PROCEEDINGS OF ISAP '96, CHIBA, JAPAN

PROCEDURES FOR COMPLIANCE TESTING OF MOBILE COMMUNICATIONS EQUIPMENT WITH SAFETY STANDARDS

Niels Kuster
Swiss Federal Institute of Technology (ETH)
CH-8092 Zurich, Switzerland

1. Introduction

Handheld mobile telecommunications equipment (MTE) have rapidly become a common and widespread consumer product. Their use has expanded from the mainly business oriented to the more general daily. With falling operation costs more frequent and lengthier conversations can be expected. At the same time there has been an increase in the public's concern about possible health risks through electromagnetic exposure from MTE. Since violation of the basic safety limits may be possible even for devices with an antenna input power of less than 200 mW, health agencies in Europe and North America are calling for demonstration of compliance with safety standards. The industry is now looking for scientifically sound procedures for compliance testing in order to maintain customer credibility and ward off the risks of potentially damaging liability suits. On the other hand, testing should not cause any undue delays in marketing the devices in view of the short product cycle times of MTE.

2. Safety Standards

Although the major safety standards have a common basis, they differ considerably in detail, whereby those of MTE are briefly discussed in the following.

USA: ANSI/IEEE C95.1-1992 [1] is an exposure standard defined in terms of the maximum permissible E-, H- and S-field strengths, which are based on the maximum tolerable specific absorption rate (SAR). Important exclusions are defined: 1) The exposure limits may be exceeded if compliance with the basic limits can be demonstrated. For the uncontrolled environment the limitation for the spatial peak SAR is 1.6 mW/g, which is defined as the SAR averaged over a volume of 1 g of tissue mass and a period of 30 minutes. 2) An exclusion for low-power devices operating in the frequency range of 100 kHz to 1.5 GHz has been defined as well. However, this exclusion only applies if the radiating structure is *not* maintained within 2.5 cm of the body. The exclusion is otherwise not in compliance with the basic restrictions [2,3]. Consequently, mobile phones cannot be covered by this exclusion.

Europe: prENV50166-2 [4] is defined in terms of SAR in the frequency range of MTE, and exposure limits have been derived to test for compliance. For the general public the spatial peak SAR limit is 2 mW/g averaged over a volume equivalent to 10 g and a period of 6 minutes [4]. No exclusions have been defined for low-power devices. Since no procedure to test MTE with the basic limits has been established, the DGIII of the European Union has mandated CENELEC to develop a measurement standard for MTE. The report of the CENELEC TC211 working group for MTE (WGMTE) will be available before the end of 1996.

Japan: The SAR limits in the fundamental guidelines of the TTC/MPT [5] are higher than those for the general public of the ANSI/IEEE and CENELEC standards. The spatial peak SAR limit is 8 mW/g (1 g and 6 minutes averaged). A clause for low-power devices excludes all devices with an input power of less 7 W for operating frequencies up to 3 GHz. This exclusion is critical since 7 W devices have the potential to induce spatial peak SAR values well above 100 mW/g [2,3].

3. Requirements for Compliance Testing Procedures

From a public health point of view, a compliance testing procedure should demonstrate compliance with the safety limits for all users and all operating conditions. From a practical point of view, the required tests should be as few in number as possible. In addition, the following technical requirements should also be satisfied: 1) accurate assessment of the SAR values defined in the safety standard; 2) high degree of reproducibility of all test results; 3) the ability to test randomly selected devices; 4) high degree of reliability; 5) simple but reliable test procedure to validate results; 6) credibility in the eyes of the experts and consumers; 7) ease of use, so that the tests can be performed not only by very specialized experts; 8) time efficiency; 9) availability for manufacturers during the design process of their products.

However, these requirements are not easy to satisfy, since the absorption strongly depends on a large number of parameters: 1) operational frequency and antenna input power; 2) position of the device with respect to the head; 3) design of the device; 4) the outer shape of the head; 5) the distribution of the different tissue types in the head; 6) the electrical properties of these tissues.

The last three factors differ for various individuals and can even change with age. Even more important are factors 2 and 3, since users have numerous habitual ways of holding MTE devices. This issue has recently been addressed by the working group WGMTE, which has drafted the definitions of the range of operational conditions which must be tested for a certification procedure [6].

4. Measurements versus Simulations

Several research groups are currently studying possible compliance testing procedures based either on measurements or computations. Our analysis has shown important advantages from the measurement versus the numerical approach.

- *Handheld MTE:* The object to certify is the actual MTE as it leaves the production line. A measurement setup which is sensitive enough to enable testing of the actual physical MTE is therefore the more superior method, since modeling of the test object is *per se* critical. For type approval this is all the more true, since the design of the MTE has proven to be very critical (see Section 6). The physical explanation is that the SAR is predominately induced by induction, i.e., it is proportional to the square of the current distribution and inversely proportional to the square of the distances between those currents and the surface of the body [2]. Therefore, minor details, even internal structures, can affect the spatial peak SAR considerably. Consequently, small modeling errors can result in SAR errors of several dBs. As long as procedures to reliably assess the uncertainty of a particular modeling are not available, certification by simulations is of doubtful value or demands large safety margins.

