

# New Advanced Methodology for Near Field Measurements for SAR and Antenna Development.

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**Abstract:** The issue of RF safety has recently come to the forefront of both public and regulatory attention. In 1996, the US FCC released its Report and Order 96-326 [1], which specified the acceptable limits for wireless devices and systems, and tightened the requirements for certification and licensing purposes. In 1998, the Industry Canada department responsible for radio licencing initiated development of certification methodology for compliance with non-ionizing radiation Specific Absorption Rate (SAR) limits established by Health Canada in its Safety Code 6 [2].

The SAR measuring system developed by APREL Laboratories and selected critical components of the system are discussed in this paper.

## INTRODUCTION

The purpose of a SAR measuring system is to provide the ability to measure the electric field inside simulated tissue to determine the RF energy that the tissue is absorbing when exposed to radiation from an RF source. RF exposure is expressed as SAR (Specific Absorption Rate). SAR is calculated from the E-field, measured in a volume grid of test points. SAR is expressed as RF power per kilogram of mass, averaged in 1 cubic centimeter of tissue (brain) or 10 cm<sup>3</sup> (hand). Current measurement practice (see Figures 1 & 2) involves E-field measurement with a small isotropic probe (output voltage proportional to E<sup>2</sup>). The probe is moved precisely from one point to next by a robot (typically 1 cm increments for area scans, 0.2-0.5 cm increments for final zoom measurements, and 0.25 cm or less for depth profiles required for extrapolation). The probe travels in a homogeneous liquid simulating brain or muscle tissue. The liquid is contained in a manikin simulating a human head and, in some systems, a torso or hand.

In Canada, the SAR measurement system elements and methodology are described in the following series of documents [3]:

SAR Measurements	SSI/DRB-TP-D01-030
Phantom Design Requirements	SSI/DRB-TP-D01-031
Probe Design & Calibration Requirements	SSI/DRB-TP-D01-032
Tissue Recipe & Calibration Requirements	SSI/DRB-TP-D01-033
Positioning and Scanning Requirements	SSI/DRB-TP-D01-034
Uncertainty assessment requirements	SSI/DRB-TP-D01-035

