Evaluation Of Compliance With SAR On The Basis Of External RF-EM-Field And Current Measurements

Kari Jokela

STUK, Radiation and Nuclear Safety Authority
P.O. Box 14, FIN -00881 Helsinki Finland

kari.jokela@stuk.fi

Exposure to uniform radio-frequency electromagnetic fields (RF-EM) can be assessed simply by measuring the electric and magnetic field strength or power density in one point occupied by the body (body removed) and comparing the results to the reference levels (ICNIRP 1998). Unfortunately, most exposure situations occur in the close vicinity of the source where the fields are more or less non-uniform and localized to a small part of the body (Jokela and Puranen 1999, Jokela 2007). In this case, the maximal field strength may considerably exceed the reference levels for the external fields without exceeding the basic restrictions expressed in terms of Specific Absorption Rate (SAR) specified as a whole body average and localized maximum value. Spatial averaging of the unperturbed external field strength or its' square over the location of the body or part of the body may be permissible, but with the important proviso that the basic restrictions for local SAR and current density are not exceeded. There is a clear need to define practical procedures for exposure measurements which full-fill these conditions but are not unnecessary restrictive. A key issue above 100 MHz is the definition of spatial averaging of the unperturbed electric and magnetic field strengths. At lower radio-frequencies, the measurement of currents induced by the electric field in the body is a very useful procedure for the exposure assessment. If the source of the fields is very localized and close to the body, closer than approximately 20 cm, the exposure assessment based on the reference levels becomes too conservative and the compliance with the limits for local SAR and current density must be verified by dosimetric measurements and numerical simulation

In this communication practical exposure assessment methods are considered in the context of three different occupational RF exposure situations which include climbing through FM/TV broadcast antennas, working in the beam of a microwave antenna and operating 27 MHz dielectric heat sealer.

FM/TV antenna

People working near or climbing through high power FM/TV broadcast antennas are exposed to relatively intense electromagnetic fields in the frequency range from 50 to 800 MHz. (Jokela and Puranen 1999). The antennas consist typically of three or four vertical dipole array antennas installed on three or four sides of the mast. Inside the mast the distance to the nearest dipoles are the order of 1 m. Additionally, the RF currents induced by the primary fields from the dipoles in the mast structures, constitute secondary sources of the exposure. RF currents may also be injected at the FM-frequencies directly to the hands and feet which are in contact with ladders and other mast structures.

Measurements show that the equivalent power density is in general higher for the electric field than for the magnetic field at FM and TV towers. Hence, the H-field measurements can be omitted in most FM/TV tower measurements. The maximal local electric field equivalent power density may be typically in maximum 6 dB higher than the power density averaged over the whole body. It seems that this body average value might be used for limiting exposure but data on dosimetric simulations is needed to ensure that local SAR remains below the basic restrictions. Near the upper end of the broadcasting range (600 -800 MHz) the considerations presented below for base station antennas and other microwave antennas might give justification to allow at least 6 dB higher peak power density.

Microwave antennas (>900 MHz)
Microwave antennas such as mobile phone and radar antennas emit electromagnetic waves which absorb electromagnetic waves in the most superficial tissue layers facing toward the antenna. Most of the power is absorbed within 2.2 cm which is the side length of a cube defined by most standards for averaging the local SAR. For increasing frequency the power only concentrates more and more on the front side of the cube, but the average does not change significantly. Simple dosimetric considerations by using planar layer tissue models and plane wave approximation indicate that there is a safety margin of at least 6 dB for local power density to exceed the body average. It is clear that at these quasi-optic frequencies the total power absorbed by the body and consequently the body average SAR is determined by the average power density deposited on the cross-section of the whole body.

RF dielectric heater
Dielectric heaters are commonly used for welding and glue drying at 13 and 27 MHz. These appliances are equipped with an open electrode, which expose operators to intense electric stray fields frequently exceeding the 60 V/m reference level. In most cases the exposure to the magnetic field is much lower than the electric field. The coupling of the human body to the electric field results in RF-currents flowing longitudinally along the limbs and torso. Because it is easy to measure the body current it is of considerable interest to examine the relationship of the currents with SAR in order to enable a true dosimetric assessment of the exposure on the workplace.

RF currents below 30 MHz can be measured with a parallel plate current meter or current transformer (Jokela and Puranen 1999). Parallel plate meter can be used only for measuring the current flowing from the both feet to the ground while for current transformers there are no requirements on the grounding. Ferrite core current transformers (Blackwell 1990) are suitable for measuring a current in a limb, but only the air core current transformers have a large aperture enough to fit round the torso. Hence this instrument is capable of measuring the distribution of the current from the head to the feet.

FDTD calculations, current measurements and electric field measurements for a model of plastic sealer operating at 27 MHz indicate that the distribution of the electric field is not well correlated with the distribution of the induced current (Jokela and Puranen 1999; Kännälä et al. 2006). Electric field strength averaged over the whole body is in better agreement with the maximum current than the local maximum field strength. The induced currents are longitudinal and relatively evenly distributed along the high conducting tissues below the skin. Hot spots in the ankles are most critical but for the electrode distance less than 0.3 m also the hot spot in the tissue most adjacent to the electrode must be taken into account. Compliance with the SAR limits is ensured if the current is below 100 mA in any of the limbs.

References
Blackwell RP. The personal current meter-A novel ankleworn device for the measurement of RF body current in a mobile subject. J. Radiol. Prot. 10:109-114; 1990.
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 74:494-522; 1998.
Jokela K, Puranen L, Occupational RF exposures. Rad. Prot. Dosim. 83 :119-124 ; 1999.
Jokela K. Assessment of complex exposure situations including inhomogeneous field distribution. Accepted to Health Physics, 2007.
Kännälä S, Puranen L, Sihvonen A-P., Jokela K. Dosimetric exposure assessment for RF dielectric heaters. The Bioelectromagnetics Society. 28 th Annual Meeting, Cancun ; 2006.