ULB

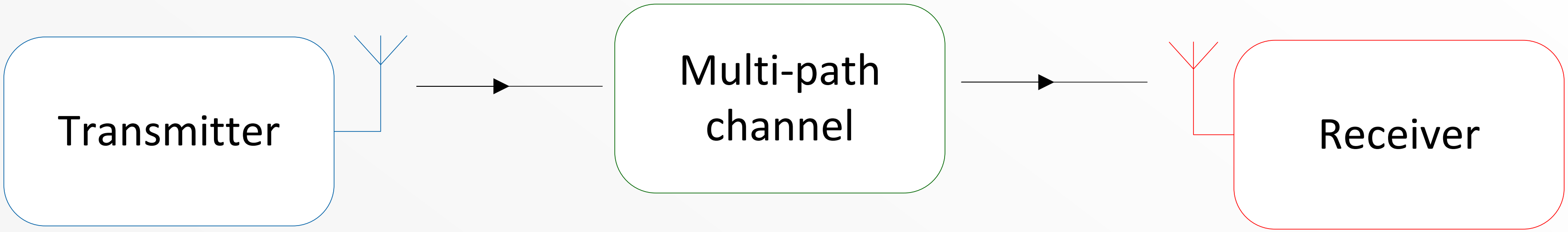
WIRELESS COMMUNICATIONS RESEARCH GROUP

OPERA.ULB.AC.BE

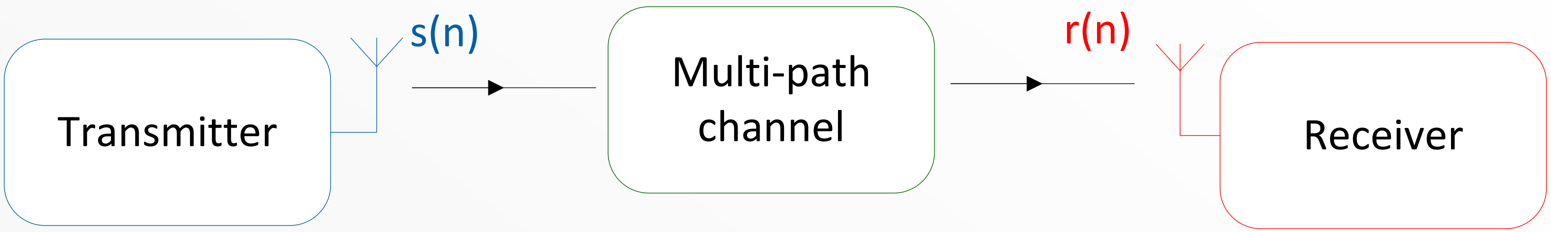
Conception of a complete OFDM communication channel

Main goal of the project

- Achieve a wireless communication on a multi-path channel



Narrowband vs Wideband



- No memory in a narrowband channel:

$$r(n) = hs(n) + w(n)$$

- Memory in a wideband channel:

$$r(n) = h(n) * s(n) + w(n)$$

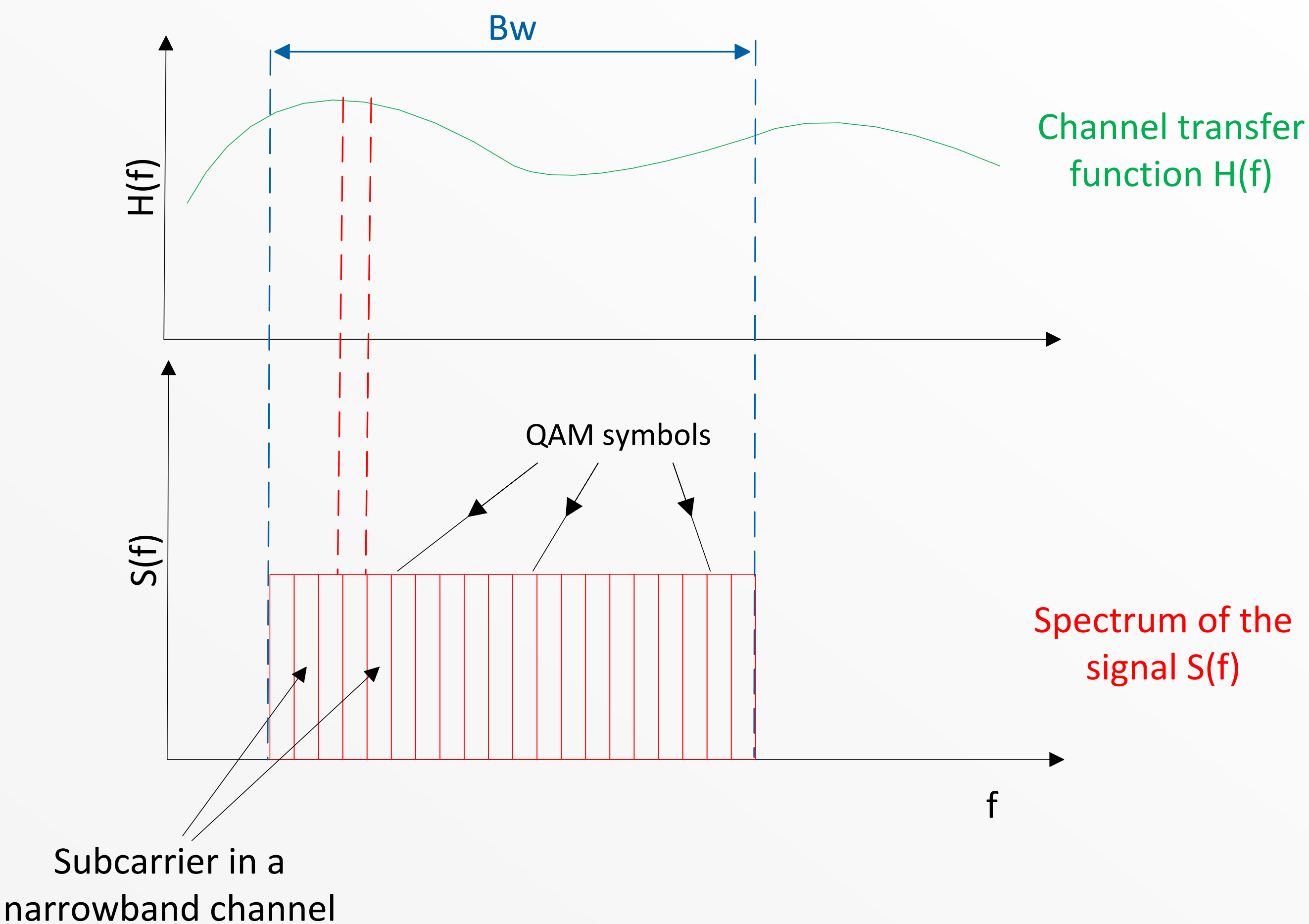
- Interferences must be compensated by the equalization

Two solutions of equalization

- Filtering in time domain
  - Creation of a filter $g(n)$ with the following property:
$$g(n) * h(n) = \delta(n)$$
  - The interferences are removed:
$$g(n) * r(n) = g(n) * h(n) * s(n) + g(n) * w(n) = s(n) + g(n) * w(n)$$
  - Complex and not very efficient for long channel memory

- Frequency domain equalization
  - OFDM: Orthogonal Frequency-Division Multiplexing
  - Most common solution (Wifi, LTE)

