Signal Drop-Out Reduction in Gradient Echo Imaging with a Hyperbolic Secant Excitation Pulse - An Evaluation Using an Anthropomorphic Head Phantom

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Introduction: Signal drop-out due to through-slice susceptibility gradient dephasing is a problem particularly in the gradient-echo echo-planar imaging (GE-EPI) sequences commonly used for fMRI acquisitions and several methods [**1,2,3**] have been proposed to reduce it. Cho and Ro [**4**] first suggested the use of an RF pulse tailored to provide a quadratic phase distribution through the selected slice for drop-out recovery but did not define the functional form or design method of the pulse. The quadratic phase variation approximately cancels the susceptibility-induced phase variation in at least part of the slice so that the signal is no longer completely dephased and does not drop out entirely, although this signal recovery comes at the expense of signal in regions where there are negligible susceptibility gradients. The idea here was to use a scaled-down Hyperbolic Secant (HS) full passage RF pulse for slice-selective 90° excitation since this pulse has been shown [**5,6**] to produce a (nearly) quadratic phase variation through the slice. An advantage of using the HS pulse for signal drop-out recovery is that the quadratic phase coefficient (C) can be easily selected [**5**] by choosing the HS pulse parameters, thereby allowing selection of the optimal pulse to compensate a given through-slice gradient.

Simulations: The results of simulations (See **Figure 1**) based on the signal equations in [**4**] show that as C is increased, there is a trade-off between the range of susceptibility gradients over which signal is retrieved and the signal in areas where there is negligible field inhomogeneity. Being able to vary C by altering HS pulse parameters could allow selection of an HS-90° pulse for optimal recovery of signal drop-out in GE-EPI of the human head.

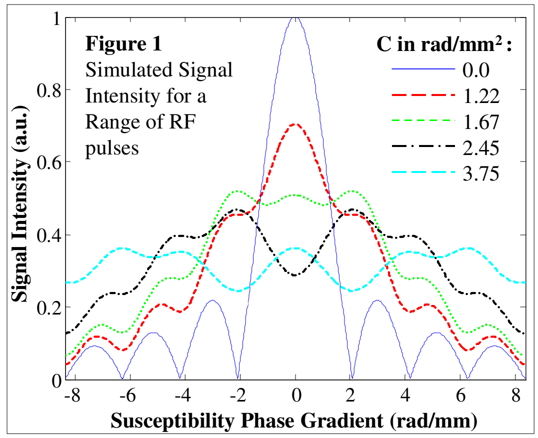


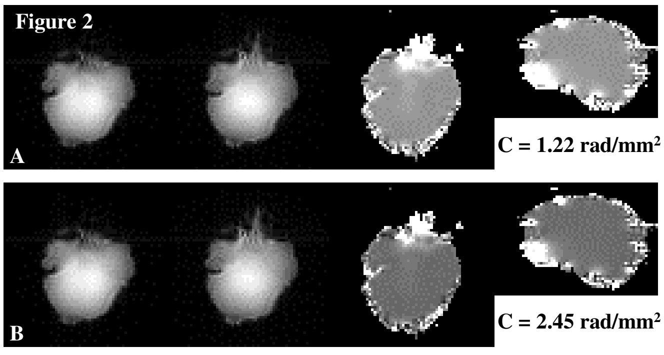
Figure 1 Simulated Signal Intensity for a Range of RF pulses

Methods: The proposed drop-out reduction technique was evaluated using an anthropomorphic head phantom [**7**] that had been developed to reproduce accurately the susceptibility artifacts found in real heads. Experiments were carried out using a SMIS MR 5000 4.7T whole-body MR scanner provided by Philips Medical Systems. Transverse GE-EPI images were acquired with both a standard Sinc excitation pulse and HS-90° excitation pulses with a range of quadratic phase coefficients: 1.22, 1.67, 2.45 and 3.75 rad/mm^2. The 1.5 kHz, 5-lobe Sinc-90° pulse lasted 4 ms. The HS-90° pulses lasted from 6.6 to 20 ms, had 1.5 or 3 kHz bandwidth and μ from 5.0 to 15.3. GE-EPI parameters were: TR = 6 s, FOV = 192 mm, matrix = 64 x 64, bandwidth = 250 kHz, slice thickness and separation = 3 mm. TE was set to the minimum for each HS pulse. SE images were acquired as a drop-out-free reference. Ratio maps were created to evaluate the extent of signal recovery by dividing the HS images by the Sinc images with the same TE.

Results: Figure 2 shows the same transverse slice of the anthropomorphic head phantom acquired with different HS pulses. In row **A** the HS pulse had C = 1.22 rad/mm^2 and in row **B** it had C = 2.45 rad/mm^2. The first column shows standard Sinc-90° GE-EPI images with signal drop-out, the second column shows the same slice acquired with the HS-90° excitation pulses and the final columns show the transverse and composite sagittal ratio maps masked with the SE reference image. The bright central regions in the first two columns are due to B_1 field inhomogeneity at this high field strength. The Sinc and HS GE-EPI images have their intensities scaled independently to emphasise the signal recovery. The ratio maps have intensities scaled between 0 (black) and 1 (white) with areas of dropped-out signal recovery appearing white.

Discussion and Conclusions: As illustrated in **Figure 2**, all the HS-90° pulses recovered signal that dropped out when the standard Sinc-90° was used, particularly in the area just above and anterior to the nasal sinuses, corresponding to the inferior frontal cortex in the real brain. The rim of noise visible illustrates the geometric distortion of the GE-EPI images relative to the SE reference. Of the HS pulses applied here, that with C = 1.22 rad/mm^2 seems to give the greatest signal recovery and the least signal reduction in areas of neglible inhomogeneity, although the specific pattern of recovery from each pulse depends on the TE, slice thickness and susceptibility gradient (as seen in **Figs 1** and **2**). Future phantom experiments could investigate whether a weighted combination of images acquired with different HS quadratic phase coefficients could further optimise the trade-off between signal reduction and drop-out recovery.

Figure 2



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Acknowledgements: This work was supported by the Wellcome Trust.