TESTING CERT #3478.01

TEST REPORT

EUT Description	**Wireless Gigabit radio installed in a Toshiba Model PT16B**
Brand	**Intel® Tri-Band Wireless-AC 18260**
Model	**Platform Toshiba Model PT16B / Intel module 18260NGW**
Serial Number	**Host Laptop: 8F025057H** (see section 4)
FCC/IC ID	**FCC ID: PD918260NG**
Hardware/Software Version	**Test SW: DRTU version 1.9.0-03587** **Driver ver.: 3.0.10085.1**
Date of Sample Receipt	**2016-04-29**
Date of start/end of Tests	**Start : 2016-08-23 End: 2016-08-25**
Date of issue	**2016-09-01**
Features	**Module: WiGig + 802.11 a/b/g/n/ac WLAN + BDR/EDR 2.1 + BLE 4.0** **Host: Toshiba Model PT16B** (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	**160329-05.TR01**
Revision Control	**Rev. 01**

The test results relate only to the samples tested.
The test report shall not be reproduced in full, without written approval of the laboratory.

Issued by	Reviewed by
Digitally signed by Walid EL HAJJ Date: 2016.09.14 17:00:06 +02'00'	Digitally signed by Olivier FARGANT DN: cn=Olivier FARGANT, o=Intel Mobile Communications, ou=WRF Lab, email=olivier.fargant@intel.com, c=FR Date: 2016.09.14 17:18:05 +02'00'
Walid EL HAJJ (RF Radiated Test Lead)	Olivier FARGANT (RF Test Lead)

Table of Contents

Printed copies are not controlled documents

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).
- ✓ Intel Mobile Communications Wireless RF Lab (Intel WRF Lab) is an Accredited Test Firm listed by the FCC, with Designation Number FR0011.
- ✓ Intel WRF Lab only provides testing services and is committed to providing reliable, unbiased test results and interpretations.
- ✓ Intel WRF Lab is liable to the client for the maintenance of the confidentiality of all information related to the item under test and the results of the test.
- ✓ Intel WRF Lab has developed calibration and proficiency programs for its measurement equipment to ensure correlated and reliable results to its customers.
- ✓ This report is only referred to the item that has undergone the test.
- ✓ This report does not imply an approval of the product by the Certification Bodies or competent Authorities.
- ✓ Complete or partial reproduction of the report cannot be made without written permission of Intel WRF Lab.

3. Environmental Conditions

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

Temperature	23ºC ± 2ºC
Humidity	40% ± 5%

Printed copies are not controlled documents

4. Test samples

Sample	Control #	Description	Model	Serial #	Date of reception
#01	160329-05.S01	Laptop	Toshiba Model PT16B	8F025057H	2016-04-29
	160329-05.S03	AC/DC Adapter Toshiba	PA519E-1AC3	G71C000J5110	2016-04-29

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	2016-08-26	M.Lefebvre	First Issue
Rev. 01	2016-09-14	W. EL HAJJ	Modifications to address FCC comments

Printed copies are not controlled documents

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 Toshiba Model PT16B.

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

The DUT was set to transmit at the highest power (5.5 dBm) conducted setting on MCS1 using proprietary software (Intel DRTU version 1.9.0-03587). The software enables the transmitter to operate at an actual maximum duty cycle of around 96% (please refer to duty cycle measurements details in Section B.1 which describes the combination of the duty cycle within burst and duty cycle over burst). The maximum EIRP measured and reported in the following table is normalized to 100% duty cycle:

Channel	Maximum EIRP (dBm)
1	21.08
2	17.52
3	16.48

A.2 Measurement system

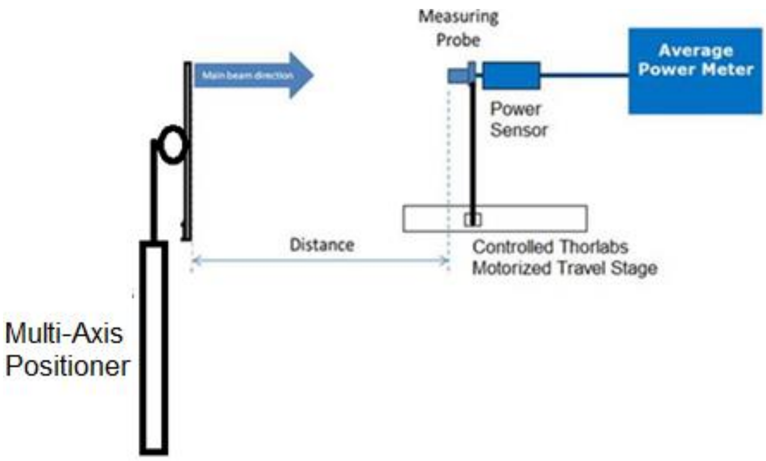
A Thorlabs Motorized Travel Stage controlled by software is used to maintain a consistent and accurate placement of the probe. A multi-axis Positioner is used for the Polarization / Elevation / Azimuth scan.

