RF Pulse Design: From Basics to the State-of-the-Art

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Highlights:

- SLR algorithm for RF pulse design
- Adiabatic RF pulse design
- Multidimensional RF pulse design

Target audience: MR engineers and scientists interested in learning about RF pulse design.

Objective: To present some of the capabilities and limitations of RF pulse designs to address the problem of selectively manipulating magnetization as a function of space, frequency, motion and RF field strength.

Purpose: RF pulses are a key component of imaging pulse sequences, serving the purpose of excitation, refocusing, and contrast preparation. Choosing the best combination of RF pulse and sequence design can have a significant impact on image SNR and contrast and so understanding the RF pulse options available is an important part of the knowledge base of a pulse sequence designer.

Methods & Results: RF pulse design is in general a difficult nonlinear problem but for most cases of interest there are simple, easily computed solutions.

In the small-tip-angle or linear regime, pulses can be simply designed knowing that the Fourier transform of the RF pulse evaluated along the excitation k-space trajectory gives the excitation profile. In the large-tip-angle regime, such as for pulses used for inversion, saturation or refocusing, the Shinnar-Le Roux (SLR) algorithm [1] allows for fast and direct calculation of 1D RF pulses. In the SLR design approach, the problem of designing these large-tip-angle pulses reduces to a linear digital filter design problem that allows easy tradeoffs to be made between performance parameters such as duration, bandwidth, selectivity, and ripple.

Adiabatic pulses are a class of pulses that are capable of uniformly exciting, inverting, or refocusing magnetization in the presence of RF field (B_1) inhomogeneity [2], making these pulses appropriate for use in high-field systems, or other situations where large B_1 variations are to be expected. Pulse design parameters have a substantial influence on bandwidth, peak RF power, selectivity and B_1 insensitivity.

Multidimensional RF pulse design can exploit the use of RF in conjunction with a gradient field and time to manipulate magnetization as a function of both space and frequency [3] or space and velocity. The typically long duration of multidimensional spatially selective RF pulses can also be accelerated when using parallel transmit arrays [4, 5] in a fashion analogous to image acquisition acceleration using parallel receive arrays.

Discussion & Conclusions: RF pulses are one of the most flexible components of an MR imaging sequence. Design choices can make them more or less sensitive to a host of physical parameters, some of which are position, frequency, velocity and RF field strength. The pulse sequence designer's choice of RF pulse components has a profound effect on MR sequence design and performance.

References:

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