adjust the instruments to the applicable frequency. Connect the power sensor to the output of the source. Measure and record Power Transmitted.

3. Connect the first pair of antennas to their respective source (Tx antenna) and power sensor (Rx antenna). Place the antennas at the selected far-field separation distance in a bore-sight configuration using a laser level to align the antennas. Measure and record Power Received.

4. Repeat step 3 for each pair of antennas.

5. Calculate the antenna gains by applying Equations (2) through (7).

C.4 Characterization Results and Validation

C.4.1 Far-Field Distance

The gain reduction (relative to the far-field gain G∞) of an antenna is estimated as a function of normalized distance.
The normalized distance is given in terms of $n = d\lambda/a^2$ where d is distance, λ is wavelength and a is the largest aperture dimension. The far-field gain holds for distances greater than about $(8a^2)/\lambda$ (n > 8).

Note that for the verification we use three aperture antennas, the far field distance is therefore calculated using the largest aperture dimension among the three antennas (in our case it is the antenna 1) and $a = 5mm$.

The minimum far field distance is calculated for each channel as follow:

Frequency (GHz)	Wavelength λ (m)	Largest aperture dimension a (m)	Ratio (a^2/λ)	Minimum distance d (cm)
58.32	0.005144033	0.005	0.00486	**3.888**
60.48	0.004960317	0.005	0.00504	**4.032**
62.64	0.004789272	0.005	0.00522	**4.176**

We decide therefore to do the characterization at **15 cm**.

C.4.2 Probe Gain

The probe under verification is noted **Antenna 3** with Gain G_3. The antennas 1 and 2 are used to perform the characterization. The verification procedure (see § 12.3) is applied as follow:

1st Path Loss measurement → In Tx : Antenna 1 / In Rx : Antenna 2

Channel	PT (dBm)	PR12 (dBm)	D (m)	f (GHz)	G1+G2 (dBi)
1	5.01	-30.53	0.15	58.32	15.74
2	7.34	-29.41	0.15	60.48	14.84
3	7.04	-28.28	0.15	62.64	16.58

2nd Path Loss measurement → In Tx : Antenna 2 / In Rx : *Antenna 3*

Channel	PT (dBm)	PR23 (dBm)	D (m)	f (GHz)	G2+G3 (dBi)
1	5.01	-35.3	0.15	58.32	10.97
2	7.34	-32.93	0.15	60.48	11.32
3	7.04	-30.66	0.15	62.64	14.199

3rd Path Loss measurement → In Tx : Antenna 1 / In Rx : *Antenna 3*

Channel	PT (dBm)	PR13 (dBm)	D (m)	f (GHz)	G1+G3 (dBi)
1	5.01	-30.76	0.15	58.32	15.51
2	7.34	-29.01	0.15	60.48	15.24
3	7.04	-27.35	0.15	62.64	17.51

The measured gains are deduced and showed as follows:

Antenna	***Channel 1 Gain (dBi)***	***Channel 2 Gain (dBi)***	***Channel 3 Gain (dBi)***
Aperture Antenna 1	10.14	9.38	9.94
Aperture Antenna 2	5.60	5.46	6.63
Open Ended Waveguide Probe Antenna	5.37	5.86	7.56