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 / Elevation / Azimuth 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 5 to 25 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 surface of the EUT and the aperture plane of the probe.



Test Setup schematics

Printed copies are not controlled documents

Before rotating the DUT, the antenna array was aligned to the measurement probe using a laser beam in order to optimize the positioning and have the probe to point exactly towards the antenna array location.

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	101280	Rohde & Schwarz	2015-05-06	2017-05-06
0015	Spectrum analyzer	FSU67	100092	Rohde & Schwarz	2015-07-31	2017-07-31
0016	Signal Generator	SMF100A	102117	Rohde & Schwarz	2016-03-24	2018-03-24
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	
0328	Laser line pointer	GCL25	505000206	Bosch	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.

Printed copies are not controlled documents

A.4 Measurement Uncertainty Evaluation

The Total Measurement Uncertainty is of **1.48 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	0.26	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	0.50	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	0.74
				Expanded Uncertainty (k=2)*	***1.48***

SG : Signal Generator TR : Transition PM : Power Meter

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

Printed copies are not controlled documents

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 measurement antenna. The FSU67 covers the 20Hz to 67GHz frequency range. Therefore the measurement is performed directly without the need of an external mixer.

Results tables

Channel 1

Description	ON Time (ms)	Period (ms)	Duty Cycle Linear
Duty Cycle Within Burst	990.38	1003.20	0.987
Duty Cycle over Burst period	1.985	2.047	0.970
Duty Cycle			0.957

Duty Cycle Correction (dB)	0.1895

Channel 2

Description	ON Time (ms)	Period (ms)	Duty Cycle Linear
Duty Cycle Within Burst	990.38	1003.20	0.987
Duty Cycle over Burst period	1.985	2.040	0.973
Duty Cycle			0.960

Duty Cycle Correction (dB)	0.1749

Printed copies are not controlled documents

Channel 3

Description	ON Time (ms)	Period (ms)	Duty Cycle Linear
Duty Cycle Within Burst	987.17	1000	0.987
Duty Cycle over Burst period	1.978	2.047	0.966
Duty Cycle			0.954

