# In vivo comparison of B1 mapping techniques for hip joint imaging at 7 Tesla

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**Target audience:** Scientists working at ultra-high field systems with interest in functional musculoskeletal MRI and $B_1^+$ mapping.

**Purpose:** First insights into ultra-high-field (UHF) clinical imaging of the human hip joint have been presented by several groups.[1-3] Besides structural imaging, there is also an increasing interest in performing functional musculoskeletal (MSK) imaging at 7T, including delayed gadolinium-enhanced MRI of cartilage (dGEMRIC), and T2, T2* relaxometry.[4] However, $B_1^+$ correction based on adequate maps of the transmit field must be incorporated into a 7T functional MSK study.[5] While $B_1^+$ mapping is already challenging in the brain at 7T,[6] there is only limited information about the quality and especially reproducibility of $B_1^+$ mapping techniques in large cross-sections like the pelvis. Hence, the purpose of this work is the comparison of three well-established $B_1^+$ mapping techniques in the hip joints.

**Methods:** A 7T research MR system (Magnetom 7T, Siemens AG, Healthcare Sector, Germany) was used in combination with an eight-channel transmit-receive body coil and an add-on system for static RF shimming. For $B_1^+$ mapping, three different techniques were applied: actual flip angle imaging (AFI),[7] Bloch-Siegert shift (BSS),[8] and dual refocusing echo acquisition mode (DREAM).[9] Axial imaging was performed with the RF coil positioned on the hip joints of 6 healthy volunteers (all male, BMI: 20.6-26.9) and with two standard shim settings, $CP^+$ and $CP^{2+}$. To assess reproducibility for a dGEMRIC protocol consisting of a native scan and a contrast-enhanced scan after intravenous application of Gadolinium and ½ hour of walking, the subjects were imaged twice with repositioning in between. Three regions of interest (ROI; left hip joint, right hip joint, total cross-section) were drawn on the center slice of each dataset to obtain mean and maximum flip angle, as well as the ratio of zero to nonzero values in each ROI. The latter was used to assess quantitatively the quality of the $B_1^+$ mapping techniques in large cross-sections like the pelvis, as existing methods typically fail to measure lower values of the flip angle and result in complete signal voids in the maps.

**Results:** Fastest imaging and lowest RF power was obtained with the DREAM method (TA: 8 sec, RF: 3 W), followed by BSS with TA of 29 sec and very high RF exposure of 124 W, and AFI with TA of 56 sec and RF power of 19 W. Both DREAM and BSS yielded much lower ratios of zero to nonzero values compared to AFI. For AFI, an increase of zeros and hence a decrease in the quality of the map was observed with increasing BMI (Figures 1, 2). Good reproducibility between scan and rescan was obtained for DREAM and BSS, while AFI yielded much higher deviations in mean and maximum $B_1^+$ between the two scans (Table 1).

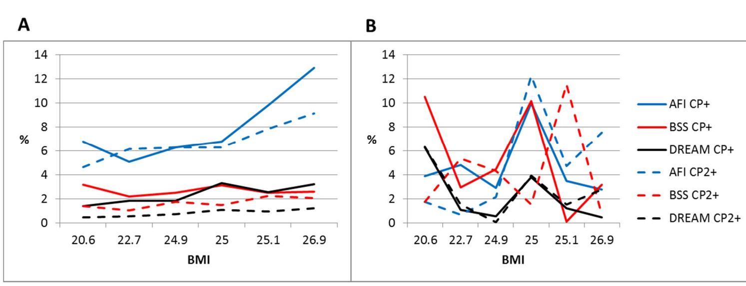


***Figure 1:*** *As an indication for the quality of the $B_1^+$ maps, the ratio of zero to nonzero values over the total cross-section are given versus BMI in (A). In (B) reproducibility of the methods is shown, again for the total cross-section and both shims. Here the deviation of the mean $B_1^+$ value between scan and rescan is plotted against BMI.*

| | | CP+ | | | CP2+ | | |
|---|---|---|---|---|---|---|---|
| | | AFI | BSS | DREAM | AFI | BSS | DREAM |
| Left ROI | dev. of mean B1 | 9.6 | 10.0 | 7.2 | 8.6 | 6.0 | 8.8 |
| | dev. of max. B1 | 24.1 | 9.2 | 9.7 | 14.9 | 16.5 | 11.7 |
| | ratio zero/nonzero | 1.9 | 0.6 | 0.6 | 1.4 | 0.4 | 0.3 |
| Right ROI | dev. of mean B1 | 15.3 | 9.5 | 3.1 | 11.5 | 6.0 | 1.5 |
| | dev. of max. B1 | 24.7 | 4.6 | 9.6 | 16.8 | 15.7 | 12.3 |
| | ratio zero/nonzero | 1.9 | 0.8 | 0.6 | 1.7 | 0.5 | 0.2 |
| Total ROI | dev. of mean B1 | 4.7 | 5.2 | 2.2 | 4.9 | 4.2 | 2.7 |
| | dev. of max. B1 | 15.5 | 7.8 | 6.6 | 10.5 | 8.8 | 5.1 |
| | ratio zero/nonzero | 8.0 | 2.7 | 2.4 | 6.7 | 1.7 | 0.9 |

***Table 1:*** *Mean deviation between scan and rescan for mean $B_1^+$ and maximum $B_1^+$ in a ROI, as well as the mean ratio of zero to nonzero values in a ROI for all three methods and both applied standard phase shims. All values are given in %.*

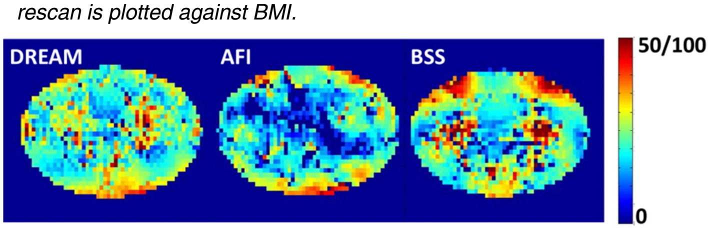


***Figure 2:*** *$B_1^+$ maps from one volunteer (BMI: 24.9) obtained in $CP^{2+}$ mode. Note that extensive signal voids are visible in the AFI map. Distribution of $B_1^+$ is similar for both techniques DREAM and BSS, except for high-intensity regions anterior on the left and right sides of the BSS map. Maps are not normalized. Same color bar scaling was used for DREAM and AFI (50) while BSS yielded higher B1 and was scaled to 100.*

**Discussion & Conclusion:** For $B_1^+$ mapping at 7T of large cross-sections like the human pelvis, the AFI technique does not appear suitable. Still not optimal due to residual signal voids, but certainly much more applicable than AFI, DREAM and BSS yielded reproducible $B_1^+$ maps. However, an asymmetry between left and right ROI was observed in the deviation of mean $B_1^+$ between scan and rescan. As acquisition time and SAR also play an important role in multi-channel UHF systems, the DREAM $B_1^+$ mapping technique can be recommended for $B_1^+$ correction in functional studies of the hip joints at 7T.

**References:**

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