Spectrum Sciences Institute
RF Dosimetry Research Board

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PHANTOM DEFINITION

Contribution to IEEE SCC34 SC2 WG 1
to facilitate preparation of Section 2 and 4.

DRAFT

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- NOTICE -

This draft was prepared to assist the IEEE SCC34 SC2 and specifically the Working Group on SAR Measurements. It is submitted as a basis for discussion only, and is not binding on APREL Inc. Subsequent study may lead to revisions of the document, both in numerical values and/or form, and after continuing study and analysis, APREL Inc. specifically reserves the right to add to, or amend the content of this contribution.

Phantom definition

Introduction

Recent experiences with measurements of SAR by various technical entities indicate that the variations in phantom design are one of the major contributors to uncertainties in intra-laboratory comparisons. In reviewing all current and previously published documentation, it is evident that the phantoms used by various laboratories are not based on a common definition for this test instrument and where such definition exists it is not clearly defined. This contribution attempts to fill this gap.

This contribution consist of four sections:

Section A. gathers facts about RF propagation and measurements
Section B. lists basic components of phantom definition
Section C. provides a list of additional characteristics for a standard phantom
Section D. is a tool for discussion to facilitate the selection of one standard phantom

A. Technical facts about RF propagation and SAR measurements within human tissue.

1. The human body, and especially the human head, consists of several tissues, each having different electrical characteristics and forming complex-shaped boundaries with respect to each other.

2. All human tissues have electrical characteristics that are very different from the normal propagation medium (air); but not so different (in relative terms) between each other. At the radio frequencies used by today's handset technologies (up to 2.4 GHz), the dielectric constant is in the range of 40 plus and conductivity is around 1 S/m. (Air and vacuum have a dielectric constant equal to 1 and air conductivity, in dry and clean condition is zero).

3. Multiple tissues may be simulated by one homogeneous liquid whose electrical characteristics match those of the tissue that is of most interest (e.g. brain in case of the head). Use of a homogeneous material contained in one volume for simulating the head and other parts of the body, has been agreed on by the IEEE SCC 34 SC 2.

   N.B.: The FDA introduced a single homogeneous bath contained in a simple parallelepipedic volume (i.e. flat phantom) to simulate complex, multiple body tissues for EMI evaluations of pacemakers; this simulation has been used by the industry for many years.

4. In the near field the E-vector and H-vector are not proportionally related as it is in the far field, where electromagnetic waves propagate. In the case of a handset or a similar device operating in proximity of the human body, there is very little radiated E-field energy absorbed by the tissue and most of the absorbed energy is induced by a radio frequency (RF) current coupling mechanism. An RF current inducing energy in the medium causes "SAR".

5. The antenna's RF current induces an RF field in the tissue simulating medium. This field strongly decreases with increasing distance between the source (radiator or radiating structure) and boundary.

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6. RF absorption (SAR) occurs as a result of RF induction at the boundary of the tissue. Peak absorption is determined by averaging over a specified volume corresponding to the "worst case" scenario. The radiator currents in areas comparable to the "averaging dimensions" are the most significant in contributing to the peak absorption. Coupling in other areas may have only secondary and not significant effects on SAR readings especially when the distance of the high RF current is close to the tissue boundary of interest.

7. In the case of a radiating structure coupled with conducting tissue for maximum SAR, the RF E-field generated at the tissue boundary propagates in the direction normal to the boundary and consequently, the E-field vector in the simulated tissue is in a plane parallel to the boundary.

8. Isotropy of the probe should make the reading independent of the direction of the E-vector. Probe uncertainty depends on the direction of the E-field vector relative to the axis of the probe. Isotropy is better in the plane perpendicular to the probe axis and poor in the plane passing through the probe axis. This means that if the probe is perpendicular to the tissue boundary, the measuring uncertainty is minimized.

9. A handset pressed against the skin will always cause the boundary to conform to the shape of the handset which is essentially flat. V-shaped handsets should be capable of being open for test to make both parts stay on one surface.

