# Reverse Polarization Method for Catheter Tracking: Phased Array Coil Studies and Real-Time TSENSE Implementations

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## INTRODUCTION

In MRI-guided vascular interventions, visualization of interventional devices is rather difficult. For this purpose many tracking techniques have been developed (1). In one of these studies, reverse polarized signal was acquired using a receive-only birdcage coil in order to separate the anatomical information from a catheter which contains a receive coupled RF (RCRF) coil (2,3). An RCRF coil is inductively coupled to an external coil only in receive mode.

In present work, the reverse polarization method has been implemented using phased array coils and real-time experiments have been conducted on phantoms using TSENSE (4,5) algorithm. As a result, reverse polarization mode of image, which consists of the catheter, and color-coded image are obtained with improved imaging frame rate. In order to show safety profile, phantom heating experiments were conducted.

## THEORY

In our design, sensitivity maps of each element of a phased array coil are utilized in order to obtain forward and reverse polarization mode images. The reverse mode contains only catheter information, whereas both catheter and anatomical information is in the forward polarization mode image (2,3). First, by fitting two dimensional polynomial function to acquired images, the sensitivity map of each coil is extracted.

$$R = \left[ I_1 \ I_2 \dots I_N \right] \cdot \begin{bmatrix} S_1 & S_2 & \cdots & S_N \\ S_1^* & S_2^* & \cdots & S_N^* \end{bmatrix}^+ \cdot \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

In the equation on the left, $R$ represents reverse polarized pixel value, $[I_1 \ I_2 \dots I_N]$ vector is complex image pixel values originated from the each of the channels. In this equation $[S_1 \ S_2 \dots S_N]$ denotes the sensitivity vector. Note that "+" and "*" are psuedoinverse and complex conjugate operations respectively. The first row of the sensitivity matrix represents forward polarization, and the second row is conjugate of the sensitivity values, which represents the reverse polarization. If the pixel data, $I$ vector, belongs to sample signal, $R$ becomes zero. On the other hand, if the pixel includes the RCRF coil data, it contains reverse polarization signal and the result will be non-zero. Having applied this operation to all of the pixels, the reverse polarization mode image is obtained. This method enables suppression of background information and extracting the signal from the catheter.

The reverse polarization method is compatible with many imaging techniques including parallel imaging methods. Some straightforward modifications to the algorithm are necessary. For example, in order to implement TSENSE (4,5) with this method, the sensitivity vector is replaced by the conjugate of the unmixing vector.

## METHOD

We have conducted two phantom imaging experiments. In the first experiments a GE 1.5 T Signa Excite was used with a 8-channel brain array coil and with the following sequence parameters: Spoiled Gradient (SPGR) sequence with TE: 3.2 ms, slice thickness: 20 mm, flip angle: 90$^o$, spacing: 1 mm, matrix: 256 X 256, FOV: 300 X 300 mm$^2$, BW: 31.25 Hz. In order to show the effectiveness of the reverse polarization method, a special phantom is prepared. The phantom contained NaCl solution with two straws and an RCRF coil in it. The RCRF coil produced less contrast than straw and enabled to test the performance of the method. The RCRF coil was 8.5-cm long and a heat shrink tube was used for isolation resulting in a prototype device with an outer diameter of 4 mm.

In the second experiments, a Siemens 1.5T Espree imaging system was used with an 15 phased array coils (9 channels from Torso Phased array and 6 from spine array coils). TrueFISP sequence was used wih the following imaging protocol: TR: 3.2 ms, flip angle: 45$^o$, slice thickness: 5 mm, spacing: 1 mm, matrix: 192 X 108, FOV: 300 X 300 mm$^2$, BW: 800 Hz/pixel The RCRF coil was 7.5-cm long and a heat shrink tube was used for isolation with an outer diameter of 2.3 mm. Above mentioned TSENSE method was implemented for real-time image reconstruction with higher frame rate.

## RESULTS

Figure 1 shows results of GE Signal Excite system results. Figure 1a is forward polarized mode image showing the catheter with the background. By using a reverse polarization method, we were able to eliminate background from the catheter image (Figure 1b) and overlaid the color-coded catheter image on the background (See Figure 1c. The results of the second experiments are shown using acceleration rate 3 in Figure 2 with the same order as the first one. Successful suppression of background and ghosting are demonstrated; artifacts are seen near the edges of the imaging volume of the short bore magnet. In the phantom heating test, the largest increase, 1.6 $^o$C in 360 seconds, was observed at a point very close to tuning capacitor of the RCRF coil as expected.

## CONCLUSION

We have demonstrated the phased array and real-time TSENSE implementations of the reverse polarization method. With this improvement, simultaneous acquisition of both inductively coupled coil and background images with the ability to color-code the instrument signal is enabled with improved imaging frame rate. This method may be used very effectively for accurate catheter tracking and for improved delineation of instrument to background signal when using wireless active catheter visualization.

**Figure 1:** The first imaging experiment results. Although gel filled straws look brighter in Figure 1a, which is squared sum image, the reverse polarization method successfully extracts the catheter image (Figure 1b). As a result, color-coded display shows catheter clearly.

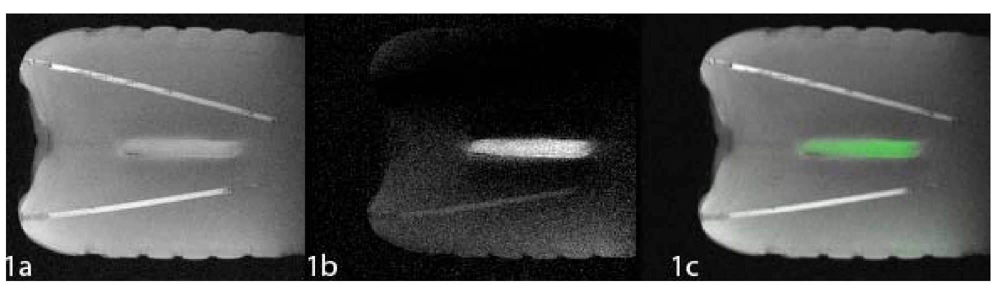



**Figure 2:** The second experiment results. Again, TSENSE rate 3 is shown for real-time catheter tracking and successful results are obtained as the first experiment. The order of the images are the same as the first experiment.

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