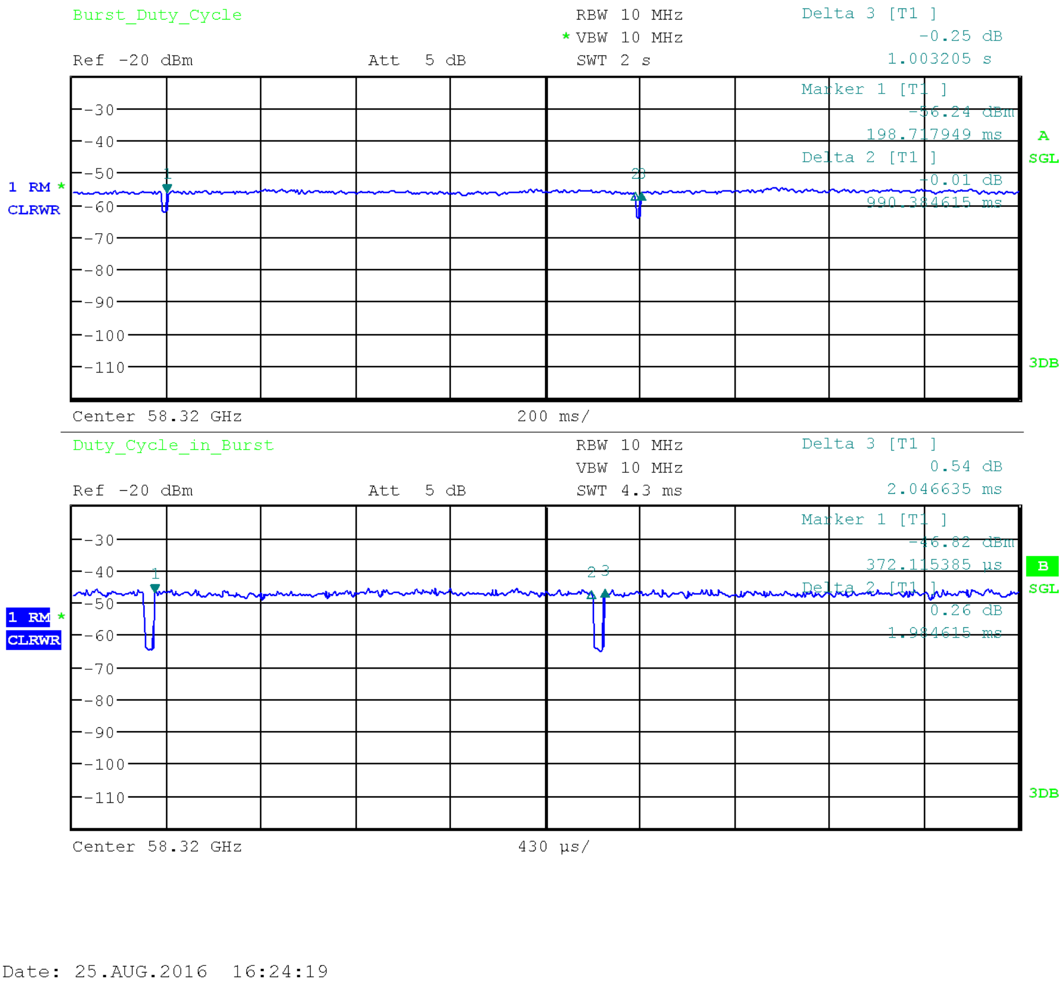
Duty Cycle Correction (dB)	0.2048

Printed copies are not controlled documents

Results screenshots

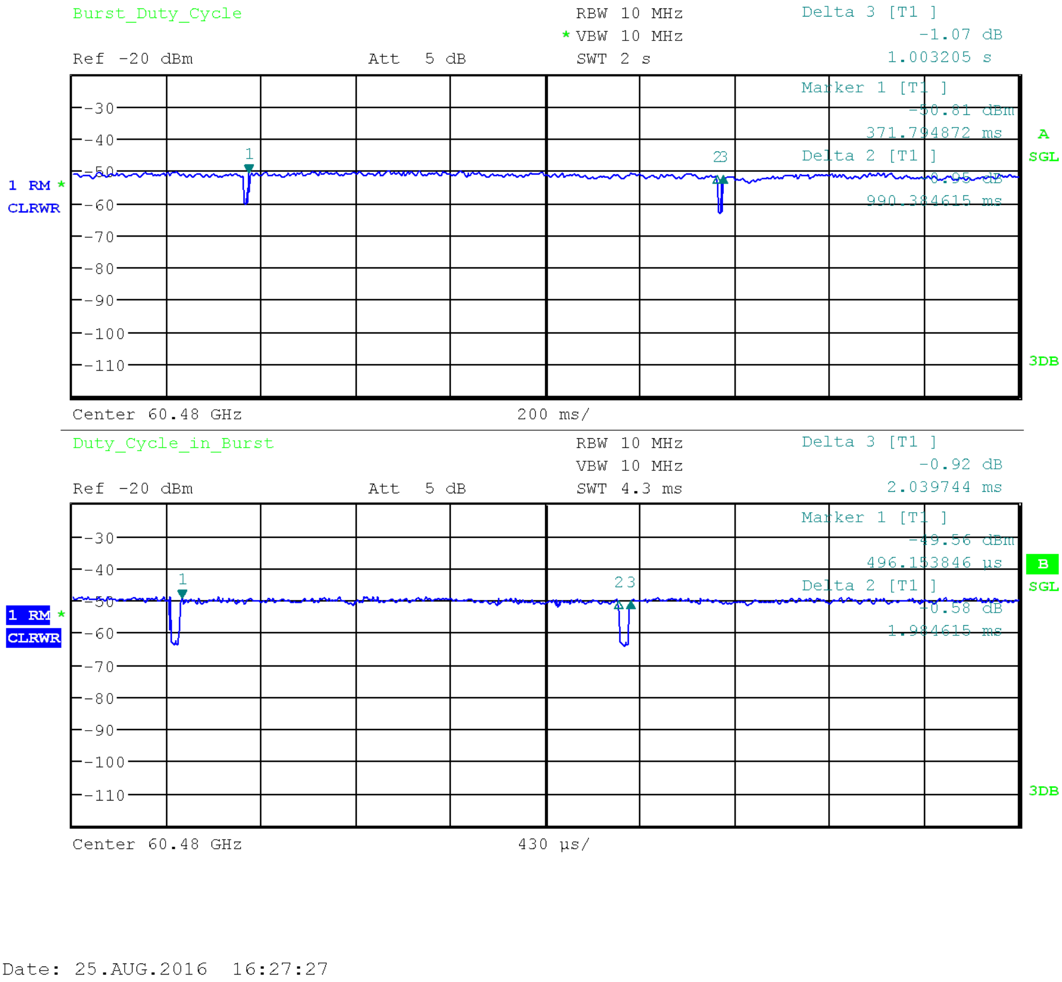
Duty Cycle

Channel 1



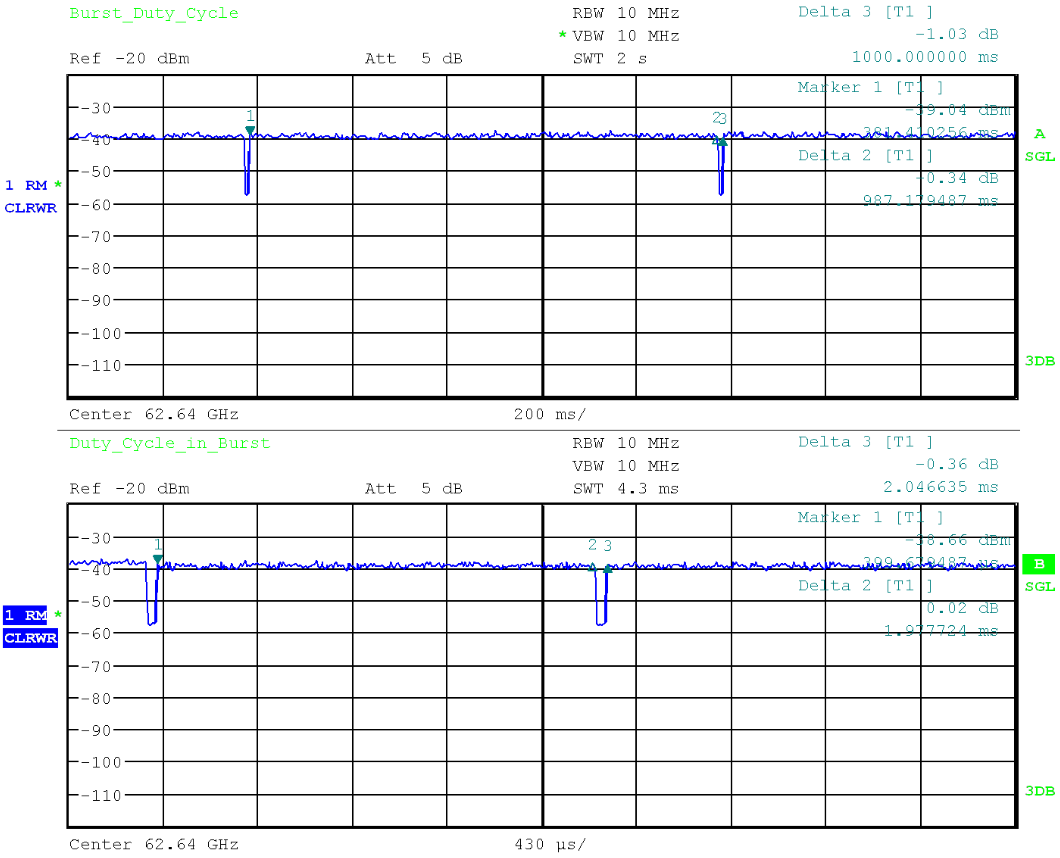
Printed copies are not controlled documents

Channel 2



Printed copies are not controlled documents

Channel 3



Date: 25.AUG.2016 16:19:58

Printed copies are not controlled documents

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:

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

Where the:

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

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:

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

Where:
Power Density is in (mW/cm^2)
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:

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

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

Printed copies are not controlled documents

Results tables

Channel 1

EUT antenna gain = 15.30 dBi

Freq (GHz)	Meas. Distance (cm)	Small Aperture Probe Gain G_R (dBi)	Free Space Attenu-ation (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)
58.32	5	5.37	41.74	-17.50	18.87	77.05	0.24525	0.1895	*19.06*
