Acadamh Ríoga na hÉireann
Royal Irish Academy

# Charlemont grant report

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| Recipient name: | Dr Laura Farina |
| Discipline and subject area: | Sciences, Engineering and Material Sciences |
| Amount and year awarded: | €2,200 in 2021 |
| Title of project: | Accurate temperature-dependent thermal characterization of phantoms for Quality Assurance of hyperthermia systems used in clinic |

**Summary of findings:**

The three phantoms employed in quality assurance (QA) of deep hyperthermia systems have been thermally and dielectrically characterised as a function of their temperature. The high-viscosity phantom presented in [2], the semi-solid phantom presented in [3] and the solid phantom presented in [4] have been exposed to temperature increase up to 45°C, i.e. up to temperatures induced in the biological tissue during hyperthermia treatments.

The study has been conducted in the Erasmus MC using the commercial thermal properties device TEMPOS from METER Group, Inc. USA. The phantoms were assessed dielectrically using the DAK dielectric assessment kit (Speag, Zurich, Switzerland) in the frequency range from 50 MHz to 500 MHz. The DAK-12 probe was connected to a Rohde and Schwarz ZNC 3 vector network analyzer (Rohde & Schwarz, Munich, Germany) with a low-loss coaxial cable. Five measurements were acquired for each phantom.

An increase in thermal properties up to 5% was observed with the temperature increase; this increase is smaller than the device accuracy (10%) and as well of the phantoms' variability (11% from [1]). The dielectric properties of the phantoms instead showed a sizable change, constant with the temperature (increasing conductivity and decreasing permittivity). These changes, linked to the temperature increase, showed to be reversible when the phantoms were brought back at room temperature.

These results are in line with what observed in biological tissues, like muscle and liver, thus the QA phantoms show to be well representative and suitable for their intended use.

These findings reinforce the value and importance of using QA phantoms for deep hyperthermia system assessment. Furthermore, a phantoms employed in quality assurance (QA) of super_cial hyperthermia systems have been included in the study. A muscle phantom for super_cial hyperthermia was thermally and dielectrically assessed at room temperature and up to 45°C. The measured values resulted comparable with reported values of muscle. Variations up to 4% of the thermal properties, smaller than the device accuracy (10%), were observed as a function of thetemperature increase. The dielectric properties changed constantly with the temperature (largely increasing in conductivity and decreasing in permittivity); but such changes showed again to be reversible when the phantom was brought back at room temperature.

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[1] Farina, L.; Sumser, K.; van Rhoon, G.; Curto, S. Thermal Characterization of Phantoms Used for Quality Assurance of Deep Hyperthermia Systems. Sensors 2020, 20, 4549. https://doi.org/10.3390/s20164549

[2] Mulder, H.T.; Curto, S.; Paulides, M.M.; Franckena, M.; van Rhoon, G.C. Systematic quality assurance of the BSD2000-3D MR-compatible hyperthermia applicator performance using MR temperature imaging. Int. J. Hyperth. 2018, 35, 305–313.

[3] Schneider, C.J.; Olmi, R.; van Dijk, J.D.P. Phantom design: Applicability and physical properties. In Thermoradiotherapy and Thermochemotherapy; Seegenschmiedt, M.H., Fessenden, P., Vernon, C.C., Eds.; Medical Radiology; Springer: Berlin/Heidelberg, Germany, 1995; pp. 381–397. ISBN 978-3-642-63382-9.

[4] Curto, S.; Aklan, B.; Mulder, T.; Mils, O.; Schmidt, M.; Lamprecht, U.; Peller, M.;Wessalowski, R.; Lindner, L.H.; Fietkau, R.; et al. Quantitative, multiinstitutional evaluation of mr thermometry accuracy for deep-pelvic MRhyperthermia systems operating in multi-vendor MR-systems using a new anthropomorphic phantom. Cancers 2019, 11, 1709.

**Plans for continuing collaboration:**

The collaboration with Erasmus MC will continue. This collaboration will continue grow within European and international networks such as MyWave Cost Action (https://www.cost.eu/actions/CA17115/#tabs|Name:overview) and the Thermal Medicine Standards Committee of the American Society of Mechanical Engineers (ASME).

