



SAR TEST REPORT

REPORT NO.: SA970930L16

MODEL NO.: WU211(refer to item 3.1 for more details)

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APPLICANT: Quanta Microsystems, Inc.

ADDRESS: 188 Wenhwa 2nd Rd., Kueishan Hsiang Taoyuan
Shien 333, Taiwan, R.O.C.

ISSUED BY: Bureau Veritas Consumer Products Services
(H.K.) Ltd., Taoyuan Branch

LAB ADDRESS: No. 47, 14th Ling, Chia Pau Tsuen, Lin Kou
Hsiang, Taipei Hsien 244, Taiwan, R.O.C.

TEST LOCATION: No. 19, Hwa Ya 2nd Rd, Wen Hwa Tsuen, Kwei
Shan Hsiang, Taoyuan Hsien 333, Taiwan, R.O.C.

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1. CERTIFICATION

PRODUCT: IEEE802.16e WiMAX USB Dongle (refer to item 3.1 for more details)
MODEL: WU211 (refer to item 3.1 for more details)
BRAND: QMI (refer to item 3.1 for more details)
APPLICANT: Quanta Microsystems, Inc.
TESTED: Jan. 07, 2009
TEST SAMPLE: ENGINEERING SAMPLE
STANDARDS: FCC Part 2 (Section 2.1093)
FCC OET Bulletin 65, Supplement C (01-01)
RSS-102

The above equipment (model: WU211) has been tested by **Bureau Veritas Consumer Products Services (H.K.) Ltd., Taoyuan Branch**, and found compliance with the requirement of the above standards. The test record, data evaluation & Equipment Under Test (EUT) configurations represented herein are true and accurate accounts of the measurements of the sample's EMC characteristics under the conditions specified in this report.

PREPARED BY : Andrea Hsia , **DATE:** Jan. 17, 2009
Andrea Hsia / Specialist

TECHNICAL ACCEPTANCE : James Fan , **DATE:** Jan. 17, 2009
Responsible for RF James Fan / Engineer

APPROVED BY : Gary Chang , **DATE:** Jan. 17, 2009
Gary Chang / Assistant Manager



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2. GENERAL INFORMATION

2.1 GENERAL DESCRIPTION OF EUT

PRODUCT	IEEE802.16e WiMAX USB Dongle (refer to NOTE for more details)
MODEL NO.	WU211 (refer to NOTE for more details)
FCC ID	T5U-WU211
POWER SUPPLY	5.0Vdc from host equipment
MODULATION TYPE	QPSK, 16QAM, 64QAM (refer to NOTE 1 for more details)
CODING RATE	1/2, 2/3, 3/4 (refer to NOTE 1 for more details)
MODULATION TECHNOLOGY	OFDMA
DUPLEX METHOD	TDD
FREQUENCY RANGE	2496MHz ~ 2690MHz
CHANNEL BANDWIDTH	5MHz, 10MHz
CONDUCTED OUTPUT POWER	Refer to Note 4
OPERATION TEMPERATURE RANGE	0°C ~ 45°C
AVERAGE SAR (1g)	1.461W/kg
ANTENNA TYPE	Printed antenna with 2.8dBi gain
DATA CABLE	0.08m USB cable without core
I/O PORTS	USB
ACCESSORY DEVICES	Refer to note 2 as below

NOTE:

1. The models as below are identical to each other except for their model designation, brand name and product name due to marketing requirement.

BRAND	MODEL	PRODUCT NAME
QMI	WU211	IEEE802.16e WiMAX USB Dongle
Alcatel-Lucent	1AF16465xxxx (The "x" means 0~9 or A~Z or blank)	Alcatel-Lucent 9799 MIMO USB Dongle 2.5 GHz

2. For the EUT with accessory devices as below:

ACCESSORY DEVICES	Remark
USB connector 1	Black
USB connector 2	Black
USB cable	White

*For the two of the convertible USB connector & USB cable, client will chose one of them random for sale.

**For the USB connector 1 & 2 were difference in internal design.

3. For the EUT with modulation type and coding rate. After pre-testing in test items of output power and spurious emissions, QPSK was found to be worst case and was selected for the final test configuration.

DOWN LINK		UP LINK	
MODULATION	CODING RATE	MODULATION	CODING RATE
QPSK	1/2	QPSK	1/2
	3/4		3/4
16QAM	1/2	16QAM	1/2
	3/4		3/4
64QAM	1/2		
	2/3		
	3/4		

4. The conducted output powers were listed as below.

Communication	5MHz QPSK 1/2	5MHz QPSK 3/4	5MHz 16QAM 1/2	5MHz 16QAM 3/4
Channel (MHz)	CONDUCTED OUTPUT POWER (dBm)			
2498.5	22.58	22.40	22.54	22.50
2587.0	22.48	22.57	22.60	22.72
2687.5	23.80	23.76	23.66	23.77
Communication	10MHz QPSK 1/2	10MHz QPSK 3/4	10MHz 16QAM 1/2	10MHz 16QAM 3/4
Channel (MHz)	CONDUCTED OUTPUT POWER (dBm)			
2501	22.45	22.48	22.49	22.46
2587	22.43	22.40	22.39	22.44
2685	23.02	23.03	23.09	23.05

5. The above EUT information was declared by manufacturer and for more detailed features description, please refers to the manufacturer's specifications or User's Manual.

2.2 GENERAL DESCRIPTION OF APPLIED STANDARDS

According to the specifications of the manufacturer, this product must comply with the requirements of the following standards:

FCC Part 2 (2.1093)

FCC OET Bulletin 65, Supplement C (01- 01)

RSS-102

IEEE 1528-2003

All test items have been performed and recorded as per the above standards.

2.3 GENERAL INFORMATION OF THE SAR SYSTEM

DASY4 (**software 4.7 Build 53**) consists of high precision robot, probe alignment sensor, phantom, robot controller, controlled measurement server and near-field probe. The robot includes six axes that can move to the precision position of the DASY4 software defined. The DASY4 software can define the area that is detected by the probe. The robot is connected to controlled box. Controlled measurement server is connected to the controlled robot box. The DAE includes amplifier, signal multiplexing, AD converter, offset measurement and surface detection. It is connected to the Electro-optical coupler (ECO). The ECO performs the conversion from the optical into digital electric signal of the DAE and transfers data to the PC.

EX3DV3 ISOTROPIC E-FIELD PROBE

CONSTRUCTION	Symmetrical design with triangular core Built-in shielding against static charges PEEK enclosure material (resistant to organic solvents, e.g., DGBE)
FREQUENCY	10 MHz to > 6 GHz Linearity: ± 0.2 dB (30 MHz to 6 GHz)
DIRECTIVITY	± 0.3 dB in HSL (rotation around probe axis) ± 0.5 dB in tissue material (rotation normal to probe axis)
DYNAMIC RANGE	10 μ W/g to > 100 mW/g Linearity: ± 0.2 dB (noise: typically < 1 μ W/g)
DIMENSIONS	Overall length: 330 mm (Tip: 20 mm) Tip diameter: 2.5 mm (Body: 12 mm) Typical distance from probe tip to dipole centers: 1 mm
APPLICATION	High precision dosimetric measurements in any exposure scenario (e.g., very strong gradient fields). Only probe which enables compliance testing for frequencies up to 6 GHz with precision of better 30%.

NOTE

1. The Probe parameters have been calibrated by the SPEAG. Please reference "APPENDIX D" for the Calibration Certification Report.
2. For frequencies above 800MHz, calibration in a rectangular wave-guide is used, because wave-guide size is manageable.
3. For frequencies below 800MHz, temperature transfer calibration is used because the wave-guide size becomes relatively large.

TWIN SAM V4.0

CONSTRUCTION

The shell corresponds to the specifications of the Specific Anthropomorphic Mannequin (SAM) phantom defined in IEEE 1528-2003, EN 62209-1 and IEC 62209. It enables the dosimetric evaluation of left and right hand phone usage as well as body mounted usage at the flat phantom region. A cover prevents evaporation of the liquid. Reference markings on the phantom allow the complete setup of all predefined phantom positions and measurement grids by manually teaching three points with the robot.

SHELL THICKNESS

$2 \pm 0.2\text{mm}$

FILLING VOLUME

Approx. 25liters

DIMENSIONS

Height: 810mm; Length: 1000mm; Width: 500mm

SYSTEM VALIDATION KITS:

CONSTRUCTION

Symmetrical dipole with I/4 balun enables measurement of feedpoint impedance with NWA matched for use near flat phantoms filled with brain simulating solutions. Includes distance holder and tripod adaptor

CALIBRATION

Calibrated SAR value for specified position and input power at the flat phantom in brain simulating solutions

FREQUENCY

2600MHz

RETURN LOSS

> 20dB at specified validation position

POWER CAPABILITY

> 100W ($f < 1\text{GHz}$); > 40W ($f > 1\text{GHz}$)

OPTIONS

Dipoles for other frequencies or solutions and other calibration conditions upon request

DEVICE HOLDER FOR SAM TWIN PHANTOM

CONSTRUCTION

The device holder for the mobile phone device is designed to cope with different positions given in the standard. It has two scales for the device rotation (with respect to the body axis) and the device inclination (with respect to the line between the ear reference points). The rotation centers for both scales is the ear reference point (ERP). Thus the device needs no repositioning when changing the angles. The holder has been made out of low-loss POM material having the following dielectric parameters: relative permittivity $\varepsilon = 3$ and loss tangent $\delta = 0.02$. The amount of dielectric material has been reduced in the closest vicinity of the device, since measurements have suggested that the influence of the clamp on the test results could thus be lowered. The device holder for the portable device makes up of the polyethylene foam. The dielectric parameters of material close to the dielectric parameters of the air.