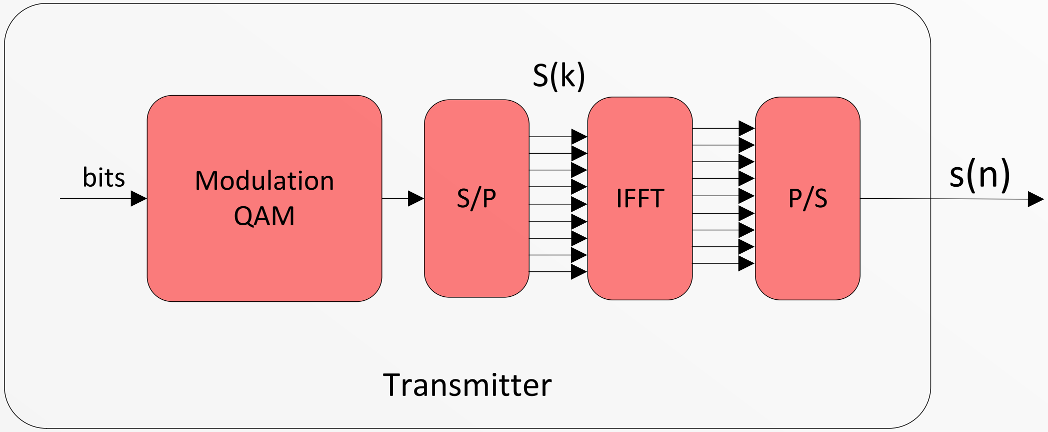
Information defined in frequency domain



Creation of an OFDM symbol

- Multi-carrier modulation
- Each sub-carrier operates over narrow-band channel

- Transmission
  - 1: Each symbol is placed on a sub-carrier
  - 2: Conversion in time domain (IFFT)



Reception of an OFDM symbol

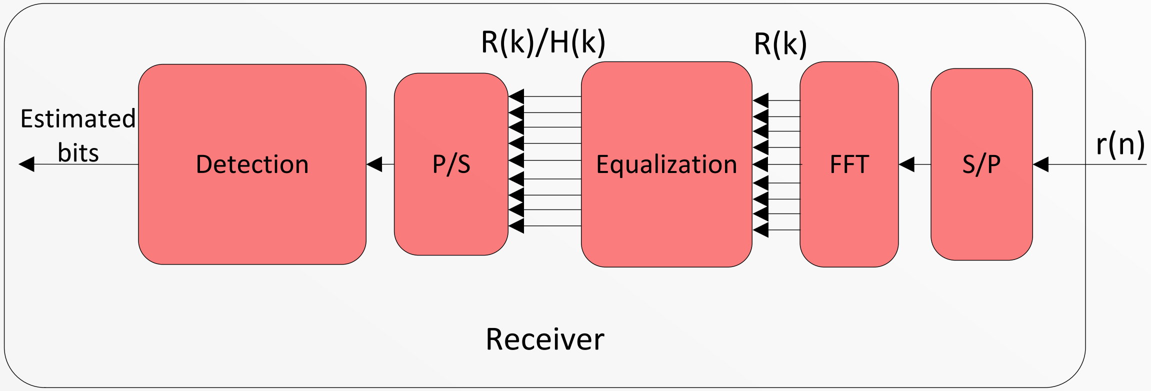
- Conversion in frequency domain (FFT)