58.32	6	5.37	43.32	-18.68	19.27	84.55	0.18690	0.1895	*19.46*
58.32	7	5.37	44.66	-19.28	20.01	100.23	0.16278	0.1895	*20.20*
58.32	8	5.37	45.82	-20.00	20.45	110.92	0.13791	0.1895	*20.64*
58.32	9	5.37	46.84	-21.09	20.38	109.22	0.10730	0.1895	*20.57*
58.32	10	5.37	47.76	-22.02	20.37	108.85	0.08662	0.1895	*20.56*
58.32	11	5.37	48.59	-22.86	20.36	108.54	0.07138	0.1895	*20.55*
58.32	12	5.37	49.34	-23.56	20.41	109.94	0.06076	0.1895	*20.60*
58.32	13	5.37	50.04	-24.07	20.60	114.74	0.05403	0.1895	*20.79*
58.32	14	5.37	50.68	-24.72	20.59	114.57	0.04652	0.1895	*20.78*
58.32	15	5.37	51.28	-25.30	20.61	115.08	0.04070	0.1895	*20.80*
58.32	16	5.37	51.84	-25.82	20.65	116.16	0.03611	0.1895	*20.84*
58.32	17	5.37	52.37	-26.43	20.57	113.95	0.03138	0.1895	*20.76*
58.32	18	5.37	52.86	-26.86	20.63	115.71	0.02842	0.1895	*20.82*
58.32	19	5.37	53.33	-27.24	20.72	118.12	0.02604	0.1895	*20.91*
58.32	20	5.37	53.78	-27.52	20.89	122.71	0.02441	0.1895	*21.08*
58.32	21	5.37	54.20	-27.98	20.85	121.69	0.02196	0.1895	*21.04*
58.32	22	5.37	54.61	-28.52	20.72	117.94	0.01939	0.1895	*20.91*
58.32	23	5.37	54.99	-28.91	20.71	117.83	0.01773	0.1895	*20.90*
58.32	24	5.37	55.36	-29.25	20.74	118.64	0.01639	0.1895	*20.93*
58.32	25	5.37	55.72	-29.54	20.81	120.42	0.01533	0.1895	*21.00*

