Influence of Electrical Connections on Catheter Heating

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Objective: Long conductive structures such as guidewires or cables pose a potential safety risk for MR guided interventions, because such structures can lead to excessive heating [1]. Since the wires inside a catheter (e.g. for active tip tracking or sensing of physiological voltages) are typically connected to some equipment, these connections also influence the safety of the device as indicated recently [2]. It is the purpose of this study, to investigate the dependence of catheter heating on the electrical connections. The approach is twofold: First, RF simulations aim at understanding the basic effects of different impedances at various positions along the connections. These include trap circuits, which are often applied, as well as high resistances or capacitors, which represent e.g. input impedances of amplifiers or generators. Corresponding experiments on RF heating are performed by varying the placement of a trap and the value of a capacitor at the connection to the Faraday cage. Secondly the tip heating is measured for several, realistic clinical active tracking set-ups. These measurements are performed for catheters equipped with a standard cable as well as a transformer-cable, which suppresses common mode RF currents [3].

Materials and Methods: In order to evaluate the influence of the device connection, a 1.5T birdcage body coil is simulated (MoM: CONCEPT II [4]) in conjunction with a Faraday cage surrounding it (5m x 3m x 3m), cf. Fig. 1a. The part of the catheter inside the body is represented by a "catheter wire" (55cm long, 0.1mm diameter, R=10Ω), with a dielectric coating, which includes the effect of the body (r=10cm, ε=80). An additional "extension wire" connects the proximal end of "catheter wire" to the Faraday cage. Different resistors and a trap circuit (180nH+0.5Ω with 31.1pF in parallel, Q≈145) are placed at varying positions on the "extension wire". In a second step, different capacitors are applied at the connection to the Faraday cage. The simulations are analyzed by calculating the E-field 2mm in front of the catheter tip. The transformer cable is modeled by three lumped capacitors (2.7pF) placed equidistantly on the "catheter wire". For the measurements, catheters are positioned ≈20cm off-axis in a saline-filled ASTM phantom located in the bore of a 1.5T MR system (Achieva, Philips Healthcare). MR sequences of 4W/kg SAR are applied. The temperature is monitored at the tip and at the insertion point by a fiber-optic thermometer (Luxtron 790). The sensors are placed in a block of saline-based agarose gel (σ=0.27S/m). In a first measurement (Fig. 2.a-i), a floating trap (described in [5], 20dB attenuation) is placed at various positions on the cable connecting to the Faraday cage. In a second measurement (Fig 2 a-ii), different capacitors are placed at the connection to the cage (w/o. traps). The experiments on realistic connection settings for active tracking were performed in a similar set-up. The different configurations are sketched in Fig.2b (i.e. unconnected, with extra extension cables of 2m total length, with additional trap circuits, placed at different positions in the cable, with and without final connection to the MR-system).

Results: The simulations show (Figs. 1b,c), that for catheters containing standard wires, resonant tip heating can occur depending mainly on the position of loads placed on the connecting cable or for certain capacitor values. These findings are qualitatively confirmed by the corresponding measurements (Fig 2c,d), the quantitative differences can be attributed to the slight differences in dimensions and geometries. In all measurements, the tip heating turned out to be significantly larger than the heating at the insertion point. The measurement of typical settings for active tracking confirmed considerable tip heating for the catheter with the standard cable in all connection configurations (tip heating ranges between 8.4K and 26.6K). An example is shown in Fig 2e. The increase of the measured tip temperature was less than 1K for the catheter containing the transformer-cable in any configuration (cf. Fig 2e), which is also supported by the corresponding simulations (Fig 1b,c).