$$\text{TD} : r(n) = h(n) * s(n) + w(n)$$

$$\text{FD} : R(k) = H(k)S(k) + W(k)$$

- Equalization of each sub-carrier independently

$$\frac{R(k)}{H(k)} = S(k) + \frac{W(k)}{H(k)}$$



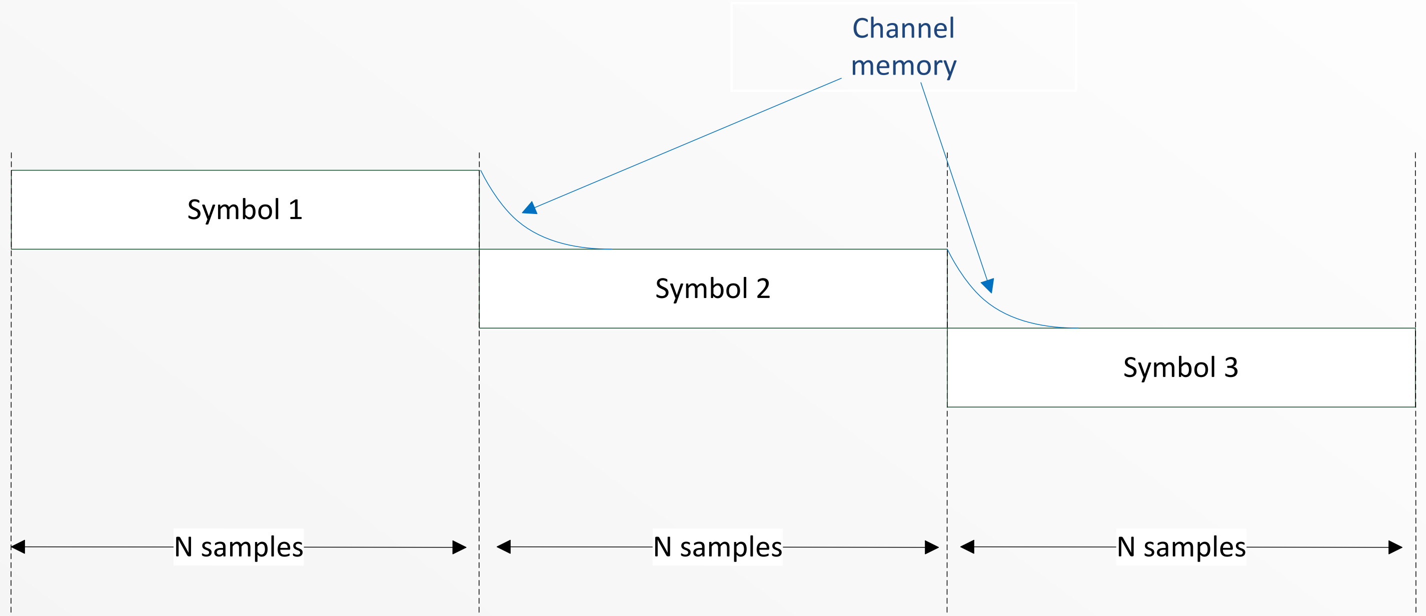
Equalization in Frequency Domain

- Complex equalization replaced by a simple division

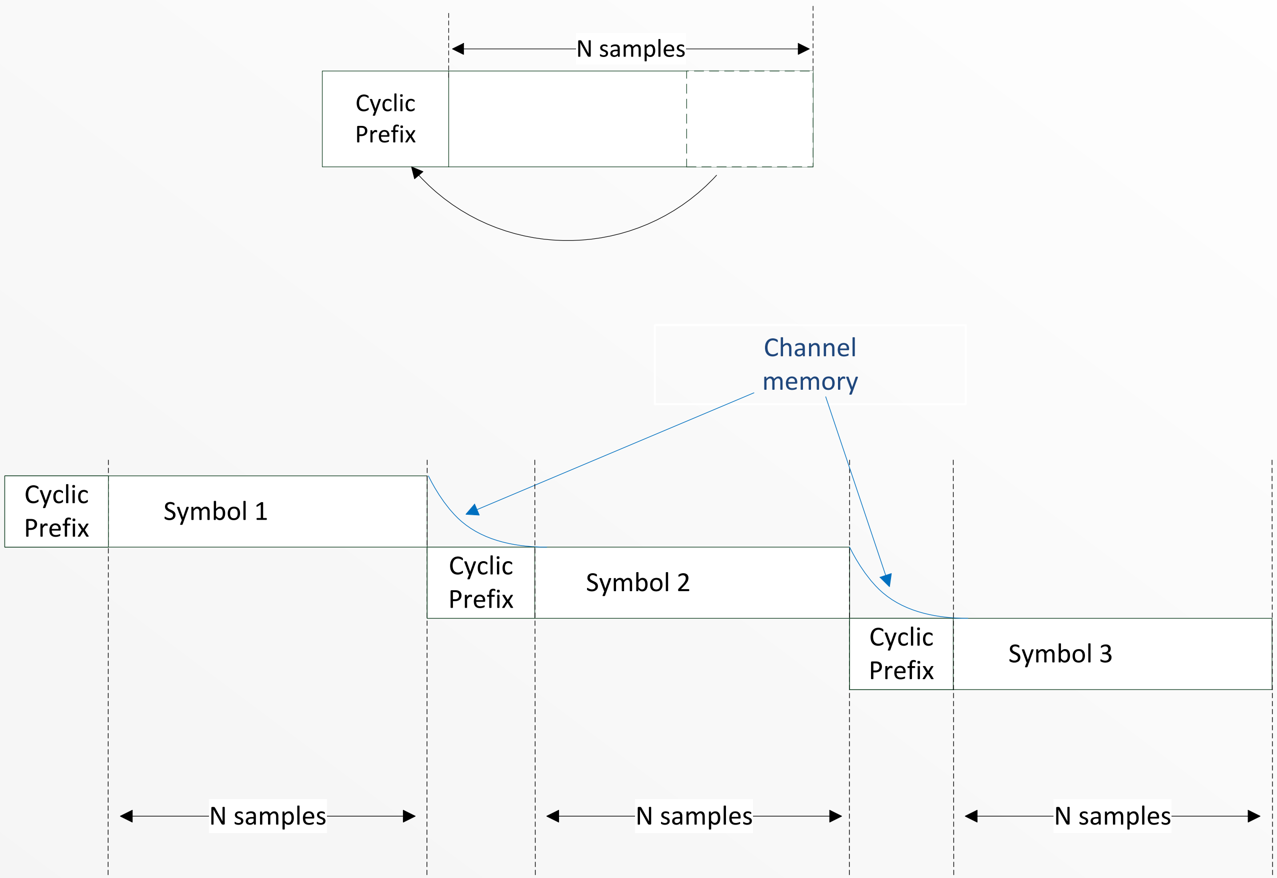
- Convolution product in time domain is equal to a multiplication in frequency domain…
- … But a cyclic prefix is also required