Printed copies are not controlled documents

Channel 2

EUT antenna gain = 15.45 dBi

Freq (GHz)	Meas. Distance (cm)	Small Aperture Probe Gain G_R (dBi)	Free Space Attenu-ation (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)
60.48	5	5.86	42.05	-20.19	16.00	39.84	0.12682	0.1749	*16.18*
60.48	6	5.86	43.64	-21.00	16.78	47.61	0.10524	0.1749	*16.95*
60.48	7	5.86	44.98	-22.12	17.00	50.07	0.08132	0.1749	*17.17*
60.48	8	5.86	46.14	-23.50	16.78	47.60	0.05918	0.1749	*16.95*
60.48	9	5.86	47.16	-24.50	16.80	47.85	0.04701	0.1749	*16.97*
60.48	10	5.86	48.07	-24.98	17.23	52.89	0.04209	0.1749	*17.41*
60.48	11	5.86	48.90	-25.70	17.34	54.22	0.03566	0.1749	*17.52*
60.48	12	5.86	49.66	-26.78	17.02	50.32	0.02781	0.1749	*17.19*
60.48	13	5.86	50.35	-27.66	16.83	48.23	0.02271	0.1749	*17.01*
60.48	14	5.86	51.00	-28.10	17.04	50.54	0.02052	0.1749	*17.21*
60.48	15	5.86	51.60	-28.81	16.93	49.27	0.01743	0.1749	*17.10*
60.48	16	5.86	52.16	-29.30	17.00	50.08	0.01557	0.1749	*17.17*
60.48	17	5.86	52.68	-29.78	17.04	50.62	0.01394	0.1749	*17.22*
60.48	18	5.86	53.18	-30.30	17.02	50.34	0.01236	0.1749	*17.19*
60.48	19	5.86	53.65	-30.70	17.09	51.16	0.01128	0.1749	*17.26*
60.48	20	5.86	54.09	-30.90	17.33	54.13	0.01077	0.1749	*17.51*
60.48	21	5.86	54.52	-31.32	17.34	54.18	0.00978	0.1749	*17.51*
60.48	22	5.86	54.92	-31.83	17.23	52.87	0.00869	0.1749	*17.41*
60.48	23	5.86	55.31	-32.10	17.35	54.31	0.00817	0.1749	*17.52*
60.48	24	5.86	55.68	-32.55	17.27	53.31	0.00737	0.1749	*17.44*
60.48	25	5.86	56.03	-32.99	17.18	52.27	0.00666	0.1749	*17.36*

