Three-dimensional Electromagnetic Models of the Human Eyes for Specific Absorption Rate Evaluation

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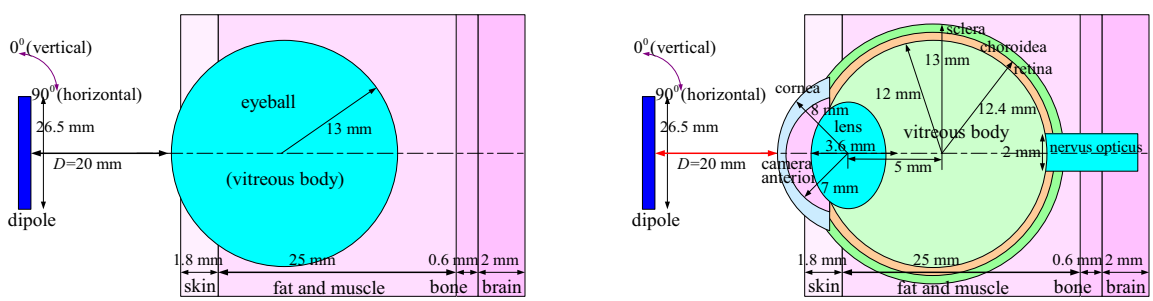
We study the effects in the human eye due to radio-frequency (RF) radiation from handheld devices. The eye is known to be particularly vulnerable to heating by RF energy because of the relative lack of blood flow dissipating the excess heat. The quantity used to characterize the heat absorption is the specific absorption rate (SAR). Regulatory bodies have set exposure limits for the SAR in the eye (IEEE C95.1-2005, ICNIRP 1998). The limit for the average SAR over 10 grams of tissue is 2 W/kg in the frequency range from 0.5 to 3.5 GHz.

We have built two electromagnetic simulation eye models shown in Fig. 1 (a) and (b). The simplified model in Fig. 1 (a) reduces the eye model to a spherical vitreous body and layers of skin, fat, bone and brain. The detailed model in Fig. 1 (b) takes into consideration more eye tissues, such as cornea, lens, sclera, etc. The dielectric properties of the eye tissues are available from (C. Gabriel, RFR Division, 1996).

We calculate the maximum SAR in the two eye models through HFSS simulations. The dipole antenna is excited at the frequency of 1.8 GHz with power of 10 mW. The distance *D* from the surface of the eye to the center of the dipole is varying from 20 mm, 40 mm, 80 mm to 160 mm. The SAR is averaged over 1 g of tissue in order to capture local effects. The maximum SARs in both eye models are listed in Table I. Overall, the difference between the simplified and the detailed eye models are no more than 15 %. We note that the maximum SAR value is consistently higher in the simplified model as opposed to the detailed model. This is due to the fact that resonant modes are supported by the simple spherical structure (Liu, URSI 2008) while they are suppressed in the detailed model by the tissue heterogeneities. Thus, the simplified model is suitable for worst-case scenario studies. In particular, we use the simplified eye model to validate novel semi-analytical methods for the estimation of the maximum SAR in the eye (Liu, URSI 2008) as well as the related measurement approaches and eye phantoms.



(a) (b)

Fig. 1. The two eye models with a dipole antenna: (a) simplified eye model, (b) detailed eye model.

TABLE I
COMPARISON OF MAXIMUM SAR (W/KG) BETWEEN TWO EYE MODELS

Frequency: 1.8 GHz	Distances (mm)			
	20	40	80	160
Simplified Eye Model Simulation	2.28	5.04e-1	1.04e-1	2.12e-2
Detailed Eye Model Simulation	2.00	4.35e-1	0.95e-1	1.87e-2
Difference %	14.0	15.0	9.0	13.3