Homogeneity of Electric Field in Racetrack Phantom for RF-Heating Test of Large Size Medical Implants

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Purpose
The safety of Magnetic Resonance imaging systems becomes more critical since the use of MRI is becoming more popular and developed for various diagnostics including the patients wearing medical implants. To estimate the risk, the implant could be evaluated in a similar artificial environment (in-vitro evaluation). These phantoms are developed and introduced in ASTM F2182 – 11a [1] as ASTM phantom and ISO/TS 10974 (technical specification) [2] as 'Race-track' oval phantom. However for both passive and active implants, the E-field should be uniform along the implantation area in terms of magnitude and phase in order to eliminate the effect of variation of electric field in absence of implant from the final test. Nevertheless the evaluation has to be performed for the maximum possible induced heating of the implant. By fulfilling these requirements, minimum uncertainty could be obtained for the evaluation. Appropriateness of Racetrack phantom for implementing large passive medical implants is studied in this article by extracting the E-field along the implantation path. Currently the ASTM phantom is the most popular and appropriate phantom for such an implants. The homogeneity of the E-field is only important wherever the field is tangential to the implant.

Method
A tuned generic birdcage coil has been used for simulations with SEMCAD X (Speag, Zurich, Switzerland) without considering the shield room. The E_{tan}-field has been extracted from full 3D simulation of phantom and the containing gel simulating the human tissue along an arbitrary closed path shaped as a generic hip implant. The defined limits in ISO/TS 10974 for active implants specifies less than 1dB variation of magnitude and less than 20 degree variation in phase shift of E_{tan}-field along the implantation area. Although the desired path is more similar to passive implants, but this could be a reference to evaluate the E-field in this study.

Results
Fig. 1 (left) exhibits the results of simulations with a tuned generic birdcage coil with two source ports as in realistic clinical coils showing a variation of maximum 0.9 dB for magnitude of E-field (by ignoring two small dimensions of the path which are perpendicular to the local E-field). The phase of E-field is plotted in Fig. 1 (right) and shows maximum 14 degree phase variation which is fulfilling the requirement of ISO/TS 10974 for even larger medical implants like hip and not only thin and long implants which is demonstrated in Annex M of standard. The measurement of E-field in an in-house built horizontal positioned racetrack phantom proves the numerically calculated E-field using SEMCAD. However the path we have specified here is a 2 dimensional path which is not realistic as a real hip implant is large in the third dimension too, therefore Racetrack phantom could not host a 3D large implant, but only thin and long or wide implant could be hosted for safety tests.

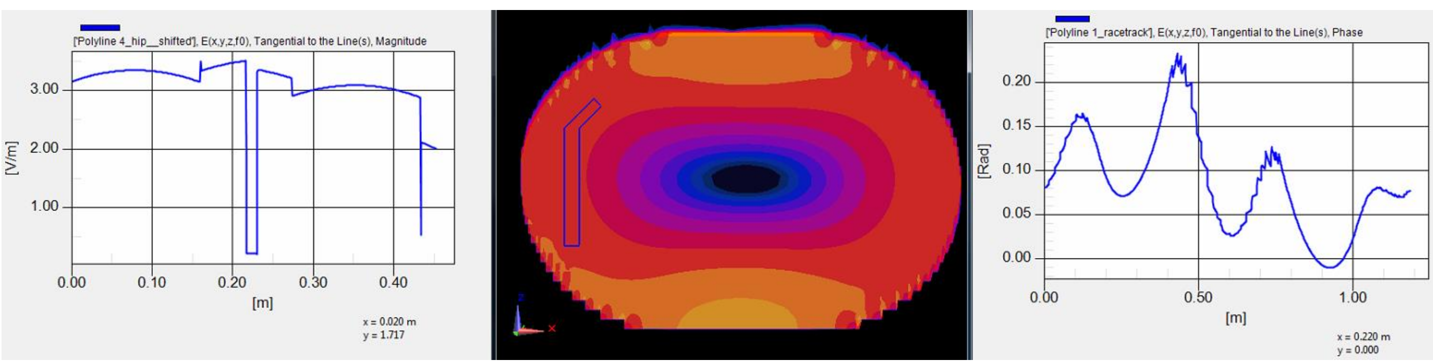

Fig.1 14° phase variation and 0.9 dB Magnitude variation of tangential E-field along the generic hip path in racetrack phantom

Conclusions
The Racetrack phantom containing the human body tissue simulating medium have been simulated and the E-field along the implantation area has been extracted in order to see whether this phantom could only be used for evaluation of larger implants. Results of simulation shows although the two dimensional large (wide) implant with limited dimension could be hosted in Racetrack phantom, but there is not enough space of locating a realistic model of a large implant and therefore ASTM phantom could take this duty over as much larger uniform space could be generated there.

References
[1] F2182 – 11a "Standard Test Method for Measurement of Radio Frequency Induced Heating On or Near Passive Implants During Magnetic Resonance Imaging". [2] Technical specification ISO/TS 10974 "Assessment of the safety of magnetic resonance imaging for patients with an active implantable medical device"1st edition 2012.