2.14 WLAN 5180MHz HEAD SAR TEST RESULTS AND COURSE AREA SCANS – 2D

SYSTEM / SOFTWARE:	SARA-C / v6.09.08	INPUT POWER DRIFT:	0 dB
DATE / TIME:	19/11/2014-15:13:12	DUT BATTERY MODEL/NO:	Integral
AMBIENT TEMPERATURE:	23.10°C	LIQUID SIMULANT:	5000Head
DEVICE UNDER TEST:	SHV31	RELATIVE PERMITTIVITY:	35.92
RELATIVE HUMIDITY:	37.90%	CONDUCTIVITY:	4.575
PHANTOM S/NO:	IXB-040	LIQUID TEMPERATURE:	22.90°C
PHANTOM ROTATION:	N/A	MAX SAR Y-AXIS LOCATION:	24.80mm
DUT POSITION:	Left-Cheek	MAX SAR Z-AXIS LOCATION:	-173.20mm
ANTENNA CONFIGURATION:	N/A	MAX E FIELD:	3.541
TEST FREQUENCY:	5180.0MHz	SAR 1g:	0.12 W/kg
TYPE OF MODULATION:	WLAN (OFDM)	SAR 10g:	N/A
MODN. DUTY CYCLE:	100%	SAR START:	0.170 W/kg
INPUT POWER LEVEL:	14.5dBm	SAR END:	0.186 W/kg
PROBE BATTERY LAST CHANGED:	19/11/2014	SAR DRIFT DURING SCAN:	9.200 %

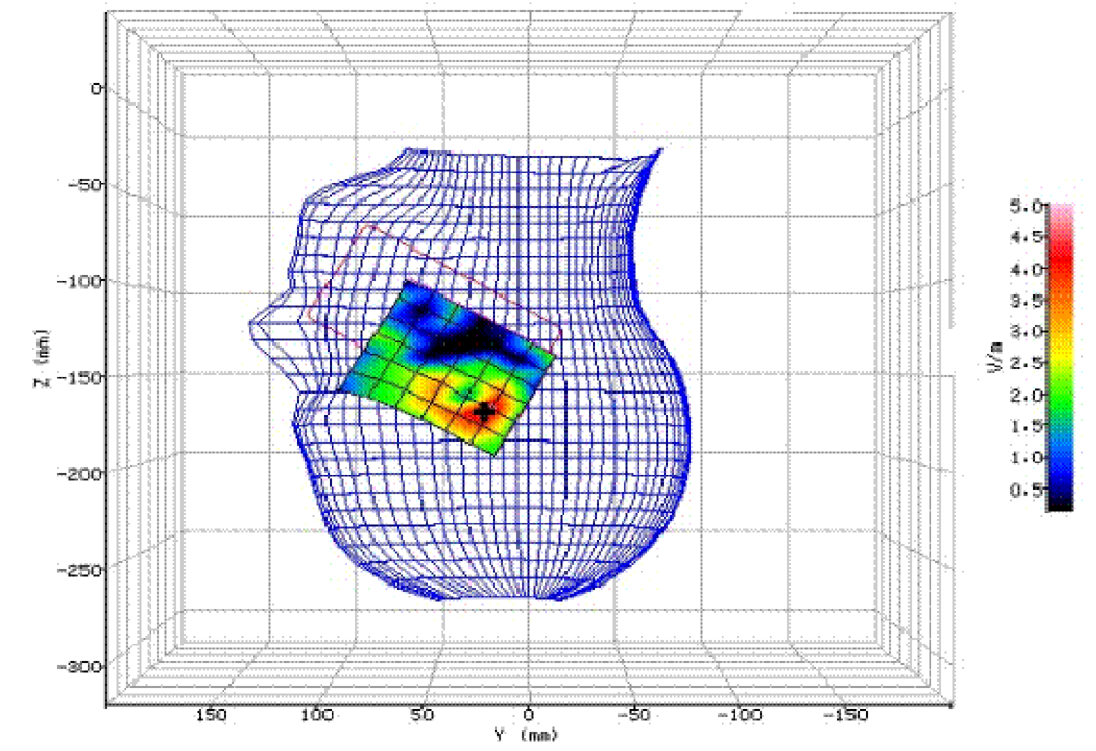

Figure 60: SAR Head Testing Results for the Sharp SHV31 Mobile Handset at 5180.0MHz.

SYSTEM / SOFTWARE:	SARA-C / v6.09.08	INPUT POWER DRIFT:	0 dB
DATE / TIME:	19/11/2014-15:38:35	DUT BATTERY MODEL/NO:	Integral
AMBIENT TEMPERATURE:	23.10°C	LIQUID SIMULANT:	5000Head
DEVICE UNDER TEST:	SHV31	RELATIVE PERMITTIVITY:	35.92
RELATIVE HUMIDITY:	37.90%	CONDUCTIVITY:	4.575
PHANTOM S/NO:	IXB-040	LIQUID TEMPERATURE:	22.90°C
PHANTOM ROTATION:	N/A	MAX SAR Y-AXIS LOCATION:	24.40mm
DUT POSITION:	Left-15°	MAX SAR Z-AXIS LOCATION:	-174.10mm
ANTENNA CONFIGURATION:	N/A	MAX E FIELD:	3.155
TEST FREQUENCY:	5180.0MHz	SAR 1g:	0.09 W/kg
TYPE OF MODULATION:	WLAN (OFDM)	SAR 10g:	N/A
MODN. DUTY CYCLE:	100%	SAR START:	0.136 W/kg
INPUT POWER LEVEL:	14.5dBm	SAR END:	0.142 W/kg
PROBE BATTERY LAST CHANGED:	19/11/2014	SAR DRIFT DURING SCAN:	4.200 %

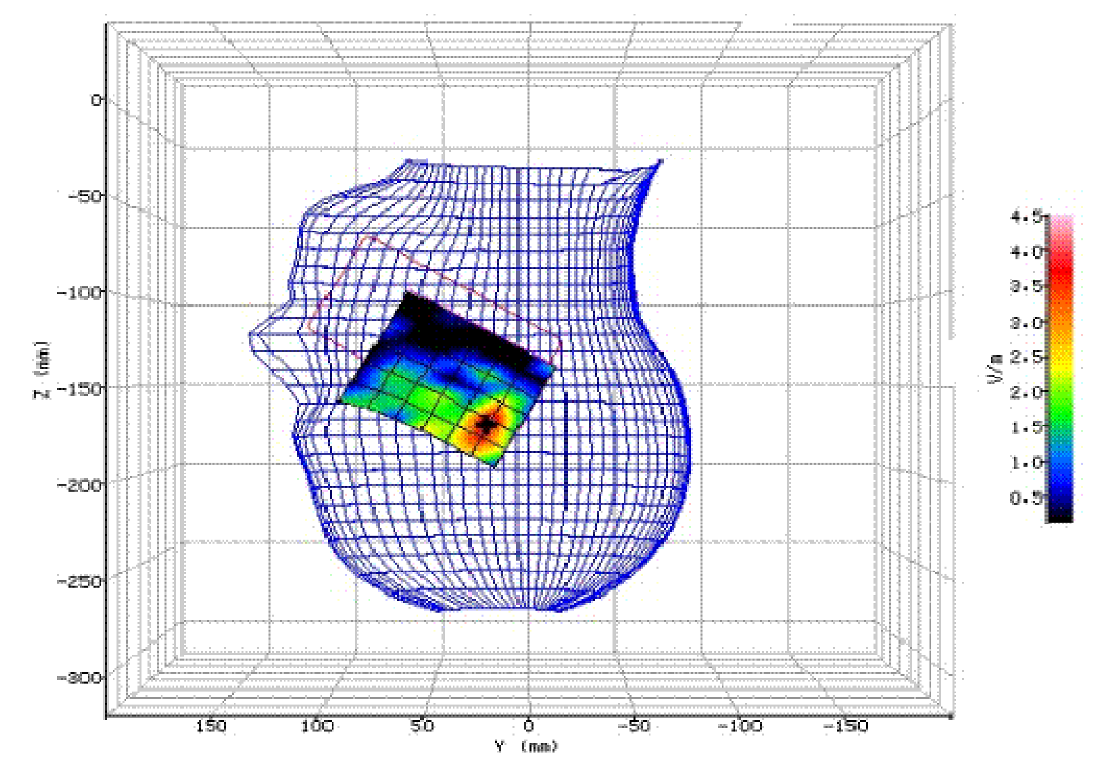

Figure 61: SAR Head Testing Results for the Sharp SHV31 Mobile Handset at 5180.0MHz.

Product Service

SYSTEM / SOFTWARE:	SARA-C / v6.09.08	INPUT POWER DRIFT:	0 dB
DATE / TIME:	19/11/2014-16:29:46	DUT BATTERY MODEL/NO:	Integral
AMBIENT TEMPERATURE:	23.10°C	LIQUID SIMULANT:	5000Head
DEVICE UNDER TEST:	SHV31	RELATIVE PERMITTIVITY:	35.92
RELATIVE HUMIDITY:	37.90%	CONDUCTIVITY:	4.575
PHANTOM S/NO:	IXB-040	LIQUID TEMPERATURE:	22.90°C
PHANTOM ROTATION:	N/A	MAX SAR Y-AXIS LOCATION:	34.40mm
DUT POSITION:	Right-Cheek	MAX SAR Z-AXIS LOCATION:	-108.40mm
ANTENNA CONFIGURATION:	N/A	MAX E FIELD:	1.557
TEST FREQUENCY:	5180.0MHz	SAR 1g:	0.03 W/kg
TYPE OF MODULATION:	WLAN (OFDM)	SAR 10g:	N/A
MODN. DUTY CYCLE:	100%	SAR START:	0.032 W/kg
INPUT POWER LEVEL:	14.5dBm	SAR END:	0.032 W/kg
PROBE BATTERY LAST CHANGED:	19/11/2014	SAR DRIFT DURING SCAN:	0.000 %

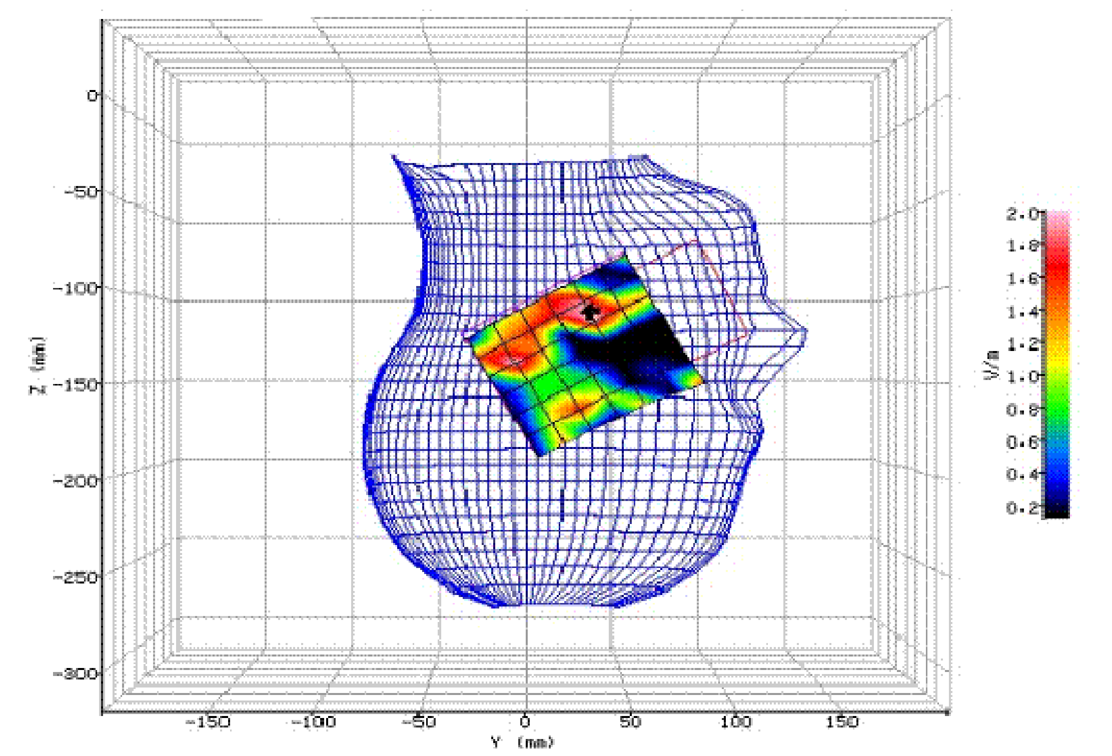

Figure 62: SAR Head Testing Results for the Sharp SHV31 Mobile Handset at 5180.0MHz.

SYSTEM / SOFTWARE:	SARA-C / v6.09.08	INPUT POWER DRIFT:	0 dB
DATE / TIME:	19/11/2014-17:00:29	DUT BATTERY MODEL/NO:	Integral
AMBIENT TEMPERATURE:	23.10°C	LIQUID SIMULANT:	5000Head
DEVICE UNDER TEST:	SHV31	RELATIVE PERMITTIVITY:	35.92
RELATIVE HUMIDITY:	37.90%	CONDUCTIVITY:	4.575
PHANTOM S/NO:	IXB-040	LIQUID TEMPERATURE:	22.90°C
PHANTOM ROTATION:	N/A	MAX SAR Y-AXIS LOCATION:	-3.60mm
DUT POSITION:	Right-15°	MAX SAR Z-AXIS LOCATION:	-131.70mm
ANTENNA CONFIGURATION:	N/A	MAX E FIELD:	1.148
TEST FREQUENCY:	5180.0MHz	SAR 1g:	0.06 W/kg
TYPE OF MODULATION:	WLAN (OFDM)	SAR 10g:	N/A
MODN. DUTY CYCLE:	100%	SAR START:	0.057 W/kg
INPUT POWER LEVEL:	14.5dBm	SAR END:	0.057 W/kg
PROBE BATTERY LAST CHANGED:	19/11/2014	SAR DRIFT DURING SCAN:	0.000 %

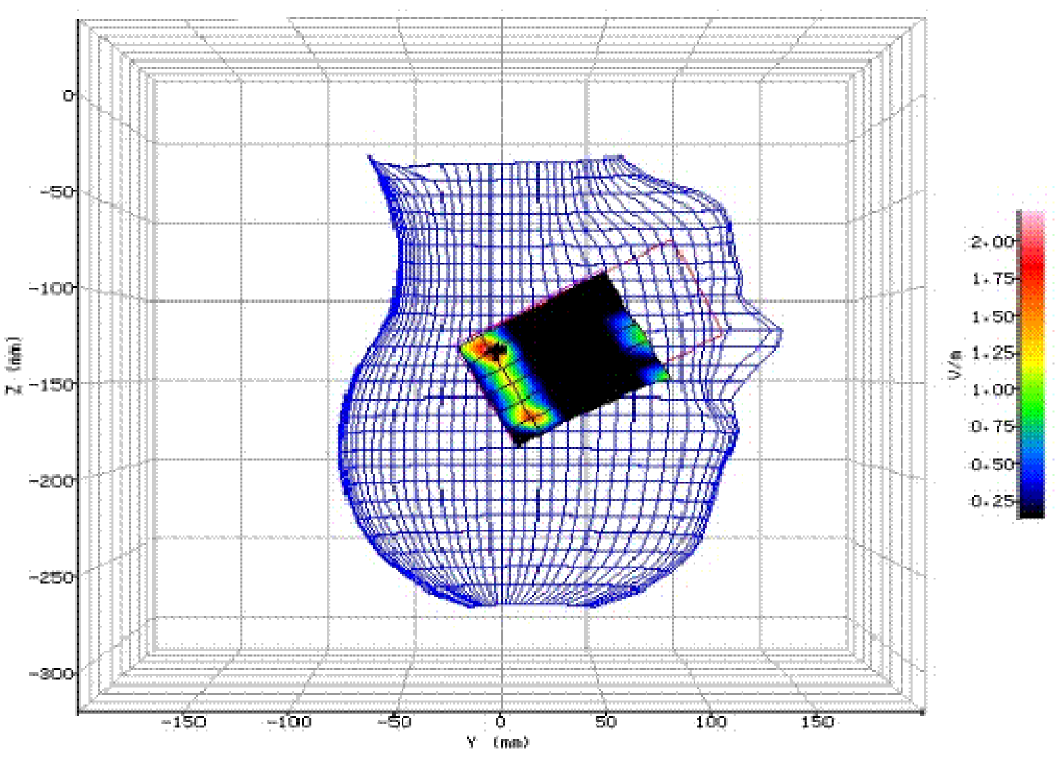

Figure 63: SAR Head Testing Results for the Sharp SHV31 Mobile Handset at 5180.0MHz.

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Product Service

2.15 WLAN 5180MHz BODY SAR TEST RESULTS AND COURSE AREA SCANS – 2D

SYSTEM / SOFTWARE:	SARA-C / v6.09.08	INPUT POWER DRIFT:	0 dB
DATE / TIME:	21/11/2014-06:44:05	DUT BATTERY MODEL/NO:	Integral
AMBIENT TEMPERATURE:	23.00°C	LIQUID SIMULANT:	5000Body
DEVICE UNDER TEST:	SHV31	RELATIVE PERMITTIVITY:	48.74
RELATIVE HUMIDITY:	37.40%	CONDUCTIVITY:	5.038
PHANTOM S/NO:	IXB-2HF	LIQUID TEMPERATURE:	23.10°C
PHANTOM ROTATION:	N/A	MAX SAR X-AXIS LOCATION:	30.90mm
DUT POSITION:	10mm-Front Facing	MAX SAR Y-AXIS LOCATION:	1.60mm
ANTENNA CONFIGURATION:	N/A	MAX E FIELD:	2.847
TEST FREQUENCY:	5180.0MHz	SAR 1g:	0.04 W/kg
TYPE OF MODULATION:	WLAN (OFDM)	SAR 10g:	N/A
MODN. DUTY CYCLE:	100%	SAR START:	0.052 W/kg
INPUT POWER LEVEL:	14.5dBm	SAR END:	0.052 W/kg
PROBE BATTERY LAST CHANGED:	21/11/2014	SAR DRIFT DURING SCAN:	0.300 %

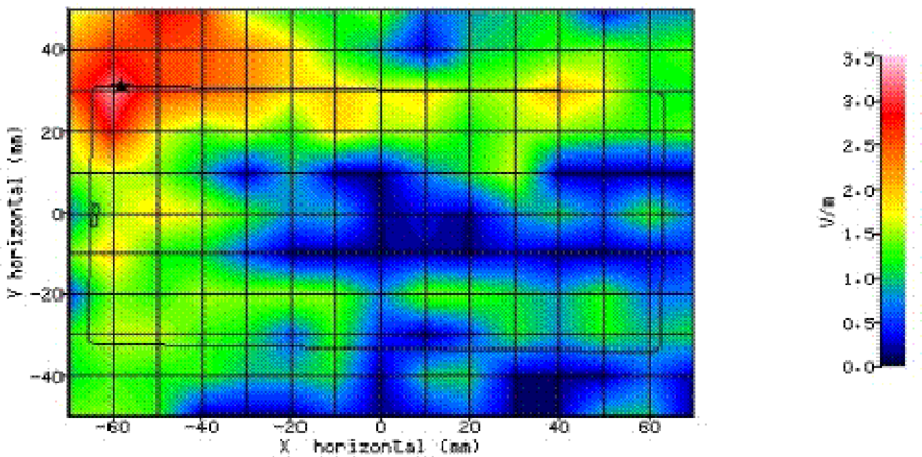

Figure 64: SAR Body Testing Results for the Sharp SHV31 Mobile Handset at 5180.0MHz.

Product Service

SYSTEM / SOFTWARE:	SARA-C / v6.09.08	INPUT POWER DRIFT:	0 dB
DATE / TIME:	21/11/2014-07:03:14	DUT BATTERY MODEL/NO:	Integral
AMBIENT TEMPERATURE:	23.00°C	LIQUID SIMULANT:	5000Body
DEVICE UNDER TEST:	SHV31	RELATIVE PERMITTIVITY:	48.74
RELATIVE HUMIDITY:	37.40%	CONDUCTIVITY:	5.038
PHANTOM S/NO:	IXB-2HF	LIQUID TEMPERATURE:	23.10°C
PHANTOM ROTATION:	N/A	MAX SAR X-AXIS LOCATION:	-28.80mm
DUT POSITION:	10mm-Rear Facing	MAX SAR Y-AXIS LOCATION:	1.60mm
ANTENNA CONFIGURATION:	N/A	MAX E FIELD:	8.111
TEST FREQUENCY:	5180.0MHz	SAR 1g:	0.29 W/kg
TYPE OF MODULATION:	WLAN (OFDM)	SAR 10g:	N/A
MODN. DUTY CYCLE:	100%	SAR START:	0.460 W/kg
INPUT POWER LEVEL:	14.5dBm	SAR END:	0.481 W/kg
PROBE BATTERY LAST CHANGED:	21/11/2014	SAR DRIFT DURING SCAN:	4.900 %

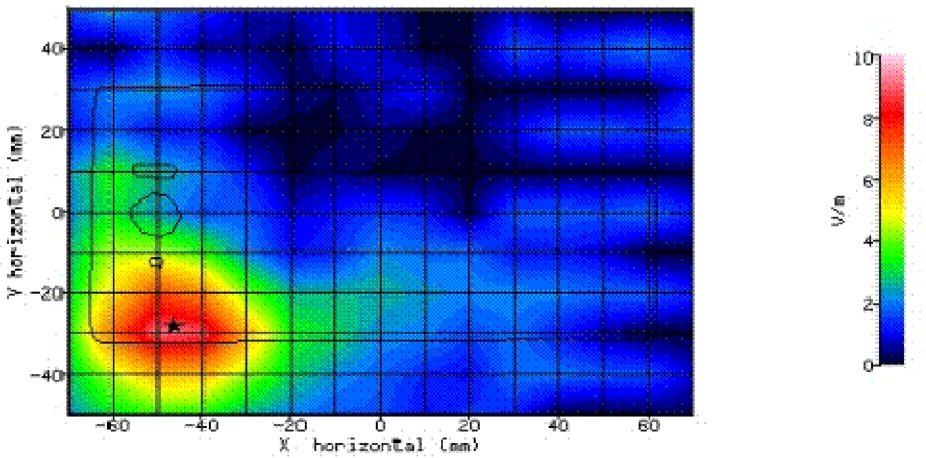

Figure 65: SAR Body Testing Results for the Sharp SHV31 Mobile Handset at 5180.0MHz.

Product Service

SYSTEM / SOFTWARE:	SARA-C / v6.09.08	INPUT POWER DRIFT:	0 dB
DATE / TIME:	21/11/2014-07:56:52	DUT BATTERY MODEL/NO:	Integral
AMBIENT TEMPERATURE:	23.00°C	LIQUID SIMULANT:	5000Body
DEVICE UNDER TEST:	SHV31	RELATIVE PERMITTIVITY:	48.74
RELATIVE HUMIDITY:	37.40%	CONDUCTIVITY:	5.038
PHANTOM S/NO:	IXB-2HF	LIQUID TEMPERATURE:	23.10°C
PHANTOM ROTATION:	N/A	MAX SAR X-AXIS LOCATION:	10.50mm
DUT POSITION:	10mm-Left Edge	MAX SAR Y-AXIS LOCATION:	1.60mm
ANTENNA CONFIGURATION:	N/A	MAX E FIELD:	6.467
TEST FREQUENCY:	5180.0MHz	SAR 1g:	0.18 W/kg
TYPE OF MODULATION:	WLAN (OFDM)	SAR 10g:	N/A
MODN. DUTY CYCLE:	100%	SAR START:	0.274 W/kg
INPUT POWER LEVEL:	14.5dBm	SAR END:	0.266 W/kg
PROBE BATTERY LAST CHANGED:	21/11/2014	SAR DRIFT DURING SCAN:	-2.700 %

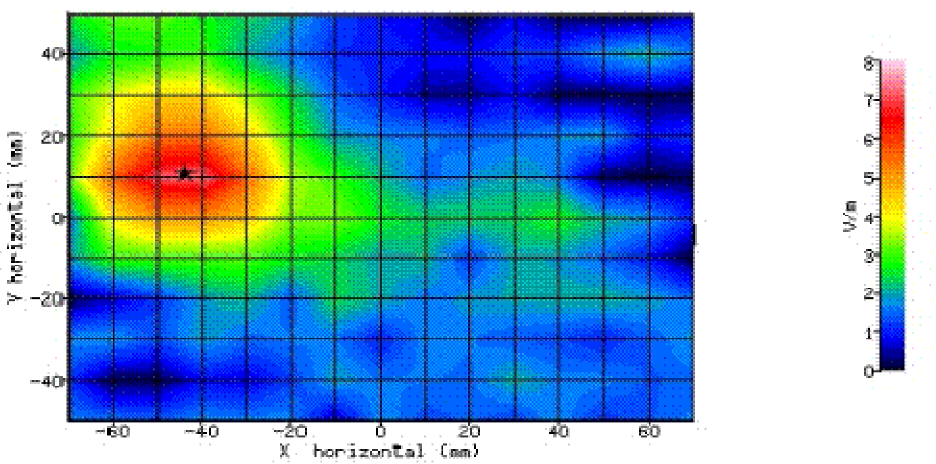

Figure 66: SAR Body Testing Results for the Sharp SHV31 Mobile Handset at 5180.0MHz.

