Creation of an Educational Simulation Tool for Digital Telecommunications Systems

Denis Albrecq and Tom Fontaine
Supervised by Véronique Moeyaert and Alexander Gros
Electromagnetism and Telecommunication department
UMONS Université de Mons
POLYTECH MONS

Introduction

Learning digital baseband telecommunications systems requires an in-depth understanding of fundamental concepts, such as line coding, power spectral density, and intersymbol interference. These concepts can sometimes be difficult to grasp, so this project aims to create an educational simulation tool in Python to assist students.

The main objective is to verify the consistency between simulation results and theoretical predictions, and to identify ways to improve the tool to make it more effective and versatile.

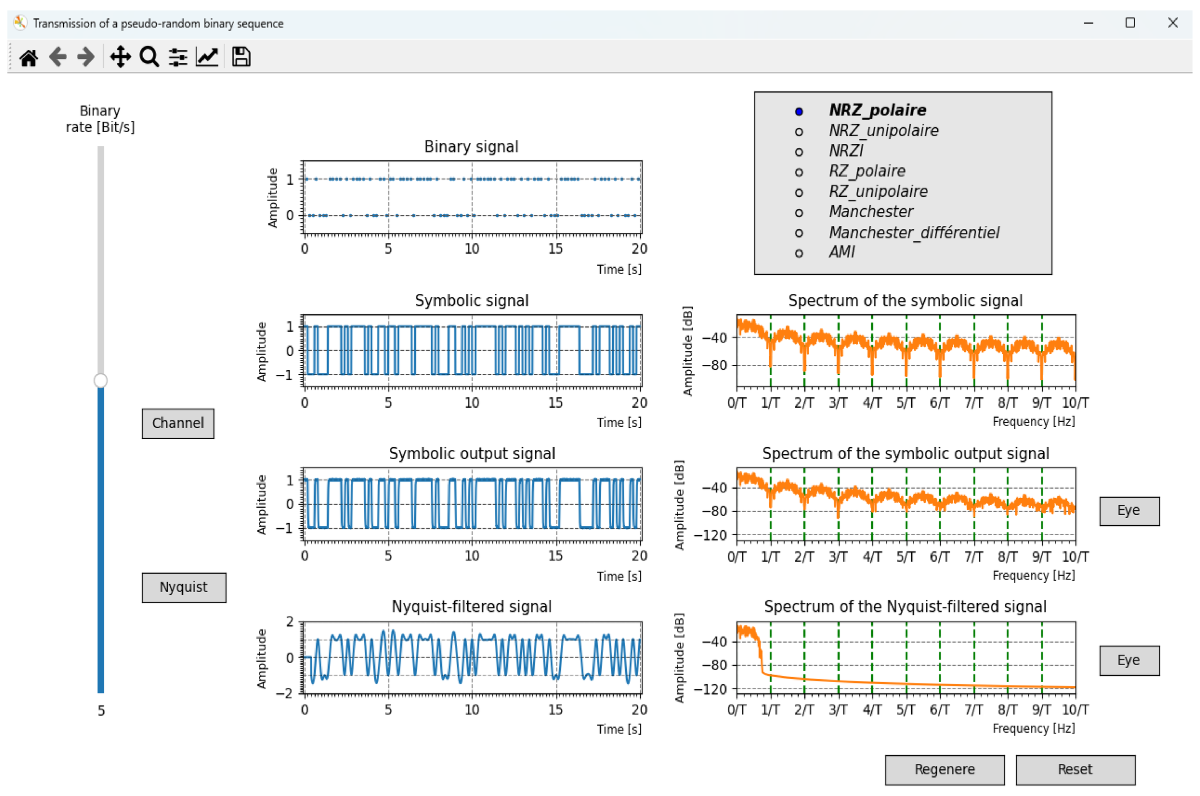

Figure 1. - Home page - Transmission of a pseudo-random binary sequence.

Methodology

To achieve the project's objectives, the following methodology was adopted :

1. Identify the essential elements to be simulated.
2. Design the simulation tool :
   - Implement different line coding.
   - Model the transmission channel.
   - Implement the Nyquist filter.
   - Create the eye diagrams.
   - Create dynamics tools (sliders, buttons, animations).
3. Comparison of simulation results with theoretical models for different coding scenarios and transmission conditions.
4. Provision of the tool with a user manual and a parameter table to simulate certain phenomena.
5. Exploration of new coding and modulation techniques to extend the capabilities of the simulation tool.