DATA ACQUISITION ELECTRONICS

CONSTRUCTION

The data acquisition electronics (DAE3) consists of a highly sensitive electrometer grade preamplifier with auto-zeroing, a channel and gain-switching multiplex, a fast 16 bit AD converter and a command decoder and control logic unit. Transmission to the measurement server is accomplished through an optical downlink for data and status information as well as an optical uplink for commands and the clock. The mechanical probe is mounting device includes two different sensor systems for frontal and sideways probe contacts. They are used for mechanical surface detection and probe collision detection. The input impedance of the DAE3 box is 200M Ω ; the inputs are symmetrical and floating. Common mode rejection is above 80 dB.

2.4 GENERAL DESCRIPTION OF THE SPATIAL PEAK SAR EVALUATION

The DASY4 post-processing software (SEMCAD) automatically executes the following procedures to calculate the field units from the micro-volt readings at the probe connector. The parameters used in the evaluation are stored in the configuration modules of the software:

Probe parameters:	- Sensitivity	Norm _i , a _{i0} , a _{i1} , a _{i2}
	- Conversion factor	ConvF _i
	- Diode compression point	dcp _i
Device parameters:	- Frequency	F
	- Crest factor	Cf
Media parameters:	- Conductivity	σ
	- Density	ρ

The first step of the evaluation is a linearization of the filtered input signal to account for the compression characteristics of the detector diode. The compensation depends on the input signal, the diode type and the DC-transmission factor from the diode to the evaluation electronics. If the exciting field is pulsed, the crest factor of the signal must be known to correctly compensate for peak power. The formula for each channel can be given as:

$$V_i = U_i + U_i^2 \cdot \frac{cf}{dcp_i}$$

V _i	=compensated signal of channel i	(i = x, y, z)
U _i	=input signal of channel i	(i = x, y, z)
Cf	=crest factor of exciting field	(DASY parameter)
dcp _i	=diode compression point	(DASY parameter)

From the compensated input signals the primary field data for each channel can be evaluated:

$$\text{E-field probes: } E_i = \sqrt{\frac{V_i}{\text{Norm}_i \cdot \text{ConvF}}}$$

$$\text{H-field probes: } H_i = \sqrt{V_i} \cdot \frac{a_{i0} + a_{i1}f + a_{i2}f^2}{f}$$

V_i	=compensated signal of channel I	(i = x, y, z)
Norm_i	=sensor sensitivity of channel i $\mu\text{V}/(\text{V/m})^2$ for E-field Probes	(i = x, y, z)
ConvF	= sensitivity enhancement in solution	
a_{ij}	= sensor sensitivity factors for H-field probes	
F	= carrier frequency [GHz]	
E_i	= electric field strength of channel i in V/m	
H_i	= magnetic field strength of channel i in A/m	

The RSS value of the field components gives the total field strength (Hermitian magnitude):

$$E_{tot} = \sqrt{E_x^2 + E_y^2 + E_z^2}$$

The primary field data are used to calculate the derived field units.

$$\text{SAR} = E_{tot}^2 \cdot \frac{\sigma}{\rho \cdot 1'000}$$

SAR	= local specific absorption rate in mW/g
E_{tot}	= total field strength in V/m
σ	= conductivity in [mho/m] or [Siemens/m]
ρ	= equivalent tissue density in g/cm ³

Note that the density is set to 1, to account for actual head tissue density rather than the density of the tissue simulating liquid. The entire evaluation of the spatial peak values is performed within the Post-processing engine (SEMCAD). The system always gives the maximum values for the 1g and 10g cubes. The algorithm to find the cube with highest averaged SAR is divided into the following stages:

1. The extraction of the measured data (grid and values) from the Zoom Scan
2. The calculation of the SAR value at every measurement point based on all stored data (A/D values and measurement parameters)
3. The generation of a high-resolution mesh within the measured volume
4. The interpolation of all measured values from the measurement grid to the high-resolution grid
5. The extrapolation of the entire 3-D field distribution to the phantom surface over the distance from sensor to surface
6. The calculation of the averaged SAR within masses of 1g and 10g.

The probe is calibrated at the center of the dipole sensors that is located 1 to 2.7mm away from the probe tip. During measurements, the probe stops shortly above the phantom surface, depending on the probe and the surface detecting system. Both distances are included as parameters in the probe configuration file. The software always knows exactly how far away the measured point is from the surface. As the probe cannot directly measure at the surface, the values between the deepest measured point and the surface must be extrapolated. The angle between the probe axis and the surface normal line is less than 30 degree.

The maximum search is automatically performed after each area scan measurement. It is based on splines in two or three dimensions. The procedure can find the maximum for most SAR distributions even with relatively large grid spacing. After the area scanning measurement, the probe is automatically moved to a position at the interpolated maximum. The following scan can directly use this position for reference, e.g., for a finer resolution grid or the cube evaluations. The 1g and 10g peak evaluations are only available for the predefined cube 7 x 7 x 7 scans. The routines are verified and optimized for the grid dimensions used in these cube measurements. The measured volume of 30 x 30 x 30mm contains about 30g of tissue. The first procedure is an extrapolation (incl. boundary correction) to get the points between the lowest measured plane and the surface. The next step uses 3D interpolation to get all points within the measured volume in a 1mm grid (42875 points). In the last



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step, a 1g cube is placed numerically into the volume and its averaged SAR is calculated. This cube is then moved around until the highest averaged SAR is found. If the highest SAR is found at the edge of the measured volume, the system will issue a warning: higher SAR values might be found outside of the measured volume. In that case the cube measurement can be repeated, using the new interpolated maximum as the center.

3. DESCRIPTION OF SUPPORT UNITS

The EUT has been tested as an independent unit together with other necessary accessories or support units. The following support units or accessories were used to form a representative test configuration during the tests.

NO.	PRODUCT	BRAND	MODEL NO.	SERIAL NO.	FCC ID
1	NOTEBOOK	DELL	D820	21498926752	FCC Doc Approved

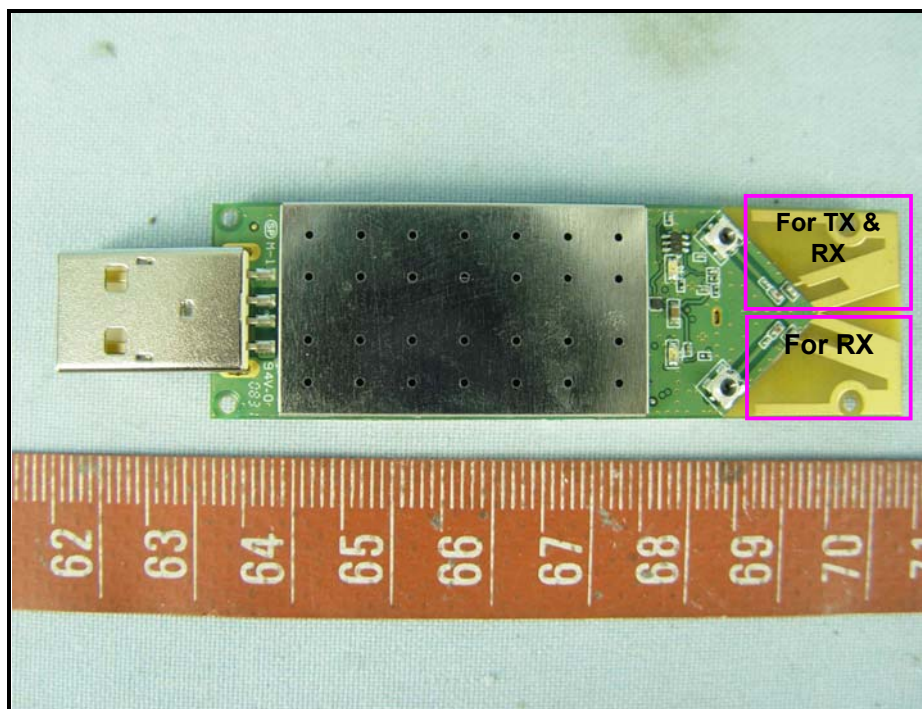
NO.	SIGNAL CABLE DESCRIPTION OF THE ABOVE SUPPORT UNITS
1	NA

NOTE 1: All power cords of the above support units are non shielded (1.8m).

NOTE 2: The length of USB cable is 11.6 inch. USB cable does not affect device radiating characteristics and output power

4. DESCRIPTION OF TEST MODES AND CONFIGURATIONS

4.1. DESCRIPTION OF ANTENNA LOCATION



NOTE: Only one antenna can transmit. This product has no antenna diversity function.

4.2. CHECK FOR WORST CASE / SCAN RESOLUTION / SWIVEL ADAPTER

Worst case determination

Choosing max output power channel of EMC report to pretest under 4 modulation types to determine worst case.

Pretest data as below:

High channel of 5MHz at bottom position		
MODULATION TYPE	OUTPUT POWER (dBm)	SAR VALUE
QPSK 1/2	23.80	1.22
QPSK 3/4	23.76	1.38
16QAM 1/2	23.66	1.27
16QAM 3/4	23.77	1.24

High channel of 10MHz at bottom position		
MODULATION TYPE	OUTPUT POWER (dBm)	SAR VALUE
QPSK 1/2	23.02	1.23
QPSK 3/4	23.03	1.25
16QAM 1/2	23.09	1.30
16QAM 3/4	23.05	1.22

Conclusion: Worst case of 5MHz channel bandwidth is QPSK 3/4.

