Implementation and Evaluation of MIMO-OFDM based Systems

Framework and Motivation

The principle of an OFDM based transmission is to divide an initial stream with high transmission data rate or low symbol time into several parallel sub-streams of lower transmission rate and, thus, longer symbol time. These streams are transmitted over different subcarriers regularly spaced in the frequency domain. Due to its properties, namely high spectral efficiency, robustness to multipath propagation, low complexity, etc, this technology has being adopted in several commercial standards. It was used for the first time in a cellular standard (for the downlink), namely in the current 4G systems also referred as Long-Term Evolution (LTE). In order to accommodate the increasing demand for wireless services that requires high data rate, the cellular systems tend to be designed with multi-antenna terminals. A system where both terminals (base station and user terminals) are equipped with multi-antennas are referred as MIMO systems, and when combined with OFDM is referred as MIMO-OFDM. Such a system can achieve both space diversity and/or multiplexing. The use of spatial diversity will be a key to effective use of the diversity inherent in wireless channels and the consequent increase system reliability. The space-time/frequency block codes efficiently exploit the diversity of wireless channels and they are very interesting from a practical standpoint, because of its simplicity and low implementation complexity. 4G systems already incorporate multi-antennas at both terminals and implementation of space-frequency Alamouti coding (SFBC).

Objectives

The main objective is to implement a MIMO-OFDM system with both terminals equipped with multi-antenna. The specific objectives are:

- Analyze the main blocks of an OFDM system based on LTE parameters (Part I)
- Implementation the Alamouti coding in both systems. In the first phase a single antenna receiver can be assumed and then its extension to 2 antenna receiver (Part II)
- Evaluation the performance of the implemented system.

PART 1-Review of a SISO-OFDM System

The main blocks of the system to be implemented are depicted in. 1.

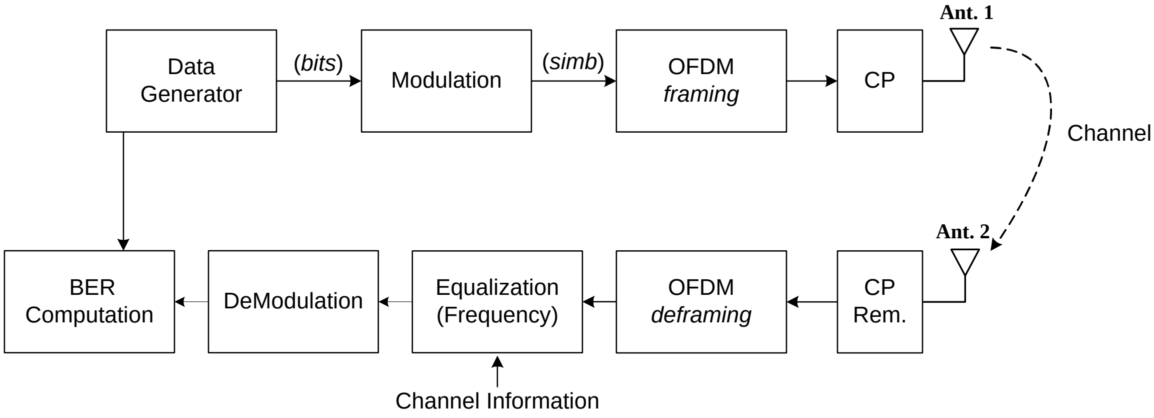


Fig. 1: SISO-OFDM System

The system was implemented taking into account the following specifications, based on LTE standard.

FFT size :	1024
Number of available subcarriers:	768
Sampling frequency:	15.36 MHz
Useful symbol duration:	66.6 µs
Cyclic prefix duration:	5.21 µs
Overall OFDM symbol duration:	71.86 µs
Sub-carrier separation:	15 kHz

Start by analysing the function of each block.

Transmitter:

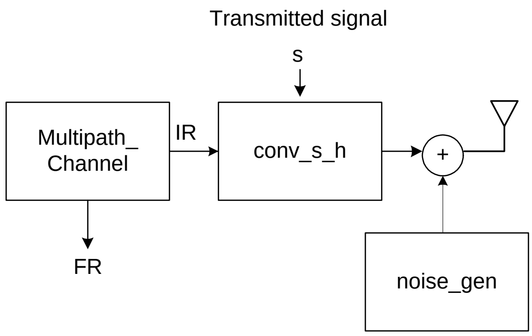
1. The function *data_gen.m* generate *bits* (0, 1) with the same probability and of size N_bits. Verify it.

