CHAPTER B6
Signal, Noise, and Contrast

INTRODUCTION

The accuracy or interpretation of MR images can be affected significantly by the presence of noise in the measurements. If the signal is in the noise level, it becomes impossible to differentiate the object itself from the noise; therefore, design and implementation of an imaging experiment requires a thorough understanding of signal and noise in MR. Since the signal has already been discussed at some length in Chapter B2, the noise behavior in MR (both in *k*-space and image domain) and its dependence on imaging parameters are the major focus of *UNIT B6.1*. Voxel signal, the noise distribution in the raw data, real and imaginary images, and magnitude, as well as phase images are discussed.

The degree to which noise affects a measurement is generally characterized by the signal-to-noise ratio (SNR), which is a key parameter for determining the effectiveness of any given imaging experiment. Based on the signal and noise properties, an expression for SNR, as a function of the imaging parameters such as T_R, T_E, resolution, readout bandwidth (BW_{read}), and imaging time is developed in *UNIT B6.2*. In MRI, each increase in SNR by a factor of $\sqrt{2}$ allows a doubling of resolution in one direction and has an order of magnitude visual effect on the quality of the image. It is therefore necessary to strive in all possible ways to optimize SNR for a fixed spatial resolution.

The main purpose of imaging is to be able to distinguish diseased from healthy tissue and one tissue type from another. This implies that there must be a signal difference, defined as contrast, between different tissues. Combining SNR with contrast leads to the quantity contrast-to-noise ratio (CNR), which is the real measure of the usefulness of an experiment. *UNIT B6.3* of this chapter studies the contrast mechanisms in MR.

Finally, the use of MR contrast agents is discussed separately in *UNIT B6.4*. Contrast agents in general are exogenous substances employed to alter T_1 or T_2 relaxation times. The goal of the use of contrast agents in MR is to enhance the contrast between normal and diseased tissues and to indicate the viability of an organ. The contrast agents used in positron emission tomography (PET) or computed tomography (CT) provide a direct effect on the observed signal. On the other hand, in MR imaging, the effect of the contrast agent is indirect. Therefore, the MR signal is not derived from the contrast agent itself but from its effect on proton relaxation times. How the contrast agent alters the relaxation times and enhances the contrast is the topic of *UNIT B6.4*.

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