Worst case of 10MHz channel bandwidth is 16QAM 1/2.

Compare with different scan resolution

With EUT hold on the worst case configuration (5MHz band / high channel) with no any change in position or setting, 2 scans with different resolutions are preformed to evaluate the impact on the SAR value.

Test data as below:

High channel of 5MHz at bottom position	
Scan resolution (mm)	SAR VALUE (W/kg)
2.5	1.32
5	1.38

Conclusion: No meaningful change detected.

Concern for swivel adapter

Since 2 swivel adapters will be supplied with the WU211, the swivel adapters were tested at the various configurations for finding the worst one.

Test data as below:

High channel of 5MHz at bottom position		High channel of 5MHz at Right edge position	
Configuration	AREA SCAN PEAK SAR VALUE (W/kg)	Configuration	AREA SCAN PEAK SAR VALUE (W/kg)
EUT only	1.530	EUT only	0.507
EUT with swivel USB connected 1 at 0°	1.510	EUT with swivel USB connected 1 at 0°	0.438
EUT with swivel USB connected 1 at 45°	0.228	EUT with swivel USB connected 1 at 45°	0.338
EUT with swivel USB connected 1 at 90°	0.203	EUT with swivel USB connected 1 at 90°	0.338
EUT with swivel USB connected 2 at 0°	1.440	EUT with swivel USB connected 2 at 0°	0.504
EUT with swivel USB connected 2 at 45°	0.323	EUT with swivel USB connected 2 at 45°	0.271
EUT with swivel USB connected 2 at 90°	0.394	EUT with swivel USB connected 2 at 90°	0.364

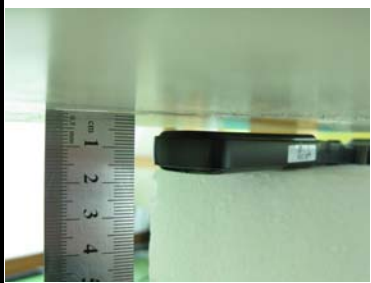
High channel of 5MHz at Left edge position		High channel of 5MHz at Tip position	
Configuration	AREA SCAN PEAK SAR VALUE (W/kg)	Configuration	AREA SCAN PEAK SAR VALUE (W/kg)
EUT only	1.290	EUT only	0.385
EUT with swivel USB connected 1 at 0°	1.230	EUT with swivel USB connected 1 at 0°	0.298
EUT with swivel USB connected 1 at 45°	1.060	EUT with swivel USB connected 1 at 45°	0.297
EUT with swivel USB connected 1 at 90°	1.230	EUT with swivel USB connected 1 at 90°	0.335
EUT with swivel USB connected 2 at 0°	1.280	EUT with swivel USB connected 2 at 0°	0.379
EUT with swivel USB connected 2 at 45°	1.230	EUT with swivel USB connected 2 at 45°	0.261
EUT with swivel USB connected 2 at 90°	1.230	EUT with swivel USB connected 2 at 90°	0.267

NOTE: SAR value shown in the table is peak SAR from area scan not final 1g SAR.

Conclusion: After the tests, the result shows EUT only is the worst case of these 3 configurations.

Test set up photo

High channel of 5MHz at bottom position

		
EUT with swivel USB connected 1 at 0°	EUT with swivel USB connected 1 at 45°	EUT with swivel USB connected 1 at 90°
		
EUT with swivel USB connected 2 at 0°	EUT with swivel USB connected 2 at 45°	EUT with swivel USB connected 2 at 90°

High channel of 5MHz at Right edge position

		
EUT with swivel USB connected 1 at 0°	EUT with swivel USB connected 1 at 45°	EUT with swivel USB connected 1 at 90°
		
EUT with swivel USB connected	EUT with swivel USB connected	EUT with swivel USB connected

2 at 0°	2 at 45°	2 at 90°
---------	----------	----------

High channel of 5MHz at Left edge position

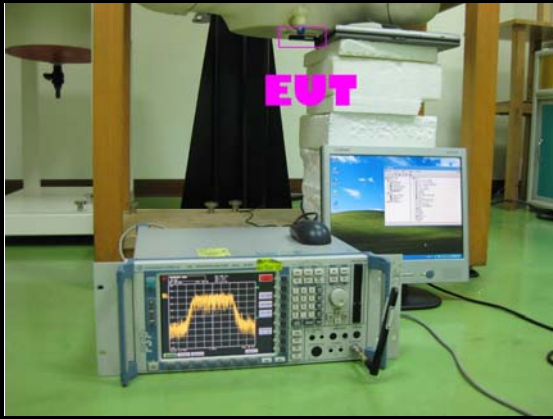
		
EUT with swivel USB connected 1 at 0°	EUT with swivel USB connected 1 at 45°	EUT with swivel USB connected 1 at 90°
		
EUT with swivel USB connected 2 at 0°	EUT with swivel USB connected 2 at 45°	EUT with swivel USB connected 2 at 90°

High channel of 5MHz at Tip position

		
EUT with swivel USB connected 1 at 0°	EUT with swivel USB connected 1 at 45°	EUT with swivel USB connected 1 at 90°
		
EUT with swivel USB connected 2 at 0°	EUT with swivel USB connected 2 at 45°	EUT with swivel USB connected 2 at 90°

4.3. DESCRIPTION OF ASSESSMENT POSITION

The following test configurations are worst case setup for each applicable configuration as concluded above and was used during the final evaluation

	
A The bottom of the EUT face to the phantom with 5mm-separation distance.	B The right edge of the EUT face to the phantom with 5mm-separation distance.
	
C The front of the EUT face to the phantom with 5mm-separation distance.	D The left edge of the EUT face to the phantom with 5mm-separation distance.
	
E The Tip of the EUT face to the phantom with 5mm-separation distance.	

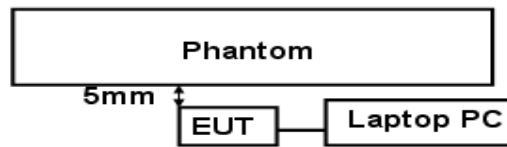
5mm-separation distance.

4.4. DESCRIPTION OF TEST MODE

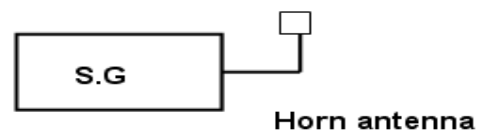
TEST MODE	COMMUNICATION	MODULATION TYPE	ASSESSMENT POSTITION	TESTED CHANNEL
1	WiMAX – 5M	QPSK 3/4	A	L, M, H
2	WiMAX – 10M	16QAM 1/2	A	L, M, H
3	WiMAX – 5M	QPSK 1/2	A	H
4	WiMAX – 5M	16QAM 1/2	A	H
5	WiMAX – 5M	16QAM 3/4	A	H
6	WiMAX – 10M	QPSK 1/2	A	H
7	WiMAX – 10M	QPSK 3/4	A	H
8	WiMAX – 10M	16QAM 3/4	A	H
9	WiMAX – 5M	QPSK 3/4	B	H
10	WiMAX – 10M	16QAM 1/2	B	H
11	WiMAX – 5M	QPSK 3/4	C	L, M, H
12	WiMAX – 10M	16QAM 1/2	C	L, M, H
13	WiMAX – 5M	QPSK 3/4	D	L, M, H
14	WiMAX – 10M	16QAM 1/2	D	L, M, H
15	WiMAX – 5M	QPSK 3/4	E	H
16	WiMAX – 10M	16QAM 1/2	E	H

4.5. TEST SETUP AND TEST SIGNAL DETAIL

The test set-up is shown in the below picture. The USB Adapter (EUT) is plugged into the notebook computer and configured exactly as it would be in the field on a normal network.



Linking up through air interface



Output power of S.G is - 20dBm

Horn antenna has 10.6dBi gain at 2.5GHz

Distance between horn antenna and EUT is 4m

The Kannon test tool is used on the laptop.

Kannon is used to instruct the USB dongle to go to full power. Under normal operating conditions the BS would be responsible for controlling the MS Tx power. When working with a BS, the MS cannot Tx at a power greater than the max power requested by Kannon.

On the network side, there is a vector signal generator as below:

Agilent E4438C ESG with below options:

N7613A: Signal Studio for 802.16-2004 WiMAX

N7615B: Signal studio for 802.16 WiMAX

Software is loaded into the E4438C ESG that produces an output signal that looks like a 29:18 WiMAX frame, the EUT detects the “network” and begins to transmit based on the commands from the ESG signal and the measurements are then taken on the EUT.

The WU211 device is 2.5 GHz WiMAX transceiver in a USB dongle configuration using Beceem chipset which supports 1xTx and 2xRx for this device. Only one antenna is used for both transmitting and receiving while the other antenna is strictly used for RX diversity. Its uplink is capable of both 10 MHz and 5 MHz bandwidths. Its uplink is capable of both 10 MHz and 5 MHz bandwidths. For the 10 MHz bandwidth, it has 35 sub-channels structured from 1024 subcarriers; 184 are used as spare/safeguard subcarriers, leaving 840 available for transmission. From this, 560 subcarriers for data transmission with 280 subcarriers intended for pilot use. For the 5 MHz bandwidth, it contains 17 sub-channels using 512 subcarriers; 104 subcarriers as spare/safeguard subcarriers, 272 for data transmission, and 136 for pilot. The up-link sub-frame is triggered by an Allocation Start Time contained in the information of UL-MAP. This information specifies the starting times of the Uplink and Downlink frames. In any UL sub-frame, the duty factor ranging and bandwidth information is used to ensure optimal system operation. In normal device transmission the device will transmit control signaling at the first 3 uplink symbols and then use the rest of the uplink symbols for data traffic bursts in the uplink sub-frame. Since the first 3 symbols are also used for ranging detection purposes and are shared among other device users, its transmitting power is much smaller than the data burst symbol power. During the testing modes the first 3 symbols have no power output and the data traffic bursts are always running at the maximum output power level. In the real usage, the data burst power will be adjusted according to the signal strength of the communication. In this way, by using the test mode arrangement we are transmitting at a worst case RF level.

