A New Method for Single-shot 2-D OVS

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Introduction: Outer Volume Suppression (OVS) is sometimes needed in MR imaging and, more often, in spectroscopy. MR Spectroscopic Imaging (MRSI) studies of the brain and other anatomical regions generally require some form of OVS to ensure that the strong lipid signals from the layer of skin and subcutaneous fat do not interfere with the desired signals from deeper tissues of interest. Typically when OVS is used in brain MRSI, the standard approach involves sequentially applying multiple slice-selective (1D) suppression pulses at different angles around the periphery of the object, an approach that has drawbacks in terms of efficiency and Specific Absorption Rate (SAR). Our method employs a single two-dimensional pulse to suppress an elliptically shaped annulus in one shot, saving both time and SAR, and in some cases providing a suppression pattern that more closely matches the anatomy.

Methods: The relatively simple sequence consists of a square RF pulse transmitted with a constant offset frequency combined with paired sine and cosine gradients on the two axes in the imaging plane (Fig 1). The use of the sine and cosine gradients makes this sequence similar to the projection presaturation method proposed by Singh and Rutt(1), but our RF pulse preforms a continuous, rather than discrete, excitation. The effect of the time-dependent gradients is to reorient the gradient-induced frequency selective axis of space continuously in time. Combining this reorientation with a consistent RF pulse leads to a time dependent excitation of two-dimensional space in an elliptical (or circular) pattern, which can then be suppressed by gradient spoiling. The size and shape of this elliptical region can be adjusted by varying the strength of the gradient and the frequency offset of the RF pulse, and the position can be adjusted by changing the gradient shape, all of which allows the suppression band to be tailored to match the specific area to be suppressed. Our calculations show that the expected SAR of this pulse is lower than a train of 8 sinc suppression pulses by a factor of 1.79. In general the pulse is very short, with pulse lengths generally on the order of 2 ms in both simulation and experiment.

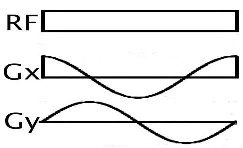

Fig 1: A diagram of the RF pulse.

Results: The RF pulse was successfully implemented on a 4-T horizontal bore magnet interfaced with a Varian INOVA console using a TEM head coil. We conducted phantom experiments to demonstrate that the pulse suppression bands match our simulated results (Fig 2). In human subjects we were able to prescribe a suppression band around the head and use this band to suppress extraneous lipid signal as shown in Figure 3. Our experiments in the head showed the lipid signals were generally attenuated by about a factor of 10. We have also explored using this suppression pulse in human calf muscle CSI studies at 4 T using a quadrature coil to suppress signals from subcutaneous fat.

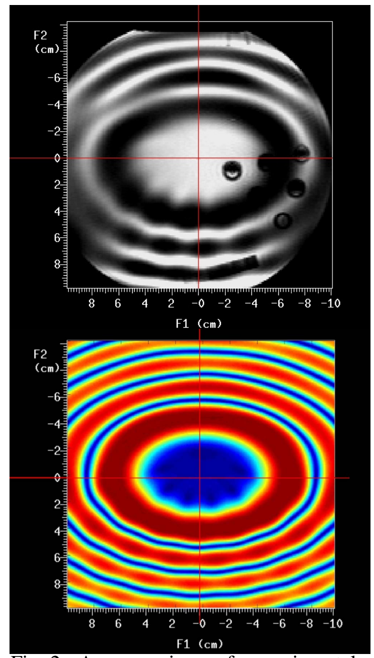

Fig 2: A comparison of experimental measurements in a water resolution phantom (top) with simulation (bottom).

Discussion: This RF pulse is not without limitations. The RF excitation does not affect the isochromats inside the main suppression band, but it does generate a pattern of concentric rings of excitation in the external space (visible in Fig 2). In the case of suppressing signal from the lipid layer of a subject's head, these rings are not a major concern, because there should be nothing to provide signal in this region of space.

While a conventional 2D pulse (2) should be able to duplicate the suppression pattern of our pulse, these pulses tend to require a long pulse length and have inconsistent performance at different offset frequencies. Our pulse, on the other hand is in general quicker and simpler, and an additional offset frequency results only in a slight change in the diameter of the ring. All these factors make it a promising new method for outer volume suppression.

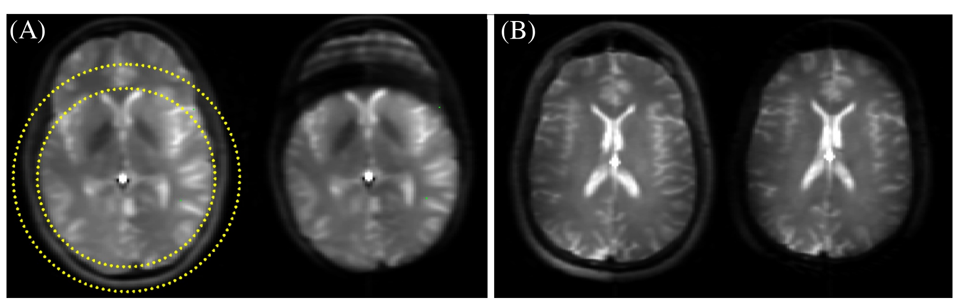

Fig 3: Comparisons from two brains, (A) using a circular suppression band (drawn over original image on the left) and (B) using an ellipse tailored to the lipid layer (right).

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References:

1) Rutt & Singh, *J. Magn. Reson.* 87, 567-583 (1990)
2) Pauly, Nishimura, & Macovski, *J. Magn. Reson.* 81, 43-56 (1989) tes