Printed copies are not controlled documents

Channel 3

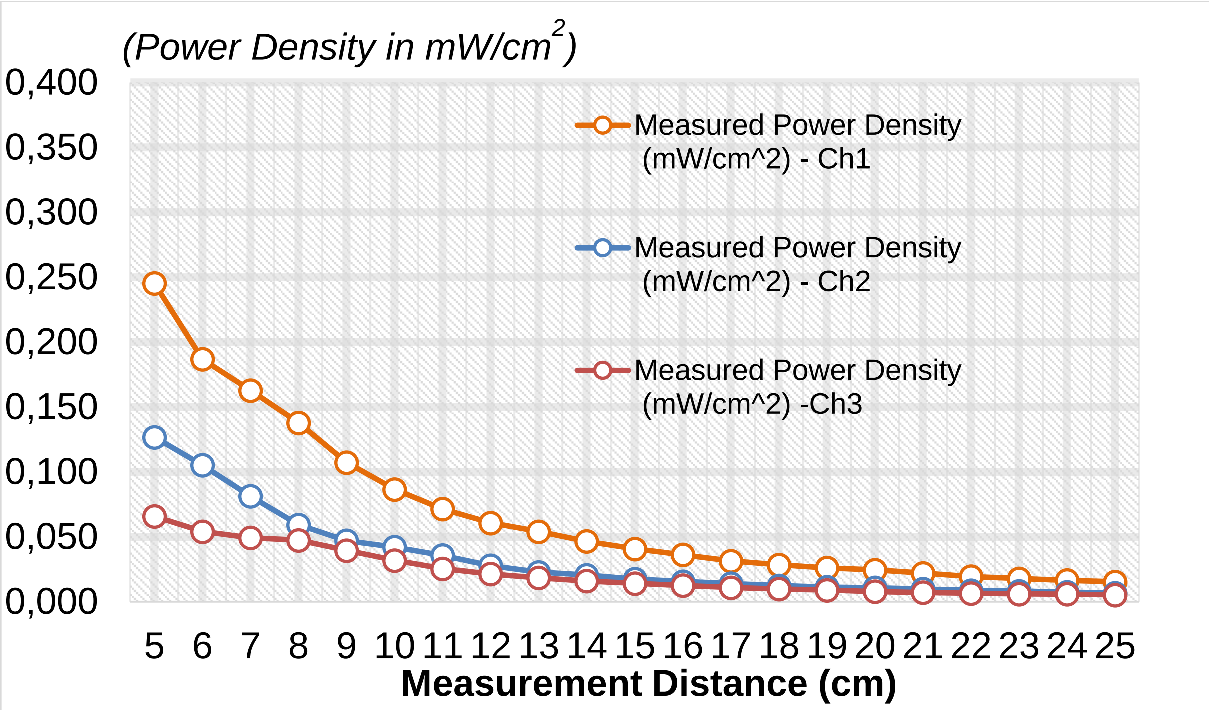
EUT antenna gain = 15.00 dBi

Freq (GHz)	Meas. Distance (cm)	Small Aperture Probe Gain G_R (dBi)	Free Space Attenu-ation (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)
62.64	5	7.56	42.36	-21.65	13.15	20.65	0.06572	0.2048	*13.35*
62.64	6	7.56	43.94	-22.50	13.88	24.44	0.05403	0.2048	*14.09*
62.64	7	7.56	45.28	-22.90	14.82	30.34	0.04928	0.2048	*15.03*
62.64	8	7.56	46.44	-23.07	15.81	38.11	0.04739	0.2048	*16.02*
62.64	9	7.56	47.46	-23.86	16.04	40.21	0.03951	0.2048	*16.25*
62.64	10	7.56	48.38	-24.80	16.02	39.98	0.03182	0.2048	*16.22*
62.64	11	7.56	49.21	-25.78	15.87	38.61	0.02539	0.2048	*16.07*
62.64	12	7.56	49.96	-26.52	15.88	38.75	0.02141	0.2048	*16.09*
62.64	13	7.56	50.66	-27.17	15.93	39.15	0.01844	0.2048	*16.13*
62.64	14	7.56	51.30	-27.79	15.95	39.37	0.01598	0.2048	*16.16*
62.64	15	7.56	51.90	-28.32	16.02	40.00	0.01415	0.2048	*16.23*
62.64	16	7.56	52.46	-28.88	16.02	40.01	0.01244	0.2048	*16.23*
62.64	17	7.56	52.99	-29.47	15.96	39.43	0.01086	0.2048	*16.16*
62.64	18	7.56	53.48	-29.92	16.00	39.85	0.00979	0.2048	*16.21*
62.64	19	7.56	53.95	-30.32	16.07	40.49	0.00893	0.2048	*16.28*
62.64	20	7.56	54.40	-30.88	15.96	39.44	0.00785	0.2048	*16.16*
62.64	21	7.56	54.82	-31.34	15.92	39.11	0.00706	0.2048	*16.13*
62.64	22	7.56	55.23	-31.72	15.95	39.33	0.00647	0.2048	*16.15*
62.64	23	7.56	55.61	-32.05	16.00	39.84	0.00599	0.2048	*16.21*
62.64	24	7.56	55.98	-32.15	16.27	42.39	0.00586	0.2048	*16.48*
62.64	25	7.56	56.34	-32.68	16.10	40.72	0.00518	0.2048	*16.30*

