Chapter 3 Calibration

1. Shimming
   1) On installation, active shimming: superconductive shim coils (to correct the magnet); passive shimming: iron rods
   2) Subject-by-subject basis, resistive shim coils (flexibility, also called “dynamic shimming”, to correct subject)
      - Spherical harmonic shimming: 0\textsuperscript{th} order, 1\textsuperscript{st} order \((x, y, z)\), 2\textsuperscript{nd} order \((xy, xz, yz, xx, yy, zz)\), typically up to 2\textsuperscript{nd} or 3\textsuperscript{rd} order
   3) manual shimming? Red box. Goal: to have the highest and sharpest water peak.

2. Prescan:
   1) Quick shimming.
   2) Coil tuning and matching. Different subjects \(\rightarrow\) different "loads"/resistance on the RF-coils. As such, the resonance frequency of the patient-coil system must be adjusted as well as the coil impedance (complex resistance) for effective energy transfer.
   3) Center frequency adjustment. Human tissues contain both water and fat in various proportions whose resonance peaks differ by a few hundred hertz (Hz). The scanner must lock on to the correct spectral peak for proper localization.
4) Transmitter attenuation/gain adjustment. The attenuator or amplifier gain of the RF pulse must be calibrated for each patient so that proper flip angle can be obtained.

5) Receive attenuation/gain adjustment. The MR signal intensity must appropriately scaled so it is neither too big nor too small for the amplifier chain.

6) Dummy cycles. These are multiple runs of a pulse sequence prior to acquiring data to allow a steady state magnetization to develop.

3. RF receive (B1-) sensitivity
   1) Boundary matters.
   2) I think it’s possible to get a full FOV field sensitivity maps. But it’s hard to measure sensitivity beyond regions with signal.

   The basic equation for k-space data \( m \) of array element \( y \) in two-dimensional Fourier-Imaging (c is the spin density of the object and \( s \) are the coil sensitivities; relaxation effects are neglected):

   \[
   m_{j}(k_{x},k_{y}) = \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} c(x,y)s_{j}(x,y)e^{-(x_{j}k_{x} + y_{j}k_{y})}dx
   \]

   In SMASH, for example, missing k-space information \( m \) is calculated from a weighted combination of neighbouring k-space data. In a somewhat more general manner we can write:

   \[
   m_{j}(k_{x},k_{y}) = \sum_{(n,m)\neq(0,0)} w_{j}(\lambda,n,m) m_{j}(k_{x} + n\Delta k_{x}, k_{y} + m\Delta k_{y}) + \sum_{(n,m)\neq(0,0)} w_{j}(\lambda,n,m) m_{j}(k_{x} + n\Delta k_{x}, k_{y} + m\Delta k_{y})
   \]

   A comparison of the two equations under the assumption that they hold for an arbitrary spin density distribution \( c \) leads to:

   \[
   s_{j}(x,y) = \sum_{(n,m)\neq(0,0)} w_{j}(\lambda,n,m) s_{j}(x,y) e^{-(x_{j}n\Delta k_{x} + y_{j}m\Delta k_{y})} + \sum_{(n,m)\neq(0,0)} w_{j}(\lambda,n,m) s_{j}(x,y) e^{-(x_{j}n\Delta k_{x} + y_{j}m\Delta k_{y})}
   \]

   or:

   \[
   \left(1 - \sum_{(n,m)\neq(0,0)} w_{j}(\lambda,n,m) e^{-(x_{j}n\Delta k_{x} + y_{j}m\Delta k_{y})}\right) s_{j}(x,y) - \sum_{(n,m)\neq(0,0)} w_{j}(\lambda,n,m) e^{-(x_{j}n\Delta k_{x} + y_{j}m\Delta k_{y})} s_{j}(x,y) = 0
   \]

4. Measure RF transmit (B1+) field:
   1) Double-angle method
      - A uniform phantom
      - 2 or more flip angles; get the image magnitude ratio
      - limitation: long TR, TR>>5*T1, inaccuracy over a large range of B1,
   2) Bloch-Siegert: B1-dependent signal phase
      - Robust to TR, T1; fast
      - Create a B1_eff no longer lying in the transverse plane

5. Field engineer
   1) Eddy current compensation
   2) B0 shimming
   3) B1 inhomogeneity