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Computed WEASAR and absorbed power density in the human eye in response to a smart contact lens

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This paper presents a numerical study of radio-frequency (RF) electromagnetic exposure of the eye tissue with and without a smart contact lens when exposed to a dipole at 2.4 GHz and 60 GHz. At 2.4 GHz, with an input power of 1W, whole-eye averaged specific absorption rate (WEASAR) increases from 18 W/kg to 43 W/kg when the distance between the eye tissue and dipole is varied from 5mm to 1mm respectively. For the 60 GHz model, peak spatial average absorbed power density is calculated for an input power of 10 dBm with peak value of 75 W/m^{2}at d/λ=0.1. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines for general public and occupational exposure are met for distances ≥ λ/5 and ≥ λ/10 respectively.

Introduction

A smart contact lens is a contact lens with integrated electronics providing sensing, actuation and wireless communication functionality [1][2], comprising electronic components, such as: electro-optical module, RF antenna, power solutions and micro controller. It is a medical solution that aims to improve the well-being of the patient[3].

The eye is a vital body part and is of particular interest in exposure assessment. RF electromagnetic exposure of the eye has been studied previously [4][5][6][7] but to the best of the author's knowledge exposure assessment of the human eye with a smart contact lens on the eye has not been investigated at both sub-6 GHz and 60 GHz frequencies. In the smart contact lens setup, the coil is on the eye, which requires the characterization of the induced exposure in the human eye. This paper presents a comparison of WEASAR, SAR, and absorbed power density values with and without smart contact lens on the eye tissue at 2.4 GHz and 60 GHz .

Materials and Methods

A smart contact lens can be wirelessly recharged using near-field communication (NFC). For this purpose two NFC coils made of perfect electric conducting (PEC) material have been embedded in the soft material of the smart contact lens. The inner and outer coils have a total length of 25 mm and 37 mm respectively. To assess the induced RF electromagnetic fields in the human eye, two scenarios have been considered: in the first case, the dipole is placed near the eye (Figure 1(a)) whereas in the second model, a contact lens with embedded NFC coils is placed on the eye and then positioned in front of the dipole (Figure 1(b)). The eye is modelled as a sphere of aqueous humor as with a diameter of 24 mm [4], it represents the largest part of the human eye. At 2.4 GHz the electrical conductivity of the eye tissue is 3.41 S/m and has a relative permittivity of 66.31. A half wavelength dipole has been designed at 2.4 GHz, where the length of each arm is 26.5 mm and the radius of each arm is 0.5 mm. The spacing between the arms is 1 mm. The same eye-dipole and eye-lens-dipole models have been designed at 60 GHz. Each arm length and radius of the half wave dipole is 1.05 mm and 0.05 mm respectively with a spacing of 0.05 mm between the two dipole arms. At 60 GHz eye tissue has an electrical conductivity of 65.758 S/m and relative permittivity of 14.18.

Results

When the dipole is placed in front of the eye, all the local tissues will be exposed to EM radiation. To understand the effect of these radiations on the eye and to have simplicity in the design, the eye is represented by its largest tissue(aqueous humor). The dipoles have been dimensioned to operate in the frequency range of interest. The reflection coefficients of the two dipoles in the stand-alone scenario and then at very small distances (1mm to 5mm) from the eye are determined. The -10 dB impedance bandwidth for the 2.4 GHz model ranges from 2.28 GHz to 2.69 GHz and from 53 GHz to 68 GHz for the 60 GHz dipole as the distance between the dipole and the eye tissue is varied from 1mm to 5mm.

We want to quantify the absorption in the eye and because the volume of the eye approximates 10g, we selected the entire volume of the eye as the averaging volume. The whole eye averaged SAR (WEASAR) is defined as SAR averaged over the entire eye[7]. It is the ratio of total dielectric loss and total mass. As mentioned above, a smart contact lens would require one node on the eye. Therefore, it is imperative to study induced RF electromagnetic fields due to the presence of this node.

Figure 2 shows a comparison of the WEASAR values with and without the lens for the 2.4 GHz dipole-lens-eye model. We observe slightly lower WEASAR values at 2.4 GHz when the smart contact lens is added on the eye surface. For example, at a distance of 5mm between the eye and dipole, WEASAR values are 20.5 W/kg and 22 W/kg with and without the smart lens respectively. The NFC coils embedded in the smart lens are now partly screening the EM radiation and therefore not all the radiations from the dipole can pass through to the eye tissue. Therefore the whole eye averaged SAR reduces.