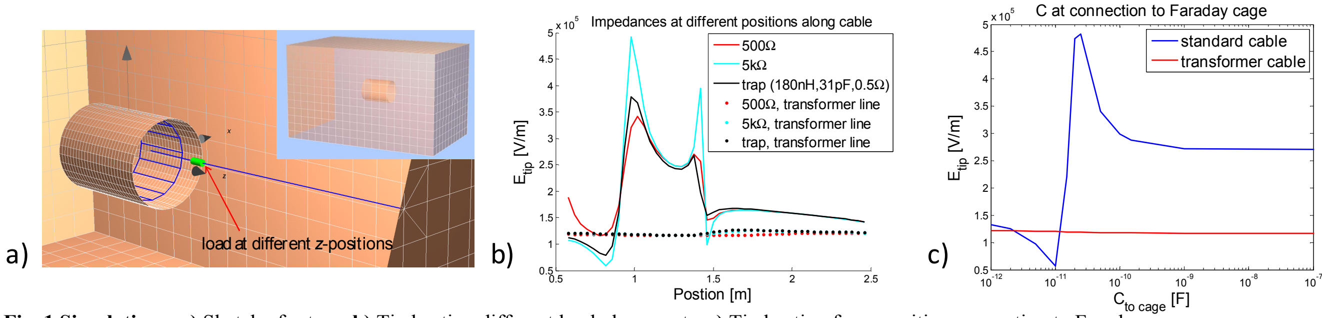

Fig. 1 Simulations: a) Sketch of set-up **b)** Tip heating different load placements **c)** Tip heating for capacitive connection to Faraday cage.

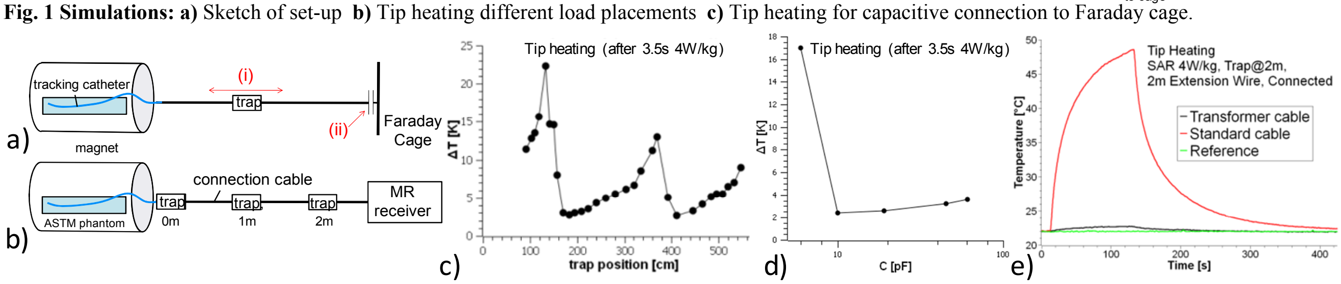

Fig 2. Measurements: a) Exp. setup varying trap (i) and C (ii) **b)** realistic configurations, **c)** Results of (i) **d)** Result of (ii) **e)** Measured heating curve.

Discussion & Conclusion: The measurements as well as the corresponding simulations confirm that tip heating of catheters strongly depends on the electrical connection. Especially high resistances and capacitors in the connecting line can cause resonant heating, if they are placed at specific positions or have certain values, respectively. It is not simple to generally avoid these conditions in clinical practice, since the required values are reasonable (e.g. for amplifiers, traps, etc.). This finding was confirmed in the measurements of typical active tracking set-ups. On the other hand, transformer cables do not show a relevant influence of the connection and do not lead to intolerable tip heating as verified by simulations and measurements. As a consequence, it is advisable to prevent resonant heating inside the catheter in order to avoid any negative influence from the electrical connections.

References: [1] W.R. Nitz et al., J. Magn. Reson. Imaging 2001;13:105–114. [2] S. O. Oduneye et al., ISMRM2010. p3895. [3] S. Weiss et al., Magn. Reson. Med. 2005;54:182–189. [4] CONCEPT II Code, TUHH. http://www.tet.tu-harburg.de/concept/index.en.html [5] D.A. Seeber et al., Conc. Magn. Res. 2004;21B:26-31