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Responses to Comments on Assessment of Polarization Dependence of Body Shadow Effect on Dosimetry Measurements in the 2.4 GHz Band

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Short running head: BODY INFLUENCE ON DOSIMETRY MEASUREMENTS

Authors would like to respond the comments by Thielens et al. of our recent publications "Assessment of Polarization Dependence of Body Shadow Effect on Dosimetry Measurements in 2.4 GHz Band". Thielens et al. opine that the propagation and absorption and polarization dependence are more complex than we bring forward in [De Miguel-Bilbao et al., 2017]. In their comments they pretend to show that the received polarization is not controlled nor constant in the experiments used in [De Miguel-Bilbao et al., 2017].

When the personal exposimeter (PEM) is worn by the user, in NLoS conditions, the E-field measured has three contributions: (1) the propagation through the human body, (2) the contribution travelling around the human body, (3) and the reflexions from the environment. Thielens et al. [2017] do not consider that these three components present the maximum underestimation in vertical polarization. Authors would like to make the following comments about these three components in order to justify the obtain results.

First, Thielens et al. affirm that the whole-body averaged specific absorption rate (SARwb) is the magnitude to quantify the absorption of the electromagnetic radiation. Our response is that it depends on the frequency band. In the range from about 300 MHz to several GHz, significant local and non-uniform absorption occurs, so the localized SAR is a more appropriate magnitude to measure the absorption [ICNIRP, 1998]. In addition, for frequencies around 2100 MHz the localized SAR in limbs and head/trunk is higher for vertical polarization, in standing position, and when waves impinges on the body from front or back [Uusitupa et al., 2010]. The results of the study [De Miguel-Bilbao et al., 2017] show a more significant underestimation in vertical than in horizontal polarization. The frequency is 2400 MHz (around 2100 MHz), the user is in standing position, and waves impinge on the body from front. In these conditions the localized SAR in limbs and head/trunk is higher for vertical polarization [Uusitupa et al., 2010]. It should be also considered that when the long axis of the human body is parallel to the electric field vector, and under plane-wave exposure conditions (i.e., far-field exposure), whole-body SAR reaches maximal values [ICNIRP, 1998].

Second, another component of the E-field measured by the PEM are the trapped surface wave signals around the body. Thielens at al. propose works where it is indicated that path losses for horizontal polarization are higher than vertical polarization. Alves et al. [2011] presents an experimental setup where the transmitter and the receiver are worn by the user. In addition Kammersgar et al. [2016] and Alves et al. [2011] are works about WBAN propagation. These works do not consider the same experimental conditions than De Miguel-Bilbao et al. [2017]: far field conditions, the receiver (PEM) is worn by the user, the transmitter is static, and the transmitter and the receiver are at the same height. Effectively, as Thielens at al. affirm, there is no clear consensus in literature that propagation of EMF waves around the human body would result in relatively more path loss or V-polarized plane waves at 2.4 GHz. But taking into account the indicated conditions of the experimental setup and the indicated environments, the underestimation of the human body is greater for vertical polarization.

Third, as Thielens et al. affirm, a fraction of the power emitted by an antenna with a certain (linear) polarization will be converted to other polarizations. The experimental measurements has been compared with simulated results obtained with a ray tracing software taking into account previous developed models [Athanasiadou and Nix, 2000; Zhong at al., 2001]. The E-field is calculated as the sum of the direct ray and the reflections and diffractions of the environment. It has been checked with the ray tracing software that if the radiation source is situated at the same height than the PEM in the cases of shadow and non-shadow, the predominant component is the vertical component in the case of vertical polarization. Meanwhile in Andersen et al. [2007] the radiation source is situated in the roof, so the experimental conditions are not the same than the considered in [De Miguel-Bilbao et al. 2017].

Finally, authors would like to remark that Bolte et al. [2011] evaluates the impact of the body user that wears the PEM for different frequencies, and they conclude that the attenuation is greater for the vertical polarization for the frequency of 2.4 GHz. The tests have been performed at an Open Area Test Site (OATS) with no reflecting ground plate. The experimental place is very similar to an anechoic chamber because ideally, there are no reflections. In De Miguel-Bilbao et al. [2017] it is found that in small indoor environments the body underestimation is similar in both polarizations. In the bigger indoor enclosure, the difference between the underestimations in both polarizations is greater than in small enclosures, similar to an open space where the influence of the human body is greater. In addition, in Figure 1, simulation results obtained with the finite difference time-domain (FDTD) show the spatial distribution of the electric field perturbed by the human body presence in comparison with the incident wave in the frequency band of 2.4 GHz, for vertical polarization in free space conditions, and with frontal incidence [Blas et al., 2007]. On the opposite side of the body, in the region shaded by the human model, the maximum attenuation was noticeable.

De Miguel-Bilbao et al. [2017] present an experimental and simulated study where it is found that the underestimation of the human body is greater in vertical than in horizontal polarization for the indicated conditions. The conclusions are justified by the exposed reasons. The results and the discussion were focused on the specific conditions of the experiment. The conditions were chosen to show as clearly as possible the differences between vertical and horizontal polarization. Other conditions such as cluttered environments or different angles of incidence in the elevation plane are clearly not the best cases to reveal these differences.

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Fig. 1. Incident wave alterations in the 2.4 GHz frequency band due to the presence of the human body. Simulation results are compared for vertical and horizontal polarization, obtained with the FDTD considering the total module of the electric field.