Digital Transmission Methods S-72.2205

Matlab homework 3

Spreading code

Spreading is a process where for transmission in the channel the information symbol is mapped to a waveform that has higher spectrum than the information signal spectrum. The spreading can be done by assigning each symbol a code which spectrum is higher than the symbol stream spectrum.
One common approach for spreading is to use orthogonal basis functions. In the system with multiple users each of them can use for communication one of the basis functions. Since such spreading codes are orthogonal the users can communicate in the same spectrum area without interfering each other.

In this exercise you have to simulate BER performance of two users transmitting at the same time in the same spectrum but separated by two different Hadamard codes with length 8.

Investigation of the spreading code

We have two Hadamard spreading codes which elements have values ± 1

$\mathbf{s}_1 = + - - + + - - +$

$\mathbf{s}_2 = + - + - - + - +$

The codes are generated by the following Matlab script

```
h1=hadamard(SpreadingCodeLen)/sqrt(SpreadingCodeLen);
sp_code1=h1(4,:)';
sp_code2=h1(6,:)';
```

1.1 Autocorrelation

Calculate in Matlab plot the convolution of the code $\mathbf{s}_1$ with itself with different shift values:

$$\left(\mathbf{s}_1 * \mathbf{s}_1\right)(m) = \sum_n \mathbf{s}_1(n) \cdot \mathbf{s}_1(m-n)$$

What is the convolution value if the shift $m = 0$.

1.2 Calculate and plot convolution between the codes

$$\left(\mathbf{s}_1 * \mathbf{s}_2\right)(m) = \sum_n \mathbf{s}_1(n) \cdot \mathbf{s}_2(m-n)$$

1.3 Comment how the shifts impacts interference in the receiver.

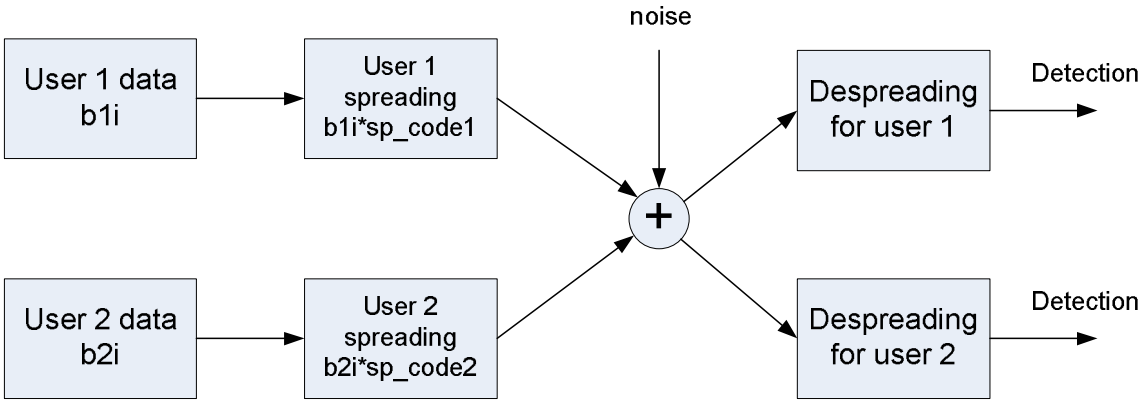
Simulation of the system performance

2. Construct a simulator and simulate BER for a single user system, where the user data signal having values ± 1 is spread with the spreading code s_1.

2.1 Normalize power of the spreading code to be 1.
What is amplitude of one chip?
What is the average signal power after de-spreading?

2.2 Simulate BER and compare it with BPSK channel BER.

3. Simulate a two user system where two user signals are separated by the given spreading sequences and summed together at the transmitter side. The channel adds a noise and at the receiver the signals of the users are detected separately. (see figure below)



The simulation system block diagram.

3.1 Simulate and plot BER as a function of the SNR. Plot the BER curves for both of users.

3.2 Simulate BER if the second user signal is delayed by one chip. Plot the BER curves for both of the users.

3.3 How many degrees of freedom are in one spreaded symbol interval? (how many degrees of freedom the spreading code has?

3.4 How many degrees of freedom one user is utilizing?

3.5 How many degrees of freedom are available?

3.6 How many independent users could communicate by transmitting at the same time if they are using different spreading sequences?