B_0-INDEPENDENT QUANTITATIVE MEASUREMENT OF LOW B_1 FIELD FOR HUMAN CARDIAC MRI AT 7T

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Introduction Cardiac MRI at 7T has several potential advantages over 1.5T and 3T, such as higher signal-to-noise ratio and higher resolution. A quantitative B1 map is routinely required at 7T to allow the management of large B1 variations across the heart. Conventional methods based on rectangular saturation pulse [1] are not accurate in this case because of large B0 inhomogeneity and low flip angle from low maximum B1 power. We propose to use a non-selective broad-band full-passage HS8 pulse that is operating outside its adiabatic state to obtain B1 maps in situations where the B1 is low and the B0 is inhomogeneous such as for cardiac applications at 7T.

Theory Below the adiabatic limit we can build an HS8 pulse that has a saturation profile insensitive to B0 [2], and its flip angle has a monotonic relationship with B1 in the target variation range (Fig.1).

Methods All scans were conducted on a whole-body 7T scanner (Siemens) with an 8-channel stripe-line transceiver array. The target B1 range in the mid-ventricular short-axis plane was 0-250Hz, and B0 offset from -250 to 250Hz. As an example, the B1 map can be used to determine whether the minimum B1 after shimming is lower than 150Hz.

The B1 mapping acquisition consists of a reference image (no saturation pulse), followed by an 8 second delay and then a saturation pulse and a 1ms spoiler followed by a second (saturation) image.

Two pulses were investigated as candidates for B1 mapping: a 1ms rectangular (hard) pulse at maximum voltage and an HS8 pulse at maximum voltage of duration 5ms and bandwidth 8 kHz. These were evaluated using an experiment that consisted of 9 separate acquisitions using a 4ms full-passage Hanning pulse [2] of 800Hz bandwidth at nine different central frequency offsets, from -400 to 400Hz. It took one breath hold for the hard/HS8 pulse method to generate a B1 map, and nine breath holds for the Hanning pulse method. The pixel-wise ratios of the saturation image to the reference image were mapped to B1 values according to numerical Bloch simulations of different pulses. The simulations of the hard pulse and the HS8 pulse did not include effects of B0 offsets. The nine measurements from the Hanning pulse were fitted to the simulated saturation profiles at different B1 and B0 offsets to determine both B1 and B0 offsets. The Hanning pulse method has been validated in phantom experiments and was used as a standard to evaluate the other two methods. B0 maps were measured with a double-echo GRE sequence.

The three methods were applied in vivo with a FLASH imaging readout on six healthy volunteers (all males, age 32±7y, and weight 72±5kg), in accordance with local ethics. All scans of the mid-ventricular short-axis plane used the same imaging parameters: FOV 380mm, matrix 192×192, slice thickness 8mm, TE/TR 1.18/2.5ms, flip angle 2° (varies with B1), and sequential ordering. Central k-space signal was collected 280ms after the saturation pulse with pulse-ox trigger time of 300ms. For each volunteer, six 2×2 ROIs were selected in the left ventricular myocardium where B0 offsets are more than 100Hz. Mean and standard deviation over 36 ROIs of the errors in B1 are reported for each method.

Results Fig.1 shows the simulated saturation profiles of the hard/HS8/Hanning pulses. Fig.2 shows B1 maps from the hard/HS8 pulse methods before and after B0 shimming, and corresponding B0 maps. The B1 maps from the HS8 pulse method are almost identical before and after significant changes of the B0 field, while the hard pulse method suggests B1 changes. The B1 error from the rectangular pulse method is -36±15Hz, and -4±4Hz from the HS8 pulse method, in regions where B0 offsets are more than 100Hz.

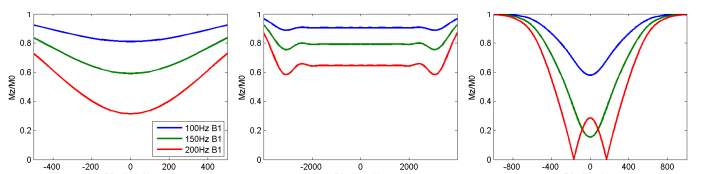

Fig.1 Saturation profiles of the rectangular (left), HS8 (middle), and Hanning pulse (right).

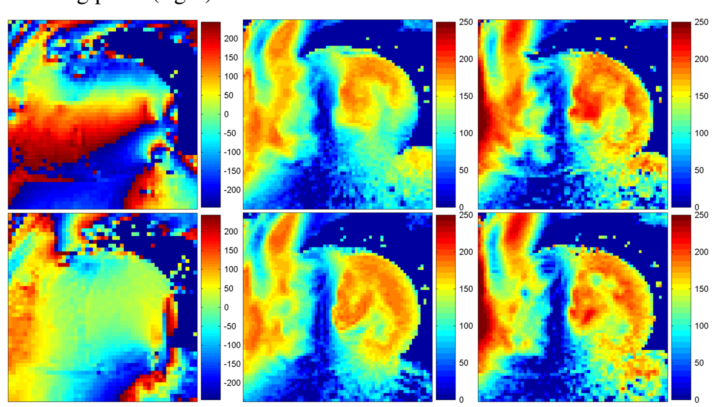

Fig.2 B0 maps (left), and B1 maps from the rectangular pulse (middle) and the HS8 pulse (right). Top row maps were obtained before B0 shim and bottom row after B0 shim. All units in Hz.

Discussion The B0-independent saturation bandwidth of the HS8 pulse is at least 2 kHz, much wider than the target B0 variation range. This explains the consistent B1 maps before and after significant B0 changes in Fig.2. It also suggests that there is space for adjustments of the HS8 pulse to suit different target B1/B0 variation ranges. Effects from relaxation are small with this technique owing to the short pulse duration.

The ability to obtain B0-independent B1 measurement is very beneficial when it is difficult to obtain a good B0 shimming over the whole myocardium. Further by performing B1 mapping before B0 shimming, we are able to obtain an improved B0 shim. This approach has been applied to 2D measurements in this work, but the use of the non-selective pulse is equally applicable to 3D.

Conclusion The non-adiabatic HS8 pulse method is more accurate than the rectangular pulse method for quantitative measurement of relatively low B1 field in the presence of large B0 inhomogeneity.

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References: 1. Brunner, DO *et al. proc.* ISMRM (2007); 2. Tannus, A *et al.* NMR Biomed 10 (1997).