Spatial Selection by Signal Spoiling with a 3 Channel Flat Gradient Coil

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Introduction: MRI spatial selection is performed using frequency-selective RF pulses and magnetic field gradients. In 2D spatial selection, zoomed imaging may be used to accelerate image acquisition or to acquire images at higher resolution. Previously a non-RF method of spatial selection was reported using signal spoiling and a PatLoc gradient coil (1,2). This method transfers the spatial selection duties from the RF pulse to an additional nonlinear phase preparation gradient. We anticipate this method to be very useful for fast imaging because it avoids the additional SAR and prolonged TE and TR of spatially selective RF pulses and can be performed at the same time as normal phase encoding or readout prephasing. The small diameter of the PatLoc gradient coil, however, made it unsuitable for whole-body, adult MRI. Using a new high performance 3-channel gradient coil ("FlatLoc coil") (3,4) integrated with the patient bed, spatial selection through signal spoiling is achieved for shapes corresponding with the anatomy of interest.

Methods: Experiments were performed on a 3 T MRI device (Siemens Healthcare) equipped with a custom, high performance, 300 A/channel, 3 channel gradient coil ("FlatLoc coil") integrated with the patient table and interfaced to a measurement controller and 3 gradient power amplifiers. Coil safety information for acoustic noise and peripheral nerve stimulation was obtained in an IRB approved study. Detailed description of the coil construction is found in (3,4). Gradient nonlinear phase preparation was integrated with a standard cine-flash sequence with the following imaging parameters: TE/TR = 3/7 ms, 1500 Hz/pixel. Images were obtained from 1 ch of an 8 ch, pTx body coil and a 32-ch Rx array.

Results: The magnetic fields generated by ch. 1 and 2 of the FlatLoc coil are shown overlayed on orthogonal views of the human torso (**Fig. 1**). The ch. 1 field is quadrupolar over a 15 cm region located 26 cm distal to the gradient coil surface and in the coronal plane (xz-plane), the ch. 1 field profile is elliptical (**Fig. 2c**). This size of the target region was proportional to the nonlinear gradient moment. The elliptic field profile enables very uniform spatial selection with a narrow transition band, but which is asymmetric in F-H direction compared to R-L (**Fig. 2b**). The k-space trajectory can be chosen to further tailor the spatial selection profile to the desired anatomy of interest. Additional linear gradient moment reduced the FOV in P-A dimension in sagittal views. The ch. 1 transition band (indicating the sharpness of the spatial selection boundary) was found to be very narrow: signal attenuation was -3 dB at 2.5 pixels and -6 dB at 3 pixels for a matrix 128 x 128 14 cm distal to ch.1 (**Fig. 3**). Increasing the matrix size, adjusting coil current or more distal positions was found to affect the width of the transition band.

Discussion: The results showed here demonstrate a simple non-RF based method for spatial selection. Spatial selection is achieved through controlled spoiling of the target volume. The boundaries of the volume are defined by choosing a k-space trajectory that corresponds to the desired anatomical shape. Controlled gradient spoiling results in a signal phase that can be eliminated by deconvolution of the k-space data with the known phase. Further suppression of spoiling artifacts is achieved using a weak Tukey window filter, such that spatial resolution is not compromised. The field profiles are nearly quadrupolar, which is ideal for spatial selection because anatomic shapes can easily be selected because spatially-varying k-space shift is linear (1). *Pulse Sequence Integration:* Gradient localization requires high performance gradients, so that the time for nonlinear phase preparation does not exceed the total time for slice rewinder, readout prephaser and phase encoding gradients. Additional linear gradient moment is required for off-center localization. Linear gradients were superimposed with existing prephaser gradients for off-center FOV. Balanced nonlinear gradients may be required for both bSSFP and SPGR to prevent spurious echoes. Despite these challenges, we have integrated the nonlinear gradient pulses with bSSFP, segmented EPI, and spin echo acquisitions, each which may have limited available time between excitation or refocusing pulses (1). Additional challenges are encountered with EPI because of spatial variation in contrast. *In Vivo Imaging:* We plan to perform in vivo imaging as soon as the custom body coil Tx system is IRB approved (the FlatLoc coil is already IRB and safety approved).

References: (1) Witschey, et al. Magn Reson Med (2011), (2) Witschey, et al. Proc. Intl. Soc. Magn. Reson. Med. (2011) (3) Littin, et al. Proc. Intl. Soc. Magn. Reson. Med. (2011). (4) Littin, et al. Eur. Soc. Magn. Reson. Med. (2011)

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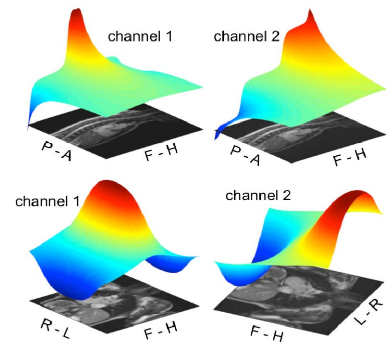

Figure 1: Magnetic field profiles (z-component) from 2 channels of the FlatLoc coil in the y-z (row 1) and x-z (row 2) planes of the magnet coordinate system overlaid on orthogonal views of the chest cavity (R-L, right to left, P-A, posterior to anterior, F-H, foot to head). The orthogonal fields allow spatial selection of anatomic shapes.

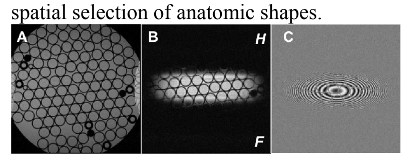

Figure 2: (a) Sagittal view through a cylinder phantom containing conical tubes. (b) The same sagittal view with current applied to ch. 1. (c) Real part of the image in (b) showing the contours of the magnetic field produced by the coil. Signal is localized predominantly in the cranial/caudal (H/F) direction due to ch. 1 geometry.

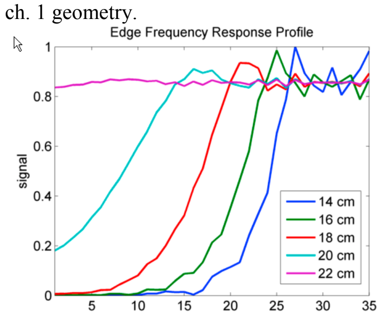

Figure 3: Sagittal views of a rectangular phantom 14-22 cm distal to the ch. 1 coil at constant current depicting spoiling efficacy, transition band and ripple.