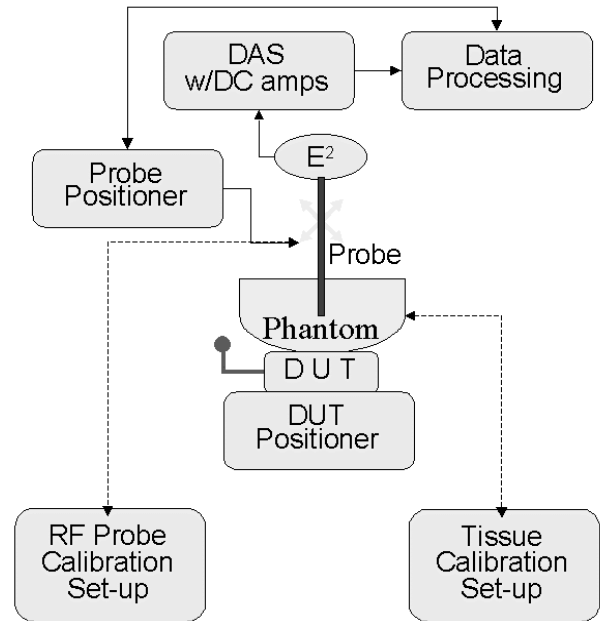


Figure 1. SAR Measurement System Schematic

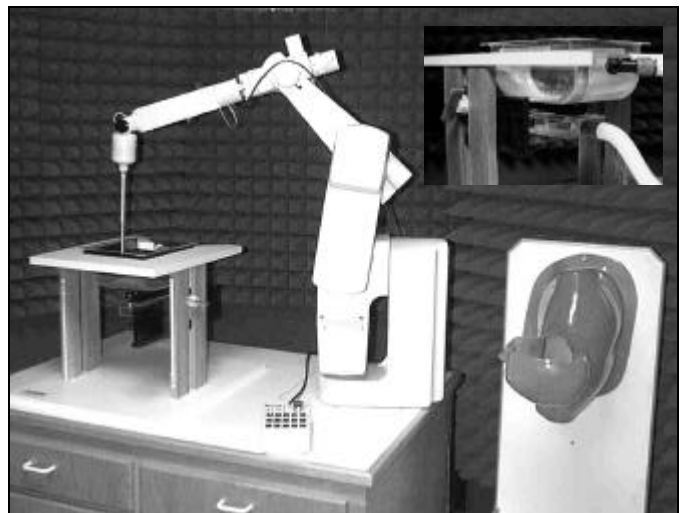


Figure 2. Photograph of a SAR Measurement System

**SYSTEM MEASUREMENT UNCERTAINTY**

The uncertainty of SAR measurements is a result of uncertainties of individual system components and the uncertainty in scan processing. The total uncertainty can be traced to the following: isotropic probe response, probe calibration, tissue properties, phantom shape, test sample position, and scan and data acquisition system. The phantom shape and position as well as probe calibration are the main contributors to the overall uncertainty.

**PHANTOM**

**Background**

A phantom is a device that simulates the size, contours and electrical characteristics of human tissue at normal body temperature. It is composed of a manikin (solid shell) and a tissue-equivalent liquid synthetic material solution.

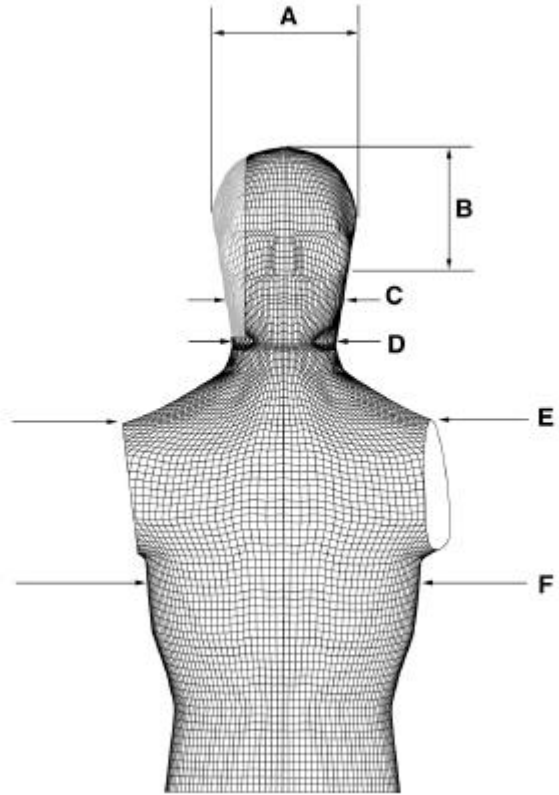
Traditional manikins (see lower right of Figure 2) are rich in features representing eyes, nose, etc. which makes them visually humanlike. The consequence of this complexity is increased uncertainty in the positioning of a test sample against the outer surface of this manikin and locating the bottom of the simulated tissue with a probe.

**Novel Phantom Design**

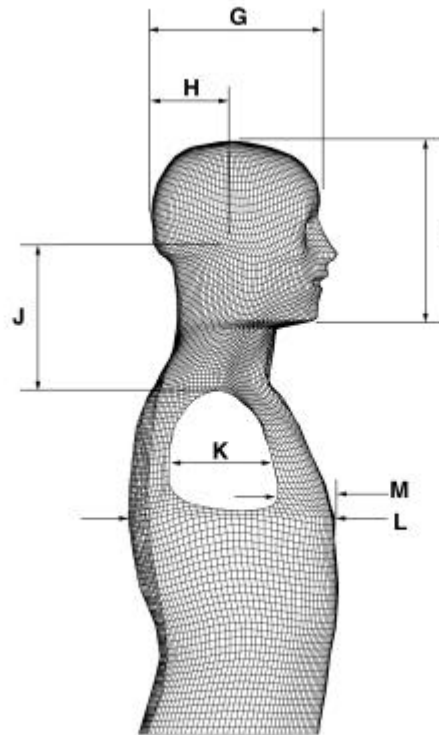
IEC 959, "Provisional head and torso simulator for acoustic measurements of air conduction hearing aids" [4], tabulates standard ergonomic data for the human head and torso. The principle dimensions of the head and torso simulator are listed in Table 1 and are shown in Figure 3 and 4.

