Advanced Wireless Communications: Algorithms and Architectures **Assignment 3.b**
Spring Semester 2013 Out: 2013-03-22
Telecommunications Circuits Laboratory Due: 2013-04-04
EPF Lausanne *Revision* : 1.3

DSSS & CDMA (Part 2)

The last exercise showed that DSSS allows to achieve a diversity gain very easily in multipath environments. Another important application of DSSS is *Code Division Multiple Access* (CDMA). Multiple users transmit at the same time, in the same (wide) frequency band. This is fundamentally different to the usual narrowband transmission systems, in which the available bandwidth and the available time is divided into a grid of slots and each transmission is assigned an exclusive frequency-time slot. Further information can be found in the lecture slide and in "Fundamentals of Wireless Communications" by Tse/Viswanath.

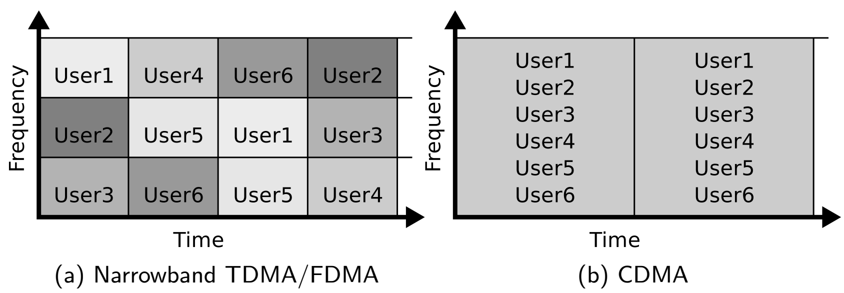
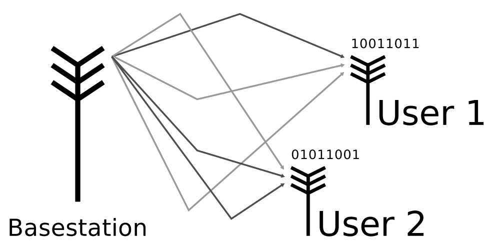


Figure 1: Time-Frequency assignment in a TDMA/FDMA narrowband and a CDMA wideband system.

Scenario

For the exercise we assume a a simple synchronous CDMA down-link of a base-station. The base-station serves multiple users at the same time in the same frequency band with different data.



Each user gets assigned a different orthogonal challenization sequence, derived from a *Hadamard matrix*. The data for each user is spread with his respective channelization code. The combined signals of all users are multiplied with a a sequence that offers a low auto-correlation as described in the lecture. We use concatenated Barker sequences.

Framework

For our simulation we use again a modified version of the framework already used in the last exercises.
The CDMA transmitter is already built-in. You can set the number of Users with `P.CDMAUsers`.
In the framework the multiple users are implemented in the same way as multiple RX antennas have been implemented in the previous cases. The important difference is, that the different received signals represent different users. The users are not cooperative. So you are not allowed to use the received vectors from the other users for decoding.
We provide an AWGN and a multipath channel model with a configurable number of taps.
The multipath channel model convolves the spread signal with the impulse response of the channel and add white Gaussian noise afterwards. The taps of the impulse response are Gaussian random variables with a variance of 1. We assume a block-fading model which means that the impulse responses are fixed during a frame. The length of the impulse response can be restricted with the `P.ChannelLength` parameter.
You can set the length of the Hadamard Sequence with the parameter `P.HamLen`. The framework will increase the sampling frequency according to the sequence length. The power of the spreading sequence will be automatically normalized.
The transmission is split into frames which are assumed to be transmitted apart in time. For each frame an independent channel realization is generated. Additionally each user faces a different channel realization.
Be sure to simulate not only a sufficient number of bits but also a sufficient number of frames to get reliable results.
The framework was programmed in a very modular fashion. Try to integrate additional coding and receiver schemes as configurable as possible. Usually you don't need to make multiple copies of the file.

Tasks

1. We provide in the `simulator.m` framework already the appropriate transmitter.

   - Analyze the structure of the transmitter.
   - Question: How does the Barker sequence change the spreading factor?
   - Question: Why is the Barker sequence needed anyway?

   `Hint`: A pen&paper approach can be very helpful. Single-step through the code and make notes of the size and alignment of the used data structures.

2. Build a receiver which demodulates the signal for each single user. The BER should be always averaged over all users. You can use the RAKE receiver scheme of last time.

   - Test your receiver in the non-fading AWGN case with one CDMA user. We provide a suitable parameter file for this (`paramawgn.m`).
   - Increase the number of CDMA users to 2 and 4. Plot a comparison of the results. What do you observe?

3. Test your receiver in a fading environment. Set the channel to `multipath` and the length to 1. We provide a suitable parameter file: (`paramfading.m`).
    - First simulate the case with one CDMA user.
    - Increase the number of CDMA users to 2, 4, and 8. Plot a comparison of the results.
    - Compare your findings to the ones of Task 2.
4. Test your receiver in a fading multipath environment. Set the channel to `multipath` and the length to 2. We provide a suitable parameter file: (`parammultipath.m`).
    - First simulate the case with one CDMA user.
    - Increase the number of CDMA users to 2, 4, and 8. Plot a comparison of the results.
    - Increase the length of the channel impulse response. Explain the effect you observe? How is it related to the number of users and the length of the channel impulse response?

Hand In Instructions

You are required to hand in one report and code for assignments 3.a and 3.b.