institute of telecommunications

TECHNISCHE UNIVERSITÄT WIEN Vienna University of Technology

Homework 6

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Important for getting a grade:

- Answer all questions tagged with boxes such as [XY] short and precise, and state the question number next to the solution.
- Put the homework into the box located at the 1st floor of the *Institute of Telecommunication*, or send it to veronika.shivaldova@nt.tuwien.ac.at.
- Attend the exercise lecture and be prepared to be called to the blackboard for presenting your results.
- In case questions arise, do not hesitate to contact me!

1 Multicarrier Modulation: OFDM I

Consider a vehicular communication system implemented based on IEEE 802.11p standard. This standard is in fact just a slight modification of the well-known IEEE 802.11a standard used for wireless local area networks (WLAN). Just as WLAN, vehicular communications are based on OFDM and support the same subcarrier modulation schemes, namely BPSK, QPSK, 16QAM and 64QAM. However the channel bandwidth was reduced from 20 MHz to 10 MHz. The maximum length of the channel impulse response for vehicular test environments is larger than that of WLAN and amounts to 1600 ns.

5 p [1] Given that the guard interval takes 20 % of the total symbol duration, how large is the frequency spacing between the subcarriers?

5 p [2] Of how many subcarriers does the transmitted payload signal consist?

5 p [3] Which subcarrier modulation scheme should be used, if the transmission rate of 24 Mbit/s is required?

5 p [4] How large is the transmit power loss (in dB) due to insertion of the guard interval?

2 p [5] Name possible reasons for reducing channel bandwidth from 20 MHz in WLAN scenarios to 10 MHz in vehicular scenarios.

2 Multicarrier Modulation: OFDM II

Consider an OFDM system with 4096 subcarriers, out of which just the half is used for data transmission and the remaining subcarriers are set to zero. The interval between two subcarriers is 250 Hz and the guard interval has a length of 2 ms. As a subcarrier modulation BPSK is used.

5 p [6] How large is the data rate of the entire system?

5 p [7] How large is the sampling frequency of the signal at the output of IDFT?

5 p [8] How many samples fall into the guard interval? Assume now, that the required bandpass energy of an OFDM symbol at the transmitter is $E_{\text{OFDM}} = 1.4\text{Ws}$. White Gaussian noise with a power spectrum of $N_0 = 6 \cdot 10^{-5}\text{Ws}$ is added in the bandpass.

5 p [9] Determine the Eb/N0 in dB.

5 p [10] Specify the bit error rate of the transmission system in terms of the complementary error function.

3 p [11] How large is the average power emitted by the transmitter?

3 Multiple Access Schemes: FDMA and TDMA

A cellular system uses 25 MHz bandwidth for the uplink and downlink voice communication. Each simplex channel is 40 kHz and is separated from the neighboring channels by a guard band of 10 kHz.

5 p [12] Find the number of channels in this system.

5 p [13] Each channel consists of eight equally large TDMA time slots. The eight time slots along with preamble and trailing bits form a frame. If the frame efficiency, i.e., the percentage of non-overhead bits per channel is 64 %, payload data rate of each user is 39 Mbps and a half-rate coding is used, how many bits are transmitted in one time slot?

5 p [14] Find the number of users that such system can support at the same time.

5 p [15] Given that each user is guaranteed to have access to at least one randomly allocated time slot per frame, how long a user must wait between two successive transmissions in the worst case?

4 Multiple Access Schemes: CDMA

In this problem you are asked to simulate a CDMA transmission in MATLAB as follows:

- First generate two random signals $c_1(t)$ and $c_2(t)$ such that:

$$c_k(t) = \sum_{n=1}^{10} a_k[n] \cdot p(t - nT_c),$$

where $a_k[n] \cdot p(t - nT_c)$ is a rectangular pulse with random amplitude $a_k \in \{\pm 1\}$ and bit duration T_c.

- Now each signal has to be spreaded using spreading sequence

$$s_k(t) = \sum_{m=1}^{4} b_k[m] \cdot p(t - mT_s),$$

where $b_k[m] \cdot p(t - mT_s)$ is a rectangular pulse of amplitude $b_k \in \{\pm 1\}$ and chip duration $T_s = T_c/l_s$ with $l_s = 4$ being spreading sequence length. The two spreading functions to be used are:

$$b_1 = [1, -1, 1, -1], \quad b_2 = [1, 1, -1, -1].$$

The signal $c_k(t)$ spreaded by $s_k(t)$ is then given as:

$$c_k s_k(t) = \sum_{n=1}^{10} (a_k[n] \cdot p(t - nT_c) \sum_{m=1}^{4} b_k[m] \cdot p(t - nT_c - mT_s)),$$

5 p [16] Using the MATLAB function `stem` plot (a sampled version of) the signals $c_1(t)$ and $c_2(t)$ and their spreaded versions $c_1 s_1(t)$ and $c_2 s_2(t)$.

- At the receiver side the received signals have to be despreaded, therefore the l_s pulses contained in a single bit duration have to be multiplied with appropriate spreading sequence $s_k(t)$, yielding the despreaded signal $d_k(t)$.

5 p [17] Using the MATLAB function `stem` show that the despreaded signals $d_1(t)$ and $d_2(t)$ are equal to transmitted signals $c_1(t)$ and $c_2(t)$.

10 p [18] Simulate the transmission of the signal $c_1 s_1(t) + c_2 s_2(t)$ and despread it.

10 p [19] Simulate a transmission over a noisy channel by generating white Gaussian noise and adding it to the transmit signal of the previous question. Consider SNR values in the range [3 dB, 45 dB] with steps of 3 dB. Calculate the SNR after the despreading operation and compare it to the SNR at the output of the channel.