Within the >6 to 300 GHz range, electromagnetic field energy is deposited predominantly in superficial tissues. Therefore for the 60 GHz model absorbed power density is assessed as recommended by ICNIRP [8] . Figure 3 shows the peak spatial average absorbed power density as a function of d/λ (λ is the free space wavelength) for both the dipole-eye and dipole-lens-eye models at 60 GHz with a transmit power of 10 dBm. Lower power density values are observed when the smart lens is added to the eye tissue due to the partial screening of the EM radiation by the NFC coils. For 60 GHz power density exposure limits defined by ICNIRP are 200 W/m^2 for occupational exposure and 40 W/m^2 for general public [8]. It can be seen from Figure 3 that for occupational people the power density is within the ICNIRP limits up to d/λ>=0.1, whereas for general public d/λ>=0.2 satisfies the ICNIRP power density limits.

Conclusions

The goal of this study was to assess the RF electromagnetic field exposure for eye tissue when a smart contact lens is placed on the eye surface for 2.4 GHz and 60 GHz models. The partial screening from the NFC coils embedded in the contact lens cause a reduction of 6.04% and 9% in the values of WEASAR and absorbed power density respectively. When compared with the ICNIRP guidelines, it is noted that we are within the absorbed power density limits for occupational people when d/λ>=0.1 whereas for general public d/λ>=0.2 satisfies the ICNIRP power density limits.

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Figures

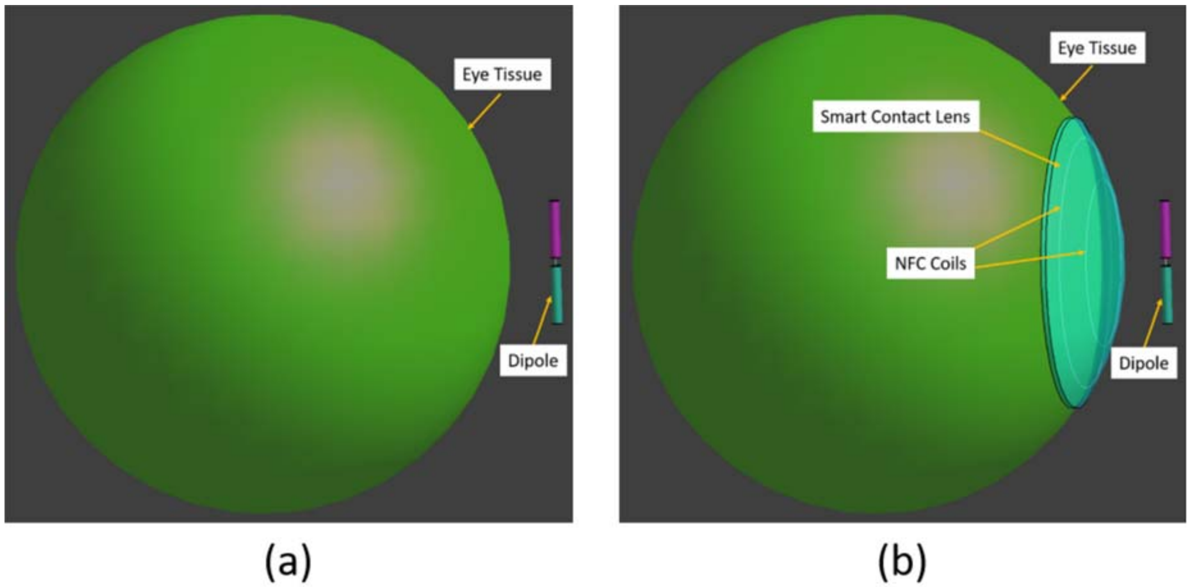

Figure 1. **(a) Model 1: Dipole in front of Eye Tissue (b) Model 2: Dipole in front of Smart Contact Lens on Eye Surface**

