7.1 SYSTEM SPECIFICATIONS

7.2 Robotic System Specifications

Specifications

POSITIONER: Stäubli Unimation Corp. Robot Model: RX90LB
Repeatability: 0.02 mm
No. of axis: 6

Data Acquisition Electronic (DAE) System

Cell Controller
Processor: Pentium III
Clock Speed: 450 MHz
Operating System: Windows NT 4.0
Data Card: DASY3 PC-Board
Data Converter
Features: Signal Amplifier, multiplexer, A/D converter, and control logic
Software: DASY3 software
Connecting Lines: Optical downlink for data and status info.
Optical uplink for commands and clock

PC Interface Card

Function: 24 bit (64 MHz) DSP for real time processing
Link to DAE3
16 bit A/D converter for surface detection system
serial link to robot
direct emergency stop output for robot

E-Field Probes

Model: ET3DV6 S/N: 1798, S/N: 1609
Construction: Triangular core fiber optic detection system
Frequency: 10 MHz to 6 GHz
Linearity: ± 0.2 dB (30 MHz to 3 GHz)

Phantom

Phantom: SAM
Shell Material: Fiberglass
Thickness: 2.0 ± 0.1 mm

Tissue Parameters

Freq. [MHz]	Liquid	Liquid Temp [°C]	Parameters	Target Value	Measured Value	Deviation [%]	Limit [%]
450MHz	Head	21.4	ε_r	43.5	43.0	-1.15	±5%
			σ	0.87	0.84	-3.45	±5%
	Body	21.4	ε_r	56.7	54.7	-3.53	±5%
			σ	0.94	0.93	-1.06	±5%

8.1 MEASUREMENT PROCESS

8.2 System Verification

Prior to assessment, the system is verified to the ±10% of the specifications at 450MHz by using the system validation kit. (Graphic Plots Attached)

Freq. [MHz]	Liquid	Liquid Temp [°C]	SAR Average	Target Value (mW/g)	Measured Value (mW/g)	Deviation [%]	Limit [%]
450 MHz D450V2, S/N: 1007	Head	21.4	1 g	4.9	5.08	+3.67	±10%

8.3 Dosimetric Assessment Setup

The evaluation was performed with the following procedure:

1. The SAR value at a fixed location above the ear point was measured and was used as a reference value for assessing the power drop.
2. The SAR distribution at the exposed side of the head was measured at a distance of 3.9mm from the inner surface of the shell. The area covered the entire dimension of the head and the horizontal grid spacing was 20mm x 20mm. Based on this data, the area of the maximum absorption was determined by spline interpolation.
3. Around this point, a volume of 32mm x 32mm x 34mm was assessed by measuring 5 x 5 x 7 points. On this basis of this data set, the spatial peak SAR value was evaluated with the following procedure:
   a. The data at the surface were extrapolated, since the center of the dipoles is 2.7mm away from the tip of the probe and the distance between the surface and the lowest measuring point is 1.2mm. The extrapolation was based on a least square algorithm [13]. A polynomial of the fourth order was calculated through the points in z-axes. This polynomial was then used to evaluate the points between the surface and the probe tip.
   b. The maximum interpolated value was searched with a straight-forward algorithm. Around this maximum the SAR values averaged over the spatial volumes (1g or 10g) were computed using the 3D-Spline interpolation algorithm. The 3D-spline is composed of three one-dimensional splines with the "Not a knot" condition (in x,y, and z directions) [13][14]. The volume was integrated with the trapezoidal algorithm. One thousand points (10 x 10 x 10) were interpolated to calculate the average.
   c. All neighboring volumes were evaluated until no neighboring volume with a higher average value was found.