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**Published work and publication plans:**

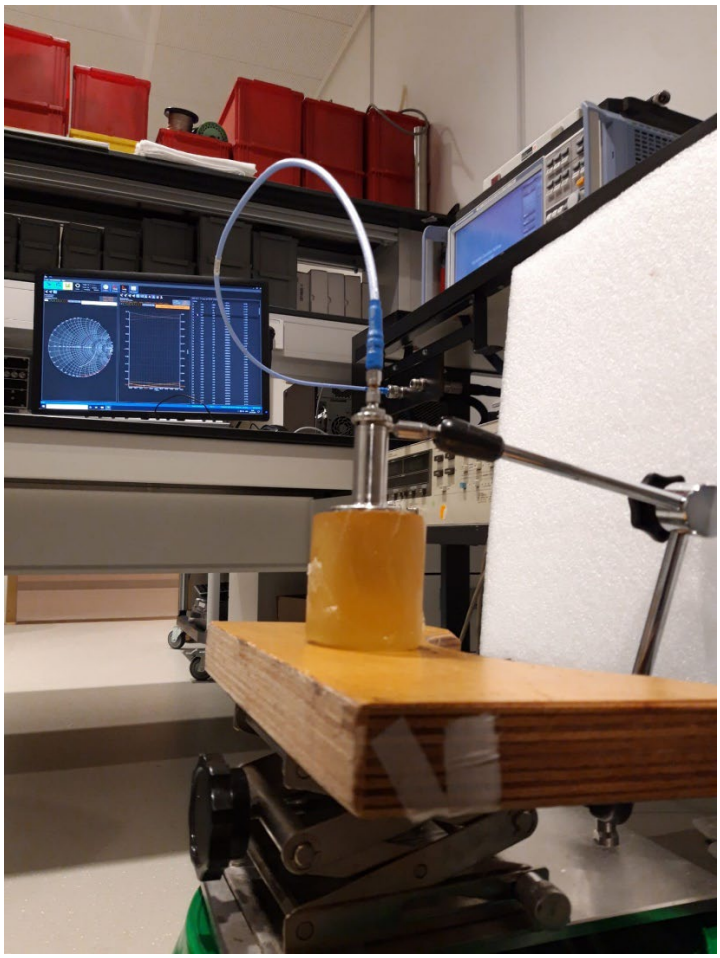
This study will result in the following publication:

1. Farina, L.; van Rhoon, G.; Curto, S., Characterization of Phantoms Used for Quality Assurance of Deep Hyperthermia Systems at hyperthermic temperatures, Sensors, Special Issue "Advances in Medical Microwave Imaging and Signal Processing, and Hyperthermic Technologies for Healthcare", 2021

2. Farina L, Silva N., de Lazzari M., Curto S., Trefna H., Thermal and dielectric assessment of Quality Assurance phantoms for superficial Hyperthermia Systems, Physics in Medicine and Biology, 2021

**Dissemination and plans for future dissemination:**

The work will be featured within the Hyperboost network https://www.hyperboost.eu/index.php and the COST MyWave network. The work will be disseminated within the communities and at working group meetings. In particular, during next COST MyWave WG1 meeting (January 2022 – to be defined), dedicated to thermal and dielectric properties of biological tissues. Contribution will be submitted to conferences of interest, e.g. 2022 IEEE International Microwave Biomedical Conference (IMBioC 2022), and European Society for Hyperthermic Oncology (ESHO) annual scientific meeting in autumn 2022 in Gothenburg, Sweden.



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**Collaborations and planned collaborations:**

The collaborative work conducted with Erasmus MC and the positive results from the deep hyperthermia QA phantoms investigation, supported by this grant, led to a further collaborative research.

The Chalmers University of Technology (Gothenburg, Sweden) showed interest in our study and in establishing a further collaboration. Chalmers University group is mainly dedicated to superficial hyperthermia and has recently proposed a novel fat phantom for QA. Thanks to the transfer of knowledge from the Chalmers University to NUIG supported by Erasmus MC, the fat phantom was manufactured and tests are currently conducted in NUIG.

Preliminary results showed that the fat phantom is well representative of the thermal and dielectric properties of human fat at room temperature. Further measurements as a function of temperature increase are currently conducted in NUIG laboratories.

**Outreach and engagement activities:**

N/A