Chapter 3

Problem 3.1

(a) Ratio is 13 dB in size, but with different sign depending on which of the two, 1/20 or 20/1, we refer to.

(b) The signal-to-noise ratio (SNR) on the decibel scale becomes

$$\mathrm{SNR_{dB}} = \left[\frac{S}{N}\right]_{\mathrm{dB}} = 10\log_{10} 99 \approx 20 \text{ dB}.$$

Problem 3.2

(a) The ratio of currents is 15 and we get (power scales as *current squared*)

$$20\log_{10}(15) \approx 23.5 \text{ dB}.$$

(b) Since power scales as *voltage squared* the voltage ratio corresponding tor the SNR in Problem 3.1(b) becomes (U_S and U_N are signal and noise *typical voltages*[1], respectively)

$$\frac{U_S}{U_N} \approx 10 \text{ times}.$$

Problem 3.3

The problem asks for an estimate of the number of words in Chapter 1. What makes more sense is an estimate of the number of characters. With something like 45 lines per page (if it is full of text) and about 80 characters per line, in the 29-page chapter, with something like 30% of the pages used for figures and other things than text, a decent estimate would be in the range of 70000 characters[2].

(a) With the simple text representation outlined in the problem, encoding Chapter 1 would require about 350000 bits of storage space.

(b) With ASCII encoding Chapter 1 would require about 560000 bits of storage space. With 8-bit ASCII we have all characters, upper and lower case, but such a stored text contains no typesetting, formatting, layout, etc.

(c) Since there are 8 bits per byte, the actual LaTeX file of about 90000 bytes carries 720000 bits. This is less than 30% larger than our estimate in (b), meaning that everything else but the raw text (typesetting, formatting, layout, etc.) only increases its size by that much. Images are not included, since they are in separate files. In all, the LaTeX way of preparing documents result in very efficient storage of material for printing.

[1] The *typical voltages* mentioned in the problem have a precise definition and the proper name is RMS voltages, where RMS is short for *root mean squared*.

[2] The true number is 68237 characters in text phrases of Chapter 1, including spaces.

Problem 3.4

To represent a 5 kHz music (pretty poor quality, in terms of covered frequency range) the sampling theorem says that we need a sampling rate of 10 kHz.

Further, to reach the specified 60 dB signal-to-(quantization)noise ratio the Six-dB rule of PCM gives

$$b = 11.2 \text{ bits/sample.}$$

Since we cannot use fractional bits per sample (unless we use more advanced techniques) and 11 bits would not guarantee 60 dB, we need to *round upwards* to 12 bits.

Hence, the bit rate becomes 120 kbit/sec.

Problem 3.5

(a) The five signals with bandwidths needs to sampled at these rates:

$$\begin{aligned} 20 \text{ Hz} &\Rightarrow 2 \cdot 20 = 40 \text{ samples/sec.} \\ 50 \text{ Hz} &\Rightarrow 2 \cdot 50 = 100 \text{ samples/sec.} \\ 200 \text{ Hz} &\Rightarrow 2 \cdot 200 = 400 \text{ samples/sec.} \end{aligned}$$

(b) With three 20 Hz sources and one source each of 50z and 200 Hz, and 8 bit/sample, the total bit rate becomes 4960 bits/sec.

Problem 3.6

Following the instructions we end up with 720 samples/sec. with 7 bits/sample (again, by rounding upwards not to violate the SNR requirement) for which an hour's worth of sonar signal requires 18 Mbit.