# Monopole-drive for RF Ablation at 64 MHz

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**Target Audience:** Anyone interested in interventional MRI and RF ablation.

**Purpose:** In this work, we present a novel monopole-drive method to enable RF ablations to be performed at the proton resonance frequency, without any ground pad. We investigate the imaging capabilities, current distribution, and heating potential of this method.

**Methods:** A monopole drive mechanism consisting of a high-Q shielded LC tank circuit was constructed (Fig. 1). This monopole driver can be interfaced with commercial ablation probes, such as the Leveen probe shown in Fig. 1, and generates current waves that travel along the insulated shaft of the probe to the probe tines. The probe can act as a transmit/receive coil to the MRI scanner.

To examine the current flow in the ablation probe, the probe was inserted in a saline gel phantom in a 1.5T scanner, and current measurements were acquired at different locations on the probe using both an optically coupled toroidal RF current sensor [1] and current estimates computed from axial Bloch-Siegert $B1^+$ maps [2,3]. The current measurements were performed with the probe tines both retracted and deployed. Axial and coronal GRE images (1.5T, TR/TE = 50/6ms, 1-cm slice thickness) using the probe as a transmit/receive coil were acquired to test the visualization capabilities.

Fluoroptic temperature probes were placed at the tip of the probe tine cluster and at the base of the probe shaft, and temperature measurements were acquired at different monopole-drive RF transmit power levels (continuous wave, 64 MHz RF) to investigate the heating ability in a saline gel phantom.

**Results:** With tines retracted, current falls off with distance from the base to the tip of the probe (Fig 2, top). Deploying the tines enables current to flow uniformly from the base to the tip (Fig. 2, bottom), indicating that current does not leak into the tissue/phantom until it reaches the tines. A transmit power level of 40W can generate 700mA-peak current in the probe.

The probe can be visualized using transmit power levels as low as 0.38W (Fig. 3c,d). Inconel probe tines appear dark in axial images (Fig. 3a-b), while copper tines of a mockup probe are bright (Fig. 3e,f).

Tip temperature exceeding 60°C can be achieved in less than 6 minutes with 100W drive power. Heating at the base of the probe was less than 5°C (Fig. 4).

**Discussion:** RF ablation is typically performed at 460kHz and requires ground pads to be placed on the thighs to close the circuit. At 460kHz, RFA depends mainly on tissue conductivity. During heating, gas formation and desiccation create impede-out conditions that limit the maximum lesion size. Moreover, RF burns can occur at the pads. However, in the VHF range of MRI, tissue permittivity is comparable to conductivity in supporting RF, and the tissue-probe now forms a lossy dielectric top-loaded antenna, obviating the need for a ground pad. We believe the higher frequencies allow a capacitive bypass in areas of changing conductivity, much like microwave ablation (MWA). Indeed this property is believed to be the reason that MWA can generate higher temperatures and more consistent lesions. VHF ablation and the demonstrated device visualization and field mapping by MRI appear to be feasible, but clearly, further work is needed to determine heat potential and lesion size in perfused tissue.

**Conclusion:** Classic RF ablation probes can be driven as insulated monopoles at MRI frequencies. We have shown that these devices can be visualized as MRI transmit/receive elements, and can effectively heat media to over 60°C, which is necessary for effective ablation.

**References:** [1] Etezadi-Amoli et al., ISMRM Workshop on MR Safety in Practice, Lund Sweden, 2012. [2] Etezadi-Amoli et al., Proc. 21st ISMRM, p723, 2013. [3] Sacolick et al., MRM 63:1315-1322, 2010. NIH grant support: R01EB008108, R33CA118276, P01CA159992.

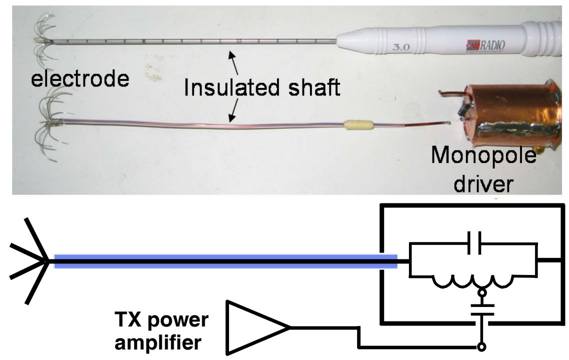


**Figure 1:** Photo of commercial ablation probe (top), copper mockup probe (middle), monopole driver and schematic.

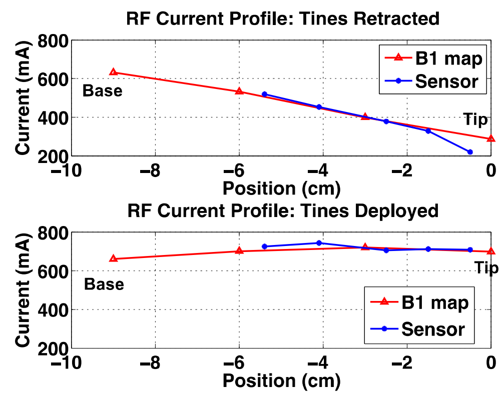


**Figure 2:** Current profile (mA-peak), probe tines retracted (top) and deployed (bottom). Deploying the probe tines allows RF current to flow uniformly from the base of the probe to the tip.

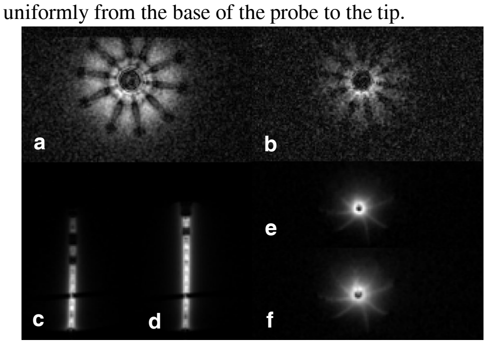


**Figure 3:** Axial GRE images of Inconel probe at 40W transmit power (a) and 1.1W transmit power (b). Coronal GRE image at 0.38W transmit power of retracted probe tines (c), deployed tines (d). Axial GRE images of copper mockup probe (e,f).

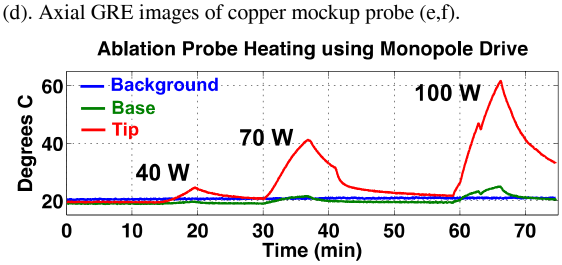


**Figure 4:** Fluoroptic temperature measurements during CW 64MHz monopole RF transmit at 40W, 70W, and 100W. Temperature increase of > 40°C can be achieved in 6 minutes.