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: 1607
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	21.6	ε_r	43.5	44.5	+2.30	±5%
			σ	0.87	0.85	-2.30	±5%
	Body	21.6	ε_r	56.7	55.4	-2.29	±5%
			σ	0.94	0.94	0.00	±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	21.6	1 g	4.9	4.92	+0.41	±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.

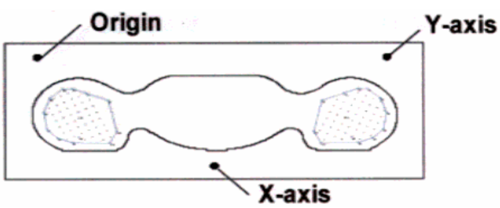

Fig. 10. SAR Measurement Point in Area Scan

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

Ambient TEMPERATURE (°C) 21.6
Relative HUMIDITY (%) 44
Atmospheric PRESSURE (kPa) 98.7

Mixture Type: 450 MHz
Dielectric Constant: 44.5
Conductivity: 0.85
Phantom Position: Face
Closest Distance (between E-Probe & Phone): 2.5 cm

11.2 Measurement Results (Mouth/ Face SAR)

Channel / Freq. (MHz)	Mode	Ant.	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
F1 (440.075)	FM	Fixed	5.03	4.71	−0.29	5.10	2.55	−0.75	6.06	3.03
F2 (455.075)	FM	Fixed	5.04	4.42	−0.57	6.39	3.195	−0.75	7.60	3.80
F3 (469.075)	FM	Fixed	5.04	4.24	−0.75	6.77	3.385	−0.75	8.05	4.02
ANSI/ IEEE C95.1 1992 – Safety Limit Spatial Peak Controlled Exposure/ Occupational						**Mouth/ Face 8 W/kg (mW/g)** Averaged over 1 gram				

Measured Depth of Simulating Tissue: 15.0cm / Liquid Temperature: 21.6℃

NOTES:

1. The SAR values found were below the maximum limit of 8 W/kg (controlled exposure).
2. The highest face-held SAR value found was 4.02W/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
5. Power Measured ☒ Conducted ☐ EIRP ☐ ERP
6. SAR Measurement System ☒ SPEAG
7. SAR Configuration ☒ Face/ Mouth ☐ Body ☐ Hand

11.1 SAR TEST DATA SUMMARY

Ambient TEMPERATURE (°C) 21.6
Relative HUMIDITY (%) 44
Atmospheric PRESSURE (kPa) 98.7

Mixture Type: 450 MHz
Dielectric Constant: 55.4
Conductivity: 0.94
Phantom Position: Body
Closest Distance (between E-Probe & Phone): 1.5 cm

11.3 Measurement Results (Body SAR)

Channel / Freq. (MHz)	Mode	Ant.	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
F1 (440.075)	FM	Fixed	5.20	4.57	−0.43	5.20	2.60	−0.75	6.18	3.09
F2 (455.075)	FM	Fixed	6.80	4.43	−0.54	6.80	3.40	−0.75	8.08	4.04
F3 (469.975)	FM	Fixed	6.06	4.33	−0.66	6.06	3.03	−0.75	7.20	3.60
ANSI/ IEEE C95.1 1992 – Safety Limit Spatial Peak Controlled Exposure/ Occupational						**Body 8W/kg (mW/g)** Averaged over 1 gram				

Measured Depth of Simulating Tissue: 15.0cm/ Liquid Temperature: 21.6

NOTES:
1. The SAR values found were below the maximum limit of 8 W/kg (controlled exposure).
2. The highest body SAR value found was 4.04w/kg(based 50% duty cycle & 2.0 mm phantom).
3. The EUT was tested for body SAR with a 1.5cm separation distance between the front of the EUT and the outer surface of the planer phantom.

4. Battery Type ☒ Standard
5. Power Measured ☒ Conducted ☐ EIRP ☐ ERP
6. SAR Measurement System ☒ SPEAG
7. SAR Configuration ☐ Face/ Mouth ☒ Body ☐ Hand

8. The SAR measurement has been performed with the external earpiece and microphone connected to the radio for the body worn SAR test.

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
HP Pavilion t000_puffer	N/A	KRJ51201TV
Windows XP 3.0GHz	N/A	-
SPEAG DAE3V1	May 05	446
SPEAG DAE3V1	May 05	447
SPEAG E-Field Probe ET3DV6	August 05	1798
SPEAG E-Field Probe ET3DV6	April 05	1607
SPEAG Dummy Probe	N/A	-
SPEAG SAM Phantom	N/A	-
SPEAG Light Alignment Sensor	N/A	265
SPEAG Validation Dipole D450V2	May 05	1007
SPEAG Validation Dipole D900V2	April 05	121
SPEAG Validation Dipole D1800V2	Sep. 05	2d007
SPEAG Validation Dipole D1900V2	April 05	5d032
SPEAG Validation Dipole D2450V2	Feb. 05	743
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)	E4419B	June 05	MY40511244
Power Sensor(A)	8481	June 05	MY41090680
Signal Generator	8664A (100kHz ~ 3GHz)	March 05	3744A02069
Power Amp	A0825-4343-R	Sep. 05	A00450
Network Analyzer	8752C (30kHz ~ 3GHz)	March 05	3410A02619
Dielectric Probe Kit	85070C	-	00721521
Dual Directional Coupler	778D	August 05	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.

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