GLOBAL CHARACTERIZATION OF MOBILE PHONES USING A REVERBERATING CHAMBER

V. Monebhurrun, A. Azoulay and J.-Ch. Bolomey
Supélec – L2S, Département de Recherche en Electromagnétisme,
3, rue Joliot-Curie, Plateau de Moulon, 91192 Gif-sur-Yvette Cedex, France.
Email : monebhurrun@supelec.fr

ABSTRACT

Antennas developed for mobile phones are characterized by their radiation properties traditionally measured in anechoic chambers. Additional SAR (Specific Absorption Rate) compliance tests are performed in a standard dosimetric test facility. Overall the radio-frequency assessment of mobile phones becomes time-consuming and inappropriate during the design stage. Radiated power measurements using a unique test facility based on the reverberation chamber is presented. Dosimetric assessment is possible using the correlation between total absorbed power and SAR. Results of the global characterization (radiated power, SAR and sensitivity) of a few commercially available mobile phones are discussed.

INTRODUCTION

Traditional anechoic chambers are employed to measure the radiation patterns of antennas. Since more recently, mobile phones also undergo complementary SAR (Specific Absorption Rate) compliance tests which are performed in a dedicated dosimetric test facility. Current standards for SAR compliance such as IEEE and CENELEC impose a rigorous but time-consuming measurement procedure [1]. Today the overall SAR compliance test of a dual-band mobile phone typically requires one day. The advent of 3G, WiFi and triple- or quad-band mobile phone models conveys additional burden to these tests. Clearly, there is a need to improve the efficiency of the global characterization of mobile phones to cope with emerging wireless communication systems.

A fast and unique antenna test facility for the characterization of mobile phones in terms of radiation pattern, radiated power and sensitivity as well as SAR has already been suggested [2]. The SAR is estimated from the knowledge of the total power dissipated in the head or phantom and by applying the so-called effective mass concept [3]. Indeed, a close correlation between the total absorbed power in the phantom and the SAR has been observed for more than three hundred mobile phones measured in a standard dosimetric test facility. The total absorbed power is easily deduced from radiated power measurements with and without the phantom. In order to apply this simple scheme, the electromagnetic near-field coupling between the mobile phone and the phantom should be taken into account. A previous study showed negligible modification of the return loss of commercial as well as generic mobile phones when used in conjunction with the phantom i.e. the difference between the power outputs of the mobile phone with and without the phantom can be safely neglected [4].

The relatively small-sized antennas developed for mobile phones usually produce omni-directional radiation patterns. The directivity of such antennas plays a minor role when used in the multipath environment inherent to mobile communications. However when invoking the multipath environment the sensitivity of the mobile phone turns out as an essential parameter. The sensitivity of a mobile phone is quantified according to the correspondence between received signal level and signal quality. It provides an indication of the robustness of a mobile phone to signals received from multiple trajectories and its capacity of synchronization to the base station.

Reverberation chambers offer the possibility to test extreme multipath environments. Commonly employed for electromagnetic compatibility tests, the reverberation chamber also appears as an interesting and cheap alternative for radiated power measurements of mobile phones. A compact reverberation chamber is herein considered for fast radiated power and sensitivity measurements. The mode-stirring of the chamber is optimized and the overall measurement system fully automated for the systematic test of mobile phones with and without the phantom.

THE REVERBERATION CHAMBER

Basically a reverberation chamber is a three dimensional resonant cavity which supports a high number of modes. For a rectangular cavity, the number of modes is obtained using Weyl's approximation:

$$N(f)=8\pi LWH\frac{f^3}{c^3} \tag{1}$$

where L, H and W are respectively the length, the height and the width of the cavity, f is the frequency and c is the velocity of light in vacuum. The mode density (i.e. the number of modes per frequency) is essentially dependent on the volume of the cavity and the frequency. To obtain meaningful results, a high mode density is required in the reverberation chamber. The 60th mode criterion imposes a minimum working frequency under which the mode density is considered insufficient.

The resonant modes can be redistributed by altering the electromagnetic environment inside the cavity or by so-called mode-stirring which is often performed mechanically, for example through the rotation of metallic panels. The principle of the measurement is to produce a statistically uniform and isotropic field by generating a sufficient number of independent field distributions inside the cavity. Henceforth, the power radiated by an equipment under test can be deduced.

