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# Spectrum Sciences Institute RF Dosimetry Research Board

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## Uncertainty Assessment Requirements

### SSI/DRB-TP-D01-035



**PART of SAR Measurements Requirements**

**SSI/DRB-TP-D01-030**

***DRAFT***

***Prepared jointly with:***

***APREL***  
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- NOTICE -

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## 1.0 INTRODUCTION

The purpose of this document is to standardize the assessment of uncertainties associated with the reported peak 1g or 10g for Specific Absorption Rate (SAR) measurements, in accordance with industry standards and practices.

This Standard defines:

- Measurement uncertainty
- Source uncertainty
- Uncertainty of covering the exposure of 80% of the entire user group
- Combined uncertainties

This Standard is part of a Certification Program Methodology as described in a separate document entitled "SSI/DBR TP-D01-030, Specific Absorption Rate (SAR) Standard For Portable Telecommunications Devices, March 1998". SSI/DBR TP-D01-035 contains specific criteria that must be met for SAR certification.

## 2.0 BACKGROUND

Facilities with specific absorption rate (SAR) measurement capabilities are concerned with the measurement of the peak SAR, and the evaluation and expression of the uncertainty of the result of their measurements. The usefulness of measurement results is to a large extent determined by the quality of the statements of uncertainty that accompany them.

Measurement uncertainty reflects the quality/accuracy of a measured result as compared to the true value. Such statements are generally required when stating results of measurements so that it is clear to the user of these measurement results that the results may differ when measurements are performed by different investigators. The differences are largely due the measurement uncertainty of these investigators' instrumentation, measurement technique and even in the standard used to set up the test itself.



## 2.1 Components of SAR Measurement Uncertainty

Typically the overall uncertainty is calculated by identifying uncertainties in the instrumentation chain used in performing each of the procedures associated with the SAR measurement evaluation. Most uncertainties are calculated using the tolerances of the instrumentation used in the measurement, the measurement setup variability, and the technique of the tester in performing the test. Components identified include:

- Phantom (representativeness with respect to the user cross-section, dielectric effects)
- Synthetic tissue (replication of human brain characteristics, uniformity over the test period)
- E-field probe (calibration including isotropy, linearity, spatial resolution, etc.)
- Probe instrumentation (voltage metering and data acquisition, including software)
- Probe placement either manually or via a robot (how well is probe location known)
- Effect of the interaction of the phantom and dielectric solution with the probe
- Interactions of the measurement equipment with the ambient fields
- Portable communication device/dipole orientation (replication of the device near field)
- Extrapolation of the measured SAR to the surface of the phantom
- 1g or 10g averaging procedure

Another component of measurement uncertainty is based on the variability of repeated measurements. This can be used to decrease the measurement uncertainty and since it uses all the components of the measurement chain, individual component uncertainty need not be measured. The disadvantage in this approach is that repeat measurements take time since the complete test setup must be disassembled and reassembled many times to determine the uncertainty.

## 2.2 E-Field Probes

E-field probe measurement uncertainties are produced by several factors. These include the accuracy of the system's calibration under standardized exposure situations, and the deviation of the measurement system's performance from an ideal, linear, isotropic, infinitesimal measurement device.

Calibration of E-field probes is a critical and difficult process that must be done properly to enable useful data to be obtained. There are several methods for performing calibrations. All methods require one to produce a known E-field or SAR in a dielectric material, and place the probe in the known field or SAR. The uncertainty of the accuracy of calibration under standardized exposure situations can be as low as  $\pm 10\%$  if extreme care is taken.

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A very important property of E-field probes is the constant response of a dipole array regardless the orientation of the E-field vector. This parameter is termed isotropicity. Accurate measurement of the total electric field strength at a point in a dielectric medium requires each of the three dipoles in the probe array to have a correct antenna pattern. If the patterns are not precisely correct, large total measurement errors will result, due to the non-isotropic response. The non-isotropic response of commercially available E-field probes has been analyzed and found to range from  $\pm 0.35$  to  $\pm 2.1$  dB for various probes. This depended on the specific design of each probe.

### 2.3 Simulated Tissues

The specific absorption rate (SAR) is directly proportional to the conductivity of the simulated tissue used in the portable communication device evaluation. The conductivity of a particular mixture of simulated tissue can typically be determined with an uncertainty of about 5%.

However, all facilities do not use the same mixture. For example: the 835 MHz brain simulating tissues in use may have conductivity's that range from 0.74 S/m (OET 65 Supplement, C Appendix C, 1997 based on Gabriel 1996) to 1.1 S/m (Hartsgrove et al, 1987). This range has a mid-point of 0.92 S/m with a rectangular spread distribution of  $\pm 20\%$ .

The conductivity of mammalian brain tissue at 835 MHz has been measured by a number of researchers to be around 0.90 S/m. On the assumption that human brain tissue is similar to other mammalian brain tissues, many laboratories are standardizing their simulated tissue formulations so that this conductivity is obtained (see SSI/DRB-TP-D01-033).

