# Mobile Phone RF Safety Testing using Magnetic Resonance Imaging

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Introduction: As specified by the Federal Communications Commission (FCC) and other regulatory bodies, specific absorption rate (SAR) from RF emitting devices must be measured prior to entering the consumer market, in order to prevent the deposition of excessive RF energy into the body [1]. Around the world, more than $1B is spent annually for testing RF emitting devices [2]. Current local SAR measurement schemes rely on electric (E) field probe measurements that are acquired in a point-by-point, grid-like fashion. Calibration of these E field probes is often non-trivial and can introduce errors into the measurement [1]. This conventional SAR measurement is often time consuming, as the probe tip is moved mechanically, and while the liquid phantom has electrical properties similar to those of human tissue, it lacks the complex anatomy presented by the human body. In this work, an alternative method is presented using MRI technology to evaluate the safety of RF emitting devices. This method is advantageous to quantify RF emissions as it measures temperature change, which is correlated with tissue damage, rather than E fields, which are a surrogate metric for heating. Furthermore, MR based measurements allow rapid probing of a multitude of spatial positions, and tests can be conducted on complex dielectric structures rather than simple homogeneous fluid samples. Results using MR thermometry to quantify RF heating generated by a GSM mobile phone are shown in this work.

Methods and Results: RF heating produced by a mobile phone was measured using a 3T whole body scanner and a birdcage knee coil (Siemens Medical Solutions, Erlangen, Germany). A cylindrical acrylic former with a diameter of 10.2cm and a height of 11cm was filled with gelatin gel by combining 600 g of sucrose (purity >99% Sigma-Aldrich, St. Louis, MO), 450 ml of distilled water (Sigma-Aldrich, St. Louis, MO) and 54g of gelatin (Kraft, Northfield, IL). The conductivity and relative permittivity of the phantom measured by a dielectric probe (Agilent 85070E, Santa Clara, CA) were 1.5 S/m and 35 respectively, emulating the electrical properties of the human brain at 1.96Ghz – the operating frequency of the GSM mobile phone used in this study. T1 and T2* of the phantom were 17ms and 1239ms, respectively. Three fluoroptic MR-compatible optical temperature probes (LumaSense, Santa Clara, CA) were inserted ~4cm into the phantom in different positions (Figure 1A) to provide an external reference for the temperature change produced by the phone (Fig. 1B). Two cylindrical oil phantoms were placed around the gelatin phantom to estimate the non-heat-related B0 drift. A baseline axial interleaved 2D GRE image was acquired with the following sequence parameters: TE=17 ms, TR=330 ms, matrix size = 64x64x16, voxel size = 4 mm$^3$, flip angle = 20 degrees and total acquisition time = 21.1 seconds. The patient table and phantom were then withdrawn from the bore and communication between a LG-CU920c cell phone (Seoul, Korea) and a MD8475A base station emulator (Anritsu, Kanagawa, Japan) was established to emulate a phone call, with the cell phone programmed to transmit at maximum power. The transmitting mobile phone was then placed on the phantom for 15 minutes to induce RF heating. The phone was then removed from the phantom, the table was placed back to its original position in the scanner, and a second post-heating GRE was acquired with the same parameters. Temperature change was calculated in accordance with the proton resonance frequency shift [3] (PRF) approach. Temperature difference maps for 6 slices in the middle of the phantom are presented in Figure 2. These maps agree well with optical probe temperature measurement at the time position indicated by the black arrow in Figure 1C. The maximum heating generated by the phone over the time of the emulated phone call was found to be 1.06 deg C close to the cell phone.

