Project Description, EITN21, fall 2020, HT1

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Task 1: You should implement a passband transmitter/receiver with the following specifications.

- Base pulse: Half cycle sinus
- Sampling frequency: 44100 samples per second
- Carrier frequency: 4000 Hz
- Symbol time: 2.2676 ms
- Modulation format: QPSK
- Multipath channel model:

$$r(t) = \sqrt{1-\beta^2}s(t) + \beta s(t-\mu) + n(t),$$

  where $s(t)$ is the transmitted signal, $n(t)$ is WGN with $\mathrm{E}\{n(t)n(t+\tau)\} = \delta(\tau)N_0/2$, $\mu = 0.00022676$ seconds and β is an attenuation factor given by

$$\beta = \frac{\text{Group number}}{50}$$

Energy should be measured as the total transmitted energy of the passband signal. In order to pass you must present a plot showing the bit error probability versus E_b/N_0 for error probabilities down to $\approx 10^{-4}$ and compare to theoretical results.

Task 2: I will provide a Matlab file *Signal.mat* that contains a signal generated according to *SystemModel1.pdf*.

- The message m is a of unknown length.
- The vector $\mathbf{u}$ is the ASCII representation of m.
- The vector $\mathbf{a}$ is the corresponding QPSK symbols. The QPSK map is defined as follows:

00	Maps to	$1+i$
10	Maps to	$-1+i$
11	Maps to	$-1-i$
01	Maps to	$1-i$

The following convention has been used: If there is an odd number of bits in **u** to transmit, a 0 bit is padded at the end of the vector **u**.

- Two pilot symbols $2+2i$ are added. One in front of the data and one at the end. Consequently, the transmitted symbol vector has the structure: $[2+2i \ \mathbf{a} \ 2+2i]$.
- Pulse shaping with a half cycle sinus pulse, unknown amplitude
- Symbol time: 2.2676 ms
- Duration of the pulse: 2.2676 ms
- Sampling frequency: 44100 samples per second
- Carrier frequency: 4000 Hz
- Channel: Unknown dispersive channel plus WGN

You have to decode the signal and send me the secret password. When you have done so, you have passed task 2.

Task 3: The system model is shown in *SystemModelTask3.pdf*. Each block in the transmitter is specified below.

- An encoded OFDM signal is received. It is known that the sampling frequency is 44100, the carrier frequency of the signal is 10 kHz, the number of subcarriers in the OFDM system is $N_{sc} = 128$, and that the cyclic prefix length is $N_{cp} = 20$. Symbol time for 1 OFDM symbol (excluding cyclic prefix) is 58 ms.

  The symbol time is defined as transmission time of N_{sc} data symbols.
- The message m is of unknown length.
- The vector **u** is the ASCII representation of m.
- **u** is encoded by the (77,45) rate 1/2 convolutional encoder which produces vector **v**. It is assumed that the encoder starts and ends in the all-zero state. Hence, the number of zeros added to **u** before encoding equals the memory length of the encoder.
- The vector **a** is the corresponding QPSK symbols. The QPSK map is defined as follows:

$$\begin{array}{lll} 00 & \text{Maps to} & 1+i \\ 10 & \text{Maps to} & -1+i \\ 11 & \text{Maps to} & -1-i \\ 01 & \text{Maps to} & 1-i \end{array}$$

The following convention has been used: If there is an odd number of bits in $\mathbf{v}$ to transmit, a 0 bit is padded at the end of the vector $\mathbf{v}$.