Product Service

SYSTEM / SOFTWARE:	SARA-C / v6.09.08	INPUT POWER DRIFT:	0 dB
DATE / TIME:	21/11/2014-08:17:19	DUT BATTERY MODEL/NO:	Integral
AMBIENT TEMPERATURE:	23.00°C	LIQUID SIMULANT:	5000Body
DEVICE UNDER TEST:	SHV31	RELATIVE PERMITTIVITY:	48.74
RELATIVE HUMIDITY:	37.40%	CONDUCTIVITY:	5.038
PHANTOM S/NO:	IXB-2HF	LIQUID TEMPERATURE:	23.10°C
PHANTOM ROTATION:	N/A	MAX SAR X-AXIS LOCATION:	18.90mm
DUT POSITION:	10mm-Top Edge	MAX SAR Y-AXIS LOCATION:	1.60mm
ANTENNA CONFIGURATION:	N/A	MAX E FIELD:	2.922
TEST FREQUENCY:	5180.0MHz	SAR 1g:	0.04 W/kg
TYPE OF MODULATION:	WLAN (OFDM)	SAR 10g:	N/A
MODN. DUTY CYCLE:	100%	SAR START:	0.042 W/kg
INPUT POWER LEVEL:	14.5dBm	SAR END:	0.042 W/kg
PROBE BATTERY LAST CHANGED:	21/11/2014	SAR DRIFT DURING SCAN:	-0.700 %

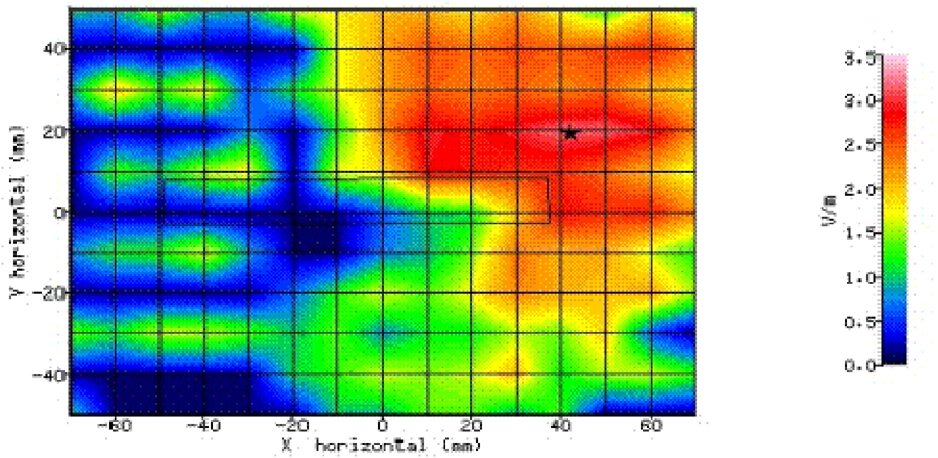

Figure 67: SAR Body Testing Results for the Sharp SHV31 Mobile Handset at 5180.0MHz.

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2.16 WLAN 5260MHz HEAD SAR TEST RESULTS AND COURSE AREA SCANS – 2D

SYSTEM / SOFTWARE:	SARA-C / v6.09.08	INPUT POWER DRIFT:	0 dB
DATE / TIME:	20/11/2014-08:02:47	DUT BATTERY MODEL/NO:	Integral
AMBIENT TEMPERATURE:	22.90°C	LIQUID SIMULANT:	5000Head
DEVICE UNDER TEST:	SHV31	RELATIVE PERMITTIVITY:	35.92
RELATIVE HUMIDITY:	35.90%	CONDUCTIVITY:	4.575
PHANTOM S/NO:	IXB-040	LIQUID TEMPERATURE:	23.00°C
PHANTOM ROTATION:	N/A	MAX SAR Y-AXIS LOCATION:	23.40mm
DUT POSITION:	Left-Cheek	MAX SAR Z-AXIS LOCATION:	-171.10mm
ANTENNA CONFIGURATION:	N/A	MAX E FIELD:	3.857
TEST FREQUENCY:	5260.0MHz	SAR 1g:	0.12 W/kg
TYPE OF MODULATION:	WLAN (OFDM)	SAR 10g:	N/A
MODN. DUTY CYCLE:	100%	SAR START:	0.228 W/kg
INPUT POWER LEVEL:	14.5dBm	SAR END:	0.245 W/kg
PROBE BATTERY LAST CHANGED:	20/11/2014	SAR DRIFT DURING SCAN:	7.300 %

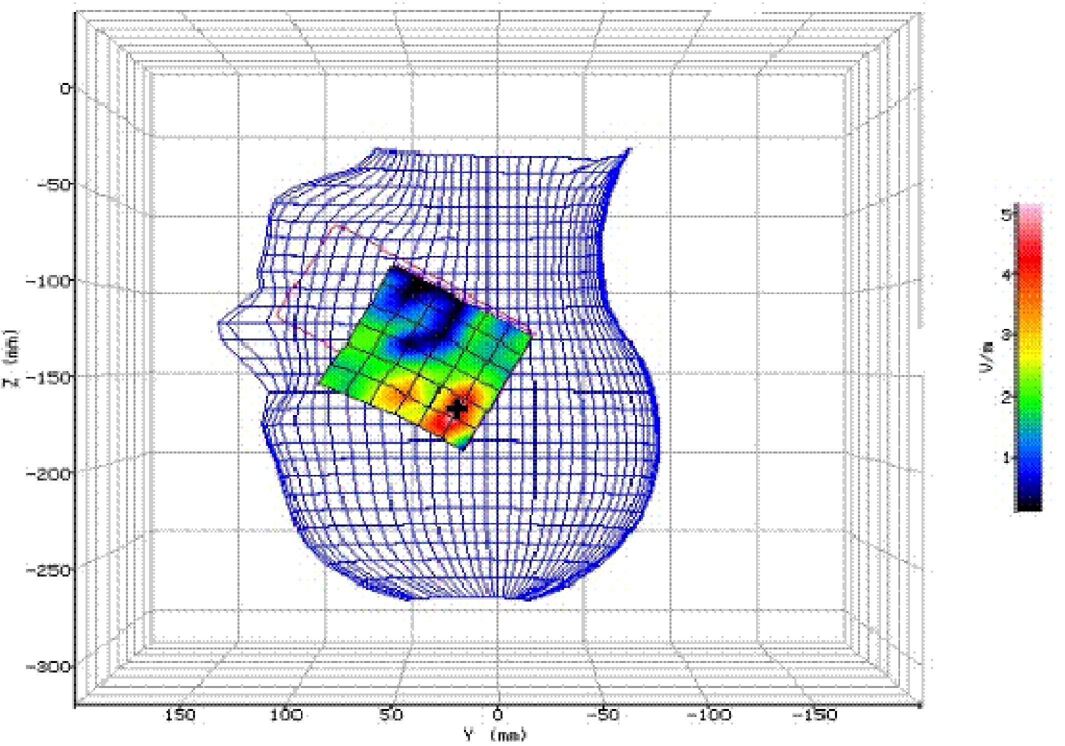

Figure 68: SAR Head Testing Results for the Sharp SHV31 Mobile Handset at 5260.0MHz.

SYSTEM / SOFTWARE:	SARA-C / v6.09.08	INPUT POWER DRIFT:	0 dB
DATE / TIME:	20/11/2014-08:32:12	DUT BATTERY MODEL/NO:	Integral
AMBIENT TEMPERATURE:	22.90°C	LIQUID SIMULANT:	5000Head
DEVICE UNDER TEST:	SHV31	RELATIVE PERMITTIVITY:	35.92
RELATIVE HUMIDITY:	35.90%	CONDUCTIVITY:	4.575
PHANTOM S/NO:	IXB-040	LIQUID TEMPERATURE:	23.00°C
PHANTOM ROTATION:	N/A	MAX SAR Y-AXIS LOCATION:	23.10mm
DUT POSITION:	Left-15°	MAX SAR Z-AXIS LOCATION:	-172.00mm
ANTENNA CONFIGURATION:	N/A	MAX E FIELD:	2.529
TEST FREQUENCY:	5260.0MHz	SAR 1g:	0.13 W/kg
TYPE OF MODULATION:	WLAN (OFDM)	SAR 10g:	N/A
MODN. DUTY CYCLE:	100%	SAR START:	0.238 W/kg
INPUT POWER LEVEL:	14.5dBm	SAR END:	0.238 W/kg
PROBE BATTERY LAST CHANGED:	20/11/2014	SAR DRIFT DURING SCAN:	0.000 %

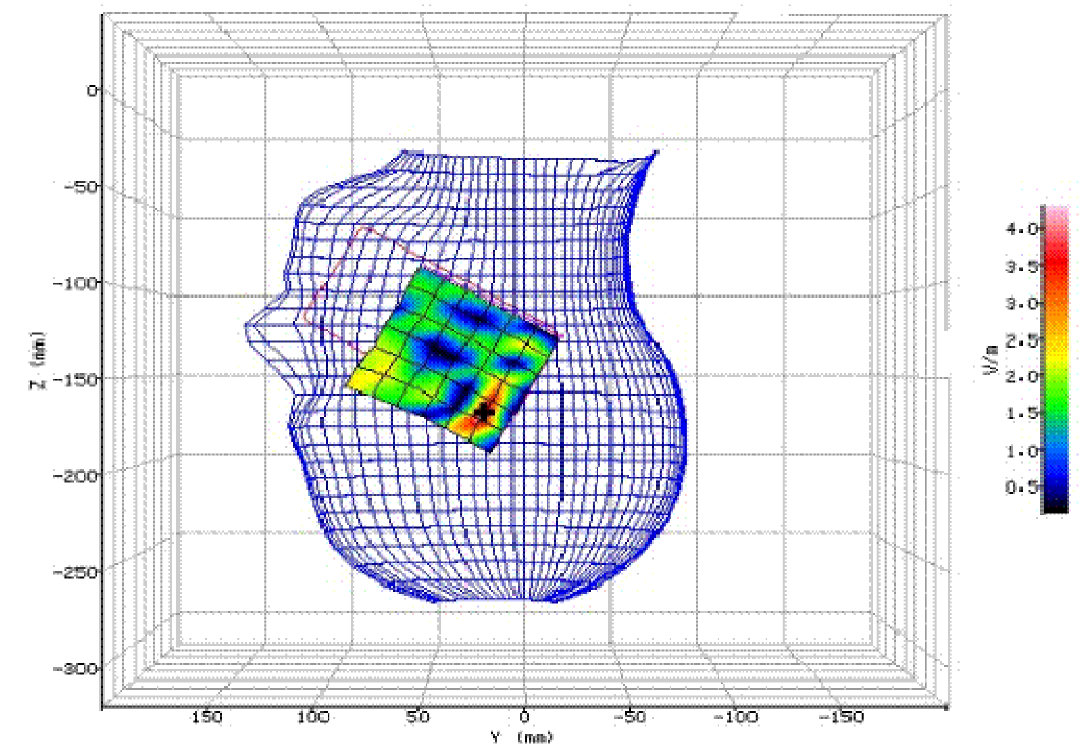

Figure 69: SAR Head Testing Results for the Sharp SHV31 Mobile Handset at 5260.0MHz.

Product Service

SYSTEM / SOFTWARE:	SARA-C / v6.09.08	INPUT POWER DRIFT:	0 dB
DATE / TIME:	20/11/2014-06:40:07	DUT BATTERY MODEL/NO:	Integral
AMBIENT TEMPERATURE:	22.90°C	LIQUID SIMULANT:	5000Head
DEVICE UNDER TEST:	SHV31	RELATIVE PERMITTIVITY:	35.92
RELATIVE HUMIDITY:	35.90%	CONDUCTIVITY:	4.575
PHANTOM S/NO:	IXB-040	LIQUID TEMPERATURE:	23.00°C
PHANTOM ROTATION:	N/A	MAX SAR Y-AXIS LOCATION:	40.10mm
DUT POSITION:	Right-Cheek	MAX SAR Z-AXIS LOCATION:	-108.10mm
ANTENNA CONFIGURATION:	N/A	MAX E FIELD:	2.685
TEST FREQUENCY:	5260.0MHz	SAR 1g:	0.05 W/kg
TYPE OF MODULATION:	WLAN (OFDM)	SAR 10g:	N/A
MODN. DUTY CYCLE:	100%	SAR START:	0.071 W/kg
INPUT POWER LEVEL:	14.5dBm	SAR END:	0.071 W/kg
PROBE BATTERY LAST CHANGED:	20/11/2014	SAR DRIFT DURING SCAN:	7.000 %

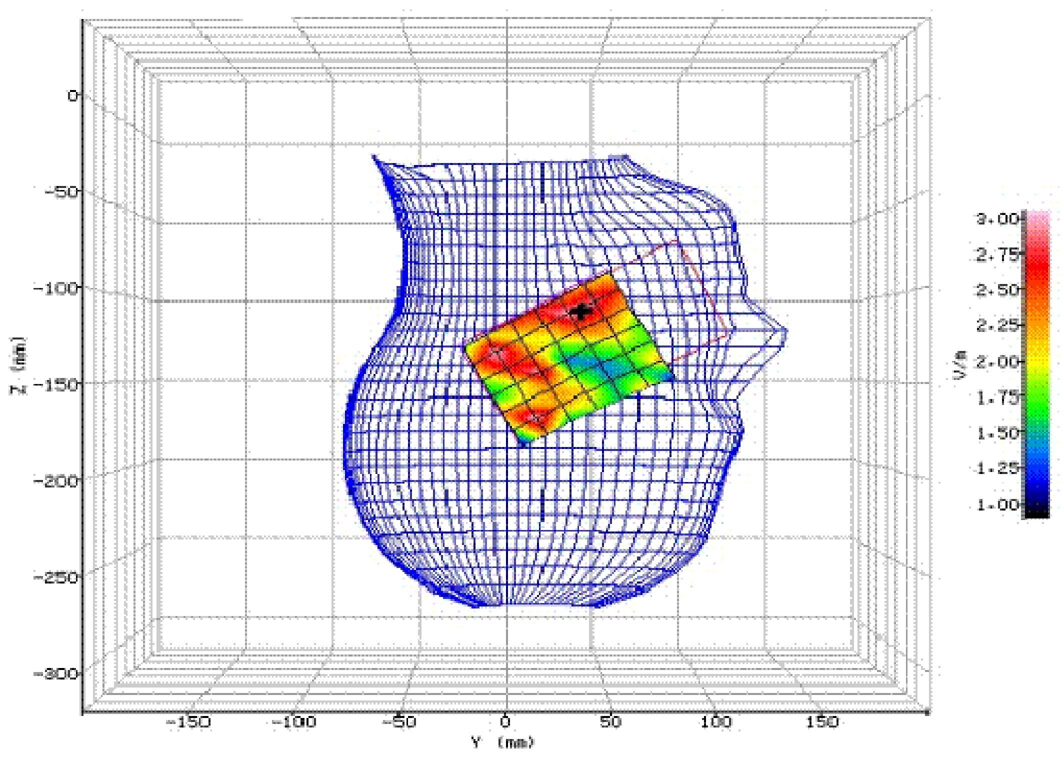

Figure 70: SAR Head Testing Results for the Sharp SHV31 Mobile Handset at 5260.0MHz.

Product Service

SYSTEM / SOFTWARE:	SARA-C / v6.09.08	INPUT POWER DRIFT:	0 dB
DATE / TIME:	20/11/2014-07:06:25	DUT BATTERY MODEL/NO:	Integral
AMBIENT TEMPERATURE:	22.90°C	LIQUID SIMULANT:	5000Head
DEVICE UNDER TEST:	SHV31	RELATIVE PERMITTIVITY:	35.92
RELATIVE HUMIDITY:	35.90%	CONDUCTIVITY:	4.575
PHANTOM S/NO:	IXB-040	LIQUID TEMPERATURE:	23.00°C
PHANTOM ROTATION:	N/A	MAX SAR Y-AXIS LOCATION:	-1.80mm
DUT POSITION:	Right-15°	MAX SAR Z-AXIS LOCATION:	-133.30mm
ANTENNA CONFIGURATION:	N/A	MAX E FIELD:	2.626
TEST FREQUENCY:	5260.0MHz	SAR 1g:	0.07 W/kg
TYPE OF MODULATION:	WLAN (OFDM)	SAR 10g:	N/A
MODN. DUTY CYCLE:	100%	SAR START:	0.068 W/kg
INPUT POWER LEVEL:	14.5dBm	SAR END:	0.068 W/kg
PROBE BATTERY LAST CHANGED:	20/11/2014	SAR DRIFT DURING SCAN:	0.000 %

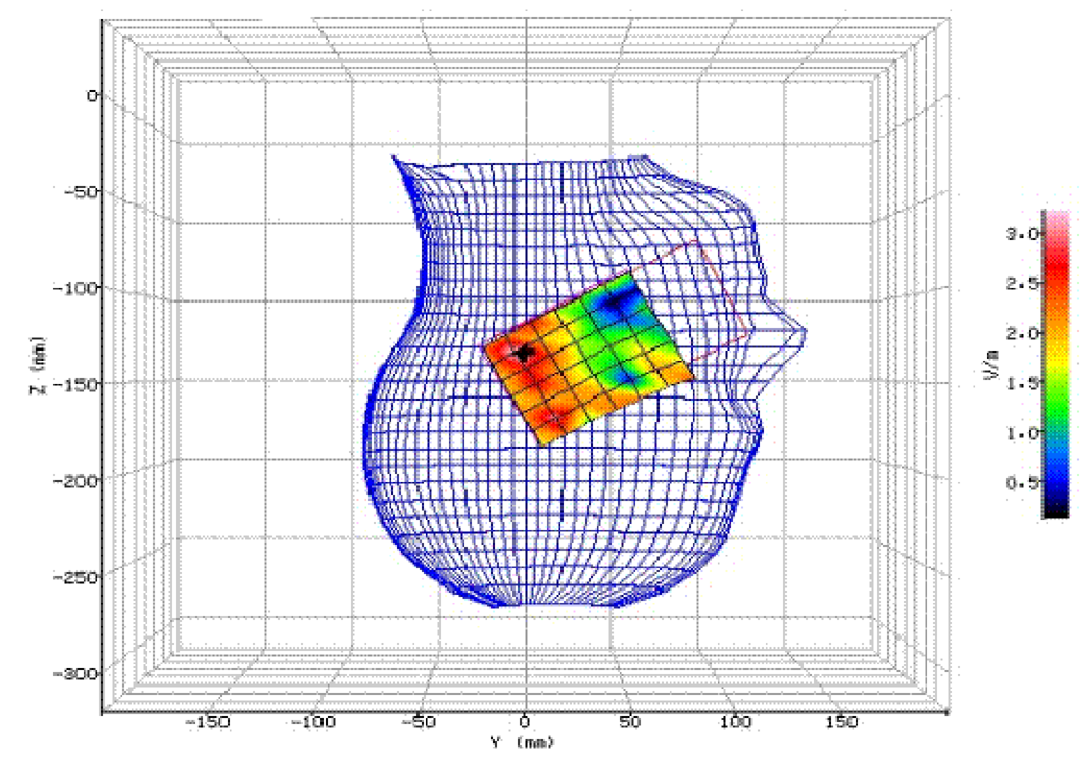

Figure 71: SAR Head Testing Results for the Sharp SHV31 Mobile Handset at 5260.0MHz.

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Product Service

2.17 WLAN 5260MHz BODY SAR TEST RESULTS AND COURSE AREA SCANS – 2D

SYSTEM / SOFTWARE:	SARA-C / v6.09.08	INPUT POWER DRIFT:	0 dB
DATE / TIME:	21/11/2014-11:56:29	DUT BATTERY MODEL/NO:	Integral
AMBIENT TEMPERATURE:	23.00°C	LIQUID SIMULANT:	5000Body
DEVICE UNDER TEST:	SHV31	RELATIVE PERMITTIVITY:	35.92
RELATIVE HUMIDITY:	35.30%	CONDUCTIVITY:	4.575
PHANTOM S/NO:	IXB-2HF	LIQUID TEMPERATURE:	23.00°C
PHANTOM ROTATION:	N/A	MAX SAR X-AXIS LOCATION:	-51.40mm
DUT POSITION:	10mm-Front Facing	MAX SAR Y-AXIS LOCATION:	37.90mm
ANTENNA CONFIGURATION:	N/A	MAX E FIELD:	2.521
TEST FREQUENCY:	5260.0MHz	SAR 1g:	0.02 W/kg
TYPE OF MODULATION:	WLAN (OFDM)	SAR 10g:	N/A
MODN. DUTY CYCLE:	100%	SAR START:	0.038 W/kg
INPUT POWER LEVEL:	14.5dBm	SAR END:	0.038 W/kg
PROBE BATTERY LAST CHANGED:	20/11/2014	SAR DRIFT DURING SCAN:	0.000 %

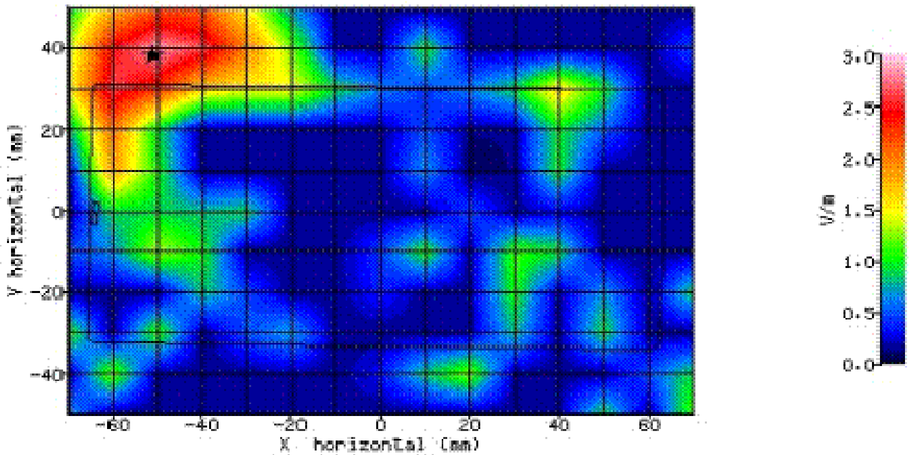

Figure 72: SAR Body Testing Results for the Sharp SHV31 Mobile Handset at 5260.0MHz.

Product Service

SYSTEM / SOFTWARE:	SARA-C / v6.09.08	INPUT POWER DRIFT:	0 dB
DATE / TIME:	21/11/2014-12:16:14	DUT BATTERY MODEL/NO:	Integral
AMBIENT TEMPERATURE:	23.00°C	LIQUID SIMULANT:	5000Body
DEVICE UNDER TEST:	SHV31	RELATIVE PERMITTIVITY:	35.92
RELATIVE HUMIDITY:	35.30%	CONDUCTIVITY:	4.575
PHANTOM S/NO:	IXB-2HF	LIQUID TEMPERATURE:	23.00°C
PHANTOM ROTATION:	N/A	MAX SAR X-AXIS LOCATION:	-40.90mm
DUT POSITION:	10mm-Rear Facing	MAX SAR Y-AXIS LOCATION:	-27.10mm
ANTENNA CONFIGURATION:	N/A	MAX E FIELD:	8.716
TEST FREQUENCY:	5260.0MHz	SAR 1g:	0.34 W/kg
TYPE OF MODULATION:	WLAN (OFDM)	SAR 10g:	N/A
MODN. DUTY CYCLE:	100%	SAR START:	0.559 W/kg
INPUT POWER LEVEL:	14.5dBm	SAR END:	0.560 W/kg
PROBE BATTERY LAST CHANGED:	20/11/2014	SAR DRIFT DURING SCAN:	0.200 %

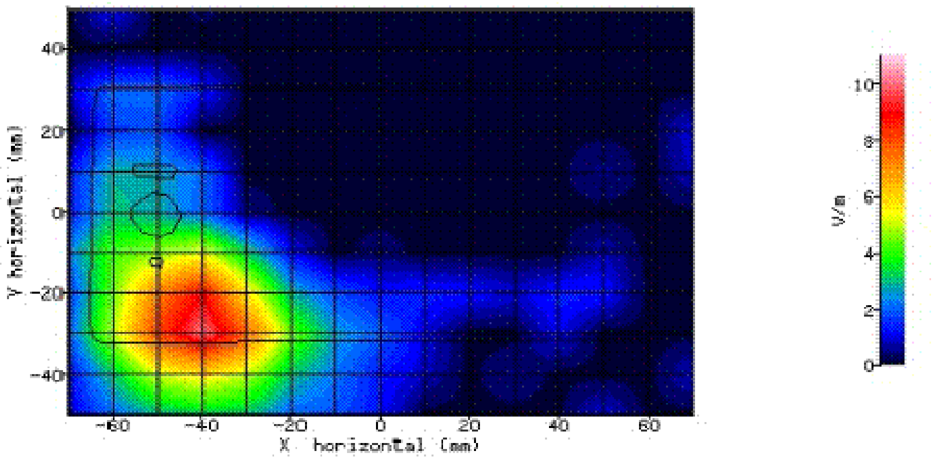

Figure 73: SAR Body Testing Results for the Sharp SHV31 Mobile Handset at 5260.0MHz.

COMMERCIAL-IN-CONFIDENCE

Product Service

SYSTEM / SOFTWARE:	SARA-C / v6.09.08	INPUT POWER DRIFT:	0 dB
DATE / TIME:	21/11/2014-10:55:54	DUT BATTERY MODEL/NO:	Integral
AMBIENT TEMPERATURE:	23.00°C	LIQUID SIMULANT:	5000Body
DEVICE UNDER TEST:	SHV31	RELATIVE PERMITTIVITY:	35.92
RELATIVE HUMIDITY:	35.30%	CONDUCTIVITY:	4.575
PHANTOM S/NO:	IXB-2HF	LIQUID TEMPERATURE:	23.00°C
PHANTOM ROTATION:	N/A	MAX SAR X-AXIS LOCATION:	-42.80mm
DUT POSITION:	10mm-Left Edge	MAX SAR Y-AXIS LOCATION:	9.70mm
ANTENNA CONFIGURATION:	N/A	MAX E FIELD:	6.796
TEST FREQUENCY:	5260.0MHz	SAR 1g:	0.18 W/kg
TYPE OF MODULATION:	WLAN (OFDM)	SAR 10g:	N/A
MODN. DUTY CYCLE:	100%	SAR START:	0.287 W/kg
INPUT POWER LEVEL:	14.5dBm	SAR END:	0.290 W/kg
PROBE BATTERY LAST CHANGED:	20/11/2014	SAR DRIFT DURING SCAN:	1.000 %

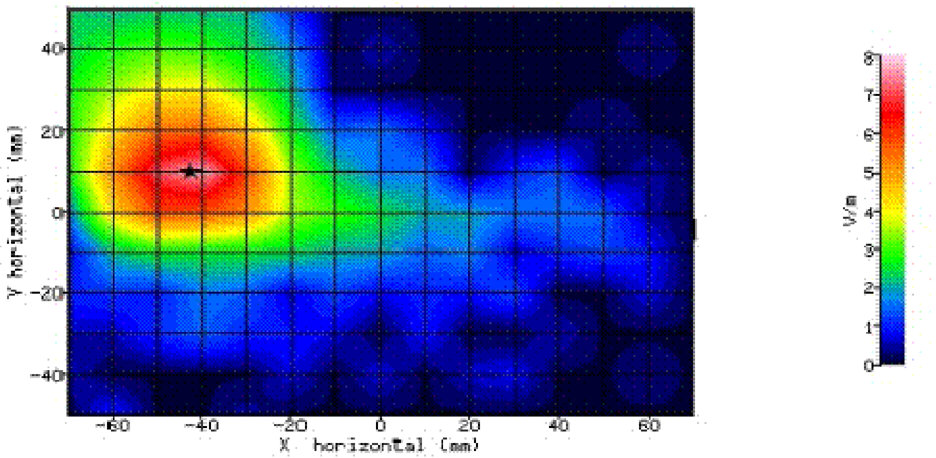

Figure 74: SAR Body Testing Results for the Sharp SHV31 Mobile Handset at 5260.0MHz.

