Novel Method for APD Evaluation Based on Artificial Electromagnetic Skin

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***Abstract* - Exploiting the millimeter-wave (mmW) spectrum is an attractive solution to enable the traffic growth for the next decade due to deployment of mmW technologies within 5G / 6G. This will allow for larger channel bandwidth, higher data rates, ultra-low latency, and reduced interference with adjacent cells. Frequencies above 6 GHz are also considered as very promising for other body-centric applications including wireless sensors networks and wireless body-area networks. These new use cases and services will involve interaction of radiating devices with the human body, both in terms of the body impact on wireless device performance, as well as in terms of user exposure. This presentation will overview a novel method for APD evaluation based on artificial electromagnetic skin. The technique was validated for various antennas demonstrating its highly promising potential for experimental dosimetry and compliance testing of wireless devices above 6 GHz.**

The continuous evolution of mobile terminals, such as smartphones, tablets, and body-worn devices, has drastically increased the wireless data traffic, which keeps growing due to video streaming applications and cloud computing. The growing need for high-performance mobile communications leads to a progressive shift of operating frequencies above 6 GHz and toward the millimeter-wave (mmWave) band. In particular, the 5G heterogeneous cellular mobile networks will exploit the FR2 bands around 26 GHz, 39 GHz, and in some countries 60 GHz.

The upcoming use of FR2 technologies will involve user exposure to mmWave radiation. This includes the near-field exposure by mobile devices operating in the vicinity of human body. mmWave radiation is not present in our natural electromagnetic background due to the strong atmospheric absorption, and the accurate control of user exposure is of upmost importance. Above 6 GHz and up to 300 GHz, power density at the skin surface, referred as the absorbed power density (APD) by ICNIRP [1] and as the epithelial power density by IEEE C95.1 [2], is used as the main dosimetric quantity. The limits (basic restrictions) are set to 10 mW/cm^2 for occupational environments (referred as restricted environments by IEEE) and 2 mW/cm^2 for the general public (referred as unrestricted environments by IEEE). The APD is to be averaged over 4 cm^2 and 6 min. To account for focal beam exposure, from 30 to 300 GHz APD is also averaged over 1 cm^2 and must not exceed two times the limits for 4 cm^2.

Compliance testing of wireless devices with respect to the exposure limits is currently performed based on free-space measurement of the incident power density (IPD) close to a device under test according to the IEC/IEEE 63195 standard [3]. For accurate exposure assessment under realistic conditions, it is important to account for antenna/body interaction, including standing waves and antenna detuning phenomena that may cause enhancement of user exposure levels [4]. To account for this, the microwave dosimetry methods, based on in-phantom E-field measurements of SAR, are commonly used below 10 GHz. However, at higher microwave frequencies they are facing physical limitations due to prohibitively high losses in biological tissues and tissue-equivalent phantoms.

Here we introduce a novel method for APD assessment above 6 GHz. It is based on a solid thin electromagnetic structure (referred as phantom) accurately reproducing the scattering properties of human skin. This allows to reproduce antenna/body interaction in measurements. The proposed reflectivity-based phantom enables two types of APD measurements: (1) free-space E-field measurements behind the phantom and back-propagation to the APD evaluation plane [5]; (2) fast infrared (IR) 2D measurements and subsequent reconstruction of APD [6].

In the first case, the phantom is optimized to maximize the through-phantom transmission to guarantee a measurable E-field behind the phantom. An open-ended waveguide is used to measure the amplitude and phase of the transmitted E-field. Free-space measurements ensure enhanced robustness with respect to the probe positioning compared with the measurements in lossy liquid phantoms with a strong spatial APD gradient. The measured E-field is then backpropagated in space to retrieve APD at the phantom surface using a plane-wave spectrum (PWS) technique.

In the second case, the phantom with enhanced absorption is used to convert the absorbed power into a heat pattern measured by an IR camera. The measured IR pattern is then used to reconstruct the APD distribution. The lock-in technique is used to enhance the signal-to-noise ratio by filtering the ambient IR noise and removing the parasitic heat conduction effect. By reducing the noise, a measurement sensitivity of the order of 1 mW/cm^2 can be achieved, which significantly surpasses the sensitivity of conventional IR-based dosimetric measurements (>10 dB).

The technique was validated for the reference antennas defined by IEC/IEEE 63195 standard for validation of the power density measurement systems [1]. The results demonstrate that the proposed method is highly promising (accuracy, fast measurements, robustness, enhances sensitivity) for experimental dosimetry and compliance testing of wireless devices operating above 6 GHz.

Acknowledgements

This work was supported by Labex CominLabs through EM-ART Project under Grant ANR-10-LABX-07-01; by Brittany Region, Ministry of Higher Education and Research, Rennes Métropole and Conseil Départemental through CPER Project CyMoCod; and by French National Center for Scientific Research (CNRS).

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