The signal generator produces a downlink DL burst every 5 milliseconds which simulates the transmission of a base-station operating under normal mode. This DL burst instructs the mobile station MS to transmit for 15 symbols in the UL data zone. This UL transmission is repeated every 5 milliseconds. The TX power of the mobile station is set to maximum power. The ESG and MS use same frequency. The ESG power is much less than the MS Tx power (Approximately 80dB less than the MS power) and so does not affect the SAR readings. Since both the signal generator (BS simulator) and MS are working in TDD mode, co-operation under same frequency is not an issue.

The ESG is loaded with a BS (Base Station) downlink signal which contains the 29:18 information. The mobile station (MS) (DUT) synchronizes to the signal from the ESG in frequency and time and then demodulates two maps contained in the ESG DL frame. The first map, called the DL map, specifies the number of DL symbols (29). The second map, called the UL map, specifies the number of UL symbols (18). The UL map also tells the MS to transmit a burst which occupies all data symbols and all sub-channels. No control channel transmissions are requested by the ESG. Measurements were taken in this configuration with the MS transmitting using the 29:18 ratio, but since there was no energy in the control symbols, the effective power is only across 15 symbols.

As mentioned above the DL:UL frame is specified in the DL and UL maps respectively. There is no ranging present when there is data traffic. The other types of control traffic are HARQ ACK/NACK, CQICH (CINR reporting) and bandwidth BW requests. BW requests are piggy-backed onto the data symbols when traffic is present. Since the BW requests are shared across the Control Symbols (traffic versus non-traffic modes) the control traffic that is relevant to the SAR calculation is CQICH and HARQ ACK/NACK. The maximum power for this control traffic is 29.1 mW(5/35 of 203.7 mW) for 10MHz and 70.55 mW(5/17 of 239.88 mW) for 5MHz.



In the test mode the UL operates in PUSC with all data sub-channels (All 35 sub-channels for 10MHz) occupied with data. During normal operation the MS will transmit on all sub-channels when maximum UL throughput is required. It is possible for the mobile-station to transmit with fewer sub-channels. The sub-channels consist of tones that are distributed over the entire signal BW and a jump every three symbols so that the spectral density and hence SAR for the fractional sub-channel case will be similar to the full sub-channel case that is tested. (Note: In the WiMAX standard a sub-channel consists of tones that are spread across the occupied bandwidth. After every three symbols, the tones that make up the sub-channel switch to a new set of frequencies spread across the band. This “jumping” is called sub-channel rotation and helps to give the sub-channel frequency diversity.)

The testing was done at 29:18 ratio as this is the max achievable ratio for the product (Please refer to manufacture declaration latter). The 29 indicates the number of downlink (from the base station) symbols, and the 18 indicates the number of uplink (transmitted from the MS) symbols. Inside the uplink, 15 of the symbols are used for data, and three of the symbols are used for sending control information to the network. During the testing, the control symbols contained no information, so did not contribute to the total energy transmitted. To compensate for the maximum energy which may presented in the 3 control symbols, following scheme is used for the up scaling:

Max output power of 5MHz is 23.8dBm =239.88mW (Reference power table of P5)

The maximum power in 5M control traffic is 70.55 mW (5/17 of 239.88 mW)

Scaled factor for 5MHz bandwidth =

$$(70.55\text{mW} \times 3 + 15 \times 239.88\text{mW}) / (15 \times 239.88\text{mW}) = 1.059$$

Max output power of 10MHz is 23.09dBm =203.7mW(Reference power table of P5)

The maximum power in 10M control traffic is 29.1 mW (5/35 of 203.7 mW)

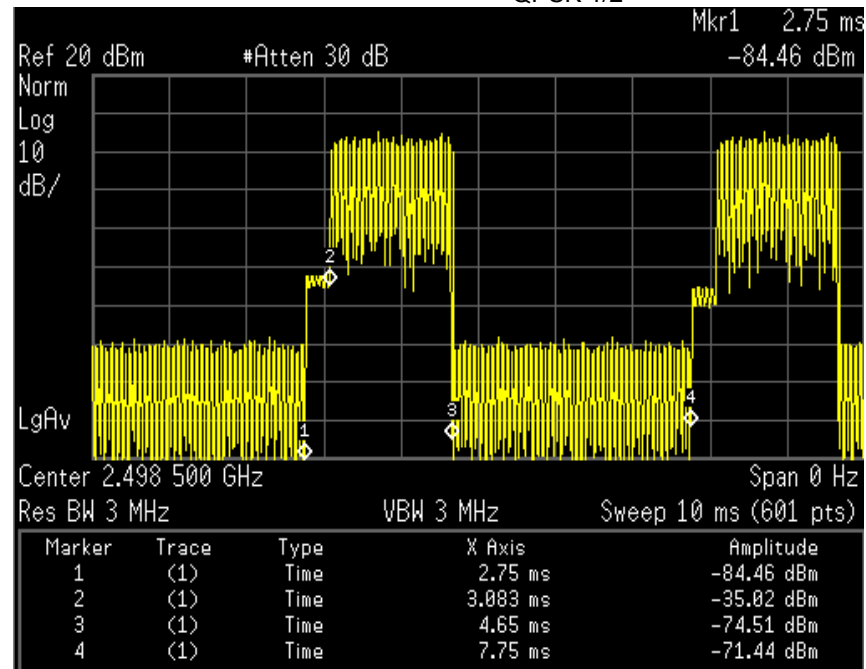
Scaled factor for 10MHz bandwidth =

$$(29.1\text{mW} \times 3 + 15 \times 203.7\text{mW}) / (15 \times 203.7\text{mW}) = 1.029$$

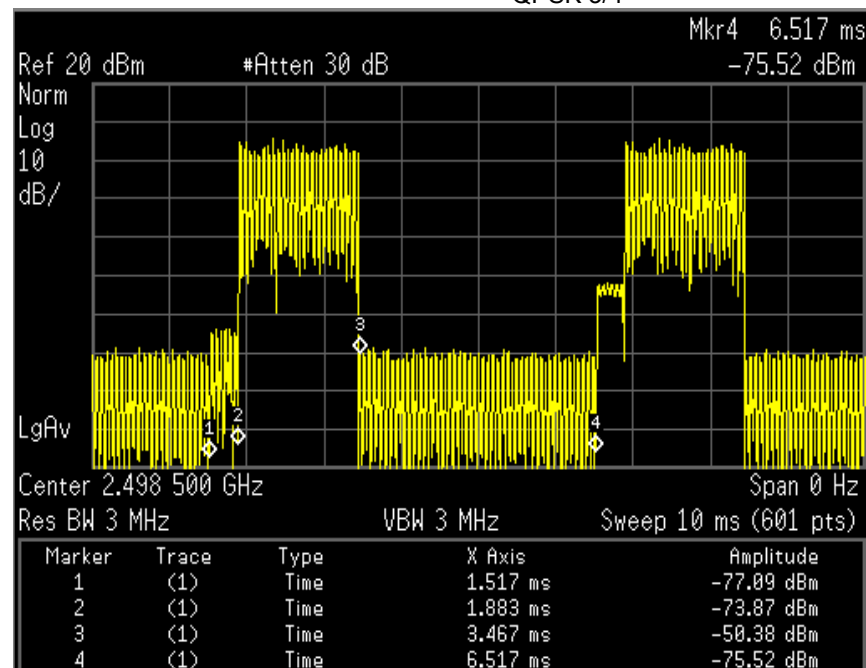
Below are the output waveforms of

29U18 waveform (QPSK)