A small reverberation chamber of size 0.8 m x 1 m x 1.6 m (Fig. 1) is used for the measurements. Mode-stirring is performed mechanically by moving horizontal and vertical metallic panels as well as by rotating a platform [5]. To reduce the measurement uncertainty, polarization stirring has also been introduced [6]. Fig. 2 shows the comparisons of the radiated power of 7 mobile phones measured in this reverberation chamber and an anechoic chamber at 900 MHz and 1800 MHz, respectively. The theoretical uncertainty of the reverberation chamber is less than 1 dB for measurements in the range 900-1800 MHz.

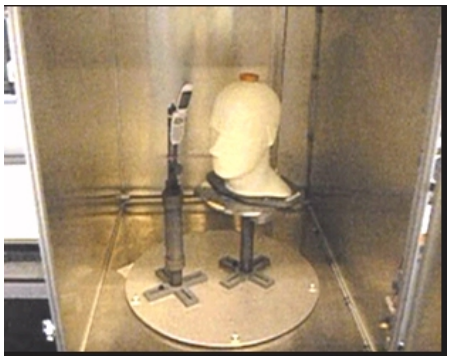

Figure 1. Compact reverberation chamber (developed by Bluetest).

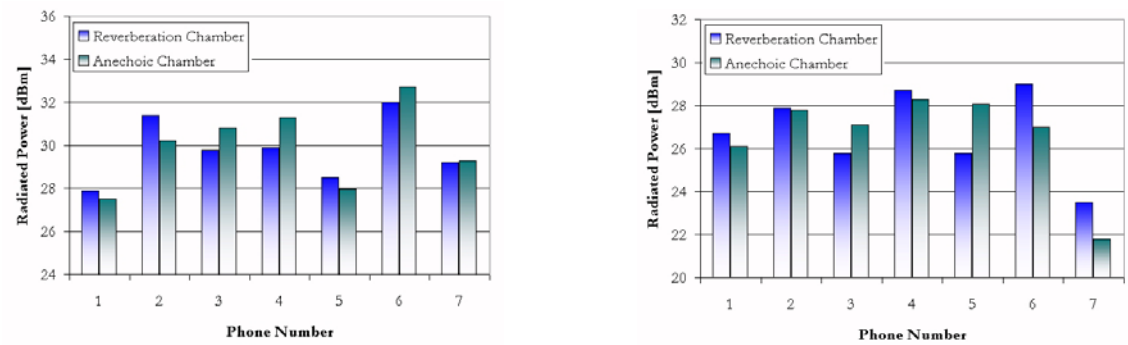

Figure 2. Comparison of radiated power measurements in reverberation and anechoic chambers at (a) 900 MHz (left) and (b) 1800 MHz (right).

TOTAL RADIATED POWER

Fig. 3(a) shows the normalized free space radiated power of 41 dual-band GSM (Global System for Mobile communications) mobile phones classified according to their design : phones numbered 1 to 24 are bar phones with built-in antennas while phones numbered 25 to 41 are clam-shells (or flip-flops). As expected the power radiated at 900 MHz is usually higher than at 1800 MHz since the average output power levels are 250 mW and 125 mW respectively. Obviously the non-linear variation between the two curves is due to antenna characteristics and electronics of the mobile phone which are not the same at the two frequencies. Clearly this figure shows that a given dual-band mobile phone can have different behaviors at the two frequencies (for example phones numbered 24 and 25).

Fig. 3(b) shows a similar comparison of the maximum averaged 10g SAR measured in a dosimetric test facility. Similar trends are observed in certain portions of the curves in-between the radiated power curves and/or SAR curves either at 900 MHz or 1800 MHz and also in-between the radiated power and SAR curves at a given frequency. The highest SAR values are observed at 900 MHz and, more interestingly, phone number 27 produces both the highest radiated power and SAR.