2. The function *mod_data.m* generate QPSK, 16-QAM or 64-QAM data symbols from the output bits generated by the previous function. Carefully review this function.

3. The block OFDM *framing* put zeros in the carriers that do not transmit data and then perform na IFFT operation, i.e. the signal is moved to time domain. Finally a CP is inserted to avoid inter-symbol-interference (ISI).

Channel:

The channel is composed by two blocks: the noise and multipath_chanel, as shows the figure.



1. The noise is generated with a Gaussian variable with zero mean and variance σ^2, then this noise should be added to the received signal as shown in the figure. The noise variance depends on the Eb/No ratio that we want to simulate, of the received signal power and the modulation scheme considered, i.e. $\sigma^2 = P_r * 10^{\left(-E_b N_0 (dB)/10\right)} / (log2(m))$, where m depends on the modulation scheme used.

2. The multipath channel block is based on the power delay profile (PDP) presented in the Table. The average power should be normalized to 1, i .e., the sum of the powers of all paths should be equal to 1.

Delay (ns)	Average Power
0	-1
50	-1
120	-1
200	0
230	0
500	0
1600	-3
2300	-5
5000	-7

LTE extended typical urban channel model (ETU)

The implemented channel Matlab has as inputs a matrix containing the PDP (*download* the file *pdp.mat*), the sampling frequency and the FFT size. The outputs of this function are the impulsive response (h*t*) and the frequency response (H*f*) of the channel.

3. The conv_s_h.m function performs the convolution of the transmitted signal with the IR of the channel. It has the signal transmitted, the RI (channel in time domain), the PDP, the sampling frequency, the FFT size and the Cyclic prefix as inputs.

Receiver:

1. After CP removal, the OFDM *deframing* block performs the FFT operations, i.e., move the received signal to frequency domain.

2. The equalization block compute the equalizer coefficients. The following channel coefficients on each carrier should be used,

$g_l = \frac{h_l^*}{|h_l|^2}$, $l = 1,\ldots,N_c$ where (*) is the conjugate of the channel in frequency domain, obtained from the FR output.

3. The *demod_data.m* function demodulate the received data, i.e., convert the complex received signals into bits

4. The BER block computes the bit error rate by comparing the transmit bits with the receiver ones.

Simulation:

Run the chain to obtain results for the BER and assuming a range of Eb/No(dB)=[0:4:32].

PART 2- Implementation of a MIMO-OFDM System

The main blocks of the system to be implemented are depicted in Fig. 2.

