Decoupling in multi-channel bilateral breast imaging with quadrature coils

S. Moeller[1], P. Vemuri[2], C. Snyder[1], L. DelaBarra[1], P. J. Bolan[1], T. Vaughan[1], K. Ugurbil[1], M. Garwood[1]

[1]Center for Magnetic Resonance Research, University of Minnesota, Minneapolis, MN, United States, [2]UCAIR department of Radiology, University of Utah, Salt Lake City, Utah, United States

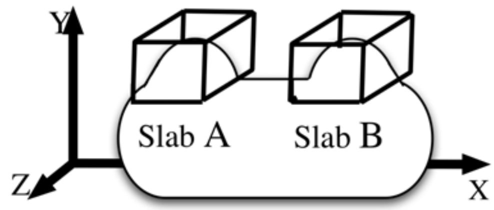
Introduction

In breast MRI, the image readout is typically set in the anterior/posterior direction to reduce cardiac and respiratory motion artifacts. To reduce scan-time for bilateral imaging, multi-band excitation pulses have been used for the acquisition of multiple sagittal FOVs simultaneously [1, 2]. The multi-slab technique is different from current parallel imaging techniques because it acquires multiple full FOVs, within one scan time, without the need for under-sampling k-space. The technique can be used in a slice selection direction, whereas conventional parallel imaging techniques only allow reduction within the image plane. Quadrature transmit/receive coils can be advantageous in such applications because of their high sensitivity compared to the single loop-element coils that are commonly used in commercial coils. However, the coupling from the quadrature coils exhibits an artificial non-linear spatial variation which cannot be removed with conventional parallel imaging methods.

Theory

$$\begin{bmatrix} R_A \\ R_B \end{bmatrix} = \begin{bmatrix} S_{AA} & S_{AB} \\ S_{BA} & S_{BB} \end{bmatrix} \begin{bmatrix} I_A \\ I_B \end{bmatrix} + \begin{bmatrix} N_A \\ N_B \end{bmatrix} \quad (1)$$

Two receiver/transceiver coils $\tilde{A}$ and $\tilde{B}$ that couple to distinctly different FOVs, I_A and I_B, are placed at locations A and B. The signal received by the coils, R_A and R_B, is given by Eq. (1), with S_{AB} and S_{BA} being any coupled signal in the opposite FOV. When the receiver coils are physically placed close together, a small amount of resonant energy will couple between the coils making the coupled sensitivities S_{AB} and S_{BA} non-zero. In the case of two loop coils, $S_{AB} = \gamma S_{BB}$ and $S_{BA} = \gamma S_{AA}$, where γ denotes the coupling. But for quadrature coils this is not the case since the two loops in $\tilde{B}$ couple with different amplitudes to coil $\tilde{A}$, making the coupling appear non-linear. In this case S_{AB} is a combination of the two unknown sensitivities in the elements composing $\tilde{B}$. Both S_{AB} and S_{BA} behave as spatially-varying coupled signals, and have distinct spatial encoding relative to either S_{AA} or S_{BB}. The coupling can be removed using the same algebraic formalism as the SENSE equation [3, 4], but only by explicitly estimating the coupled sensitivity profiles S_{AB} or S_{AB}. For unilateral studies the non-linear coupled signal can be used to generate spatial sub-encoding even though only one coil has an actual sensitivity to the volume.