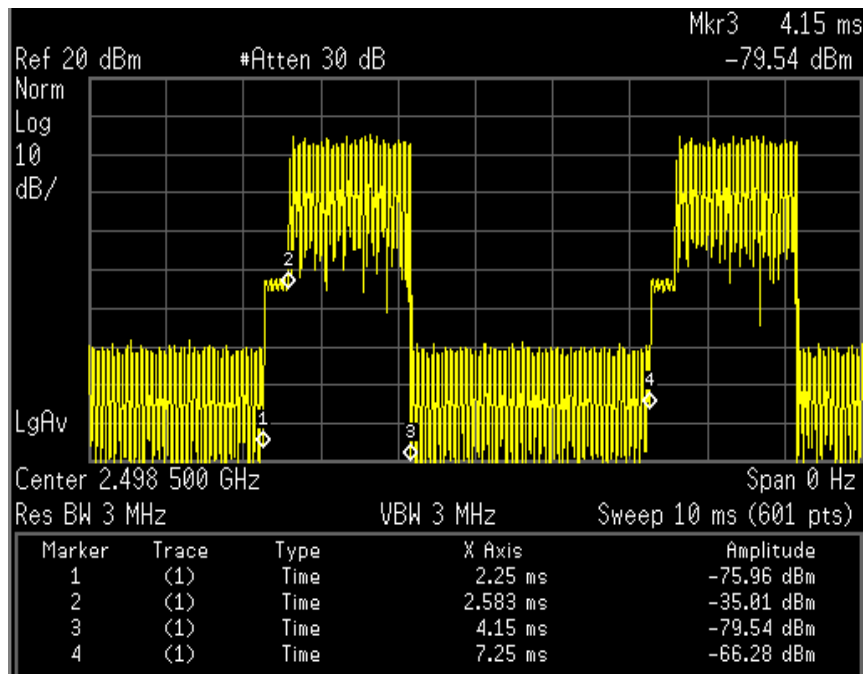
QPSK 1/2



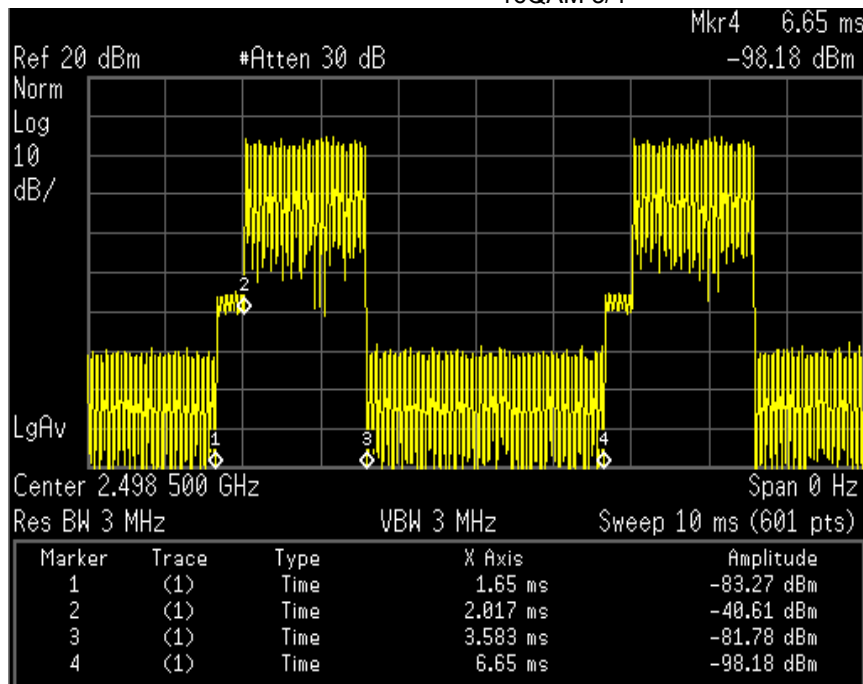
QPSK 3/4



16QAM 1/2



16QAM 3/4



Duty cycle calculated formula = (Mark 3 – Mark 2) / (Mark 4 – Mark 1) *100 %

Modulation	Duty cycle (%)
QPSK 1/2	31.34
QPSK 3/4	31.68
16QAM 1/2	31.34
16QAM 3/4	31.32

4.6. SUMMARY OF TEST RESULTS

Measurement data

MODULATION TYPE	QPSK 3/4 for 5MHz, 16QAM 1/2 for 10MHz	
	MEASURED VALUE OF 1g SAR (W/kg)	
TEST MODE	1	2
BANDWIDTH	5MHz	10MHz
LOW CHANNEL	1.220	1.180
MID. CHANNEL	1.020	1.000
HIGH CHANNEL	1.380	1.300

	MEASURED VALUE OF 1g SAR (W/kg)					
MODULATION TYPE	QPSK 1/2	16QAM 1/2	16QAM 3/4	QPSK 1/2	QPSK 3/4	16QAM 3/4
BANDWIDTH	5MHz	5MHz	5MHz	10MHz	10MHz	10MHz
TEST MODE	3	4	5	6	7	8
HIGH CHANNEL	1.22	1.27	1.24	1.23	1.25	1.22

MODULATION TYPE	QPSK 3/4 for 5MHz, 16QAM 1/2 for 10MHz							
	MEASURED VALUE OF 1g SAR (W/kg)							
TEST MODE	9	10	11	12	13	14	15	16
BANDWIDTH	5MHz	10MHz	5MHz	10MHz	5MHz	10MHz	5MHz	10MHz
LOW CHANNEL	-	-	0.418	0.403	0.751	0.734	-	-
MID. CHANNEL	-	-	0.576	0.556	0.770	0.762	-	-
HIGH CHANNEL	0.368	0.376	0.791	0.742	1.060	0.987	0.293	0.292

NOTE: The worst value has been marked by boldface.

Scaled data

MODULATION TYPE	QPSK 3/4 for 5MHz, 16QAM 1/2 for 10MHz	
	MEASURED VALUE OF 1g SAR (W/kg)	
TEST MODE	1	2
BANDWIDTH	5MHZ	10MHZ
SCALED FACTOR	1.059	1.029
LOW CHANNEL	1.292	1.214
MID. CHANNEL	1.080	1.029
HIGH CHANNEL	1.461	1.338

	MEASURED VALUE OF 1g SAR (W/kg)					
MODULATION TYPE	QPSK 1/2	16QAM 1/2	16QAM 3/4	QPSK 1/2	QPSK 3/4	16QAM 3/4
TEST MODE	3	4	5	6	7	8
BANDWIDTH	5MHZ	5MHZ	5MHZ	10MHZ	10MHZ	10MHZ
SCALED FACTOR	1.059	1.059	1.059	1.029	1.029	1.029
HIGH CHANNEL	1.292	1.345	1.313	1.266	1.286	1.255

MODULATION TYPE	QPSK 3/4 for 5MHz, 16QAM 1/2 for 10MHz							
	MEASURED VALUE OF 1g SAR (W/kg)							
TEST MODE	9	10	11	12	13	14	15	16
BANDWIDTH	5MHZ	10MHZ	5MHZ	10MHZ	5MHZ	10MHZ	5MHZ	10MHZ
SCALED FACTOR	1.059	1.029	1.059	1.029	1.059	1.029	1.059	1.029
LOW CHANNEL	-	-	0.443	0.415	0.795	0.755	-	-
MID. CHANNEL	-	-	0.610	0.572	0.815	0.784	-	-
HIGH CHANNEL	0.390	0.387	0.838	0.764	1.123	1.016	0.310	0.300

NOTE:

1. The worst value has been marked by boldface.

Enhanced Energy Coupling At Increased Separation Distances

Initial Position:

The probe tip is positioned at the peak SAR location of high channel in test mode 1, at a distance of one half the probe tip diameter from the phantom surface. Under this condition to get a single SAR value.

5mm Increments From Initial Position:

With the probe fixed at this location, the device is moved away from the phantom in 5 mm increments from the initial touching or minimum separation position. A single point SAR is measured for each of these device positions until the SAR is less than 50% of that measured at the initial position.

TEST POSITION	SAR VALUE (mW/g)
INITIAL POSITION	2.50
5mm INCREMENTS FROM INITIAL POSITION	1.12

RESULT: No Enhancement Energy Coupling observed.

5. TEST RESULTS

5.1 TEST PROCEDURES

Use the software to control the EUT channel and transmission power. Then record the conducted power before the testing. Place the EUT to the specific test location. After the testing, must writing down the conducted power of the EUT into the report. The SAR value was calculated via the 3D spline interpolation algorithm that has been implemented in the software of DASY4 SAR measurement system manufactured and calibrated by SPEAG. According to the IEEE 1528 standards, the recommended procedure for assessing the peak spatial-average SAR value consists of the following steps:

- Power reference measurement
- Verification of the power reference measurement
- Area scan
- Zoom scan
- Power reference measurement

The area scan was performed for the highest spatial SAR location. The zoom scan with 30mm x 30mm x 30mm volume was performed for SAR value averaged over 1g and 10g spatial volumes.

In the zoom scan, the distance between the measurement point at the probe sensor location (geometric center behind the probe tip) and the phantom surface is 3mm and maintained at a constant distance of $\pm 0.5\text{mm}$ during a zoom scan to determine peak SAR locations. The distance is 3mm between the first measurement point and the bottom surface of the phantom. The secondary measurement point to the bottom surface of the phantom is with 8mm separation distance. The cube size is 7 x 7 x 7 points consists of 343 points and the grid space is 5mm.

The measurement time is 0.5s at each point of the zoom scan. The probe boundary effect compensation shall be applied during the SAR test. Because of the tip of the probe to the Phantom surface separated distances are longer than half a tip probe diameter.

In the area scan, the separation distance is 3mm between the each measurement point and the phantom surface. The scan size shall be included the transmission portion of the EUT. The measurement time is the same as the zoom scan. At last the reference power drift shall be less than $\pm 5\%$.



A D T

5.2 MEASURED SAR RESULTS

ENVIRONMENTAL CONDITION		Air Temperature : 23.6°C, Liquid Temperature : 22.6°C Humidity : 58%RH				
TESTED BY		Sam Onn			DATE	Jan. 07, 2009
FREQ. (MHz)	MODULATION Type	CONDUCTED POWER (W)		POWER DRIFT (%)	DEVICE TEST MODE	MEASURED 1g SAR (W/kg)
		BEGIN TEST	AFTER TEST			
2498.5 (Low)	QPSK	0.174	0.171	-1.72	1	1.220
2587.0 (Mid.)	QPSK	0.181	0.177	-2.21	1	1.020
2687.5 (High)	QPSK	0.238	0.232	-2.52	1	1.380
2501.0 (Low)	16QAM	0.177	0.172	-2.82	2	1.180
2587.0 (Mid.)	16QAM	0.173	0.168	-2.89	2	1.000
2685.0 (High)	16QAM	0.204	0.198	-2.94	2	1.300
2687.5 (High)	QPSK	0.240	0.238	-0.83	3	1.220
2687.5 (High)	16QAM	0.232	0.230	-0.86	4	1.270
2687.5 (High)	16QAM	0.238	0.235	-1.26	5	1.240
2685.0 (High)	QPSK	0.200	0.199	-0.50	6	1.230
2685.0 (High)	QPSK	0.201	0.199	-1.00	7	1.250
2685.0 (High)	16QAM	0.202	0.198	-1.98	8	1.220

NOTE:

1. Test configuration of each mode is described in section 4.3.
2. In this testing, the limit for General Population Spatial Peak averaged over 1g, **1.6 W/kg**, is applied.
3. Please see the Appendix A for the data.
4. The variation of the EUT conducted power measured before and after SAR testing should not over 5%.