Product Service

SYSTEM / SOFTWARE:	SARA-C / v6.09.08	INPUT POWER DRIFT:	0 dB
DATE / TIME:	21/11/2014-11:14:02	DUT BATTERY MODEL/NO:	Integral
AMBIENT TEMPERATURE:	23.00°C	LIQUID SIMULANT:	5000Body
DEVICE UNDER TEST:	SHV31	RELATIVE PERMITTIVITY:	35.92
RELATIVE HUMIDITY:	35.30%	CONDUCTIVITY:	4.575
PHANTOM S/NO:	IXB-2HF	LIQUID TEMPERATURE:	23.00°C
PHANTOM ROTATION:	N/A	MAX SAR X-AXIS LOCATION:	25.70mm
DUT POSITION:	10mm-Top Edge	MAX SAR Y-AXIS LOCATION:	26.30mm
ANTENNA CONFIGURATION:	N/A	MAX E FIELD:	2.804
TEST FREQUENCY:	5260.0MHz	SAR 1g:	0.03 W/kg
TYPE OF MODULATION:	WLAN (OFDM)	SAR 10g:	N/A
MODN. DUTY CYCLE:	100%	SAR START:	0.045 W/kg
INPUT POWER LEVEL:	14.5dBm	SAR END:	0.045 W/kg
PROBE BATTERY LAST CHANGED:	20/11/2014	SAR DRIFT DURING SCAN:	0.000 %

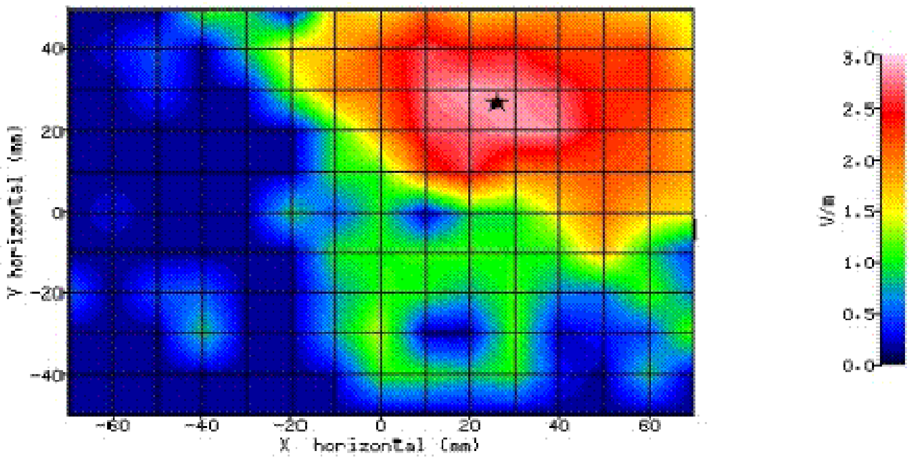

Figure 75: SAR Body Testing Results for the Sharp SHV31 Mobile Handset at 5260.0MHz.

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Product Service

2.18 WLAN 5640MHz HEAD SAR TEST RESULTS AND COURSE AREA SCANS – 2D

SYSTEM / SOFTWARE:	SARA-C / v6.09.08	INPUT POWER DRIFT:	0 dB
DATE / TIME:	20/11/2014-09:43:53	DUT BATTERY MODEL/NO:	Integral
AMBIENT TEMPERATURE:	22.90°C	LIQUID SIMULANT:	5000Head
DEVICE UNDER TEST:	SHV31	RELATIVE PERMITTIVITY:	35.05
RELATIVE HUMIDITY:	35.90%	CONDUCTIVITY:	4.940
PHANTOM S/NO:	IXB-040	LIQUID TEMPERATURE:	23.00°C
PHANTOM ROTATION:	N/A	MAX SAR Y-AXIS LOCATION:	23.30mm
DUT POSITION:	Left-Cheek	MAX SAR Z-AXIS LOCATION:	-172.40mm
ANTENNA CONFIGURATION:	N/A	MAX E FIELD:	2.715
TEST FREQUENCY:	5640.0MHz	SAR 1g:	0.18 W/kg
TYPE OF MODULATION:	WLAN (OFDM)	SAR 10g:	N/A
MODN. DUTY CYCLE:	100%	SAR START:	0.146 W/kg
INPUT POWER LEVEL:	14.5dBm	SAR END:	0.146 W/kg
PROBE BATTERY LAST CHANGED:	20/11/2014	SAR DRIFT DURING SCAN:	0.000 %

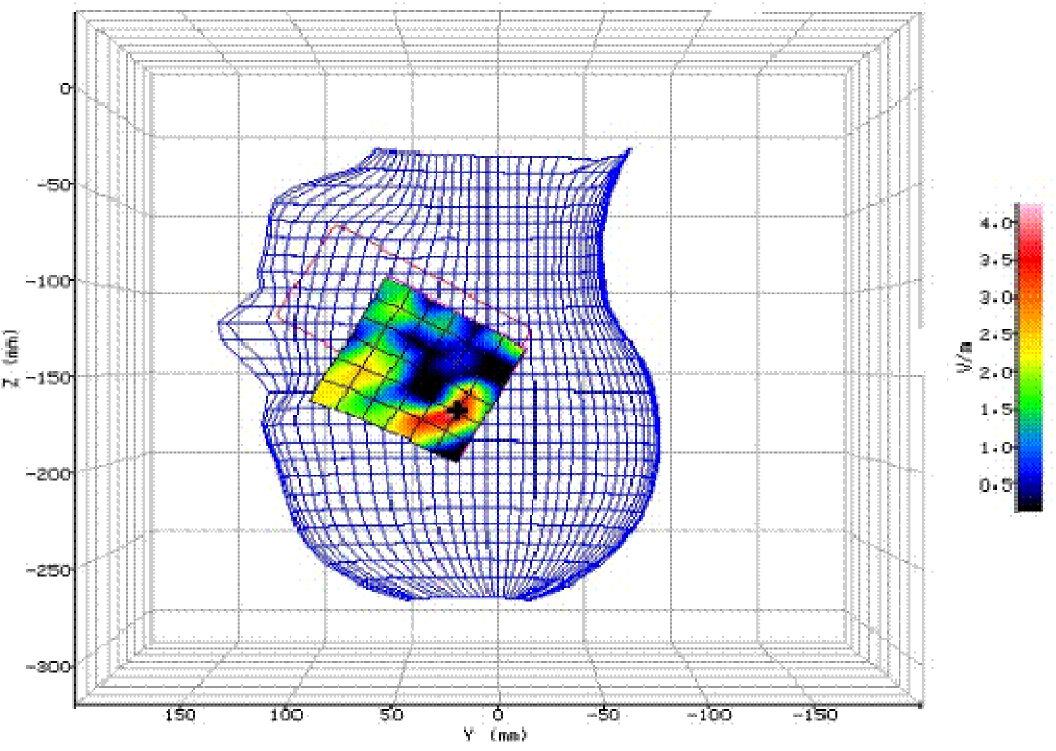

Figure 76: SAR Head Testing Results for the Sharp SHV31 Mobile Handset at 5640.0MHz.

SYSTEM / SOFTWARE:	SARA-C / v6.09.08	INPUT POWER DRIFT:	0 dB
DATE / TIME:	20/11/2014-10:20:09	DUT BATTERY MODEL/NO:	Integral
AMBIENT TEMPERATURE:	22.90°C	LIQUID SIMULANT:	5000Head
DEVICE UNDER TEST:	SHV31	RELATIVE PERMITTIVITY:	35.05
RELATIVE HUMIDITY:	35.90%	CONDUCTIVITY:	4.940
PHANTOM S/NO:	IXB-040	LIQUID TEMPERATURE:	23.00°C
PHANTOM ROTATION:	N/A	MAX SAR Y-AXIS LOCATION:	26.80mm
DUT POSITION:	Left-15°	MAX SAR Z-AXIS LOCATION:	-175.40mm
ANTENNA CONFIGURATION:	N/A	MAX E FIELD:	2.860
TEST FREQUENCY:	5640.0MHz	SAR 1g:	0.05 W/kg
TYPE OF MODULATION:	WLAN (OFDM)	SAR 10g:	N/A
MODN. DUTY CYCLE:	100%	SAR START:	0.112 W/kg
INPUT POWER LEVEL:	14.5dBm	SAR END:	0.103 W/kg
PROBE BATTERY LAST CHANGED:	20/11/2014	SAR DRIFT DURING SCAN:	-8.500 %

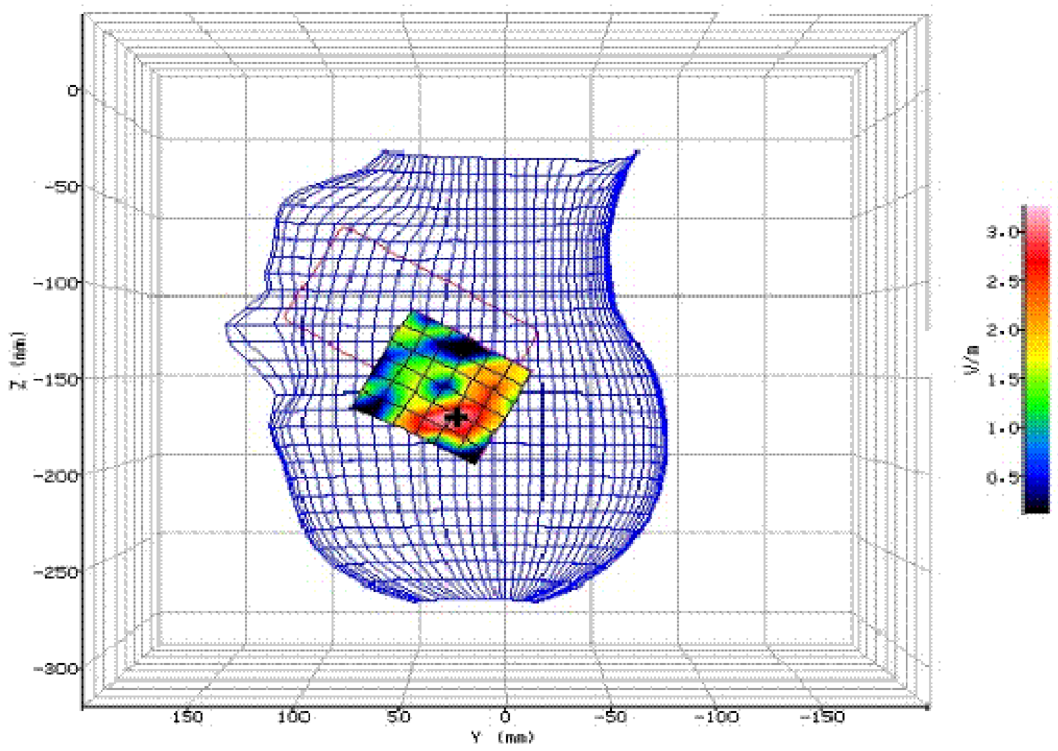

Figure 77: SAR Head Testing Results for the Sharp SHV31 Mobile Handset at 5640.0MHz.

SYSTEM / SOFTWARE:	SARA-C / v6.09.08	INPUT POWER DRIFT:	0 dB
DATE / TIME:	20/11/2014-11:19:26	DUT BATTERY MODEL/NO:	Integral
AMBIENT TEMPERATURE:	22.90°C	LIQUID SIMULANT:	5000Head
DEVICE UNDER TEST:	SHV31	RELATIVE PERMITTIVITY:	35.05
RELATIVE HUMIDITY:	35.90%	CONDUCTIVITY:	4.940
PHANTOM S/NO:	IXB-040	LIQUID TEMPERATURE:	23.00°C
PHANTOM ROTATION:	N/A	MAX SAR Y-AXIS LOCATION:	1.60mm
DUT POSITION:	Right-Cheek	MAX SAR Z-AXIS LOCATION:	-117.50mm
ANTENNA CONFIGURATION:	N/A	MAX E FIELD:	2.164
TEST FREQUENCY:	5640.0MHz	SAR 1g:	0.04 W/kg
TYPE OF MODULATION:	WLAN (OFDM)	SAR 10g:	N/A
MODN. DUTY CYCLE:	100%	SAR START:	0.047 W/kg
INPUT POWER LEVEL:	14.5dBm	SAR END:	0.047 W/kg
PROBE BATTERY LAST CHANGED:	20/11/2014	SAR DRIFT DURING SCAN:	0.000 %

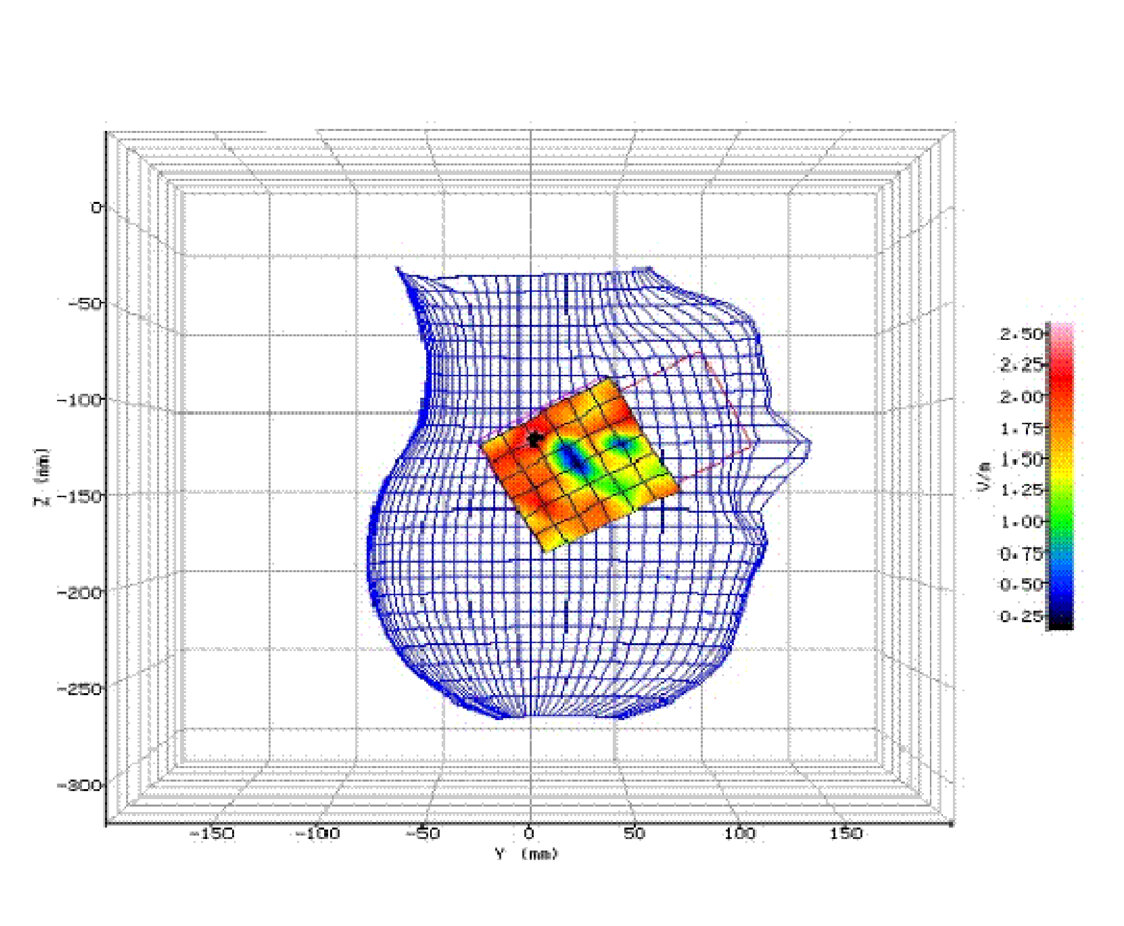

Figure 78: SAR Head Testing Results for the Sharp SHV31 Mobile Handset at 5640.0MHz.

SYSTEM / SOFTWARE:	SARA-C / v6.09.08	INPUT POWER DRIFT:	0 dB
DATE / TIME:	20/11/2014-11:49:32	DUT BATTERY MODEL/NO:	Integral
AMBIENT TEMPERATURE:	22.90°C	LIQUID SIMULANT:	5000Head
DEVICE UNDER TEST:	SHV31	RELATIVE PERMITTIVITY:	35.05
RELATIVE HUMIDITY:	35.90%	CONDUCTIVITY:	4.940
PHANTOM S/NO:	IXB-040	LIQUID TEMPERATURE:	23.00°C
PHANTOM ROTATION:	N/A	MAX SAR Y-AXIS LOCATION:	-8.40mm
DUT POSITION:	Right-15°	MAX SAR Z-AXIS LOCATION:	-143.90mm
ANTENNA CONFIGURATION:	N/A	MAX E FIELD:	2.004
TEST FREQUENCY:	5640.0MHz	SAR 1g:	0.03 W/kg
TYPE OF MODULATION:	WLAN (OFDM)	SAR 10g:	N/A
MODN. DUTY CYCLE:	100%	SAR START:	0.021 W/kg
INPUT POWER LEVEL:	14.5dBm	SAR END:	0.021 W/kg
PROBE BATTERY LAST CHANGED:	20/11/2014	SAR DRIFT DURING SCAN:	0.000 %

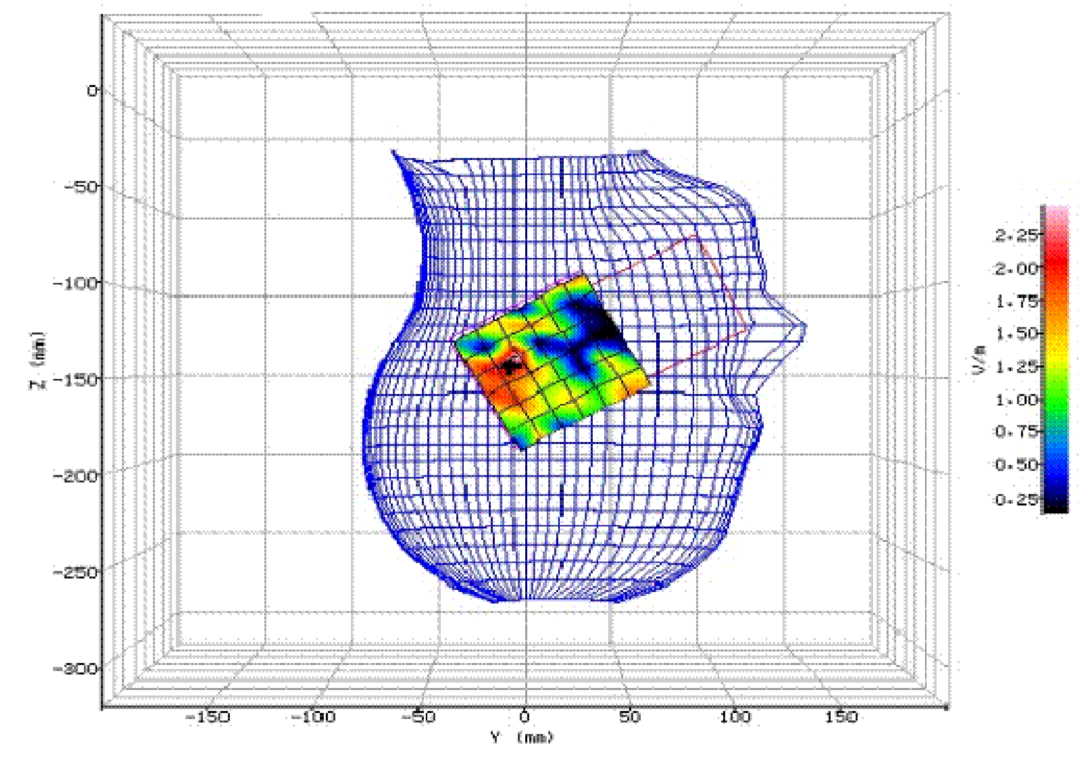

Figure 79: SAR Head Testing Results for the Sharp SHV31 Mobile Handset at 5640.0MHz.

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2.19 WLAN 5640MHz BODY SAR TEST RESULTS AND COURSE AREA SCANS – 2D

SYSTEM / SOFTWARE:	SARA-C / v6.09.08	INPUT POWER DRIFT:	0 dB
DATE / TIME:	21/11/2014-13:08:51	DUT BATTERY MODEL/NO:	Integral
AMBIENT TEMPERATURE:	22.90°C	LIQUID SIMULANT:	5000Body
DEVICE UNDER TEST:	SHV31	RELATIVE PERMITTIVITY:	47.74
RELATIVE HUMIDITY:	44.30%	CONDUCTIVITY:	5.514
PHANTOM S/NO:	IXB-2HF	LIQUID TEMPERATURE:	23.00°C
PHANTOM ROTATION:	N/A	MAX SAR X-AXIS LOCATION:	-44.70mm
DUT POSITION:	10mm-Front Facing	MAX SAR Y-AXIS LOCATION:	39.30mm
ANTENNA CONFIGURATION:	N/A	MAX E FIELD:	2.818
TEST FREQUENCY:	5640.0MHz	SAR 1g:	0.04 W/kg
TYPE OF MODULATION:	WLAN (OFDM)	SAR 10g:	N/A
MODN. DUTY CYCLE:	100%	SAR START:	0.060 W/kg
INPUT POWER LEVEL:	14.5dBm	SAR END:	0.060 W/kg
PROBE BATTERY LAST CHANGED:	20/11/2014	SAR DRIFT DURING SCAN:	0.000 %

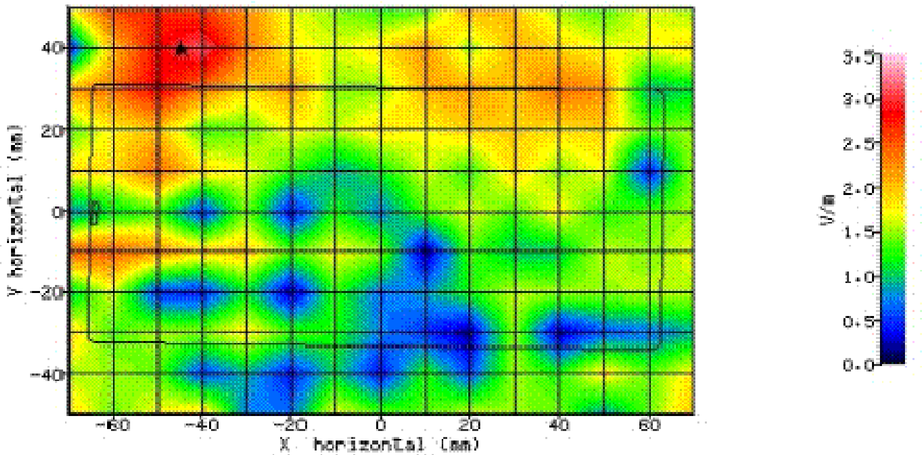

Figure 80: SAR Body Testing Results for the Sharp SHV31 Mobile Handset at 5640.0MHz.

SYSTEM / SOFTWARE:	SARA-C / v6.09.08	INPUT POWER DRIFT:	0 dB
DATE / TIME:	21/11/2014-13:31:52	DUT BATTERY MODEL/NO:	Integral
AMBIENT TEMPERATURE:	22.90°C	LIQUID SIMULANT:	5000Body
DEVICE UNDER TEST:	SHV31	RELATIVE PERMITTIVITY:	47.74
RELATIVE HUMIDITY:	44.30%	CONDUCTIVITY:	5.514
PHANTOM S/NO:	IXB-2HF	LIQUID TEMPERATURE:	23.00°C
PHANTOM ROTATION:	N/A	MAX SAR X-AXIS LOCATION:	-47.40mm
DUT POSITION:	10mm-Rear Facing	MAX SAR Y-AXIS LOCATION:	-21.00mm
ANTENNA CONFIGURATION:	N/A	MAX E FIELD:	5.616
TEST FREQUENCY:	5640.0MHz	SAR 1g:	0.13 W/kg
TYPE OF MODULATION:	WLAN (OFDM)	SAR 10g:	N/A
MODN. DUTY CYCLE:	100%	SAR START:	0.238 W/kg
INPUT POWER LEVEL:	14.5dBm	SAR END:	0.247 W/kg
PROBE BATTERY LAST CHANGED:	20/11/2014	SAR DRIFT DURING SCAN:	3.500 %

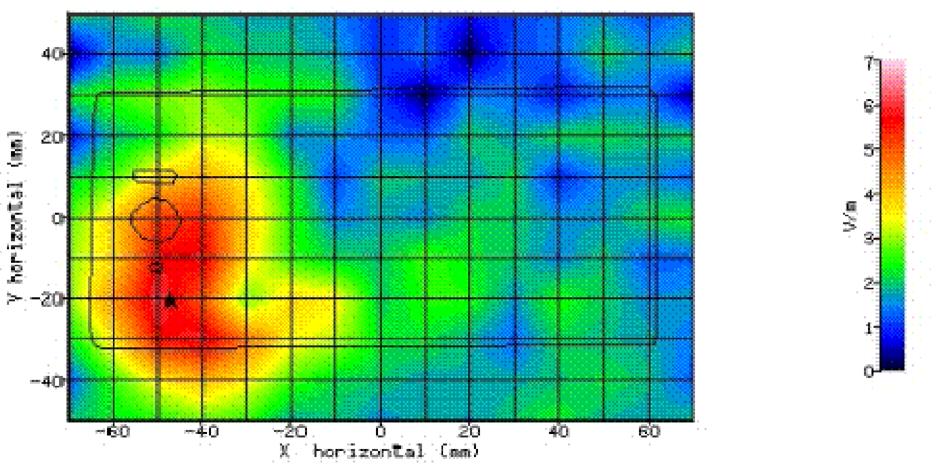

Figure 81: SAR Body Testing Results for the Sharp SHV31 Mobile Handset at 5640.0MHz.

