The Uncertainties and Repeatability Limitations of Transmitter and Receiver Performance Assessments Posed by Head Phantoms

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INTRODUCTION

Standards for assessing performance in mobile test laboratories are being developed to minimize costly non-standardized field measurements. The US-based Cellular Telecommunications & Internet Association (CTIA) is the only organization that has issued a mandatory standard for over-the-air performance tests [1]. The basis of the test is measurement of the 3-D radiation pattern in order to obtain the magnitude and direction of radiating energy while the phone is mounted on a head phantom in a talking position. The key parameters are:

- the total radiated power (TRP),
- the peak effective isotropic radiated power (EIRP),
- the antenna efficiency,
- the antenna gain and
- the near-horizontal partial radiated power (NHRP+/-30°'a1, NHRP+/-45°'a1).
- the phone must be compliant with the electromagnetic safety limits, e.g., [2].

OBJECTIVES

The objectives of this paper are to determine the effect of various parameters such as shell thickness as well as neck and phone position on the endpoints TRP, NHRP, efficiency and peak spatial SAR.

HEAD PHANTOMS

To determine the sensitivity of different parameters, six different numerical phantoms were developed for this study:

SAM 1 (CTIA): The CTIA phantom [1] as defined by the IEEE Standards Coordinating Committee 34 [2]. The head was extended below the neck region according to the data given in CENELEC EN50361:2001 [3] to obtain an overall height of 300 mm.

Figure 1: SAM1

SAM 2: SAM V4.5 was developed prior to the definition of CTIA. It extended the neck differently and integrated a phone holder allowing precise positioning of the phone at the head. The rationale for these measures were the following: 1) the neck was extended such that air bubbles would not affect the measurements and 2) the holder was developed to minimize positioning uncertainties, since positioning error was assumed to be one of the major sources of uncertainties.

SAM 3: Equivalent to SAM 2 but without holder.

SAM 4 / SAM 5: Same as SAM 1 but filled with different tissue simulating liquids (*SAM 4* with permittivity +5% and conductivity -5%; *SAM 5* with permittivity -5% and conductivity +5%).

SAM 6: Same as SAM 1 but with shell thickness reduced by 1mm.

METHOD

The evaluation was conducted using SEMCAD X (www.SEMCAD.com). The tool allows the simulation of highly detailed CAD based commercial phones [4], [5], [6]. The uncertainty for differences in radiation pattern including the positioning uncertainty is estimated to be less than 0.1dB and thus considerably better than for measurements.

The differences of SAM 1–6 was tested by comparing the all relevant parameters of three commerical phones:

- Motorola T250
- Motorola V180
- Nokia 8310

In addition, the positioning uncertainty was evaluated by rotating the phone by 2° and 5° away from the phantom, and by horizontal shift of 10 mm up and down along the reference line connecting ear and mouth.

RESULTS

The results are shown in Figure 4 and Tables 1, 2 and 4 und the uncertainty budget is summarized in Table 3.

(a) (b) (c)

Figure 1: SEMCAD X models of the commercial phones used in this study: (a) candy bar phone ith helix antenna, (b) clam shell phone with helix antenna and (c) a candy bar phone with internal PIFA antenna

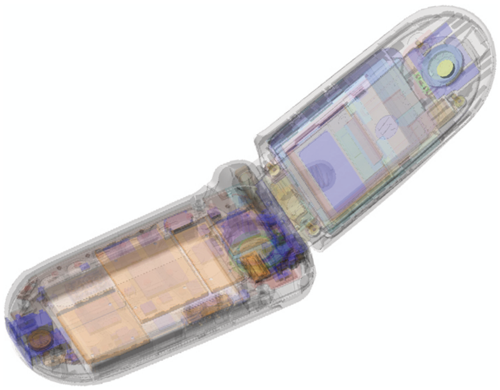

Figure 2: Detailed CAD model of clam shell phone in SEMCAD X consisting of >1'000 distinguished CAD parts

