Signal-to-Noise Ratio (SNR) in MRI

Consider an imaging sequence with the following parameters:

- N_{RO} (N_x): Frequency encoding (readout) matrix size
- N_y: In-plane phase encoding matrix size
- N_z: Number of slices
- TR: Repetition time
- TE: Echo time
- NEX: Number of excitations (number of averages)
- FOV_x: Field-of-view in the readout direction
- FOV_y: Field-of-view in the phase encoding direction
- FOV_z: Field-of-view in the slice direction
- Δz: Slice thickness (= FOV_z/N_z for 3D)
- ΔV: voxel size
- BW: sampling bandwidth (in frequency encoding encoding direction)

- Basics:
  - Noise $\propto$ BW
  - Signal $\propto$ voxel size
  - Averaging is the only mechanism to make the SNR better
  - Phase encoding involves averaging (independent measurements)
  - Observe the inverse relationship between acquisition time and SNR

- General SNR Expression:

$$SNR \propto \Delta V \cdot \frac{\sqrt{N_{PE} \cdot NEX}}{\sqrt{BW}} \tag{1}$$

  where,

$$N_{PE} = \begin{cases} N_y & (Multislice) \\ N_y \cdot N_z & (3D) \end{cases} \tag{2}$$

$$\Delta V = \left(\frac{FOV_x}{N_x}\right) \cdot \left(\frac{FOV_y}{N_y}\right) \cdot \Delta z \tag{3}$$