Methods

All experiments were performed on an Oxford 4T ([1]H frequency = 169.3 MHz) magnet with a Varian Unity Inova console, and Siemens Sonata gradients with a Symphony/Harmony gradient amplifier. An actively detunable TEM body coil [5] tuned to 169.3 MHz was used as the transmitter, with quadrature receive-only coils. Dual-breast receiver coils consisted of two sets of two orthogonal loops collected in quadrature. Each receiver was approximately 12 cm in diameter; built from 12 mm wide copper strips attached to PTFE with distributed (ATC 100C) capacitors and secured to a molded former. Each element was independently tuned to 169.3 MHz and partially decoupled from the other three via geometric overlap [3], and interconnected capacitors [6]. Two sequences have been tested. A double-banded hyperbolic secant pulse was used for the excitation. T1-weighted sagittal images were acquired with a steady state, fast gradient echo sequence (matrix = 256 x 256 x 64; FOV = 16cm x 16 cm x 16cm; TE = 4.7 ms; TR = 13.5 ms; flip angle = 30°), and a 2D fast gradient echo sequence (TE=5.1 ms, TR=390 ms flip angle=90°) and slice-thickness 2.5 cm. The sensitivity profiles of the individual coils are estimated using the technique described in [7], which requires a short pre-scan (only 20% of *k*-space (51x51)) of each individual breast using a single-banded slab excitation. The region of dominant tissue (either adipose or fibroglandular) is used for the estimation of the smooth magnitude of the coil sensitivity profiles and also the phase difference between the signals pertaining to the same FOV.

Results and Discussion

Sagittal images of the left breast before and after processing are shown in the top row of Fig 2. The coupling between the two quadrature coils is less than 5%. Without additional decoupling techniques the images display ghosting and image non-uniformities due to signal cancellation. The ghost (white arrow) seen in Fig 2(a) is not visible after processing of the data using our algorithm in Fig 2(b). From the slice profiles in Fig 2(c), it can be seen that the ghost is effectively removed, and the background noise is left intact. The sensitivities are not reliant on a spatial masking, and with their smooth spatial dependence are very insensitive to small motion of successive acquisitions. The coupling creates an artificial sensitivity profile that can be used for spatial sub-encoding acquisition in the slab, and can be combined with additional elements when more than two receiver channels are available. The method is independent of whether a body-coil or the quadrature coils are used for transmit, and works equally for both the 2D and 3D acquisitions.

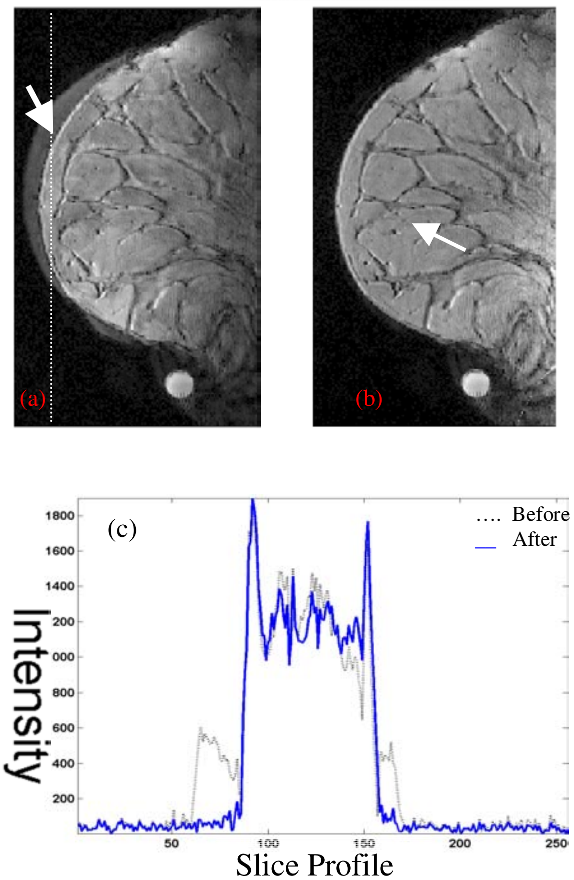


Figure 2: Sagittal images of the left breast reconstructed using the (a) standard sum-of-squares algorithm; and (b) our algorithm. The white arrow in Fig 2(a) indicates the coupled signal (ghost) from the right breast which is removed after processing in Fig 2(b). The white arrow in Fig 2b indicates signal cancellation with a RSOS construction that has been recovered with our algorithm. The slice profiles before and after processing in the images of the left breast (c). The circular dot is a MR marker.

References

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Acknowledgements: Supported by MIND Institute, KECK Foundation, NIH R33 CA94313, R01 CA94200, R01 CA92004 and P41 RR08079.