HW#5 51:185

Due: Friday, May 6, 2005

Preliminary Notes) We often assume that the output of a medical imaging device is a random variable (or a collection of random variables), which is composed of two components. These components are *S*, referred to as the *signal*, and *N*, referred to as *noise*. A useful way to quantify the amount of noise is to calculate the signal-to-noise ratio (SNR). The SNR calculates the relative strength of the signal *S* to that of the noise *N*.

Most frequently the SNR is expressed as the ratio of the signal amplitude to noise amplitude as

$$SNR_a = \frac{\text{Amplitude}(S)}{\text{Amplitude }(N)} \tag{1.1}$$

Another way of expressing the SNR is the ratio of the signal power to noise power as

$$SNR_p = \frac{\text{Power}(S)}{\text{Power }(N)} \tag{1.2}$$

Consider an object (or target) of interest placed on a background. Let f_t and f_b be the average image intensities within the target and background, respectively. A useful choice for SNR is obtained by taking the "signal" to be the difference in average intensity values between the target and the background integrated over the area *A* of the target, and taking the "noise" to be the random fluctuations of the image intensity from the mean over an area *A* of the background. This leads to the *differential signal-to-nose ratio* $\left(SNR_{diff}\right)$ given by

$$SNR_{diff} = \frac{A(f_t - f_b)}{\sigma_b(A)} \tag{1.3}$$

where $\sigma_b(A)$ is the standard deviation of image intensity values from their mean over an area *A* of the background. The *local contrast* is sometimes defined as

$$C = \frac{f_t - f_b}{f_b} \tag{1.4}$$

Substituting (1.4) into (1.3) yields

$$SNR_{diff} = \frac{CAf_b}{\sigma_b(A)} \tag{1.5}$$

which relates the differential SNR to contrast.

SNR is often expressed in *decibels* (dB). When the SNR is the ratio of amplitudes, such as with the amplitude SNR or the differential SNR, then

$$SNR(\text{in dB}) = 20 \times \log_{10} SNR \tag{1.6}$$

When the SNR is the ratio of powers, as with the power SNR, then

$$SNR(\text{in dB}) = 10 \times \log_{10} SNR \tag{1.7}$$

Under *Supplementary Material/Image examples/MRI/MR3T* you will find three files containing MR images of a phantom. The first file is *MR_0002_0001.dcm* and contains an image obtained with standard MR settings. The second file *MR_0003_0001.dcm* was obtained while using twice the number of averages (*NEX*, which is the number of excitations in our textbook and notes). The second file *MR_0004_0001.dcm* was obtained while the bandwidth (BW) of the RF transmitter and receiver was doubled. The bandwidth can be changed by changing the sampling rate of the A/D converter when sampling the FID while the readout gradient is turned on. The textbook predicts that the SNR could be calculated as:

$$SNR \approx \frac{\sqrt{NEX}}{\sqrt{BW}} \tag{1.8}$$

Problem 1: We desire a slice thickness of 2.5 mm. The *z*-gradient strength is G_z=1 G/cm. what RF frequency range should be excited?

Problem 2: Briefly describe the gradient echo technique. How is it different from the spin echo technique that we studied inn class? How is it the same?

Problem 3: Calculate the differential SNR (in dB) of the imaging system under standard conditions.

Problem 4: Use *MR_0002_0001.dcm*, *MR_0003_0001.dcm* and *MR_0004_0001.dcm* to answer the following question: Is (1.8) a good approximation to the SNR? Does the SNR vary as predicted in (1.8)?