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Accreditation No.: **SCS 0108**

Client **UL CCS USA**

Certificate No: **EF3-4041_Mar19**

CALIBRATION CERTIFICATE

Object **EF3DV3- SN:4041**

Calibration procedure(s) **QA CAL-02.v9, QA CAL-25.v7
Calibration procedure for E-field probes optimized for close near field
evaluations in air**

Calibration date: **March 22, 2019**

This calibration certificate documents the traceability to national standards, which realize the physical units of measurements (SI).
The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.

All calibrations have been conducted in the closed laboratory facility: environment temperature (22 ± 3)°C and humidity < 70%.

Calibration Equipment used (M&TE critical for calibration)

Primary Standards	ID	Cal Date (Certificate No.)	Scheduled Calibration
Power meter NRP	SN: 104778	04-Apr-18 (No. 217-02672/02673)	Apr-19
Power sensor NRP-Z91	SN: 103244	04-Apr-18 (No. 217-02672)	Apr-19
Power sensor NRP-Z91	SN: 103245	04-Apr-18 (No. 217-02673)	Apr-19
Reference 20 dB Attenuator	SN: S5277 (20x)	04-Apr-18 (No. 217-02682)	Apr-19
DAE4	SN: 789	14-Jan-19 (No. DAE4-789_Jan19)	Jan-20
Reference Probe ER3DV6	SN: 2328	09-Oct-18 (No. ER3-2328_Oct18)	Oct-19
Secondary Standards	ID	Check Date (in house)	Scheduled Check
Power meter E4419B	SN: GB41293874	06-Apr-16 (in house check Jun-18)	In house check: Jun-20
Power sensor E4412A	SN: MY41498087	06-Apr-16 (in house check Jun-18)	In house check: Jun-20
Power sensor E4412A	SN: 000110210	06-Apr-16 (in house check Jun-18)	In house check: Jun-20
RF generator HP 8648C	SN: US3642U01700	04-Aug-99 (in house check Jun-18)	In house check: Jun-20
Network Analyzer E8358A	SN: US41080477	31-Mar-14 (in house check Oct-18)	In house check: Oct-19

Calibrated by:	Name Jeton Kastrati	Function Laboratory Technician	Signature
Approved by:	Name Katja Pokovic	Function Technical Manager	Signature

Issued: March 23, 2019

This calibration certificate shall not be reproduced except in full without written approval of the laboratory.



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Glossary:

NORM _{x,y,z}	sensitivity in free space
DCP	diode compression point
CF	crest factor (1/duty_cycle) of the RF signal
A, B, C, D	modulation dependent linearization parameters
En	incident E-field orientation normal to probe axis
Ep	incident E-field orientation parallel to probe axis
Polarization φ	φ rotation around probe axis
Polarization ϑ	ϑ rotation around an axis that is in the plane normal to probe axis (at measurement center), i.e., $\vartheta = 0$ is normal to probe axis
Connector Angle	information used in DASY system to align probe sensor X to the robot coordinate system

Calibration is Performed According to the Following Standards:

- IEEE Std 1309-2005, " IEEE Standard for calibration of electromagnetic field sensors and probes, excluding antennas, from 9 kHz to 40 GHz", December 2005
- CTIA Test Plan for Hearing Aid Compatibility, Rev 3.1.1, May 2017

Methods Applied and Interpretation of Parameters:

- NORM_{x,y,z}**: Assessed for E-field polarization $\vartheta = 0$ for XY sensors and $\vartheta = 90$ for Z sensor ($f \leq 900$ MHz in TEM-cell; $f > 1800$ MHz: R22 waveguide).
- NORM(f)_{x,y,z}** = NORM_{x,y,z} * frequency_response (see Frequency Response Chart).
- DCP_{x,y,z}**: DCP are numerical linearization parameters assessed based on the data of power sweep with CW signal (no uncertainty required). DCP does not depend on frequency nor media.
- PAR**: PAR is the Peak to Average Ratio that is not calibrated but determined based on the signal characteristics
- A_{x,y,z}; B_{x,y,z}; C_{x,y,z}; D_{x,y,z}; VR_{x,y,z}**: A, B, C, D are numerical linearization parameters assessed based on the data of power sweep for specific modulation signal. The parameters do not depend on frequency nor media. VR is the maximum calibration range expressed in RMS voltage across the diode.
- Spherical isotropy (3D deviation from isotropy)**: in a locally homogeneous field realized using an open waveguide setup.
- Sensor Offset**: The sensor offset corresponds to the offset of virtual measurement center from the probe tip (on probe axis). No tolerance required.
- Connector Angle**: The angle is assessed using the information gained by determining the NORM_x (no uncertainty required).