Product Service

SYSTEM / SOFTWARE:	SARA-C / v6.09.08	INPUT POWER DRIFT:	0 dB
DATE / TIME:	21/11/2014-14:09:45	DUT BATTERY MODEL/NO:	Integral
AMBIENT TEMPERATURE:	22.90°C	LIQUID SIMULANT:	5000Body
DEVICE UNDER TEST:	SHV31	RELATIVE PERMITTIVITY:	47.74
RELATIVE HUMIDITY:	44.30%	CONDUCTIVITY:	5.514
PHANTOM S/NO:	IXB-2HF	LIQUID TEMPERATURE:	23.00°C
PHANTOM ROTATION:	N/A	MAX SAR X-AXIS LOCATION:	-38.40mm
DUT POSITION:	10mm-Left Edge	MAX SAR Y-AXIS LOCATION:	7.30mm
ANTENNA CONFIGURATION:	N/A	MAX E FIELD:	5.496
TEST FREQUENCY:	5640.0MHz	SAR 1g:	0.13 W/kg
TYPE OF MODULATION:	WLAN (OFDM)	SAR 10g:	N/A
MODN. DUTY CYCLE:	100%	SAR START:	0.213 W/kg
INPUT POWER LEVEL:	14.5dBm	SAR END:	0.213 W/kg
PROBE BATTERY LAST CHANGED:	20/11/2014	SAR DRIFT DURING SCAN:	0.400 %

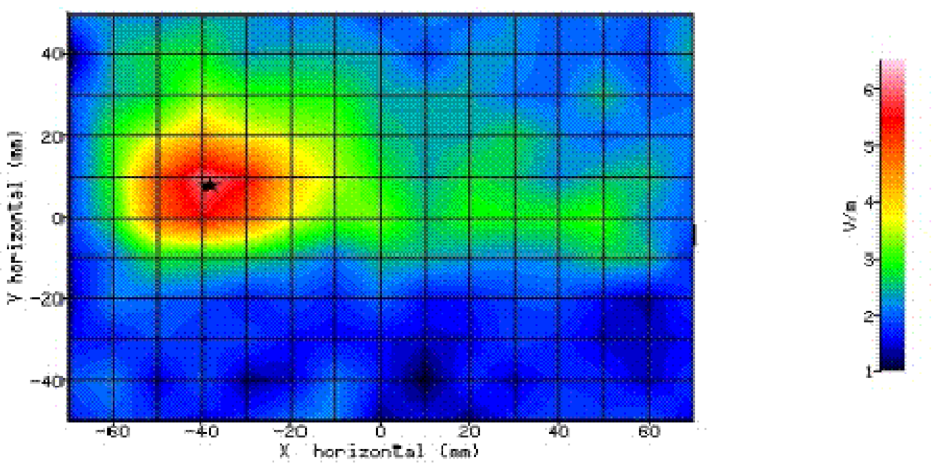

Figure 82: SAR Body Testing Results for the Sharp SHV31 Mobile Handset at 5640.0MHz.

Product Service

SYSTEM / SOFTWARE:	SARA-C / v6.09.08	INPUT POWER DRIFT:	0 dB
DATE / TIME:	21/11/2014-14:28:34	DUT BATTERY MODEL/NO:	Integral
AMBIENT TEMPERATURE:	22.90°C	LIQUID SIMULANT:	5000Body
DEVICE UNDER TEST:	SHV31	RELATIVE PERMITTIVITY:	47.74
RELATIVE HUMIDITY:	44.30%	CONDUCTIVITY:	5.514
PHANTOM S/NO:	IXB-2HF	LIQUID TEMPERATURE:	23.00°C
PHANTOM ROTATION:	N/A	MAX SAR X-AXIS LOCATION:	19.20mm
DUT POSITION:	10mm-Top Edge	MAX SAR Y-AXIS LOCATION:	14.20mm
ANTENNA CONFIGURATION:	N/A	MAX E FIELD:	3.691
TEST FREQUENCY:	5640.0MHz	SAR 1g:	0.05 W/kg
TYPE OF MODULATION:	WLAN (OFDM)	SAR 10g:	N/A
MODN. DUTY CYCLE:	100%	SAR START:	0.086 W/kg
INPUT POWER LEVEL:	14.5dBm	SAR END:	0.086 W/kg
PROBE BATTERY LAST CHANGED:	20/11/2014	SAR DRIFT DURING SCAN:	0.000 %

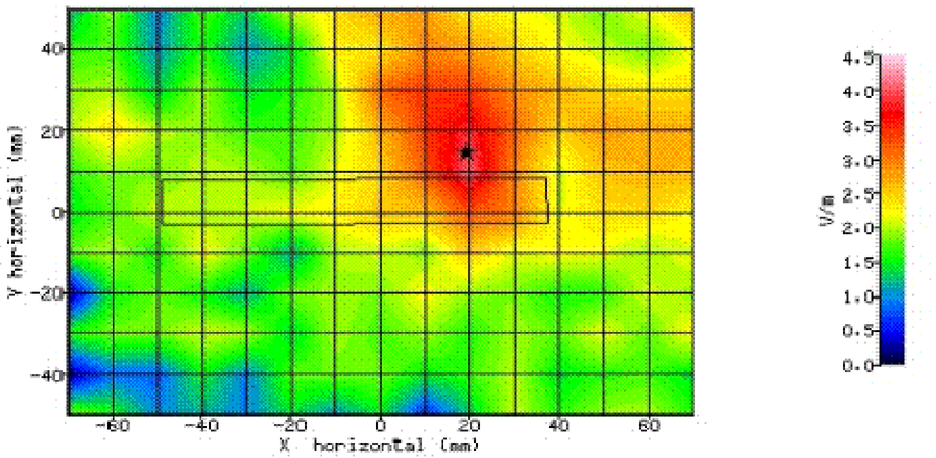

Figure 83: SAR Body Testing Results for the Sharp SHV31 Mobile Handset at 5640.0MHz.

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Product Service

SECTION 3

TEST EQUIPMENT USED

3.1 TEST EQUIPMENT USED

The following Test equipment used at TÜV SÜD Product Service:

Instrument Description	Manufacturer	Model Type	TE Number	Cal Period (months)	Calibration Due Date
Signal Generator	Hewlett Packard	ESG4000A	38	12	21-May-2015
10MHz - 2.5GHz, 3W, Amplifier	Vectawave Technology	VTL5400	51	-	TU
Directional Coupler	Krytar	1850	58	-	TU
Power Sensor	Rohde & Schwarz	NRV-Z1	60	12	11-Jun-2015
Signal Generator	Hewlett Packard	ESG4000A	61	12	1-Jul-2015
Thermometer	Digitron	T208	64	12	29-Apr-2015
Thermocouple (Type K)	TUV SUD Product Service	TYPE K	65	12	29-Apr-2015
Amplifier (5GHz)	IndexSar Ltd	5GHz	157	-	TU
Power Sensor	Rohde & Schwarz	NRV-Z1	178	12	20-May-2015
Communications Tester	Rohde & Schwarz	CMU 200	442	12	8-Dec-2014
Directional Coupler	Hewlett Packard	11692D	452	-	TU
Attenuator (20dB, 10W)	Weinschel	37-20-34	482	12	22-Oct-2015
Attenuator (20dB, 20W)	Narda	766F-20	483	12	4-Jun-2015
Dipole Positioner/Support (plastic)	IndexSar Ltd	IXH-020	1585	-	TU
Bi-directional Coupler	IndexSar Ltd	7401 (VDC0830-20)	2414	-	TU
Validation Amplifier (10MHz - 2.5GHz)	IndexSar Ltd	VBM2500-3	2415	-	TU
Hygromer	Rotronic	I-1000	2784	12	10-Apr-2015
Power Sensor	Rohde & Schwarz	NRV- Z5	2878	12	11-Jun-2015
Antenna (Omnidirectional)	Katherin Scala Division	OG-890/1990/DC	2905	-	TU
Antenna (Omnidirectional)	Katherin Scala Division	OG-890/1990/DC	2906	-	TU
Power Meter	Rohde & Schwarz	NRVD	2979	12	20-May-2015
Hygrometer	Rotronic	I-1000	3068	12	10-Apr-2015
Dual Channel Power Meter	Rohde & Schwarz	NRVD	3259	12	12-Jun-2015
Signal Generator: 10MHz to 20GHz	Rohde & Schwarz	SMR20	3475	12	10-Feb-2015
Power Sensor	Rohde & Schwarz	NRV-Z1	3563	12	20-May-2015
Meter & T/C	R.S Components	Meter 615-8206 & Type K T/C	3612	12	24-Sep-2015
SAR 1800 MHz dipole	Speag	D1800V2	3855	36	19-Feb-2017
SAR 900 MHz dipole	Speag	D900V2	3856	36	19-Feb-2017
SAR 835 MHz dipole	Speag	D835V2	3857	36	19-Feb-2017
SAR 2450 MHz dipole	Speag	D2450V2	3875	36	19-Feb-2017
SAR 1900 MHz dipole	Speag	D1900V2	3876	36	19-Feb-2017
Head Phantom	IndexSar Ltd	IXB-040 Inverted SAM phantom	4075	-	TU
Part of SARAC System	IndexSar Ltd	Robot Controller	4076	-	TU
Part of SARAC System	IndexSar Ltd	Cartesian Leg Extension	4078	-	TU
Cartesian 4-axis Robot	IndexSar Ltd	SARAC	4079	-	TU
Part of SARAC System	IndexSar Ltd	White Benchtop	4080	-	TU
Part of SARAC System	IndexSar Ltd	Wooden Bench	4081	-	TU
Wideband Radio Communication Tester	Rohde & Schwarz	CMW 500	4144	12	7-Nov-2015
Head Phantom	IndexSar Ltd	IXB-040 Inverted SAM phantom	4254	-	TU

Instrument Description	Manufacturer	Model Type	TE Number	Cal Period (months)	Calibration Due Date
Part of SARAC System	IndexSar Ltd	Wooden Bench	4266	-	TU
Part of SARAC System	IndexSar Ltd	Robot Controller	4267	-	TU
Cartesian 4-axis Robot	IndexSar Ltd	SARAC	4269	-	TU
Part of SARAC System	IndexSar Ltd	White Benchtop	4270	-	TU
SAR 5GHz Di-pole	Speag	D5GHzV2	4309	-	TU
SAR Probe	IndexSar Ltd	IPX-020	4443	24	23-Apr-2015
SAR Probe	IndexSar Ltd	IPX-025	4444	24	21-Mar-2016
Immersible SAR Probe	IndexSar Ltd	IXP-025	4310	24	21-Mar-2016
Immersible SAR Probe	IndexSar Ltd	IXP-021	4311	24	21-Mar-2016
Immersible SAR Probe	IndexSar Ltd	IPX-050	4313	24	7-Mar-2015
Immersible SAR Probe	IndexSar Ltd	IPX-020	4317	24	24-Apr-2015
700MHz Head Fluid	IndexSar Ltd	Batch 20	N/A	1	06-Dec-2014
700MHz Body Fluid	IndexSar Ltd	Batch 13	N/A	1	06-Dec-2014
835MHz Head Fluid	IndexSar Ltd	Batch 20	N/A	1	06-Dec-2014
835MHz Body Fluid	IndexSar Ltd	Batch 13	N/A	1	06-Dec-2014
1900MHz Head Fluid	IndexSar Ltd	Batch 8	N/A	1	06-Dec-2014
1900MHz Body Fluid	IndexSar Ltd	Batch 4	N/A	1	06-Dec-2014
2450MHz Head Fluid	IndexSar Ltd	Batch 11	N/A	1	06-Dec-2014
2450MHz Body Fluid	IndexSar Ltd	Batch 7	N/A	1	06-Dec-2014
5000MHz Head Fluid	IndexSar Ltd	Batch 4	N/A	1	06-Dec-2014
5000MHz Body Fluid	IndexSar Ltd	Batch 3	N/A	1	06-Dec-2014

TU – Traceability Unscheduled

3.2 TEST SOFTWARE

The following software was used to control the TÜV SÜD Product Service SARAC System.

Instrument	Version Number	Date
SARA-C system	v.6.09.08	23 July 2014
IFA-10 Probe amplifier	Version 2	-

3.3 DIELECTRIC PROPERTIES OF SIMULANT LIQUIDS

The fluid properties of the simulant fluids used during routine SAR evaluation meet the dielectric properties required KDB 865665.

IEEE 1528 Recipes

Frequency (MHz)	300	450		835	900			1450	1800				1900		1950	2000	2100		2450		3000
Recipe#	1	1	3	1	1	2	3	1	1	2	2	3	1	2	4	1	1	2	2	3	2
Ingredients (% by weight)																					
1, 2-Propanediol						64.81															
Bactericide	0.19	0.19	0.50	0.10	0.10		0.50													0.50	
Diacetin			48.90				49.20													49.45	
DGBE								45.41	47.00	13.84	44.92		44.94	13.84	45.00	50.00	50.00	7.99	7.99		7.99
HEC	0.98	0.96		1.00	1.00																
NaCl	5.95	3.95	1.70	1.45	1.48	0.79	1.10	0.67	0.36	0.35	0.18	0.64	0.18	0.35				0.16	0.16		0.16
Sucrose	55.32	56.32		57.00	56.50																
Triton X-100										30.45				30.45				19.97	19.97		19.97
Water	37.56	38.56	48.90	40.45	40.92	34.40	49.20	53.80	52.64	55.36	54.90	49.43	54.90	55.36	55.00	50.00	50.00	71.88	71.88	49.75	71.88
Measured dielectric parameters																					
ε_r'	46.00	43.40	44.30	41.60	41.20	41.80	42.70	40.9	39.3	41.00	40.40	39.20	39.90	41.00	40.10	37.00	36.80	41.10	40.30	39.20	37.90
σ (S/m)	0.86	0.85	0.90	0.90	0.98	0.97	0.99	1.21	1.39	1.38	1.40	1.40	1.42	1.38	1.41	1.40	1.51	1.55	1.88	1.82	2.46
Temp (ºC)	22	22	20	22	22	22	20	22	22	21	22	20	21	21	20	22	22	20	20	20	20
Target dielectric parameters (Table 2)																					
ε_r'	45.30	43.50		41.5	41.50			40.50	40.00								39.80		39.20		38.50
σ (S/m)	0.87	0.87		0.9	0.97			1.20	1.40								1.49		1.80		2.40

NOTE – Multiple columns for any single frequency are optional recipe #, reference: 1 (Kanda et al. [B185]), 2 (Vigneras [B143]), 3 (Peyman and Gabriel [B119]), 4 (Fukunaga et al [B50])

The dielectric properties of the tissue simulant liquids used for the SAR testing at TÜV SÜD Product Service are as follows:-

Fluid Type and Frequency	Relative Permittivity εR (ε') Target	Relative Permittivity εR (ε') Measured	Conductivity σ Target	Conductivity σ Measured
700 MHz Body	55.7	55.45	0.96	0.99
835MHz Head	41.5	43.43	0.90	0.92
835MHz Body	55.2	56.90	0.97	1.00
1900MHz Head	40.0	41.41	1.40	1.46
1900MHz Body	53.3	52.82	1.52	1.59
2450 MHz Head	39.2	37.88	1.80	1.78
2450MHz Body	52.7	50.73	1.95	1.99
5200MHz Head	36.0	35.92	4.66	4.58
5200MHz Body	49.0	48.74	5.30	5.04
5500MHz Head	35.6	35.05	4.96	4.94
5500MHz Body	48.6	47.74	5.65	5.51

Product Service

3.4 TEST CONDITIONS

3.4.1 Test Laboratory Conditions

Ambient temperature: Within +15°C to +35°C.
The actual temperature during the testing ranged from 22.7°C to 23.1°C.
The actual humidity during the testing ranged from 23.4% to 43.3% RH.

3.4.2 Test Fluid Temperature Range

Frequency	Body / Head Fluid	Min Temperature °C	Max Temperature °C
700MHz	Body	23.0	23.1
835MHz	Head	23.1	23.1
835MHz	Body	23.0	23.0
1900MHz	Head	23.1	23.1
1900MHz	Body	23.0	23.0
2450MHz	Head	22.9	22.9
2450MHz	Body	22.9	22.9
5200MHz	Head	22.9	23.0
5200MHz	Body	23.0	23.1
5500MHz	Head	23.0	23.0
5500MHz	Body	23.0	23.0

3.4.3 SAR Drift

The SAR Drift was within acceptable limits during scans. The maximum SAR Drift, drift due to the handset electronics, was recorded as 9.2% (0.92 dB) for head and 8.5% (1.09 dB) for body. The measurement uncertainty budget for this assessment includes the maximum SAR Drift figures for Head and/or Body as applicable.

Product Service

3.5 MEASUREMENT UNCERTAINTY

Head SAR Measurements.

Source of Uncertainty	Description	Tolerance / Uncertainty ± %	Probability distribution	Div	c_i (1g)	Standard Uncertainty ± % (1g)	v_i or v_{eff}
Measurement System							
Probe calibration	7.2.1	8.73	N	1	1	8.73	∞
Isotropy	7.2.1.2	3.18	R	1.73	1	1.84	∞
Probe angle >30deg	additional	12.00	R	1.73	1	6.93	∞
Boundary effect	7.2.1.5	0.49	R	1.73	1	0.28	∞
Linearity	7.2.1.3	1.00	R	1.73	1	0.58	∞
Detection limits	7.2.1.4	0.00	R	1.73	1	0.00	∞
Readout electronics	7.2.1.6	0.30	N	1	1	0.30	∞
Response time	7.2.1.7	0.00	R	1.73	1	0.00	∞
Integration time (equiv.)	7.2.1.8	1.38	R	1.73	1	0.80	∞
RF ambient conditions	7.2.3.6	3.00	R	1.73	1	1.73	∞
Probe positioner mech. restrictions	7.2.2.1	5.35	R	1.73	1	3.09	∞
Probe positioning with respect to phantom shell	7.2.2.3	5.00	R	1.73	1	2.89	∞
Post-processing	7.2.4	7.00	R	1.73	1	4.04	∞
Test sample related							
Test sample positioning	7.2.2.4	1.50	R	1.73	1	0.87	∞
Device holder uncertainty	7.2.2.4.2	1.73	R	1.73	1	1.00	∞
Drift of output power	7.2.3.4	9.2	R	1.73	1	5.54	∞
Phantom and set-up							
Phantom uncertainty (shape and thickness tolerances)	7.2.2.2	2.01	R	1.73	1	1.16	∞
Liquid conductivity (target)	7.2.3.3	5.00	R	1.73	0.64	1.85	∞
Liquid conductivity (meas.)	7.2.3.3	5.00	N	1	0.64	3.20	∞
Liquid permittivity (target)	7.2.3.4	5.00	R	1.73	0.6	1.73	∞
Liquid permittivity (meas.)	7.2.3.4	3.00	N	1	0.6	1.80	∞
Combined standard uncertainty			RSS			11.97	
Expanded uncertainty (95% confidence interval)			K=2			23.94	

Body SAR Measurements.

Source of Uncertainty	Description	Tolerance / Uncertainty ± %	Probability distribution	Div	c_i (1g)	Standard Uncertainty ± % (1g)	v_i or v_{eff}
Measurement System							
Probe calibration	7.2.1	8.73	N	1	1	8.73	∞
Isotropy	7.2.1.2	3.18	R	1.73	1	1.84	∞
Boundary effect	7.2.1.5	0.49	R	1.73	1	0.28	∞
Linearity	7.2.1.3	1.00	R	1.73	1	0.58	∞
Detection limits	7.2.1.4	0.00	R	1.73	1	0.00	∞
Readout electronics	7.2.1.6	0.30	N	1	1	0.30	∞
Response time	7.2.1.7	0.00	R	1.73	1	0.00	∞
Integration time (equiv.)	7.2.1.8	1.38	R	1.73	1	0.80	∞
RF ambient conditions	7.2.3.6	3.00	R	1.73	1	1.73	∞
Probe positioner mech. restrictions	7.2.2.1	0.60	R	1.73	1	0.35	∞
Probe positioning with respect to phantom shell	7.2.2.3	2.00	R	1.73	1	1.15	∞
Post-processing	7.2.4	7.00	R	1.73	1	4.04	∞
Test sample related							
Test sample positioning	7.2.2.4	1.50	R	1.73	1	0.87	∞
Device holder uncertainty	7.2.2.4.2	1.73	R	1.73	1	1.00	∞
Drift of output power	7.2.3.4	8.5	R	1.73	1	4.73	∞
Phantom and set-up							
Phantom uncertainty (shape and thickness tolerances)	7.2.2.2	2.01	R	1.73	1	1.16	∞
Liquid conductivity (target)	7.2.3.3	5.00	R	1.73	0.64	1.85	∞
Liquid conductivity (meas.)	7.2.3.3	5.00	N	1	0.64	3.20	∞
Liquid permittivity (target)	7.2.3.4	5.00	R	1.73	0.6	1.73	∞
Liquid permittivity (meas.)	7.2.3.4	3.00	N	1	0.6	1.80	∞
Combined standard uncertainty			RSS			11.59	
Expanded uncertainty (95% confidence interval)			K=2			23.17	

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SECTION 4

ACCREDITATION, DISCLAIMERS AND COPYRIGHT

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4.1 ACCREDITATION, DISCLAIMERS AND COPYRIGHT

UKAS TESTING 0141

This report relates only to the actual item/items tested.

Our UKAS Accreditation does not cover opinions and interpretations and any expressed are outside the scope of our UKAS Accreditation.

Results of tests not covered by our UKAS Accreditation Schedule are marked NUA (Not UKAS Accredited).

ANNEX A

PROBE CALIBRATION REPORT

TÜV SÜD Product Service

INDEXSAR

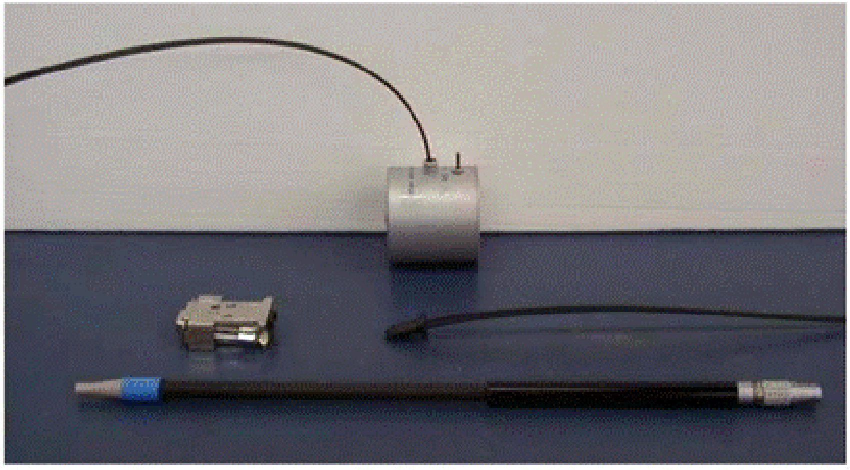
IMMERSIBLE SAR PROBE

CALIBRATION REPORT

Part Number: IXP – 050

S/N 0204

April 2013



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Calibration Certificate 1304/0204
Date of Issue: 23rd April 2013
Immersible SAR Probe

Type:	IXP-050
Manufacturer:	IndexSAR, UK
Serial Number:	0204
Place of Calibration:	IndexSAR, UK
Date of Receipt of Probe:	N/A
Calibration Dates:	14th January – 7th March 2013
Customer:	TUV Sud

IndexSAR Ltd hereby declares that the IXP-050 Probe named above has been calibrated for conformity to the current versions of IEEE 1528, IEC 62209-1, IEC 62209-2, and FCC OET65 standards using the methods described in this calibration document. Where applicable, the standards used in the calibration process are traceable to the UK's National Physical Laboratory.

Calibrated by:	A. Brinklow	**Technical Manager**
Approved by:	[signature]	**Director**

Please keep this certificate with the calibration document. When the probe is sent for a calibration check, please include the calibration document.

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INTRODUCTION

Straight probes can work on either SARA-C (to measure SAR values in flat phantoms containing Body tissue simulant fluid) or on SARA2 (where they can measure either in a flat phantom with Body fluid, or in a SAM phantom containing Head fluid).

This Report presents measured calibration data for a particular Indexsar SAR probe (S/N 0204) for use on SARA-C only. **The calibration factors do not apply to, and will not give correct readings on, the IndexSAR SARA2 system.**

Indexsar probes are characterised using procedures that, where applicable, follow the recommendations of IEC 62209-1 [Ref 1], IEEE 1528 [Ref 2], IEC 62209-2 [Ref 3] and FCC OET65 [Ref 4] standards. The procedures incorporate techniques for probe linearisation, isotropy assessment and determination of liquid factors (conversion factors). Calibrations are determined by comparing probe readings with analytical computations in canonical test geometries (waveguides) using normalised power inputs.

Each step of the calibration procedure and the equipment used is described in the sections below.

CALIBRATION PROCEDURE

1. Objectives

The calibration process comprises the following stages

1) Determination of the channel sensitivity factors which optimise the probe's overall axial isotropy in 900MHz brain fluid
2) Measure the incidental spherical isotropy using these derived channel sensitivity factors.
3) Since isotropy and channel sensitivity factors are frequency independent, these channel sensitivity factors can be applied to model the exponential decay of SAR in a waveguide fluid cell at each frequency of interest, and hence derive the liquid conversion factors at that frequency.

2. Probe output

The probe channel output signals are linearised in the manner set out in Refs [1] - [4]. The following equation is utilized for each channel:

$$U_{lin} = U_{o/p} + U_{o/p}{}^2 / DCP \qquad (1)$$

where U_{lin} is the linearised signal, $U_{o/p}$ is the raw output signal in mV and DCP is the diode compression potential, also in mV.

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DCP is determined from fitting equation (1) to measurements of U_{lin} versus source feed power over the full dynamic range of the probe. The DCP is a characteristic of the Schottky diodes used as the sensors. For the IXP-020 probes with CW signals the DCP values are typically 100mV.

For this value of DCP, the typical linearity response of IXP-050 probes to CW and to GSM modulation is shown in Figure 7, along with departures of this same dataset from linearity.

In turn, measurements of E-field are determined using the following equation:

$$E_{liq}^2\ (V/m) = U_{linx} * \text{Air Factor}_x * \text{Liq Factor}_x + U_{liny} * \text{Air Factor}_y * \text{Liq Factor}_y + U_{linz} * \text{Air Factor}_z * \text{Liq Factor}_z \quad (3)$$

Here, "Air Factor" represents each channel's sensitivity, while "Liq Factor" represents the enhancement in signal level when the probe is immersed in tissue-simulant liquids at each frequency of interest.

3. Selecting channel sensitivity factors to optimise isotropic response

Within SARA-C, an L-probe's predominant mode of operation is with the tip pointing directly towards the source of radiation. Consequently, optimising the probe's response to boresight signals ("axial isotropy") is far more important than optimising its spherical isotropy (where the direction, as well as the polarisation angle, of the incoming radiation must be taken into account).