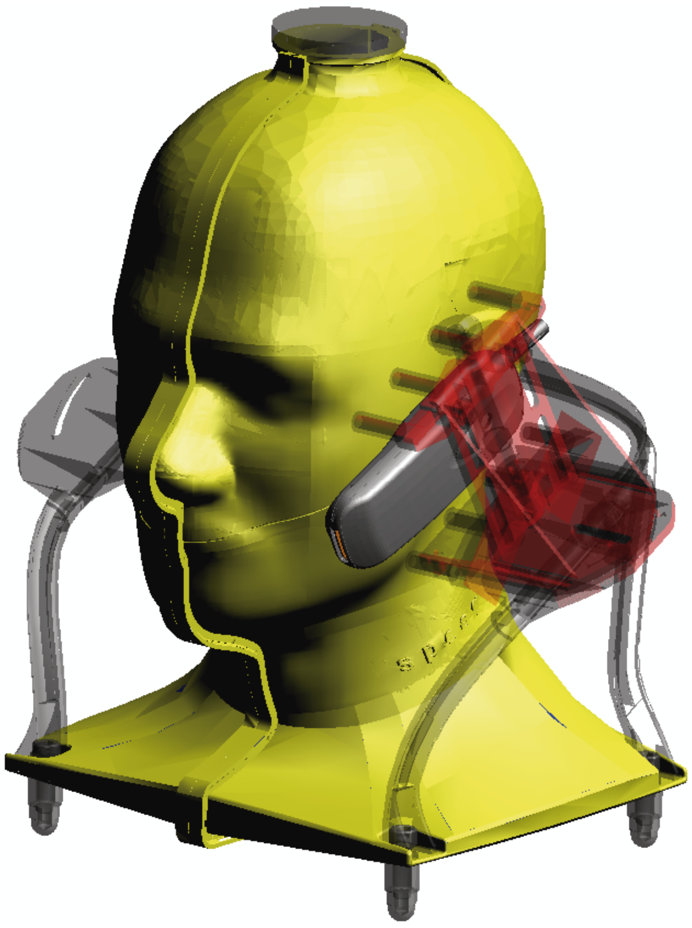

Figure 3: SAM V4.5 (SPEAG) including mounted bar-type mobile phone in SEMCAD□X CAD and modeling environment

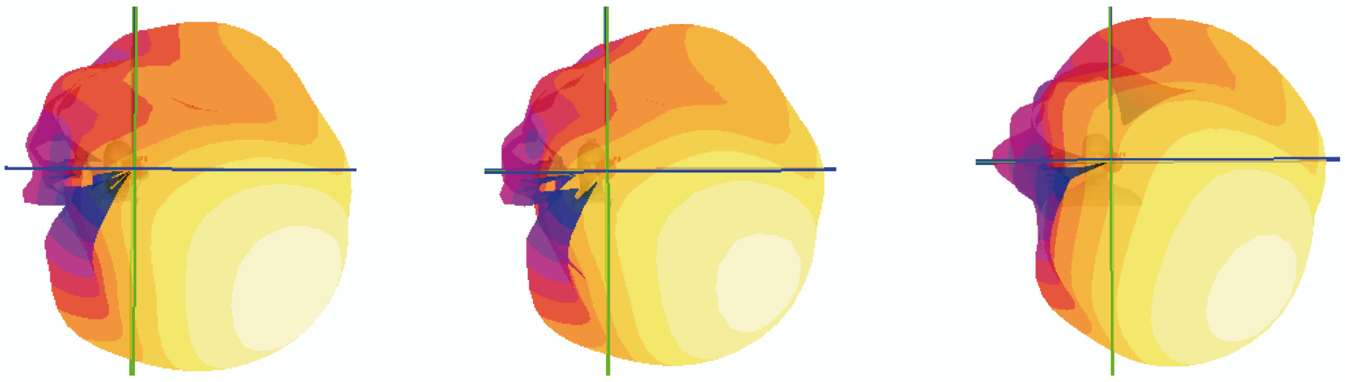

Figure 4: Three-dimensional radiation pattern of the candy bar phone with helical antenna next to SAM1-SAM3 (left to right)

(902 MHz)	**SAM 1**	**SAM 2**	**SAM 3**	**Diff. SAM 2–SAM 1**	**Diff. SAM 3–SAM 1**	**Diff. SAM 3–SAM 2**
TRP	21.52 dBm	21.65 dBm	21.51 dBm	0.13 dB	-0.02 dB	-0.14 dB
NHPRP±45°	20.41 dBm	20.73 dBm	20.58 dBm	0.32 dB	0.17 dB	-0.15 dB
NHPRP±30°	19.14 dBm	19.55 dBm	19.40 dBm	0.41 dB	0.26 dB	-0.15 dB
Av. SAR	0.924 W/kg	0.921 W/kg	0.929 W/kg	-0.01 dB	0.03 dB	0.04 dB
(1747 MHz)						
TRP	25.11 dBm	25.02 dBm	24.85 dBm	-0.09 dB	-0.26 dB	-0.17 dB
NHPRP±45°	23.97 dBm	23.96 dBm	23.92 dBm	-0.01 dB	-0.05 dB	-0.04 dB
NHPRP±30°	22.62 dBm	22.58 dBm	22.65 dBm	-0.04 dB	0.03 dB	0.07 dB
Av. SAR	1.053 W/kg	1.041 W/kg	1.064 W/kg	-0.05 dB	0.04 dB	0.09 dB