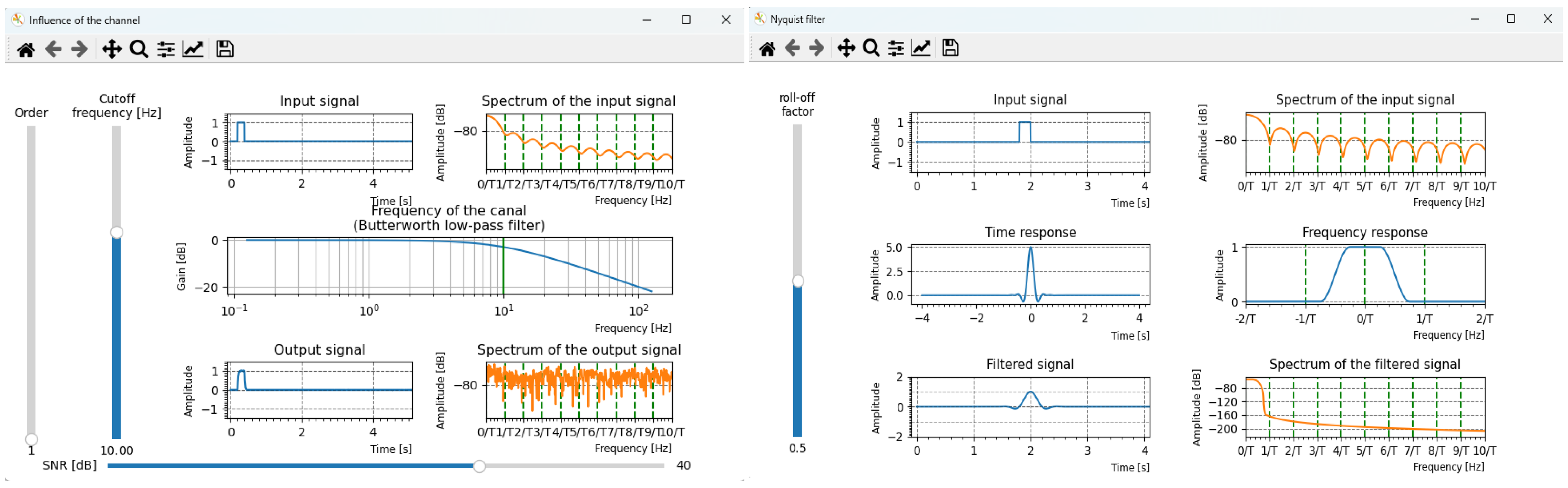

Figure 2. - Window - Influence of the channel and Nyquist filter

Results

The tool allows for the observation and analysis of the characteristics of each type of coding, as well as the effects of the transmission channel and the Nyquist filter on the signal.

The simulator represent faithfully the spreading of symbols caused by the transmission channel as well as the impact of noise. The tool also allows for the simulation of both poor and ideal channels. (cf. **Figure 1** and **2**)

The application of the Nyquist filter has reduced inter-symbol interference and improved the quality of the signals, which has been validated by more open eye diagrams. (cf. **Figure 3**)

Discussion

The results show that the simulation tool is effective for teaching baseband transmission concepts. However, some areas for improvement have been identified :

The current tool does not yet support all advanced coding types and more sophisticated modulation techniques, limiting the scope of possible simulations.

The creation of the initial signal could be done using a shift register or by allowing the user to choose the bit configuration.

Consider creating the final transmission step: symbol regeneration by designing a phase-locked loop (PLL).

