Sp 516 - Télécommunications Spatiales: Project de cursus

Matlab implementation and analysis of a digital communication system

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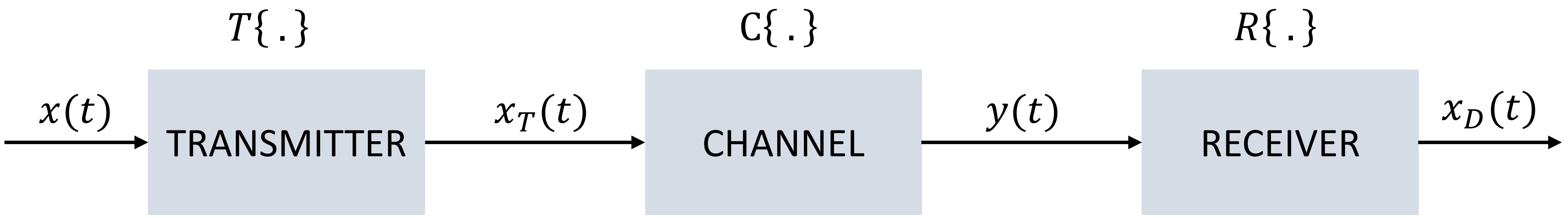
Summary

During the course and in the TD, we studied the main building blocks of a digital communication system.

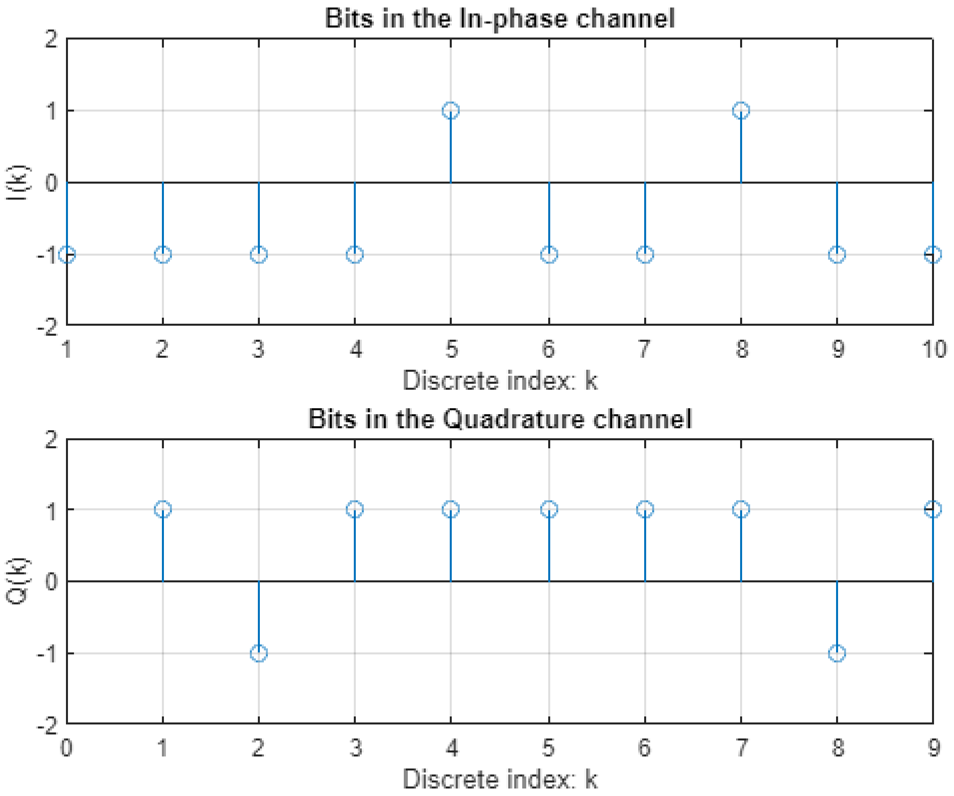
We have three fundamental blocks:

- The transmitter : aim to make the signal informations less sensitive to random perturbations
- The channel : represent the atmospheric medium
- The receiver : has the crucial task of processing the output of the channel and make it the closest to the original signal emitted $x(t)$



During this project, we will simulate all of them in Matlab. We will perform a time domain and a frequency domain analysis of the various signals obtained through the process.

I. The random sequences of $\mathrm{I}[m]$ and $\mathrm{Q}[m]$:



Here you can see an example of the sequences:

- In-phase $I[m]$
- Quadrature $Q[m]$

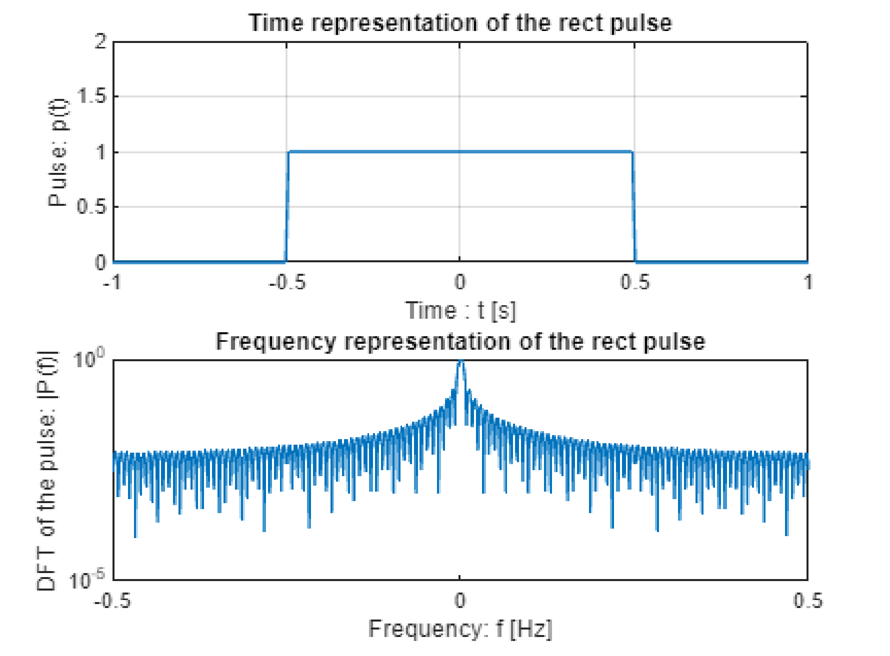
$M = 10$ (Max number of index)

$m = \{0, 1, \dots, M_{-1}\}$ (Sequence index)

II. The rectangular and root-raised cosine pulse:

RECTANGULAR PULSE

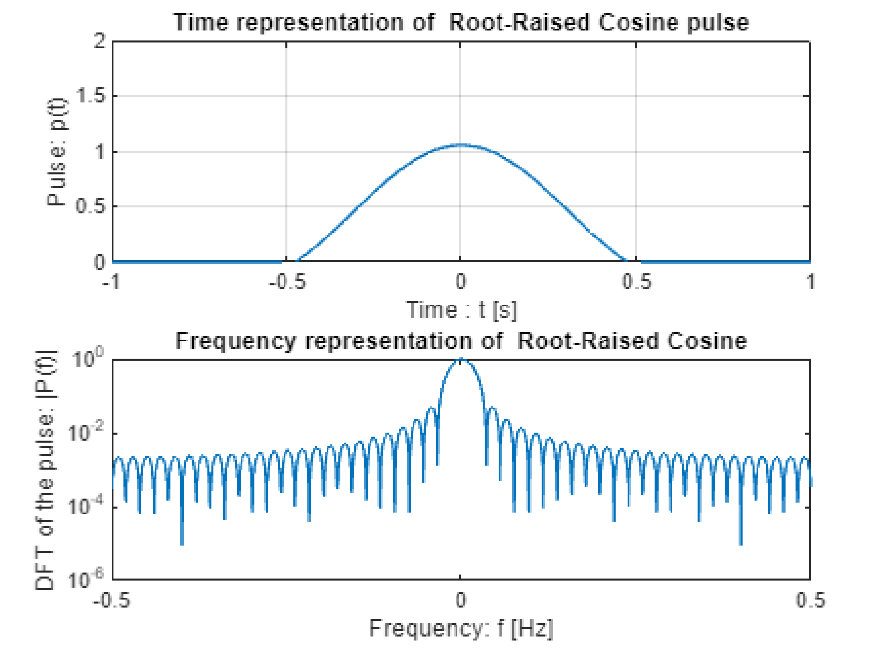
$$p(t) = A_c \mathrm{rect}\left(\frac{t}{T_s}\right)$$



*Ts (symbol/second) = 1s
*Ac is used to choose the transmitted power

ROOT-RAISED COSINE PULSE

$$p(t) = \frac{\sin(2\pi t(1-\alpha)/T_s) + \frac{8\alpha t}{T_s}\cos(2\pi t(1+\alpha)/T_s)}{\frac{2\pi t}{T_s}(1-(8\alpha t/T_s)^2)}$$