A D T

ENVIRONMENTAL CONDITION		Air Temperature : 23.6°C, Liquid Temperature : 22.6°C Humidity : 58%RH				
TESTED BY		Sam Onn			DATE	Jan. 07, 2009
FREQ. (MHz)	MODULATION Type	CONDUCTED POWER (W)		POWER DRIFT (%)	DEVICE TEST MODE	MEASURED 1g SAR (W/kg)
		BEGIN TEST	AFTER TEST			
2687.5 (High)	QPSK	0.238	0.236	-0.84	9	0.368
2685.0 (High)	16QAM	0.204	0.202	-0.98	10	0.376
2498.5 (Low)	QPSK	0.174	0.172	-1.15	11	0.418
2587.0 (Mid.)	QPSK	0.181	0.178	-1.66	11	0.576
2687.5 (High)	QPSK	0.238	0.234	-1.68	11	0.791

NOTE:

1. Test configuration of each mode is described in section 4.3.
2. In this testing, the limit for General Population Spatial Peak averaged over 1g, **1.6 W/kg**, is applied.
3. Please see the Appendix A for the data.
4. The variation of the EUT conducted power measured before and after SAR testing should not over 5%.



A D T

ENVIRONMENTAL CONDITION		Air Temperature : 23.6°C, Liquid Temperature : 22.6°C Humidity : 58%RH				
TESTED BY		Sam Onn			DATE	Jan. 07, 2009
FREQ. (MHz)	MODULATION Type	CONDUCTED POWER (W)		POWER DRIFT (%)	DEVICE TEST MODE	MEASURED 1g SAR (W/kg)
		BEGIN TEST	AFTER TEST			
2501.0 (Low)	16QAM	0.177	0.174	-1.69	12	0.403
2587.0 (Mid.)	16QAM	0.173	0.170	-1.73	12	0.556
2685.0 (High)	16QAM	0.204	0.200	-1.96	12	0.742
2498.5 (Low)	QPSK	0.174	0.173	-0.57	13	0.751
2587.0 (Mid.)	QPSK	0.181	0.179	-1.10	13	0.770
2687.5 (High)	QPSK	0.238	0.235	-1.26	13	1.060
2501.0 (Low)	16QAM	0.177	0.173	-2.26	14	0.734
2587.0 (Mid.)	16QAM	0.173	0.169	-2.31	14	0.762
2685.0 (High)	16QAM	0.204	0.199	-2.45	14	0.987
2687.5 (High)	QPSK	0.238	0.232	-2.52	15	0.293
2685.0 (High)	16QAM	0.204	0.198	-2.94	16	0.292

NOTE:

1. Test configuration of each mode is described in section 4.3.
2. In this testing, the limit for General Population Spatial Peak averaged over 1g, **1.6 W/kg**, is applied.
3. Please see the Appendix A for the data.
4. The variation of the EUT conducted power measured before and after SAR testing should not over 5%.

5.3 SAR LIMITS

HUMAN EXPOSURE	SAR (W/kg)	
	(GENERAL POPULATION / UNCONTROLLED EXPOSURE ENVIRONMENT)	(OCCUPATIONAL / CONTROLLED EXPOSURE ENVIRONMENT)
Spatial Average (whole body)	0.08	0.4
Spatial Peak (averaged over 1 g)	1.6	8.0
Spatial Peak (hands / wrists / feet / ankles averaged over 10 g)	4.0	20.0

NOTE:

1. This limits accord to 47 CFR 2.1093 – Safety Limit.
2. The EUT property been complied with the partial body exposure limit under the general population environment.

5.4 RECIPES FOR TISSUE SIMULATING LIQUIDS

For the measurement of the field distribution inside the SAM phantom, the phantom must be filled with 25 liters of tissue simulation liquid.

The following ingredients are used :

- **WATER-** Deionized water (pure H₂O), resistivity ≥ 16 M - as basis for the liquid
- **SUGAR-** Refined sugar in crystals, as available in food shops - to reduce relative permittivity
- **SALT-** Pure NaCl - to increase conductivity
- **CELLULOSE-** Hydroxyethyl-cellulose, medium viscosity (75-125mPa.s, 2% in water, 20°C),
CAS # 54290 - to increase viscosity and to keep sugar in solution
- **PRESERVATIVE-** Preventol D-7 Bayer AG, D-51368 Leverkusen, CAS # 55965-84-9 - to prevent the spread of bacteria and molds
- **DGMBE-** Diethylenglycol-monobutyl ether (DGMBE), Fluka Chemie GmbH, CAS # 112-34-5 - to reduce relative permittivity

THE RECIPES FOR 2600MHz SIMULATING LIQUID TABLE

Ingredient	Muscle Simulating Liquid 2600MHz (MSL-2600)
Water	69.83%
DGMBE	30.17%
Salt	NA
Dielectric Parameters at 22°C	f= 2600MHz $\epsilon = 52.5 \pm 5\%$ $\sigma = 2.16 \pm 5\%$ S/m

Testing the liquids using the Agilent Network Analyzer E8358A and Agilent Dielectric Probe Kit 85070D. The testing procedure is following as

1. Turn Network Analyzer on and allow at least 30min. warm up.
2. Mount dielectric probe kit so that interconnecting cable to Network Analyzer will not be moved during measurements or calibration.
3. Pour de-ionized water and measure water temperature ($\pm 1^\circ$).
4. Set water temperature in Agilent-Software (Calibration Setup).
5. Perform calibration.
6. Validate calibration with dielectric material of known properties (e.g. polished ceramic slab with $>8\text{mm}$ thickness $\epsilon' = 10.0$, $\epsilon'' = 0.0$). If measured parameters do not fit within tolerance, repeat calibration (± 0.2 for ϵ' : ± 0.1 for ϵ'').
7. Conductivity can be calculated from ϵ'' by $\sigma = \omega \epsilon_0 \epsilon'' = \epsilon'' f [\text{GHz}] / 18$.
8. Measure liquid shortly after calibration. Repeat calibration every hour.
9. Stir the liquid to be measured. Take a sample ($\sim 50\text{ml}$) with a syringe from the center of the liquid container.
10. Pour the liquid into a small glass flask. Hold the syringe at the bottom of the flask to avoid air bubbles.
11. Put the dielectric probe in the glass flask. Check that there are no air bubbles in front of the opening in the dielectric probe kit.
12. Perform measurements.
13. Adjust medium parameters in DASY4 for the frequencies necessary for the measurements ('Setup Config', select medium (e.g. Brain 900MHz) and press 'Option'-button.
14. Select the current medium for the frequency of the validation (e.g. Setup Medium Brain 900MHz).

FOR WIMAX BAND SIMULATING LIQUID

LIQUID TYPE		MSL-2600		
SIMULATING LIQUID TEMP.		22.6		
TEST DATE		Jan. 07, 2009		
TESTED BY		Sam Onn		
FREQ. (MHz)	LIQUID PARAMETER	STANDARD VALUE	MEASUREMENT VALUE	ERROR PERCENTAGE
2498.50	Permittivity (ϵ)	52.60	52.70	0.19
2501.00		52.60	52.70	0.19
2587.00		52.50	52.40	-0.19
2600.00		52.50	52.40	-0.19
2685.00		52.40	52.10	-0.57
2687.50		52.40	52.10	-0.57
2498.50	Conductivity (σ) S/m	2.02	2.06	1.98
2501.00		2.03	2.06	1.48
2587.00		2.14	2.13	-0.47
2600.00		2.16	2.13	-1.39
2685.00		2.28	2.25	-1.32
2687.50		2.29	2.25	-1.75
Dielectric Parameters Required at 22°C		f= 2600MHz ε= 52.5 ± 5% σ= 2.16 ± 5% S/m		

5.5 TEST EQUIPMENT FOR TISSUE PROPERTY

ITEM	NAME	BRAND	TYPE	SERIES NO.	DATE OF CALIBRATION	DUE DATE OF CALIBRATION
1	Network Analyzer	Agilent	E5071C	MY46104190	Nov. 28, 2008	Nov. 27, 2009
2	Dielectric Probe	Agilent	85070D	US01440176	NA	NA

NOTE:

1. Before starting, all test equipment shall be warmed up for 30min.
2. The tolerance ($k=1$) specified by Agilent for general dielectric measurements, deriving from inaccuracies in the calibration data, analyzer drift, and random errors, are usually $\pm 2.5\%$ and $\pm 5\%$ for measured permittivity and conductivity, respectively. However, the tolerances for the conductivity is smaller for material with large loss tangents, i.e., less than $\pm 2.5\%$ ($k=1$). It can be substantially smaller if more accurate methods are applied.