DASY/EASY - Parameters of Probe: EF3DV3 - SN:4041

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm ($\mu\text{V}/(\text{V}/\text{m})^2$)	0.90	0.81	1.02	$\pm 10.1\%$
DCP (mV) ^B	97.7	93.5	94.3	

Calibration results for Frequency Response (30 MHz – 6 GHz)

Frequency MHz	Target E-Field V/m	Measured E-field (En) V/m	Deviation E-normal in %	Measured E-field (Ep) V/m	Deviation E-normal in %	Unc (k=2) %
30	77.3	77.0	-0.4%	77.4	0.1%	$\pm 5.1\%$
100	77.2	78.5	1.7%	78.1	1.2%	$\pm 5.1\%$
450	77.0	78.4	1.8%	77.9	1.2%	$\pm 5.1\%$
600	77.1	78.1	1.2%	77.6	0.7%	$\pm 5.1\%$
750	77.1	77.8	0.8%	77.3	0.2%	$\pm 5.1\%$
1800	140.3	136.9	-2.4%	137.1	-2.3%	$\pm 5.1\%$
2000	133.2	129.5	-2.7%	129.5	-2.8%	$\pm 5.1\%$
2200	125.0	121.7	-2.7%	122.8	-1.8%	$\pm 5.1\%$
2500	123.7	120.6	-2.5%	121.7	-1.6%	$\pm 5.1\%$
3000	77.0	75.0	-2.6%	76.1	-1.2%	$\pm 5.1\%$
3500	255.9	247.7	-3.2%	245.9	-3.9%	$\pm 5.1\%$
3700	249.4	239.0	-4.2%	238.7	-4.3%	$\pm 5.1\%$
5200	50.8	50.8	0.0%	51.2	1.0%	$\pm 5.1\%$
5500	49.7	48.9	-1.5%	48.8	-1.6%	$\pm 5.1\%$
5800	48.9	49.1	0.4%	49.4	1.0%	$\pm 5.1\%$

Calibration Results for Modulation Response

UID	Communication System Name		A dB	B dB $\sqrt{\mu\text{V}}$	C	D dB	VR mV	Max dev.	Unc ^E (k=2)
0	CW	X	0.0	0.0	1.0	0.00	140.1	$\pm 3.5\%$	$\pm 4.7\%$
		Y	0.0	0.0	1.0		126.0		
		Y	0.0	0.0	1.0		150.0		

Note: For details on UID parameters see Appendix

The reported uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k=2, which for a normal distribution corresponds to a coverage probability of approximately 95%.

^B Numerical linearization parameter: uncertainty not required.

^E Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

DASY/EASY - Parameters of Probe: EF3DV3 - SN:4041

Sensor Frequency Model Parameters

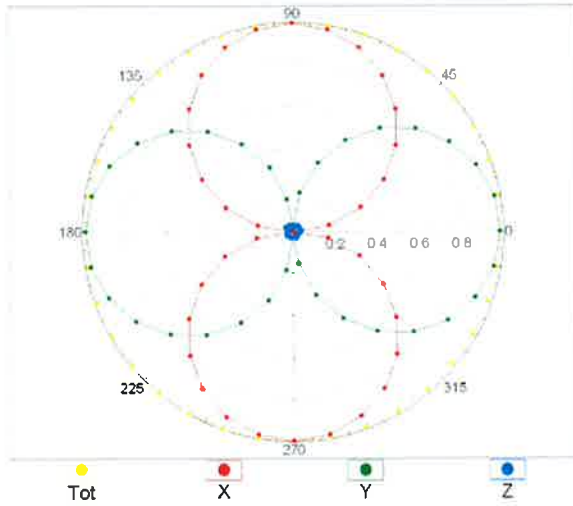
	Sensor X	Sensor Y	Sensor Z
Frequency Corr. (LF)	0.77	0.18	3.92
Frequency Corr. (HF)	2.82	2.82	2.82