The setup for measuring the probe's axial isotropy is shown in **Error! Reference source not found.**. Since isotropy is frequency-independent, measurements are normally made at a frequency of 900MHz as lower frequencies are more tolerant of positional inaccuracies.

A 900MHz waveguide containing head-fluid simulant is selected. Like all waveguides used during probe calibration, this particular waveguide contains two distinct sections: an air-filled launcher section, and a liquid cell section, separated by a dielectric matching window designed to minimise reflections at the air-liquid interface.

The waveguide stands in an upright position and the liquid cell section is filled with 900MHz brain fluid to within 10 mm of the open end. The depth of liquid ensures there is negligible radiation from the waveguide open top and that the probe calibration is not influenced by reflections from nearby objects.

During the measurement, a TE_{01} mode is launched into the waveguide by means of an N-type-to-waveguide adapter. The probe is then lowered vertically into the liquid until the tip is exactly 10mm above the centre of the dielectric window. This particular separation ensures that the probe is operating in a part of the waveguide where boundary corrections are not necessary.

Care must also be taken that the probe tip is centred while rotating.

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The exact power applied to the input of the waveguide during this stage of the probe calibration is immaterial since only relative values are of interest while the probe rotates. However, the power must be sufficiently above the noise floor and free from drift.

The dedicated Indexsar calibration software rotates the probe in 10 degree steps about its axis, and at each position, an Indexsar 'Fast' amplifier samples the probe channels 500 times per second for 0.4 s. The raw $U_{o/p}$ data from each sample are packed into 10 bytes and transmitted back to the PC controller via an optical cable. U_{linx}, U_{liny} and U_{linz} are derived from the raw $U_{o/p}$ values and written to an Excel template.

Once data have been collected from a full probe rotation, the Air Factors are adjusted using a special Excel Solver routine to equalise the output from each channel and hence minimise the axial isotropy. This automated approach to optimisation removes the effect of human bias.

Figure 2 represents the output from each diode sensor as a function of probe rotation angle.

4. Measurement of Spherical Isotropy

As mentioned earlier, in SARA-C a straight probe is always positioned so as to be end-on to the incoming signal source. The probe's axial isotropy response is therefore far more important than its spherical isotropy, which is included here for completeness only.

The setup for assessing the probe's spherical isotropy is shown in Figure 1.

A box phantom containing 900MHz head fluid is irradiated by a tuned dipole, mounted to the side of the phantom on the SARA2 robot's seventh axis. During calibration, the spherical response is generated by rotating the probe about its axis in 15 degree steps and changing the dipole polarisation in 10 degree steps.

The relative channel sensitivities are fixed by the earlier measurement of, and optimisation for, axial isotropy. The effect on spherical isotropy is shown in Figure 3.

5. Determination of Conversion ("Liquid") Factors at each frequency of interest

A lookup table of conversion factors for a probe allows a SAR value to be derived at the measured frequencies, and for either brain or body fluid-simulant.

The method by which the conversion factors are assessed is based on the comparison between measured and analytical rates of decay of SAR with height above a dielectric window. This way, not only can the conversion factors for that frequency/fluid combination be determined, but an allowance can also be made for the scale and range of boundary layer effects.

The theoretical relationship between the SAR at the cross-sectional centre of the lossy waveguide as a function of the longitudinal distance (z) from the

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dielectric separator is given by Equation 4:

$$SAR(z) = \frac{4(P_f - P_b)}{\rho a b \delta} e^{-2z/\delta} \quad (4)$$

Here, the density ρ is conventionally assumed to be 1000 kg/m^3, ab is the cross-sectional area of the waveguide, and P_f and P_b are the forward and reflected power inside the lossless section of the waveguide, respectively. The penetration depth δ (which is the reciprocal of the waveguide-mode attenuation coefficient) is a property of the lossy liquid and is given by Equation (5).

$$\delta = \left[\mathrm{Re}\left\{ \sqrt{(\pi / a)^2 + j\omega\mu_o(\sigma + j\omega\varepsilon_o\varepsilon_r)} \right\} \right]^{-1} \quad (5)$$

where σ is the conductivity of the tissue-simulant liquid in S/m, ε_r is its relative permittivity, and ω is the radial frequency (rad/s). Values for σ and ε_r are obtained prior to each waveguide test using an Indexsar DiLine measurement kit, which uses the TEM method as recommended in [2]. σ and ε_r are both temperature- and fluid-dependent, so are best measured using a sample of the tissue-simulant fluid immediately prior to the actual calibration.

Wherever possible, all DiLine and calibration measurements should be made in the open laboratory at 22 $\pm$ 2.0°C; if this is not possible, the values of σ and ε_r should reflect the actual temperature. Values employed for calibration are listed in the tables below.

By ensuring the liquid height in the waveguide is at least three penetration depths, reflections at the upper surface of the liquid are negligible. The power absorbed in the liquid is therefore determined solely from the waveguide forward and reflected power.

Different waveguides are used for 700MHz, 835/900MHz, 1450MHz, 1800/1900MHz, 2100/2450/2600MHz and 5200/5800MHz measurements. Table A.1 of [1] can be used for designing calibration waveguides with a return loss greater than 20 dB at the most important frequencies used for personal wireless communications, and better than 15dB for frequencies greater than 5GHz. Values for the penetration depth for these specific fixtures and tissue-simulating mixtures are also listed in Table A.1.

According to [1], this calibration technique provides excellent accuracy, with standard uncertainty of less than 3.6% depending on the frequency and medium. The calibration itself is reduced to power measurements traceable to a standard calibration procedure. The practical limitation to the frequency band of 800 to 5800 MHz because of the waveguide size is not severe in the context of compliance testing.

During calibration, the probe is lowered carefully until it is just touching the cross-sectional centre of the dielectric window. 200 samples are then taken and written to an Excel template file before moving the probe vertically

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upwards. This cycle is repeated 150 times. The vertical separation between readings is determined from practical considerations of the expected SAR decay rate, and range from 0.2mm steps at low frequency, through 0.1mm at 2450MHz, down to 0.05mm at 5GHz.

Once the data collection is complete, a Solver routine is run which optimises the measured-theoretical fit by varying the conversion factor, and the boundary correction size and range.

For calibrations at 450MHz, where waveguide calibrations become unfeasible, a full 3D SAR scan over a tuned dipole is performed, and the conversion factor adjusted to make the measured 1g and 10g volume-averaged SAR values agree with published targets.

CALIBRATION FACTORS MEASURED FOR PROBE S/N 0204

The probe was calibrated at 450, 835, 900, 1800, 2100, 2450 and 2600MHz in liquid samples representing brain and body liquid at these frequencies.

The calibration was for CW signals only, and the axis of the probe was parallel to the direction of propagation of the incident field i.e. end-on to the incident radiation. The axial isotropy of the probe was measured by rotating the probe about its axis in 10 degree steps through 360 degrees in this orientation.

The reference point for the calibration is in the centre of the probe's cross-section at a distance of 2.7 mm from the probe tip in the direction of the probe amplifier. A value of 2.7 mm should be used for the tip to sensor offset distance in the software. The distance of 2.7mm for assembled probes has been confirmed by taking X-ray images of the probe tips (see Figure 8).

It is important that the diode compression point and air factors used in the software are the same as those quoted in the results tables, as these are used to convert the diode output voltages to a SAR value.

CALIBRATION EQUIPMENT

The table on page 20 indicates the calibration status of all test equipment used during probe calibration.

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MEASUREMENT UNCERTAINTIES

A complete measurement uncertainty analysis for the SARA-C measurement system has been published in Reference [6]. Table 17 from that document is re-created below, and lists the uncertainty factors associated just with the calibration of probes.

Source of uncertainty	Uncertainty value ± %	Probability distribution	Divisor	c_i	Standard uncertainty ui ± %	v_i or v_{eff}
Forward power	3.92	N	1.00	1	3.92	∞
Reflected power	4.09	N	1.00	1	4.09	∞
Liquid conductivity	1.308	N	1.00	1	1.31	∞
Liquid permittivity	1.271	N	1.00	1	1.27	∞
Field homgeneity	3.0	R	1.73	1	1.73	∞
Probe positioning	0.22	R	1.73	1	0.13	∞
Field probe linearity	0.2	R	1.73	1	0.12	∞
Combined standard uncertainty		**RSS**			**6.20**	

At the 95% confidence level, therefore, the expanded uncertainty is ±12.4%

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SUMMARY OF CAL FACTORS FOR PROBE IXP-020 S/N 0204

Relative Channel Sensitivities (to optimise Axial Isotropy)				
	X	Y	Z	
Air Factors	91.78	66.90	81.32	$(V/m)^2/mV$
DCPs	100	100	100	mV

Measured Isotropy	(+/-) dB
Axial Isotropy	0.02
Spherical Isotropy	0.66

Additional Information	
Sensor offset (mm)	2.7
Elbow – Tip dimension (mm)	0.0

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SAR Conversion Factors/ Boundary Corrections

	Head Fluid			Body Fluid			
Frequency* (MHz)	**SAR Conv Factor**	**Boundary Correction f(0)**	**Boundary Correction d(mm)**	**SAR Conv Factor**	**Boundary Correction f(0)**	**Boundary Correction d(mm)**	**Notes**
450	0.317	0	1	0.317	0	1	3
700	-	-	-	-	-	-	-
835	0.310	1.69	1.08	0.327	0.59	1.91	1,2
900	0.313	0.80	1.52	0.327	1.17	1.31	1,2
1450	-	-	-	-	-	-	-
1800	0.357	0.77	1.68	0.381	0.64	2.07	1,2
1900	0.366	0.71	1.83	0.388	0.64	2.12	1,2
2100	0.397	0.70	1.96	0.413	0.78	1.86	1,2
2450	0.397	1.09	1.44	0.440	1.09	1.51	1,2
2600	0.394	1.26	1.35	0.449	1.17	1.46	1,2
Notes							
1)	Calibrations done at 22°C +/-2°C						
2)	Waveguide calibration						
3)	By validation						

*The valid frequency of SARA-C probe calibrations are ±100MHz (F<300MHz) and ±200MHz (F>300MHz).

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PROBE SPECIFICATIONS

Indexsar probe 0204, along with its calibration, is compared with BSEN 62209-1 and IEEE standards recommendations (Refs [1] and [2]) in the Tables below. A listing of relevant specifications is contained in the tables below:

Dimensions	S/N 0204	BSEN [1]	IEEE [2]
Overall length (mm)	350		
Tip length (mm)	10		
Body diameter (mm)	12		
Tip diameter (mm)	5.2	8	8
Distance from probe tip to dipole centers (mm)	2.7		

Typical Dynamic range	S/N 0204	BSEN [1]	IEEE [2]
Minimum (W/kg)	0.01	<0.02	0.01
Maximum (W/kg) N.B. only measured to > 100 W/kg on representative probes	>100	>100	100

Isotropy (measured at 900MHz)	S/N 0204	BSEN [1]	IEEE [2]
Axial rotation with probe normal to source (+/- dB)	0.02	0.5	0.25
Spherical isotropy covering all orientations to source (+/- dB)	0.66	N/A	N/A

NB Isotropy is frequency independent

Construction	Each probe contains three orthogonal dipole sensors arranged on a triangular prism core, protected against static charges by built-in shielding, and covered at the tip by PEEK cylindrical enclosure material. No adhesives are used in the immersed section. Outer case materials are PEEK and heat-shrink sleeving.
Chemical resistance	Tested to be resistant to TWEEN20 and sugar/salt-based simulant liquids but probes should be removed, cleaned and dried when not in use. NOT recommended for use with glycol or soluble oil-based liquids.

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REFERENCES

References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.

For a specific reference, subsequent revisions do not apply.

For a non-specific reference, the latest version applies.

[1] IEC 62209-1.
Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices — Human models, instrumentation, and procedures — Part 1: Procedure to determine the specific absorption rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300 MHz to 3 GHz)

[2] IEEE 1528
Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques

[3] IEC 62209-2
Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Human models, Instrumentation, and procedures – Part 2: Procedure to determine the specific absorption rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)

[4] FCC OET65
Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields

[5] Indexsar Report IXS-0300, October 2007.
Measurement uncertainties for the SARA2 system assessed against the recommendations of BS EN 62209-1:2006

[6] SARA-C SAR Testing System: Measurement Uncertainty, v1.0.3. October 2011.

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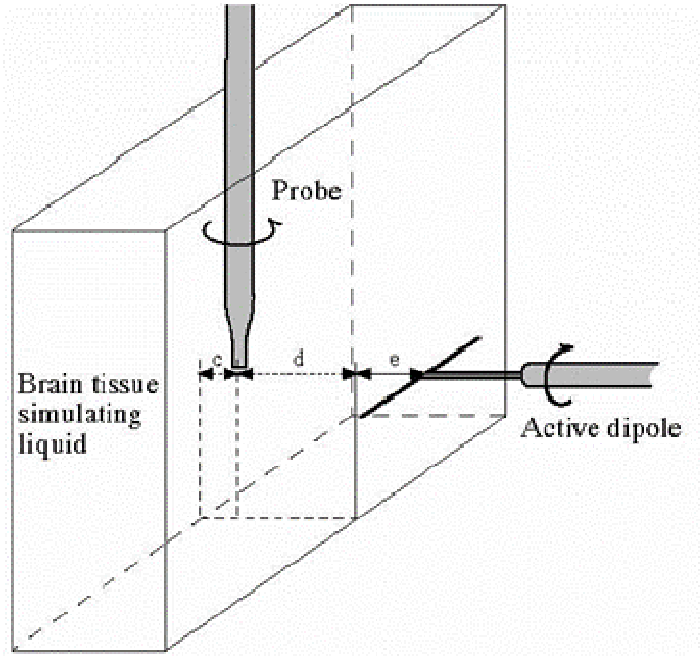

Figure 1. Spherical isotropy jig showing probe, dipole and box filled with simulated brain liquid (see Ref [2], Section A.5.2.1)

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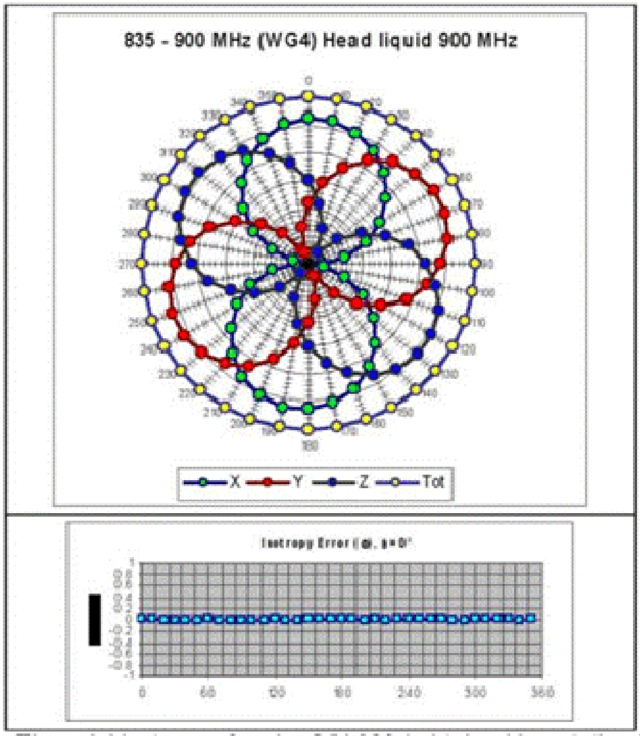

Figure 2. The axial isotropy of probe S/N 0204 obtained by rotating the probe in a liquid-filled waveguide at 900 MHz. (NB Axial Isotropy is frequency independent)

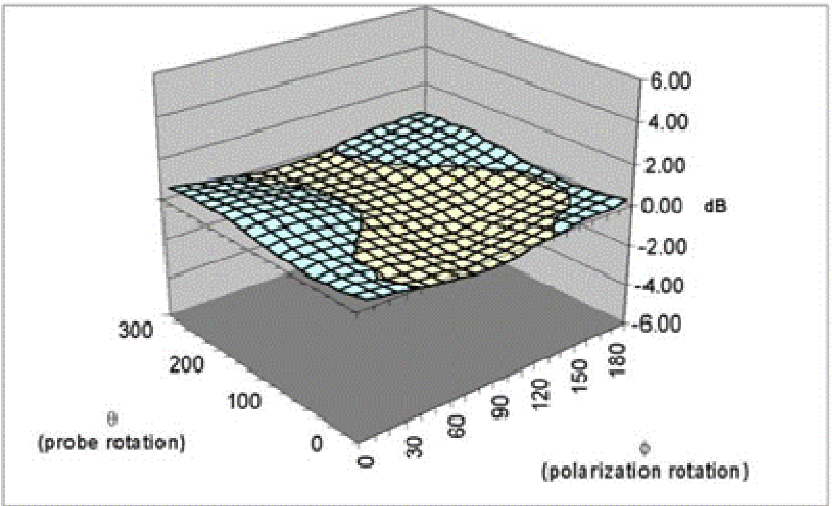

Figure 3 Spherical isotropy diagram after optimisation of relative channel sensitivities for axial isotropy

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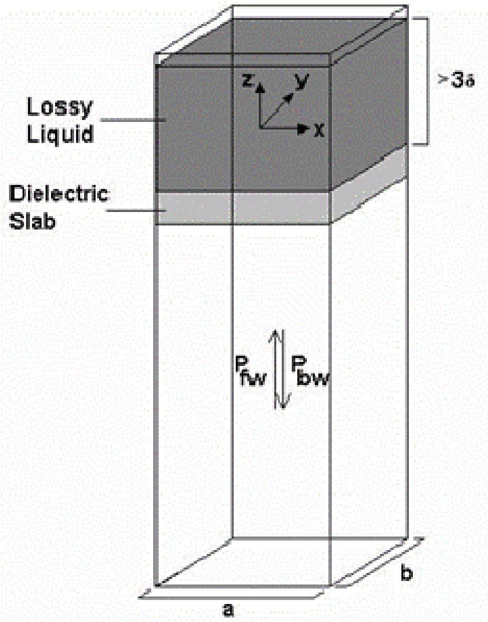

Figure 4. Geometry used for waveguide calibration (after Ref [2], Section A.3.2.2)

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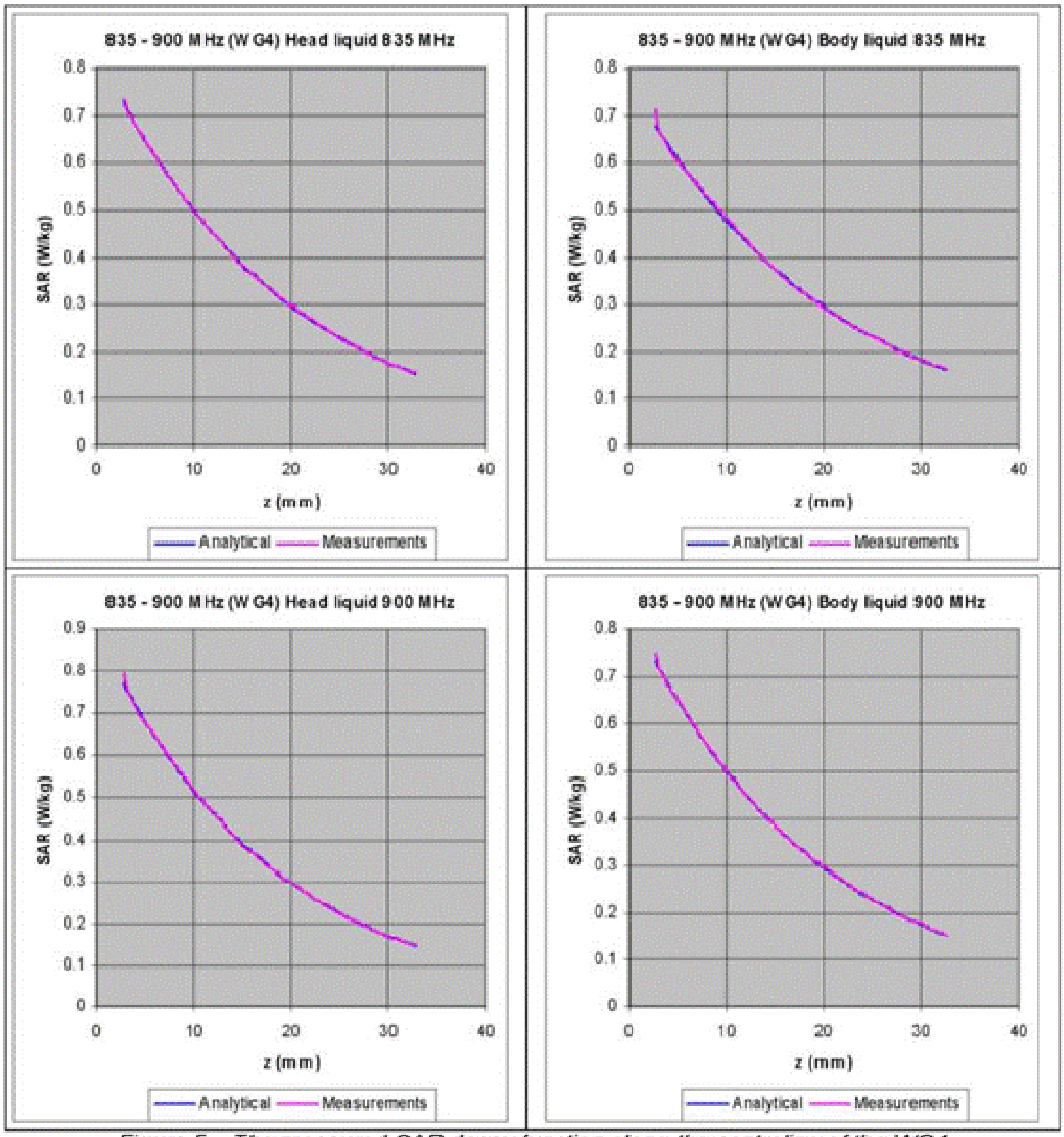

Figure 5. The measured SAR decay function along the centreline of the WG4 waveguide with conversion factors adjusted to fit to the theoretical function for the particular dimension, frequency, power and liquid properties employed.

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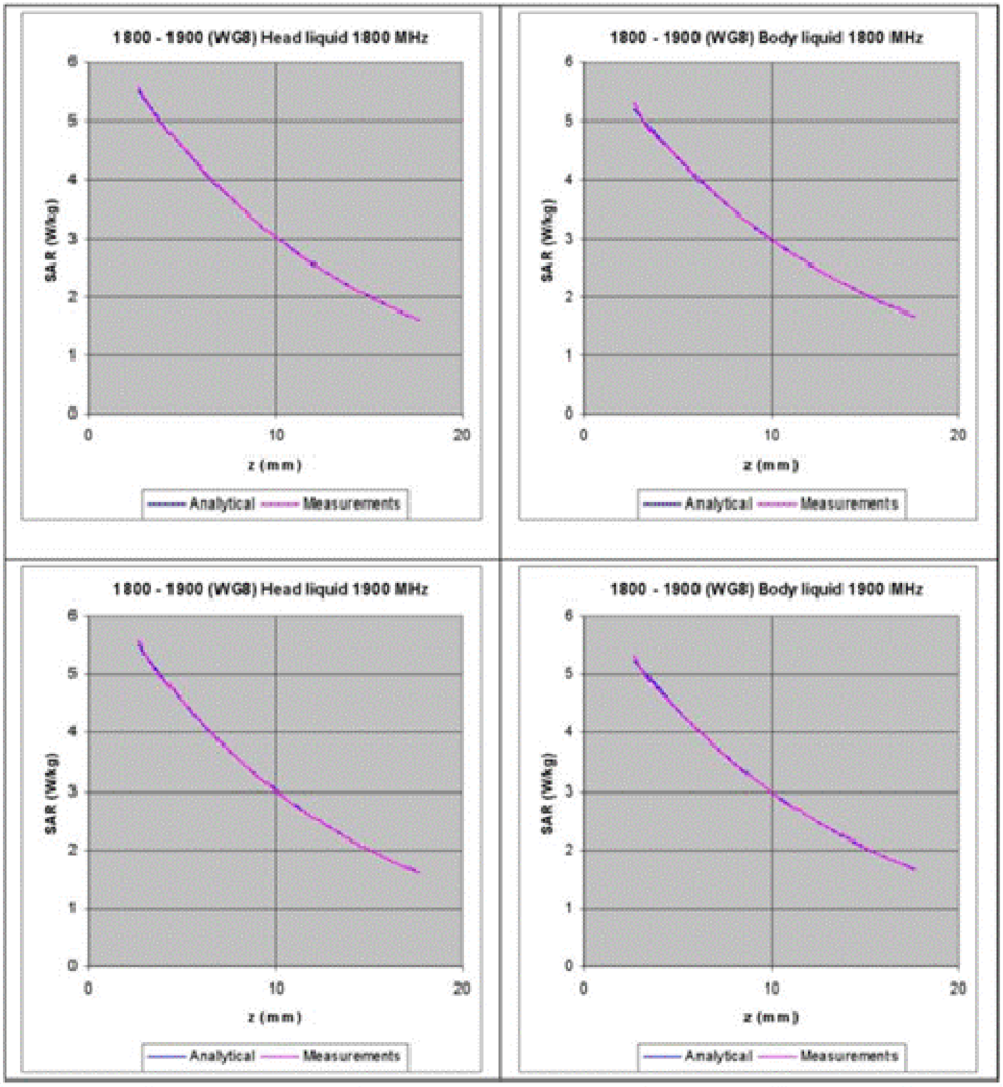

