# Passive Tracking of a Catheter With Multiple Tuned Fiducial Markers Using Interleaved Sequences

S. R. Hegde[1], M. E. Miquel[1], R. Boubertakh[1], D. Gilderdale[2], I. Young[2], S. F. Keevil[1], D. L. Hill[1], R. S. Razavi[1]
[1]Imaging Sciences, Kings College,London, London, United Kingdom, [2]Imperial College, London, United Kingdom

**Introduction:**

The feasibility of Magnetic Resonance guided cardiac catheterisation of patients has recently been demonstrated [1]. Although, it has been possible to carry out clinical procedures partly or totally under MR guidance on patients by passive visualization of standard cardiac catheters [2] the current lack of CE marked or FDA approved MR compatible catheters and guide wires is an important obstacle to widespread clinical use of MR guided endovascular procedures. Even though passive tracking of catheter with a $CO_2$ filled-balloon tip is feasible, the visibility of the catheter can become poor due to artefacts in the image and partial volume effects when thick slices are required to cover tortuous vessels. There is also a serious risk of forming knots as only the tip of the catheter and not the whole length is visualised. Consequently, incorporating markers with good MR visibility in the catheter would greatly improve real time position monitoring of interventional procedures. Prototypes of a suitable fiducial marker comprising a tuned circuit around a small NMR signal source, which allows direct visualization of the signal source within a MR image, have been reported [3-4]. It would, however, be a major advantage to design a catheter, which could combine such markers and current passive visualization techniques. The fiducial markers would need to be visible in state-of-the art cardiovascular imaging sequences, which include real-time and interactive Steady State Free Precession (SSFP) imaging. This abstract presents the preliminary work on a catheter with multiple fiducial markers.

**Methods:**

*Markers:* Six coils each comprising 5 turns of 0.12mm OD enamelled wire close wound obliquely 45$^o$ to long axis of catheter. This structure produces an inductance of ~54nH with a Q of ~50 at 63.89 MHz. The coils are resonated with multiple layer ceramic chip capacitors with silver palladium terminations.

*Catheter preparation:* Six pre-wound fiducial markers were mounted onto the surface of a 5Fr balloon angiographic catheter (Arrow, Reading, PA) 17mm apart and aligned 45 $^o$ to the long axis of the catheter [Fig1].

*Imaging:* We used the standard real time interactive environment of a 1.5T whole body Intera system (Philips Medical Systems, Best, Netherlands) for imaging. The catheter was manipulated in a polyethylene tube of size 20mm taped on to the chest of a volunteer. We implemented a pulse sequence, which allowed us to interleave an image with a smaller flip angle (1° or 2°) every 5 or 10 images in real time and interactive mode. The later allows manipulation of the slice plane and other imaging parameters during scanning. The first sequence was a real time spoiled gradient echo (fast field echo-FFE: TE 1.2ms, TR 2.3 ms, $\alpha$=50°, slice thickness 20mm) followed by an interactive FFE sequence with interleaving of scans with flip angles of 2$^o$ and 50$^o$ and a frame rate of 4/s.

**Results**

The flickering of the marker and the excellent signal contrast between the fiducial and the background allowed for good visualization [Fig2]. The increased Q allows for very small flip angles to produce quite large fiducial flips and signals so that they can be excited without exciting the body as a whole. There was no noticeable degradation of signal of the marker upto slice thickness of 20mm. Visualization and tracking of the catheter length [Fig3] was possible in the FFE sequence without compromising significantly on the background signal though temporal resolution was sacrificed. SSFP real time imaging at fast frame rate lead to image artefacts and with interleaved interactive sequence there was loss of steady state. The markers maintained signal, though reduced in intensity, when the catheter was moved from perpendicular to parallel to the $B_1$ field. The orientation dependence could be overcome by using quadrature coils as recently proposed [4].

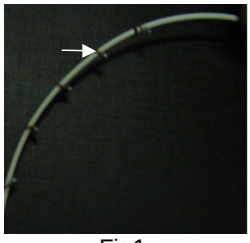

Fig1

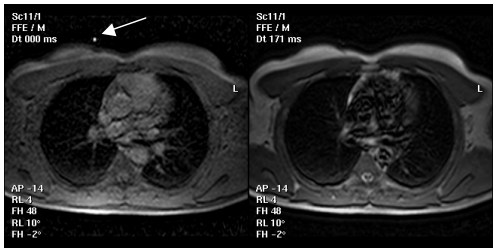


Fig 2


Fig3-Catheter tracked along its length in a tube over a human torso

**Discussion**

We have shown that with tuned fiducial markers incorporated into a catheter and using interleaved sequences for real time and interactive scanning, one can visualise both the tip and along the length of the catheter. The close wound design of the marker has the added advantage of only slightly decreasing the flexibility of the catheter, which is an important consideration. Passive visualization of fiducial coils is a novel wireless approach with the potential to extract device coordinates without requiring additional scanner hardware or receive channels [5].

The design of even smaller fiducials which are orientation independent and compact along with faster imaging sequences that can be used to interrogate the fiducials without significantly affecting the background signal should be the focus of future research.

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