Letter	Characteristic	Dimension (mm)
A	Head breadth	152
B	Head height	125
C	Bitragion diameter	143
D	Neck diameter	113
E	Shoulder breadth	440
F	Chest breadth	282
G	Head length	191
H	Tragion to occipital wall	97
I	Chin-vertex length	224
J	Tragion to shoulder	175
K	Shoulder depth	110
L	Chest depth	235
M	Shoulder position	80

**Table 1. Principle Dimensions of the Head and Torso.**



**Figure 3. Frontal View of Human Head and Torso.**



**Figure 4. Right Side View of Human Head and Torso.**



This is an adequate representation of the coupling between the source generating RF energy (e.g. handset) and the tissue in which absorbed RF energy is measured. However, it is important that, in addition to shape, the depth of tissue used in not introducing errors. Figure 6 shows that a shallow phantom may over- or under-estimate SAR. The appropriate depth required for 835MHz SAR measurement is at least 8cm.

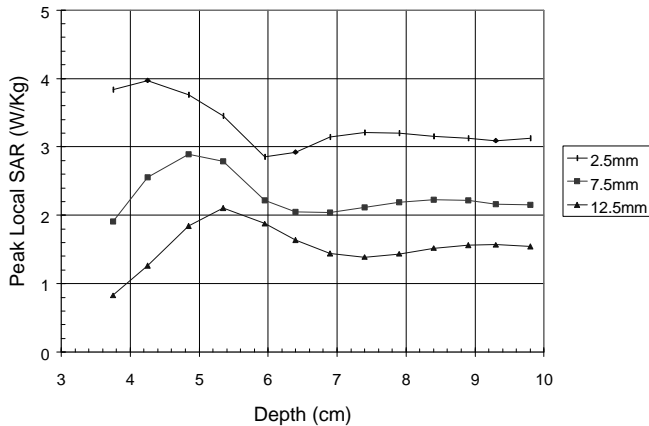


Figure 6. Effect of Liquid Depth on Peak Local SAR

SYSTEM APPLICATION AND PROBE DESIGN AND CALIBRATION

The miniature isotropic electric field probe is a three-channel device used to measure RF electric fields. The sensors are three mutually orthogonal dipoles, each 2.5 mm or less in length. For each channel of the probe, the dipole and two high-impedance lines are deposited on a planar substrate. The center of the dipole is a microwave diode. The substrates are assembled to form a beam. The probe is enclosed in a protective sleeve to avoid contact with the simulated tissue. Figure 9 shows three configurations of the probe dipoles found in today's dosimetry systems. The probe does not perturb significantly the field being measured. It is isotropic so that no matter how the probe is positioned relative to the electric field, the sum of the outputs of the three channels always gives the same value.

The SAR measuring system is a perfect tool to assist in the development of small antennas. An X-Y-Z probe allows the direction of individual E-field vectors to be identified.

Free space calibration of E-field probes is typically performed using a TEM cell (Figure 10), waveguide or a reference dipole. An example of the resulting graphs for a triangular probe configuration is shown in bottom of Figure 9. This data is the basis for determining the sensitivity of the individual sensors and the isotropy of the probe in air. Additional calibration is required with the probe immersed in tissue simulation (Figure 11) to determine the tissue enhancement factor (alternatively known as the conversion factor) and the isotropy in the liquid.

