B. Simultaneous Rotor Tracking

An MR scanner can provide both power and feedback sensing for closed-loop motor control. Though ferrous particles cannot be imaged with an MR scanner, these particles can be used to selectively discriminate the resonance frequency of a fiducial marker placed a set distance from the particle.

This method was used in (ref Bergeles) to track a single rotor. Rotating the fiducial marker axially offset from the ferrous particle, as shown in Fig [??] allows using a single, configuration-independent RF-frequency to image the marker.

To image a marker, the offset resonance frequency of the excitation Radio Frequency (RF) pulse is

.

Here, is the RF offset, is the gyromagnetic ratio ( is 42.57 MHz/T) and is the magnitude in Tesla of the magnetic field induced by the ferrous particle at distance *p* from the marker.

Real-time 2D tracking of the rotor is accomplished by first acquiring two orthogonal projections, and then using a peak detection algorithm to locate the marker.

Localizing several rotors is difficult because their projections often overlap. One method to avoid overlapping signals, uses unique distances between markers and ferrous particles on each rotor.

By the appropriate choice of the offset resonance frequency and its bandwidth, only one rotor at a time could be made visible on any acquired projection. However, this method requires an additional tracking sequence for each rotor.

Alternatively, the rotors and projections can be designed so the paths of the markers do not intersect in any projection. In this way, n rotors can be simultaneously tracked with a single acquisition sequence, followed by detecting n non-intersecting peaks on each projection. Figure 2a shows an example of three orthogonal projections used for tracking three orthogonal rotors. The reconstructed rotors positions are depicted in Figure 2b. This tracking sequence requires 25ms, enabling real-time positioning of the rotors.

MRItrackingSequence.pdf

Figure 1 MRI Fast Spin Echo sequence used for tracking three orthogonal rotors.