Printed copies are not controlled documents

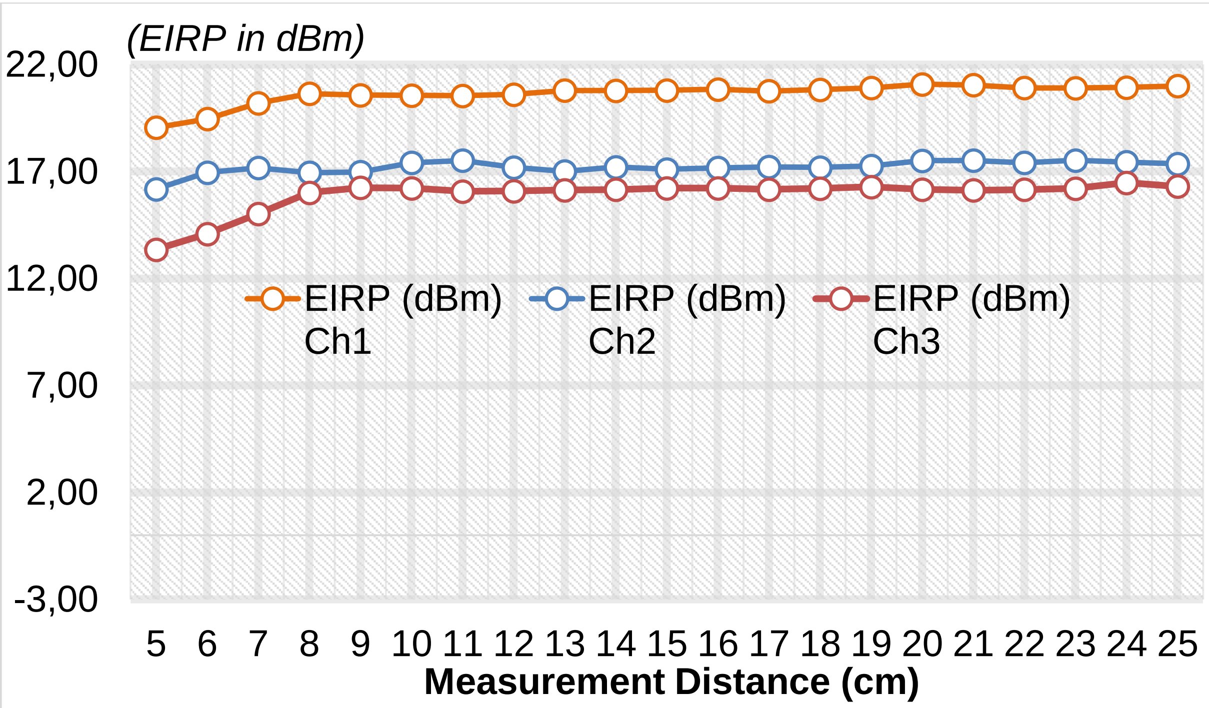
Results graph

Power Density



Power Density in mW/cm^2 measured during the tests (i.e. with the ~ 96 % duty cycle measured in B.1)

EIRP



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

Printed copies are not controlled documents

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:

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

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

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

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

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

Printed copies are not controlled documents

Where:

A= (G₁ + G₂) is the sum of the gains of Antennas 1 and 2
B= (G₁ + G₃) is the sum of the gains of Antennas 1 and 3
C= (G₂ + G₃) 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:

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

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).

Printed copies are not controlled documents

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	-35.30	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	14.20

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

Printed copies are not controlled documents

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)

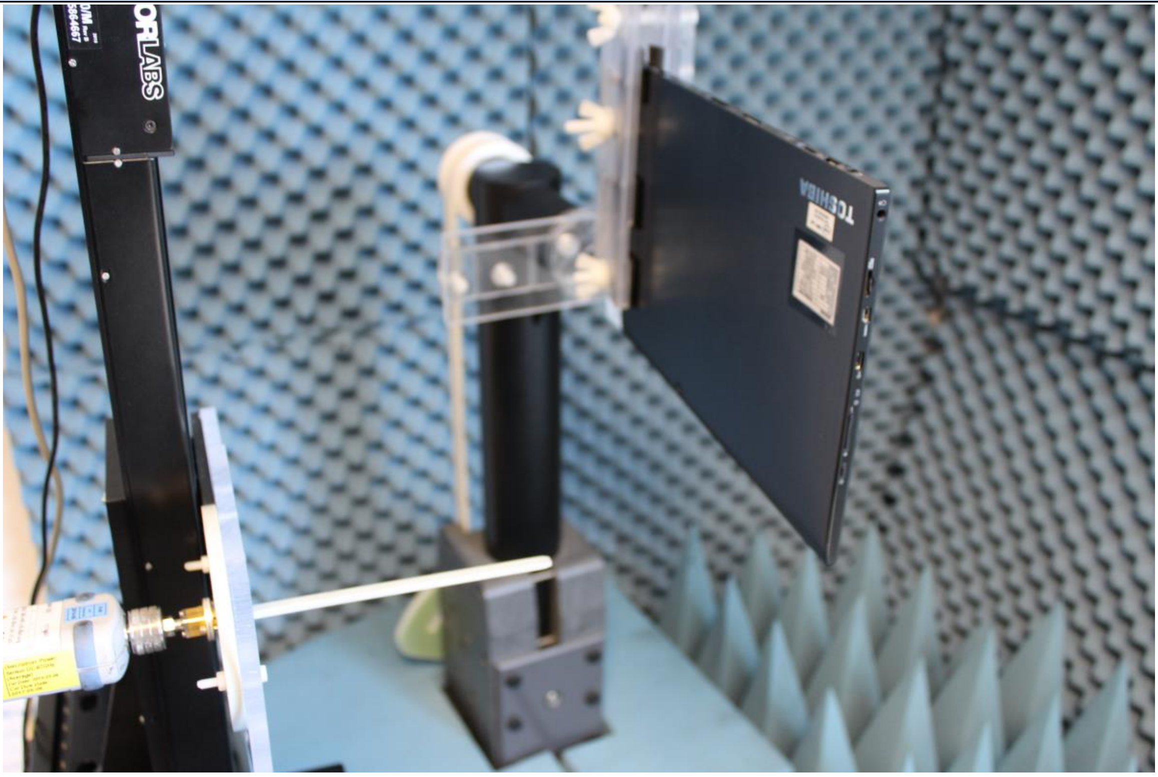
Channel	**Frequency (GHz)**	**Dimension a (m)**	**Theoretical Gain (dBi)** $10\log(21.6 \cdot f[GHz] \cdot a)$	**Measured Gain (dBi)**	**Delta to Theoretical Gain (dB)**
1	58.32	0.00376	6.75	5.37	1.38
2	60.48	0.00376	6.91	5.86	1.05
3	62.64	0.00376	7.06	7.56	0.50

