

A Novel Method for Coil Array Synthesis and Application to Breast MRI

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Introduction. The primary purpose of this work is to introduce and validate a novel method of synthesizing image data for an RF coil array given data from a second coil array. This would enable future studies comparing two coil arrays (source and reference coil arrays) for situations where it is not practical to acquire data with both such as dynamic contrast-enhanced MRI. The source coil array must have higher or equivalent SNR to that of the reference coil array for the synthesis to be feasible.

The procedure and the validation process for the coil array synthesis are developed for fully-sampled, volunteer T1-weighted (T1W) breast data. The proposed coil array synthesis is based upon calibration scans rather than circuit models of an RF coil as in previous studies [1,2]. We evaluated this method using a reader survey, in which 5 radiologists rated their preference between synthesized and the actual reference images in 50 pairs of images.

Methods. The coil array synthesis requires equating both coil sensitivity and noise. This can be achieved by using a uniform-sensitivity reconstruction [3] and adding noise to the source image to equate the SNR map to that of an equivalent reference image (Fig. 1a-c). Assuming that the ratio of SNRs between images acquired with two coil arrays is independent of the sequence used, we calculate the amount of noise to add using calibration SNR maps and the source T1W SNR map. Image registration of the calibration SNR maps is necessary since each coil array warps the shape of the breasts differently. We perform a uniform-sensitivity reconstruction on the source T1W images and add the appropriate noise. It follows that we can assume that the resultant images have a uniform sensitivity profile and similar SNR to that of the equivalent images acquired with the reference coil array.

We performed all imaging on a GE MR750 3T scanner. The source coil array is a previously-described 18-channel custom-fitted array [4] that provides 3.6x higher SNR than the reference coil array, an 8-channel HD Breast Array [GE Healthcare]. For validation, we designed a survey to compare ROIs from synthesized images with ROIs from images actually acquired with the reference coil array. We cropped the axial T1W images of 5 healthy volunteers to 6.6x6.6 cm² square ROIs to avoid reader bias. Five radiologists trained in breast MRI rated 50 pairs of randomized image ROIs (synthesized vs reference) on five aspects of image quality: overall preference, graininess, fat/skin, fat/fibroglandular and skin/air delineations on a five point scale.

Results. Examples of the images used in the comparison are shown in Fig. 2. The synthesized image is similar to the reference coil array image with a uniform-sensitivity reconstruction, aside from some warping of the tissue. The uniform-sensitivity reconstruction corrected for the B1 receive inhomogeneities in both cases and the noise addition process resulted in comparable apparent SNR between the two images. Actual measurements of noise in reference and synthesized images showed a mean SNR difference of less than 5%. Survey results show that the median rating for all aspects was zero, which was also the most common rating for all aspects except "Overall Preference." The Kendall's concordance coefficient among readers shows that the agreement among readers was low and highly variable (Table 1). Under the assumption that the ratings reflect an underlying continuous value with an approximately normal distribution, equivalence of the mean rating to zero was demonstrated to within one-quarter of a rating point (Table 1). Overall, the survey results support the fact that the image quality within pairs is very similar.

Discussion. We have demonstrated and validated the ability to synthesize breast images to resemble images from another, generally lower SNR, coil array. The desired application is the comparison of two coil arrays in dynamic contrast-enhanced MRI where it is only practical to acquire data with the higher-SNR coil array due to logistical concerns, dose and subject compliance issues. We simplified the representation of a coil array by using a uniform sensitivity reconstruction and by measuring SNR maps, therefore this method could be widely applicable for other contrast applications or dynamic studies that are difficult to repeat. We have developed a more complicated analysis to synthesize different parallel imaging acceleration factors and resolutions. In a survey of experienced breast radiologists, we showed equivalence of the overall preference between the synthesized and reference coil array images.

Conclusion. Our coil array synthesis algorithm is a useful tool that allows comparison of the performance of two coil arrays in applications where only one data acquisition is possible, such as dynamic contrast-enhanced imaging.

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References. [1] Ibrahim et al. MRI 2000; 18:835. [2] Kozlov et al. JMR 2009; 200:147.[3] Roemer et al. MRM 1990; 16:192.[4] Nnewihe et al. MRM 2011; 66:281.

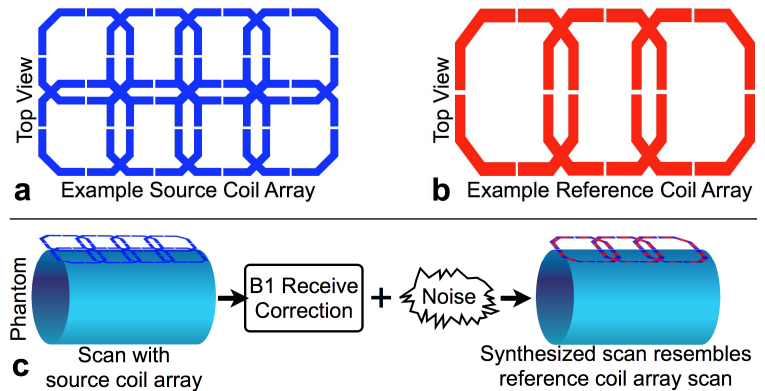


Figure 1. Overview of the Coil Array Synthesis.

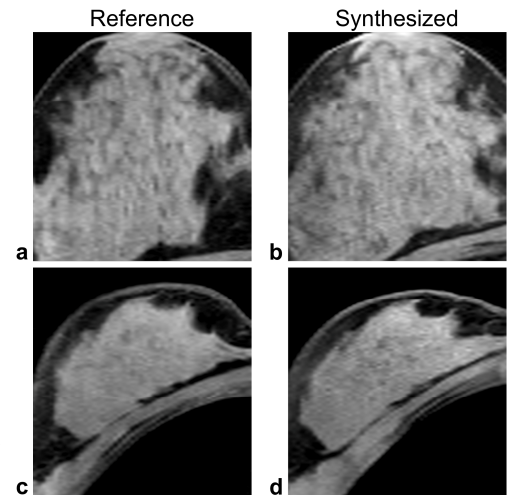


Figure 2. Reference coil array images (a,c) and synthesized images (b,d) for two subjects. The images are distorted differently by the coil arrays, but otherwise are very similar. Survey results confirm the similarity between the images.

Aspect	Equivalence (-2 to +2 scale)			Kendall's Concordance Coefficient	
	Equivalence Interval	95% CI of Mean Rating	p-value*	Kendall W	p-value
Graininess	-0.25 — +0.25	-0.15 — +0.04	0.001	0.337	0.001
Fat/Skin	-0.25 — +0.25	-0.06 — +0.15	0.002	0.406	0.001
Fat/Fibro	-0.25 — +0.25	-0.10 — +0.11	0.001	0.397	0.001
Skin/Air	-0.25 — +0.25	-0.13 — +0.05	0.001	0.419	0.001
Overall	-0.25 — +0.25	-0.16 — +0.07	0.004	0.407	0.001

Preference: (-2)Strong Reference (-1)Mild Reference (0)Neutral (1)Mild Synthesized (2)Strong Synthesized
 * Larger p-value from the two one-sided t-tests

Table 1. Survey results show equivalence of mean rating to zero was demonstrated to within one-quarter of a rating point for all categories.