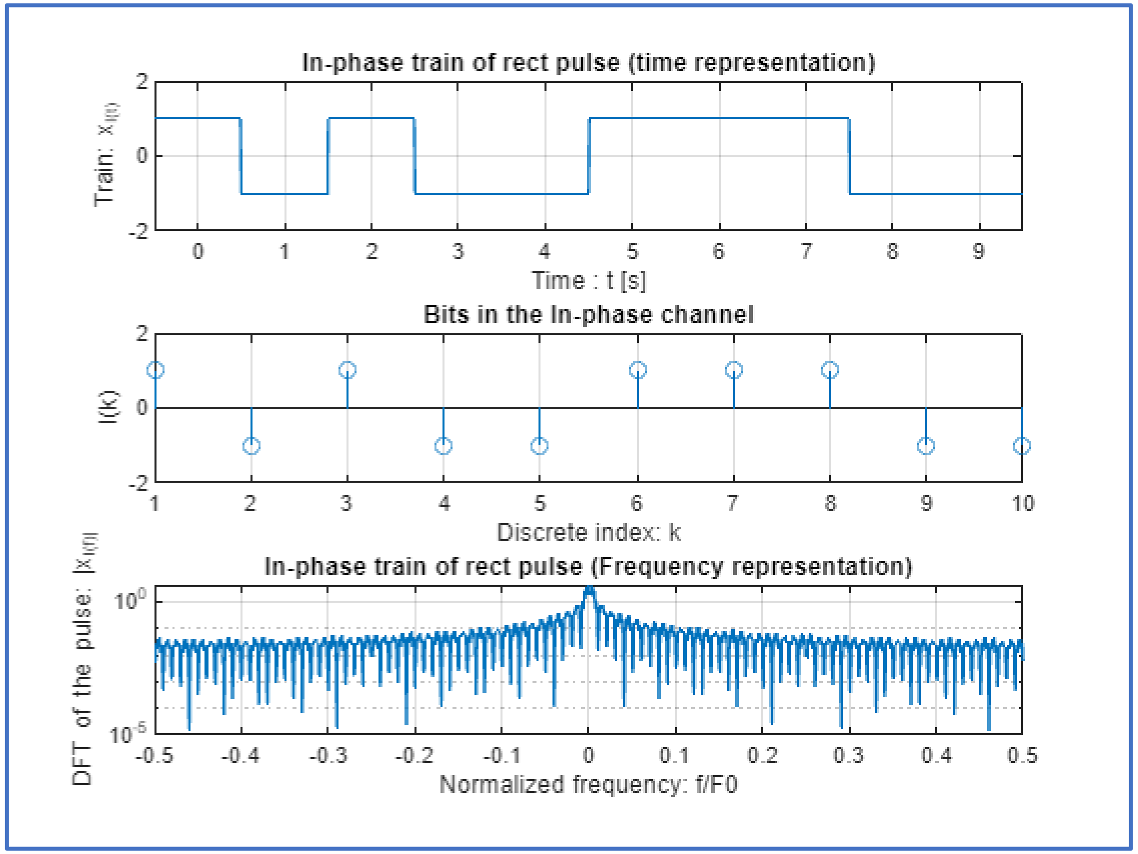


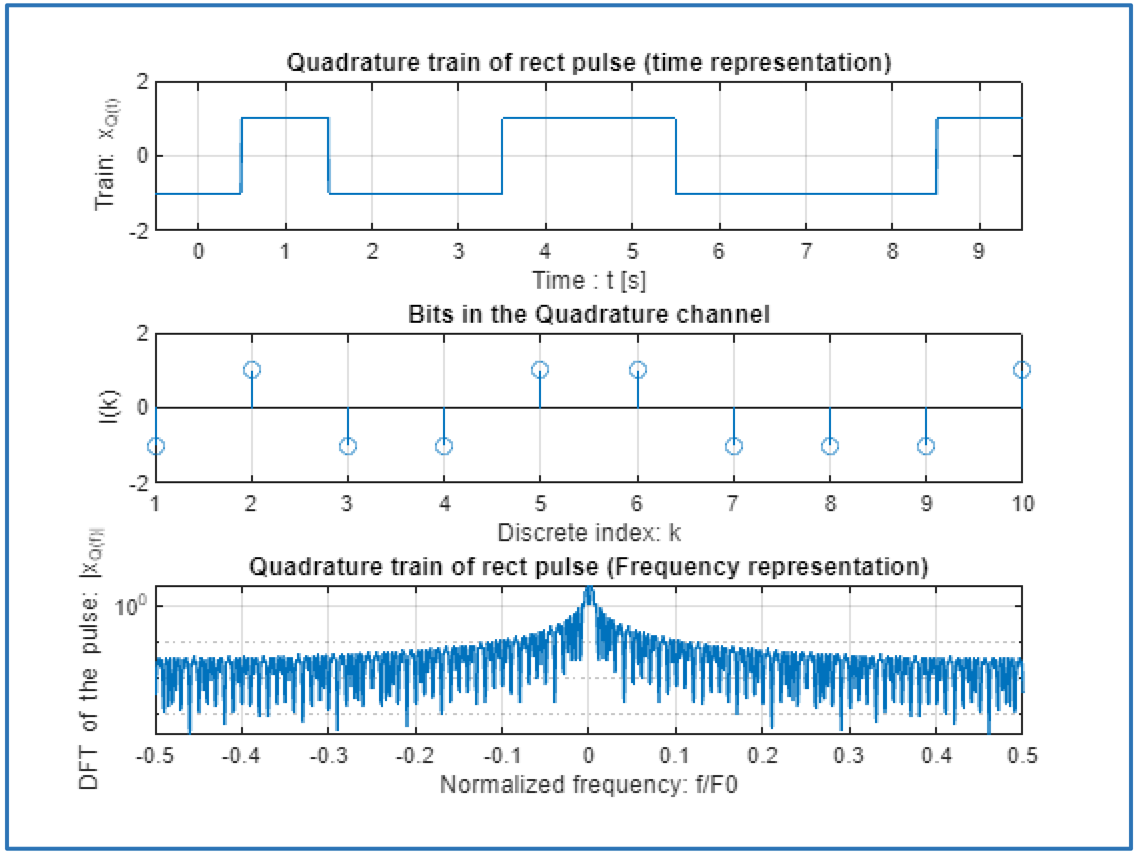
*Ts (symbol/second) = 1s
*α is a parameter <1 and >0

III. Rectpulse In-phase and Quadrature information signals:

In-phase information signal: $s_I(t) = \sum_{k=-\infty}^{+\infty} I[k]p(t - kT_s)$

Quadrature information signal: $s_Q(t) = \sum_{k=-\infty}^{+\infty} Q[k]p(t - kT_s)$

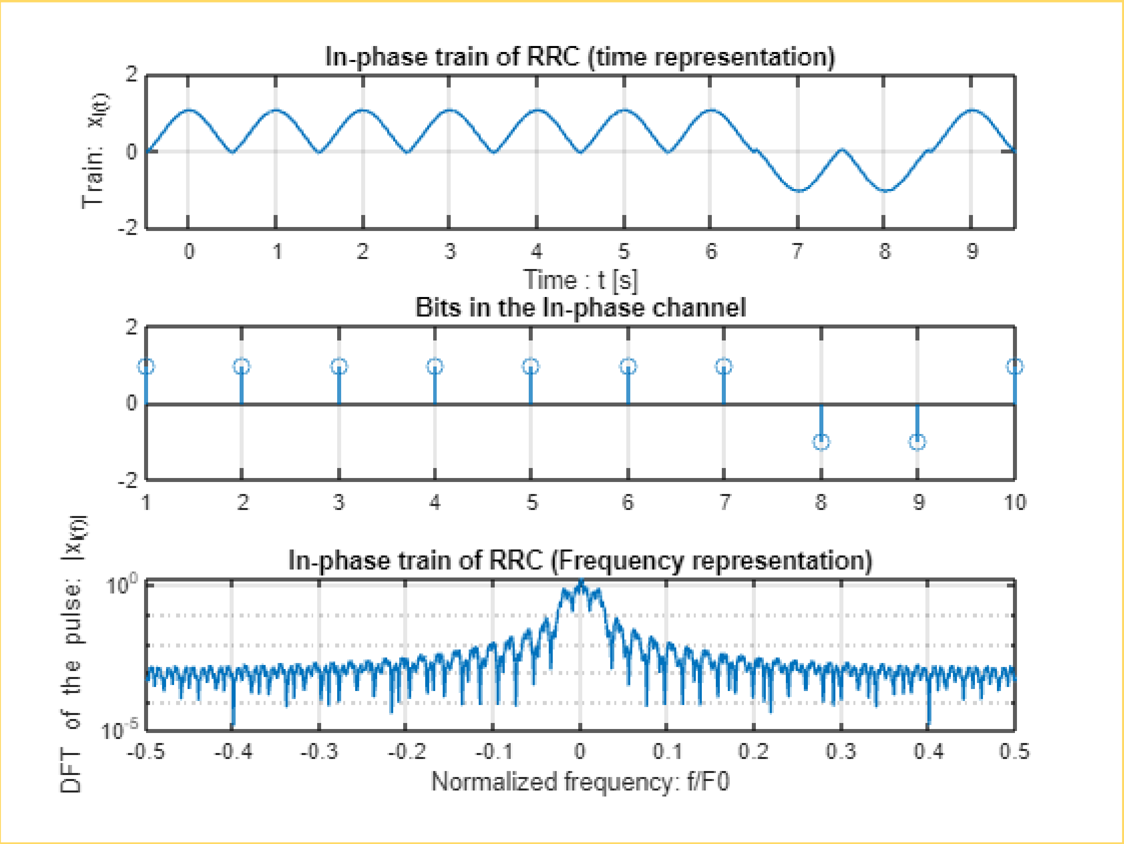


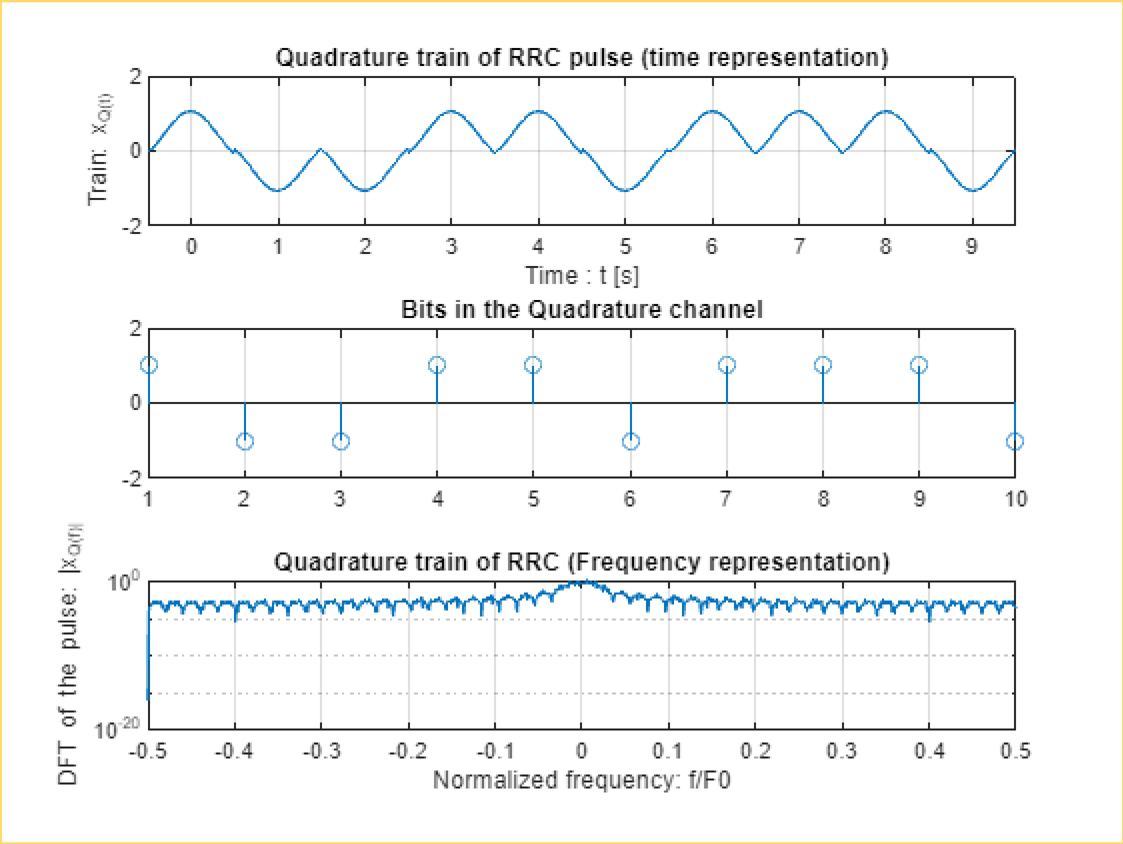


IV. RRC In-phase and Quadrature information signals:

In-phase information signal: $s_I(t) = \sum_{k=-\infty}^{+\infty} I[k]p(t - kT_s)$