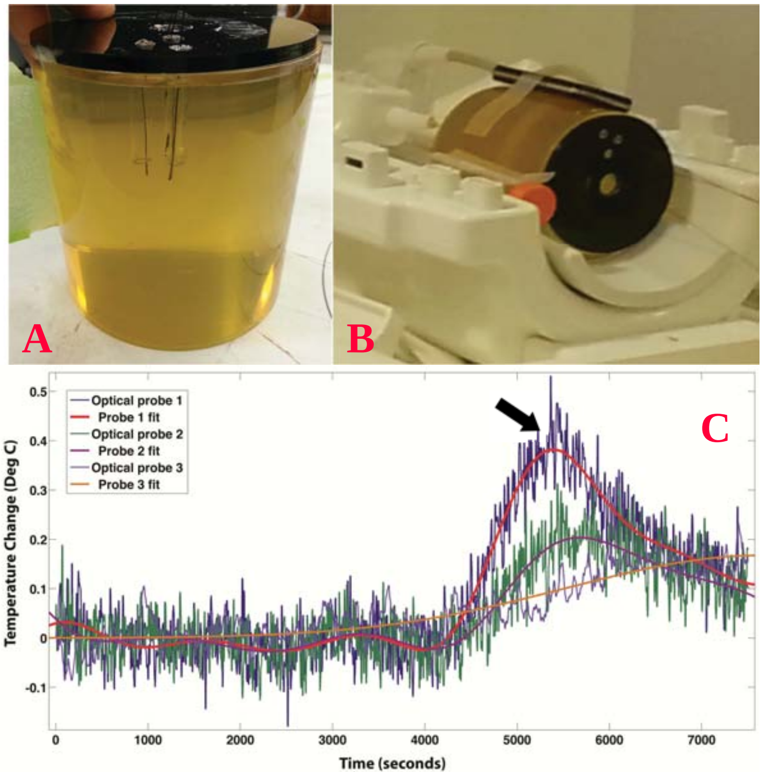

Figure 1. A. Gelatin phantom with 3 fluoroptic temperature probes. B. Phantom positioned inside a knee coil with an oil phantom on its side. C. Raw and fitted temperature probe data acquired during the experiment. The phantom was heated for a duration of 15 minutes, beginning approximately 4100 seconds after the start of the experiment. The black arrow indicates the points in time where the second MR thermometry GRE sequences were run.

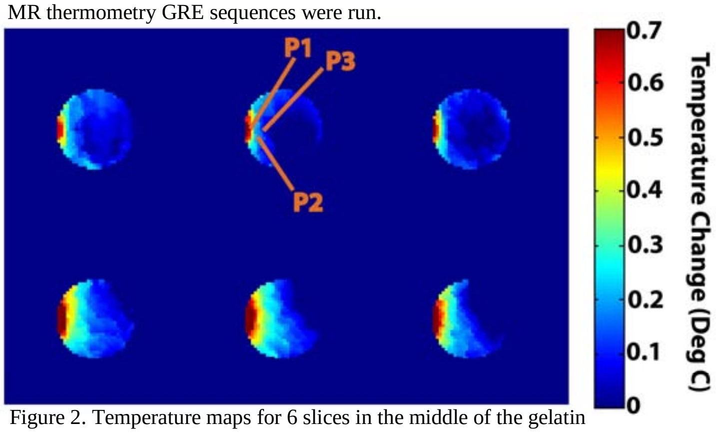

Figure 2. Temperature maps for 6 slices in the middle of the gelatin phantom. P1-3 (shown in orange), indicate the location of the fluoroptic temperature probes.

Discussion and Conclusion: This work shows the use of MR to quantify RF power deposition from a RF transmitting device such as a mobile phone. Results shown here can be extended to other RF emitting devices that operate at a range of frequencies, such as Wi-Fi antennas, tablet PCs, 4G antennas and more. Since MR temperature mapping can be conducted rapidly and robustly, this method can provide potentially better safety testing of wireless devices compared to conventional SAR testing methods.

References: [1] Cardis, E., et al. Occup Environ Med. 2011 September; 68(9): 686–693. [2] Federal Communications Commission market research. [3] Ishihara et al. MRM 1995;34:814-823.