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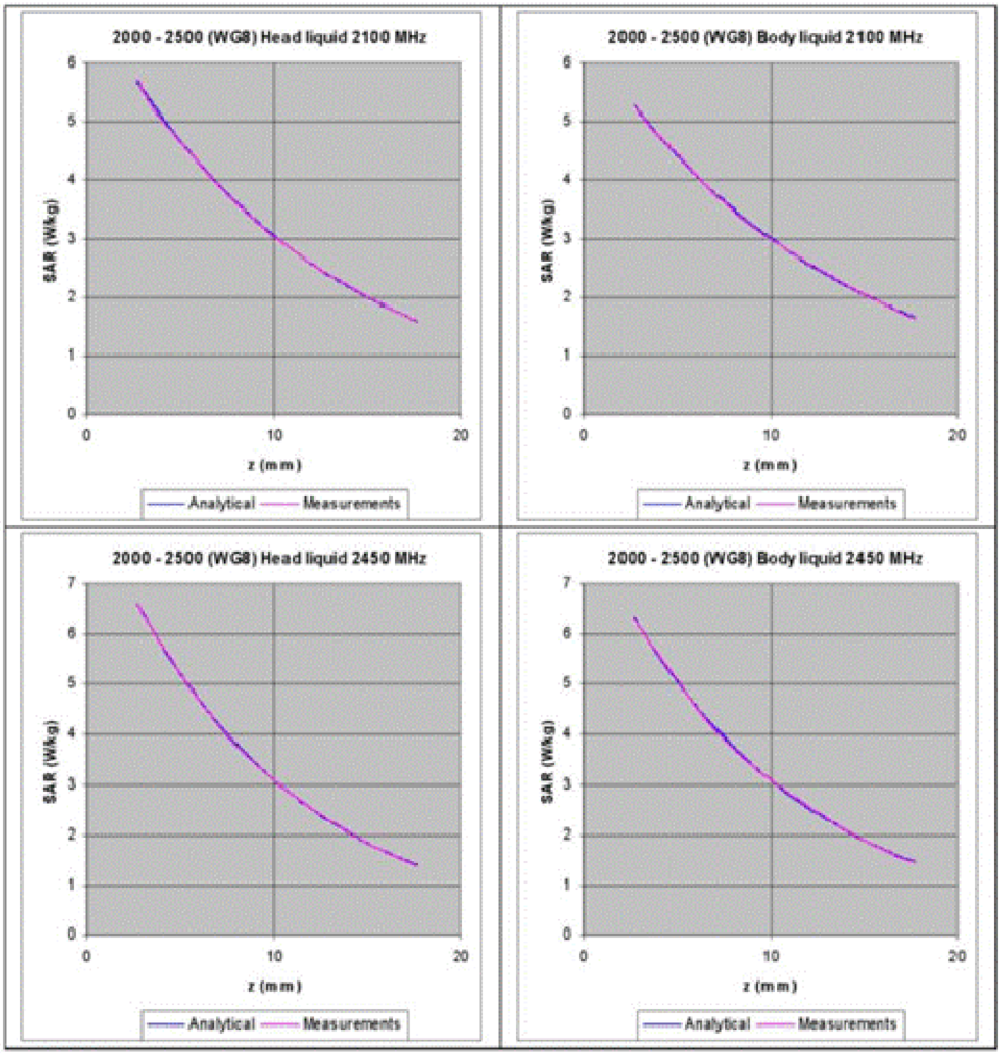
2000 - 2500 (WG8) Head liquid 2100 MHz
2000 - 2500 (WG8) Body liquid 2100 MHz
2000 - 2500 (WG8) Head liquid 2450 MHz
2000 - 2500 (WG8) Body liquid 2450 MHz
SAR (W/kg)
z (mm)
Analytical
Measurements

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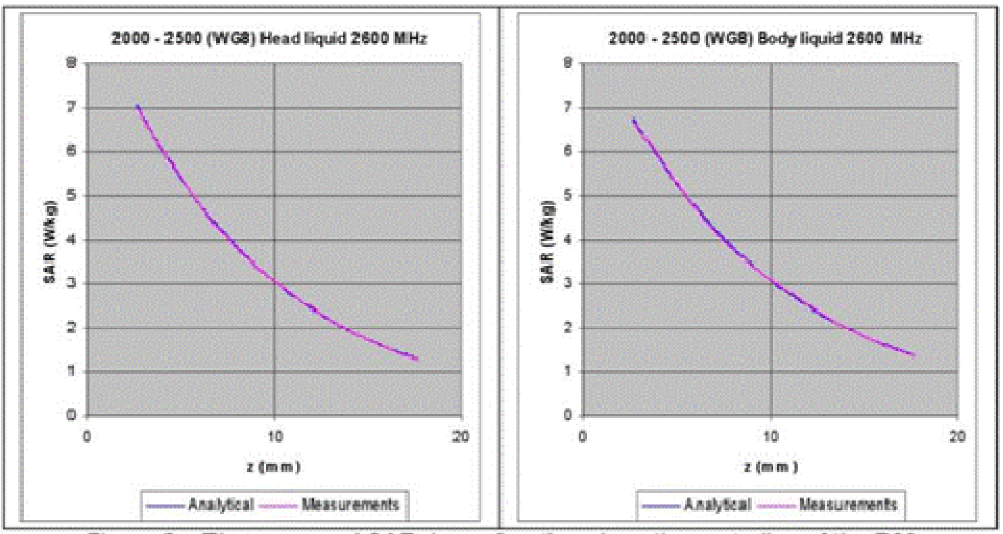

Figure 6 . The measured SAR decay function along the centreline of the R22 waveguide with conversion factors adjusted to fit to the theoretical function for the particular dimension, frequency, power and liquid properties employed.

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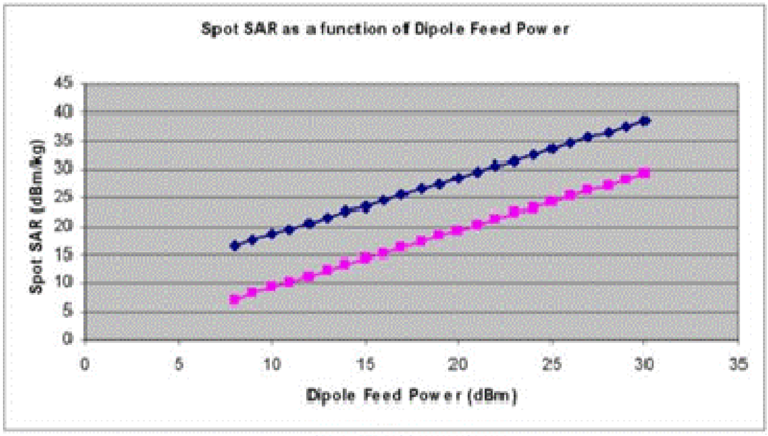

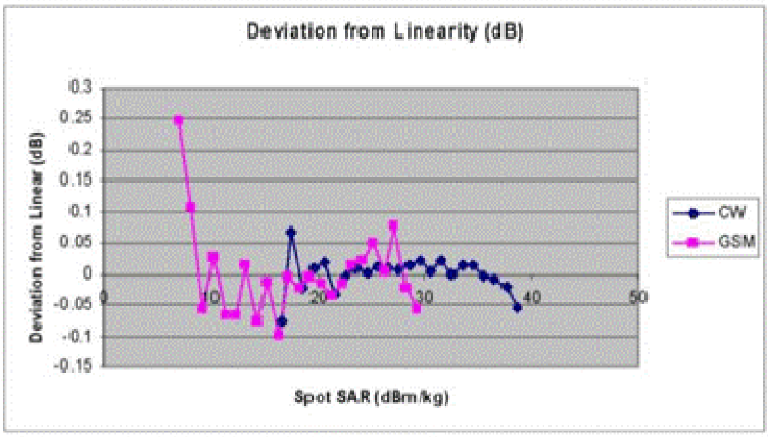

Figure 7 : The typical linearity response of IXP-050 probes to both CW (blue) and GSM (pink) modulation in close proximity to a source dipole. The top diagram shows the SAR reading as a function of dipole feed power, with GSM modulation being approx a factor of 8 (ie 9dB) lower than CW. The lower diagram shows the departure from linearity of the same two datasets.

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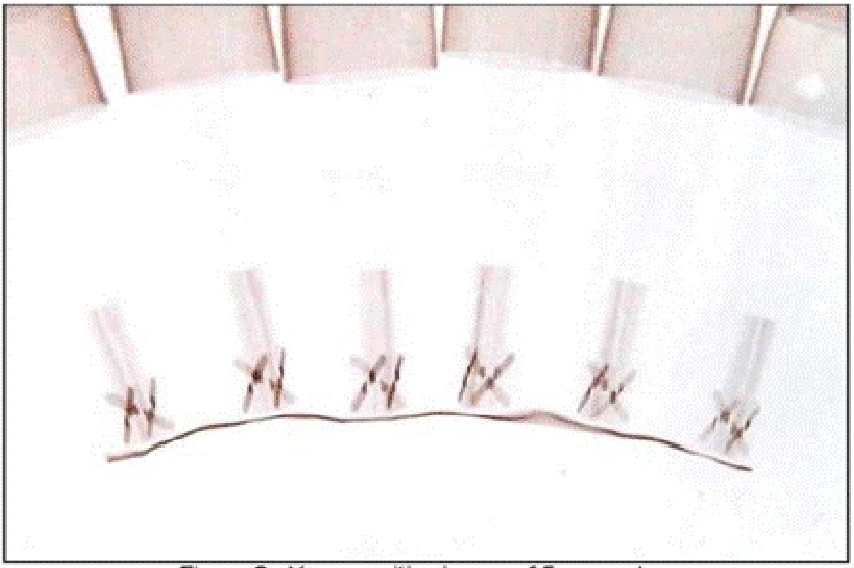

Figure 8 : X-ray positive image of 5mm probes

Product Service

Table indicating the dielectric parameters of the liquids used for calibrations at each frequency

Frequency (MHz)	Fluid Type	Relative Permittivity	Conductivity (S/m)	Relative Permittivity	Conductivity (S/m)	Relative Permittivity	Conductivity	Relative Permittivity	Conductivity
450	Head	44.33	0.835	43.5	0.87	1.9	-4.0	Pass	Pass
835		42.25	0.900	41.5	0.90	1.8	0.0	Pass	Pass
900		41.45	0.962	41.5	0.97	-0.1	-0.8	Pass	Pass
1800		39.92	1.395	40.0	1.40	-0.2	-0.4	Pass	Pass
1900		39.67	1.400	40.0	1.40	-0.8	0.0	Pass	Pass
2100		40.96	1.500	39.8	1.49	2.9	0.7	Pass	Pass
2450		39.81	1.821	39.2	1.80	1.6	1.2	Pass	Pass
2600		39.30	1.971	39.0	1.96	0.8	0.6	Pass	Pass
450	Body	57.53	0.902	56.7	0.94	1.5	-3.7	Pass	Pass
835		55.14	0.958	55.2	0.97	-0.1	-1.2	Pass	Pass
900		54.53	1.023	55	1.05	-0.9	-2.6	Pass	Pass
1800		53.07	1.521	53.3	1.52	-0.4	0.1	Pass	Pass
1900		52.85	1.533	53.3	1.52	-0.8	0.9	Pass	Pass
2100		53.92	1.568	53.2	1.62	1.4	-3.2	Pass	Pass
2450		52.90	1.957	52.7	1.95	0.4	0.4	Pass	Pass
2600		52.47	2.132	52.5	2.16	-0.1	-1.3	Pass	Pass

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Product Service

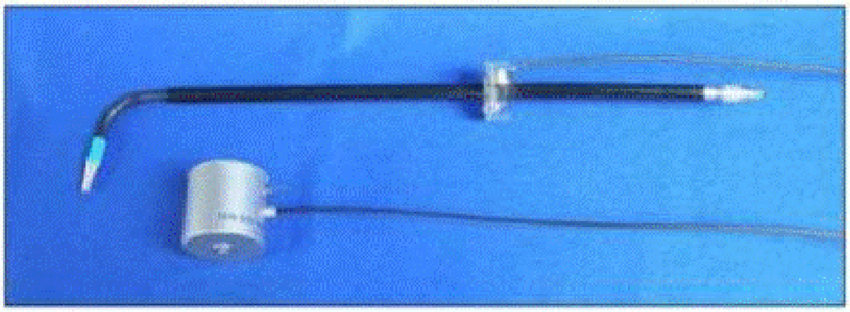
IMMERSIBLE SAR PROBE

CALIBRATION REPORT

Part Number: IXP–020

S/N L0006

April 2013



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Calibration Certificate 1304/L0006
Date of Issue: 24 April 2013
Immersible SAR Probe

Type:	IXP-020
Manufacturer:	IndexSAR, UK
Serial Number:	L0006
Place of Calibration:	IndexSAR, UK
Date of Receipt of Probe:	N/A
Calibration Dates:	15 March – 23 April 2013
Customer:	TUV Sud

IndexSAR Ltd hereby declares that the IXP-050 Probe named above has been calibrated for conformity to the current versions of IEEE 1528, IEC 62209-1, IEC 62209-2, and FCC OET65 standards using the methods described in this calibration document. Where applicable, the standards used in the calibration process are traceable to the UK's National Physical Laboratory.

Calibrated by:	A. Brinklow	**Technical Manager**
Approved by:	[signature]	**Director**

Please keep this certificate with the calibration document. When the probe is sent for a calibration check, please include the calibration document.

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Product Service

INTRODUCTION

L-shaped probes are designed solely for use on the SARA-C SAR-measuring system. They are not designed to work on SARA2.

This Report presents measured calibration data for a particular Indexsar SAR probe (S/N L0006) only and describes the procedures used for characterisation and calibration.

Indexsar probes are characterised using procedures that, where applicable, follow the recommendations of IEC 62209-1 [Ref 1], IEEE 1528 [Ref 2], IEC 62209-2 [Ref 3] and FCC OET65 [Ref 4] standards. The procedures incorporate techniques for probe linearisation, isotropy assessment and determination of liquid factors (conversion factors). Calibrations are determined by comparing probe readings with analytical computations in canonical test geometries (waveguides) using normalised power inputs.

Each step of the calibration procedure and the equipment used is described in the sections below.

CALIBRATION PROCEDURE

1. Objectives

The calibration process comprises the following stages:-

1) Determination of the relative channel sensitivity factors which optimise the probe's overall axial isotropy in 900MHz brain fluid.

2) Measure the incidental spherical isotropy using these derived channel sensitivity factors.

3) Since isotropy and channel sensitivity factors are frequency independent, these channel sensitivity factors can be applied to model the exponential decay of SAR in a waveguide fluid cell at each frequency of interest, and hence derive the liquid conversion factors at that frequency.

2. Probe output

The probe channel output signals are linearised in the manner set out in Refs [1] - [4]. The following equation is utilized for each channel:

$$U_{lin} = U_{o/p} + U_{o/p}^{\ 2} / DCP \qquad (1)$$

where U_{lin} is the linearised signal, $U_{o/p}$ is the raw output signal in mV and DCP is the diode compression potential, also in mV.

DCP is determined from fitting equation (1) to measurements of U_{lin} versus source feed power over the full dynamic range of the probe. The DCP is a characteristic of the Schottky diodes used as the sensors. For the IXP-020 probes with CW signals the DCP values are typically 100mV.

For this value of DCP, the typical linearity response of IXP-050 probes to CW and to GSM modulation is shown in Figure 7, along with departures of this same dataset from linearity.

In turn, measurements of E-field are determined using the following equation:

$$E_{liq}^2\ (V/m) = U_{linx} * \text{Air Factor}_x * \text{Liq Factor}_x + U_{liny} * \text{Air Factor}_y * \text{Liq Factor}_y + U_{linz} * \text{Air Factor}_z * \text{Liq Factor}_z \quad (3)$$

Here, "Air Factor" represents each channel's sensitivity, while "Liq Factor" represents the enhancement in signal level when the probe is immersed in tissue-simulant liquids at each frequency of interest.

3. Selecting channel sensitivity factors to optimise isotropic response

Within SARA-C, an L-probe's predominant mode of operation is with the tip pointing directly towards the source of radiation. Consequently, optimising the probe's response to boresight signals ("axial isotropy") is far more important than optimising its spherical isotropy (where the direction, as well as the polarisation angle, of the incoming radiation must be taken into account).

The setup for measuring the probe's axial isotropy is shown in Figure 1, and this allows spherical isotropy to be measured at the same time. Moreover, since isotropy is frequency-independent, measurements are normally made at a frequency of 900MHz as lower frequencies are more tolerant of positional inaccuracies.

A box phantom containing 900MHz head fluid is irradiated by a tuned dipole, mounted at the side of the phantom on the SARA2 robot's seventh axis. Note: although the probe is used on SARA-C, it is actually calibrated on SARA2. The dipole is connected to a signal generator and amplifier via a directional coupler and power meter. The absolute power level is not important as long as it is stable, with stability being monitored using the coupler and power meter.

During calibration, the spherical isotropy response is measured by changing the orientation of the probe sensors with respect to the dipole, while keeping the long shaft of the probe vertical and the probe sensors at precisely the same position in space. Correctly aligning the probe sensors in this way is essential to an accurate measurement of isotropy.

Initially, the short shaft of the probe is positioned parallel to the phantom wall with its sensors at the same vertical height as the centre of the source dipole and the line joining sensors to dipole perpendicular to the phantom wall (see Figure 1). In this position, the probe is said to be at a position angle of -90 degrees. During the scan, the probe is rotated from -90 to +90 degrees in 10 degree steps, and at each position angle, the dipole polarisation changes

Product Service

Here, the density ρ is conventionally assumed to be 1000 kg/m^3, *ab* is the cross-sectional area of the waveguide, and P_f and P_b are the forward and reflected power inside the lossless section of the waveguide, respectively. The penetration depth δ (which is the reciprocal of the waveguide-mode attenuation coefficient) is a property of the lossy liquid and is given by Equation (5).

$$\delta = \left[\mathrm{Re}\left\{ \sqrt{(\pi / a)^2 + j\omega\mu_o \left(\sigma + j\omega\varepsilon_o\varepsilon_r \right)} \right\} \right]^{-1} \qquad (5)$$

where σ is the conductivity of the tissue-simulant liquid in S/m, ε_r is its relative permittivity, and ω is the radial frequency (rad/s). Values for σ and ε_r are obtained prior to each waveguide test using an Indexsar DiLine measurement kit, which uses the TEM method as recommended in [2]. σ and ε_r are both temperature- and fluid-dependent, so are best measured using a sample of the tissue-simulant fluid immediately prior to the actual calibration.

Wherever possible, all DiLine and calibration measurements should be made in the open laboratory at 22 ± 2.0°C; if this is not possible, the values of σ and ε_r should reflect the actual temperature. Values employed for calibration are listed in the tables below.

Dedicated waveguides have been designed to accommodate the geometry of an L-shaped probe as it traces out the decay profile. Traditional straight probes measure the decay rate of a vertical-travelling signal above a horizontal dielectric window; for the L-shaped probes, the geometry has had to be changed, and the waveguide now lies horizontally and instead of being open at the end, is capped with a metal plate (see Figure 2). A slot is cut in the top ("b") face through which tissue simulant fluid can be poured, and through which the probe can enter the guide and be offered up to the now vertical waveguide window.

During calibration, the probe tip is moved carefully towards the dielectric window until the flat face of the tip is just touching the exact centre of the face. 200 samples are then taken and written to an Excel template file before moving the probe into the liquid away from the waveguide window. This cycle is repeated 150 times at each separation. The spatial separation between readings is determined from practical considerations of the expected SAR decay rate, and range from 0.2mm steps at low frequency, through 0.1mm at 2450MHz, down to 0.05mm at 5GHz.

Once the data collection is complete, a Solver routine is run which optimises the measured-theoretical fit by varying the conversion factor, and the boundary correction size and range.

By ensuring the waveguide cap is at least three penetration depths, reflections are negligible. The power absorbed in the liquid is therefore determined solely from the waveguide forward and reflected power.

Product Service

Different waveguides are used for 700MHz, 835/900MHz, 1450MHz, 1800/1900MHz, 2100/2450/2600MHz and 5200/5800MHz measurements. Table A.1 of [1] can be used for designing calibration waveguides with a return loss greater than 20 dB at the most important frequencies used for personal wireless communications, and better than 15dB for frequencies greater than 5GHz. Values for the penetration depth for these specific fixtures and tissue-simulating mixtures are also listed in Table A.1.

According to [1], this calibration technique provides excellent accuracy, with standard uncertainty of less than 3.6% depending on the frequency and medium. The calibration itself is reduced to power measurements traceable to a standard calibration procedure. The practical limitation to the frequency band of 800 to 5800 MHz because of the waveguide size is not severe in the context of compliance testing.

For calibrations at 450MHz, where waveguide calibrations become unfeasible, a full 3D SAR scan over a tuned dipole is performed, and the conversion factor adjusted to make the measured 1g and 10g volume-averaged SAR values agree with published targets.

CALIBRATION FACTORS MEASURED FOR PROBE S/N L0006

The probe was calibrated at 450, 835, 900, 1800, 1900, 2100, 2450 and 2600 MHz in liquid samples representing brain liquid at these frequencies.

The calibration was for CW signals only, and the horizontal axis of the probe was parallel to the direction of propagation of the incident field i.e. end-on to the incident radiation.

The reference point for the calibration is in the centre of the probe's cross-section at a distance of 2.7 mm from the probe tip in the direction of the probe amplifier. A value of 2.7 mm should be used for the tip to sensor offset distance in the software. The distance of 2.7mm for assembled probes has been confirmed by taking X-ray images of the probe tips (see Figure 9).

It is important that the diode compression point and air factors used in the software are the same as those quoted in the results tables, as these are used to convert the diode output voltages to a SAR value.

CALIBRATION EQUIPMENT

The Table on page 21 indicates the calibration status of all test equipment used during probe calibration.

Product Service

MEASUREMENT UNCERTAINTIES

A complete measurement uncertainty analysis for the SARA-C measurement system has been published in Reference [3]. Table 17 from that document is re-created below, and lists the uncertainty factors associated just with the calibration of probes.

Source of uncertainty	Uncertainty value ± %	Probability distribution	Divisor	c_i	Standard uncertainty ui ± %	v_i or v_{eff}
Forward power	3.92	N	1.00	1	3.92	∞
Reflected power	4.09	N	1.00	1	4.09	∞
Liquid conductivity	1.308	N	1.00	1	1.31	∞
Liquid permittivity	1.271	N	1.00	1	1.27	∞
Field homgeneity	3.0	R	1.73	1	1.73	∞
Probe positioning	0.22	R	1.73	1	0.13	∞
Field probe linearity	0.2	R	1.73	1	0.12	∞
Combined standard uncertainty		RSS			6.20	

At the 95% confidence level, therefore, the expanded uncertainty is 12.4%

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SUMMARY OF CAL FACTORS FOR PROBE IXP-020 S/N L0006

Relative Channel Sensitivities (to optimise Axial Isotropy)				
	X	Y	Z	
Air Factors	72.81	90.02	77.16	$(V/m)^2/mV$
CW DCPs	100	100	100	mV

Measured Isotropy at 900MHz	Probe orientation range relative to dipole	(+/-) dB
Axial Isotropy	0°(end-on to dipole)	0.01
Spherical Isotropy	±20°	0.17
	±30°	0.28
	±60°	0.58
	±90°	0.63

SAR Conversion Factors/ Boundary Corrections (Head Fluid)				
Frequency* (MHz)	**SAR Conv Factor**	**Boundary Correction f(0)**	**Boundary Correction d(mm)**	**Notes**
450	0.298	0.0	1.0	3
835	0.304	0.8	1.5	1,2
900	0.305	1.0	1.4	1,2
1800	0.373	0.9	1.5	1,2
1900	0.382	0.5	2.3	1,2
2100	0.396	0.6	2.0	1,2
2450	0.423	0.9	1.5	1,2
2600	0.427	1.1	1.4	1,2
Notes				
1)	Calibrations done at 22°C +/-2°C			
2)	Waveguide calibration			
3)	By validation			

*The valid frequency of SARA-C probe calibrations are ±100MHz (F<300MHz) and ±200MHz (F>300MHz).

Physical Information	
Sensor offset (mm)	2.7
Elbow – Tip dimension (mm)	84.55

Product Service

PROBE SPECIFICATIONS

Indexsar probe L0006, along with its calibration, is compared with BSEN 62209-1 and IEEE standards recommendations (Refs [1] and [2]) in the Tables below. A listing of relevant specifications is contained in the tables below:

Dimensions	S/N L0006	BSEN [1]	IEEE [2]
Vertical shaft (mm)	510		
Horizontal shaft (mm)	90		
Tip length (mm)	10		
Body diameter (mm)	12		
Tip diameter (mm)	5.2	8	8
Distance from probe tip to dipole centers (mm)	2.7		

Dynamic range	S/N L0006	BSEN [1]	IEEE [2]
Minimum (W/kg)	0.01	<0.02	0.01
Maximum (W/kg) N.B. only measured to > 100 W/kg on representative probes	>100	>100	100

Isotropy (measured at 900MHz)		S/N L0006	BSEN [1]	IEEE [2]
Axial	Probe at 0°	0.01	0.5	0.25
Spherical	Probe at ±20°	0.17	N/A	N/A
	Probe at ±30°	0.28		
	Probe at ±60°	0.58		
	Probe at ±90°	0.63		

Construction	Each probe contains three orthogonal dipole sensors arranged on a triangular prism core, protected against static charges by built-in shielding, and covered at the tip by PEEK cylindrical enclosure material. Outer case materials are PEEK and heat-shrink sleeving.
Chemical resistance	Tested to be resistant to TWEEN and sugar/salt-based simulant liquids but probes should be removed, cleaned and dried when not in use. NOT recommended for use with glycol or soluble oil-based liquids.

Product Service

REFERENCES

References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.

For a specific reference, subsequent revisions do not apply.

For a non-specific reference, the latest version applies.

[1] IEC 62209-1.
Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices — Human models, instrumentation, and procedures — Part 1: Procedure to determine the specific absorption rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300 MHz to 3 GHz)

[2] IEEE 1528
Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques

[3] IEC 62209-2
Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Human models, Instrumentation, and procedures – Part 2: Procedure to determine the specific absorption rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)

[4] FCC OET65
Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields

[5] Indexsar Report IXS-0300, October 2007.
Measurement uncertainties for the SARA2 system assessed against the recommendations of BS EN 62209-1:2006

[6] SARA-C SAR Testing System: Measurement Uncertainty, v1.0.3. October 2011.