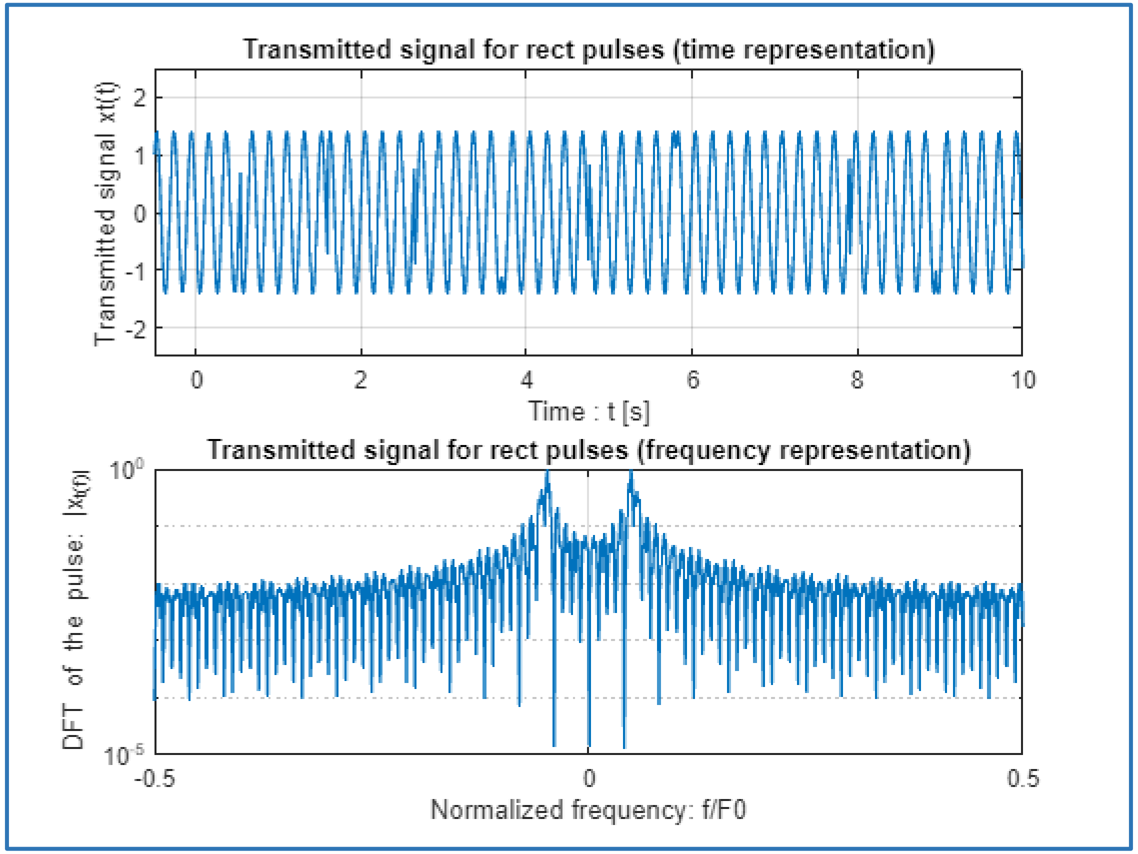
Quadrature information signal: $s_Q(t) = \sum_{k=-\infty}^{+\infty} Q[k]p(t - kT_s)$.

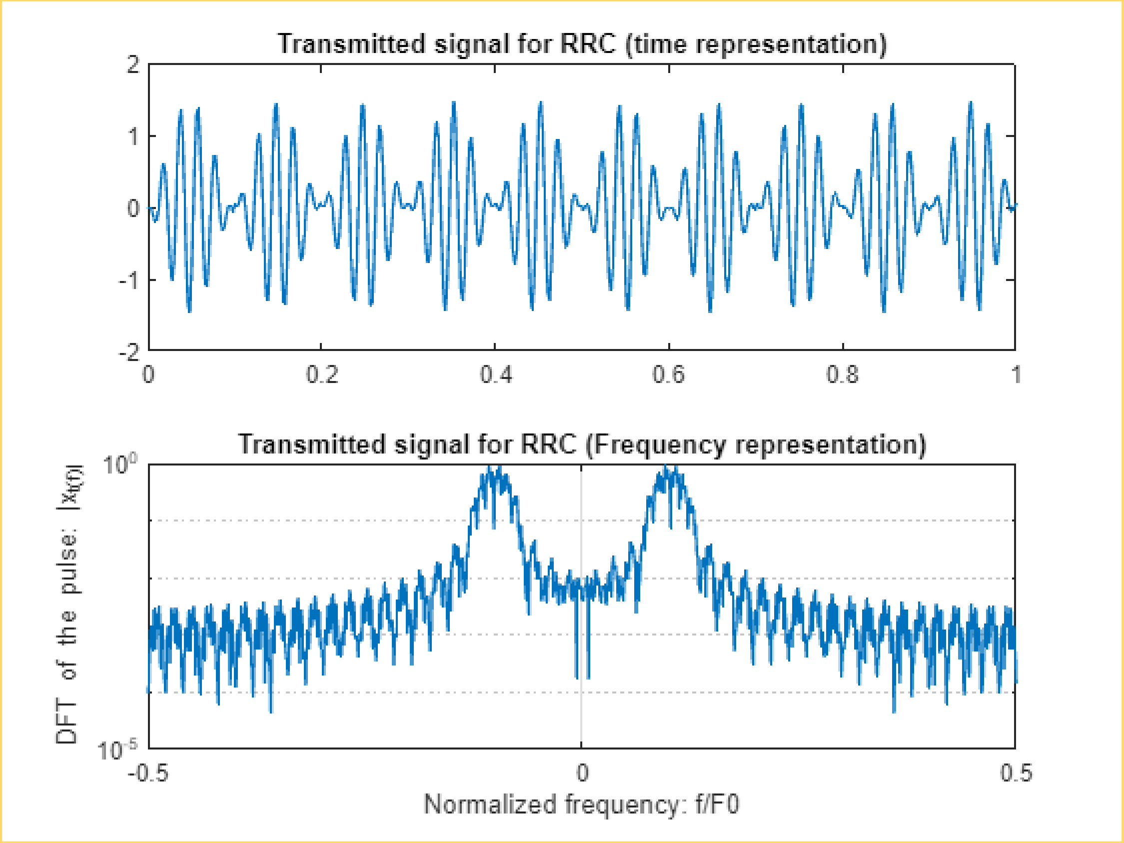




V. Generating the rectpulse and RRC transmitted signal

Transmitted signal: $x_T(t) = \sum_{k=-\infty}^{+\infty} I[k]p(t-kT_s)\cos(2\pi f_c t) - \sum_{k=-\infty}^{+\infty} Q[k]p(t-kT_s)\sin(2\pi f_c t)$

