# Fourier Component Imaging of water resonance in human breast: a new source of MRI contrast

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**Introduction:** As breast MRI is seeing increased application, further improvements in specificity are desired. The needed additional information is likely to come from a previously untapped source of contrast. Work in this laboratory has exploited the spectral line shape of the water resonance from each small image voxel to improve specificity (1). Here we evaluate contrast in images of the Fourier components of the water resonance. The water resonance in small tissue voxels is often inhomogeneously broadened, and sometimes contains multiple resolved components, arguably corresponding to sub-voxelar, perhaps microscopic environments (e.g. vasculature). (2-4) Previous work demonstrated that the water resonance components can be successfully imaged using high spectral and spatial resolution (HiSS) imaging. (4) Here we show in a large number of patients that it is possible to reproducibly generate images proportional to the intensity of the individual Fourier components of the water resonance – Fourier Component Images (FCIs) – and that off-peak FCIs frequently show anatomical features that are distinctly different from those in resonance peak FCIs.

**Methods:** Sagittal HiSS images (0.65 mm x 0.65 mm x 2.6 Hz resolution, 4 mm thick) were acquired using echo-planar spectroscopic imaging (EPSI) (5) on a 1.5 T GE SIGNA$^{TM}$ scanner. A single slice through a suspicious area previously identified on a mammogram was imaged in 32 women (biopsy-confirmed diagnoses: benign, n=9; ductal carcinoma *in situ*, n=3; invasive disease, n = 19). The HiSS scan was incorporated into the clinical protocol, and acquired prior to contrast administration. The highest intensity spectral bin in the water resonance was assigned "zero" frequency. FCIs were generated as proportional to the signal at various offsets from this "zero" frequency. FCIs were scaled to same average intensity and subtracted from the zero-offset FCI (proportional to water resonance peak height) to reveal differences in inherent contrast. Differences were deemed significant if they exceeded 5 standard deviations of RMS noise over at least five connected voxels (Fig. 1).

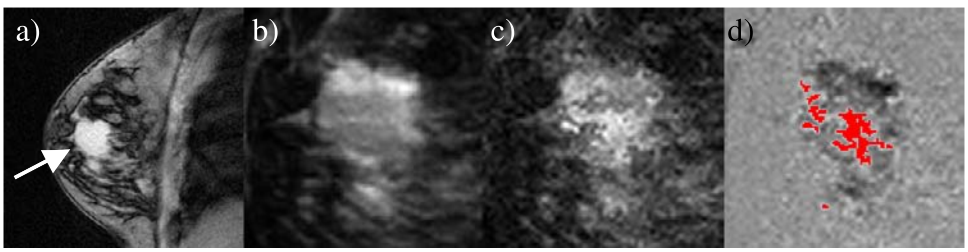


Figure 1: Sagittal slice through grade II invasive ductal carcinoma. (a) The arrow in (a) points to the lesion, shown in (b-d). The FCIs generated at zero offset (peak height image) (b), and an offset of -10.6Hz (c) are shown. The difference between 'c' and 'b' after scaling the FCI's to the same average intensity is shown in (d). Features that are prominent in off-center FCI, but not in the peak FCI, appear red in the difference image when they extend over five or more voxels at more then 5 standard deviations above RMS noise.

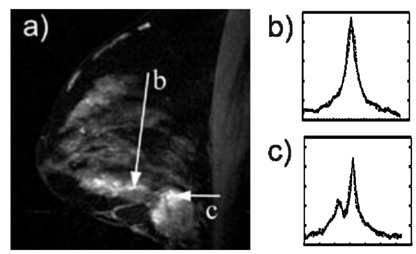


Figure 2: Water resonance peak height image of a grade III invasive ductal carcinoma with sclerosing adenosis. (a) Spectra from two voxels (arrows), measured in two consecutive acquisitions (solid and dashed lines), demonstrate high reproducibility of HiSS imaging ('b' and 'c')..

**Results:** High reproducibility of water spectra was achieved (Fig. 2), and this translated to highly reproducible FCIs. Images generated from off-peak components are qualitatively different from images generated from the peak of the water resonance. Anatomical features, well above noise level, that do not show up in peak height images, are often present (Fig. 1c,d). These differences are statistically highly significant, as the p-value for our significance criterion is vanishingly small. When complex structure in the water resonance was observed, it was most often in the form of two Lorentzian lines (Fig. 2b), consistent with the observation that significant differences were most frequently seen at the offset of approximately –11Hz. Significant differences between water peak height images and off-peak FCIs were more frequently observed in invasive cancers than in benign breast lesions (79% vs. 33%). In our sample, this result had a one-sided p-value of less than 0.01.

**Conclusion:** FCIs can be reproducibly generated from the complex structure of the water resonance. Off-peak FCI's are qualitatively different from peak FCIs, and potentially are a new source of contrast in MRI. The inhomogenous broadening of the water lines that gives rise to off-peak features (Fig. 2c) is likely due to distinct populations of water molecules in different sub-voxelar compartments. Such compartments might include extra- and intra-cellular space, vasculature etc. Images of these components provide novel contrast and may have great clinical utility.

**References:**

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