Project Description, EITN15, Spring 2011

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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: 2.3 ms
- Modulation format: QPSK
- Multipath channel model:

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

  where $s(t)$ is the transmitted signal, $n(t)$ is WGN with $\mathrm{E}\{n(t)n(t+\tau)\} = \delta(\tau)N_0/2$, $\mu = .00023$ seconds and α is an attenuation factor given by

$$\alpha = \frac{\text{Group number}}{100}$$

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 $\approx 10^{-4}$.

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 $\mathbf{u}$ to transmit, a 0 bit is padded at the end of the vector $\mathbf{u}$.

- 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: 2.3 ms
- Duration of the pulse: 2.3 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 $\mathbf{u}$ is the ASCII representation of m.
- $\mathbf{u}$ is encoded byt the (77,45) rate 1/2 convolutional encoder which produces vector $\mathbf{v}$. It is assumed that the encoder starts and ends in the all-zero state. Hence, the number of zeros added to $\mathbf{u}$ before encoding equals the memory length of the encoder.
- The vector $\mathbf{a}$ 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:

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

- 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

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

- 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.

Task 4: This task deals with a MIMO-OFDM system. A system model is shown in *systemmodeltask4.odf.* The specifications of the system are as follows.

- There are two users in present. Each user transmits data from a single antenna.
- User 1 and 2 transmit vector $\mathbf{u}_1$ and $\mathbf{u}_2$ consisting of 635 information bits (0/1).
- Both users are encoding their data with the (77,45) convolutional code. This produces the two vectors $\mathbf{v}_1$ and $\mathbf{v}_2$, both of length 1280 bits.
- QPSK map. The same map as in task 3 is used. This produces the two vectors $\mathbf{a}_1$ and $\mathbf{a}_2$, both of length 640 QPSK symbols.
- Pilot insertion. Two OFDM symbols with pilots are inserted.
  1. Similarily to Task 3, create pilots with

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

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

  2. For user 1, the output of the pilot insertion block is

     $$\mathbf{x}_1 = [\underbrace{2p_1\, 0\, 2p_2\, 0 \dots 2p_{N_{sc}/2}\, 0}_{Pilots\ for\ user\ 1} \ \underbrace{0\, 0\, 0\, 0 \dots 0\, 0}_{Pilots\ for\ user\ 2} \ \mathbf{a}_1]$$

  3. For user 2, the output of the pilot insertion block is

     $$\mathbf{x}_2 = [\underbrace{0\, 0\, 0\, 0 \dots 0\, 0}_{Pilots\ for\ user\ 1} \ \underbrace{2p_1\, 0\, 2p_2\, 0 \dots 2p_{N_{sc}/2}\, 0}_{Pilots\ for\ user\ 2} \mathbf{a}_2]$$

4. As seen in 3., User 1 and 2 are not transmitting pilots at the same time.

- OFDM block. $N_{sc} = 64$ and $N_{cp} = 20$.

- D/A converter. A linear interpolation has been used. This means that two consecutive samples in $\mathbf{z}$ are connected by a straight line. It is known that the sampling frequency is 44100, the carrier frequency of the signal is 10 kHz. The same symbol time as in Task 3 is used. The analog signal corresponding to user 1 is transmitted on antenna 1, and the signal corresponding to user 2 is transmitted on antenna 2.

- Receiver. The receiver is equipped with 2 antennas. I will provide the noisy received continuous time signals at these two antennas.

- Presentation. There is no secret message hidden in the signals in task 4. Instead, you should hash the vector $[\mathbf{u}_1\, \mathbf{u}_2]$ with the MD2 hash function (implemented in the routine hash.m available on the homepage). I will provide you with the true hash value. As soon as your hash value matches the one I provide, you have finished this task

Form of presentation: Task 1 and Task 2 should be presented no later than Friday, April 8, 2011, at 12.00. Book a time with either Fredrik or Meifang well in advance. If you fail to meet this deadline, you will not pass the course.

The deadline for presenting task 3 and task 4 is Friday June 3 at 12.00. Book a time with either Fredrik or Meifang well in advance. If you fail to meet this deadline, you will not pass the course.

There will be no public presentation, but a short, 1-2 pages, written report including a block diagram of the receiver and a plot of the results from task 1 must be handed in as well.

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