# DESIGNING A HYPERBOLIC SECANT EXCITATION PULSE TO REDUCE SIGNAL DROPOUT IN 2D GRADIENT ECHO IMAGING AT 7T

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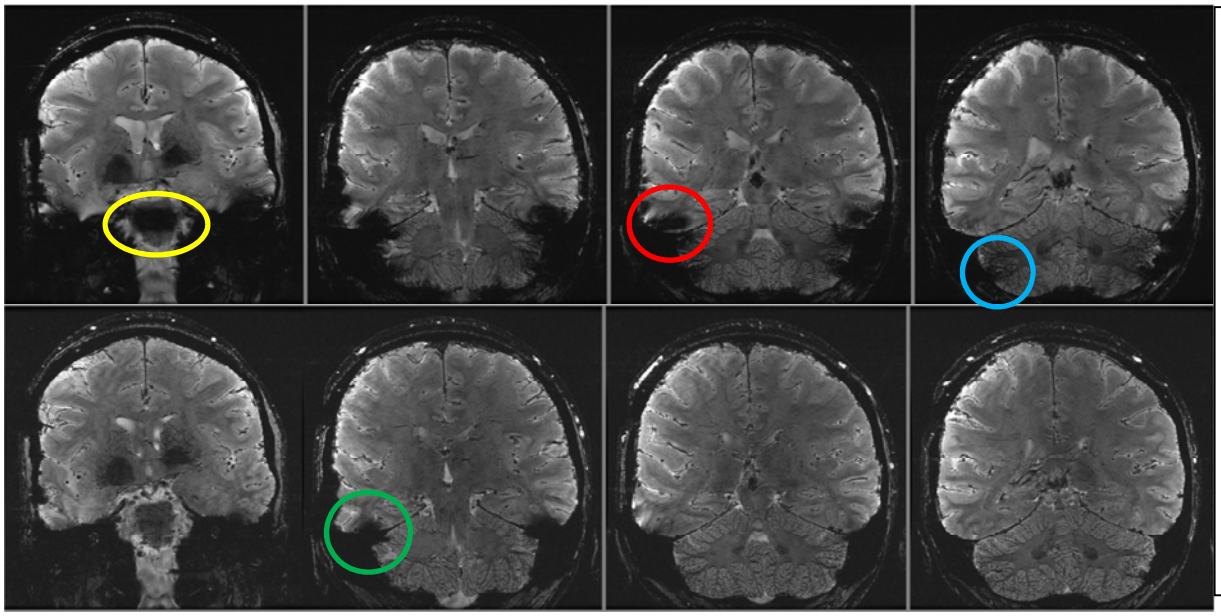
**Target audience:** This work will be of interest to researchers and clinicians performing 2D gradient-echo based imaging of regions of the brain commonly affected by susceptibility-induced signal dropout at 7T.

**Purpose:** Images acquired using a 2D gradient-echo pulse sequence suffer from signal-dropout in numerous regions of the brain, notably the orbitofrontal cortex and inferior temporal lobes. At 1.5 and 3T it has been shown that this artifact can be reduced using RF excitation pulses with quadratic phase profiles [2] such as full-passage scaled-down Hyperbolic Secant (HS) pulses [3-5], which partially cancel the phase dispersion due to susceptibility gradients in the slice-selection direction, $G_{sus}$ [2,5]. Using a recently developed algorithm [5] we design a HS pulse with parameters optimised to give the most uniform signal response across the range of susceptibility gradients observed in the human head at 7T. Using our optimised pulse we have observed recovery of signal in the pons, the inferior temporal lobe and the lateral portion of the cerebellar hemisphere in two human subjects.

**Theory:** Complex hyperbolic secant (HS) pulses have both a time varying phase and $\phi(t)=\mu.\ln[\mathrm{sech}(\beta t)]$ and amplitude $A(t)=A_0\mathrm{sech}(\beta t)$. $A_0$, the maximum amplitude of the pulse, is related to the desired flip angle, $\alpha$. $\beta$ is the modulation angular frequency which, for a given pulse duration $T_{RF}$, controls the ripple in the stop-band of the slice profile. $\mu$ determines both the degree of quadratic phase [4,5] and the sharpness of the slice profile [3].

**Methods:** Using the algorithm described in Wastling et al. [5] we designed HS pulses to achieve a near uniform signal response from grey matter ($T_1$=1.94s [6]) over the range of susceptibility gradients observed in the human head at 7T ($-500\mu Tm^{-1}<G_{sus}<500\mu Tm^{-1}$). The pulse was optimised for 2mm slices acquired with TR=250ms and TE=20ms on a 7T GE MR950 system (General Electric, Waukesha, WI, USA) equipped with gradients with slew of 200 T/m/s and max amplitude 50 mT/m. The pulse duration $T_{RF}$=3.2ms was chosen to match the sinc excitation pulse used as standard in 2D gradient echo imaging on the GE scanner. To maximise signal, the flip angle was set to the Ernst angle for grey-matter at 7T i.e. $\alpha$=28.5°. The resulting optimal pulse parameters were $\mu$=3.0, $\beta$=3175 Hz and $A_0$=4.09$\mu$T (bandwidth was 3406 Hz). 2D oblique coronal data were acquired in two volunteers (one male, one female) using a gradient echo pulse sequence with the conventional sinc pulse and with the optimized HS pulse. 7 coronal slices were acquired with 3 signal averages in a scan time of 6 minutes. The field-of-view was 16x16 cm with a 512×512 matrix. The Nova Medical 2-channel birdcage coil was used for RF transmission and the Nova Medical 32-channel array coil for signal reception.



**Results:** The figure shows 4 example images from a volunteer acquired with Gradient Echo with standard sinc pulses (top) and the Hyperbolic Secant pulse (bottom). Data from one subject is shown.
SNR was reduced by 40% or more in the HS-GRE images in regions not affected by susceptibility, as expected from simulations.
Signal drop-out is reduced or eliminated in the inferior temporal lobe (red circle), the pons (yellow ellipse) and the lateral portion of the cerebellar hemisphere (blue circle). Some drop-out remains (green circle).

**Discussion and Conclusions:** The signal recovery in the pons can tentatively be explained by considering that this structure lies posterior to the clivus bone and the sphenoid sinus, which together create an anterior-posterior susceptibility gradient which is corrected by the HS pulse during selection of the coronal slice.
Some susceptibility gradients induced in the brain have a more complex geometry which cannot be corrected by the HS pulse, as evidenced in one slice in the inferior temporal lobe (green circle in the figure).
The SNR loss associated with the HS pulse is significant, but acceptable when compared to most drop-out compensation schemes, which commonly incur a factor of two (or more) increase in scan time.
The RF power deposition is significantly increased in the sequence with the HS pulse, but this did not prove to be a limitation in this study.
Finally, we note that vascular contrast appears to be more uniform in the HS-GRE images.
Future work could include investigation of these vascular effects and optimisation of the sequence parameters. Combining these images with the acquisition of a B0-mapping sequence would further quantify and understand the effect of the interaction of the HS pulse with the complex and strong B0 field variations which occur at 7T in the brain.

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