A Simple Method for Measuring B0 Eddy Currents

P. Gurney[1], J. Pauly[1], D. G. Nishimura[1]
[1]Electrical Engineering, Stanford University, Stanford, CA, United States

Introduction: When applying gradients, B0 eddy currents can cause undesired phase accumulation, which can degrade image reconstruction or RF excitation. Some applications, such as echo-planar imaging or spectral-spatial excitation pulses, are greatly improved by correcting for B0 eddy current effects [1]. Typical methods used to measure these eddy currents either require special phantoms placed in specific locations [2] or many readouts using “self-encoding” pulses [3]. Duyn presented a simple method which allows the linear term of the eddy currents to be measured with only two readouts per axis [4]. Here, we present an extension to Duyn’s method, which measures the constant (or B0) term of the eddy currents.

Methods: To measure the B0 term of the eddy currents produced by a gradient on a given axis, we alternately excite two thin slices (shown in Figure 1(b)) which are exactly equidistant from isocenter. This is accomplished by inverting the slice select gradient. For each slice, we repeat the acquisition 3 times: one with no gradient waveform (a baseline acquisition), one with the waveform under test, and one with the waveform inverted. The gradient waveform is played out in the axis perpendicular to the excited slice, so that all excited spins experience the same magnetic field variation due to the gradient.

The phase from each of these acquisitions can be unwound and combined to give the phase accumulation due to B0 eddy currents. First, the phase from the baseline acquisition should be subtracted from the other acquisitions, in order to correct for inhomogeneity/susceptibility over the excited slice.

Next, the difference in phase between the measurements from the positive and the negative waveforms should be taken, in order to correct for phase accumulation due to concomitant gradients (Maxwell terms). Since the phase accumulation due to concomitant gradients is proportional to the square of the amplitude of the gradient, this term should be the same for both the gradient waveform under test and its inverted form. Phase due to B0 eddy correct is linear with amplitude, and so the subtraction will leave only the desired phase.

Finally, the difference between the corrected phase measurement from each slice should be taken. This will cancel out the linear effects of the gradient (traversal through k-space and linear terms of the eddy currents). Dividing the result by 4 gives the phase accumulation due to B0 eddy currents.

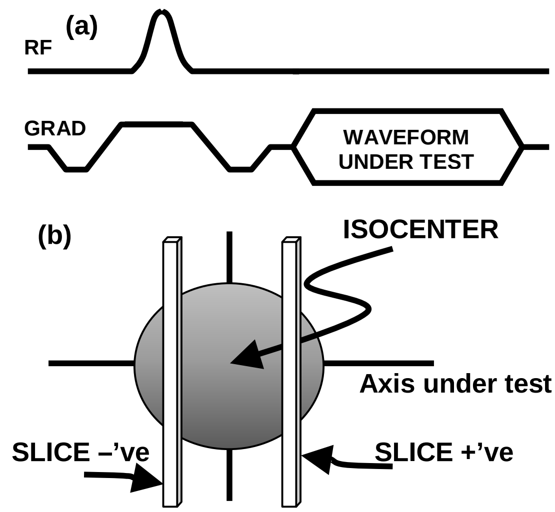

Figure 1 *(a) Pulse sequence (b) Schematic of excited slice locations.*

Results: Figure 2b shows the phase due to the B0 eddy currents for a simple phase encode gradient waveform (Figure 2a) played out on each of the x, y and z axes on a GE Excite 1.5T scanner. A slice thickness of 0.3 mm was used. Of particular interest are the components that do not seem to be modeled by decaying exponentials (especially the sharp discontinuities in the z-axis and the oscillatory terms in the y-axis, which may be due to acoustic vibration). On our scanner, it takes approximately 800 us for the B0 eddy currents to die away.

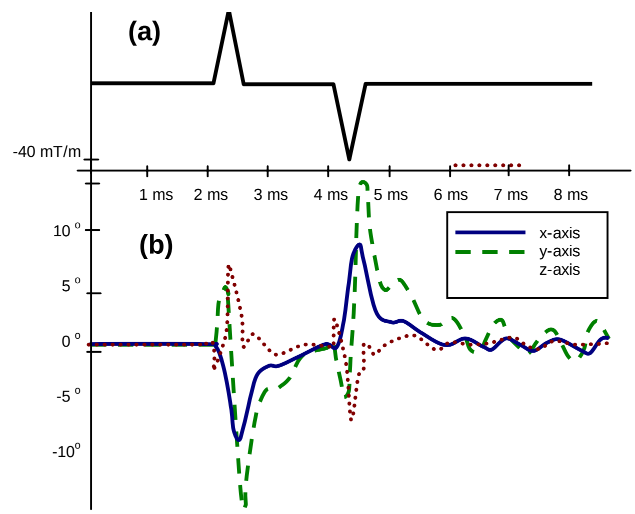

Figure 2 *(a) Gradient Waveform Under Test (b) Resulting measured phase due to B0 eddy currents*

Discussion: Since phase noise is a function of the signal amplitude, this method is somewhat sensitive to $T2^*$ and susceptibility, especially for the measurement of long gradient waveforms (>10ms). For example, if the excited slice contains fat and water in roughly equal proportions, signal amplitude may decay quickly and the resulting phase noise may be too high to achieve a good estimate. Also, in order to maintain significant signal amplitude over the readout, the slice thickness used for measurement must be at most $1/(2k_{max})$, where k_{max} is the maximum deviation from the origin in k-space due to the gradient waveform under test. For example, if a gradient waveform achieves a resolution of 1mm, then the slice thickness used for B0 measurement must be less than 1mm.

Conclusion: This simple and fast method to measure the phase caused by B0 eddy currents is a useful tool. It can be used without specially designed or placed phantoms and can generate the desired information with only 6 readouts per axis. Once the phase due to the B0 eddy currents is known for a given gradient waveform on a particular axis, this information can be used to improve the results of image reconstruction and RF excitation.

References:

[1] Block et al, MRM (1997) 38; [2] Crozier et al, JMR (1992) 97; [3] Takahashi, Proc. SMRM 1993 #424 [4] Duyn et al. JMR (1998) 132(1).