Catheter Tracking Using Transmit Array System

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INTRODUCTION:

Although, soft tissue contrast of MRI is effectively high, visualization of the internal devices, such as guidewires and catheters, is not straight forward. In order to achieve better identification of these devices, various tracking techniques have been developed. Passive tracking methods (1) are easy to implement, but they are not sufficiently reliable. The main problem of active tracking techniques (2-4) is uneasy device handlings. They need to be connected to imager with cables. In addition, these cables create safety problems. There are also hybrid methods, using inductively coupled RF (ICRF) (4) and receive coupled RF (RCRF) (5) coils.

In our study, we propose a new method using ICRF coils and transmit array system. Presented method enables simultaneous acquisition of anatomy and catheter images.

THEORY:

MRI signal can be expressed as $S = BM_b(k_x,k_y)$. Sine and cosine RF excitations cause shifting directly proportional to frequency of sine or cosine in an acquisition.

As we write the signal equation, two RF signal function contributes total signal as:

$$S_f(t) = BM_b(k_x,k_y)\left\{\cos\left(2\pi\Delta y k_y f\right) + \sin\left(2\pi\Delta y k_y f\right)\right\}$$

where f is number of RF polarization vector turns per acquisition, Δy is resolution in y direction. Fourier transform gives the image equation as $m_f(x,y) = Bm_b(x,y) * \{\delta(y - f\Delta y/2)\}$ which states that, oscillating RF polarization will result with a shift of $f/2$ pixels in phase direction.

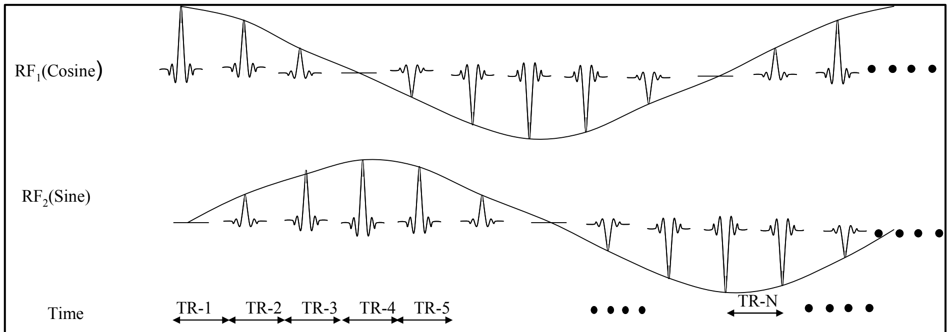

Figure 1: RF oscillations. The first RF signal is a function of cosine. On the other hand, the second RF oscillates with sine function

If an inductively coupled RF coil is placed inside of the anatomy, shifting mechanism changes, because of the orientation dependence of the ICRF coil. Any linear polarized field can be decomposed into two orthogonal fields, where, one of the components can be expressed as perpendicular to the surface normal vector of the ICRF coil. This perpendicular component cannot induce current on the ICRF coil, therefore no signal can be observed.

For simplicity, assume RF_2 is perpendicular surface normal vector of the ICRF coil. Then, resulted image will depend on cosine only: $S_f^c(t) = CM_c(k_x,k_y)\left\{\cos\left(2\pi\Delta y k_y f\right)\right\}$ which gives $\mathbf{m}_\mathbf{f}^\mathbf{c}(x,y) = Cm_c(x,y) * \frac{1}{2}\{\delta(y - f\Delta y/2) + \delta(y + f\Delta y/2)\}$. This equation states that, the ICRF coil signal is shifted both *y* and *–y* directions. Therefore, one of the components can be color-coded and placed inside the anatomy.

Quadrature body coil has one channel, but, a transmit array system enables two channel excitation without using quadrature hybrid. These channels are physically 90 degrees separated. As a result, the body coil can be used with two different polarizations.

In our design, two channels are excited linearly and no offset phase difference applied. In addition, channel amplitudes changed at each TR such that combined RF field oscillated between 0 to 360^0. To do this, one of the channels is oscillated by cosine, the other is oscillated by sine function (Figure 1). As a result, two channels created an RF field with a constant amplitude (Figure 2).

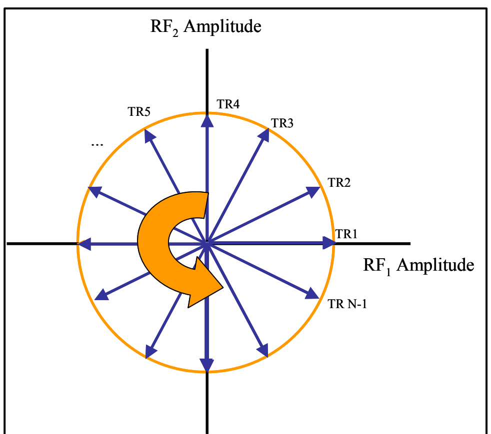

Figure 2: RF polarization rotations.

METHOD:

In our work we used a Siemens TimTrio transmit array system and head matrix coil. A small inductively coupled RF loop was placed on a naso-gastric tube inserted into saline solution. Flash sequence is modified in order to get different polarizations with following parameters: TR 20 ms, TE 4 ms, slice thickness 10 mm, flip angle 30^0, FOV 225X225, imaging matrix 256X256,

RESULTS:

A reference image is acquired in order to show the original data without using oscillated RF field (Figure 3a). In the result of the steering RF catheter tracking method, anatomy was shifted up, on the other hand, ICRF coil was shifted both up and down. Note that, two ghosts of the ICRC coil and some residual components phantom are observed because of imperfections of the body coil. Images show the effectiveness of the method. Shifted ICRF coil image can be color-coded for better tracking of the device.

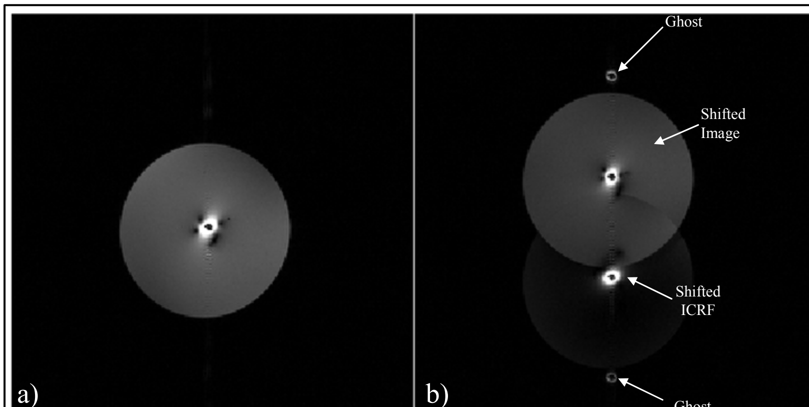

Figure 3: a) Reference image without oscillator RF field. b) Shifted ICRF coil and phantom image.

CONCLUSION:

A new method for simultaneous acquisition of both an ICRF coil and background body images. This method can be used very effectively for accurate catheter tracking. In addition, wires instead of ICRF coil can also be used with modifications.

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