

Dualband Spectral-Spatial Pulses in Prostate MRSI

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Introduction

MR spectroscopic imaging (MRSI) of the prostate has demonstrated clinical utility for characterizing the spatial extent of prostate cancer. However, conventional PRESS CSI methods are limited by inadequate water/lipid suppression and chemical shift misregistration. While spectral-spatial pulses [1,2] can address these problems, the complete suppression of water prevents it from being used as a reference for phase and frequency correction [3]. Furthermore, RF pulses with the necessary spatial selectivity have high peak power requirements, which can be a serious limitation for many patient studies. The goal of this study was to develop dualband echo-planar spin-echo (EPSE) 180° pulses with reduced excitation of the water resonance, minimal excitation of the lipid resonances, an optimal passband over the metabolite resonances, and quadratic phase modulation to reduce power requirements.

Methods

To create the EPSE pulses, a complex dualband digital filter was designed using an implementation of the Parks-McClellan algorithm. The frequency passband for exciting prostatic metabolites at 1.5T was designed to pass the choline (96 Hz, referenced from water) to citrate (120-140 Hz) resonances and completely suppress lipids starting at 200 Hz. A second passband of approximately 100Hz centered on water was designed to attenuate water by a factor of 100 starting at 50 Hz. Signals downfield of -50Hz were designed to be completely suppressed. A digital filter with these specifications was designed and then converted to an RF pulse using the inverse Shinnar-Le Roux (SLR) transform.

Using custom tools we introduced quadratic phase modulation in the spectral axis, and a new pulse was created that had the same profiles as the original pulse but with smaller peak RF amplitude. Two of these phase-modulated pulses were introduced into the PRESS excitation sequence, by replacing both of the traditional 180° pulses. Since the PRESS sequence employs two of these pulses, the phases were self-compensated.

The dualband pulse PRESS sequence was tested in phantom experiments and then applied in ten prostate cancer patient exams. For comparison, in the first seven exams the dualband MRSI sequence was added to the current clinical MRSI protocol, which uses the dual BASING scheme for water and lipid suppression [3]. Prior to PRESS box selection, a train of very selective saturation (VSS) pulses separated by crusher gradients was added to provide spatial suppression [4]. All experiments were run on a GE 1.5T Signa system using an endorectal phased-array coil. Data acquisition parameters were TE = 130ms, TR = 1000ms, 16x8x8 phase encode steps, CSI resolution = 0.34 cm³, and total scan time = 17 min. The PRESS box size was approximately 50x25x30 mm³ (RLxAPxSI).

Results

The final optimized pulse is shown in Fig. 1. The frequency profile of the spin echo produced by the PRESS sequence using a pair of these pulses is also plotted (Fig. 1d). The two dualband pulses are selective on the x- and z-axis, respectively. The pulse was 36 ms in duration and had a time-bandwidth product of 7.2. The slice profile was unity for the choline, creatine, and citrate resonances and was 72 Hz wide. The water band was also 72 Hz wide and was specified to be 10%, resulting in an overall water suppression factor of 100 when both pulses were applied. The peak RF power of the non-modulated pulse was 0.20G (0.85 kHz) and 0.12G (0.51 kHz) for the phase-modulated version, but their frequency profiles were identical.

Phantom tests demonstrated the intended degree of water suppression while demonstrating no loss in metabolite intensities, as compared to conventional PRESS CSI acquisitions. Also chemical shift misregistration was greatly reduced by using the dualband spectral-spatial pulses. Whereas conventional excitation yielded significant

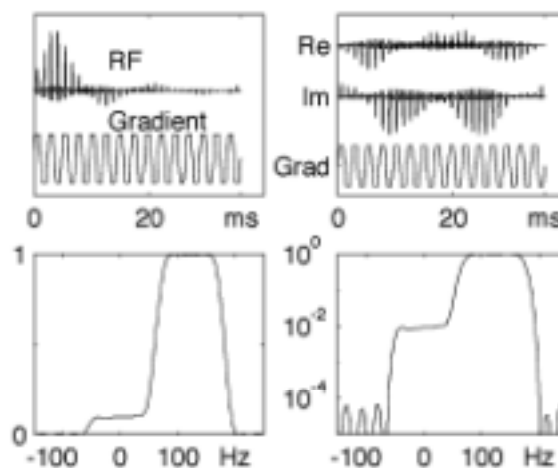


Figure 1: (a) RF waveform and gradient (b) Phase-modulated waveforms (real/imaginary components) and gradient (c) Frequency profile of one pulse (d) Semi-log plot of echo amplitude.

differences in (choline + creatine) / citrate ratios between edge and middle voxels, the dualband pulse scheme produced uniform spectra with no significant differences across all voxels.

Patient exams with the EPSE MRSI sequence demonstrated equivalent signal-to-noise and improved spatial selection as compared to current techniques. The dualband excitation allowed controlled water excitation and a 40% reduction in peak power compared to conventional spectral-spatial pulses [3]. Sample voxels from a prostate patient examination are shown in Fig. 2. The amount of lipid suppression provided by the dualband sequence was equivalent to that provided by BASING scheme. There was no baseline distortion and lipid signals are nearly completely suppressed. The 100X water attenuation leaves a water peak approximately 5 times as intense as the citrate peak.

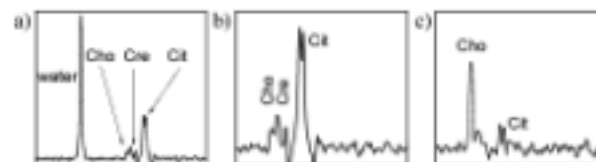


Figure 2: (a) Healthy voxel with metabolite peaks and residual water peak; (b) The same voxel zoomed in on the choline (cho), creatine (cre), and citrate (cit); (c) A prostate cancer voxel, revealing increased choline and decreased citrate.

Discussion

The study demonstrated the feasibility and clinical benefits of an MRSI sequence employing dualband spectral-spatial pulses for prostate cancer studies. These high bandwidth pulses greatly reduced chemical shift misregistration effects while passing an attenuated water resonance for phase and frequency referencing. The quadratic phase modulation was also critical for greatly reducing peak power, which is often a severe constraint in current clinical MRSI studies of the prostate.

References

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