Impact of the channel memory on a sequence of symbols

- Interference of symbol 1 on symbol 2
- Equalization impossible



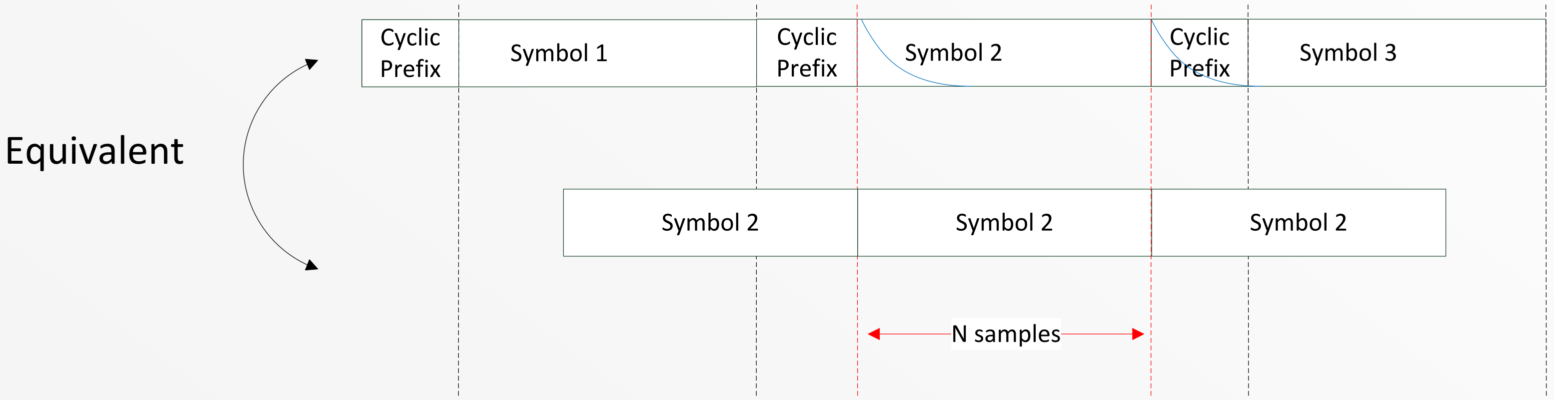
Problem solved with a cyclic prefix



Why does it work?

- This relation : $y(n) = h(n) * s(n) \Rightarrow Y(k) = H(k)S(k)$ works only if $s(n)$ is periodic

- Illusion of periodicity created with the help of a cyclic prefix



Demonstration

- Burst model (see course)

- Use the circular convolution property of the DFT: [1]