Other Probe Parameters

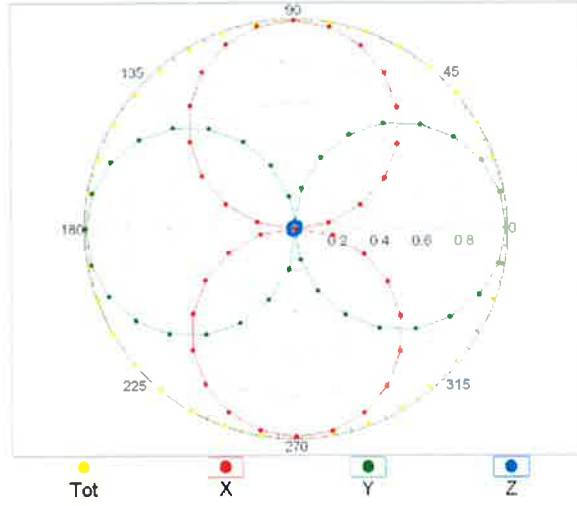
Sensor Arrangement	Rectangular
Connector Angle (°)	33.8
Mechanical Surface Detection Mode	enabled
Optical Surface Detection Mode	disabled
Probe Overall Length	337 mm
Probe Body Diameter	12 mm
Tip Length	25 mm
Tip Diameter	4 mm
Probe Tip to Sensor X Calibration Point	1.5 mm
Probe Tip to Sensor Y Calibration Point	1.5 mm
Probe Tip to Sensor Z Calibration Point	1.5 mm