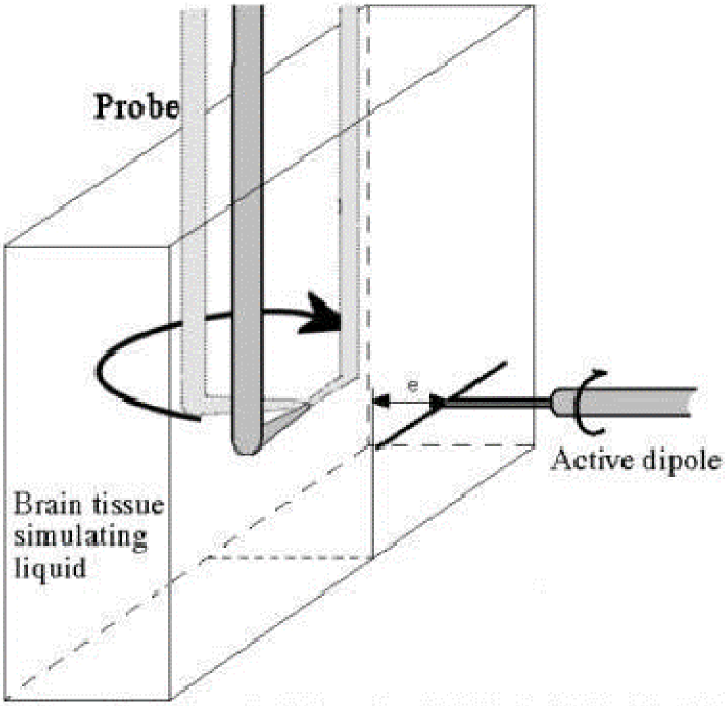

Figure 1 Isotropy jig showing probe, dipole and box filled with simulated brain liquid (see Ref [2], Section A.5.2.1)

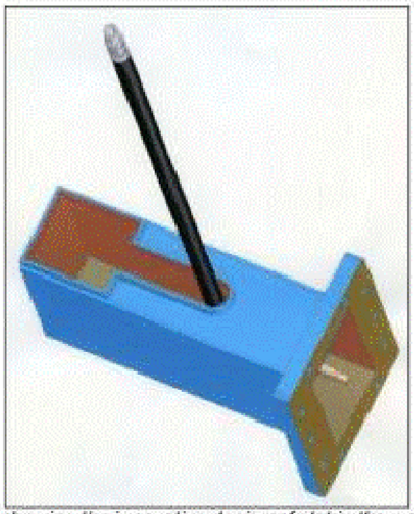

Figure 2 Schematic showing the innovative design of slot in the waveguide termination

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Product Service

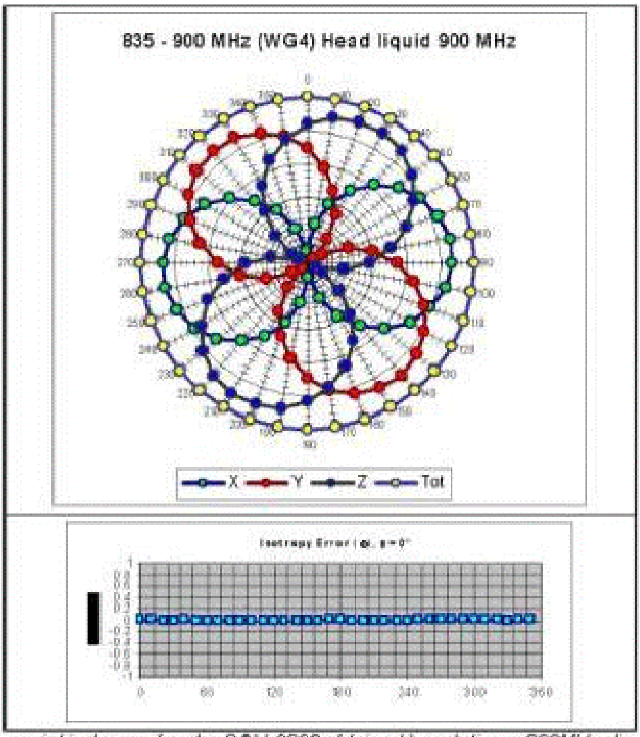

Figure 3 The axial isotropy of probe S/N L0006 obtained by rotating a 900MHz dipole with probe tip aligned with dipole boresight (NB Axial Isotropy is frequency independent)

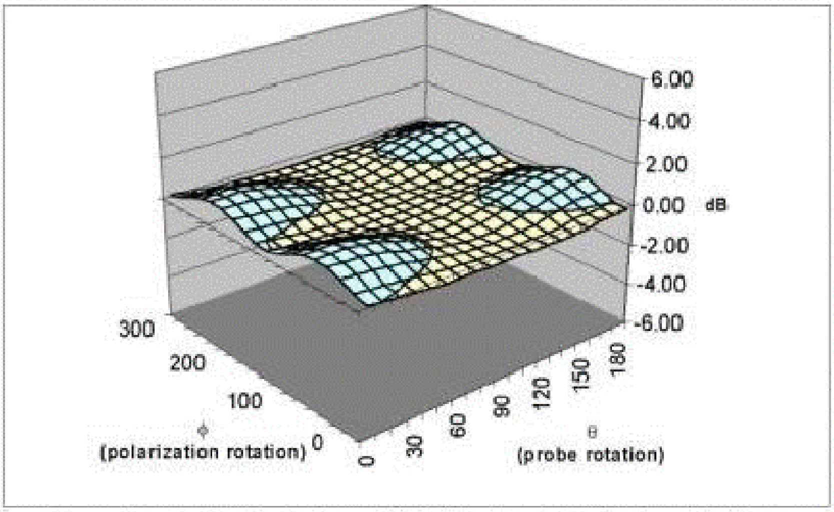

Figure 4 Residual Surface Isotropy at 900 MHz after optimisation for axial isotropy

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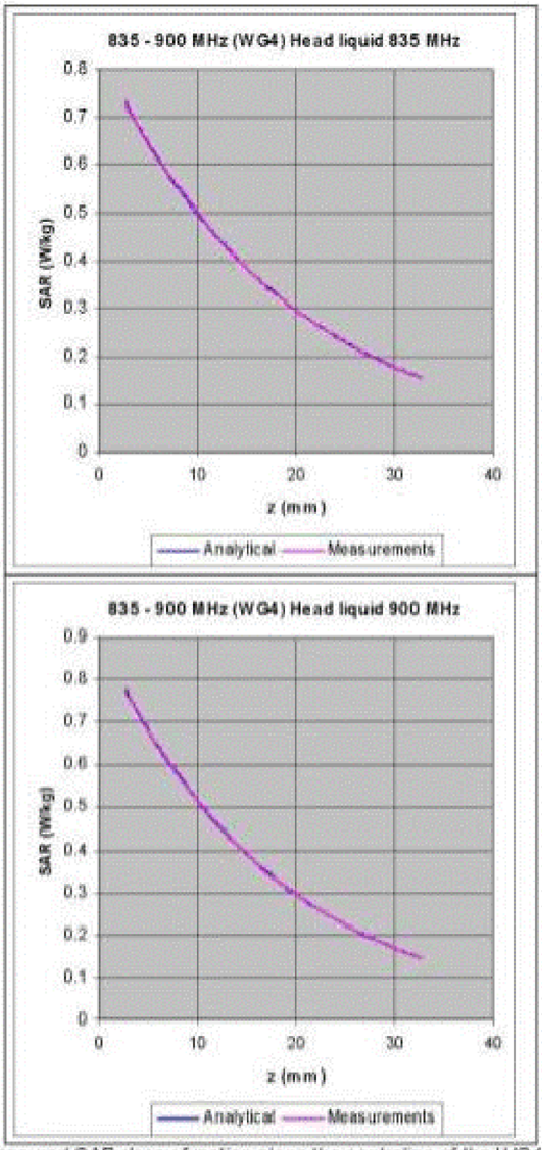
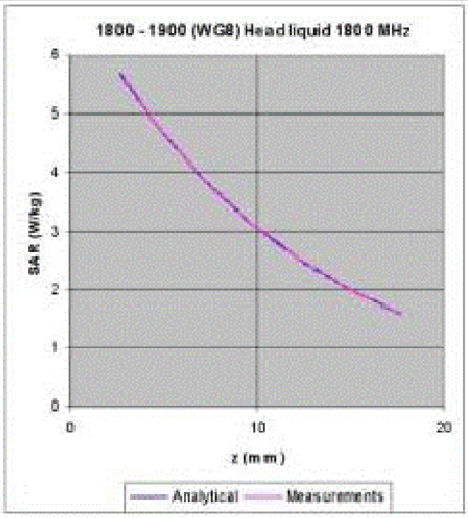
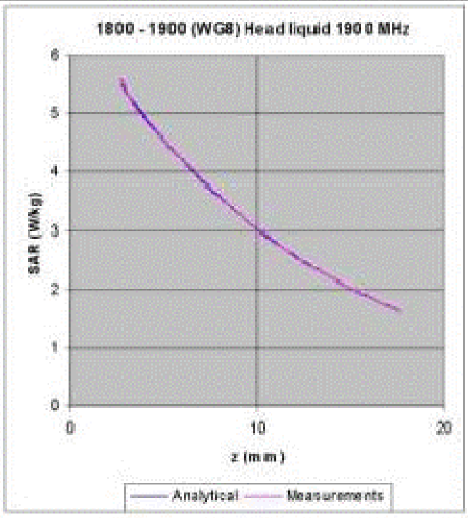


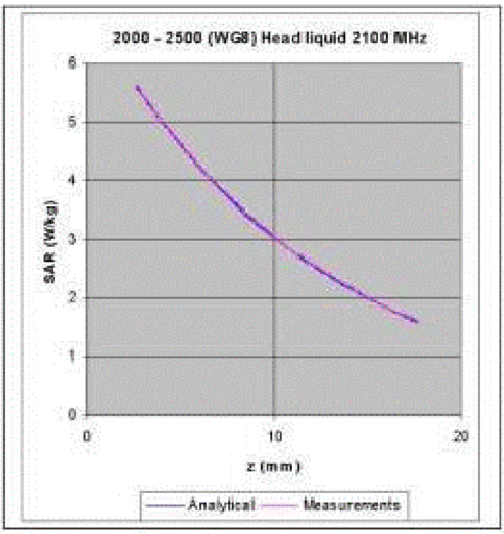
Figure 5 The measured SAR decay function along the centreline of the WG4 waveguide with conversion factors adjusted to fit to the theoretical function for the particular dimension, frequency, power and liquid properties employed.

Product Service





Page 15 of 21


2000 - 2500 (WG8) Head liquid 2100 MHz
SAR (W/kg)
z (mm)
Analytical
Measurements

Product Service

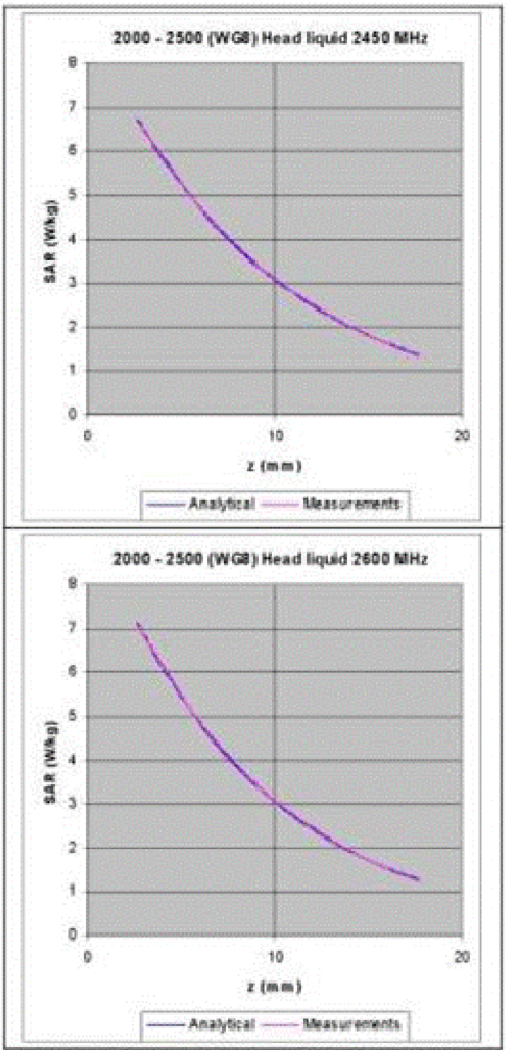


Figure 6. The measured SAR decay function along the centreline of the R22 waveguide with conversion factors adjusted to fit to the theoretical function for the particular dimension, frequency, power and liquid properties employed.

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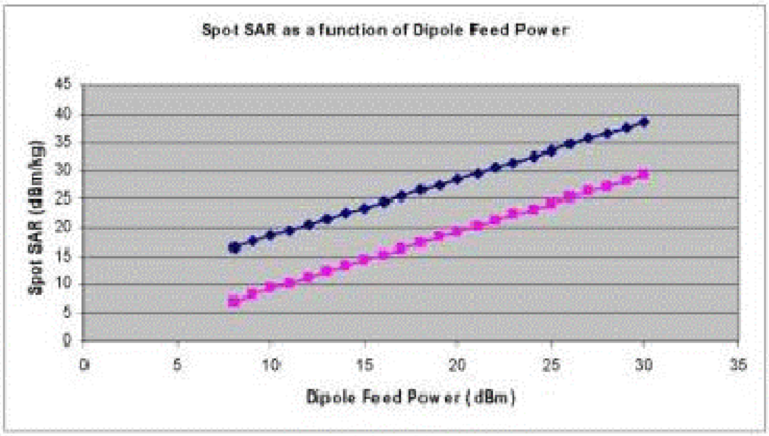

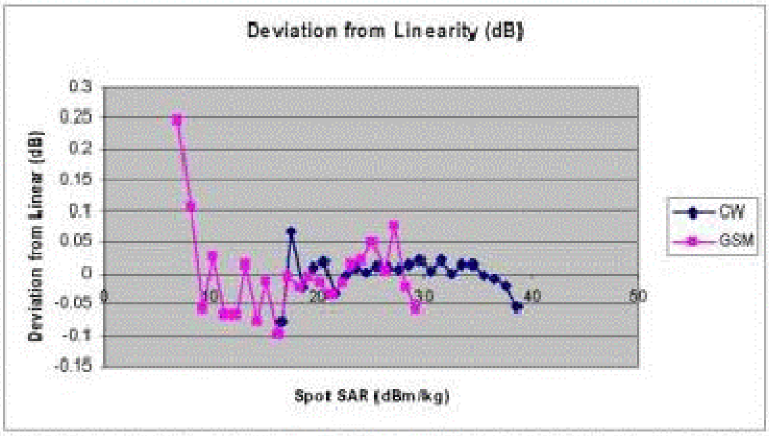

Figure 7: The typical linearity response of 5mm probes to both CW (blue) and GSM (pink) modulation in close proximity to a source dipole. The top diagram shows the SAR reading as a function of dipole feed power, with GSM modulation being approx a factor of of 8 (ie 9dB) lower than CW. The lower diagram shows the departure from linearity of the same two datasets.

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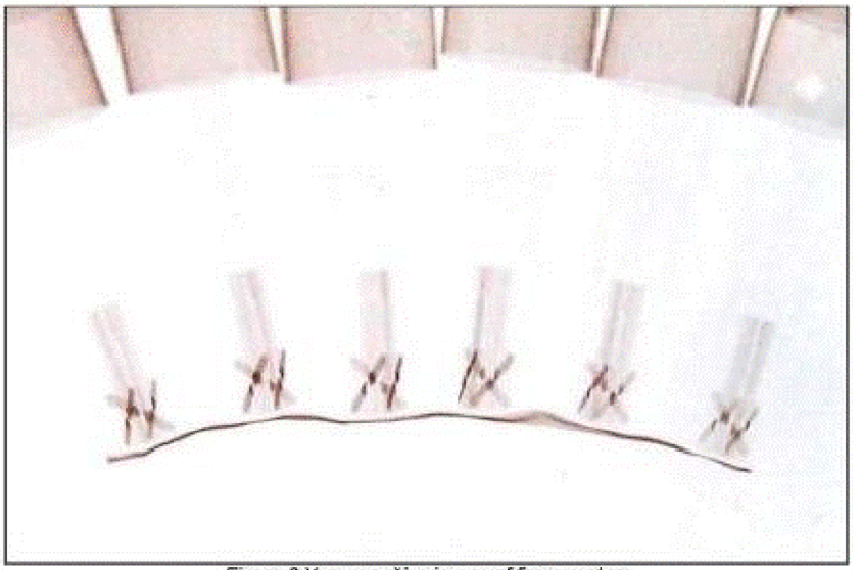

Figure 8 X-ray positive image of 5mm probes

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Table indicating the dielectric parameters of the liquids used for calibrations at each frequency

Frequency (MHz)	Fluid Type	Measured		Target		% Deviation		Verdict	
		Relative Permittivity	Conductivity (S/m)	Relative Permittivity	Conductivity (S/m)	Relative Permittivity	Conductivity	Relative Permittivity	Conductivity
450	Head	44.142	0.845	43.5	0.87	1.5	-2.9	Pass	Pass
835		42.114	0.901	41.5	0.90	1.5	0.1	Pass	Pass
900		41.13	0.961	41.5	0.97	-0.9	-0.9	Pass	Pass
1800		39.719	1.428	40.0	1.40	-0.7	2.0	Pass	Pass
1900		39.744	1.396	40.0	1.40	-0.6	-0.3	Pass	Pass
2100		40.541	1.463	39.8	1.49	1.9	-1.8	Pass	Pass
2450		39.265	1.815	39.2	1.80	0.2	0.8	Pass	Pass
2600		38.715	1.975	39.0	1.96	-0.7	0.8	Pass	Pass

TÜV SÜD Product Service

INDEXSAR

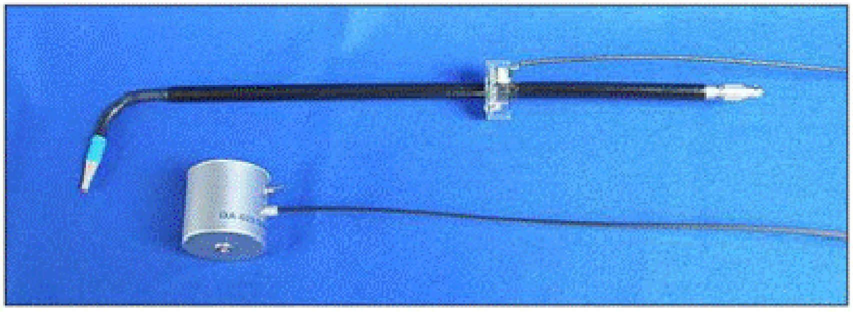
IMMERSIBLE SAR PROBE

CALIBRATION REPORT

Part Number: IXP–021

S/N LG0018

March 2014



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Calibration Certificate 1403/LG0018
Date of Issue: 24th March 2014
Immersible SAR Probe

Type:	IXP-021
Manufacturer:	IndexSAR, UK
Serial Number:	LG0018
Place of Calibration:	IndexSAR, UK
Date of Receipt of Probe:	30 January 2014
Calibration Dates:	11-21 March 2014
Customer:	TUV Sud

IndexSAR Ltd hereby declares that the IXP-025 Probe named above has been calibrated for conformity to the current versions of IEEE 1528, IEC 62209-1, IEC 62209-2, and FCC OET65 standards using the methods described in this calibration document. Where applicable, the standards used in the calibration process are traceable to the UK's National Physical Laboratory.

Calibrated by:	A. Brinklow	**Technical Manager**
Approved by:	[signature]	**Director**

Please keep this certificate with the calibration document. When the probe is sent for a calibration check, please include the calibration document.

Page 2 of 18

INTRODUCTION

This Report presents measured calibration data for a particular Indexsar SAR probe (S/N LG0018) only and describes the procedures used for characterisation and calibration.

Indexsar probes are characterised using procedures that, where applicable, follow the recommendations of IEC 62209-1 [Ref 1], IEEE 1528 [Ref 2], IEC 62209-2 [Ref 3] and FCC OET65 [Ref 4] standards. The procedures incorporate techniques for probe linearisation, isotropy assessment and determination of liquid factors (conversion factors). Calibrations are determined by comparing probe readings with analytical computations in canonical test geometries (waveguides) using normalised power inputs.

Each step of the calibration procedure and the equipment used is described in the sections below.

CALIBRATION PROCEDURE

1. Objectives

The calibration process comprises the following stages

1) Determination of the channel sensitivity factors which optimise the probe's overall axial isotropy

2) Use of these channel sensitivity factors to compare the SAR decay curve in a waveguide fluid cell with an analytical curve at each frequency of interest, and hence derive the liquid conversion factors at that frequency.

2. Probe output

The probe channel output signals are linearised in the manner set out in Refs [1] and [2]. The following equation is utilized for each channel:

$$U_{lin} = U_{o/p} + U_{o/p}{}^{2} / DCP \qquad (1)$$

where U_{lin} is the linearised signal, $U_{o/p}$ is the raw output signal in mV and DCP is the diode compression potential, also in mV.

DCP is determined from fitting equation (1) to measurements of U_{lin} versus source feed power over the full dynamic range of the probe. The DCP is a characteristic of the Schottky diodes used as the sensors. For the IXP-021 probes with CW signals the DCP values are typically 100mV.

In turn, measurements of E-field are determined using the following equation:

$$E_{liq}{}^{2}\ (V/m) = U_{linx} * \text{Air Factor}_{x} * \text{Liq Factor}_{x}$$

$$+ U_{liny} * \text{Air Factor}_y * \text{Liq Factor}_y$$
$$+ U_{linz} * \text{Air Factor}_z * \text{Liq Factor}_z \quad (3)$$

Here, "Air Factor" represents each channel's sensitivity, while "Liq Factor" represents the enhancement in signal level when the probe is immersed in tissue-simulant liquids at each frequency of interest.

3. Selecting channel sensitivity factors to optimise isotropic response

Within SARA-C, a probe's predominant mode of operation is with the tip pointing directly towards the source of radiation. Consequently, optimising the probe's response to boresight signals ("axial isotropy") is far more important than optimising its spherical isotropy (where the direction, as well as the polarisation angle, of the incoming radiation must be taken into account).

A 5-6GHz waveguide containing head-fluid simulant is selected. Like all waveguides used during probe calibration, this particular waveguide contains two distinct sections: an air-filled launcher section, and a liquid cell section, separated by a dielectric matching window designed to minimise reflections at the air-liquid interface.

The waveguide stands in an upright position on a turntable and the liquid cell section is filled with 5-6GHz brain fluid to within 1 mm of the open end. The depth of liquid ensures there is negligible radiation from the waveguide open top and that the probe calibration is not influenced by reflections from nearby objects.

During the measurement, a TE_{01} mode is launched into the waveguide by means of an N-type-to-waveguide adapter. The probe is held by the robot in a dedicated jig with the probe's long shaft horizontal and the short shaft pointing vertically down over the centre of the waveguide opening, Figure 1. In this position, the short shaft lies directly along the waveguide's main axis in the direction of signal travel. The probe is then lowered along the waveguide axis directly into the liquid until the tip is exactly 5mm above the centre of the dielectric window. This particular separation ensures that the probe is operating in a part of the waveguide where boundary corrections are not necessary.

The exact power applied to the input of the waveguide during this stage of the probe calibration is immaterial since only relative values are of interest during the assessment of axial isotropy. However, the power must be sufficiently above the noise floor and free from drift.

With the probe's short shaft lying directly along the waveguide axis, the probe's axial isotropy can be measured by changing their relative position angle. This can be done by either spinning the probe while the waveguide remains stationery (usual procedure for straight probes) or, as is the case for L-probes, the waveguide is turned by hand while the probe does not move. The dedicated Indexsar calibration software requests that the user rotates the waveguide in 10 degree steps about its axis, and at each position, an Indexsar 'Fast' amplifier samples the probe channels 500 times per second for

0.4 s. The raw $U_{o/p}$ data from each sample are packed into 10 bytes and transmitted back to the PC controller via an optical cable. U_{linx}, U_{liny} and U_{linz} are derived from the raw $U_{o/p}$ values and written to an Excel template.

Once data have been collected from a full probe rotation, the Air Factors are adjusted using a special Excel Solver routine to equalise the output from each channel and hence minimise the axial isotropy. This automated approach to optimisation removes the effect of human bias.

Figure 3 represents the output from each diode sensor as a function of probe rotation angle.

4. Determination of Conversion ("Liquid") Factors at each frequency of interest

A lookup table of conversion factors for a probe allows a SAR value to be derived at the measured frequencies, and for either brain or body fluid-simulant.

The method by which the conversion factors are assessed is based on the comparison between measured and analytical rates of decay of SAR with perpendicular distance from a dielectric window. This way, not only can the conversion factors for that frequency/fluid combination be determined, but an allowance can also be made for the scale and range of boundary layer effects.

The theoretical relationship between the SAR at the cross-sectional centre of the lossy waveguide as a function of the longitudinal distance (z) from the dielectric separator is given by Equation 4:

$$SAR(z) = \frac{4\left(P_f - P_b\right)}{\rho ab\delta} e^{-2z/\delta} \qquad (4)$$

Here, the density ρ is conventionally assumed to be 1000 kg/m^3, ab is the cross-sectional area of the waveguide, and P_f and P_b are the forward and reflected power inside the lossless section of the waveguide, respectively. The penetration depth δ (which is the reciprocal of the waveguide-mode attenuation coefficient) is a property of the lossy liquid and is given by Equation (5).

$$\delta = \left[\mathrm{Re}\left\{\sqrt{(\pi / a)^2 + j\omega\mu_o\left(\sigma + j\omega\varepsilon_o\varepsilon_r\right)}\right\}\right]^{-1} \qquad (5)$$

where σ is the conductivity of the tissue-simulant liquid in S/m, ε_r is its relative permittivity, and ω is the radial frequency (rad/s). Values for σ and ε_r are obtained prior to each waveguide test using an Indexsar DiLine measurement kit, which uses the TEM method as recommended in [2]. σ and ε_r are both temperature- and fluid-dependent, so are best measured using a sample of the tissue-simulant fluid immediately prior to the actual calibration.

Wherever possible, all DiLine and calibration measurements should be made in the open laboratory at 22 $\pm$ 2.0^{0}C; if this is not possible, the values of σ and ε_r should reflect the actual temperature. Values employed for calibration are listed in the tables below.

There are two ways of accommodating the geometry of an L-shaped probe as it traces out the decay profile. Above 3GHz, as here, the waveguide's fluid cell is short enough that the probe's short shaft can be lowered vertically down into the waveguide without the long shaft fouling on the waveguide edge, Figure 1. By contrast, at lower frequencies, the measurement geometry has to be changed, and the waveguide now lies horizontally and the fluid cell has to be capped with a metal plate at least three penetration depths away from the dielectric window (see Figure 2). A slot is cut in the top ("b") face through which tissue simulant fluid can be poured, and through which the probe can enter the guide and be offered up to the now vertical waveguide window.

During high frequency calibration, the probe is lowered carefully until the flat face of the tip is just touching the cross-sectional centre of the dielectric window. 200 samples are then taken and written to an Excel template file before moving the probe away from the waveguide window. This cycle is repeated 150 times, with a different separation each time, in steps of 0.35mm.