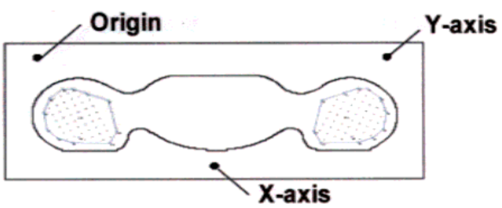

Fig. 10. SAR Measurement Point in Area Scan

9.1 ANSI/ IEEE C95.1 - 1992 RF EXPOSURE LIMITS

HUMAN EXPOSURE	UNCONTROLLED ENVIRONMENT General Population (W/kg) or (mW/g)	CONTROLLED ENVIRONMENT Occupational (W/kg) or (mW/g)
SPATIAL PEAK SAR * (Brain)	1.60	8.00
SPATIAL AVERAGE SAR ** (Whole Body)	0.08	0.40
SPATIAL PEAK SAR *** (Hands / Feet / Ankle / Wrist)	4.00	20.00

Table 2. Safety Limits for Partial Body Exposure

NOTES:

* The Spatial Peak value of the SAR averaged over any 1 gram of tissue (defined as a tissue volume in the shape of a cube) and over the appropriate averaging time.

** The Spatial Average value of the SAR averaged over the whole-body.

******* The Spatial Peak value of the SAR averaged over any 10 grams of tissue (defined as a tissue volume in the shape of a cube) and over the appropriate averaging time.

Uncontrolled Environments are defined as locations where there is the exposure of individuals who have no knowledge or control of their exposure.

Controlled Environments are defined as locations where there is exposure that may be incurred by persons who are aware of the potential for exposure, (i.e.as a result of employment or occupation).

10.1 MEASUREMENT UNCERTAINTIES

Measurement uncertainties in SAR measurements are difficult to quantify due to several variables including biological, physiological, and environmental. However, we estimate the measurement uncertainties in SAR to be less than 15-25 % [16].

According to ANSI/IEEE C95.3, the overall uncertainties are difficult to assess and will vary with the type of meter and usage situation. However, accuracy's of ± 1 to 3 dB can be expected in practice, with greater uncertainties in near-field situations and at higher frequencies (shorter wavelengths), or areas where large reflecting objects are present. Under optimum measurement conditions, SAR measurement uncertainties of at least ± 2dB can be expected.[3]

According to CENELEC [17], typical worst-case uncertainty of field measurements is ± 5 dB. For well-defined modulation characteristics the uncertainty can be reduced to ± 3 dB.

Error Description	Uncertainty value ±%	Probability Distribution	Divisor	ci 1 1g	Standard unc. (1g)	vi 2 or Veff
Measurement System						
Probe calibration	± 4.4	normal	1	1	± 4.4%	∞
Axial isotropy of the probe	± 4.7	rectangular	√3	(1-cp) 1/2	± 1.9%	∞
Sph. isotropy of the probe	± 9.6	rectangular	√3	(cp) 1/2	± 3.9%	∞
Spatial resolution	±0.0	rectangular	√3	1	± 0.0%	∞
Boundary effects	± 5.5	rectangular	√3	1	± 3.2%	∞
Probe linearity	± 4.7	rectangular	√3	1	± 2.7%	∞
Detection limit	± 1.0	rectangular	√3	1	± 0.6%	∞
Readout electronics	± 1.0	normal	1	1	± 1.0%	∞
Response time	± 0.8	rectangular	√3	1	± 0.5%	∞
Integration time	± 1.4	rectangular	√3	1	± 0.8%	∞
RF ambient conditions	± 3.0	rectangular	√3	1	± 1.7%	∞
Mech. constrains of robot	± 0.4	rectangular	√3	1	± 0.2%	∞
Probe positioning	± 2.9	rectangular	√3	1	± 1.7%	∞
Extrap. and integration	± 3.9	rectangular	√3	1	± 2.3%	∞
Test Sample Related						
Device positioning	± 6.0	normal	0.89	1	± 6.7%	12
Device holder uncertainty	± 5.0	normal	0.84	1	± 5.9%	8
Power drift	± 5.0	rectangular	√3	1	± 2.9%	∞
Phantom and Setup						
Phantom uncertainty	± 4.0	rectangular	√3	1	± 2.3%	∞
Liquid conductivity (target)	± 5.0	rectangular	√3	0.6	± 1.7%	∞
Liquid conductivity (meas.)	± 10.0	rectangular	√3	0.6	± 3.5%	∞
Liquid permittivity (target)	± 5.0	rectangular	√3	0.6	± 1.7%	∞
Liquid permittivity (meas.)	± 5.0	rectangular	√3	0.6	± 1.7%	∞
Combined Standard Uncertainty					± 13.6%	
Expanded Standard Uncertainty(k=2)					**± 27.1%**	

