# Statistical Analysis of B1 Mapping Techniques

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**INTRODUCTION:** B1 mapping is important for parallel transmit pulse design, transmit gain adjustment, T1 mapping, and other quantitative MRI applications [1]. Recently two new phase-based B1 mapping methods have been introduced: the Bloch-Siegert (BS) method [1], and the phase-sensitive (PS) method [2]. Both methods have been compared to accepted B1 mapping techniques like dual-angle gradient recalled echo (DA-GRE) and 'actual flip angle imaging' (AFI) [3,4]. However, the methods have not yet been directly compared to each other. In this work, we provide such a comparison. A statistical analysis of the phase sensitive, Bloch-Siegert, DA-GRE, and AFI methods of B1 mapping is presented using the framework introduced by Morrell et al. [3].

**METHODS:** PS B1 mapping uses the phase introduced by a compound RF pulse of $2\alpha$ about the x axis followed by $\alpha$ about the y axis [2]. BS phase mapping is done using an off-resonance excitation pulse immediately following the standard on-resonance excitation pulse. The off-resonance pulse introduces a phase proportional to the square of the B1 field [1,4]. DA-GRE B1 mapping uses the intensity variation in the two magnitude images taken at flip angles of $\alpha$ and $2\alpha$ respectively [5]. AFI uses two interleaved TRs to generate magnitude contrast based on the B1 field, both with the same flip angle $\alpha$ [6].

Bloch simulations were performed for each of the methods, with Gaussian random noise added to the simulated signal levels. A Monte Carlo simulation was performed (N = 40,000) to ascertain the statistical characteristics (mean and standard deviation) of flip angle estimate for each of the B1 mapping techniques. To compare the methods a system SNR was defined as the SNR an image would have if given an ideal 90° flip. The simulations were repeated assuming noise consistent with system SNRs of 5, 10 and 25.

Each B1 mapping method is valid over a range of flip angles. For fair comparison, a nominal flip angle was chosen at a midpoint of the dynamic range of each method ($\alpha_0$): 90° for BS and PS, 45° for DA-GRE, and 50° for AFI. Methods are compared relative to these values. TR=500ms and T1 = 500ms were assumed for simulations of the DA-GRE, BS, and PS methods; TR1=30ms, TR2=150ms, T1=500ms, and NEX=6 for the AFI method.

**RESULTS:** Figure 1 shows consistently high performance for the PS method, even in low SNR environments. The PS method also demonstrates a lower standard deviation along with a smaller mean bias in higher SNR environments than each of the other methods. However, the PS method is sensitive to off-resonance (B0 field inhomogeneity and chemical shift) [2], so it may not be ideal for all applications. Additionally, the BS method can be used in a multi-transmit environment to accurately map small B1 field because of its relative independence from excitation [4], which was not addressed here.

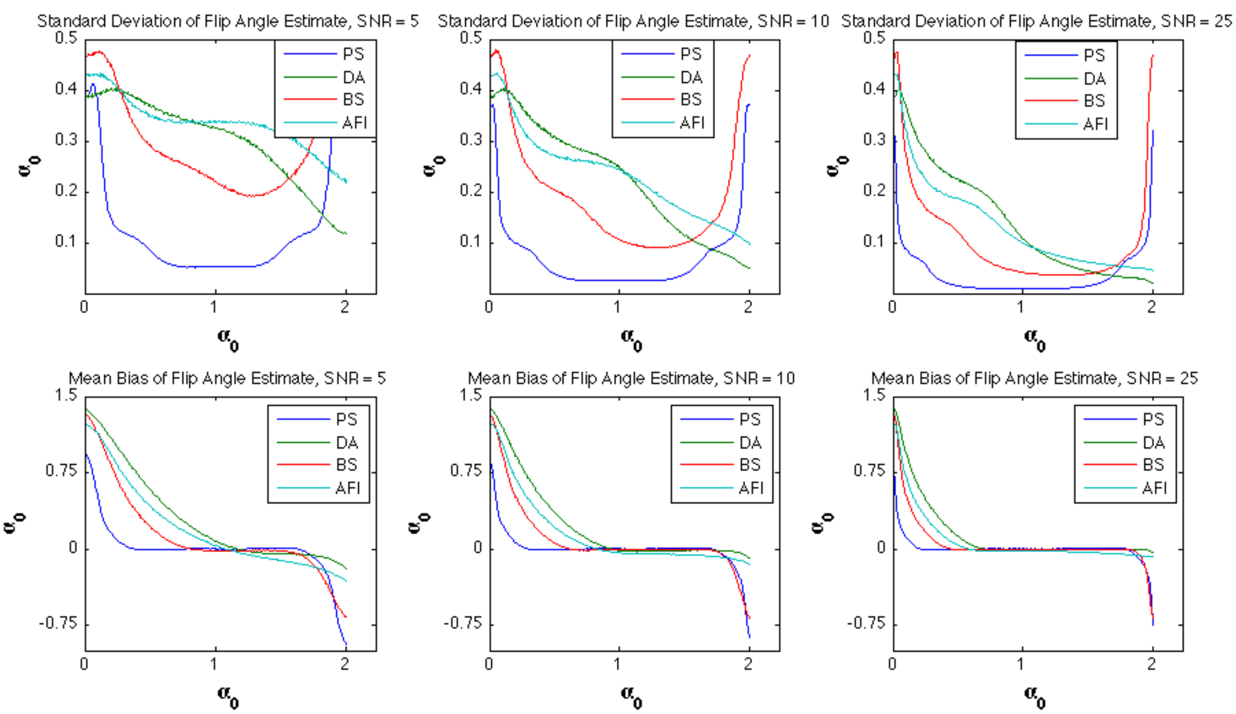


**Figure 1: Results of Monte Carlo Simulations**

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