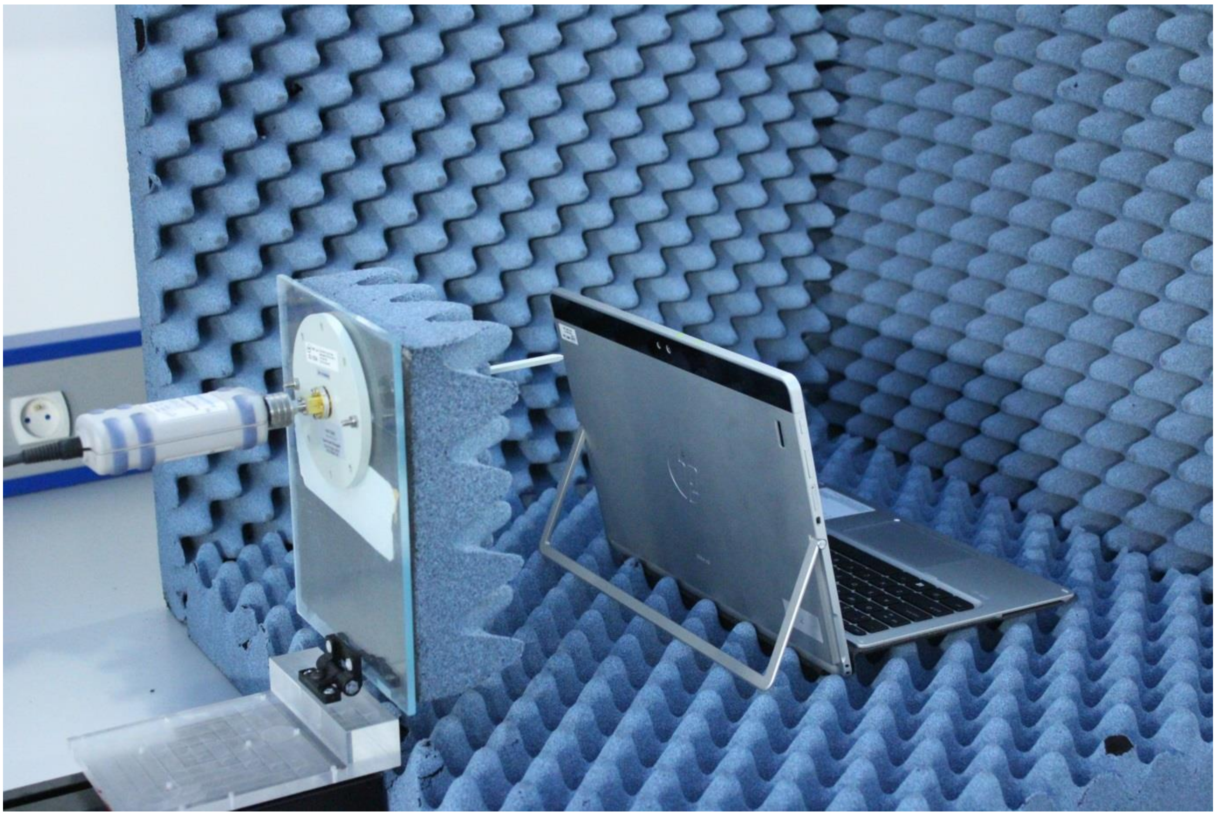
C.4.3 Validation

The measured gain of the original probe antenna is compared to the realized gain from a theoretical model of common open-ended waveguide apertures with a two-to-one aspect ratio, i.e., a /b = 2, provided by IEEE Std C95.3 Clause 5.5.1.1.3 equation (4)

Channel	**Frequency (GHz)**	**Dimension a (m)**	**Theoretical Gain (dBi)** $10\log(21.6 \cdot f[GHz] \cdot a)$	**Measured Gain (dBi)**	**Delta to Theoretical Gain (dB)**
1	58.32	0.00376	6.75	5.37	1.38
2	60.48	0.00376	6.91	5.86	1.05
3	62.64	0.00376	7.06	7.56	0.50

Annex D. Photographs

Test Setup



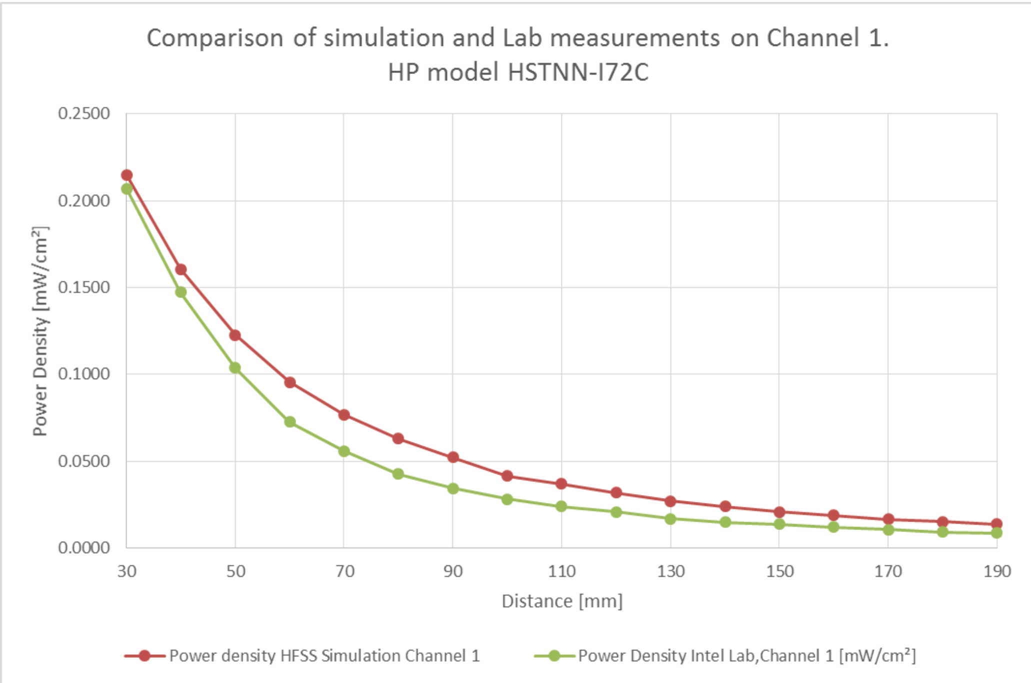
Annex E Correlation between test measurements and simulations