Receiving Pattern (ϕ), $\vartheta = 0^\circ$

f=600 MHz,TEM,0°

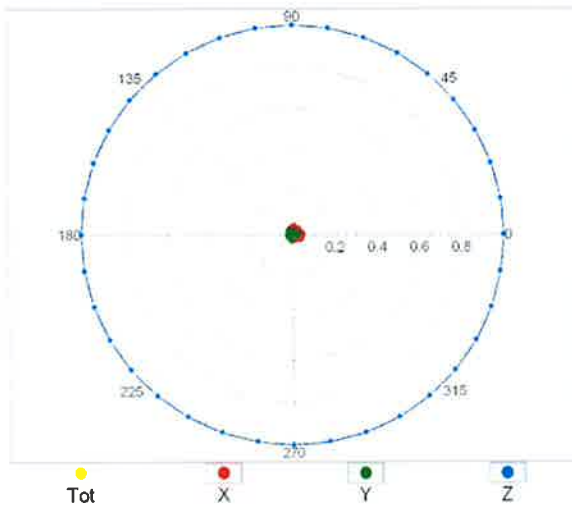


f=1800 MHz,R22,0°

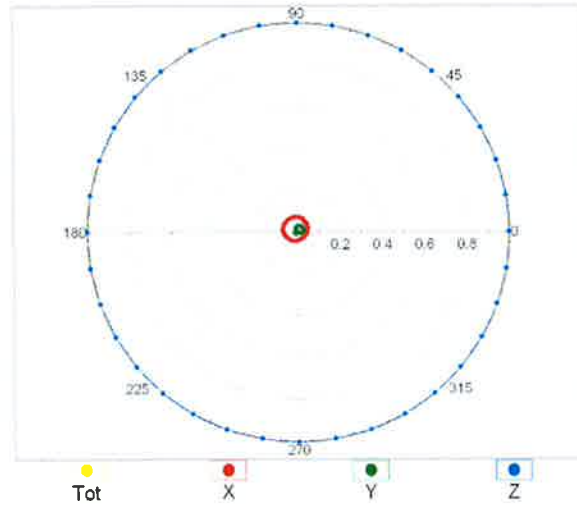


Receiving Pattern (ϕ), $\vartheta = 90^\circ$

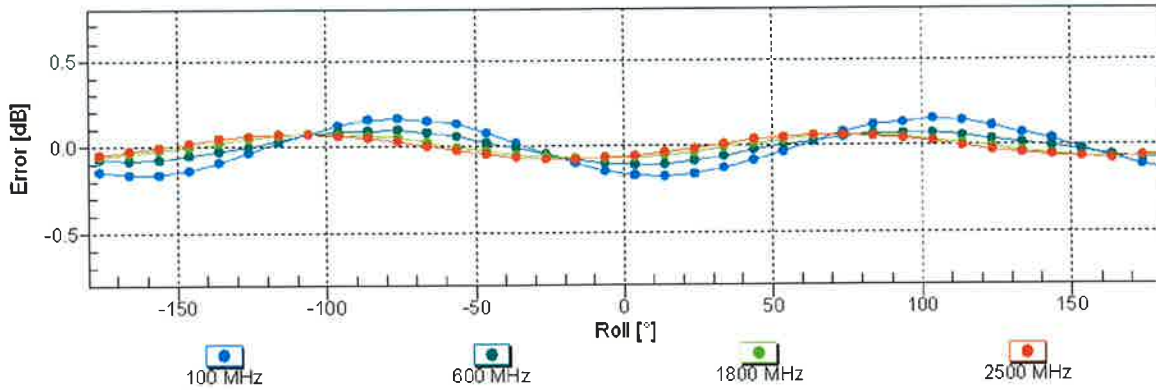
f=600 MHz,TEM,90°



f=1800 MHz,R22,90°

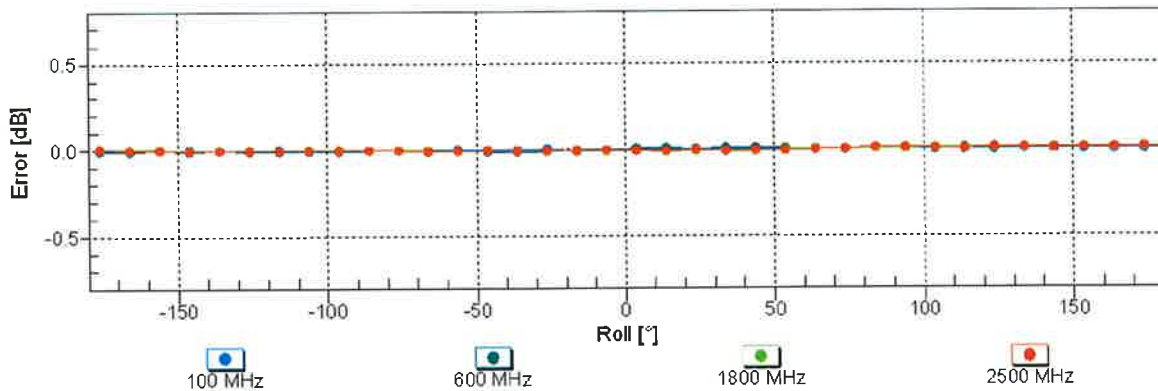


Receiving Pattern (ϕ), $\vartheta = 0^\circ$



Uncertainty of Axial Isotropy Assessment: $\pm 0.5\%$ (k=2)

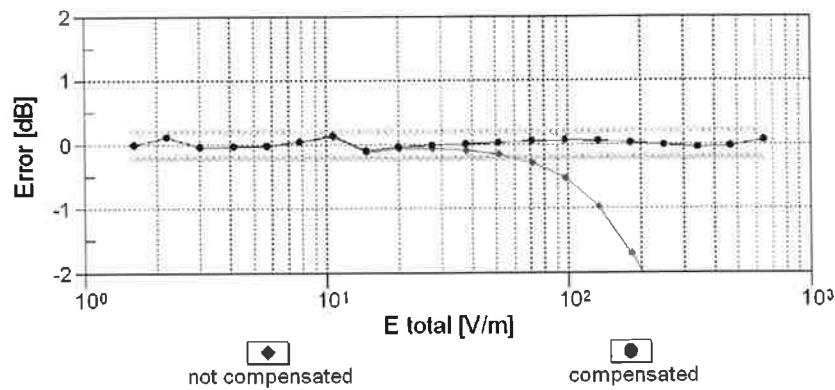
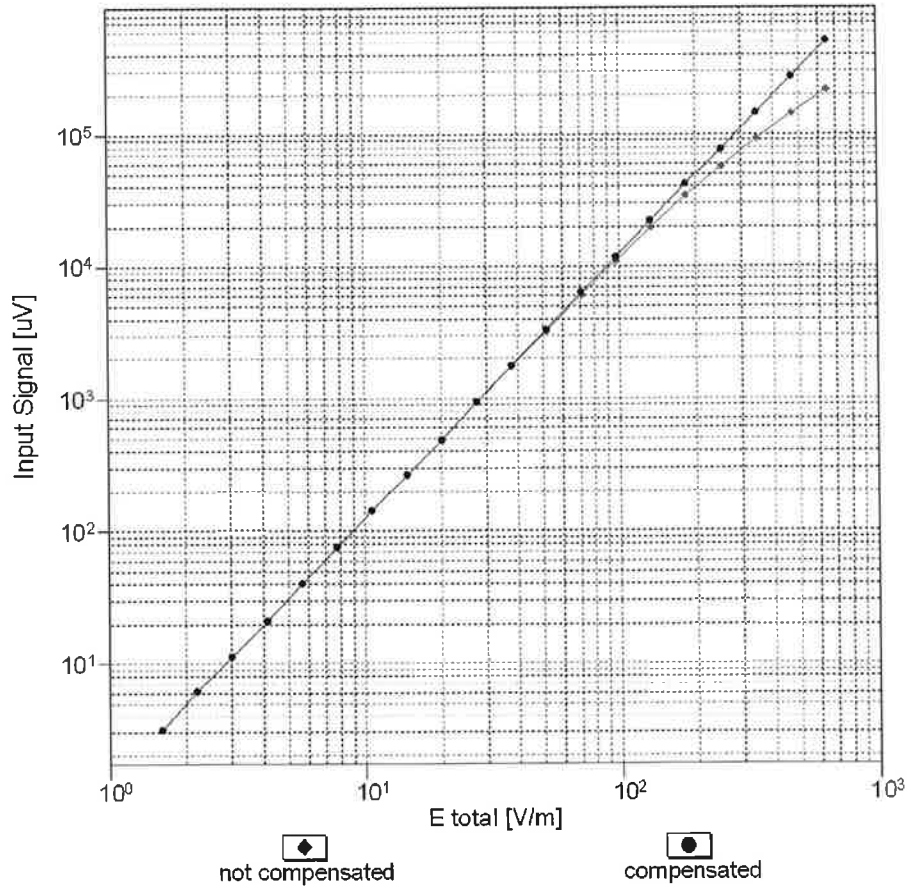
Receiving Pattern (ϕ), $\vartheta = 90^\circ$