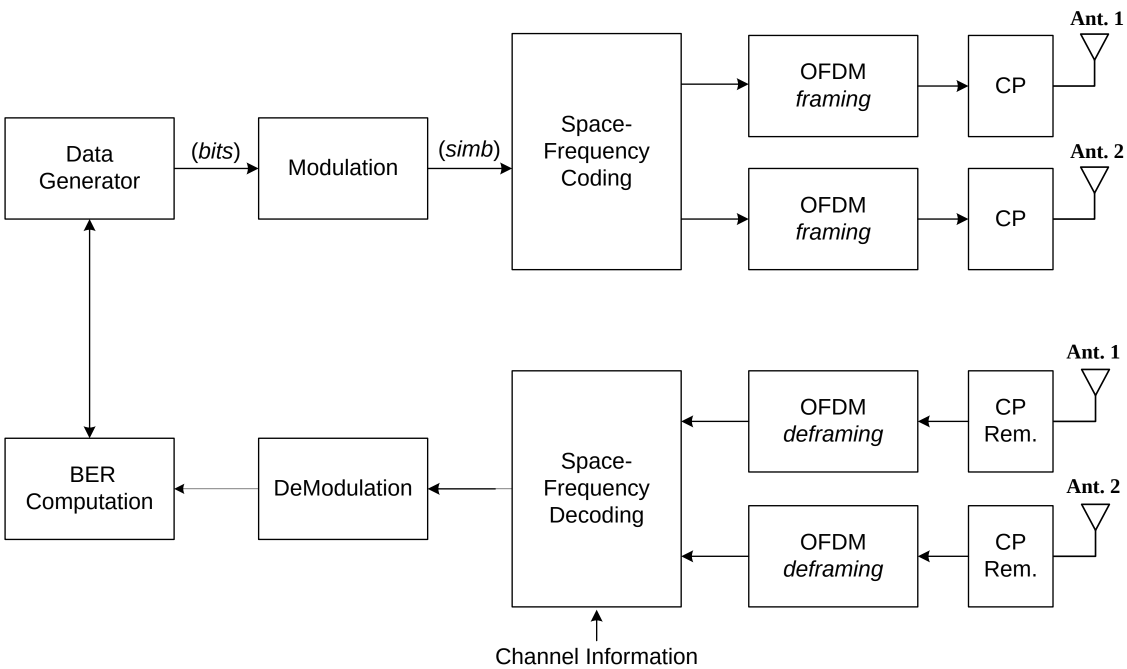


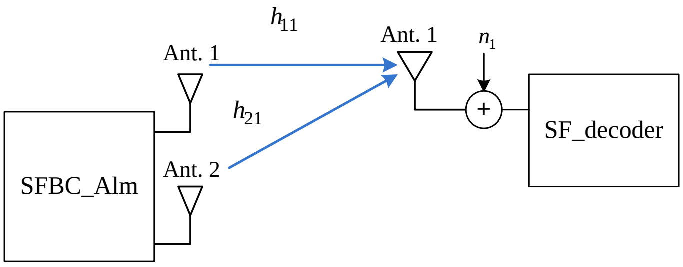
Fig. 2: MIMO-OFDM system with 2 antennas at both terminals.

For an efficient implementation you should start by doing sequentially each of the following steps:

1. Start by creating a Matlab file named as *trab_mimo_ofdm_xxxx.m*, where *xxxxx* represents the student number.

2. Add to that simulation chain the *space-frequency coding* block. Create a MatLab function with the *sf_coding.m*. The aim of this function is to implement the Alamouti Coding, i.e., the data symbols at the output of the modulator block must be coded in space-frequency domains, using the Alamouti coding discussed in chapter 3.

3. Generate 2 uncorrelated channels responses h_{11} e h_{21}, one for each link between a given transmit antenna and the receive antenna, as shown in the figure. You can use the same channel block considered in the first work.

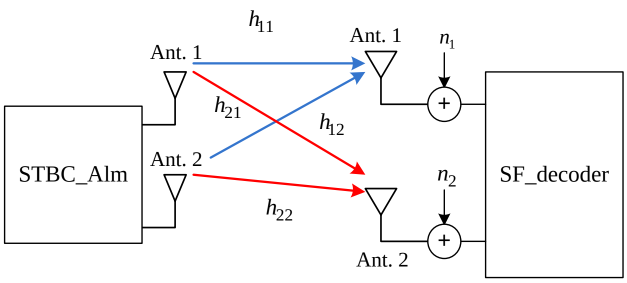


4. Add to the receiver, of the simulation chain developed in the first work, the *space-frequency decoding* block. Create a MatLab function with name *sf_decoding.m*. This function should decode the received data symbols. The inputs are the received signal and the 2 channels and the output an estimate of the transmitted data symbols.

5. Compute the BER results for a range of Eb/No(dB)=[0:2:20]. Compare the obtained curve with the one obtained with the SISO chain. Comment the obtained results.

6. Now you should extend the previous system for the case where the receiver is also equipped with 2 antennas, i.e., for a 2x2 system:

   a. Generate 4 independent channels (you can use the previous 2 generated for the 2x1 system and now generate more 2, h_{12} e h_{22}), one for each link between a given transmit antenna and a given receive antenna, as show the figure.



   b. Update the *sf_decoding.m* block to incorporate the second antenna at the receiver. The 2x2 system can be seen as the addition of the 2, 2x1 systems (2x1 blue e 2x1 a red).

7. Compute the BER results for a range of Eb/No(dB)=[0:2:20]. Compare the obtained curve with the previous ones. Comment the obtained results.