A New Design of an Implanted Medical Lead to Reduce RF Heating in MRI

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Introduction: Magnetic Resonance Imaging (MRI) has become the one of the most popular imaging procedure for diagnosis. Unlike conventional radiography and computed tomographic imaging, MRI has many advantages including its no ionizing nature and the ability to discriminate different soft tissues without contrast media. However, the substantial benefits of MRI are often not applicable to those patients who have implanted medical devices such as pacemakers (PM), implantable cardioverter devices (ICD) and deep brain stimulators (DBS). These implanted medical devices interact with the magnetic fields in MRI and one of the remaining challenges is the tissue heating by the induced scattered electric field from radio frequency (RF) coils in the MRI systems. The RF field existing inside body tissues during MRI is scattered by an implanted medical lead (Fig. 1). A very intense scattered electric field can exist in certain parts of an implant such as the tip of the long medical lead or the ends of elongated metal parts. This intense scattered electric field at the medical lead tip causes the flow of conduction currents in the tissue. Due to limited conductivity of the tissue, energy is deposited as heat as a result of ohmic loss in the tissue and generates hot spots around the lead tip. The scattered electric field can also cause image artifacts resulting in distorting the integrity of the MR scans. In this paper, a new design to reduce induced scattered electric fields near the medical lead tip has been introduced.

Methods: As shown in Fig. 2, the lead model implant considered for the calculations is a 40-cm long insulated wire with 1 cm removed insulation (Teflon) at one side end (capped lead). The wire (copper) diameter is 1.6 mm and the outer insulation diameter is 2.5 mm. These are the standard dimensions recently suggested by the Food and Drug Administration (FDA) for the implant model. The constitutive parameters of the embedding medium corresponding the human tissue at 64 MHz are ε_r=60, σ=0.6 S/m. A solenoid of 15-mm long (10 turns, and distance between the turn is 1.5 mm) has been used as a RF-excitation source. A distance (D) between the lead tip and RF-excitation source is varied and the scattered electric field has been calculated near the lead tip at 64 MHz (1.5 T MRI system) using Ansoft HFSS. In order to reduce the scattered electric field near the lead tip, proposed metal nails have been placed along the length of the lead. The dimension of a nail has also shown in Fig. 2. The numbers of nails in one turn (Nn), the number of nails set (Ns) and the dimension of the nail (Wx, lx, Wz, lz) have been varied to check the variation of the scattered electric field near the lead tip. Scattered electric field also calculated for uncapped (1cm of insulation removed from both side ends) lead for the comparison.

Results: The scattered electric field can be reduced significantly by using proposed nails (Fig. 3). As expected, by installing more no. of nails set (Ns), the electric field is reduced significantly. However, by increasing the no. of nails in one turn (Nn) doesn't necessarily decrease the electric field at all points (Fig. 4(a)). Fig. 4(b) shows, Nn=1, Ns=30 configuration produces the best result overall, whereas Nn=1, Ns=20 configuration increases the electric field within the last 10 cm of the lead. For Nn=1, Ns=10 configuration, the electric field increases at all points. The dimensions of the nails have least effect on the scattered electric field except the dimension, Wx. As shown in Fig. 4 (c), the shorter Wx from 0.45 mm results in the more scattered electric field near the lead tip.

Conclusion: The MRI heating problem with ICD or pacemaker has become a major concern over the past few years. In this paper, by introducing nails in the medical implant provide a way to reduce the electric field near the lead tip. In future, it is necessary to check the result for different lengths of medical implant (e.g.; 20 cm, 60 cm) and at different MRI frequencies (128 MHz, 300MHz) as well.

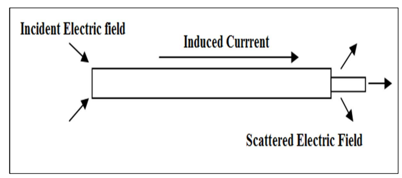

Fig. 1. Scattered electric field in the medical lead tip

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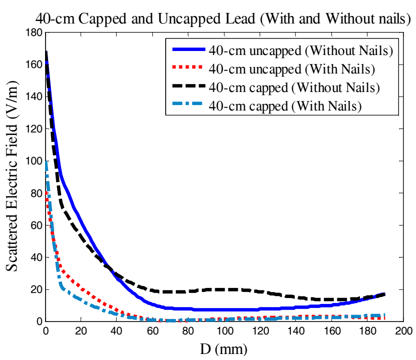

Fig. 3. Simulation results for with and without nails configuration of 40-cm capped and uncapped lead

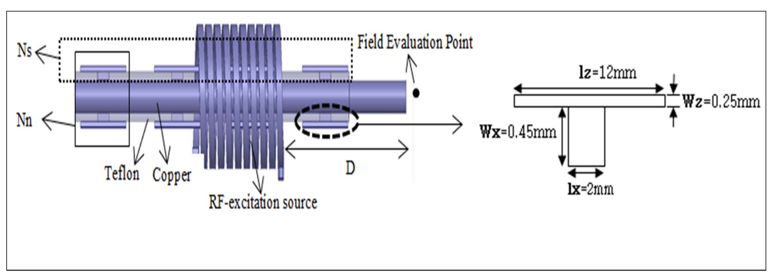

Fig. 2. Model of the medical lead Implant with proposed nails and RF source

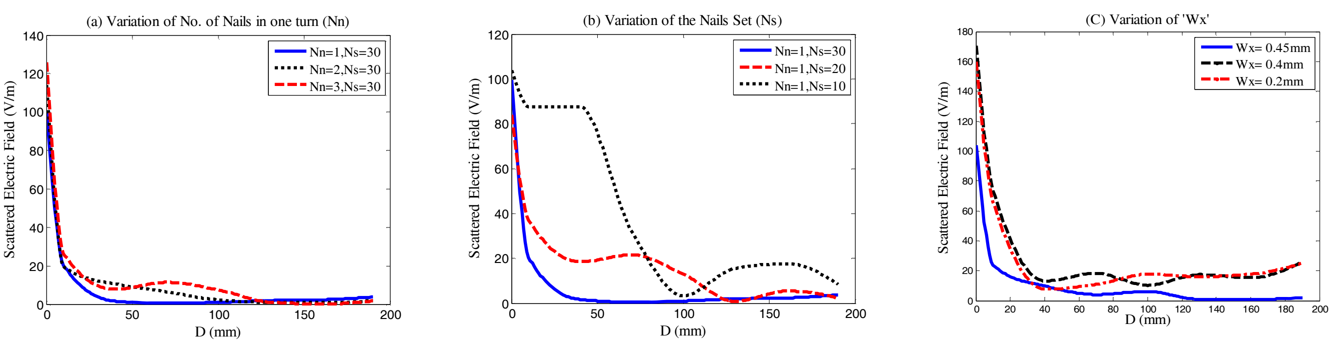

Fig. 4. Simulation results for variation of **(a)** No. of nails in one turn, Nn; **(b)** Nails set, Ns; **(c)** Nail length, Wx