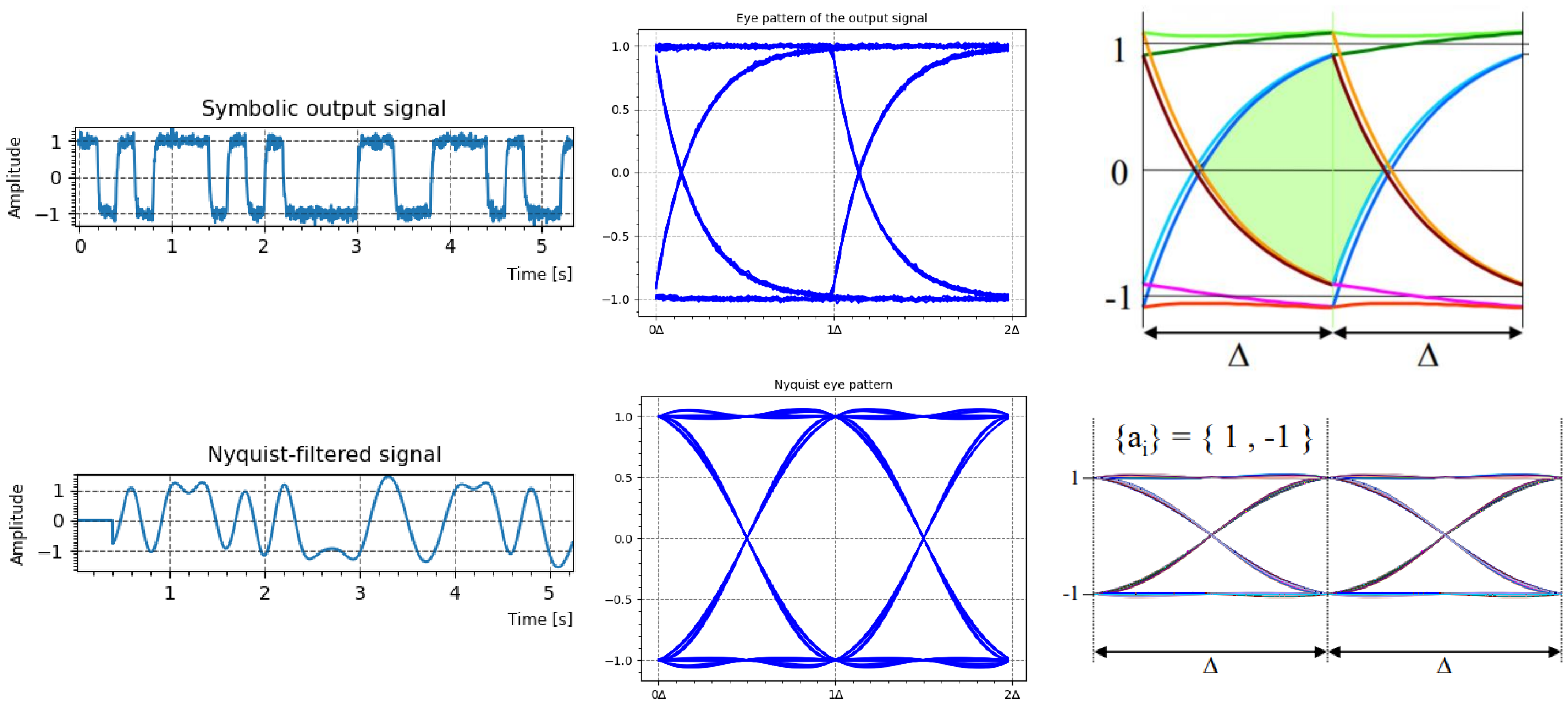

Figure 3. - Simulation and theoretical eye pattern for the symbolic output signal and the Nyquist-filtered signal. (SNR = 20 [dB], bit rate = 5 [bit/s], rolloff factor = 1)

Conclusion

The simulations carried out have confirmed the validity of theoretical concepts and have highlighted the impact of inter-symbol interference and noise on signal quality.

This project has enabled the implementation of an educational simulation tool in Python that facilitates the understanding of digital telecommunications systems and provides a solid foundation for the further development of educational simulation tools in this field.

References

[1] Z. L. Arturo and A. C. Carlos. Digital signal processing course on jupyter python notebook for electronics undergraduates. Comp Applic In Engineering, 28 :10451057, 2020. doi : 10.1002/cae.22277.
[2] T. Dutoit. Cours de "théorie des circuits", 2023. Université de Mons, Faculté polytechnique.
[3] E. Gopi. Digital Signal Processing for Wireless Communication using Matlab. Springer International Publishing, 2016.
[4] J. Hunter, D. Dale, E. Firing, M. Droettboom, and the Matplotlib development team.matplotlib.animation.animation. https://matplotlib.org/stable/api/_as_gen/matplotlib.animation.Animation.html, 2024.
[5] J. W. Leis. Communication sytems principles using Matlab. John Wiley Sons, Inc.,2018.
[6] V. Mathuranathan. Digital Modulations using Python. 2019.
[7] G. Matten, J.-M. Friedt, and E. Carry. Prototypage de traitements numériques des signaux au moyen d'un outil libre : Gnuradio.J3eA, 14 :1011, 2015. doi : 10.1051/j3ea/2015011.
[8] J. G. Proakis and M. Salehi. Contemporary communication systems using Matlab.PWS Publishing Company, 1998.
[9] E. Rius and C. Quendo. Simulation sous matlab/simulink d'une chaîne de transmission numérique en bande de base. application au codage canal. J3eA, 2 :14, 2003. doi : 10.1051/bib-j3ea:2003014.31
[10] M. Wuilpart and V. Moeyaert. Cours de "principes des télécommnications numériques", 2023. Université de Mons, Faculté polytechnique.