NOVA SCHOOL OF
SCIENCE & TECHNOLOGY

MEEC/MIEEC

Radio Frequency Circuits and Systems

Communication Link Simulation in GNU-Radio Testing of a Low-IF receiver (SDR)

Authors:

Diogo Matos Novais (70118) dm.novais@campus.fct.unl.pt
Francisco Simões Coelho Sá da Costa (70386) fsc.costa@campus.fct.unl.pt
Martim Duarte Agostinho (70392) md.agostinho@campus.fct.unl.pt
Sofia Margarida Mafra Dias Inácio (58079) sm.inacio@campus.fct.unl.pt

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Contents

List of Figures

List of Tables

1 Introduction (objectives)

2 GNU Radio setup, simulation results and comments

2.1 AM Communication

- arquitetura - tone test - teste com musica

2.2 Digital Modulation

Explicar: Symbol Mapping, Constellation Diagrams, and Gray Coding Falar to piloto algures

For this labwork, different mapping strategies were used, QPSK and 16-QAM.

QPSK places four equally spaced points on the unit circle:

$$s_k = e^{j\frac{\pi}{2}\left(k+\frac{1}{2}\right)}, \qquad k \in \{0, 1, 2, 3\}.$$

Figure 1a, shows the mapping in the cartesian plane.

The mapper groups the encoded bit stream into two-bit tuples (b_1, b_0), converts each tuple to an integer index $(k = 2b_1 + b_0)$ and outputs s_k.

The theoretical bit-error probability for QPSK in an AWGN channel is given by Equation 1.

$$P_b^{\text{QPSK}} = Q\left(\sqrt{2\frac{E_b}{N_0}}\right) \text{ [1]} \tag{1}$$

For **QPSK**, demodulation is performed by simply de-mapping the bit values.

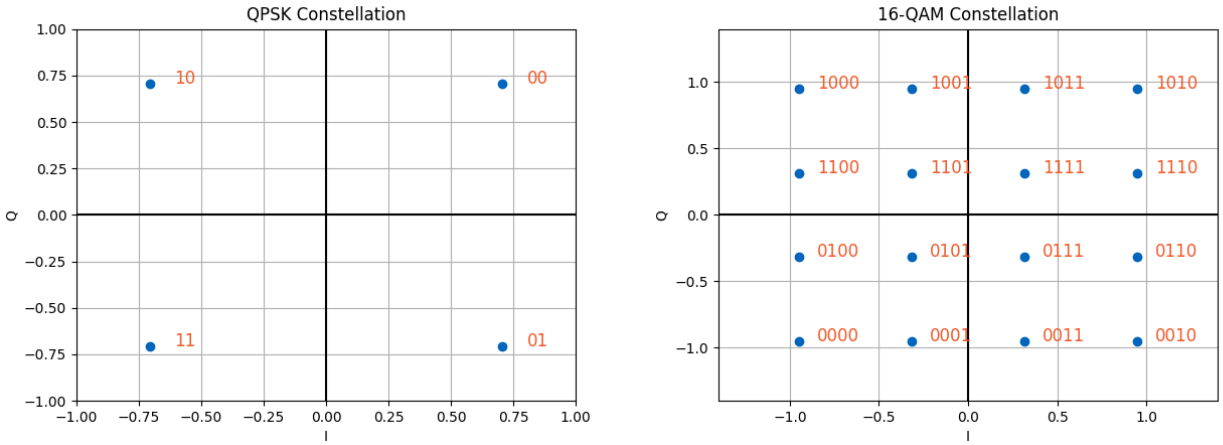
A square 4×4 16-QAM constellation is used. What changes comparing to the previous mapping approach is the fact that the amplitude also changes and for this specific mapping the phase and amplitude will not change consistently. The symbol position in the cartesian frame will be:

$$I, R \in \{\pm 3,\ \pm 1\}$$

For **16-QAM** the theoretical **BER** for an AWGN channel with gray mapping is given by Equation 2.

$$P_b^{\text{16QAM}} \approx \frac{3}{4} \cdot Q\left(\sqrt{\frac{4}{5}\frac{E_b}{N_0}}\right) \text{ [1]} \tag{2}$$

The constellation points are labelled with *Gray coding*, thus every nearest neighbour differs in *exactly one* bit, this will minimize **BER**, since the most likely symbol error produces only one wrong bit. Figure 1b, shows how the codes are mapped.



(a) QPSK Constellation. **(b)** 16-QAM Constellation.

Figure 1: Digital Modulation Constellations.

TODO: escrever os topicos condicoes: LP : Transition 500hz cutoff 40k SimbRate: 20k a3 emitter = 0 a3 receiver = 0 no Bandpass

Dizer que bate certo com os valores teoricos e que 16 qam produz mais erros.

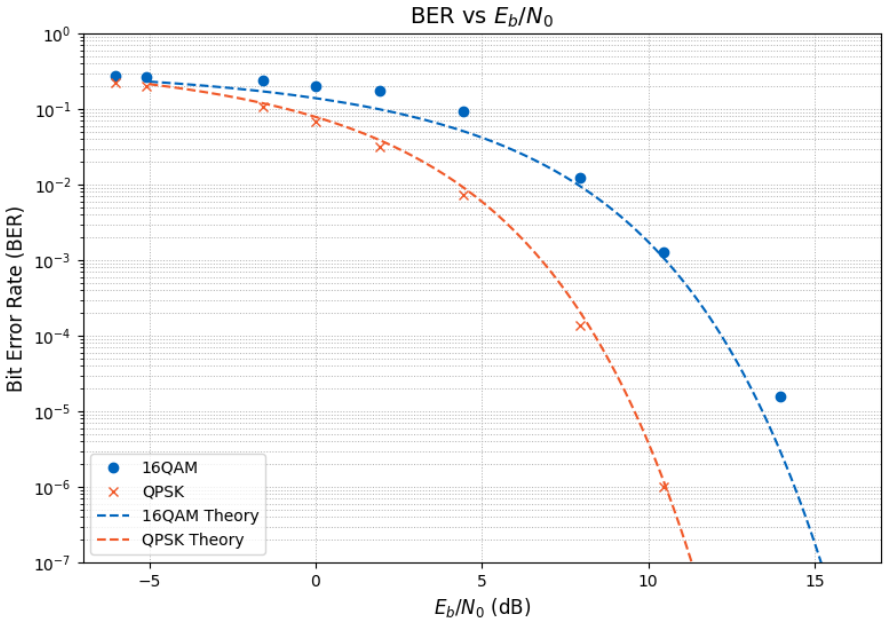


Figure 2: BER vs E_b/N_0

References

[1] P. Montezuma, "Transmissão de alta capacidade - topics," 2025, departamento de Engenharia Eletrotécnica, Universidade Nova de Lisboa, FCT.