Uncertainty of Axial Isotropy Assessment: $\pm 0.5\%$ (k=2)

Dynamic Range f(E-field)

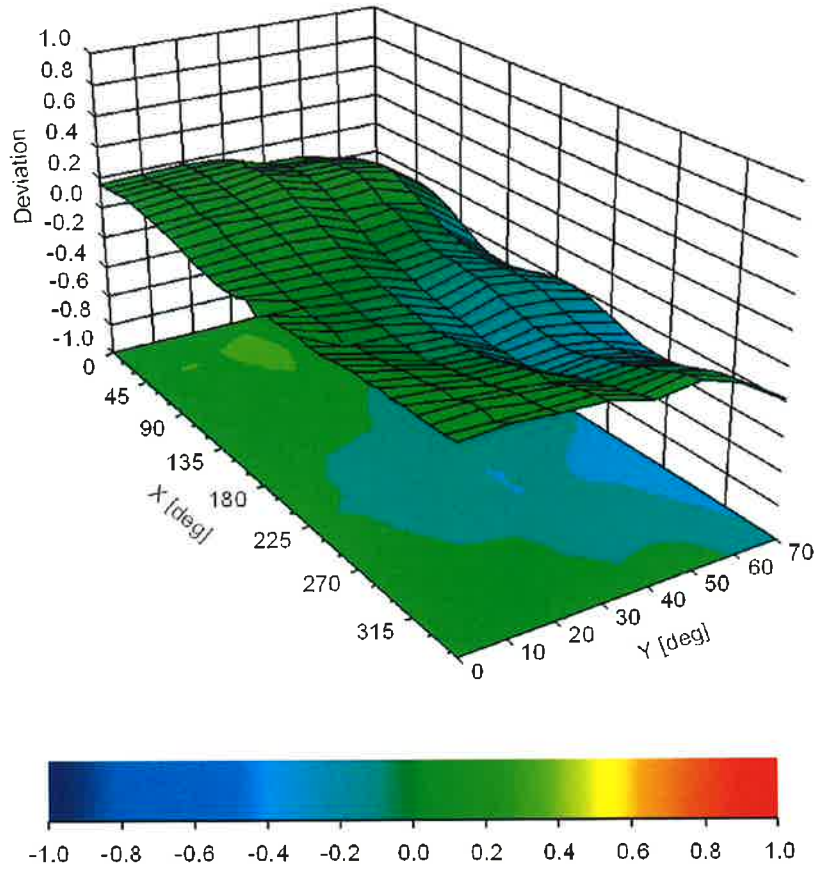
(TEM cell, f = 900 MHz)



Uncertainty of Linearity Assessment: ± 0.6% (k=2)

Deviation from Isotropy in Air

Error (ϕ , θ), $f = 900$ MHz



Uncertainty of Spherical Isotropy Assessment: $\pm 2.6\%$ ($k=2$)