Table 1: The candy bar phone with helix antenna: TRP, NHPRP and 1g Averaged SAR Values

	SAM 1		**SAM V4.5**	
Neck (k=1)	negligible	0 dB	eqv. SAM 3	0.25 dB
Neck + holder (k=1)	n.a.		eqv. SAM 2	0.1 dB
Phone positioning (k=1)	2.5°/5mm	0.47 dB	1°/2mm	0.2 dB
Rim in the middle of the head	n.a.			0 dB
Shell thickness (k=1)	+/-0.2mm	0.02 dB	+/-0.2mm	0.02 dB
Liquid (k=1)	+/-5%	0.06 dB	+/-5%	0.06 dB
Total uncertainty (k=1)		0.5 dB		0.35 dB
Total uncertainty (k=2)		**1.0 dB**	eqv. SAM 2	**0.7 dB**

Table 3: Uncertainty assessment of the head phantom (this table does not address the uncertainty of air bubbles and deformations for horizontal head mounting)

CONCLUSIONS

Head-related uncertainties are dominated by:

- positioning uncertainty
- head deformations due to stability issues
- distortions from air-bubbles for horizontal head configurations

The study has shown that the neck region has relatively little effect. Positioners can be constructed such that the uncertainty introduced by the holder is much smaller than the uncertainty reduction by more accurate and reproducible positioning. Other low loss dielectric add-ons at the head can be neglected at sufficient distances. Thus, these elements can be used to limit the uncertainties caused by positioning, stability and air bubbles.

Head phantoms contribute between 0.7 – 1 dB (k=2) to the overall uncertainty budget.

(902 MHz)	**SAM 1**	**SAM 2**	**SAM 3**	**Diff. SAM 2–SAM 1**	**Diff. SAM 3–SAM 1**	**Diff. SAM 3–SAM 2**
TRP	21.50 dBm	21.29 dBm	21.20 dBm	-0.21 dB	-0.30 dB	-0.09 dB
NHPRP±45°	20.07 dBm	20.19 dBm	20.09 dBm	0.12 dB	0.02 dB	-0.10 dB
NHPRP±30°	18.66 dBm	18.86 dBm	18.75 dBm	0.20 dB	0.09 dB	-0.11 dB
Av. SAR	1.222 W/kg	1.169 W/kg	1.141 W/kg	-0.19 dB	-0.30 dB	-0.10 dB
(1747 MHz)						
TRP	24.72 dBm	24.54 dBm	24.54 dBm	-0.18 dB	-0.18 dB	-0.00 dB
NHPRP±45°	23.52 dBm	23.56 dBm	23.55 dBm	0.05 dB	0.04 dB	-0.01 dB
NHPRP±30°	22.10 dBm	22.18 dBm	22.19 dBm	0.08 dB	0.09 dB	0.01 dB
Av. SAR	0.370 W/kg	0.386 W/kg	0.387 W/kg	0.18 dB	0.19 dB	-0.01 dB

Table 2: The candy bar phone with internal PIFA antenna: TRP, NHPRP and 1g Averaged SAR Values

(1747 MHz)	**SAM 1**	**SAM 2**	**SAM 3**	**Diff. SAM 2–SAM 1**	**Diff. SAM 3–SAM 1**	**Diff. SAM 3–SAM 2**
TRP	25.76 dBm	25.67 dBm	25.55 dBm	-0.09 dB	-0.21 dB	-0.12 dB
NHPRP±45°	24.11 dBm	24.34 dBm	24.21 dBm	0.23 dB	0.10 dB	-0.13 dB
NHPRP±30°	22.61 dBm	22.86 dBm	22.74 dBm	0.25 dB	0.13 dB	-0.12 dB
Av. SAR	0.664 W/kg	0.674 W/kg	0.695 W/kg	0.07 dB	0.20 dB	0.14 dB

Table 4: The clam shell phone with helix antenna: TRP, NHPRP and 1g averaged SAR Values

REFERENCES

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[6] Case Study: Nokia 8310, IT'IS Project Report, May 2003.