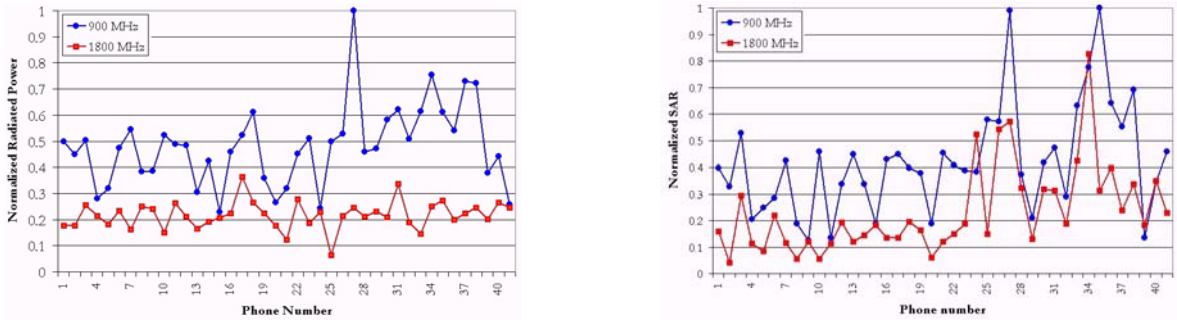

Figure 3. (a) Normalized radiated powers of the mobile alone (left) and (b) normalized SAR measured in a standard dosimetric test facility (right).

TOTAL ABSORBED POWER

Fig. 4(a) and (b) show comparisons of SAR and total absorbed power for the cheek position at 900 MHz and 1800 MHz, respectively. Similar trends are observed for the left and right positions either for the SAR or for the total absorbed power. Due to the specific location of the antenna in a mobile phone, the left and right positions do not produce symmetric measurement configurations. Nevertheless the power measurements show the existence of symmetry between the left and right configurations. Plots of the radiated power of the mobile phone alone against the maximum absorbed power show that about two-thirds of the power are absorbed in the phantom at 900 MHz and less than half at 1800 MHz (Fig. 5).

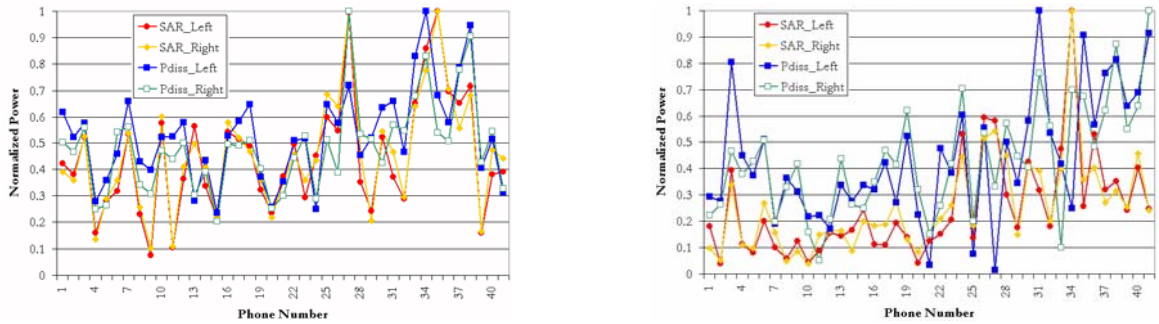

Figure 4. Normalized SAR and total absorbed power at (a) 900 MHz (left) and (b) 1800 MHz (right) for the left cheek and right cheek measurement configurations.

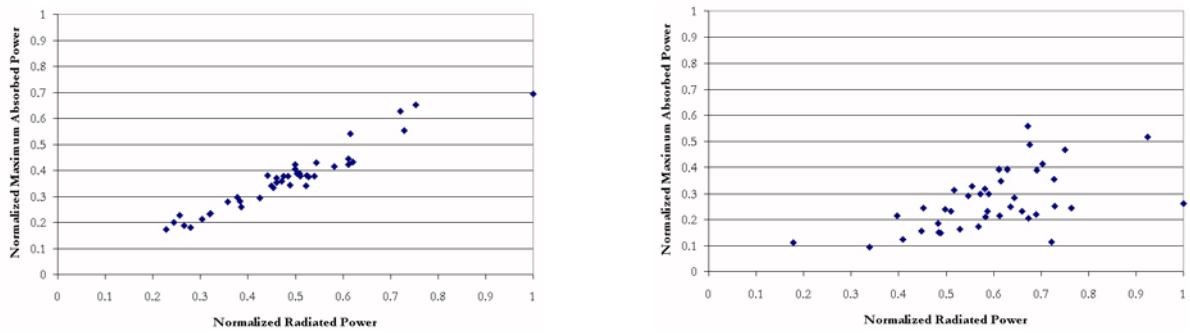

Figure 5. Normalized radiated power and total absorbed power at (a) 900 MHz (left) and (b) 1800 MHz (right).