- *Phantom:* The advantage of simulations as compared to measurements is that the internal anatomy of the human head can also be modeled with high resolution. However, recent studies have shown that the spatial peak SAR values induced in homogeneous phantoms in the region above the ear only slightly overestimate the values in highly nonhomogeneous modeling of human heads. The overestimation in the spatial peak SAR was less than 10% at 900 MHz [7] and 20% at 1800 MHz [8]. This indicates that a homogeneous phantom is preferable to nonhomogeneous modeling of the human head, because homogeneous modeling minimizes the number of tests required to assess the maximum exposure occurring within the entire user group. In addition, it also covers possible enhancements due to optical glasses and jewelry [8].

- *Time Efficiency:* Using robot-based measurement setups, compliance tests can be fully automated. For example, the assessment of the spatial peak SAR for a particular condition can be completed within 15 minutes with the system described in the next section. On the other hand, a numerical modeling of medium resolution (5–10 million voxels) requires several hours of CPU time on a high-end workstation. Although the CPU time will

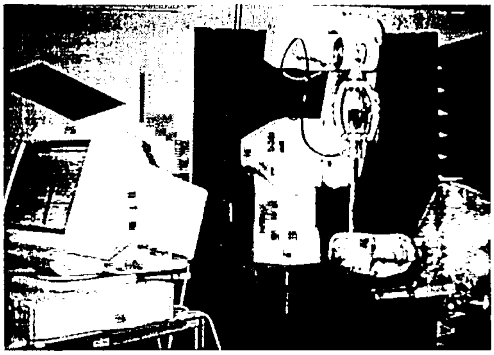

Figure 1: Dosimetric assessment system DASY2 (6-axis robot, isotropic E-field probe, data acquisition electronics and PC) and the anatomically shaped shell phantom.

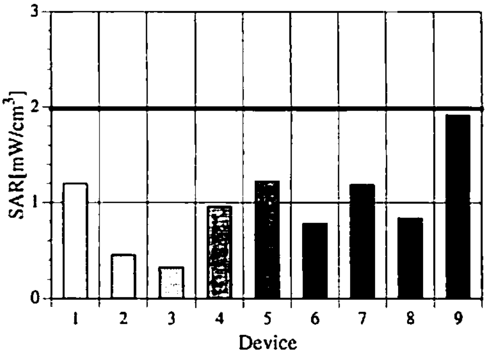

Figure 2: Maximum spatial peak SAR of nine GSM devices (nominal time averaged P_{in}: 250 mW) averaged over 10 cm³, measured according to the test conditions described in the WGMTE draft.

be substantially reduced by future computer technology, the discretization of the MTE and especially the modeling validation will remain a major efficiency bottleneck for the numerical approach.

- *Reproducibility:* In case of measurements, reproducibility – also between different laboratories – can be ensured to much better than ±10% with precision reference sources. The reproducibility of the numerical approach cannot currently be determined, owing to the lack of methods for validating the modeling.

A further drawback of the numerical approach is the high level of expertise required to perform meaningful simulations, whereas accurate measurements can be performed by any well-trained engineer.

5. Measurement Setup

Automated E-field scanning systems for dosimetric assessments of MTEs have been developed during the last few years [9], [10]. The one used to perform the experimental studies reported in the next section is shown in Figure 1 and has recently been made commercially available by Schmid & Partner Engineering AG. It is based on miniaturized E-Field probes optimized for dosimetric measurements in tissue simulating liquids. The probes are positioned by a 6-axis precision robot (Stäubli RX90). An optical surface-detecting system is integrated into the probes, which enables the accurate positioning of the probe with respect to the phantom's inner surface. The SAR distribution can be measured in any predefined volume. Measurement, data processing, evaluation and visualization are controlled by software. The assessment of the special peak SAR as required by ANSI/IEEE [1] and prENV50166-2 [4] is fully automated and is completed in less than 15 minutes. A thorough error analysis has shown that the measurement uncertainty is less than 20% (for the spatial peak SAR values). This was achieved by breakthroughs in probe design [11], calibration [7] and data evaluation. The probes are distinguished by largely improved isotropicity, immunity to ELF and RF fields and enlarged frequency and dynamic ranges. The long term stability and the proper functioning of the system is ensured by means of an easy-to-use validation kit, which has a reproducibility of better than ±5%.

6. Test Results

Preliminary assessments have been performed according to the definitions of the latest draft of the WGMTE document [6] using the system described above. Since the description of the phantom to be tested has not yet been worked out by WGMTE, the measurements were performed with the widely used phantom shown in Figure 1. It is an anatomically-shaped shell phantom made of fiberglass (thickness 2–3 mm). Since the total uncertainty cannot yet be assessed, owing to the lack of definition of the standard phantom, only the uncertainties of measurement have been added to the measured values, i.e., +20%.

Nine GSM devices are compared (Figure 2) operating at highest power level (250 mW nominal time averaged antenna input power). All of these models have appeared on the market within the last two years. Remarkable is that the two devices with the lowest absorption are latest generation devices. Although the possibilities of improvement have not yet been fully exhausted, the differences illustrate the great scope in potential improvements. Any reduction of the spatial peak SAR will also improve the overall efficiency of the the MTE.

7. Conclusions

Compliance tests can be efficiently performed by using accurate and sensitive E-field scanners. Recent improvements in sensitivity and accuracy enable testing of the actual physical MTE with low measurement uncertainties. System validation kits have been developed to provide excellent reproducibility, even between different laboratories. Homogeneous phantoms have proven to be better than nonhomogeneous modeling, owing to the fact that the number of tests needed to ensure compliance for all users has been considerably reduced.

The availability of measurement and simulation tools during the development phase of MTE will result in a considerable reduction of user exposure and – at the same time – in improved radiation efficiency of the MTE.

8. References

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