Coil Combination Method for Peak-Combination HARP

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Introduction: Myocardial tagging such as CSPAMM [1] combined with harmonic phase-analysis (HARP) [2] is a powerful method to quantify myocardial motion of healthy and diseased hearts. CSPAMM data are typically acquired using a phased array coil. In order to achieve optimal tracking results, combination of the signals from all coil elements is desirable.

Using the root-mean-square (RMS) combination, images of different coil elements can easily be combined into modulus images, which can then be used in the HARP method. However, the modulus operation doubles the tag frequency and reduces the intensity of the displacement-encoded peaks in k-space by shifting parts of the signal to higher order harmonics and to an additional peak at zero spatial frequency. The increased number of phase-wraps and the resultant crowding in k-space may lead to errors in HARP evaluation. Another technique for combining the signals from different coil elements is the Roemer combination [3]. Taking into account a body-coil image, it produces images with constant signal amplitude across the field of view and phase contributions from different coil locations are removed. However, the Roemer combination requires an additional scan to calculate coil sensitivity maps. Especially in the presence of patient movement, e.g. in an exam with physiological stress conditions, misregistration of sensitivity information and actual data may occur, which results in errors of myocardial motion quantification.

In this work, an efficient algorithm for combining signals from multiple coil elements using peak-combination HARP [4] is presented. Phase contributions originating from the different spatial locations of the coil elements are compensated for without requiring an additional coil calibration scan.

Methods: In conventional HARP, either the positive or the negative harmonic peak is extracted in k-space, whereas for peak-combination HARP, both peaks are used [4]. The corresponding harmonic phases of the positive ($P^+(x)$) and the negative peak ($P^-(x)$) are: $P^{\pm}(x)=\pm\varphi(x)+\beta(x)$, where $\varphi(x)$ describes the displacement-encoded phase contrast resulting from tagging. $\beta(x)$ contains any remaining phase unrelated to motion, including the coil phases. With peak-combination HARP, $P^-(x)$ is subtracted from $P^+(x)$: $P^+(x)-P^-(x)=2\varphi(x)$, thus eliminating any phase contribution from the different coil elements. Hence, the peak-combined HARP images of different coil elements can be combined in a straightforward fashion: The coil combined HARP phase $P(x)$ is calculated by first weighing the peak-combined HARP-image $P_c(x)$ of each coil element c with the weight $w_c(x)$ and then calculating the complex average over all coil elements (Fig.1): $P(x)=arg(\sum w_c(x)e^{iP_c(x)})$. For the coil weight $w_c(x)$, the low-pass filtered harmonic magnitude (HARM) images are calculated for the corresponding coil element and averaged over all time frames (Fig.1e,f).

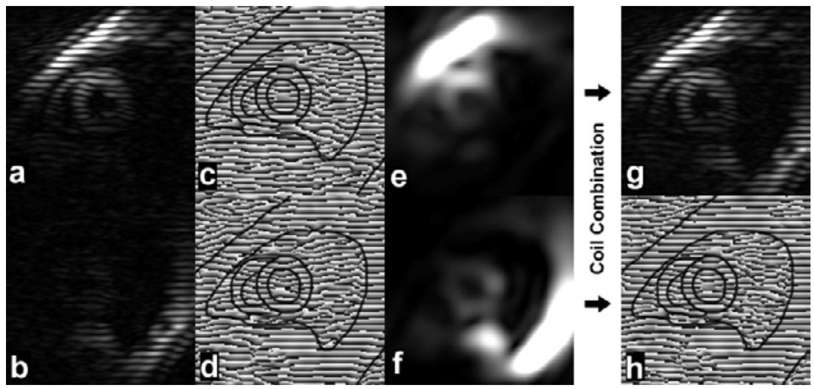


Figure 1: Illustration of the HARP-coil combination method for the case of two coil elements: a,b) Tagged magnitude images. c,d) Peak-combined HARP-images. e,f) HARM-images, used as weights. g) Combined magnitude image. h) Combined HARP-image.