### 2.4 Treatment of Uncertainties

Tolerances for the estimation of the accuracy and precision of each of the critical characteristics of the above items are generally readily available. To compute standard uncertainties from tolerances, there is a need to specify the distributions of these tolerances among all the possible values of the values for which the tolerances are specified. For example, if the values are equally likely within the tolerances specified, a rectangular distribution is applied in computing that component standard uncertainty. The most common guidance document for such evaluations is NIS 81, "The Treatment of Uncertainty in EMC Measurements". In this document, common distribution functions are

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identified as well as how to apply them to tolerances and then combining the individual measurement component standard uncertainties to get the combined standard uncertainty.

There then needs to be a level of confidence associated with the combined standard uncertainty. Usually a confidence level of 95% is applied to the combined standard uncertainty yielding an expanded uncertainty. For a normal distribution, this factor is 2, which is multiplied by the standard uncertainty to get the expanded uncertainty.

## 2.5 Conclusion

The uncertainty of the assessed SAR values should be carefully determined following standard procedures for error assessments. The maximum (peak) uncertainty for each of the non-statistical error sources must be determined, as well as the double standard deviation for the statistical error sources (i.e. 95% confidence level).

Although many measurement techniques are being improved, standardized procedures have not yet been established. Therefore, the lowest attainable margin of error for typical measurement systems is directly related to the latest technical developments for SAR evaluation. The total measurement uncertainty of SAR is at best  $\pm 20\%$  for state-of-the-art E-field probe systems in known liquids, but is usually significantly poorer.

Information on SAR measurement uncertainties is relevant to SAR evaluation and should be included in reports to support compliance with SAR exposure limits. Systems that use unreliable techniques or that does not produce repeatable results should not be used to test devices for Industry Canada compliance.



### 3.0 REFERENCES

- "Protocol of the Uncertainty Budget", submitted by Thomas Schmid to IEEE Standards Committee – 34, Subcommittee –2 (Certification of Wireless Handsets), held at Siemens, Richardson, Texas, March 12 & 13, 1998.
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- "Guide to the Expression of Uncertainty in Measurement", ISO, Geneva, Switzerland, 1995.
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- "Determining and Reporting Measurement Uncertainties", RP-12, National Conference of Standards Laboratories, 1 February 1994.
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- "Compilation of the Dielectric Properties of Body Tissues at RF and Microwave Frequencies," C. Gabriel, 1996, Brooks Air Force Technical Report AL/OE-TR-1996-0037.
- "Simulated Biological Materials for electromagnetic Radiation Absorption Studies," G. Hartsgrrove, A. Kraszewski and A. Surowiec, 1987, Bioelectromagnetics, 8, pp. 29-36.



## 4.0 PROCEDURE

The uncertainty budget shall be determined according to the NIS 81 and ISO “Guide to the Expression of Uncertainty in Measurement” documents and described in the following tables.<sup>1</sup> Weighting factors may be introduced where an uncertainty component has a reduced affect on the spatial peak SAR value. This is the case when the evaluation procedure partially compensates for the error or when the setup prevents situations in which an error component gives high values. The applied evaluation technique as well as the basis for the weighting factor shall be given for each component.

### 4.1 Measurement Uncertainty

Uncertainty Description	Error	Distrib.	Weight	Std. Dev.	Offset
<b>Probe Uncertainty</b>					
- axial isotropy			Normal	0.5	
- spherical isotropy			Normal	0.5	
- isotropy from gradient			Normal	0	
- spatial resolution			Normal	1	
- linearity error			Rectang.	1	
- calibration error			Normal	1	
<b>SAR Evaluation Uncertainty</b>					
- data acquisition error			Rectang.	1	
- ELF and RF disturbance			Normal	1	
- conductivity assessment			Rectang.	1	
<b>Spatial Peak SAR Evaluation Uncertainty</b>					
- extrapol + boundary effects			Normal	1	
- probe positioning error			Normal	1	
- integration and cube orient.			Normal	1	
- cube shape inaccuracies			Rectang.	1	
<b>Combined Measurement Uncertainty</b>					

<sup>1</sup> A set of these tables filled out for a Schmid and Partner’s DASY3 SAR measurement system can be found in Attachements



## 4.2 Source Uncertainty

Uncertainty Description	Error	Distrib.	Weight	Std. Dev.	Offset
- device positioning			Normal	1	
- device output power (including power drift, frequency response, etc.)			Normal	?	
- laboratory setup			Normal	1	
<b>Combined Source Uncertainty</b>					

## 4.3 Uncertainty of Covering the Exposure of 80% of the Entire User Group

Uncertainty Description	Error	Distrib.	Weight	Std. Dev.	Offset
- internal anatomy (tissue distribution)					
- shape					
- other influences					
<b>Combined Phantom Uncertainty</b>					

## 4.4 Combined Uncertainties

Uncertainty Description	Uncertainty	Offset
- combined measurement uncertainty		
- combined source uncertainty		
- combined phantom uncertainty		
<b>Combined Uncertainty</b>		
<b>Expanded Uncertainty (K=2)</b>		

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