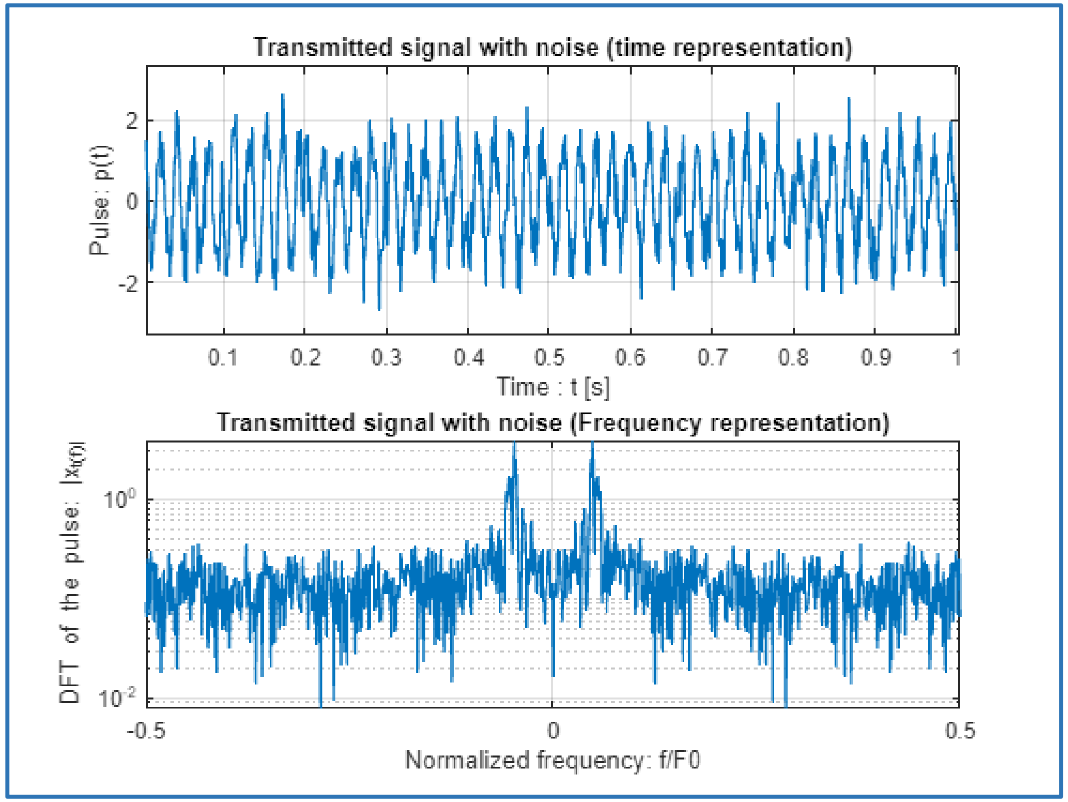


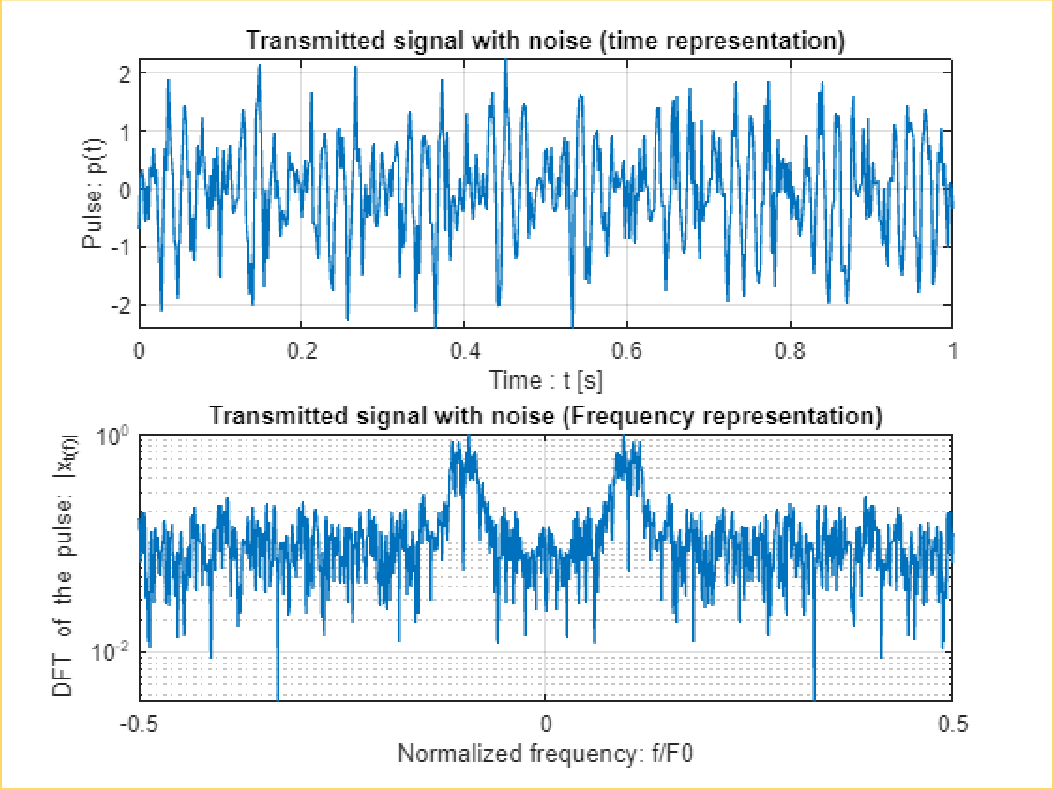


I. Generating the transmitted signal with noise :

We assume an ideal “distortionless” channel with gaussian random disturbance
We get : $x_R(t) = x_T(t) + \sigma_n n(t)$

*$n(t)$ White Gaussia random noise
*σ_n is a coefficient controlling the power
*$F_0 > 2\ f_{max}$ (Nyquist’s condition)



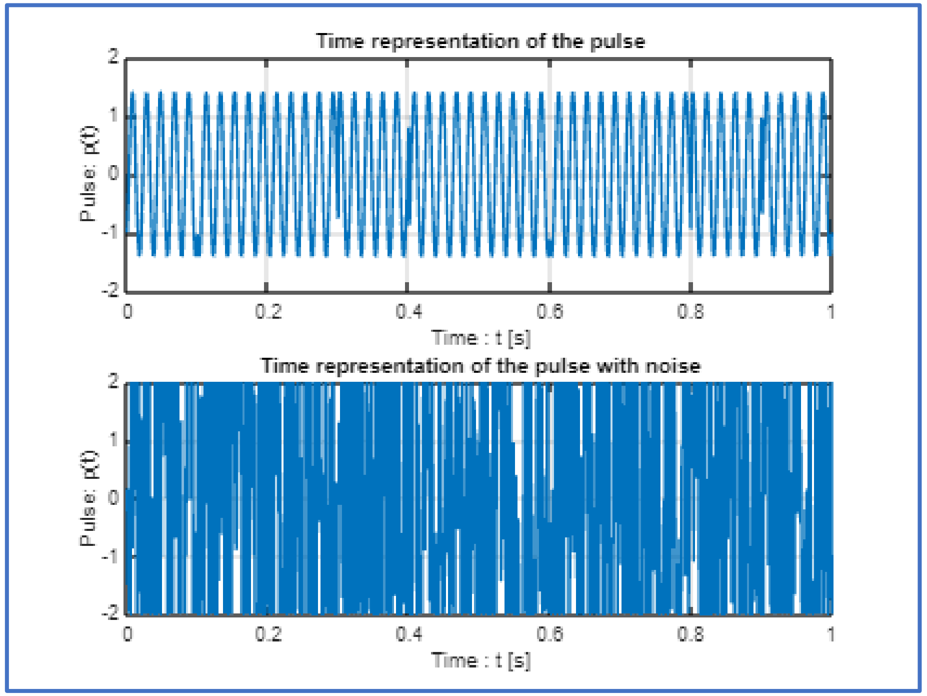


I. Generating the transmitted signal with noise : what impact ?

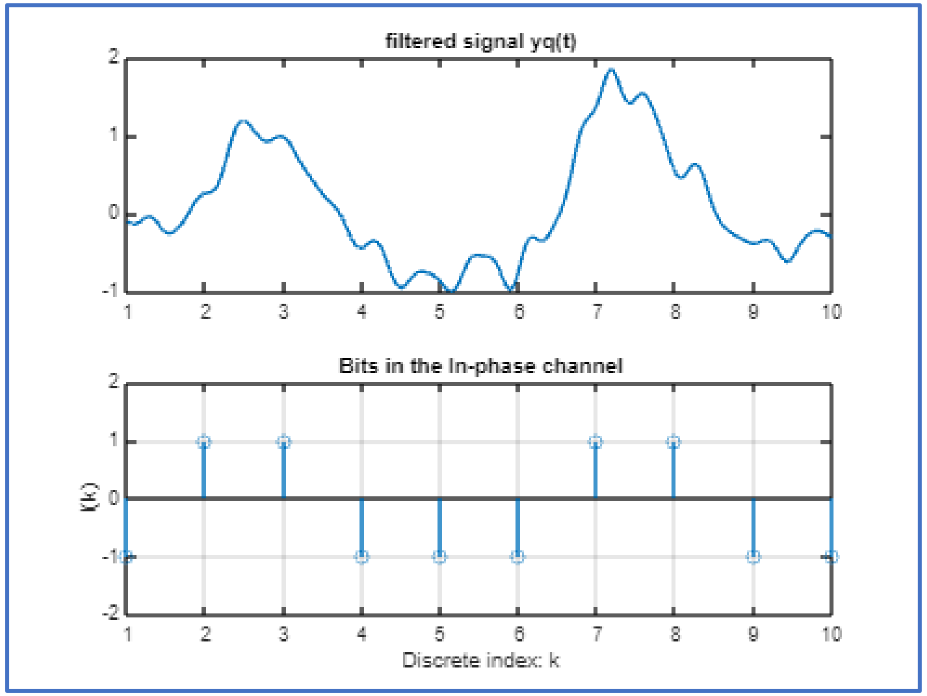
We get : $x_R(t) = x_T(t) + \sigma_n n(t)$