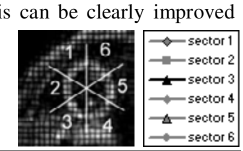
The tagged magnitude images are typically used for the delineation of the myocardial borders. A conventional RMS combination of the tagged magnitude images from multiple coil elements results in a more homogeneous image intensity distribution over the whole myocardium (Fig.1g).

Equatorial slice-following CSPAMM images with a tag-line distance of 8 mm were acquired in a healthy volunteer using a 32-element phased array coil. An EPI-sequence was applied on a 1.5T Scanner (Philips Medical Systems, Best, NL) with the following scan parameters: FOV:360mm, matrix:128x44, reconstructed matrix:256x256, EPI-factor:11, ramped flip angles, max. flip angle:20°, 20 cardiac phases, temporal resolution:32ms, total scan time:17s. A midwall contour consisting of 72 landmark points was HARP-tracked through the cardiac cycle and circumferential shortening was calculated for six sectors over the myocardium. Tracking results were compared for data obtained from only the coil element closest to the heart and for data with all 32 coil elements using one of the following coil combination methods: the RMS combination, the Roemer combination and the proposed coil combination method.

Results: Fig.2 shows that the variability of circumferential shortening over different sectors is clearly increased for the HARP-tracking with only one coil element and the RMS combination compared to the combination of all coil elements applying the Roemer combination or the proposed method. Particularly, myocardial sectors which are more distant from the coil (sectors 4 and 5 in Fig.2), benefit from a better SNR due to coil combination, resulting in less tracking errors and smoother curves for the circumferential shortening. HARP-tracking using the RMS combination fails if the motion between two consecutive time frames becomes large, e.g. during diastolic rapid filling. This can be explained with the increased number of wraps in the HARP-phase for the RMS combination. Results obtained with the Roemer combination (Fig.2c) and with the proposed method (Fig.2d) are very similar.

Conclusion: A new method for combining tagged images from multiple coil elements has been proposed. Compared to the coil combination method by Roemer [3], no additional reference scan is needed for the calculation of coil sensitivities. The tracking results of both methods are in good agreement and myocardial motion quantification is significantly improved compared to the analysis with only one coil element and the RMS combination. HARP-analysis can be clearly improved applying the proposed coil combination method.

References: [1] Fischer SE, et al., 1993, MRM 30: 191-200. [2] Osman N, et al., 1999, MRM 42: 1048-60. [3] Roemer PB, et al., 1990, MRM 16: 192-225. [4] Ryf S, et al., 2004, JMRI 20: 874-8.



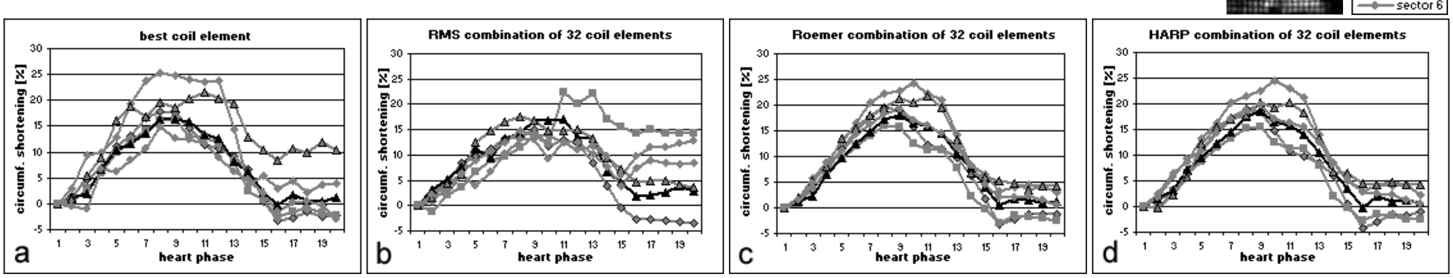


Figure 2: Tracking results for six sectors over the myocardium