Validation of Computational Models of Wireless Devices by Comparing Measured and Simulated One-port Quantities due to Near-field Perturbations

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Abstract — Compliance with radio frequency (RF) dosimetric standards, characterized by specific absorption rate (SAR), are essential to bring wireless portable devices to market. There is an increasing demand to replace some of the complicated measurements required to determine the SAR by software simulation that is, by numerical field calculation. This requires, however, the validation of the numerical model of the device under test (DUT) by simpler measurements. Guidelines for this are given in IEEE/IEC 62704. The validation procedure currently in use is performed by measuring the electric field in specially designed shielded measurement chambers. With increasing frequency even these simplified measurements become more costly and complex, thus, novel methods need to be introduced. A cost-effective alternative validation technique is to measure and simulate a one-port characteristic of the DUT antenna. For the validation procedure, a control object is placed in the vicinity of the antenna, which perturbs the field and changes the input impedance of the device. This change — according to the first-order Born-approximation — is proportional to the $|E|^2$ without the control object, from which the SAR is derived. The $|E|^2$ field can be recovered from the impedance change values measured in function of the control object position using deconvolution. Thus, the validation of the near field can be performed indirectly.

In this work, we present the derivation of the formula underlying this new validation method. We consider two configurations including the antenna: (1) the DUT is placed in an environment characterized by its permittivity and permeability ($\varepsilon_1$, $\mu_1$) with the input impedance $Z_1$ and the electric field $E_1$; and (2) configuration with $E_2$, $Z_2$ where the only difference from (1) is that a dielectric control object $\Omega$ with given ($\varepsilon_2 \neq \varepsilon_1$, $\mu_2 = \mu_1$) is placed near the antenna. In both cases the antenna is fed by current source $I_0$. Applying the reciprocity theorem we derived that the impedance change due to the presence of $\Omega$ is

$$\text{Im} \{ \Delta Z \} = \text{Im} \{ Z_2 - Z_1 \} = \frac{2\pi f (\varepsilon_2 - \varepsilon_0)}{|I_0|^2} \int_{\Omega} \text{Re} \{ \vec{E}_1 \cdot \vec{E}_2^* \} d\Omega,$$

where $f$ is the source frequency and Re, Im are the real and the imaginary part of the complex quantity, respectively. When $\varepsilon_2$ is close to $\varepsilon_1$, we can apply the first-order Born-approximation as $E_1 \approx E_2$, so the volume integral changes to $\int_{\Omega} |E_1|^2 d\Omega$. Note that the resulting formula is similar to the one presented in a former study [1], however, in this case the $|E|^2$ is directly validated. To evaluate the impedance change formula, we perform numerical simulations for a planar inverted-F and a microstrip patch antenna, and investigate their impedance variation at 1–3 GHz as a function of the position of a control object.

REFERENCES