Prof. Dr. Niels Kuster

Director Foundation IT'IS
Professor of Swiss Federal Institute of Technology – ETHZ
Phone +41 1 245 9690 · kuster@itis.ethz.ch

Guidelines for the Evaluation of Exposure from Wireless Power Transmission Systems

Mark G. Douglas, Ph.D., Andreas Christ, Ph.D. and Niels Kuster, Ph.D.

October 9, 2009

Two international standards exist that set safety limits on human exposure to radiofrequency (RF) fields [1], [2]. At frequencies that are applicable for wireless power transmission systems, the limits are set to protect against excessive tissue heating, as thermal effects were found to be "the only established adverse effect of exposure to RF energy at frequencies above 100 kHz" [2].

There are two types of limits that are applied in these standards: basic restrictions and reference levels. The basic restrictions are based on induced fields in the body. The reference levels are based on incident fields outside the body. In the frequency range applicable for wireless power transmission systems (1 - 15 MHz), both standards define the basic restrictions in terms of specific absorption rate (SAR). SAR has a direct relation to the temperature increase in tissue [3]. Therefore, it is a metric that directly relates to adverse effects of RF energy.

The reference levels are secondary limits that are derived or estimated from the basic restrictions. These are defined as maximum permissible electric fields, magnetic fields or power densities. The reason for defining them in the safety standards is that they are typically much easier to measure, and can be measured with simpler instrumentation. However, the main disadvantage of using the reference levels is that they do not directly relate to the temperature or SAR in the body. There is no simple relationship between the reference levels (i.e., fields outside the body) and the basic restrictions (i.e., fields induced in the body), as this relationship depends on the body geometry, the distance to the source, the field polarization and other factors. The relationship is especially complicated in the very close near field region [4].

In international safety standards, the reference levels are determined from the basic restrictions for the worst case under all circumstances. Therefore, if an exposure scenario is compliant with the reference levels (both E- and H-fields) at any point in space, it is also compliant with the basic restrictions. However, the opposite is not true. If the exposure scenario is not compliant with the reference levels, the basic restrictions are not necessarily violated.

For wireless power systems, people will typically be in the very close near field of the transmitter. For this reason, reference levels (E- and H-fields) cannot and shall not be applied to characterize the exposure. Application of the reference levels will likely lead to a very high overestimate of the actual exposure.

[1] ICNIRP, "International commission on non-ionizing radiation protection guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz)," *Health Phys.*, vol. 74, no. 4, pp. 494–522, Apr. 1998.

[2] *IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz*, IEEE Standard C95.1-2005.

[3] Pennes, H.H. "Analysis of tissue and arterial blood temperatures in the resting human forearm. *J. Appl. Physiol*, vol. 1, pp. 93–122, 1948.

[4] Kuster, N. and Balzano, Q., "Energy absorption mechanism by biological bodies in the near field of dipole antennas above 300 MHz," *IEEE Transactions on Vehicular Technology,* Vol. 41, No. 1, pp. 17–23, Feb. 1992.