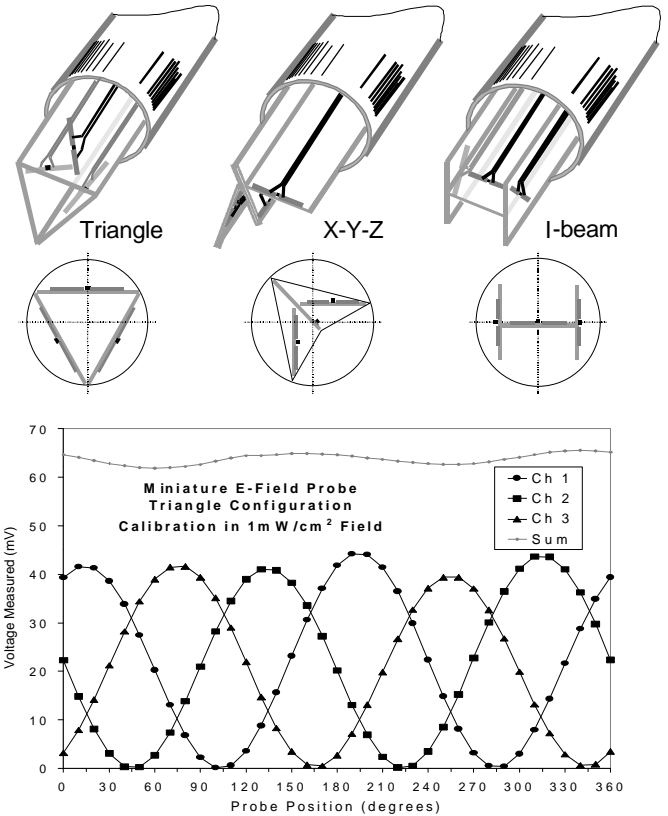


Figure 9. Miniature Orthogonal RF Probe Constructions and Typical Calibration of the Triangular Configuration.

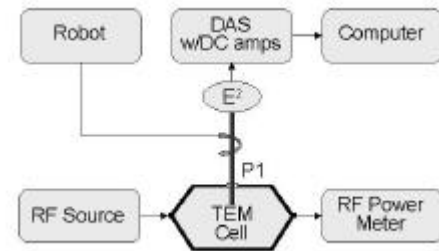


Figure 10. Air Calibration of Probe.

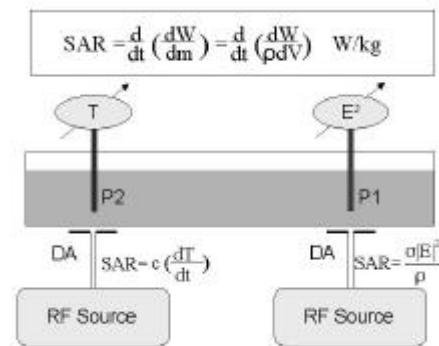


Figure 11. Liquid Calibration of Probe.

## CONCLUSION

The head simulator is an engineering tool. It allows repeatable measurements to be performed with devices in various positions in relation to the head, which electrically loads the RF source, as well as to evaluate the impact of the hand on the performance of handheld devices, and to measure the SAR levels in the hand. This engineering head and hand simulation is a significant departure from previous models of anthropomorphic phantoms used in research, and should allow better repeatability in testing.

## REFERENCES

- [1] FCC 96-326, "Guidelines for evaluating the environmental effects of radiofrequency radiation," Federal Communication Commission, Washington, DC, Aug. 1996.
- [2] Proposed Revision of Safety Code 6, Health Canada, Ottawa, ON, July 1997.
- [3] Wojcik, J.J. and Cardinal, P.G., "Development of Certification Methodology for Compliance with Non-ionizing Radiation Specific Absorption Rate (SAR) Limits Established by Health Canada", Nepean, ON, Mar. 1998.
- [4] IEC 959, "Provisional head and torso simulator for acoustic measurements of air conduction hearing aids," International Electrotechnical Commission, 1990-04.
- [5] Tilley, A.R. and Dreyfuss, H., *The Measure of Man and Woman: Human Factors in Design*, Watson-Guptill, 1993.
- [6] Wojcik, J., "Oreille externe humaine moyenne pour l'etalonnage des ecouteurs circumauraux", *Electroacoustique*, Bulletin du Laboratoire d'Electroacoustique (Institut Montefiore), Université de Liège, N° 23, Déc. 1973.