6. SYSTEM VALIDATION

The system validation was performed in the flat phantom with equipment listed in the following table. Since the SAR value is calculated from the measured electric field, dielectric constant and conductivity of the body tissue and the SAR is proportional to the square of the electric field. So, the SAR value will be also proportional to the RF power input to the system validation dipole under the same test environment. In our system validation test, 250mW RF input power was used.

6.1 TEST EQUIPMENT

ITEM	NAME	BRAND	TYPE	SERIES NO.	DATE OF CALIBRATION	DUE DATE OF CALIBRATION
1	SAM Phantom	S & P	QD000 P40 CA	TP-1150	NA	NA
2	Signal Generator	Anritsu	68247B	984703	May 27, 2008	May 26, 2009
3	E-Field Probe	S & P	EX3DV3	3506	Sep. 30, 2008	Sep. 29, 2009
4	DAE	S & P	DAE	579	Mar. 13, 2008	Mar. 12, 2009
5	Robot Positioner	Staubli Unimation	NA	NA	NA	NA
6	Validation Dipole	S & P	D2600V2	1003	Jan. 30, 2008	Jan. 29, 2009
8	Power Meter	Anritsu	ML2487A	6K00001475	Jan. 26, 2008	Jan. 25, 2009
9	Power Sensor		MA2491A	030942	Jan. 26, 2008	Jan. 25, 2009

NOTE: Before starting the measurement, all test equipment shall be warmed up for 30min.

6.2 TEST PROCEDURE

Before the system performance check, we need only to tell the system which components (probe, medium, and device) are used for the system performance check; the system will take care of all parameters. The dipole must be placed beneath the flat section of the SAM Twin Phantom with the correct distance holder in place. The distance holder should touch the phantom surface with a light pressure at the reference marking (little cross) and be oriented parallel to the long side of the phantom. Accurate positioning is not necessary, since the system will search for the peak SAR location, except that the dipole arms should be parallel to the surface. The device holder for mobile phones can be left in place but should be rotated away from the dipole.

1. The "Power Reference Measurement" and "Power Drift Measurement" jobs are located at the beginning and end of the batch process. They measure the field drift at one single point in the liquid over the complete procedure. The indicated drift is mainly the variation of the amplifier output power. If it is too high (above ± 0.1 dB), the system performance check should be repeated; some amplifiers have very high drift during warm-up. A stable amplifier gives drift results in the DASY system below ± 0.02 dB.
2. The "Surface Check" job tests the optical surface detection system of the DASY system by repeatedly detecting the surface with the optical and mechanical surface detector and comparing the results. The output gives the detecting heights of both systems, the difference between the two systems and the standard deviation of the detection repeatability. Air bubbles or refraction in the liquid due to separation of the sugar-water mixture gives poor repeatability (above ± 0.1 mm). In that case it is better to abort the system performance check and stir the liquid. The difference between the optical surface detection and the actual surface depends on the probe and is specified with each probe. (It does not depend on the surface reflectivity or the probe angle to the surface within $\pm 30^\circ$.) However, varying breaking indices of different liquid compositions might also influence the distance. If the indicated difference varies from the actual setting, the probe parameter "optical surface

3. The "Area Scan" job measures the SAR above the dipole on a plane parallel to the surface. It is used to locate the approximate location of the peak SAR. The proposed scan uses large grid spacing for faster measurement; due to the symmetric field, the peak detection is reliable. If a finer graphic is desired, the grid spacing can be reduced. Grid spacing and orientation have no influence on the SAR result.
4. The "Zoom Scan" job measures the field in a volume around the peak SAR value assessed in the previous "Area Scan" job (for more information see the application note on SAR evaluation).

About the validation dipole positioning uncertainty, the constant and low loss dielectric spacer is used to establish the correct distance between the top surface of the dipole and the bottom surface of the phantom, the error component introduced by the uncertainty of the distance between the liquid (i.e., phantom shell) and the validation dipole in the DASY4 system is less than $\pm 0.1\text{mm}$.

$$SAR_{\text{tolerance}} [\%] = 100 \times \left(\frac{(a + d)^2}{a^2} - 1 \right)$$

As the closest distance is 10mm, the resulting tolerance $SAR_{\text{tolerance}} [\%]$ is <2%.

6.3 VALIDATION RESULTS

SYSTEM VALIDATION TEST OF SIMULATING LIQUID					
FREQUENCY (MHz)	REQUIRED SAR (mW/g)	MEASURED SAR (mW/g)	DEVIATION (%)	SEPARATION DISTANCE	TESTED DATE
MSL2600	14.5 (1g)	13.4	-7.59	10mm	Jan. 07, 2009
TESTED BY	Sam Onn				

NOTE: Please see Appendix for the photo of system validation test.

6.4 SYSTEM VALIDATION UNCERTAINTIES

In the table below, the system validation uncertainty with respect to the analytically assessed SAR value of a dipole source as given in the IEEE 1528 standard is given. This uncertainty is smaller than the expected uncertainty for mobile phone measurements due to the simplified setup and the symmetric field distribution.

Error Description	Tolerance (±%)	Probability Distribution	Divisor	(C _i)		Standard Uncertainty (±%)		(v _i)
				(1g)	(10g)	(1g)	(10g)	
Measurement System								
Probe Calibration	5.50	Normal	1	1	1	5.50	5.50	∞
Axial Isotropy	4.70	Rectangular	√3	0.7	0.7	1.90	1.90	∞
Hemispherical Isotropy	9.60	Rectangular	√3	0.7	0.7	3.88	3.88	∞
Boundary effects	1.00	Rectangular	√3	1	1	0.58	0.58	∞
Linearity	4.70	Rectangular	√3	1	1	2.71	2.71	∞
System Detection Limits	1.00	Rectangular	√3	1	1	0.58	0.58	∞
Readout Electronics	0.30	Normal	1	1	1	0.30	0.30	∞
Response Time	0.80	Rectangular	√3	1	1	0.46	0.46	∞
Integration Time	2.60	Rectangular	√3	1	1	1.50	1.50	∞
RF Ambient Noise	3.00	Rectangular	√3	1	1	1.73	1.73	∞
RF Ambient Reflections	3.00	Rectangular	√3	1	1	1.73	1.73	∞
Probe Positioner	0.40	Rectangular	√3	1	1	0.23	0.23	∞
Probe Positioning	2.90	Rectangular	√3	1	1	1.67	1.67	∞
Max. SAR Eval.	1.00	Rectangular	√3	1	1	0.58	0.58	∞
Dipole Related								
Dipole Axis to Liquid Distance	2.00	Rectangular	√3	1	1	1.15	1.15	145
Input Power Drift	4.70	Rectangular	√3	1	1	2.71	2.71	∞
Phantom and Tissue parameters								
Phantom Uncertainty	4.00	Rectangular	√3	1	1	2.31	2.31	∞
Liquid Conductivity (target)	5.00	Rectangular	√3	0.64	0.43	1.85	1.24	∞
Liquid Conductivity (measurement)	2.83	Normal	1	0.64	0.43	1.81	1.22	∞
Liquid Permittivity (target)	5.00	Rectangular	√3	0.6	0.49	1.73	1.41	∞
Liquid Permittivity (measurement)	2.10	Normal	1	0.6	0.49	1.26	1.03	∞
Combined Standard Uncertainty						9.70	9.42	
Coverage Factor for 95%						Kp=2		
Expanded Uncertainty (K=2)						19.39	18.85	

NOTE: About the system validation uncertainty assessment, please reference the section 7.

7. MEASUREMENT SAR PROCEDURE UNCERTAINTIES

The assessment of spatial peak SAR of the hand handheld devices is according to IEEE 1528 / EN 62209-1. All testing situation shall be met below these requirements.

- The system is used by an experienced engineer who follows the manual and the guidelines taught during the training provided by SPEAG.
- The probe has been calibrated within the requested period and the stated uncertainty for the relevant frequency bands does not exceed 4.8% ($k=1$).
- The validation dipole has been calibrated within the requested period and the system performance check has been successful.
- The DAE unit has been calibrated within the within the requested period.
- The minimum distance between the probe sensor and inner phantom shell is selected to be between 4 and 5mm.
- The operational mode of the DUT is CW, CDMA, FDMA or TDMA (GSM, DCS, PCS, IS136 and PDC) and the measurement/integration time per point is >500 ms.
- The dielectric parameters of the liquid have been assessed using Agilent 85070D dielectric probe kit or a more accurate method.
- The dielectric parameters are within 5% of the target values.
- The DUT has been positioned as described in section 3.

7.1. PROBE CALIBRATION UNCERTAINTY

SPEAG conducts the probe calibration in compliance with international and national standards (e.g. IEEE 1528, EN 62209-1, IEC 62209, etc.) under ISO17025. The uncertainties are stated on the calibration certificate. For the most relevant frequency bands, these values do not exceed 4.8% ($k=1$). If evaluations of other bands are performed for which the uncertainty exceeds these values, the uncertainty tables given in the summary have to be revised accordingly.

7.2. ISOTROPY UNCERTAINTY

The axial isotropy tolerance accounts for probe rotation around its axis while the hemispherical isotropy error includes all probe orientations and field polarizations. These parameters are assessed by SPEAG during initial calibration. In 2001, SPEAG further tightened its quality controls and warrants that the maximal deviation from axial isotropy is $\pm 0.20\text{dB}$, while the maximum deviation of hemispherical isotropy is $\pm 0.40\text{dB}$, corresponding to $\pm 4.7\%$ and $\pm 9.6\%$, respectively. A weighting factor of c_p equal to 0.5 can be applied, since the axis of the probe deviates less than 30 degrees from the normal surface orientation.