B. Definition of an engineering model of the phantom

1. The phantom shall be a dielectric shell containing simulated tissue.

2. The phantom shall be an engineering representation of the human: (a) head, (b) body.

3. The phantom shall allow repeatable measurements of RF energy absorbed by the tissue of interest in a typical "worst case" coupling scenario. The phantom shall facilitate reproducible detection of the highest RF current present in the radiator consisting of an antenna and handset (transmitter) structure.

4. Only statistically significant features, from an RF coupling point of view, shall be simulated. Statistically non-significant features should not be replicated in the phantom.

5. The phantom shall realistically represent body features responsible for coupling between the RF source's current carrying elements and the tissue under examination.

6. The boundary shall be flat with the exception of the curvatures representing the areas where the radiator is never closely coupled to the tissue (e.g. upper part of the head and the chin).

7. In the location of the highest SAR within the phantom, the depth of the simulated tissue shall be 10 ± 1 cm.

8. The phantom model selected as the standard for engineering SAR evaluation shall be describable by technical drawings and easily reproducible from such drawings.

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C. Additional desirable characteristics of the phantom

1. Since E-M fields within the phantom propagate normal to the boundary, a probe, close to a position of maximum SAR, should have its axis in normal orientation to the boundary of tissue to minimize the uncertainty resulting from axial non-isotropy.

2. The shape of the phantom should allow easy, unmistakable and repeatable coupling between the tissue boundary and the handset part carrying maximum RF current. This should be achieved without resorting to a search for a maximal coupling position as is proposed in some standards (e.g. CENELEC, ARIB & FCC's guidelines for left/right ear).

3. It is desirable to have a multifunction phantom that can double as a head phantom, with or without a hand simulation, and a body phantom.

4. The calibration (validation) of the system should be performed under the same conditions as a measurement is performed with an actual measurement set-up. This will allow the simple transfer of uncertainties from "primary instruments" (i.e. power meter, attenuator, RF load, mass, distance), thus avoiding the summation of uncertainties, several of which are outside the direct control of SAR experimenters.

5. It is desirable to have a single easily reproducible phantom design for all technical entities involved in the certification for SAR.

D. Present phantom configurations

Flat phantom
A variety of flat phantoms are being used to represent other parts of the human body than the head, for SAR measurements. They are also used for experimental setup verification and probe calibration. The size and materials of these phantoms are not currently specified. Setups are easy and repeatable.

Spherical phantom
This phantom could only be used as a head simulation (e.g. for correlation with computed SAR) although it misrepresents its shape. The human head has flat parts such as the cheek side of head. Setups are tricky and not easily reproducible.

Human-like phantoms
There are two different kinds of human-like phantoms, first the human-head phantom and second human-torso phantom. The biggest problem with this phantom is the large variety of models and their different sizes and shapes including different features. Setups are challenging and not easily reproducible.

Combination of canonical shapes - Universal Head phantom
This phantom is engineered from standardized ergonomic human head data. It can be used as a head or a body simulator thanks to its flat part. The curved areas are a representation of the upper head (above the ear) and the chin. This shape is easily reproducible from technical drawings. Setups are easy and repeatable.
(For phantom design and positioning requirements refer to draft standards SSI/DRB TP-D 01-031 and SSI/DRB TP-D 01-034).

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E. Example of analysis of alternatives

The ranking tables can be used as a tool in the evaluation of the different phantom configurations. The ranking below (scale 0-10) is a guideline only and should encourage discussion.

Phantom type \ criterion	B1	B2a	B2b	B3	B4	B5	B6	B7	B8	**Total**
Flat phantom	10	5	10	10	5	5	2	N/A	10	**57**
Spherical phantom	10	3	0	3	2	5	1	N/A	10	**34**
Human-like head phantom	10	7	0	7	4	6	4	N/A	2	**40**
Combination of canonical shapes (e.g. Universal Head)	10	10	10	10	10	10	10	N/A	10	**80**

Phantom type \ criterion	C1	C2	C3	C4	C5	**Total**
Flat phantom	8	10	5	10	10	**43**
Spherical phantom	5	3	2	2	10	**22**
Human-like head phantom	4	5	4	1	2	**16**
Combination of canonical shapes (e.g. Universal Head)	9	10	10	10	10	**49**

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