*$n(t)$ White Gaussia random noise
*σ_n is a coefficient controlling the power

$\sigma_n = 4$

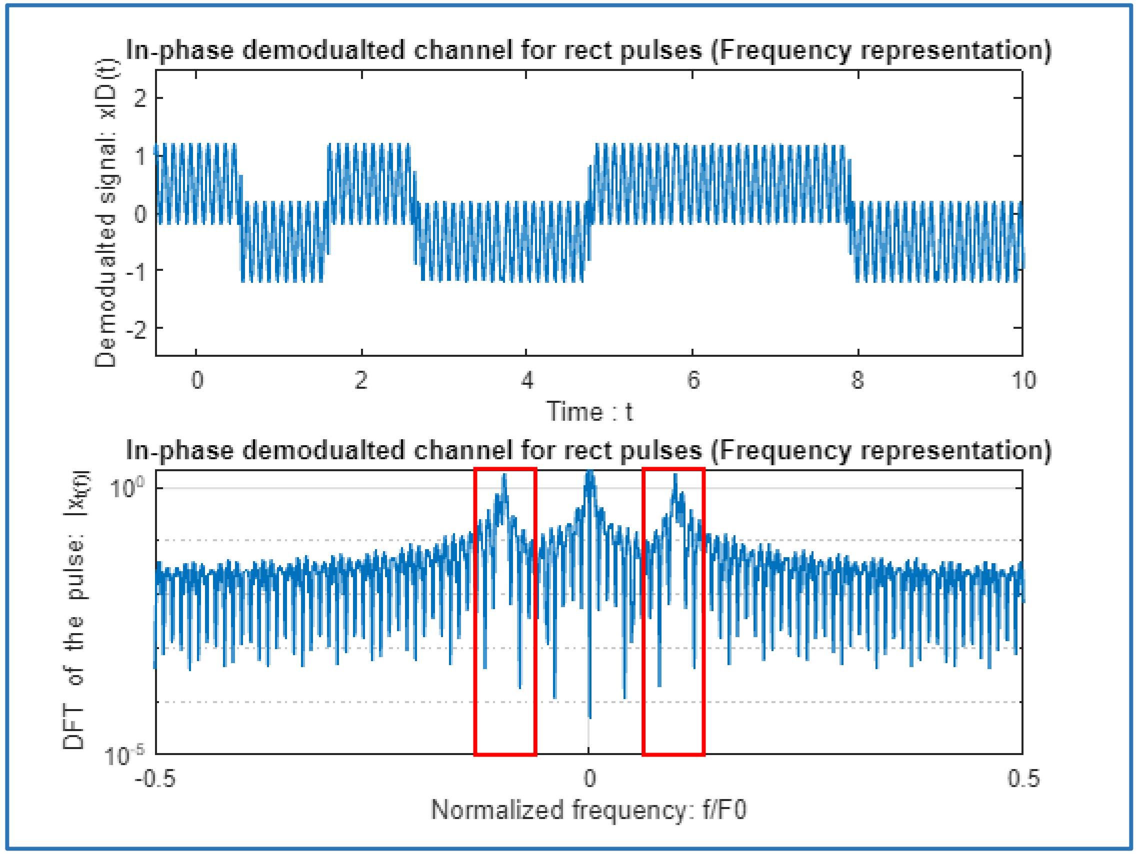


highly affects the demodulation and the motive



I. Demodulation of the signal received:

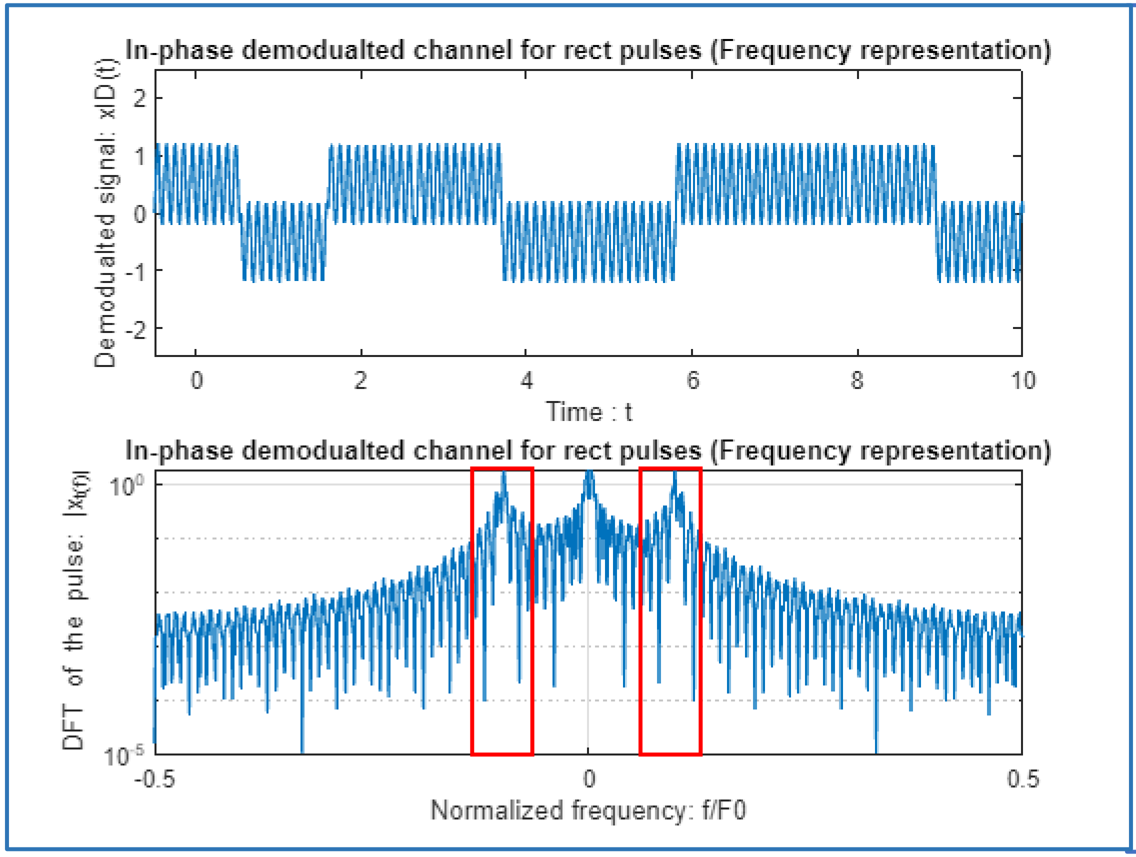
We know from the course that the first task to perform at the receiver is the demodulation

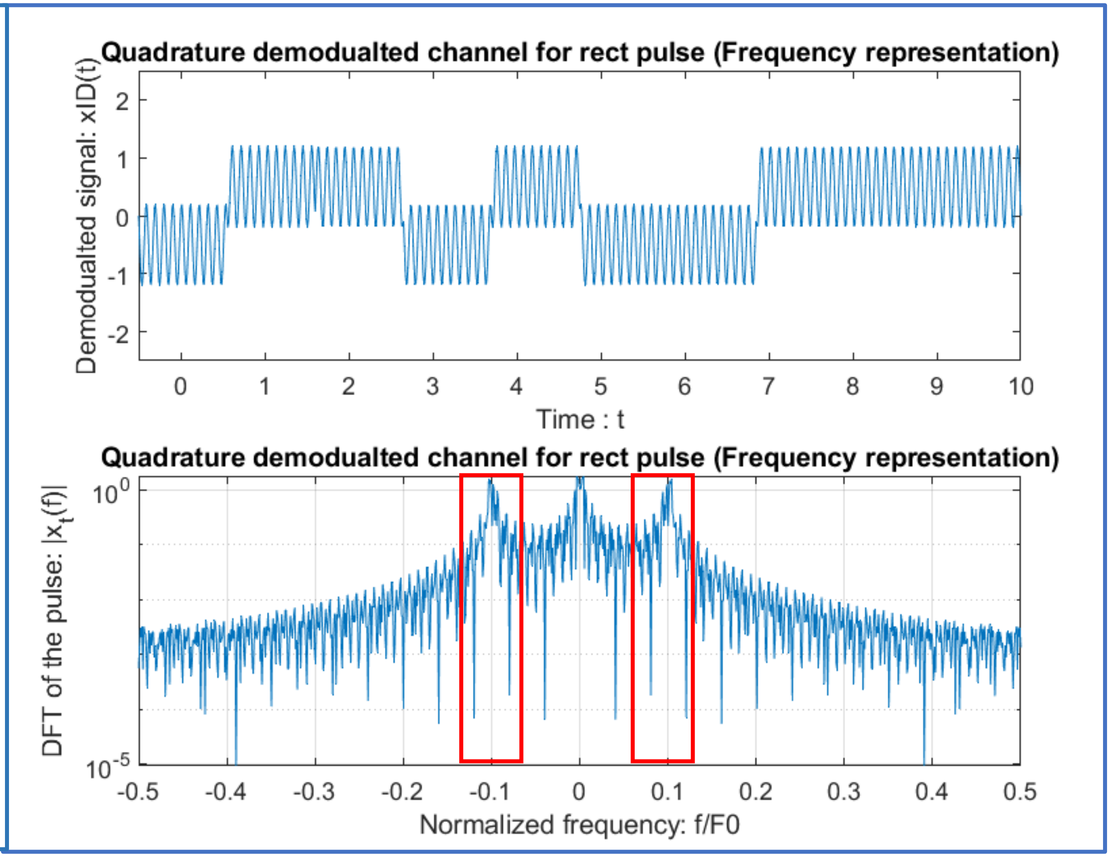


We can see on the first graph our signal multiplied by $\cos(2\pi f_c t)$

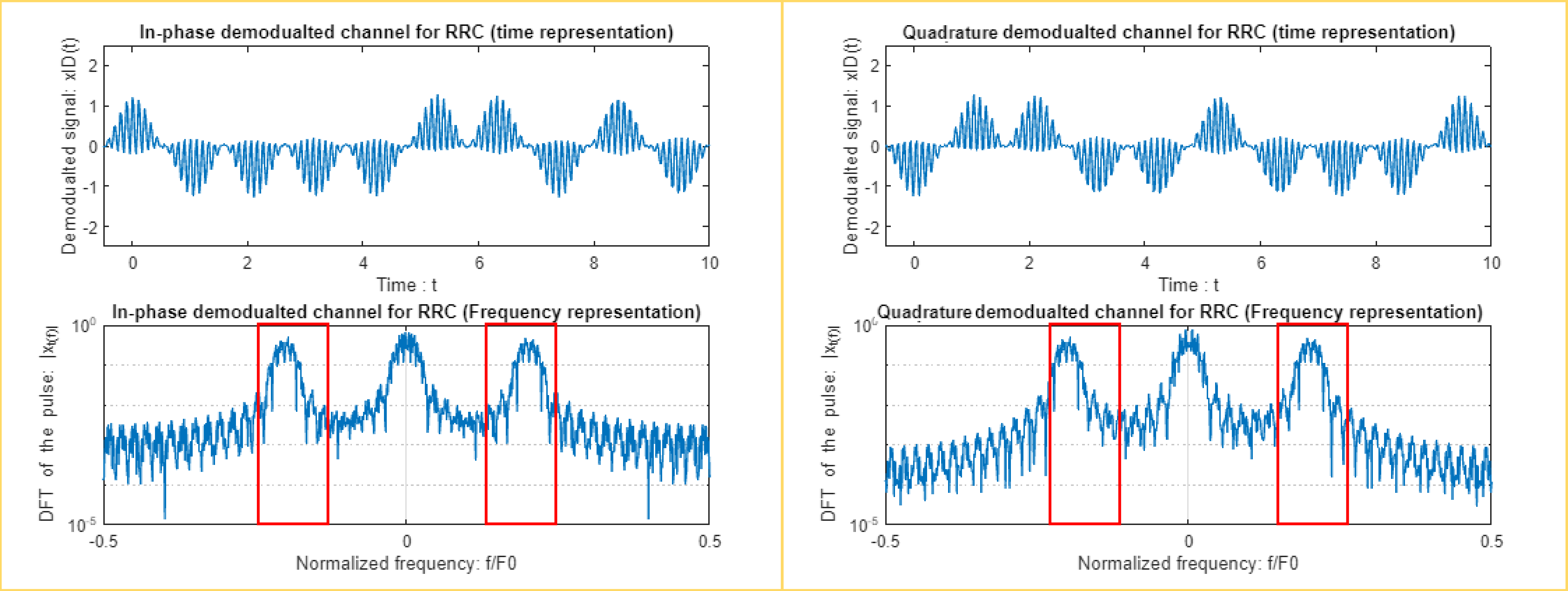
Followed by the second graph where we can clearly see the « useless » replicas

