A Novel Nanomaterial Coil for High Resolution Prostate Imaging

R. Viswanathan[1], B. Goldstein[1], K. Anderson[2], and A. Krieger[3]
[1]Tursiop Technologies, LLC, Cleveland, OH, United States, [2]Sunnybrook Health Sciences Center, University of Toronto, Toronto, Ontario, Canada, [3]Sentinelle Medical Inc., Toronto, Ontario, Canada

Introduction

Recently an emerging RF coil technology based on a new nanostructured material was introduced [1]. The nanomaterial can be macroscopically configured in a ribbon or string form and is comprised of a dense array of carbon nanotubes. The macroscopic configuration is mechanically robust and is held together densely by van der Waals forces. It was demonstrated in [1] that this material holds significant promise for the construction of high performance MR imaging coils. In contrast to metallic conductors, the bulk carbon nanotube material shows negligible skin effect over the frequency range of interest for MRI applications, so that with a sufficiently large packing density the resistance of a given length of nanomaterial can be made smaller than that expected for a metallic conductor of similar geometry. Furthermore, ballistic charge transport within an individual carbon nanotube results in a kinetic inductance due to higher effective charge carrier inertia, leading to larger electrical inductance. The combination of increased inductance and reduced resistance can be used to build receive coils with enhanced SNR. Here this is explicitly demonstrated in a prototype prostate imaging coil that was built to fit into a commercially available endorectal probe for prostate imaging and biopsy.

Materials and Methods

Carbon nanotubes were grown in a furnace process and drawn into a continuous, macroscopic nanomaterial yarn or wire form by a spinning process. Four strips of the nanomaterial, each about 8 cm in length and about 300 microns in diameter, were attached to metal electrodes and formed into conductor strips to construct a long rectangular two-turn coil with capacitors placed between successive strips. The coil had approximate dimensions of 1.6 cm x 7.6 cm and was attached to a circuit board with suitable tuning and matching circuitry that included an active PIN diode-based block for detuning during transmit. A preamplifier proximal to the circuit board amplified the signal from the coil before it was routed to the scanner. The coil was designed to be capable of easy insertion into a small profile, rigid endorectal prostate imaging coil housing (Sentinelle Dual-Channel Endo Coil Array, Sentinelle Medical Inc., Toronto, Canada), Figure 1. The single-channel prototype nanomaterial-based imaging coil was tested on a 1.5T GE Signa scanner in a prostate phantom consisting of $MnCl_2$-doped saline and designed with a 35 mm diameter plastic tube through the center of the phantom for insertion of imaging coils. The new nanomaterial-based coil was compared to imaging results acquired with a single-channel Medrad endorectal imaging coil (eCoil ®, Medrad, Indianola, PA, USA), and with a standard Sentinelle dual-channel endo coil array placed in the same phantom. All three coils were oriented towards the bottom of the phantom, with the smaller diameter standard Sentinelle dual-channel endo coil array and the nanomaterial coil laying on the bottom of the plastic tube inside the phantom. The same spin echo scan sequence was used in each case (SE, TE = 14 ms, TR = 450 ms, FOV = 20 cm x 20 cm, slice thickness 5 mm, 122 Hz pixel bandwidth).

Results

SNR contour maps were constructed for the nanomaterial-based imaging coil (nanocoil), the Medrad eCoil ®, and the Sentinelle dual-channel endo coil array, in each case using an axial image slice through the phantom located approximately at the middle of the length of the coil (the axial image slice is shown in Figure 2 for the nanocoil). While the single channel nanocoil was somewhat longer than either of the commercial coils, Figure 3 illustrates that it yielded significantly higher SNR numbers than the Medrad eCoil ®, and SNR profiles very similar to the Sentinelle dual-channel endo coil array.

Fig. 1: Photo of Sentinelle Dual-Channel Endo Coil Array

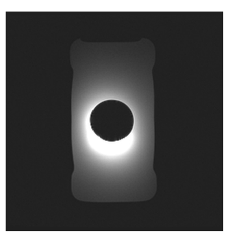

Fig. 2: Axial image from nanocoil placed in the prostate phantom

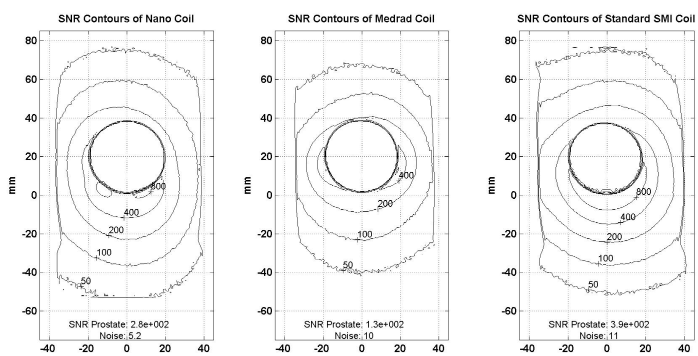

Fig. 3: SNR contours for the nanocoil (left), the Medrad coil (middle) and the standard Sentinelle dual-channel coil (right)

Conclusions

We have directly shown the benefits associated with RF coils constructed from a nanostructured material comprising carbon nanotubes in the context of a new prostate imaging coil that can, with only a single receive channel, yield SNR profiles very similar to state-of-the-art dual channel coils. While this coil was constructed to be compatible with the housing of the Sentinelle dual-channel endo coil array, it was not optimized. Significant gains in SNR are anticipated from coil geometry optimization and the incorporation of a second receive channel, with positive implications for high resolution prostate imaging and improved diagnostics. This development effort is in progress and will be reported on in the future.

Reference

[1] R. Viswanathan, B. Goldstein, K. Anderson, M.J. Bronskill, R. Baughman, M. Zhang, S. Fang, A. Zakhidov, A.Aliev, *Beyond Copper: MR Imaging with Carbon Nanotube Receiver Coils*, Proceedings, ISMRM 2009, page 504.