- The overhead block (OH):
  - The first N_{sc} components of $\mathbf{x}$ are pilot symbols with the following structure: Every second symbol equals 0. The other $N_{sc}/2$ components are generated in Matlab according to

$$randn('state', 100);$$

$$P = sign(randn(1, Nsc/2));$$

$$x(1:2:end) = 2 * P;$$

    Observe that only half of the sub channels have pilot symbols. The other half must be estimated based on interpolation.
  - The length of the message $\mathbf{m}$ is then encoded as follows: Let the length of $\mathbf{m}$ be ℓ_m. This is represented as a binary sequence $\mathbf{u}_m$ of length 10. The vector $\mathbf{u}_m$ is encoded by the (77,45) encoder in order to produce $\mathbf{v}_m$. It is assumed that the encoder starts and ends in the all-zero state. Hence, the number of zeros added to $\mathbf{u}_m$ equals the memory length of the encoder.
  - Let ℓ_{v_m} denote the length of $\mathbf{v}_m$. Then $2N_{sc} - \ell_{v_m}$ zero-symbols are inserted so that $\mathbf{v}_m$ has length $2N_{sc}$. The sequence $\mathbf{v}_m$ is mapped to a sequence $\mathbf{v}_\ell$ by the QPSK map above. Hence, $\mathbf{v}_\ell$ has length N_{sc} and the length information of $\mathbf{m}$ is transmitted in a separate OFDM symbol.
  - Finally the data symbols $\mathbf{a}$ are inserted with the following convention: A sufficient number of zeros are inserted at the end of the block to ensure that the length of $\mathbf{a}$ is a multiple of N_{sc}.

  In total, the vector $\mathbf{x}$ has the following structure:

$$\mathbf{x} = [\underbrace{2p_1\,0\,2p_2\,0\ldots 2p_{N_{sc}/2}\,0}_{Pilots} \quad \underbrace{\mathbf{v}_l}_{length\,of\,\mathbf{m}} \quad \underbrace{\mathbf{a}\,0\,0\ldots 0}_{multiple\,of\,N_{sc}}\ ]$$

- Partition $\mathbf{x}$ as

$$\mathbf{x} = [\mathbf{x}_1\ \mathbf{x}_2\ \mathbf{x}_3\ldots]$$

  where each block $\mathbf{x}_k$ contain N_{sc} symbols the outputs are concatentaed into a new vector $x_k[1], \ldots, x_k[N_{sc}]$. Then apply the IFFT to each block $\mathbf{x}_k$ and denote the output as the outputs are concatentaed into a new vector$\mathbf{y}_k$. Concatenate all blocks into the vector $\mathbf{y}$, which has the structure:

$$\mathbf{y} = [\underbrace{y_1[1]\, y_1[2], \ldots y_1[N_{sc}]}_{\mathbf{y}_1} \quad \underbrace{y_2[1]\, y_2[2], \ldots y_2[N_{sc}]}_{\mathbf{y}_2} \quad \underbrace{y_3[1]\, y_3[2], \ldots y_3[N_{sc}]}_{\mathbf{y}_3} \ldots].$$

- Then the cyclic prefix has been applied in order to generate the outputs are concatentaed into a new vector $\mathbf{z}$ which gets the structure

$$\mathbf{z} = [\underbrace{y_1[N_{sc}-N_{cp}+1] \ldots y_1[N_{sc}]}_{CP} \underbrace{y_1[1] \ldots y_1[N_{sc}]}_{\mathbf{y}_1} \quad \underbrace{y_2[N_{sc}-N_{cp}+1] \ldots y_2[N_{sc}]}_{CP} \underbrace{y_2[1] \ldots y_2[N_{sc}]}_{\mathbf{y}_2} \ldots].$$

- Digital to Analog conversion (D/A): A linear interpolation has been used. This means that two consecutive samples in $\mathbf{z}$ are connected by a straight line.

Form of presentation: Presentations will be in the examination week in October. Book a time for the presentation well in advance and submit your report for task 1 - 3 no later than October 23, 2020, at 12.00. If you fail to meet the deadline, the next time to present is in the re-exam period. There will be ONE chance to correct and resubmit the report direcly after the presentation if necessary, further resubmissions are examined during the re-exam periods.

The report should be a 3-4 page written report including a block diagram of the receiver. A plot of the results from task 1 should be included. As an engineer you of course compare your results to theoretical results where applicable, and show that you have reached the goal or met the requirements. The report should look nice, and be written using proper English. Graphs should be crisp and have readable labels and axis descriptions. Include your full code as an appendix at the end of the report.

Super important! Both members of the group will be examined individually! All details of the system must be known to both group members.