Table 3. Breakdown of Errors [18]

11.1 SAR TEST DATA SUMMARY

Mixture Type: 450 MHz
Dielectric Constant: 43.0
Conductivity: 0.84
Phantom Position: Face
Closest Distance (between E-Probe & Phone): 2.5 cm

Ambient TEMPERATURE (°C) 21.1
Relative HUMIDITY (%) 45
Atmospheric PRESSURE (kPa) 98.5

11.2 Measurement Results (Mouth/ Face SAR)

Channel / Freq. (MHz)	Mode	Ant.	Battery Manufacture	Power (W)			Measured SAR 1g (W/Kg)		Max. Power Drift (dB)	Scaled SAR 1g (W/Kg)	
				Initial	End	Power Drift (dB)	100% Duty Cycle	50% Duty Cycle		100% Duty Cycle	50% Duty Cycle
1 (462.5625)	GMRS	Fixed	Rocket	3.70	3.171	-0.74	1.280	0.640	-1.13	1.66	**0.83**
15 (462.5500)	GMRS	Fixed	Rocket	3.610	2.989	-0.51	1.330	0.665	-1.13	1.73	**0.86**
22 (462.7250)	GMRS	Fixed	Rocket	3.600	3.022	-1.13	1.370	0.685	-1.13	1.78	**0.89**
8 (467.5625)	FRS	Fixed	Rocket	0.800	0.713	-0.81	0.231	0.116	-1.13	0.3	**0.15**
22 (462.7250)	GMRS	Fixed	Energizer	3.610	3.080	-1.02	1.170	0.585	-1.13	1.52	**0.76**
22 (462.7250)	GMRS	Fixed	Duracell	3.710	3.136	-0.82	1.200	0.600	-1.13	1.56	**0.78**
8 (467.5625)	FRS	Fixed	Energizer	0.800	0.726	-0.81	0.253	0.127	-1.13	0.33	**0.16**
8 (467.5625)	FRS	Fixed	Duracell	0.830	0.760	-0.79	0.291	0.146	-1.13	0.38	**0.19**
ANSI/ IEEE C95.1 1992 – Safety Limit Spatial Peak Uncontrolled Exposure/ General Population						**Mouth/ Face 1.6 W/kg (mW/g)** Averaged over 1 gram					

Measured Depth of Simulating Tissue: 15.0cm / Liquid Temperature: 21.4℃

NOTES:
1. The SAR values found were below the maximum limit of 1.6 W/kg (uncontrolled exposure).
2. The highest face-held SAR value found was 0.89 W/kg(based 50% duty cycle & 2.0 mm phantom).
3. The EUT was tested for face-held SAR with a 2.5cm separation distance between the front of the EUT and the outer surface of the planer phantom.
4. Battery Type ☒ Standard (x4) AA Alkaline batteries (1.5VDC)
5. Power Measured ☒ Conducted ☐ EIRP ☐ ERP
6. SAR Measurement System ☒ SPEAG
7. SAR Configuration ☒ Face/ Mouth ☐ Body ☐ Hand
8. SAR Measurement Time : 15 minutes

Figure 11. Mouth Face

Report prepared by : Ki-Soo Kim

Manager of Product Compliance Team

11.1 SAR TEST DATA SUMMARY

Ambient TEMPERATURE (°C) 21.1
Relative HUMIDITY (%) 45
Atmospheric PRESSURE (kPa) 98.5

Mixture Type: 450 MHz
Dielectric Constant: 54.7
Conductivity: 0.93
Phantom Position: Body
Closest Distance (between E-Probe & Phone): 1.5 cm

