Problems related to the lecture notes on OFDM in the course Digital Communication, advanced course (ETTN01). Study period 2, 2016.

X1. a) Verify the numbers on bit rate and bandwidth given in the IEEE 802.11n example on page 7 in the lecture notes.

b) Which QAM symbol is carried by the reference carrier frequency f_{rc} if:
i) K=451 ii) K=900

c) Consider the equivalent complex baseband OFDM signal illustrated in Figure 3b in the lecture notes. At which baseband sub-carrier frequency will the QAM symbols a_0 and a_{K-1} appear if: i) K=451 ii) K=900

X2. a) It is given that $T_s = 105\ \mu s$ and $T_{CP} = 5\ \mu s$. Calculate an approximate bandwidth of the high-frequency OFDM signal if K=800.

b) When considering samples of the complex baseband OFDM signal corresponding to the case in a), is it then reasonable to use the sampling frequency $f_{samp} = 10.24$ Msamples per second?

X3. The complex baseband QAM signal $x_k(t)$ that carries a_k is given in Equation (2.8) on page 11. N samples from this signal results in the discrete-time signal given in Equation (2.22) on page 18. Consider now the Fourier transform of this discrete-time signal, given in Equation (2.23). Show that a frequency-domain sample of this Fourier transform sampled at $\nu = \frac{g_n}{N}$ results in the value $a_n N$.

X4 a) Show how to derive Equation (2.13).
b) Show how to derive the IDFT expression in Equation (2.18), where Equations (2.19) – (2.21) are used.
c) Study carefully the IDFT examples on page 16.
d) Consider the case illustrated in Figure 6. Determine the frequency-domain samples (DFT) $X_0, X_1, \dots, X_{11}$.

X5. How do we obtain the desired time-domain samples when we have found the frequency-domain samples in problem X4 c) and d)?

X6. Assume that K=9 and N=12.
a) Use Equations (2.27) and (2.29) to determine the frequency-domain samples (DFT) $X_0, X_1, \dots, X_{11}$.
b) Use Equation (2.31), and the matrix given on page 21, to determine the frequency-domain samples (DFT) $X_0, X_1, \dots, X_{11}$. Check that the same result as in a) is obtained.

X7. Consider the time-domain samples of the complex baseband OFDM signal $x(t)$ in Equation (2.3) on page 9, which are the outputs from the IDFT. Assume that N=64, and that the CP is three samples. Specify the samples that constitute the CP, in terms of the outputs from the IDFT.

X8. Study the example on pages 35-36 so that you understand Equation (6.8) and the conclusions on page 36.

X9. Note that the "equivalent channel" parameter $H_{eq,k}$ appearing in Equations (6.15) and (6.16) on page 39, is not the same as the channel parameter $H(f_k)$ that appears in Equations (5.12)-(5.13) on page 34. Explain why.

X10. Explain why the noise-less part $\boldsymbol{X}_r$ of the frequency-domain samples $\boldsymbol{R}$ obtained from the DFT in the receiver can be expressed according to Equation (6.26) on page 44.

X11. Formulate the final, **extremely important**, result from the OFDM receiver (detector).