# Radiofrequency ($B_1$) Field Mapping In the Heart and Lungs Using a HASTE Double Angle Method

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**Introduction:** Heterogeneity in the radiofrequency ($B_1$) field is a well known problem at high magnetic field strengths (≥3T) where it results in significant variations in signal intensity and SAR. While the $B_1$ fields in clinical field strength MRI scanners (1.5T) are sufficiently uniform for the purposes of diagnostic imaging, there is enough variation to confound quantitative measurements that rely on absolute values of signal intensity. Numerous methods exist for determining $B_1$ fields *in vivo*, but many rely on custom pulse sequences [1,2] and none have investigated the $B_1$ fields in the lungs. A $B_1$ field mapping approach is described that can be applied in the heart and lungs with breath-hold length duration acquisitions or during free-breathing. Large $B_1$ field variations, as low as 66% of the prescribed field, are observed in the heart and lungs at 1.5T.

**Methods:** The $B_1$ field can be characterized by the spatial variations in flip angle experienced by a subject. Insko's double angle method [3] can be used to calculate the actual flip angle experienced at a location by combining two gradient echo images with different flip angles ($\theta_1$ and $\theta_2$, commonly $\theta_2 = 2\theta_1$) using a simple analytical equation. We have adopted this technique to use the HASTE (half-Fourier single shot turbo spin echo) pulse sequence, where only the excitation flip angle is varied. By repeating each of the two flip angle images multiple times during normal respiration and using the diaphragm position to select images of similar respiratory phase, we have overcome the limitation of breath-hold imaging typically used in chest MRIs. Alternatively, the two images can be acquired in a breath-hold to reduce the total scan duration.

All imaging was performed on a Siemens Sonata 1.5T scanner using the HASTE pulse sequence. Typical HASTE parameters: cardiac gating (diastole), 60° and 120° flip angle images, body coil excite and receive, 360×270mm FOV, 8mm thick slices, 128×54 matrix size, 2.75ms echo spacing, 18ms TE, and 4-5s effective TR. For free-breathing acquisitions, each flip angle image was repeated 10 times, with a total acquisition time of ~80 seconds per slice. Breath-hold acquisition reduces the total time to ~10 seconds per slice. The desired tissue was identified in each image and averaged within square regions of interest (~3.5cm$^2$) to increase signal to noise. Slice prescriptions: 5 sagittal slices through the lungs, 3 short axis and a four chamber view of the heart.

**Results:** $B_1$ flip angle maps were calculated for six healthy volunteers (22-27yrs; 4 male, 2 female) lying supine. A four chamber view (Fig. 1) in a representative subject (26yrs female) shows the flip angle distribution across the lungs and heart. Results are expressed as the actual flip angle experienced for a prescribed 90° flip angle. The profile in Figure 2 shows $B_1$ field varying continuously across the chest, with flip angles starting at ~70° in the right lung, falling to ~60° in the right ventricular region, increasing again from ~75° at the apex to the ~85° in the left ventricular free wall and left lung. While $B_1$ maps show minor spatial variations between individuals due to the unique coil loading and dielectric effects of each body, several trends are seen in all subjects. The right lung experiences an average flip angle ~20° less than the left lung, with the largest spatial gradients around the heart. Within each sagittal slice of the lungs, the flip angles had a standard deviation of less than 5°. The three short axis slices in Figure 1 show $B_1$ field gradient from the left to right heart and slightly lower values at the apex (1C) as compared to the base (1A). The average flip angle across the lungs and heart in the four chamber view ranges between 70° and 78° in 6 subjects studied, highlighting the systematic error in the auto-tuning of the $B_1$ field, which is intended to produce an average flip angle of 90°. Free-breathing and breath-hold studies yield similar $B_1$ field maps (not shown). The HASTE double angle method was validated by comparison with the traditional GRE double angle method on a water phantom where HASTE showed a flip angle lower than GRE by an average of 3±2°.

**Conclusion:** The double angle method in conjunction with the HASTE pulse sequence allows $B_1$ field mapping within the chest with a few breath-holds or during free breathing. Similarly large variations in flip angles have been observed by others at 1.5T across the torso [2]. Larger variations with different spatial patterns have also been observed within the heart at 3T [1]. The HASTE $B_1$ field mapping approach is applicable to other regions; we have validated $B_1$ field maps in the brain and leg at 1.5T by comparison to conventional GRE approaches, with an acceleration factor of 50 to 100 times. At higher field strengths, SAR concerns with high flip angle refocusing pulses can be ameliorated by reducing the flip angle of the refocusing pulses [4]. We have successfully used the HASTE approach at 4.7T in the brain using the reduced refocusing flip angle approach.

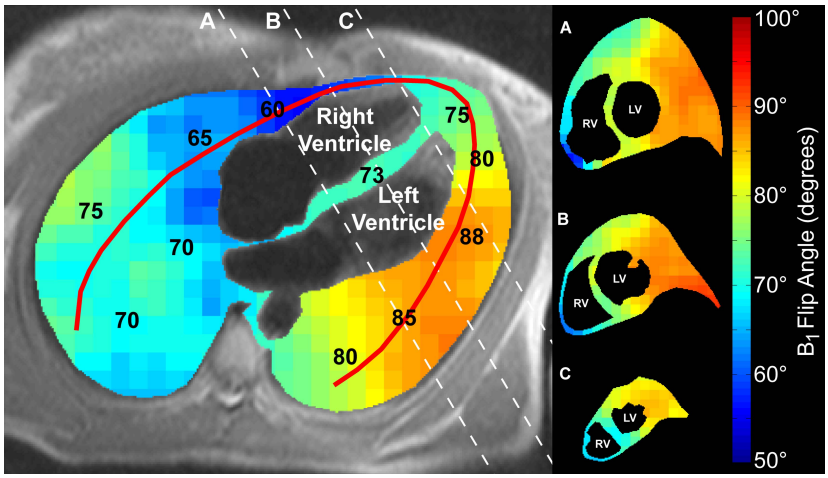


**Fig. 1**. *Left*: A 4 chamber view shows the $B_1$ flip angles across the chest. *Right*: $B_1$ flip angles in 3 short axis slices (A, B, C) of the heart.

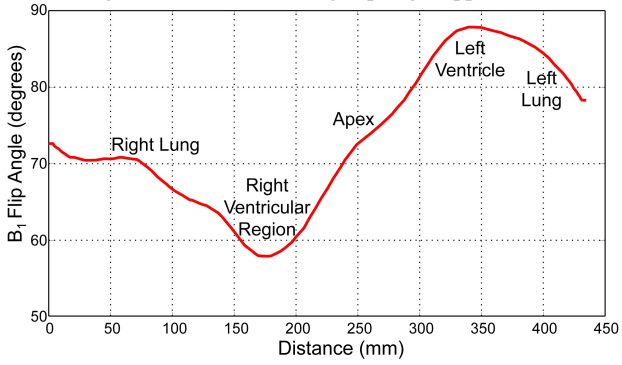


**Fig. 2**. A profile of $B_1$ flip angles through the chest. Profile location is indicated on Fig. 1 (red line).

**References:**

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**4)** Alsop DC. Magn Reson Med 1997;37(2):176-184.