Advanced Wireless Communications: Algorithms and Architectures	**Assignment 2**
Spring Semester 2013	Out: 2013-03-08
Telecommunications Circuits Laboratory	Due: 2013-03-14
EPF Lausanne	$Revision: 1.5$

Introduction

In practical radio communication systems engineers do not only have to cope with the distortion of the desired signal by noise, but also with random fluctuations of the received signal strength. This effect is called fading.
The reasons for fading can be divided in two groups:

- Large-scale fading, slow varying attenuation of the signal due to the distance to the transmitter (path loss) or large obstacles (mountains etc).
- Small-scale fading, fast changing signal strength due to constructive and destructive interference.

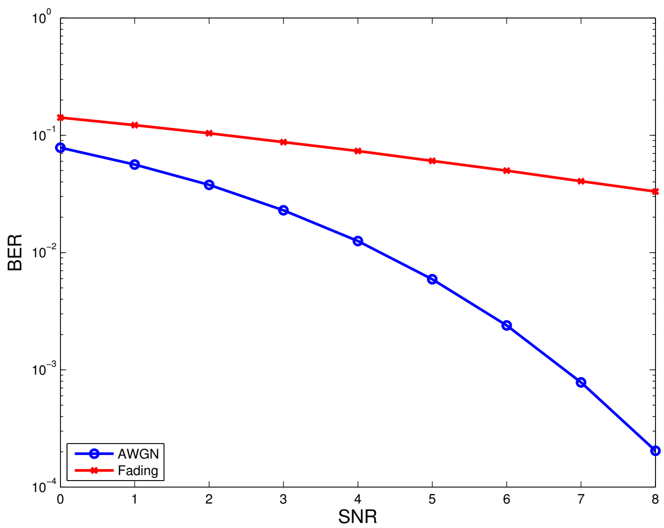
Throughout this exercise we are only interested in dealing with the small-scale fading case.
The presence of small-scale fading changes the input-output relation from the pure additive white gaussian-noise (AWGN) case

$$y = x + n \tag{1}$$

to

$$y = hx + n \tag{2}$$

where h is a (complex) random variable with certain statistical properties that are given by the channel. You will notice that in small-scale fading environment the BER decays muchs slower with increasing SNR compared to the AWGN case. (Note: Besides the misleading naming there is an AWGN component also in the fading case).



Channel

We have seen in the channel estimation exercise that the propagation conditions do not change instantanieous hence, subsequent channel coefficients are usually not independent random variables but correlated in time and frequency.
The coefficients of the channel change slowly. Which means that if the channel is in a bad condition, then neigboring (in time or frequency) channel coefficients are also very likely in a bad condition.
The correlation of the channel coefficients is usually described by two parameters: The **coherence time** and the **coherence bandwidth**. These parameters describe the distance in time or frequency over which the channel changes significantly.
Please note that while these measurements look very intuitive there is no strict definition of how large or likely the change of the channel has to be. There are multiple different definitions of the term. So consider these numbers not as precise values, but as orders of magnitude.

Diversity

In the lecture we saw that the probability of an error becomes significant if the channel coefficient h is below a certain threshold. We sometimes refer to such an event as outage. The probability for an outage event is p_{out}. Hence the probability of successfull transmission is:

$$p_{success} \approx 1 - p_{out}$$

If the same data is sent over L **independent** channel realizations, then all coefficients have to be in outage for none of the copies to be received with proper signal strength. The probability of successfull transmission is therefor much higher and becomes

$$p_{success} \approx 1 - (p_{out})^L$$

The independence of the realizations is the crucial condition to exploit the full gain of diversity.

Receive Diversity

It is possible to achieve diversity on the receiver side without any modifications of the transmission system. One can employ multiple antennas in order to receive the same signal multiple times under different fading conditions. The antennas have to be sufficiently spaced apart so that their distance exceeds the coherence distance. Therefor this is also called space diversity.
There are two common schemes to make use of space diversity.

Antenna Selection Diversity

Antenna selection diversity is a cheap way too implement receive diversity. It is achieved by attaching two or more sufficiently spaced antennas with a switch to the same receiver. The receiver periodically compares the signal strength at the antennas and selects the strongest signal for reception.

$$h_{equivalent} = max(h_1, h_2, ..) \tag{3}$$

This approach offers the advantage that it is very cheap in terms of hardware costs as only one RX chain is required. On the downside this scheme can not exploit the full possible diversity gain.

Maximum Ratio Combining

In the lecture you have also seen a more elaborate way of exploiting receive diversity. A maximum ratio combiner takes advantage of the signal from all receive paths to further increase the diversity gain. We consider the following input-output relation. The scalar equation has now transformed to a vector problem.

$$\mathbf{y} = \mathbf{h}x + \mathbf{n} \tag{4}$$

A matched filter of the form

$$\mathbf{h_{mf}} = \frac{\mathbf{h}^*}{||\mathbf{h}||} \tag{5}$$

leads to an equivalent channel of:

$$h_{equivalent} = ||\mathbf{h}|| \tag{6}$$

Framework

For our simulation we assume a flat fading **single carrier** environment.

$$y_i = h_i x_i + n_i$$

There is no inter-symbol interference. The noise n is a zero mean Gaussian. The fading coefficients h_i are correlated Gaussian random variables. You can set the coherence time with the corresponding parameter of the framework.

The transmission is split into frames which are assumed to be transmitted apart in time. For each frame an independent channel realization is generated. Hence the channel coefficients h_i are correlated within a frame but not between different frames. Be sure to simulate not only a sufficient number of bits but also a sufficient number of frames to get reliable results.

For the tasks we will always assume a single carrier environment which means that `NumberOfCarriers` equals 1.

The `P.RX` parameter determines the number of simulated receive antennas. Different antennas are always assumed to be completely independent.

The framework was programmed in a very modular fashion. Try to integrate additional coding and receiver schemas as configurable as possible (e.g do not create multiple copies of the simulation environment).

Exercises

Task 1

In the first exercise you will get used to the simulation environment. Download all MATLAB files from the Moodle website of the lecture. The provided simulation framework uses individual files to define the parameters of the simulation. The simulation itself is called as a function `simulator.m` from these startup files. We also provide a `plotchannel.m` function which allows to plot realizations of the channel.

- Use the `plotchannel.m` function in order to generate different channel realizations with a coherence time of 100,1000 and 10000. Plot examples of the channel realizations.
- Create a new MATLAB script which simulates the AWGN and the Fading case and outputs a comparison BER plot similar to the one at the beginning of this exercise.

Please Note: The channels are generated according to statistical criteria. Have a look at multiple channel realizations to get a feeling of the variety of possible channel outcomes.

Task 2

Now we want to add diversity to the system by adding a second receive antenna. We assume that the receiver has always perfect knowledge of the channel realizations. (coherence time = 100)

- Create a new simulation parameter file with `P.RX` set to 2 and implement an antenna-selection diversity receiver, which always selects the better antenna on a per-symbol base.
- Now implement addtionally a receiver with maximum-ratio-combining. Plot a comparison between the antenna-selection and the MRC receiver of the BER over an SNR range from 0 dB to 10 dB.
- Now add a third RX antenna and plot the comparison between 1,2, and 3 RX antennas (using MRC) in a way that one can see the diversity gain only.
- Question: What changes if the coherence time is 200?

Hand In Instructions

You can submit your solutions online on to the moodle website of the lecture until 14.03.2013.