E.1 Annex Summary

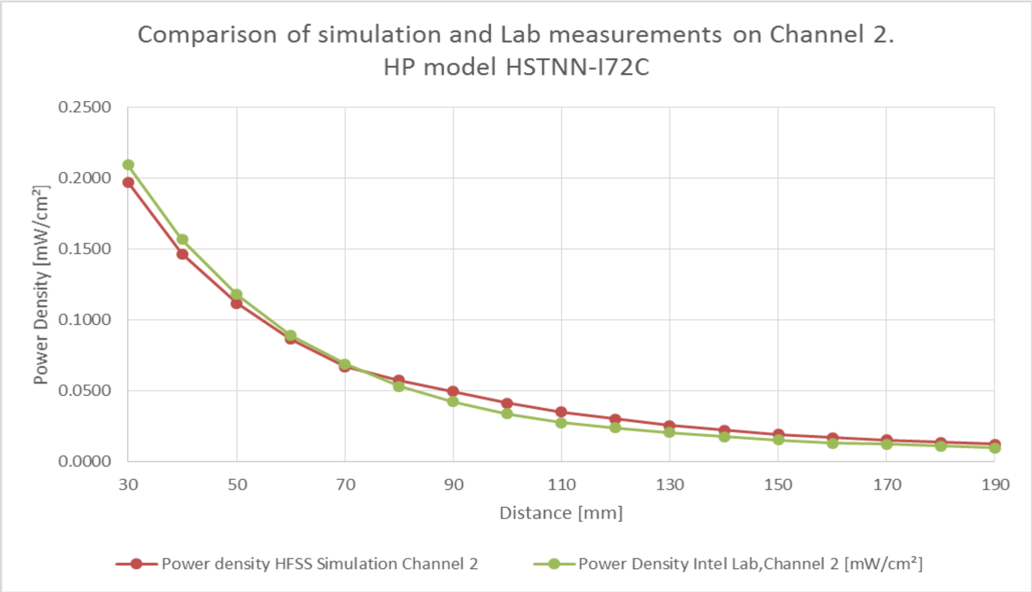
This annex discusses a comparison between the tests results presented in the Annex B.2 and the simulation results performed separately by the applicant and presented in the Power Density Simulation Report corresponding to product model name 18260NGW.
This Annex has been added to this document following the applicant's request based on a specific inquiry from the FCC.