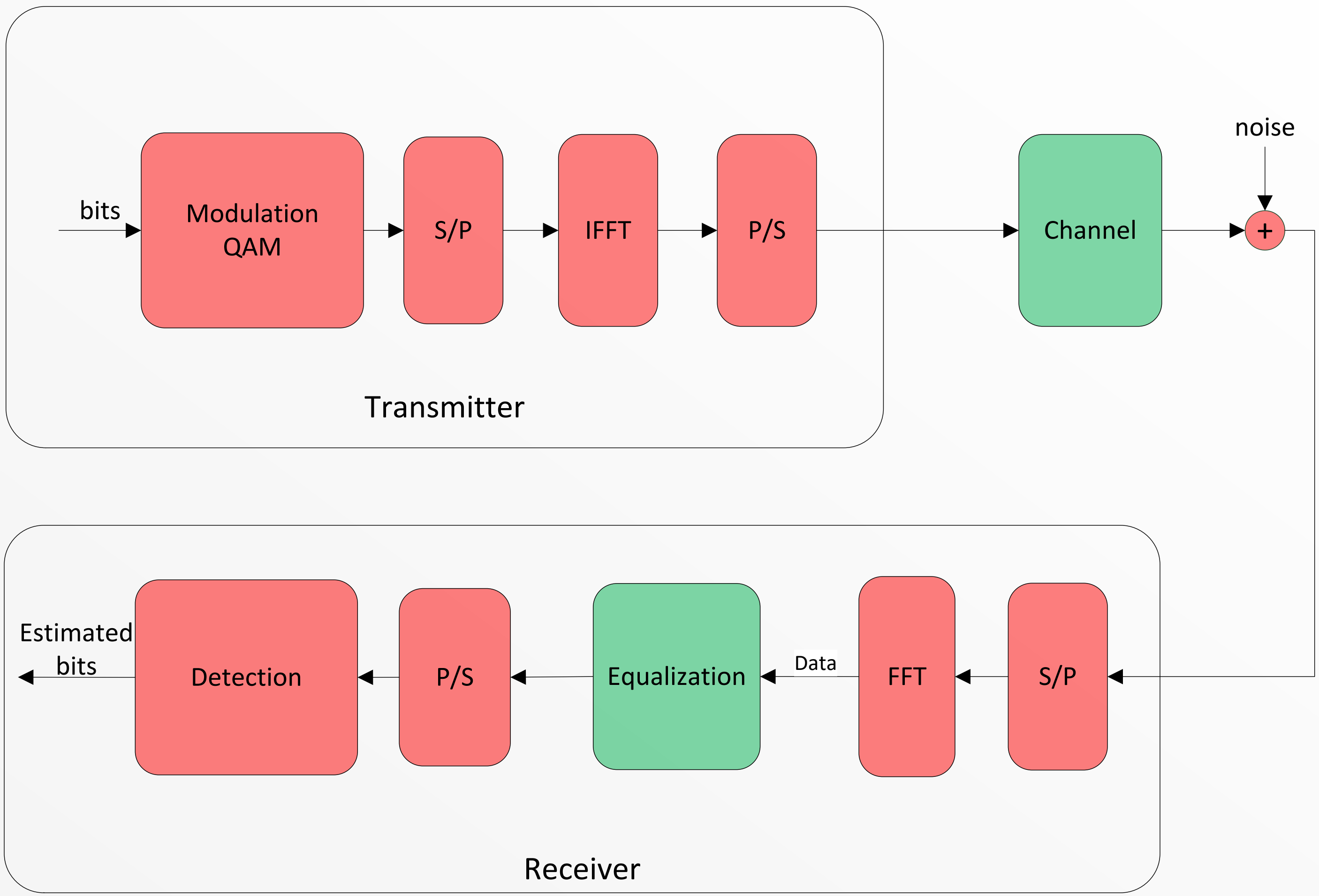
$$Y(q) = H(q)X(q) \leftrightarrow y(n) = h(n) \otimes x(n)$$

where $\otimes$ denotes a circular convolution

$$h(n) \otimes x(n) = \sum_{l=0}^{Q-1} h(l)x(n-l) mod Q$$

[1]: Fundamentals of WiMax, Andrews et. al., pp 117-120

Objective



bits
Modulation
QAM
S/P
IFFT
P/S
Channel
noise
+
Transmitter
Estimated
bits
Detection
P/S
Equalization
Data
FFT
S/P
Receiver

Objective

- Implement the OFDM transceiver (AWGN channel)
- Assess the BER performance
- Include the statistical channel model (known by the receiver)
- Explain why we need the Cyclic Prefix
- Compare the performances in the LOS and NLOS cases
- Discuss the impact of the channel and modulation parameters
- Confirm that each sub-channel is affected by a narrowband channel