# Catheter Tracking with Phase Information

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## Introduction

Active catheter tracking techniques utilize small receive coils located at the distal end of the catheter. A popular method for tracking the tip of the catheter involves projecting the signal received from a microcoil onto three orthogonal axes. The peaks of these projections are then considered to correspond to the position of the microcoil. [1]. There are limitations associated with such methods. Depending on the signal characteristics of the anatomy immediately surrounding the catheter and the medium inside the catheter, the position of the signal peak may not correspond to the exact centre of the receive coil. The peaks of the projections can also change significantly depending on coil orientation in the magnet. Also, no information about catheter orientation is generated from a single coil. In this study we propose a new active technique for catheter tip tracking that exploits properties of the phase information introduced into the MR signal by a small microcoil located at the distal tip of the catheter. Phase information is directly related to the position and orientation of a small circular receive coil and is able to provide information about both position and orientation.

## Theory

The position and orientation of a microcoil can be described by the parameters depicted in Fig 1. The theory of reciprocity and the law of Biot-Savart can be used to calculate phase images one would expect to acquire in various planes around the microcoil. Theoretical studies indicate that a phase image acquired using a non-slice-selective excitation in the axial plane (illustrated in Fig 2a) has the unique and useful property that it is independent of coil pitch (rotation φ). As such, a phase image acquired in this plane can be fitted to determine the x-y position of the microcoil as well as its rotation θ about the main static field. Once determined, a second phase image can be acquired in an oblique plane through the microcoil (illustrated in Fig 2b) and fitted to complete a five-degree-of-freedom description of the position and orientation of the microcoil.

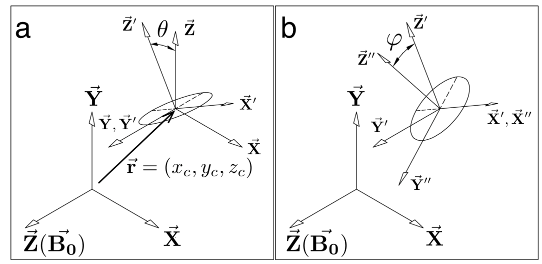


**Fig 1.** Illustration of the parameters that enable a 5-degree-of-freedom description of a circular microcoil. The vector **r** describes the position of the centre of the microcoil using the coordinate system of the imaging system. The orientation of the microcoil is described by two successive rotations. The first is a rotation θ ("roll") about the main static field **(a)**. The second is a rotation φ ("pitch") about the **X'** axis **(b).**

## Materials and Methods

A rigid catheter with a 4-turn, 4mm-diameter microcoil located at the distal tip was fabricated and positioned at various locations and orientations in a 2% polyacrylic acid gel phantom. Phase images (SPGR, FOV=26cm, 256x256) were acquired using a 1.5T system (GE Medical Systems) as outlined above. Errors due to static field inhomogeneities were corrected using a field map acquired with a surface coil. The surface coil was also used to measure and compensate for any drifting system reference phase and to remove phase errors due to gradient delays. The position and orientation parameters were fitted by minimizing a difference metric that preferentially weighted higher SNR data, specifically the phase acquired closer to the microcoil. An x-ray system (Innova, GE Medical Systems) was then used to perform a cone-beam acquisition and associated three-dimensional isotropic volumetric reconstruction of the entire apparatus (FOV=16cm, RES=220um). The position and orientation of the microcoil was measured with respect to multi-modality fiducial markers and compared to the position and orientation parameters calculated through the fitting of the acquired phase images.

## Results and Discussion

Good visual agreement between the acquired (Fig 2c,d) and fitted (Fig 2e,f) phase images was seen. Overall, the parameters that describe the position and orientation of the microcoil as determined through the use of phase information show good correlation with those measured using the x-ray system. Bland-Altman plots of the position and orientation parameters are shown in Fig 3. The position of the microcoil and the angle between the vectors that describe the orientation of the microcoil as measured by both methods were found to differ in an absolute sense by an average of approximately 2.5mm and 5 degrees respectively across five test positions.

Phase information is directly related to position and orientation parameters. This is in contrast to projection methods that determine only a location of maximum MR signal. In addition, phase images are richer in spatial information when compared to magnitude projection data. These factors yield the potential for a more accurate tracking method. There is also a great deal of redundancy in the phase images. Useful phase can be collected over a spherical volume of several coil diameters before the signal is lost due to an inadequate SNR.

**References:** [1] Dumoulin et al., Magn Reson Med, vol. 29, pp. 411-5, Mar 1993.

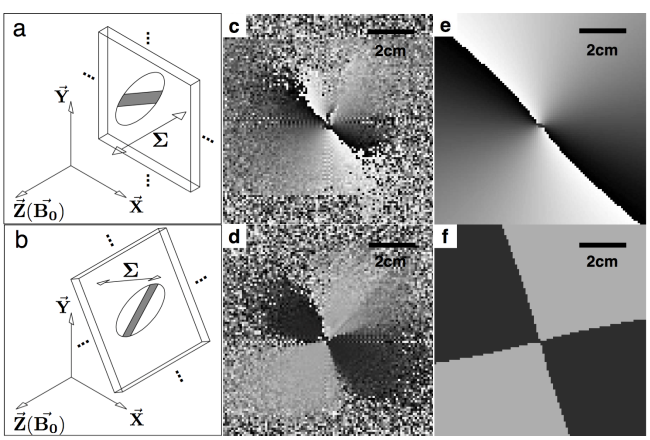


**Fig 2.** Two non-slice-selective phase image acquisitions are used to determine the position and orientation of the microcoil: **(a)** one in the axial plane; and **(b)** one in an oblique plane in the traveling through the centre of the microcoil orientated at angle θ. A representative set of experimental phase images acquired from the microcoil in the planes are shown in **(c)** and **(d)**. The corresponding fitted phase images are shown in **(e)** and **(f)**.

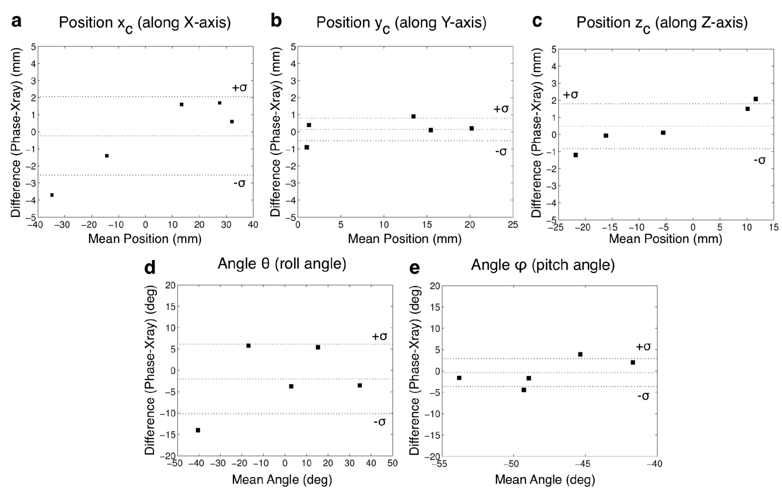


**Fig 3.** Bland-Altman plots illustrating the difference between the parameters that described the position **(a-c)** and orientation **(d-e)** of the microcoil as determined using phase information and as measured on the x-ray images.