I. Demodulation of the signal received:





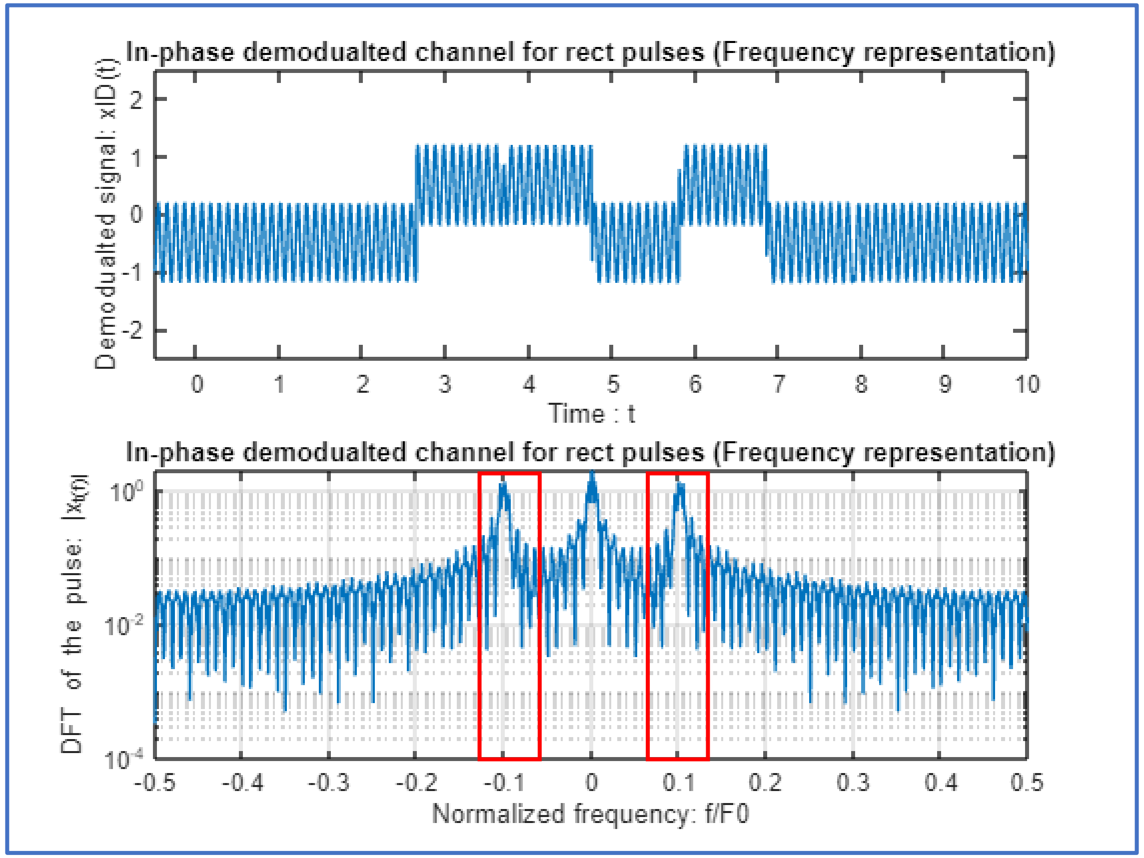
I. Demodulation of the signal received:

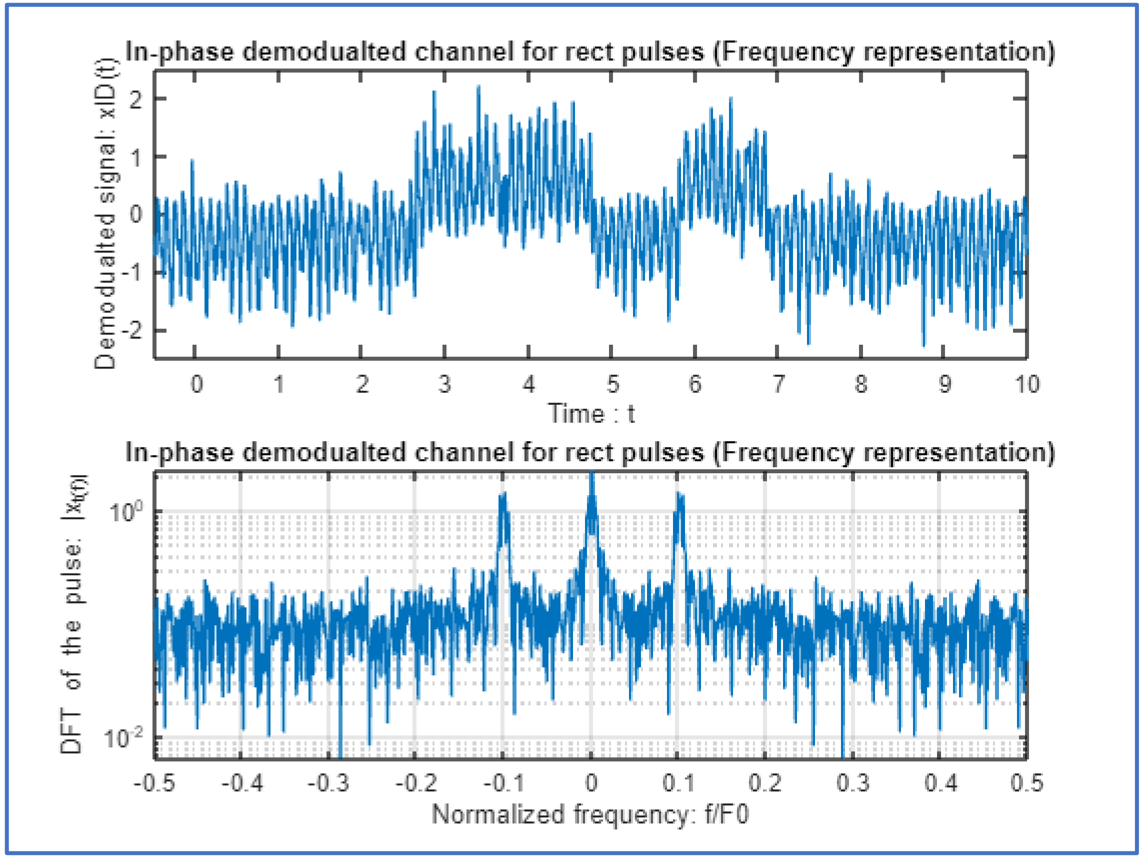


I. Demodulation of the signal received:

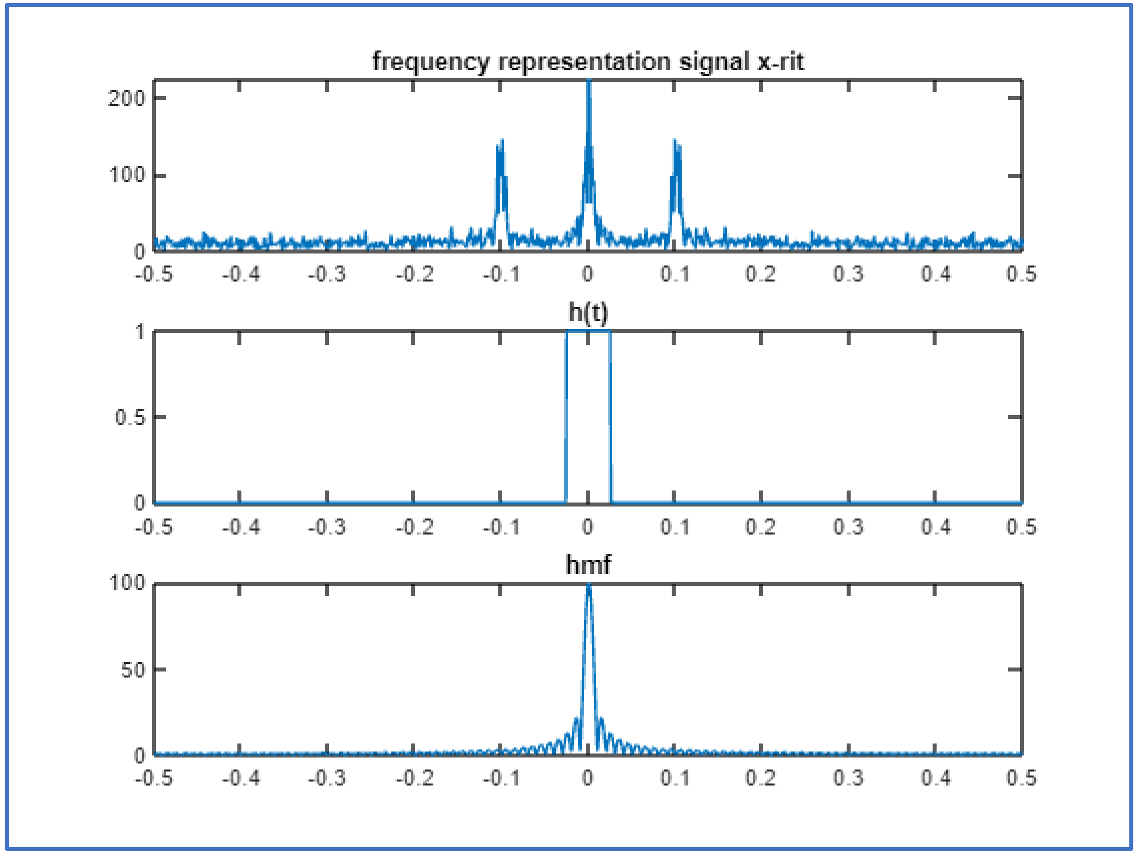
Signal sI(t)

Signal $x_{RI}(t) = x_R(t)\,(\cos(2\pi f_c t))$.