Once the data collection is complete, a Solver routine is run which optimises the measured-theoretical fit by varying the conversion factor, and the boundary correction size and range.

Different waveguides are used for 835/900MHz, 1800/1900MHz, 2100/2450/2600MHz and 5200/5800MHz measurements. Table A.1 of [1] can be used for designing calibration waveguides with a return loss greater than 20 dB at the most important frequencies used for personal wireless communications, and better than 15dB for frequencies greater than 5GHz. Values for the penetration depth for these specific fixtures and tissue-simulating mixtures are also listed in Table A.1.

For 450 MHz calibrations, a slightly different technique must be used — the equatorial response of the probe-under-test is compared with the equivalent response of a probe whose 450MHz characteristics have already been determined by NPL. The conversion factor of the probe-under-test can then be deduced.

According to [1], this calibration technique provides excellent accuracy, with standard uncertainty of less than 3.6% depending on the frequency and medium. The calibration itself is reduced to power measurements traceable to a standard calibration procedure. The practical limitation to the frequency band of 800 to 5800 MHz because of the waveguide size is not severe in the context of compliance testing.

CALIBRATION FACTORS MEASURED FOR PROBE S/N LG0018

The probe was calibrated at 5200, 5500 and 5800 MHz in liquid samples representing brain tissue at these frequencies.

The calibration was for CW signals only, and the horizontal axis of the probe was parallel to the direction of propagation of the incident field i.e. end-on to the incident radiation.

The reference point for the calibration is in the centre of the probe's cross-section at a distance of 1.39 mm from the probe tip in the direction of the probe amplifier. A value of 1.39 mm should be used for the tip to sensor offset distance in the software. The distance of 1.39 mm for assembled probes has been confirmed by taking X-ray images of the probe tips (see Figure 9).

It is important that the diode compression point and air factors used in the software are the same as those quoted in the results tables, as these are used to convert the diode output voltages to a SAR value.

CALIBRATION EQUIPMENT

The Table on page 18 indicates the calibration status of all test equipment used during probe calibration.

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MEASUREMENT UNCERTAINTIES

A complete measurement uncertainty analysis for the SARA-C measurement system has been published in Reference [3]. Table 17 from that document is re-created below and lists the uncertainty factors associated just with the calibration of probes.

Source of uncertainty	Uncertainty value ± %	Probability distribution	Divisor	c_i	Standard uncertainty ui ± %	v_i or v_{eff}
Forward power	3.92	N	1.00	1	3.92	∞
Reflected power	4.09	N	1.00	1	4.09	∞
Liquid conductivity	1.308	N	1.00	1	1.31	∞
Liquid permittivity	1.271	N	1.00	1	1.27	∞
Field homgeneity	3.0	R	1.73	1	1.73	∞
Probe positioning	0.22	R	1.73	1	0.13	∞
Field probe linearity	0.2	R	1.73	1	0.12	∞
Combined standard uncertainty		RSS			6.20	

At the 95% confidence level, therefore, the expanded uncertainty is ±12.4%

SUMMARY OF CAL FACTORS FOR PROBE IXP-021 S/N LG0018

SAR Calibration Factors / Boundary Corrections*								
Freq (MHz)	Tissue Type	Air Factor X ((V/m)^2/mV)	Air Factor Y ((V/m)^2/mV)	Air Factor Z ((V/m)^2/mV)	Rotational Isotropy (± dB)	SAR Conv Factor	Boundary Correction f(0)	Boundary Correction d(mm)
5200	Head	289.0	322.7	348.3	0.10	0.788	0.55	1.1
5500						0.800	0.50	1.5
5800						0.800	0.66	1.0

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PROBE SPECIFICATIONS

Indexsar probe LG0018, along with its calibration, is compared with BSEN 62209-1 and IEEE standards recommendations (Refs [1] and [2]) in the Tables below. A listing of relevant specifications is contained in the tables below:

Dimensions	S/N LG0018	BSEN [1]	IEEE [2]
Vertical shaft (mm)	510		
Horizontal shaft (mm)	84.15		
Tip length (mm)	10		
Body diameter (mm)	12		
Tip diameter (mm)	2.55	8	8
Distance from probe tip to dipole centers (mm)	1.39		

Dynamic range	S/N LG0018	BSEN [1]	IEEE [2]
Minimum (W/kg)	0.01	<0.02	0.01
Maximum (W/kg) N.B. only measured to > 100 W/kg on representative probes	>100	>100	100

Rotational Isotropy (at 5.2GHz)	S/N LG0018	BSEN [1]	IEEE [2]
Axial rotation with probe normal to source (+/- dB)	0.10	0.5	0.25

Construction	Each probe contains three orthogonal dipole sensors arranged on a triangular prism core, protected against static charges by built-in shielding, and covered at the tip by PEEK cylindrical enclosure material. Outer case materials are PEEK and heat-shrink sleeving.
Chemical resistance	Tested to be resistant to TWEEN and sugar/salt-based simulant liquids but probes should be removed, cleaned and dried when not in use. NOT recommended for use with glycol or soluble oil-based liquids.

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REFERENCES

References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.

For a specific reference, subsequent revisions do not apply.

For a non-specific reference, the latest version applies.

[1] IEC 62209-1.
Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices — Human models, instrumentation, and procedures — Part 1: Procedure to determine the specific absorption rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300 MHz to 3 GHz)

[2] IEEE 1528
Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques

[3] IEC 62209-2
Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Human models, Instrumentation, and procedures – Part 2: Procedure to determine the specific absorption rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)

[4] FCC OET65
Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields

[5] Indexsar Report IXS-0300, October 2007.
Measurement uncertainties for the SARA2 system assessed against the recommendations of BS EN 62209-1:2006

[6] SARA-C SAR Testing System: Measurement Uncertainty, v1.0.3. October 2011.

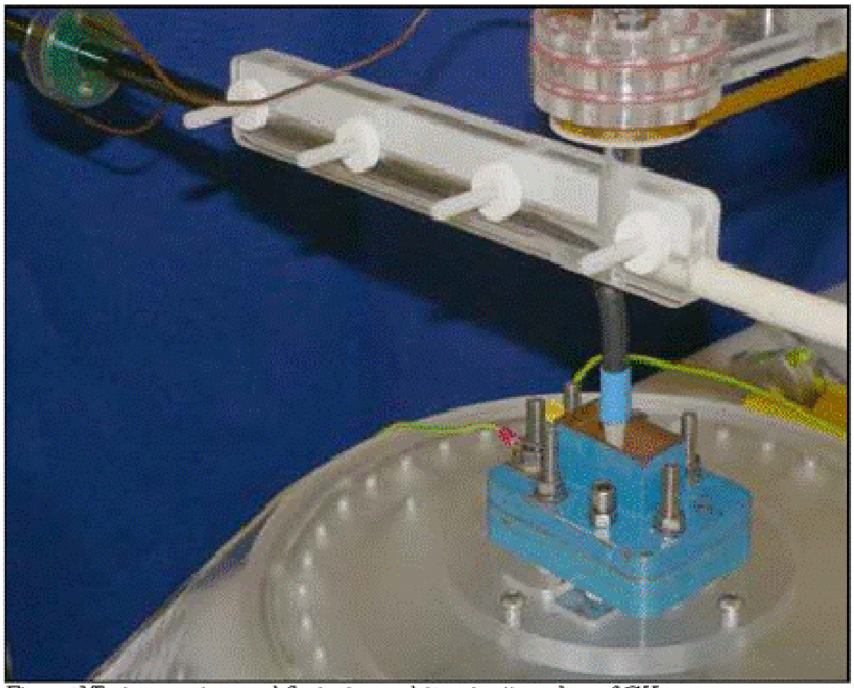

Figure 1 Test geometry used for isotropy determination above 3GHz

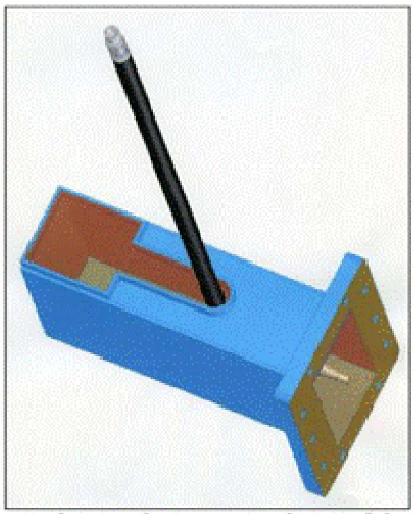

Figure 2. Schematic showing the innovative design of slot in the waveguide termination

Product Service

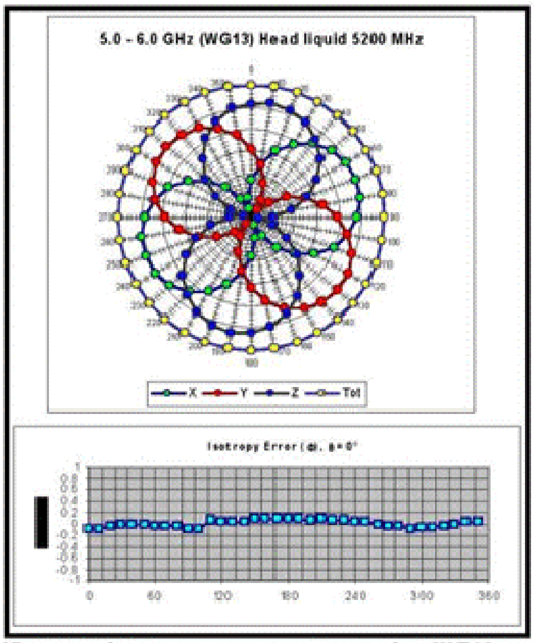

Figure 3Rotational isotropy measurements inside a WG13 waveguide.

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COMMERCIAL-IN-CONFIDENCE

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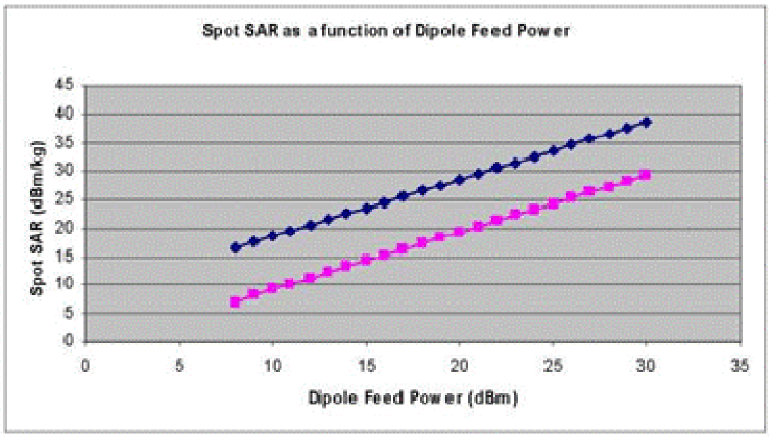

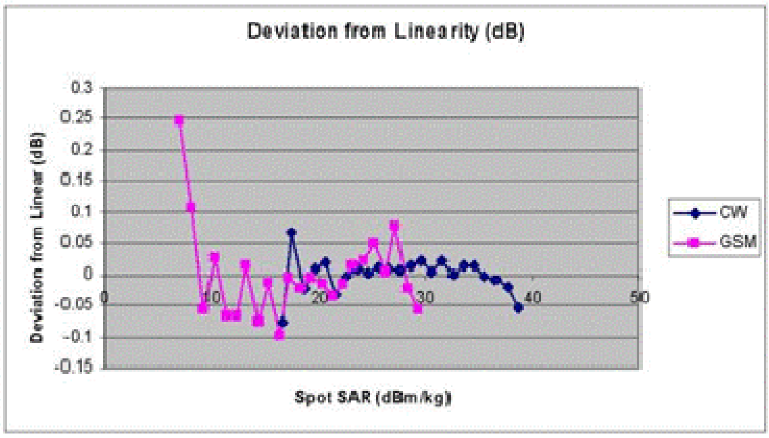

Figure 4 The typical linearity response of IXP-021 probes to both CW (blue) and GSM (pink) modulation in close proximity to a source dipole. The top diagram shows the SAR reading as a function of dipole feed power, with GSM modulation being approx a factor of 8

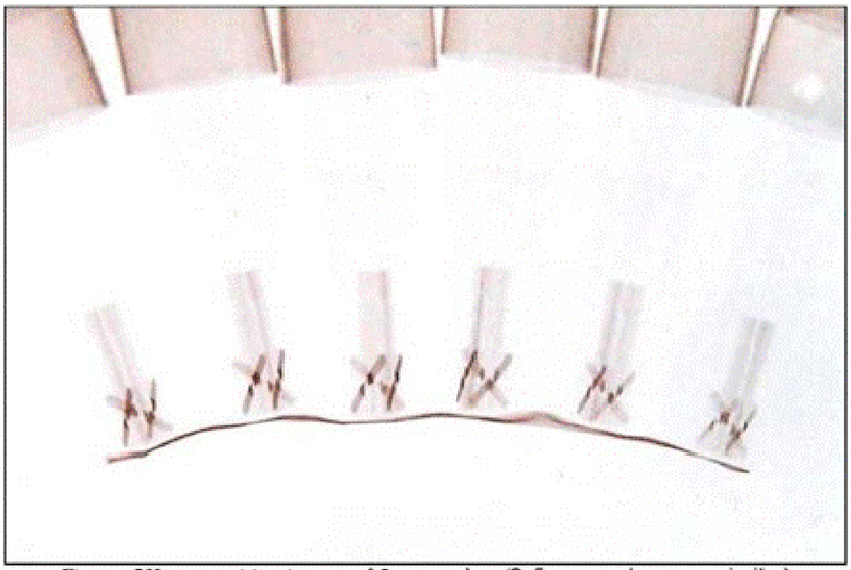

Figure 5X-ray positive image of 5mm probes (2.5mm probes are similar)

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Table indicating the dielectric parameters of the liquids used for calibrations at each frequency

Frequency (MHz)	Fluid Type	Measured		Target		% Deviation		Verdict	
		Relative Permittivity	Conductivity (S/m)	Relative Permittivity	Conductivity (S/m)	Relative Permittivity	Conductivity	Relative Permittivity	Conductivity
5200	Head	37.39	4.72	36.0	4.66	3.9	1.3	Pass	Pass
5500		36.36	5.12	35.7	4.97	2.0	3.2	Pass	Pass
5800		35.51	5.49	35.3	5.27	0.6	4.2	Pass	Pass

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Table of test equipment calibration status as at time of probe calibration

Instrument description	Supplier / Manufacturer	Model	Serial No.	Last calibration date	Calibration due date
Power sensor	Rohde & Schwarz	NRP-Z23	100063	09/08/2012	09/08/2014
Dielectric property measurement	Indexsar	DiLine (sensor lengths: 160mm, 80mm and 60mm)	N/A	(absolute) – checked against NPL values using reference liquids	N/A
Vector network analyser	Anritsu	MS6423B	003102	21/01/2014	21/01/2015
SMA autocalibration module	Anritsu	36581KKF/1	001902	21/01/2014	21/01/2015

Product Service

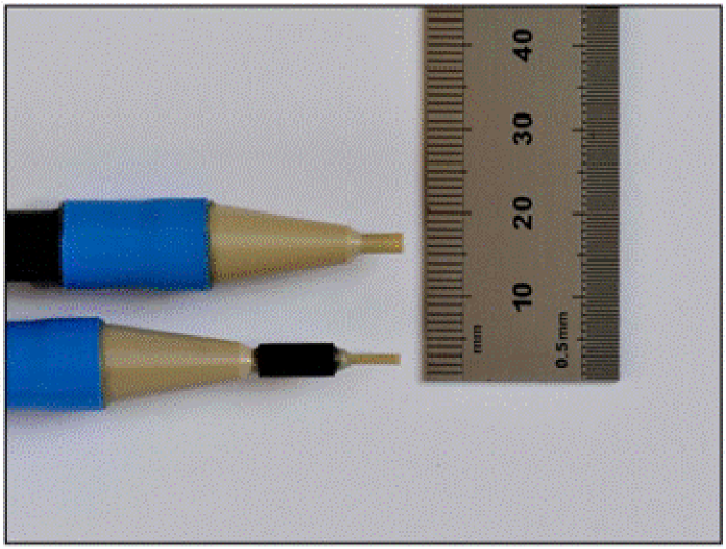
IMMERSIBLE SAR PROBE

CALIBRATION REPORT

Part Number: IXP – 025

S/N G0006

March 2014



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Calibration Certificate 1403/G0006
Date of Issue: 24 March 2014
Immersible SAR Probe

Type:	IXP-025
Manufacturer:	IndexSAR, UK
Serial Number:	G0006
Place of Calibration:	IndexSAR, UK
Date of Receipt of Probe:	30 January 2014
Calibration Dates:	11-21 March 2014
Customer:	TUV Sud

IndexSAR Ltd hereby declares that the IXP-025 Probe named above has been calibrated for conformity to the current versions of IEEE 1528, IEC 62209-1, IEC 62209-2, and FCC OET65 standards using the methods described in this calibration document. Where applicable, the standards used in the calibration process are traceable to the UK's National Physical Laboratory.

Calibrated by:	A. Brinklow	**Technical Manager**
Approved by:	[signature]	**Director**

Please keep this certificate with the calibration document. When the probe is sent for a calibration check, please include the calibration document.

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INTRODUCTION

Straight probes work on either SARA-C (to measure SAR values in flat phantoms containing Body tissue simulant fluid), or on SARA2 (where they, too, can measure in a flat phantom with Body fluid, or in a SAM phantom containing Head fluid).

This Report presents measured calibration data for a particular Indexsar SAR probe (S/N G0006) for use on SARA-C only. **The calibration factors do not apply to, and will not give correct readings on, the IndexSAR SARA2 system.**

Indexsar probes are characterised using procedures that, where applicable, follow the recommendations of IEC 62209-1 [Ref 1], IEEE 1528 [Ref 2], IEC 62209-2 [Ref 3] and FCC OET65 [Ref 4] standards. The procedures incorporate techniques for probe linearisation, isotropy assessment and determination of liquid factors (conversion factors). Calibrations are determined by comparing probe readings with analytical computations in canonical test geometries (waveguides) using normalised power inputs.

Each step of the calibration procedure and the equipment used is described in the sections below.

CALIBRATION PROCEDURE

1. Objectives

The calibration process comprises the following stages

1) Determination of the channel sensitivity factors which optimise the probe's overall axial isotropy

2) Use of these channel sensitivity factors to compare the SAR decay curve in a waveguide fluid cell with an analytical curve at each frequency of interest, and hence derive the liquid conversion factors at that frequency.

2. Probe output

The probe channel output signals are linearised in the manner set out in Refs [1] - [4]. The following equation is utilized for each channel:

$$U_{lin} = U_{o/p} + U_{o/p}{}^{2} / DCP \qquad (1)$$

where U_{lin} is the linearised signal, $U_{o/p}$ is the raw output signal in mV and DCP is the diode compression potential, also in mV.

DCP is determined from fitting equation (1) to measurements of U_{lin} versus source feed power over the full dynamic range of the probe. The DCP is a characteristic of the Schottky diodes used as the sensors. For the IXP-020 probes with CW signals the DCP values are typically 100mV.

For this value of DCP, the typical linearity response of IXP-025 probes to CW and to GSM modulation is shown in Figure 3, along with departures of this same dataset from linearity.

In turn, measurements of E-field are determined using the following equation:

$$E_{liq}^2\ (V/m) = U_{linx} * \text{Air Factor}_x * \text{Liq Factor}_x + U_{liny} * \text{Air Factor}_y * \text{Liq Factor}_y + U_{linz} * \text{Air Factor}_z * \text{Liq Factor}_z \quad (3)$$

Here, "Air Factor" represents each channel's sensitivity, while "Liq Factor" represents the enhancement in signal level when the probe is immersed in tissue-simulant liquids at each frequency of interest.

3. Selecting channel sensitivity factors to optimise isotropic response

Within SARA-C, a probe's predominant mode of operation is with the tip pointing directly towards the source of radiation. Consequently, optimising the probe's response to boresight signals ("axial isotropy") is far more important than optimising its spherical isotropy (where the direction, as well as the polarisation angle, of the incoming radiation must be taken into account).

A 5-6GHz waveguide containing head-fluid simulant is selected. Like all waveguides used during probe calibration, this particular waveguide contains two distinct sections: an air-filled launcher section, and a liquid cell section, separated by a dielectric matching window designed to minimise reflections at the air-liquid interface.

The waveguide stands in an upright position and the liquid cell section is filled with 5-6GHz brain fluid to within 1 mm of the open end. The depth of liquid ensures there is negligible radiation from the waveguide open top and that the probe calibration is not influenced by reflections from nearby objects.

During the measurement, a TE_{01} mode is launched into the waveguide by means of an N-type-to-waveguide adapter. The probe is then lowered vertically into the liquid until the tip is exactly 5mm above the centre of the dielectric window. This particular separation ensures that the probe is operating in a part of the waveguide where boundary corrections are not necessary.

Care must also be taken that the probe tip is centred while rotating.

The exact power applied to the input of the waveguide during this stage of the probe calibration is immaterial since only relative values are of interest while the probe rotates. However, the power must be sufficiently above the noise floor and free from drift.

The dedicated Indexsar calibration software rotates the probe in 10 degree steps about its axis, and at each position, an Indexsar 'Fast' amplifier samples the probe channels 500 times per second for 0.4 s. The raw $U_{o/p}$ data from each sample are packed into 10 bytes and transmitted back to the PC

Product Service

controller via an optical cable. U_{linx}, U_{liny} and U_{linz} are derived from the raw $U_{o/p}$ values and written to an Excel template.

Once data have been collected from a full probe rotation, the Air Factors are adjusted using a special Excel Solver routine to equalise the output from each channel and hence minimise the axial isotropy. This automated approach to optimisation removes the effect of human bias.

Figure 1 represents the output from each diode sensor as a function of probe rotation angle.

4. Determination of Conversion ("Liquid") Factors at each frequency of interest

A lookup table of conversion factors for a probe allows a SAR value to be derived at the measured frequencies, and for either brain or body fluid-simulant.

The method by which the conversion factors are assessed is based on the comparison between measured and analytical rates of decay of SAR with height above a dielectric window. This way, not only can the conversion factors for that frequency/fluid combination be determined, but an allowance can also be made for the scale and range of boundary layer effects.

The theoretical relationship between the SAR at the cross-sectional centre of the lossy waveguide as a function of the longitudinal distance (*z*) from the dielectric separator is given by Equation 4:

$$SAR(z) = \frac{4\left(P_f - P_b\right)}{\rho ab\delta} e^{-2z/\delta} \qquad (4)$$

Here, the density ρ is conventionally assumed to be 1000 kg/m^3, *ab* is the cross-sectional area of the waveguide, and P_f and P_b are the forward and reflected power inside the lossless section of the waveguide, respectively. The penetration depth δ (which is the reciprocal of the waveguide-mode attenuation coefficient) is a property of the lossy liquid and is given by Equation (5).

$$\delta = \left[\mathrm{Re}\left\{\sqrt{(\pi/a)^2 + j\omega\mu_o\left(\sigma + j\omega\varepsilon_o\varepsilon_r\right)}\right\}\right]^{-1} \qquad (5)$$

where σ is the conductivity of the tissue-simulant liquid in S/m, ε_r is its relative permittivity, and ω is the radial frequency (rad/s). Values for σ and ε_r are obtained prior to each waveguide test using an Indexsar DiLine measurement kit, which uses the TEM method as recommended in [2]. σ and ε_r are both temperature- and fluid-dependent, so are best measured using a sample of the tissue-simulant fluid immediately prior to the actual calibration.

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Wherever possible, all DiLine and calibration measurements should be made in the open laboratory at 22 ± 2.0°C; if this is not possible, the values of σ and ε_r should reflect the actual temperature. Values employed for calibration are listed in the tables below.

By ensuring the liquid height in the waveguide is at least three penetration depths, reflections at the upper surface of the liquid are negligible. The power absorbed in the liquid is therefore determined solely from the waveguide forward and reflected power.

Different waveguides are used for 700MHz, 835/900MHz, 1450MHz, 1800/1900MHz, 2100/2450/2600MHz and 5200/5800MHz measurements. Table A.1 of [1] can be used for designing calibration waveguides with a return loss greater than 20 dB at the most important frequencies used for personal wireless communications, and better than 15dB for frequencies greater than 5GHz. Values for the penetration depth for these specific fixtures and tissue-simulating mixtures are also listed in Table A.1.

According to [1], this calibration technique provides excellent accuracy, with standard uncertainty of less than 3.6% depending on the frequency and medium. The calibration itself is reduced to power measurements traceable to a standard calibration procedure. The practical limitation to the frequency band of 800 to 5800 MHz because of the waveguide size is not severe in the context of compliance testing.

During calibration, the probe is lowered carefully until it is just touching the cross-sectional centre of the dielectric window. 200 samples are then taken and written to an Excel template file before moving the probe vertically upwards. This cycle is repeated 150 times. The vertical separation between readings is determined from practical considerations of the expected SAR decay rate, and range from 0.2mm steps at low frequency, through 0.1mm at 2450MHz, down to 0.05mm at 5GHz.

Once the data collection is complete, a Solver routine is run which optimises the measured-theoretical fit by varying the conversion factor, and the boundary correction size and range.

For calibrations at 450MHz, where waveguide calibrations become unfeasible, a full 3D SAR scan over a tuned dipole is performed, and the conversion factor adjusted to make the measured 1g and 10g volume-averaged SAR values agree with published targets.

CALIBRATION FACTORS MEASURED FOR PROBE S/N G0006

The probe was calibrated at 5.2, 5.5 and 5.8GHz in liquid samples representing brain and body liquid at these frequencies.

The calibration was for CW signals only, and the axis of the probe was parallel to the direction of propagation of the incident field i.e. end-on to the incident radiation. The axial isotropy of the probe was measured by rotating the probe about its axis in 10 degree steps through 360 degrees in this orientation.

The reference point for the calibration is in the centre of the probe's cross-section at a distance of 1.39 mm from the probe tip in the direction of the probe amplifier. A value of 1.39 mm should be used for the tip to sensor offset distance in the software. The distance of 1.39mm for assembled probes has been confirmed by taking X-ray images of the probe tips (see Figure 4).

It is important that the diode compression point and air factors used in the software are the same as those quoted in the results tables, as these are used to convert the diode output voltages to a SAR value.

CALIBRATION EQUIPMENT

The table on page 20 indicates the calibration status of all test equipment used during probe calibration.