Lowering the $B_1$ Threshold for BEAR $B_1$ Mapping
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PURPOSE: The recently proposed BEAR method1 is a phase-based $B_1$ mapping method, with linear phase sensitivity to variations in $B_1$. The method relies on two hyperbolic secant (HS1) pulses operating in their adiabatic regime used for refocusing, which limits the range of $B_1$ that can be measured due to the adiabatic threshold of the pulses. Here, we redesign the BEAR method to use HSn pulses, which have lower adiabatic thresholds2. By optimizing the HSn pulse parameters, we can reliably acquire $B_1$ maps for lower nominal peak $B_1$ ($B_{1,nom}$) than with the original BEAR method. We validate the performance of BEAR with HSn pulses via simulation and in vivo at 3T.

METHODS: Fig. 1 shows the BEAR sequence with HSn pulses2, where $n_1$ and $n_2$ determine the shape of the magnitude sweep for each pulse, $sech(\beta \tau)$, and can be non-integer. The adiabatic threshold ($B_{1,A}$, the minimum $B_1$ that ensures refocusing of 90% $|M_{XY}|$) decreases with increasing $n$. Thus, increasing $n$ reduces the sequence adiabatic threshold ($-B_{1,A}/\delta$, where $\delta$ is the ratio of the two pulse magnitudes), allowing for use of a lower $B_{1,nom}$.

The BEAR method using HS1 pulses has a flat phase response with respect to off-resonance frequency. BEAR with HSn pulses has a moderate quadratic variation in phase with respect to off-resonance frequency. This quadratic phase variation can be largely canceled by choosing appropriate values of $n_1/n_2$. Specifically, given an $n_1$, we choose $n_2$ to cancel any phase variation over the slice profile within a range of expected $B_1$ variation, for a given $B_{1,nom}$. $n_2$ is chosen by minimizing the maximum percent off-resonance phase difference from the on-resonance phase, over the expected $B_1$ range and slice profile. The expected variation in $B_1$ depends on the transmit coil used, so we have optimized the method with different $n_1$’s for different $B_1$ ranges.

The adiabatic pulse parameters3,4 were $T/\beta/\mu=12$ ms/5.3 rad/5.5 and $\delta=0.9$. A 40° tip angle, TE/TR=49/200 ms, was used for a single 2DFT acquisition on a GE 3T scanner. To eliminate unwanted sources of phase variation, phase-difference images were made with the second acquisition reversing the order of the two adiabatic pulses.

RESULTS: Fig. 2a-c show Bloch simulation results for BEAR using a set of optimized HSn pulses ($n_1/n_2=4/4.153$). The magnitude and phase of the refocused $M_{XY}$ as a function of $B_1$ and off-resonance frequency (Fig. 2a-b) show its insensitivity to off-resonance over the given $B_1$ range. Fig. 2c illustrates that the percent phase difference due to off-resonance can be largely canceled by choosing appropriate $n_1/n_2$. Optimizations of a few $B_1$ ranges were made since different amounts of variation are expected, depending on the transmit coil (e.g., the 50% variation in $B_1$ is typical for a head transmit coil at 7T). Scan results showed the method’s accurate $B_1$ mapping ability even for low $B_{1,nom}$. We expect this method to be useful for acquiring $B_1$ maps at lower $B_{1,nom}$.

DISCUSSION/CONCLUSION: The BEAR method has been redesigned to use HSn pulses, reducing the peak RF amplitude required for accurate $B_1$ measurement, while maintaining its insensitivity to off-resonance frequency, and linear phase sensitivity to $B_1$ variations. The method minimizes the $B_1$ map error seen within a $B_1$ range by selecting a particular $n_2$. Optimizations of a few $B_1$ ranges were made since different amounts of variation are expected, depending on the transmit coil (e.g., the 50% variation in $B_1$ is typical for a head transmit coil at 7T). Scan results showed the method’s accurate $B_1$ mapping ability even for low $B_{1,nom}$. We expect this method to be useful for acquiring $B_1$ maps at lower $B_{1,nom}$.

Acknowledgment: The authors thank Bob Dougherty for access to Stanford CNI’s 3T scanner.