E.2 Correlation Discussion

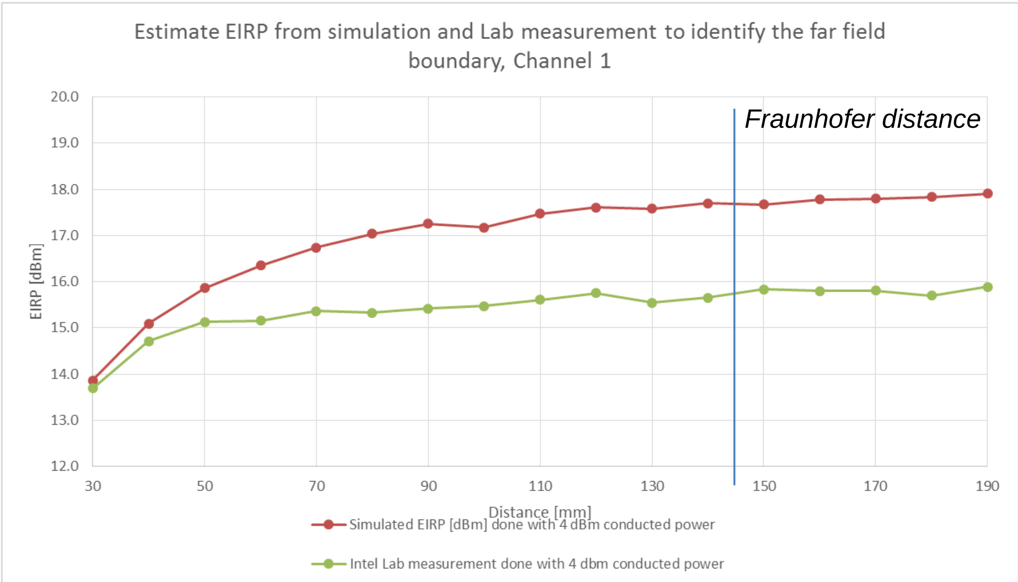
The power density and E.I.R.P. graphs presented below are normalized to 100% duty cycle.



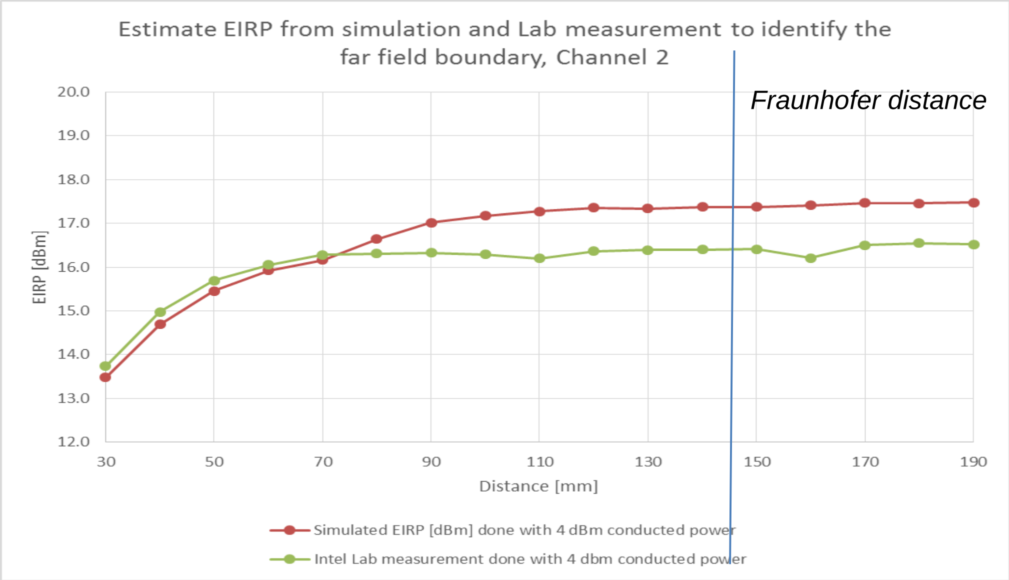
Comparison of Power Density simulation to lab measurements on Channel 1 (Normalized for 100% duty cycle)



Comparison of Power Density simulation to lab measurements on Channel 2 (Normalized for 100% duty cycle)



Estimate EIRP of Simulation vs. lab measurements and far field boundary (Ch1) (Normalized for 100% duty cycle)



Estimate EIRP of Simulation vs lab measurements and far field boundary (Ch2) (Normalized for 100% duty cycle)

<u>Discussion – correlation results:</u>

The following observations can be made according to the graphs above:

1. EIRP increased to a steady state, demonstrating we are in the near/transition field below 7-9cm (shorter than the Fraunhofer distance).
2. Very good correlation can be seen in the graph shape and trends between lab measurements and simulation results.
3. Good correlation can be seen in the far field results between lab measurements to measured data. In both cases the simulation predict higher value than the measured data (reasonable results), where in channel 1 the simulation is higher by up to 2dB while in channel 2 the simulation is higher by ~1dB.

Summary – as explained, good to very good correlation can be seen between measured to simulated data.