11.3 Measurement Results (Body SAR)

Channel / Freq. (MHz)	Mode	Ant.	Battery Manufa-cture	Power (W)			Measured SAR 1g (W/Kg)		Max. Power Drift (dB)	Scaled SAR 1g (W/Kg)	
				Initial	End	Power Drift (dB)	100% Duty Cycle	50% Duty Cycle		100% Duty Cycle	50% Duty Cycle
1 (462.5625)	GMRS	Fixed	Rocket	3.710	3.150	-0.91	2.060	1.030	-1.13	2.67	**1.34**
15 (462.5500)	GMRS	Fixed	Rocket	3.600	3.022	-1.05	1.930	0.965	-1.13	2.50	**1.25**
22 (462.7250)	GMRS	Fixed	Rocket	3.600	2.994	-0.79	2.120	1.060	-1.13	2.75	**1.38**
8 (467.5625)	FRS	Fixed	Rocket	0.810	0.732	-0.79	0.374	0.187	-1.13	0.49	**0.24**
1 (462.5625)	GMRS	Fixed	Energizer	3.600	3.078	-1.09	2.150	1.075	-1.13	2.79	**1.39**
1 (462.5625)	GMRS	Fixed	Duracell	3.700	3.200	-0.86	2.000	1.000	-1.13	2.59	**1.30**
8 (467.5625)	FRS	Fixed	Energizer	0.810	0.747	-0.90	0.392	0.196	-1.13	0.51	**0.25**
8 (467.5625)	FRS	Fixed	Duracell	0.820	0.755	-1.00	0.410	0.205	-1.13	0.53	**0.27**
ANSI/ IEEE C95.1 1992 – Safety Limit Spatial Peak Uncontrolled Exposure/ General Population							**Mouth/ Face 1.6 W/kg (mW/g)** Averaged over 1 gram				

Measured Depth of Simulating Tissue: 15.0cm/ Liquid Temperature: 21.3℃

NOTES:

1. The SAR values found were below the maximum limit of 1.6 W/kg (uncontrolled exposure).
2. The highest body SAR value found was 1.39W/kg(based 50% duty cycle & 2.0 mm phantom).
3. The EUT was tested for body SAR with a 1.5 cm separation distance between the front of the EUT and the outer surface of the planer phantom.
4. Battery Type ☒ Standard (x4) AA Alkaline batteries (1.5VDC)
5. Power Measured ☒ Conducted ☐ EIRP ☐ ERP
6. SAR Measurement System ☒ SPEAG
7. SAR Configuration ☐ Face/ Mouth ☒ Body ☐ Hand
8. SAR Measurement Time : 15 minutes

Figure 12. Body SAR

Report prepared by : Ki-Soo Kim

Manager of Product Compliance Team

12.1 SAR TEST EQUIPMENT

Type / Model	Calib. Date	S/N
Staubli Robot RX90L	N/A	F01/ 5K09A1/A/01
Staubli Robot ControllerCS7MB	N/A	F99/5A82A1/C/01
Staubli Teach Pendant (Joystick)	N/A	D221340.01
Dell OptiPlex GX100	N/A	HY4640
Windows NT 4.0	N/A	-
SPEAG DAE3V1	June 03	447
SPEAG E-Field Probe ET3DV6	October 03	1798
SPEAG Dummy Probe	N/A	-
SPEAG SAM Phantom	N/A	TP-1019
SPEAG SAM Phantom	N/A	TP-1173
SPEAG Light Alignment Sensor	N/A	265
SPEAG Validation Dipole D450V2	July 02	1007
SPEAG Validation Dipole D835V2	October 03	441
SPEAG Validation Dipole D1800V2	October 03	2d007
SPEAG Validation Dipole D1900V2	May 03	5d032
Robot Table	N/A	-
Phone Holder	N/A	-
A/B Power Indicator	N/A	-
Remote Power Switch	N/A	-
Phantom Cover D9F09QG0009	N/A	-

NOTE:

The E-field probe was calibrated by SPEAG, by temperature measurement procedure. Dipole Validation measurement is performed by HCT Lab. before each test. The brain simulating material is calibrated by HCT using the dielectric probe system and network analyzer to determine the conductivity and permittivity (dielectric constant) of the brain-equivalent material.