SENSITIVITY

The sensitivity measurements were performed using a small radio-frequency coupling box commonly used for simple mobile phone tests and the reverberation chamber with the phantom. The multipath environment produced in the reverberation chamber results in frequent breaks in the communication link between the mobile phone and the base station emulator. To alleviate the measurement procedure the reverberation chamber was employed without any stirring

when performing the sensitivity measurements. Sensitivity levels better than –102 dBm and –100 dBm are expected by the GSM standard at 900 MHz and 1800 MHz respectively. Fig. 6(a) and (b) show that the coupling box provides a more favorable environment than the reverberation chamber at these two frequencies. The sensitivity tests are also successful using the reverberation chamber at 900 MHz. However this is not the case for about fifty percent of mobile phones tested in the chamber at 1800 MHz.

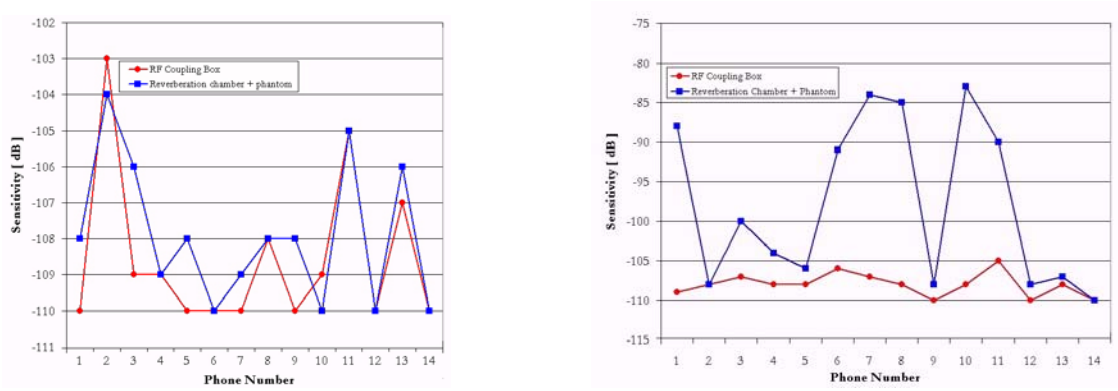

Figure 6. Comparison between sensitivity measurements using a small RF coupling box and the reverberation chamber with the phantom at (a) 900 MHz (left) and (b) 1800 MHz (right).

CONCLUSION

The global characterization of mobile phones using a reverberation chamber is presented. The accuracy of radiated power measurements in the reverberation chamber is evaluated through comparisons with anechoic chamber measurements. A fully automated system provides the radiated power measurements with and without the phantom in less than 30 min. for a dual-band mobile phone. Simple dosimetric assessment is possible using the correlation which exists between SAR and radiated power with or without the phantom. The extreme multi-path environment prevailing in the reverberation chamber is profitably used to test the robustness of mobile phones to multiple trajectories.

REFERENCES

1. CENELEC, “Basic standard for the measurement of Specific Absorption Rate related to human exposure to electromagnetic fields from mobile phones (300 MHz - 3 GHz),” EN50361-2001.
2. L. Duchesne, M. Legoff, P. Garreau, V. Monebhurrun and J.-Ch. Bolomey, “Non-invasive statistical SAR assessment from rapid near-field measurements in a spherical antenna test range,” in *Proc. IEEE Wireless and Radio Conf., RAWCON’2002,* Boston, Aug. 2002, pp. 129-132.
3. V. Monebhurrun, J.-Ch. Bolomey, A. Azoulay, L. Duchesne, M. Legoff and P. Garreau, “Statistical analysis of SAR data: the effective mass concept,” in *Proc. 6th International Congress of the BioElectromagnetics Association, EBEA’2003,* Budapest, Nov. 2003, p. 76.
4. V. Monebhurrun, J.-Ch. Bolomey, L. Duchesne, M. Legoff and P. Garreau, “Routine SAR evaluation using the effective mass concept,” in *Proc. Bioelectromagnetics Society Conference, BEMS’2005,* Dublin, June 2005.
5. K. Rosengren, P-S. Kildal, C. Carlsson and J. Carlsson, “Characterization of terminal antennas in reverberation chambers : improved accuracy by platform stirring,” *Microw. Opt. Technol. Lett..,* Vol. 30, No. 20, pp. 391-397, Sept. 2001.
6. P-S. Kildal and C. Carlsson, “Detection of a polarization imbalance in reverberation chambers and how to remove it by polarization stirring when measuring antenna efficiencies,” *Microw. Opt. Technol. Lett..,* Vol. 32, No. 2, pp. 145-149, July 2002.