

The Interventional Loopless Antenna at 7 Tesla

Mehmet Arcan Erturk^{1,2}, AbdEl-Monem M. El-Sharkawy², and Paul A. Bottomley^{1,2}

¹Electrical & Computer Engineering Department, Johns Hopkins University, Baltimore, Maryland, United States, ²Department of Radiology, Johns Hopkins University, Baltimore, Maryland, United States

Introduction. The interventional loopless antenna detector potentially offers near-quadratic gains in signal-to-noise ratio (SNR) with B_0 [1]. Higher SNR offers the potential for MRI microscopy of internal anatomy at $<100\mu\text{m}$ resolution, larger effective fields-of-view (FOV) and/or high-speed MRI endoscopy [2]. Here we report the development and performance of the first intravascular loopless antenna for use on a 7T MRI scanner [3]. The absolute SNR was determined theoretically using numerical computations, confirmed by measurements at 7T, and compared to 3T. Safety testing suggests that the device can be operated safely at 7T. Finally, high-resolution ($58\mu\text{m}$) *in vitro* MRI of intact human arterial specimen is presented.

Methods. 7T and 3T loopless antennae were fabricated

from $\frac{1}{4}$ -wave-lengths of UT-85C coaxial cables with inner conductors extended to form resonant whips. Antennae were connected via baluns, decoupling, and match/tune circuitry [1], to the scanner's preamplifier/ interface.

Absolute SNR was measured with the probes parallel to B_0 , placed in a 20cm-diameter, 20cm-long saline phantom whose electrical properties were comparable to biological tissue (conductivity, 0.63S/m; dielectric constant 80). The SNR at 7T was corrected for the non-uniform RF excitation field (B_1). Noise was determined from images acquired with the pulses turned-off. Absolute SNR for the identical geometry and phantom set-up was computed numerically at 3T and 7T by the electromagnetic (EM) method-of-moments (*FEKO, Inc, South Africa*).

Safety was tested both numerically using *FEKO* and experimentally at 7T with the loopless antenna inside a 20-cm head-sized phantom, filled with saline gel of the same electrical properties as above. Experimental antennae were placed at two different geometries in the phantoms, at locations chosen as having the highest local specific absorption rate (SAR), based on the computed SAR distribution. Temperature changes at fixed locations on the antenna were measured with fiber-optic temperature sensors (*Fiso Inc, Quebec*). Temperature measurements performed at identical sites with the antenna absent, were used to determine the applied SAR, and to normalize the temperature change (ΔT) at the device for a 4W/kg applied SAR [1]. The 7T head coil was driven with a 25W continuous power in a screen room and ΔT 's recorded from the thermal sensors.

In vitro turbo spin-echo (TSE) MRI at 7T was performed on human specimens obtained from our institution's autopsy service.

Results. Fig. 1 shows the measured (colored points), and computed (black circular contours) absolute SNR of the 7T loopless antenna. The measurements agree with theory, showing an SNR increase of 5.7 ± 1.5 times at 7T compared to 3T, and an increase in useful FOV area ($\text{SNR} > 50,000 \text{ Hz}^{1/2} \text{ ml}^{-1}$) of approximately 10-fold compared to 3T. At an applied SAR 1.1-3.7W/kg during 15 minutes, recorded ΔT did not exceed 1°C . After normalization to 4W/kg uniform exposure, maximum ΔT at the antenna was 1.9°C . Fig. 2 shows SSFP images at $58\mu\text{m}$ in-plane resolution acquired with the loopless antennae from inside a human carotid artery in a saline bath. The dark area is a large calcification within an atherosclerotic plaque.

Conclusion. The results show that $\text{SNR} \sim B_0^2$ extends at least up to 7T for interventional loopless antennae, and suggest possible safe usage at 7T [3]. Given prior results showing a 3.8-fold SNR at 3T vs 1.5T, the extra 5.7-fold SNR gain shown here at 7T, results in a net SNR gain of about 20-fold at 7T vs 1.5T, offering a new window for MRI microscopy.

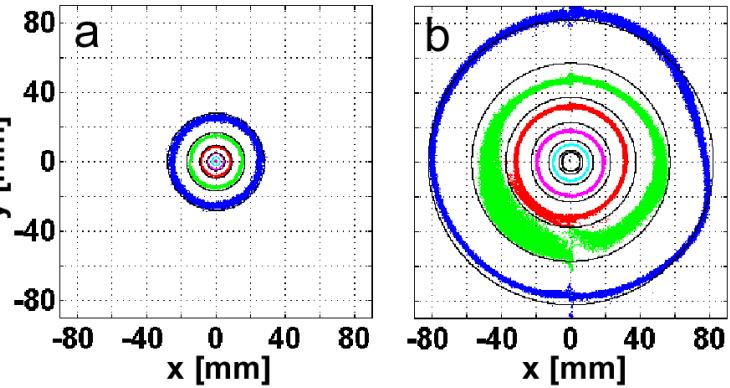


Fig. 1: (a) Absolute SNR on the axial plane at the junction of 3T, and (b) 7T loopless antenna. (black contours: computed. Experimental data are blue=50k; green= 100k; red=200k; purple=400k; cyan=800k $\text{Hz}^{1/2} \text{ ml}^{-1}$)

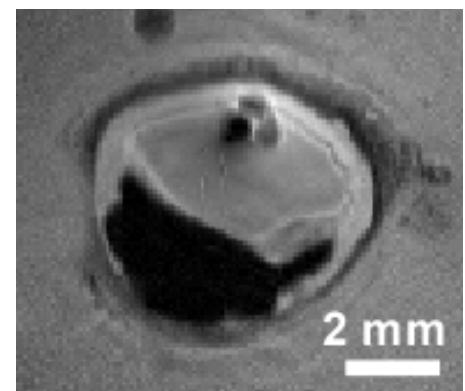


Fig. 2: 7T TSE image from human carotid artery (3D TSE, TR/TE=1500/32ms, Voxel size = $58 \times 58 \mu\text{m}^2 \times 1\text{mm}$)

[1] El-Sharkawy AM et al. *Med Phys* 2008; 35:1995-2006.

[3] Erturk MA et al. *Magn Reson Med*, in press.

[2] Sathyaranayana et al. *JACC-Cardiovasc Imag* 2010; 3:1158-1165.

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