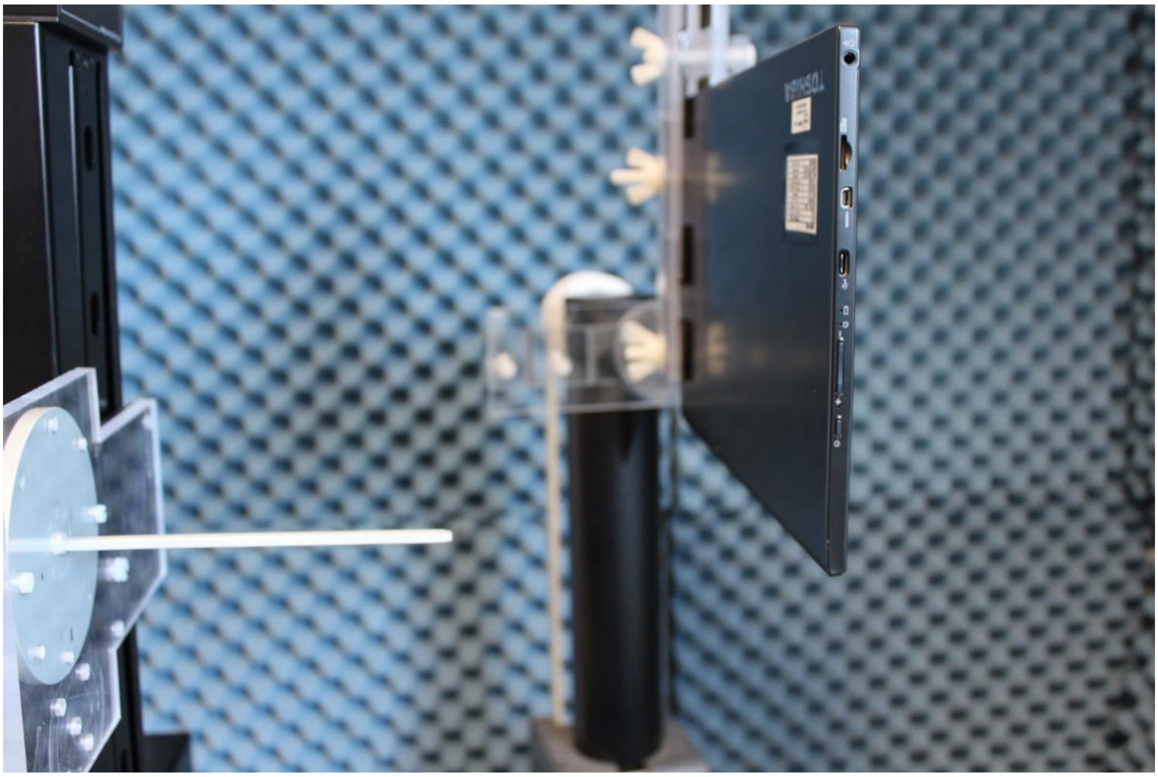
Printed copies are not controlled documents

Annex D. Photographs

Test Setup

RF exposure setup





Printed copies are not controlled documents