Appendix: Modulation Calibration Parameters

UID	Communication System Name		A dB	B dB√μV	C	D dB	VR mV	Max dev.	Unc ^E (k=2)
10021-DAC	GSM-FDD (TDMA, GMSK)	X	1.69	65.3	11.5	9.39	143.5	±1.7 %	± 4.7 %
		Y	1.68	67.6	13.4		128.4		
		Z	1.24	63.7	11.2		111.4		
10023-DAC	GPRS-FDD (TDMA, GMSK, TN 0)	X	1.71	65.3	11.7	9.57	139.1	±2.2 %	± 4.7 %
		Y	1.57	66.4	13.1		123.7		
		Z	1.35	65.2	12.3		108.6		
10024-DAC	GPRS-FDD (TDMA, GMSK, TN 0-1)	X	1.20	63.6	9.4	6.56	138.6	±1.4 %	± 4.7 %
		Y	1.05	63.4	9.8		123.2		
		Z	0.87	61.4	8.4		138.1		
10027-DAC	GPRS-FDD (TDMA, GMSK, TN 0-1-2)	X	0.58	58.8	6.1	4.80	123.4	±1.7 %	± 4.7 %
		Y	0.93	65.5	10.6		146.0		
		Z	0.58	59.7	6.8		129.1		
10028-DAC	GPRS-FDD (TDMA, GMSK, TN 0-1-2-3)	X	0.50	58.4	4.3	3.55	138.9	±1.4 %	± 4.7 %
		Y	0.64	61.1	6.3		125.4		
		Z	0.48	58.6	5.2		145.8		
10030-CAA	IEEE 802.15.1 Bluetooth (GFSK, DH1)	X	0.94	61.7	7.0	5.30	118.4	±1.2 %	± 4.7 %
		Y	0.87	61.9	7.6		140.0		
		Z	0.65	59.2	5.8		122.7		
10061-CAB	IEEE 802.11b WiFi 2.4 GHz (DSSS, 11 Mbps)	X	3.00	71.1	21.1	3.60	128.2	±0.7 %	± 4.7 %
		Y	2.76	69.0	20.2		115.9		
		Z	3.34	73.1	22.1		136.8		
10069-CAC	IEEE 802.11a/h WiFi 5 GHz (OFDM, 54 Mbps)	X	10.65	70.0	24.4	10.56	129.7	±3.0 %	± 4.7 %
		Y	10.55	69.1	23.9		116.8		
		Z	10.71	69.8	24.3		139.3		
10077-CAB	IEEE 802.11g WiFi 2.4 GHz (DSSS/OFDM, 54 Mbps)	X	9.61	69.1	24.4	11.00	110.3	±2.7 %	± 4.7 %
		Y	9.97	70.1	25.2		135.1		
		Z	9.64	68.9	24.3		116.7		
10173-CAG	LTE-TDD (SC-FDMA, 1 RB, 20 MHz, 16-QAM)	X	6.06	73.3	26.4	9.48	130.7	±3.3 %	± 4.7 %
		Y	5.77	70.9	25.1		118.2		
		Z	5.68	70.7	24.8		135.2		
10235-CAF	LTE-TDD (SC-FDMA, 1 RB, 10 MHz, 16-QAM)	X	6.04	73.0	26.2	9.48	130.8	±3.0 %	± 4.7 %
		Y	5.78	71.0	25.1		118.1		
		Z	5.70	70.9	24.9		135.6		
10238-CAF	LTE-TDD (SC-FDMA, 1 RB, 15 MHz, 16-QAM)	X	6.06	73.2	26.3	9.48	131.0	±3.3 %	± 4.7 %
		Y	5.75	70.9	25.0		118.1		
		Z	5.71	70.9	24.9		135.6		
10295-AAB	CDMA2000, RC1, SO3, 1/8th Rate 25 fr.	X	5.33	69.6	26.1	12.49	111.8	±1.7 %	± 4.7 %
		Y	4.96	67.2	25.2		99.6		
		Z	4.57	64.2	22.9		86.2		
10647-AAF	LTE-TDD (SC-FDMA, 1 RB, 20 MHz, QPSK, UL Subframe=2,7)	X	6.48	75.4	29.7	11.96	129.0	±3.0 %	± 4.7 %
		Y	6.10	73.0	28.7		145.3		
		Z	5.73	70.8	27.1		126.3		