Simultaneous multi-slice excitation done differently

Olaf Dietrich*, Munich

2017-12-15

Last week, Koray Ertan and colleagues published an MRM paper (doi: 10.1002/mrm.27031) (expanding on an ISMRM abstract presented earlier this year) with an interesting approach for simultaneous multi-slice excitation. So, what's it about?

In MRI, we are frequently interested in data from a single two-dimensional slice of the imaged subject or object – or actually in data from several such slices. These slices are then displayed as conventional 2D MR images. A procedure called *slice selection* is used to restrict our data acquisition to each single slice. To understand slice selection, one has to know that MRI is based on the resonant excitation of spins in a static magnetic field B_0. Spins have a characteristic, so-called Larmor frequency $\omega = \gamma B$ depending on the magnetic field B (the constant of proportionality γ is the gyromagnetic ratio). By applying a radio-frequency (rf) field with exactly this Larmor frequency, spins can be excited (i. e., they can be made to generate a measurable signal).

The basic idea of slice selection is to excite only spins in a single slice by (first) superposing a linear magnetic field gradient g_z e. g. in z direction, resulting in the spatial field distribution (shown in the first figure):

$$B(x, y, z) = B_0 + g_z z.$$

(These linear magnetic fields or *gradient fields* are one of the basic ingredients of MR imaging. Each MR imager comes with built-in coils to apply gradient fields in all possible spatial orientations.)

Then, by choosing an rf frequency $\omega_{\mathrm{slc}} = 2\pi f_{\mathrm{slc}}$, we can select a plane in space where

$$\omega_{\mathrm{slc}} = \gamma B(x, y, z) = \gamma B_0 + \gamma g_z z_{\mathrm{slc}},$$

and only spins in this plane centered around $z_{\mathrm{slc}} = (\omega_{\mathrm{slc}}/\gamma - B_0)/g_z$ are excited (see first figure).

*Please send comments, corrections, or suggestions to <olaf@dtrx.de>.

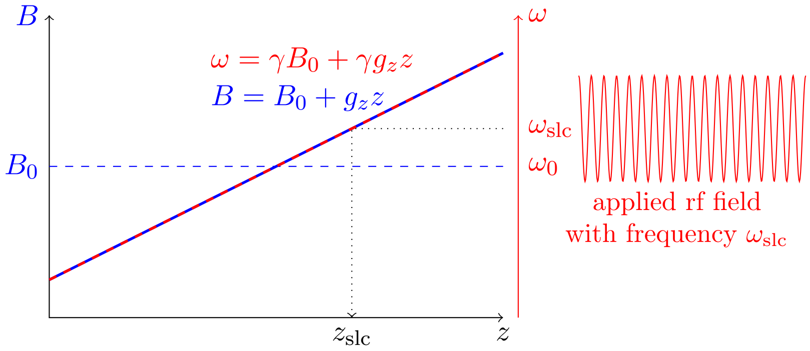

Figure 1: Slice selection of a single slice in z direction

More advanced MRI techniques can excite several spatially separated slices at once by applying rf fields with more than one frequency – the difficult part is then to separate data acquired from these slices for reconstruction.

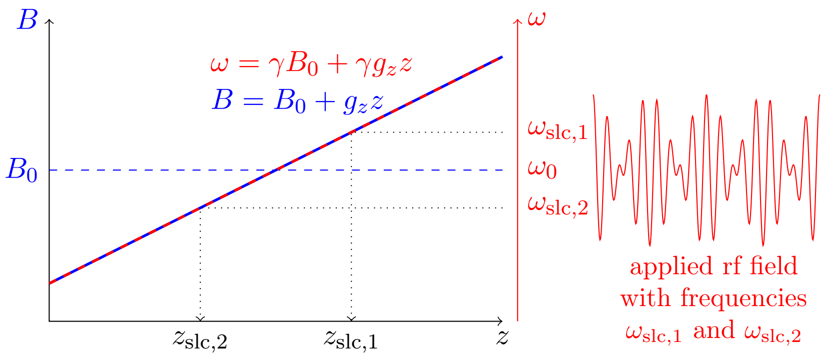

Figure 2: Simultaneous slice selection of two slices in z direction

The nice idea realized in the paper by Koray Ertan et al. is to excite multiple slices *not* by applying rf fields with a mixture of several frequencies, but instead by modifying the gradient field to a spatially non-linear magnetic field. Consequently the mapping between frequencies ω and spatial positions (z) is no longer one-to-one, but several positions can correspond to a single frequency:

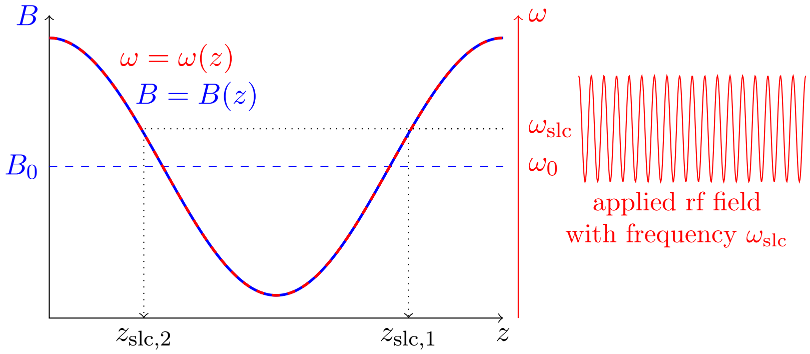

Figure 3: Simultaneous slice selection of two slices in z direction using non-linear magnetic fields

So, depending on the shape of the magnetic field variation two or more slices can be excited using a single excitation frequency. This has the advantage that we can use short and simple standard rf pulses for slice excitation. The obvious disadvantage is that it requires additional gradient hardware providing the non-linear magnetic fields, which is currently not available at existing MRI systems.

However, this may change in future, since there are currently some promising approaches for non-linear encoding fields. In particular, I'm thinking about an impressive MRM paper (doi: 10.1002/mrm.26700) by Sebastian Littin and colleagues published also this year, in which an 84-channel matrix gradient coil is presented, which is capable of providing very flexible linear or non-linear field configurations.

Keywords: MRI, physics, publications