The following list of equipment was used to calibrate the brain equivalent material:

Power Meter(A) HP 438A	July 03	2822A05909
Power Sensor(A) HP8481B	July 03	3318A08777
Power Meter(B) HP 438A	Nov. 03	2427A00963
Power Sensor(B) HP8481A	Oct. 03	2349A37617
Signal Generator HP-8664A (100kHz ~ 3GHz)	Nov. 03	3744A01608
Power Amp A0825-4343-R	Sep. 03	A00450
Network Analyzer HP-8753D (30kHz ~ 3GHz)	Sep. 03	3401J02111
Dielectric Probe Kit HP85070C	-	00721521
Dual Directional Coupler	July 03	16072

13.1 CONCLUSION

The SAR measurement indicates that the EUT complies with the RF radiation exposure limits of the ANSI/ IEEE C95.1 1992.

These measurements are taken to simulate the RF effects exposure under worst-case conditions. Precise laboratory measures were taken to assure repeatability of the tests.

15.1 REFERENCES:

[1] Federal Communications Commission, ET Docket 93-62, Guidelines for Evaluating the Environmental Effects of Radio frequency Radiation, Aug. 1996.

[2] ANSI/IEEE C95.1 - 1991, American National Standard safety levels with respect to human exposure to radio frequency electromagnetic fields, 300kHz to 100GHz, New York: IEEE, Aug. 1992

[3] ANSI/IEEE C95.3 - 1991, IEEE Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields - RF and Microwave, New York: IEEE, 1992.

[4] NCRP, National Council on Radiation Protection and Measurements, Biological Effects and Exposure Criteria for Radio Frequency Electromagnetic Fields, NCRP Report No. 86, 1986. Reprinted Feb. 1995.

[5] T. Schmid, O. Egger, N. Kuster, Automated E-field scanning system for dosimetric assessments, IEEE Transaction
on Microwave Theory and Techniques, vol. 44, Jan. 1996, pp. 105-113.

[6] K. Pokovic, T. Schmid, N. Kuster, Robust setup for precise calibration of E-field probes in tissue simulating liquids at mobile communications frequencies, ICECOM97, Oct. 1997, pp. 120-124.

[7]K. Pokoviº, T. Schmid, and N. Kuster, E-field Probe with improved isotropy in brain simulating liquids, Proceedings of the ELMAR, Zadar, Croatia, June 23-25, 1996, pp. 172-175.

[8] Schmid & Partner Engineering AG, Application Note: Data Storage and Evaluation, June 1998, p2.

[9] V. Hombach, K. Meier, M. Burkhardt, E. Kuhn, N. Kuster, The Dependence of EM Energy Absorption upon Human Head Modeling at 900 MHz, IEEE Transaction on Microwave Theory and Techniques, vol. 44 no. 10, Oct. 1996, pp. 1865-1873.

[10] N. Kuster and Q. Balzano, Energy absorption mechanism by biological bodies in the near field of dipole antennas above 300MHz, IEEE Transaction on Vehicular Technology, vol. 41, no. 1, Feb. 1992, pp. 17-23.

[11] G. Hartsgrove, A. Kraszewski, A. Surowiec, Simulated Biological Materials for Electromagnetic Radiation Absorption Studies, University of Ottawa, Bioelectro magnetics, Canada: 1987, pp. 29-36.

[12] Q. Balzano, O. Garay, T. Manning Jr., Electromagnetic Energy Exposure of Simulated Users of Portable Cellular Telephones, IEEE Transactions on Vehicular Technology, vol. 44, no.3, Aug. 1995.

[13] W. Gander, Computer mathematick, Birkhaeuser, Basel, 1992.

[14] W.H. Press, S.A. Teukolsky, W.T. Vetterling, and B.P. Flannery, Numerical Recepies in C, The Art of Scientific
Computing, Second edition, Cambridge University Press, 1992.

[15] Federal Communications Commission, OET Bulletin 65, Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields. Supplement C, Dec. 1997.

[16] N. Kuster, R. Kastle, T. Schmid, Dosimetric evaluation of mobile communications equipment with known precision, IEEE Transaction on Communications, vol. E80-B, no. 5, May 1997, pp. 645-652.

[17] CENELEC CLC/SC111B, European Prestandard (prENV 50166-2), Human Exposure to Electromagnetic Fields
High-frequency: 10kHz-300GHz, Jan. 1995.

[18] Prof. Dr. Niels Kuster, ETH, EidgenØssische Technische Hoschschule Zòrich, Dosimetric Evaluation of the Cellular Phone.