Exercise Sheet 3
Communication and Networking

Unless specified otherwise, use the following constants throughout this document:

- Speed of light $c = 3 \times 10^8$ m/s

B2 – Basic Communication Principles

Exercise E3.1
Explain why Fourier Transforms help in describing the effects of a band-pass filter. How can band-pass filters be 'represented' in the frequency domain?

Exercise E3.2
An analogue signal is sampled at 20 kHz. If the number of quantizing levels is 64, find the time duration of one bit of binary encoded signal.

Exercise E3.3
Find the Nyquist rate for the message signal represented by

$$m(t) = 6\cos(2000\pi t) \cdot (\sin(5000\pi t) + \cos(1000\pi t))$$

Exercise E3.4 *(Sampling Theorem)*
A binary channel with a capacity of 48 kbit/s is used for PCM voice transmission. If the highest frequency component in the message signal is taken as 3.2 kHz, find appropriate values for the sampling rate f_s, number of quantizing levels L and number of bits n used per sample.

Exercise E3.5
A satellite points with a red laser of frequency 4.3×10^{14} Hz towards the ISS. If the satellite is heading *towards* the space station at 50 km/s, what frequency will an astronaut on board the ISS observe?

B3 – Link Budget & Multiplexing

Exercise E3.6 *(Multiple Choice)*
Check the correct answer. There is only one correct answer per question.

(a) What does the "white" in white noise stand for?

☐ It is evenly spread over the entire frequency spectrum
☐ It is a high amplitude increase
☐ The noise is induced by the white sunlight

(b) A power ratio of 100 dB is 1000 times more intense than a 70 dB power ratio.

☐ True ☐ False

(c) The absorption loss due to gases in the atmosphere or rain is typically maximal at the highest elevation angle (i.e. the satellite being right above the ground station).

☐ True ☐ False

Exercise E3.7

Convert 1 W, 1 mW, and 1 µW each to dBm and dBW.

Exercise E3.8

Assume P to be the total power radiated by a point source (e.g. omnidirectional isotropic radiator). At a 20 m distance, we measure the radiation intensity I. Compute the distance r_h from the point source at which this intensity is halved and the distance r_t at which this intensity is tripled.

Exercise E3.9

Recall Friis transmission equation from the lecture:

$$P_R = P_T G_T G_R \left(\frac{\lambda}{4\pi d} \right)^2$$

In decibels, this equation 'simplifies' to:

$$P_R^{[\mathrm{dB}]} = P_T^{[\mathrm{dB}]} + G_T^{[\mathrm{dB}]} + G_R^{[\mathrm{dB}]} - 20 \log_{10} \left(\frac{4\pi d}{\lambda} \right)$$

Convince yourself, that the second formula is actually correct by mathematically deriving it from the first one yourself. Use the definition of a decibel.

Exercise E3.10

Assume a transmitting and a receiving antenna with a gain of 40 dB each. Further, assume that the minimum acceptable receiver power is 1 µW. The carrier frequency is 4 GHz and the distance between the antennas is 50 km. Compute the required transmitter power.

Exercise E3.11

A geostationary satellite has a round-trip propagation delay variation of 40 ns/s due to station-keeping errors. If the time synchronisation of DS-CDMA signals from different Earth stations is not to exceed 20 % of the chip duration, determine the maximum allowable chip rate so that a station can make a correction once per satellite round-trip delay. Assume the satellite round-trip delay to be equal to 280 ms.