# Comments on Assessment of Polarization Dependence of Body Shadow Effect on Dosimetry Measurements in 2.4 GHz Band

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Radio-frequency (RF) exposure measurements using personal dosimeters or exposimeters are influenced by the presence of the body, which reflects, diffracts, and absorbs the RF electromagnetic fields (EMFs) that one wishes to measure [Bolte et al., 2011]. Two of these effects are a reduction in registered electric field (E-Field) strength and the influence of polarization. The latter one is caused by differences in propagation around the human body, according to De Miguel-Bilbao et al. [2017]. In their research, they find that "*the attenuation due to the body-shadow effect is greater when the antenna is vertically polarized*" [De Miguel-Bilbao et al., 2017]. This would be mainly attributed to "*a greater effective area where incident waves are scattered*" [De Miguel-Bilbao et al., 2017]. In our opinion, the propagation and absorption mechanisms are more complex, in particular the polarization dependence, than what the authors of [De Miguel-Bilbao et al., 2017] bring forward in the discussion section of their paper. Moreover, as we will show in this manuscript, the received polarization is not controlled nor constant in the experiments used in [De Miguel-Bilbao et al., 2017].

When RF EMFs are incident on a subject, a part of the incident RF EMFs will be absorbed, another part will be reflected away from the measurement devices, and a third part can propagate towards the exposimeters. This propagation has several components: propagating modes around the human body: specular components including the line-of-sight (LOS) component between the source and the exposimeter and reflections from the environment, and the diffuse multipath component (DMC). This DMC is the part of the incident power density that cannot be attributed to any incident angle [Bamba et al., 2015] (in contrast to the specular components).

First, the loss of EM power due to absorption in the human body is quantified using the whole-body averaged specific absorption rate ($SAR_{wb}$). Existing literature on the absorption of RF frequencies above > 2 GHz is not conclusive on the polarization dependence of the $SAR_{wb}$.

Some studies find a higher absorption for horizontally polarized (H-polarized) incident plane waves [Hirata et al., 2009; Uusitupa et al., 2010; Bamba et al., 2015] at frequencies higher than 2 GHz. Others, Kuhn et al. [2009] and Bakker et al. [2010], find only slightly higher absorption values for vertically polarized (V-polarized) incident plane waves at frequencies higher than 2 GHz.

Second, the propagation around the human body is indeed polarization dependent. However, there is again no clear consensus in literature that propagation of EMF waves around the human body would result in relatively more path loss for V-polarized plane waves at 2435 MHz in comparison to H-polarized EMFs. Alves et al. [2011] found a higher path loss for E-fields polarized parallel to the main axis of a lossy cylinder in comparison to E-fields polarized orthogonal to the surface of the same cylinder at 2.4 GHz, for EMFs that are emitted in very close proximity to the cylinder. Kammersgaard et al. [2016] found less path loss at the back of a lossy cylinder for a V-polarized incident wave at 2.45 GHz than for an H-polarized incident plane wave. They also indicate that the path loss depends heavily on the dielectric properties of the cylinder. Syed et al. [1991] and Mavridis et al. [2013] indicate that a difference in path loss between both polarizations depends on the size and dielectric properties of the phantom (cylinder) w.r.t. the used wavelength. Moreover, it is not clear how the two considered polarizations H and V would convert into parallel and orthogonally propagating modes on the body as both incident polarizations will have components alongside both on body orientations (parallel and orthogonal to the body).

Third, the specular reflections are polarization dependent. A fraction of the power emitted by an antenna with a certain (linear) polarization will be converted to other polarizations [Gaspard, 2015; Quitin et al., 2010]. This effect is commonly quantified using the cross-polarization ratio (XPR). This is a statistical quantity that depends on the size of the indoor environment [Gaspard, 2015], the separation between transmitter and receiver [Quitin et al., 2010], and their relative orientations [Gaspard, 2015; Quitin et al., 2010]. Given the information provided in De Miguel-Bilbao et al. [2017], one cannot assume one of the two considered polarizations H and V are reflected more or less efficient in the studied rooms, nor can one determine what the XPR is at the location of the receiver.

Finally, in the indoor configurations shown in De Miguel-Bilbao et al. [2017] a considerable amount of incident power density can be found in the DMC [Andersen et al., 2007]. The DMC has an XPR closer to 1 [Gaspard, 2015; Landmann, et al., 2007; Quitin et al., 2010], which means that received power is less dependent on the polarization of the source antenna. Bamba et al. [2012] demonstrated that the DMC at 2.3 GHz in an indoor environment contains considerable amounts of incident power density. At 6 and 10 m from the transmitting antenna, more than 50% and 70%, respectively, of all incident power will be in the DMC. In a follow-up study, Bamba et al. [2014] also demonstrated that the power loss due to absorption of DMC does not depend on polarization of the transmitting antenna.

In order to validate the polarization dependency of exposimeters we suggest the use of measurements in an anechoic chamber [Thielens et al., 2013] where only specular components with a controlled polarization are present, and a reverberation chamber [Aminzadeh et al., 2016] where the XPR can be controlled using mechanical stirring [Kildal and Carlsson, 2002].

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