Specialty Area: MR Physics for Physicists

Session: Electromagnetic Fields in MRI: From Theory to Practice

Title: RF Field Generation: B1 Field Non-Uniformity & SAR

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Highlights:

- B1 mapping methods are generally categorized as magnitude-based or phase-based
- The ideal B1 mapping method is independent of T1, T2, B0, insensitive to spoiling errors, has high signal-to-noise ratio per unit scan time, high dynamic range and low SAR
- B1 mapping methods can be compared based on a unified noise propagation theory and efficiency analysis; such analysis shows that phase-based methods are more efficient than magnitude-based methods

Target Audience: Physicists and Engineers working in MRI

OUTCOME/Objectives: To understand the non-uniformity in B1 field that occurs at high field, and the known methods of mapping B1 field amplitude. To understand how SAR distributions are different than B1 field distributions and the implications of these non-uniformities and different distributions.

PURPOSE: There is currently a great deal of interest in mapping the excitation or flip angle, α, or the B_1^+ transmit field. These methods are generally lumped together and referred to today as B1 mapping methods. This interest has been motivated by the trend toward higher main field magnets. Higher field results in higher signal-to-noise ratio, but requires shorter wavelength radio frequency (RF) pulses, leading to a non-uniform excitation field magnitude $|B_1^+|$, and consequently a non-uniform α.

METHODS AND RESULTS: The ideal B1 mapping method would have the following characteristics: 1) No dependence on tissue relaxation times (T1 and T2); 2) No dependence on B0 inhomogeneity; 3) High angle to noise ratio (ANR); 4) Short scan time; 5) High dynamic range; 6) Low bias due to imperfect spoiling or RF profile change; 7) Low RF deposition (low SAR). No single B1 mapping method is perfect; the best present-day methods meet some but not all of the above characteristics. We will review the general categories of B1 mapping methods and draw some comparisons between the known methods, particularly in terms of the above ideal characteristics.

There are now quite a few methods for B1 mapping, many of which have only recently been proposed. We can categorize B1 mapping methods into two broad categories: those that are based on encoding B1 information into image magnitude, and those that are based on encoding B1 information into image phase. The magnitude-based methods are older and more established, although there have been new such methods proposed. These magnitude-based methods are typically based on incremented flip angles, or interleaved repetition times. A partial list of existing B1 mapping methods is: 1) Dual Angle Method (DAM) and variants; 2) Actual Flip angle Imaging (AFI); 3) DREAM; 4) DALL, DtauLL, niDALL; 5) Phase Sensitive; 6) Bloch-Siegert, Adiabatic Bloch-Siegert. While these methods have been well outlined in the literature and are becoming widely adopted, there is less published literature on the direct comparison between B1 mapping methods. One useful method of comparing methods exploits the concept of mapping efficiency. The concept of T1 mapping efficiency was previously developed as a tool to compare and optimize different T1 mapping techniques. By a propagation of noise analysis, it is possible to predict the noise that will be introduced into the derived quantitative measurement, under the assumption of a constant scan time. This approach has been adapted to B1 mapping and has been used to optimize and compare existing techniques.

DISCUSSION AND CONCLUSIONS: B1 mapping methods have found important application in many new and advanced MR methods. A few of these are: 1) parallel transmit RF pulse design; 2) computation of optimal RF shim weights; 3) correction for B1 inhomogeneity in quantitative relaxometry; 4) RF coil design and optimization. At ultra-high field, it is now believe that B1 mapping over an entire volume of tissue (eg the human head) must be accomplished quickly (a few seconds), accurately and precisely, during the pre-scan stage of a patient examination. This B1 mapping, similar to B0 mapping, will then be used to make optimal adjustments to transmit parameters (transmit gains, RF shim weights, pTx pulse designs) to maximize B1 or flip angle uniformity in subsequent imaging. The acquired B1 maps will also likely be used to correct quantitative image values. Finally, B1 mapping may have an increasing role in electrical properties mapping applications.