7.3. BOUNDARY EFFECT UNCERTAINTY

The effect can be estimated according to the following error approximation formula

$$SAR_{tolerance} [\%] = SAR_{be} [\%] \times \frac{(d_{be} + d_{step})^2}{2d_{step}} e^{\frac{d_{be}}{\delta/2}}$$

$$d_{be} + d_{step} < 10\text{mm}$$

The parameter d_{be} is the distance in mm between the surface and the closest measurement point used in the averaging process; d_{step} is the separation distance in mm between the first and second measurement points; δ is the minimum penetration depth in mm within the head tissue equivalent liquids (i.e., $\delta = 13.95\text{mm}$ at 3GHz); SAR_{be} is the deviation between the measured SAR value at the distance d_{be} from the boundary and the wave-guide analytical value SAR_{ref} . DASY4 applies a boundary effect compensation algorithm according to IEEE 1528, which is possible since the axis of the probe never deviates more than 30 degrees from the normal surface orientation. $SAR_{be} [\%]$ is assessed during the calibration process and SPEAG warrants that the uncertainty at distances larger than 4mm is always less than 1%. In summary, the worst case boundary effect SAR tolerance [%] for scanning distances larger than 4mm is $< \pm 0.8\%$.

7.4. PROBE LINEARITY UNCERTAINTY

Field probe linearity uncertainty includes errors from the assessment and compensation of the diode compression effects for CW and pulsed signals with known duty cycles. This error is assessed using the procedure described in IEEE 1528 / EN 62209-1. For SPEAG field probes, the measured difference between CW and pulsed signals, with pulse frequencies between 10Hz and 1kHz and duty cycles between 1 and 100, is $< \pm 0.20\text{dB}$ ($< \pm 4.7\%$).

7.5. READOUT ELECTRONICS UNCERTAINTY

All uncertainties related to the probe readout electronics (DAE unit), including the gain and linearity of the instrumentation amplifier, its loading effect on the probe, and accuracy of the signal conversion algorithm, have been assessed accordingly to IEEE 1528 / EN 62209-1. The combination (root-sum-square RSS method) of these components results in an overall maximum error of $\pm 1.0\%$.

7.6. RESPONSE TIME UNCERTAINTY

The time response of the field probes is assessed by exposing the probe to a well-controlled electric field producing SAR larger than 2.0W/kg at the tissue medium surface. The signal response time is evaluated as the time required by the system to reach 90% of the expected final value after an on/of switch of the power source. Analytically, it can be expressed as:

$$SAR_{\text{tolerance}} [\%] = 100 \times \left(\frac{T_m}{T_m + \tau e^{-T_m/\tau}} - 1 \right)$$

where T_m is 500 ms, i.e., the time between measurement samples, and τ the time constant. The response time τ of SPEAG's probes is $< 5\text{ms}$. In the current implementation, DASY4 waits longer than 100 ms after having reached the grid point before starting a measurement, i.e., the response time uncertainty is negligible.

7.7. INTEGRATION TIME UNCERTAINTY

If the device under test does not emit a CW signal, the integration time applied to measure the electric field at a specific point may introduce additional uncertainties due to the discretization and can be assessed as follows

$$SAR_{tolerance} [\%] = 100 \times \sum_{all\ sub-frames} \frac{t_{frame}}{t_{integration}} \frac{slot_{idle}}{slot_{total}}$$

The tolerances for the different systems are given in Table 7.1, whereby the worst-case $SAR_{tolerance}$ is 2.6%.

System	$SAR_{tolerance} \%$
CW	0
CDMA*	0
WCDMA*	0
FDMA	0
IS-136	2.6
PDC	2.6
GSM/DCS/PCS	1.7
DECT	1.9
Worst-Case	2.6

TABLE 7.1

7.8. PROBE POSITIONER MECHANICAL TOLERANCE

The mechanical tolerance of the field probe positioner can introduce probe positioning uncertainties. The resulting SAR uncertainty is assessed by comparing the SAR obtained according to the specifications of the probe positioner with respect to the actual position defined by the geometric center of the probe sensors. The tolerance is determined as:

$$SAR_{tolerance} [\%] = 100 \times \frac{d_{ph}}{\delta/2}$$

The specified repeatability of the RX robot family used in DASY4 systems is $\pm 25\mu\text{m}$. The absolute accuracy for short distance movements is better than $\pm 0.1\text{mm}$, i.e., the $SAR_{tolerance} [\%]$ is better than 1.5% (rectangular).

7.9. PROBE POSITIONING

The probe positioning procedures affect the tolerance of the separation distance between the probe tip and the phantom surface as:

$$SAR_{tolerance} [\%] = 100 \times \frac{d_{ph}}{\delta/2}$$

where d_{ph} is the maximum deviation of the distance between the probe tip and the phantom surface. The optical surface detection has a precision of better than 0.2mm, resulting in an $SAR_{tolerance} [\%]$ of <2.9% (rectangular distribution). Since the mechanical detection provides better accuracy, 2.9% is a worst-case figure for DASY4 system.

7.10. PHANTOM UNCERTAINTY

The SAR measurement uncertainty due to SPEAG phantom shell production tolerances has been evaluated using

$$SAR_{tolerance} [\%] \cong 100 \times \frac{2d}{a}, \quad d \ll a$$

For a maximum deviation d of the inner and outer shell of the phantom from that specified in the CAD file of $\pm 0.2\text{mm}$, and a 10mm spacing a between source and tissue liquid, the calculated phantom uncertainty is $\pm 4.0\%$.

7.11. DASY4 UNCERTAINTY BUDGET

Error Description	Tolerance (±%)	Probability Distribution	Divisor	(C _i)		Standard Uncertainty (±%)		(v _i)
				(1g)	(10g)	(1g)	(10g)	
Measurement Equipment								
Probe Calibration	5.50	Normal	1	1	1	5.50	5.50	∞
Axial Isotropy	4.70	Rectangular	√3	0.7	0.7	1.90	1.90	∞
Hemispherical Isotropy	9.60	Rectangular	√3	0.7	0.7	3.88	3.88	∞
Boundary effects	1.00	Rectangular	√3	1	1	0.58	0.58	∞
Linearity	4.70	Rectangular	√3	1	1	2.71	2.71	∞
System Detection Limits	1.00	Rectangular	√3	1	1	0.58	0.58	∞
Readout Electronics	0.30	Normal	1	1	1	0.30	0.30	∞
Response Time	0.80	Rectangular	√3	1	1	0.46	0.46	∞
Integration Time	2.60	Rectangular	√3	1	1	1.50	1.50	∞
RF Ambient Noise	3.00	Rectangular	√3	1	1	1.73	1.73	∞
RF Ambient Reflections	3.00	Rectangular	√3	1	1	1.73	1.73	∞
Probe Positioner	0.40	Rectangular	√3	1	1	0.23	0.23	∞
Probe Positioning	2.90	Rectangular	√3	1	1	1.67	1.67	∞
Max. SAR Eval.	1.00	Rectangular	√3	1	1	0.58	0.58	∞
Test Sample Related								
Device Positioning	0.69	Normal	1	1	1	0.69	0.69	10
Device Holder	3.60	Normal	1	1	1	3.60	3.60	5
Power Drift	5.00	Rectangular	√3	1	1	2.89	2.89	∞
Phantom and Tissue parameters								
Phantom Uncertainty	4.00	Rectangular	√3	1	1	2.31	2.31	∞
Liquid Conductivity (target)	5.00	Rectangular	√3	0.64	0.43	1.85	1.24	∞
Liquid Conductivity (measurement)	2.83	Normal	1	0.64	0.43	1.81	1.22	∞
Liquid Permittivity (target)	2.30	Rectangular	√3	0.6	0.49	0.80	0.65	∞
Liquid Permittivity (measurement)	2.10	Normal	1	0.6	0.49	1.26	1.03	∞
Combined Standard Uncertainty						10.23	10.01	
Coverage Factor for 95%						Kp=2		
Expanded Uncertainty (K=2)						20.47	20.03	

TABLE 7.2

The table 7.2: Worst-Case uncertainty budget for DASY4 assessed according to IEEE 1528. The budget is valid for the frequency range 300MHz ~ 3GHz and represents a worst-case analysis. For specific tests and configurations, the uncertainty could be considerable smaller.

8. INFORMATION ON THE TESTING LABORATORIES

We, Bureau Veritas Consumer Products Services (H.K.) Ltd., Taoyuan Branch, were founded in 1988 to provide our best service in EMC, Radio, Telecom and Safety consultation. Our laboratories are accredited and approved by the following approval agencies according to ISO/IEC 17025.

USA	FCC, NVLAP
GERMANY	TUV Rheinland
JAPAN	VCCI
NORWAY	NEMKO
CANADA	INDUSTRY CANADA, CSA
R.O.C.	TAF, BSMI, NCC
NETHERLANDS	Telefication
SINGAPORE	GOST-ASIA (MOU)
RUSSIA	CERTIS (MOU)

Copies of accreditation certificates of our laboratories obtained from approval agencies can be downloaded from our web site:

www.adt.com.tw/index.5/phtml. If you have any comments, please feel free to contact us at the following:

Linko EMC/RF Lab:

Tel: 886-2-26052180

Fax: 886-2-26051924

Hsin Chu EMC/RF Lab:

Tel: 886-3-5935343

Fax: 886-3-5935342

Hwa Ya EMC/RF/Safety/Telecom Lab:

Tel: 886-3-3183232

Fax: 886-3-3185050

Web Site: www.adt.com.tw

The address and road map of all our labs can be found in our web site also.

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