

## LARFET (Low Amplitude RF at Echo Time) for Catheter Tracking

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**INTRODUCTION:** Active tracking can be achieved with a tuned microcoil at the catheter tip. This coil acquires signal only from nearby tissues; as it gets smaller, the signal gets weaker. Following the additional loss along the transmission cable, the SNR shows further decrease at the proximal end. Amplifying the MR signal right at the catheter tip before transmitting it over long cables has been shown to increase the SNR [1]. In addition to the amplification, frequency downconverting at the tip can provide further increase in the SNR due to the relatively less losses occurring at lower frequencies during transmission [2]. The mixing signal for frequency downconverting could be provided by an oscillator placed at the catheter tip next to the LNA and mixer [2]. In our previous work we suggested the use of the intrinsic 125 MHz signal of Siemens 3T scanners as a reference signal [3]. Here we propose utilization of a very low amplitude, rectangular and off-center RF pulse (applied during echo detection), LARFET (Low Amplitude RF at Echo Time), that is to be used as the reference for frequency downconversion at the catheter tip.

**METHODS:** A microcoil (2 mm diameter, 8-turn, 180 nH) utilized as the tip antenna to collect the MR signals and low amplitude RF pulses, an LNA ( $A=52$  dB,  $NF=0.9$  dB), a mixer in Gilbert Cell configuration with both inputs connected to the output of the LNA and a band-pass filter with gain ( $f_L=10$  kHz,  $f_H=1$  MHz,  $A_V=1000$ ). All blocks were built out of discrete components. 1D projection pulse sequence was applied ( $FA=5^\circ$ ,  $1$  kHz/cm). During the echo, we applied an additional RF pulse with an amplitude of 300-500 mV and a frequency of 300 kHz ( $\Delta f$ ) below the isocenter ( $f=f_c-\Delta f$ ). It had no effect on imaging magnetization (had almost  $0^\circ$  flip angle!), but it was detectable inside the bore with the catheter microcoil. This off-center RF pulse was acquired by the antenna together with the simultaneous echo signal at the frequency  $f_c$  which is dependent on the catheter position. Both were amplified by the LNA and then fed into both inputs of the mixer. Since the Gilbert Cell multiplies the signals applied to its inputs, at the output we had the input signal squared, with one component around 300 kHz which carried the position information. The amount of offset from 300 kHz gives the location with respect to the isocenter. The band-pass filter allowed only this particular component to pass and following further amplification it was converted to digital form for the final frequency analysis.

**RESULTS:** After developing the hardware, we conducted the initial tracking experiments using a LARFET- modified 1D projection imaging sequence. First we placed the antenna and circuitry on the patient table (reference position). Then by elevating the antenna using objects with known heights (5 cm, 8 cm and 13 cm), additional signals were obtained. Figure 1 displays a sample signal spectrum. The location of the signal peak corresponds to the physical location of the catheter. Figure 2 compares the displacements measured by LARFET method with the actual distances the catheter was moved between the experiments. The found locations match the true positions within an error range of  $\pm 0.3$ mm.

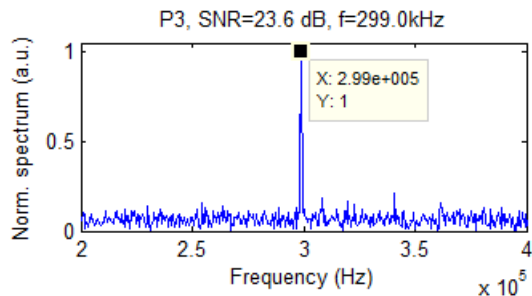


Figure 1: Normalized spectrum of a sample 1D projection echo signal of LARFET after tip processing

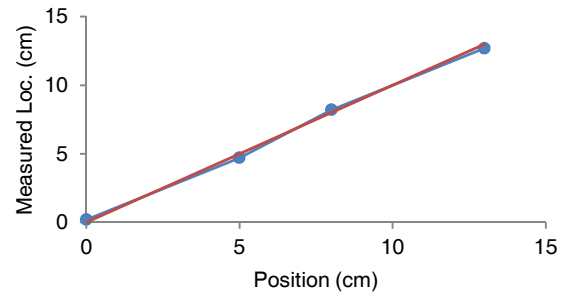


Figure 2: Comparison of the distances computed by the delta freq. with actual differences.

**CONCLUSION:** Very low amplitude, off-center RF pulse was applied at echo detection time during a projection-based tracking sequence and utilized for frequency down-conversion at the catheter tip. LARFET was used as the reference signal by an in-house developed (and soon to be miniaturized) electronic system. Experimental results show that LARFET method can give the location of a moving catheter, by measuring frequency shift of the down-converted signal. We believe the errors arose mainly due to the inaccurate placements of the catheter rather than the inaccuracy of the system.

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**REFERENCES:** [1] C Pitsaer et al., ISMRM 2010 (Abstract 1852), [2] J Anders et al., ISMRM 2010 (Abstract 18), [3] M Tümer et al., iMRI 2012 (Abstract 89).