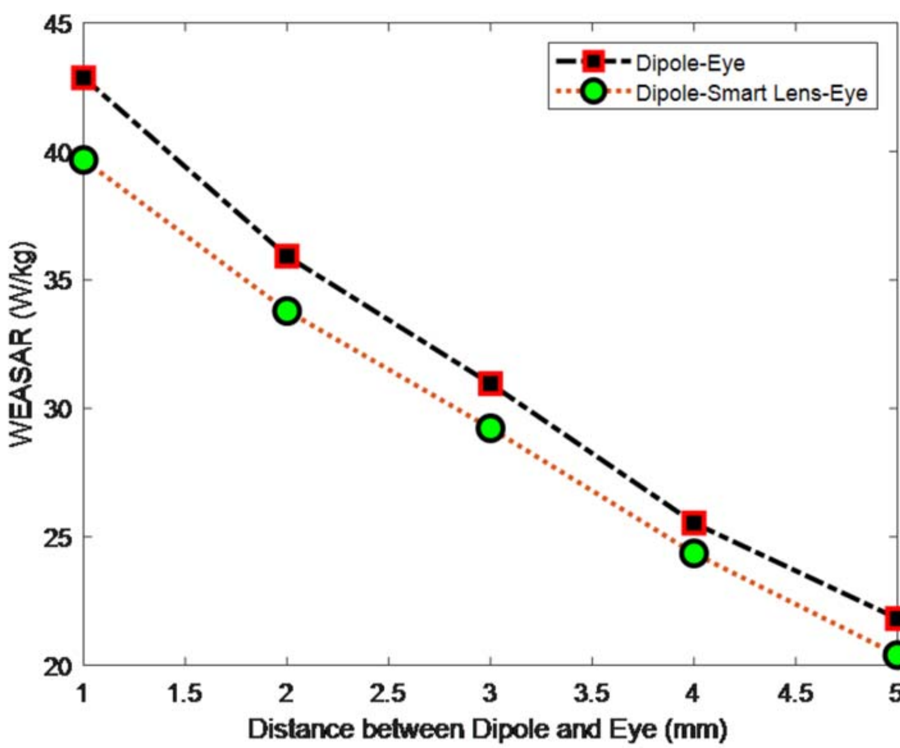

Figure 2. **Comparison of WEASAR values with and without Smart Contact Lens at 2.4 GHz**

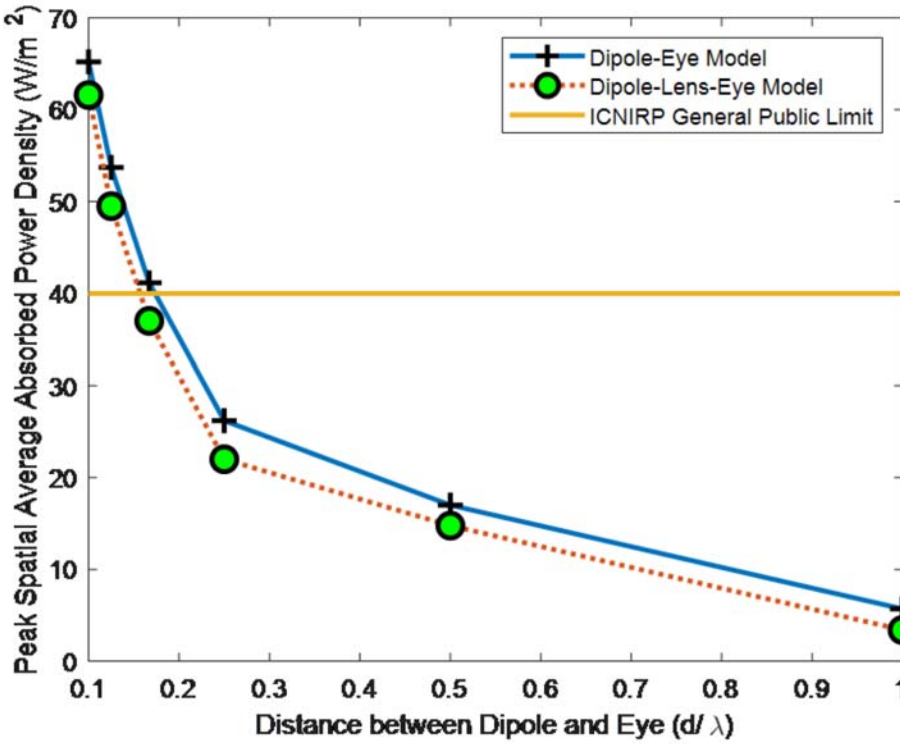

Figure 3. **Peak spatial average absorbed power density with and without smart contact lens at 60 GHz**

S09-7 [09:30]

EXPOAUTO – An international research project on cumulative exposure of people of different ages to radiofrequency electromagnetic fields from new technologies in automotive services and connected objects

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Presented by: Gabriella Tognola

The paper presents the objectives, the architecture, and the partnership of the international Project EXPOAUTO 'Cumulative real smart car exposure to radiofrequency electromagnetic fields in people of different ages from new technologies in automotive services and connected objects" financed by the French National Research Program for Environmental and Occupational Health of Anses (2020/2 RF/05).

Abstract

The automotive sector is evolving toward the concept of 'intelligent' mobility where cars are smart inter-connected 'ecosystems' that can sense the environment (e.g., detect blind spots during parking through

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