I. The expression of $y_I(t)$ and $y_Q(t)$ in time :



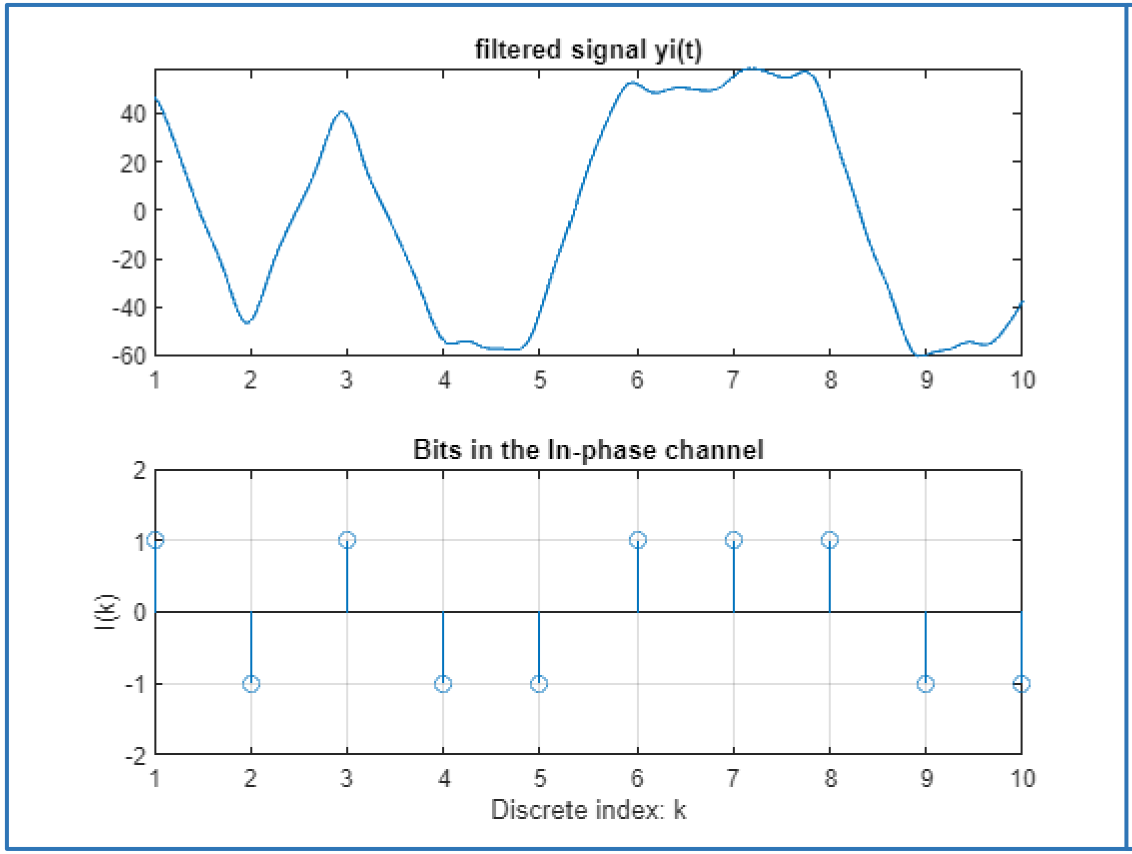
After the demodulation, we need to apply the matched filter $h_{MF}(t)$ to maximize the Signal-to-Noise Ratio.

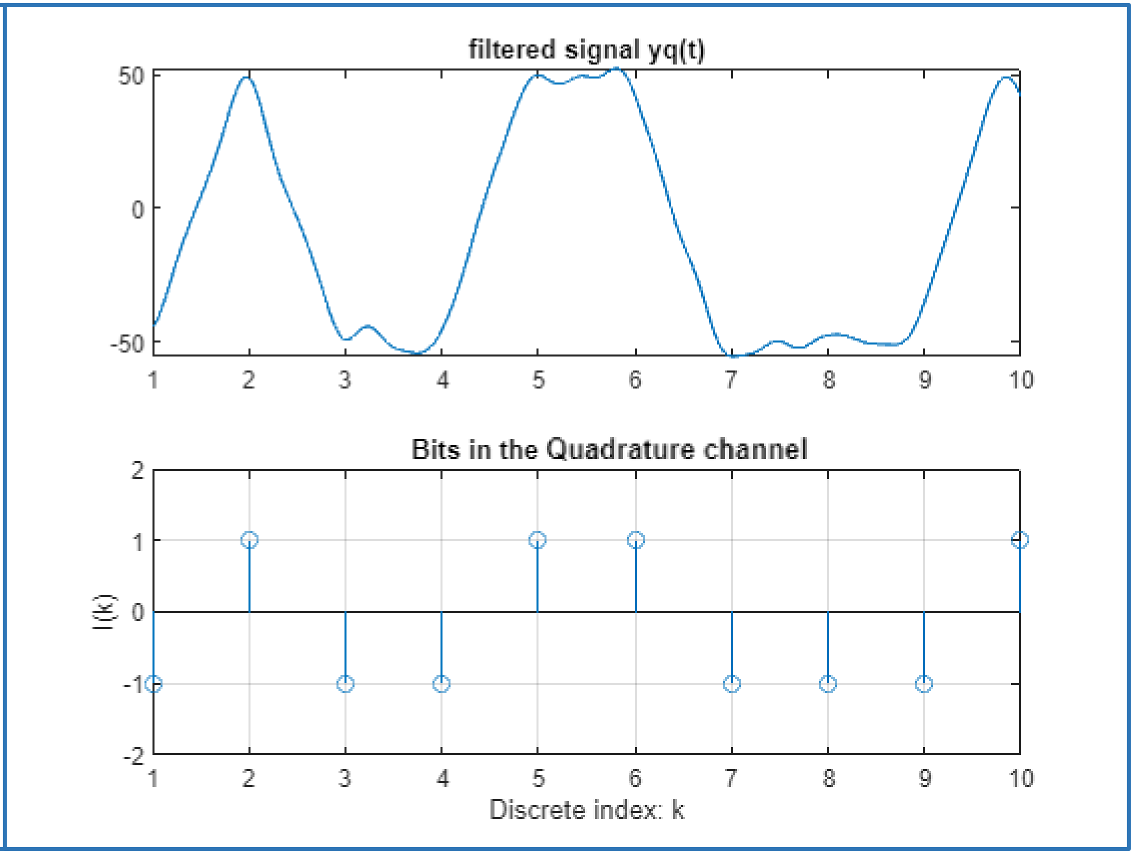
With $X_{RI}(t) = X_R(t)\cos(2\pi f_c t)$ the demodulated signal

the signal after the matched filter can be indicated as:

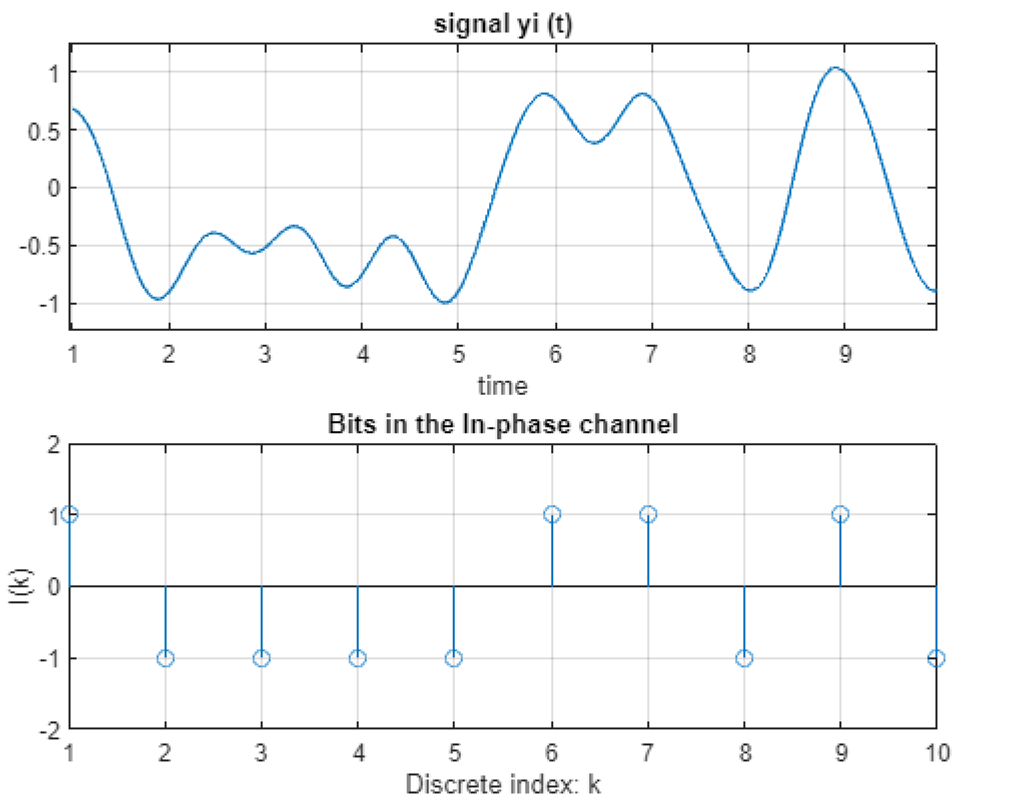
$$y_I(t) = h_{MF}(t) * h(t) * x_{RI}(t), \quad h_{MF}(t) \triangleq p(-t).$$

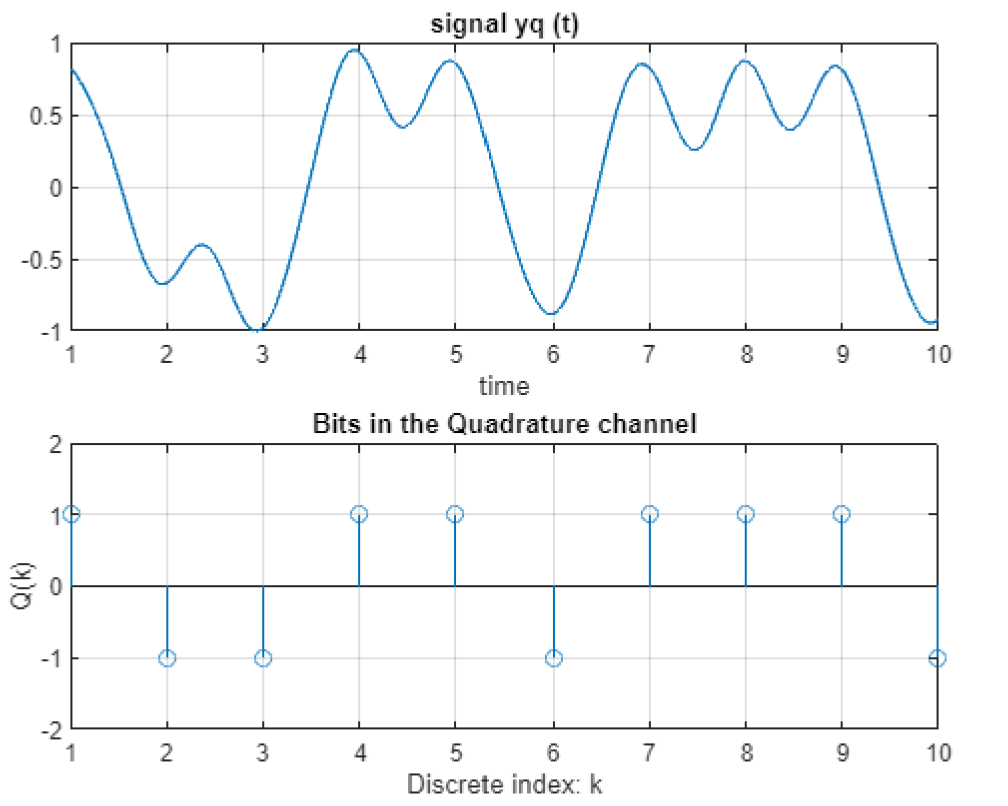
II. The expression of $y_I(t)$ and $y_Q(t)$ for the Rectpulse:



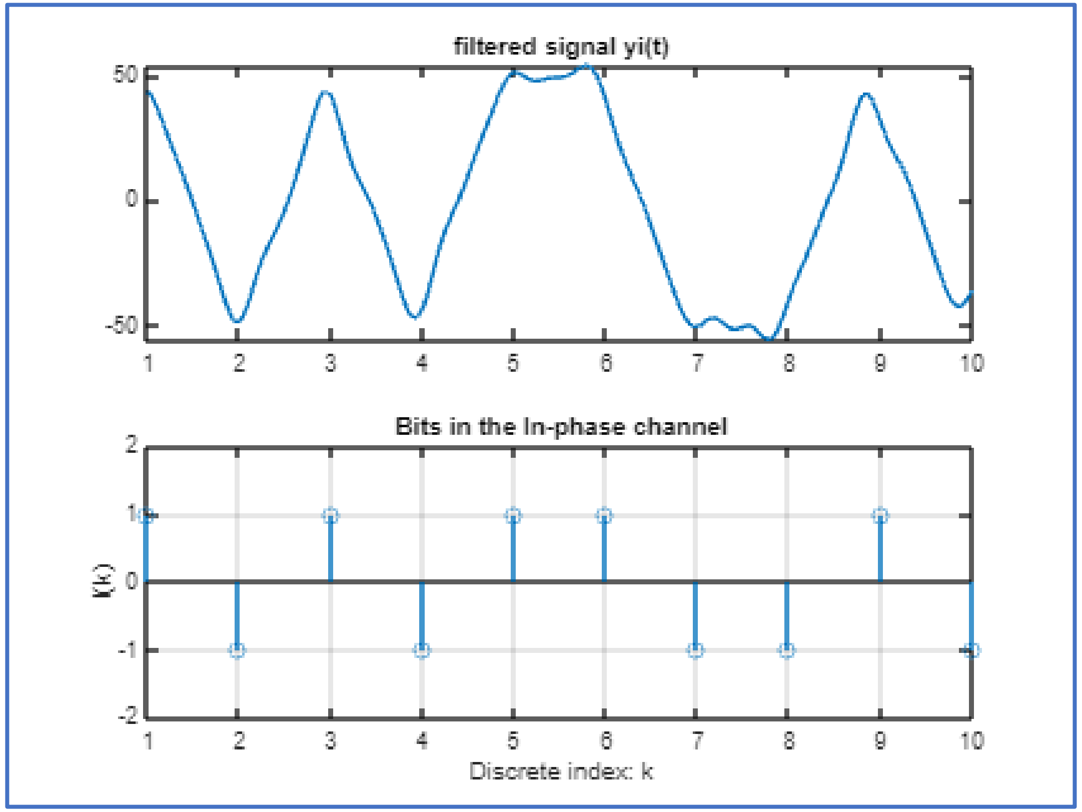


II. The expression of $y_I(t)$ and $y_Q(t)$ for the RRC:





III. The expression of $y_I(t)$ and $y_Q(t)$ in frequence :



We can do the same but with the frequential domain.

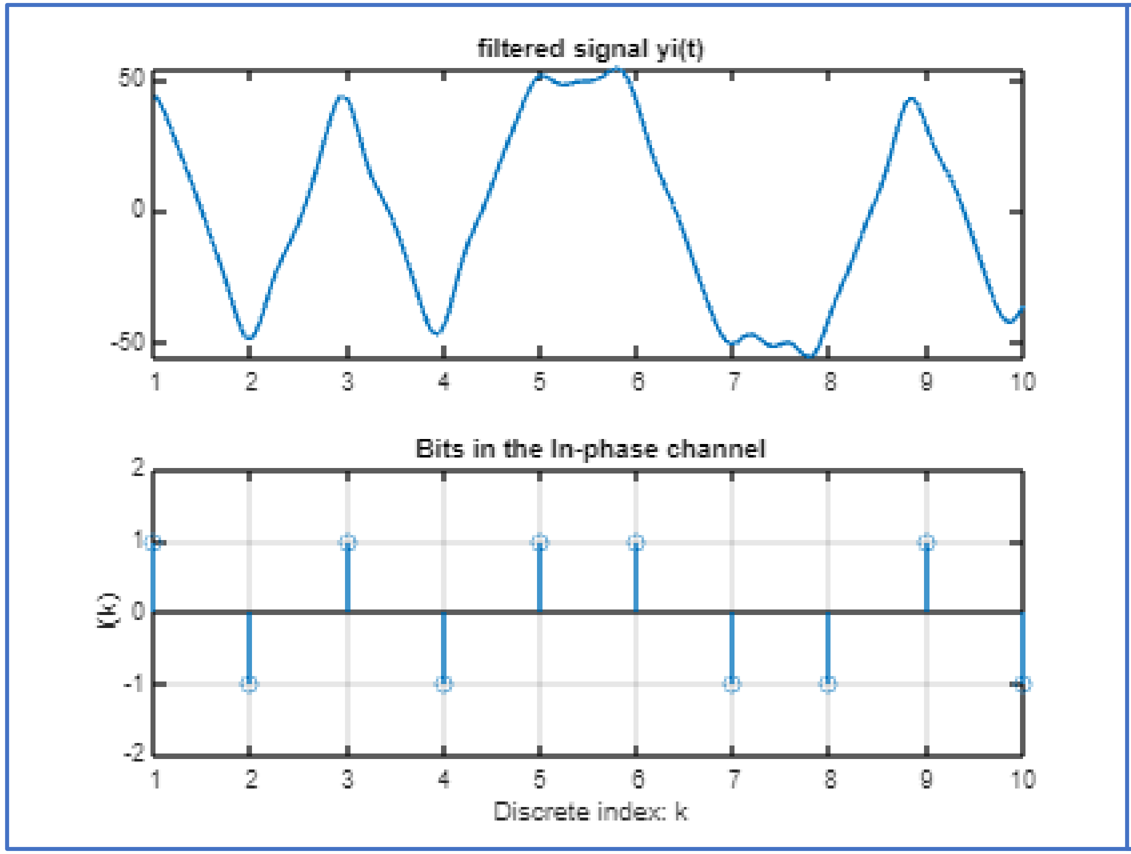
the signal after the matched filter can be indicated as:

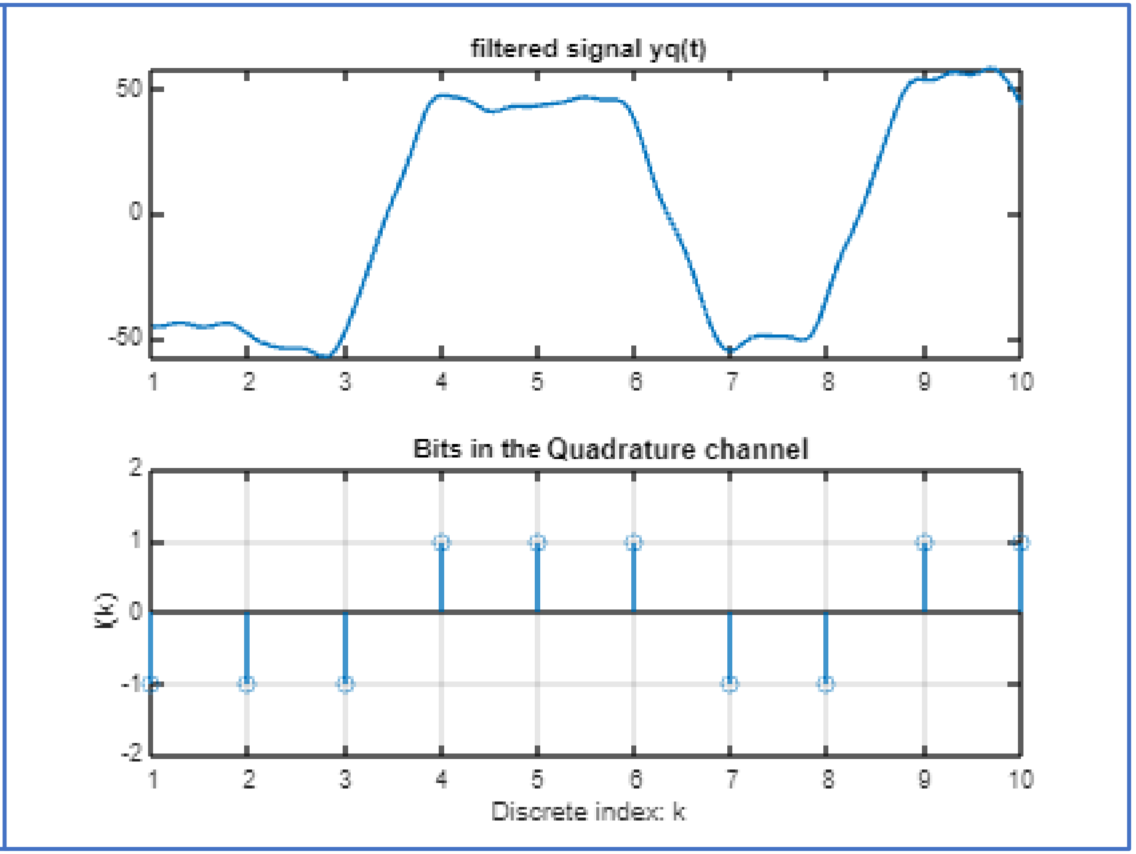
$$y_I(t) = \mathcal{F}^{-1}\{H_{MF}(f)H(f)X_{RI}(f)\}$$

$$H_{MF}(f) = (\mathcal{F}\{p(t)\})^* \text{ and } X_{RI}(f) = \mathcal{F}\{x_{RI}(t)\}.$$

Reconstruction of the signal

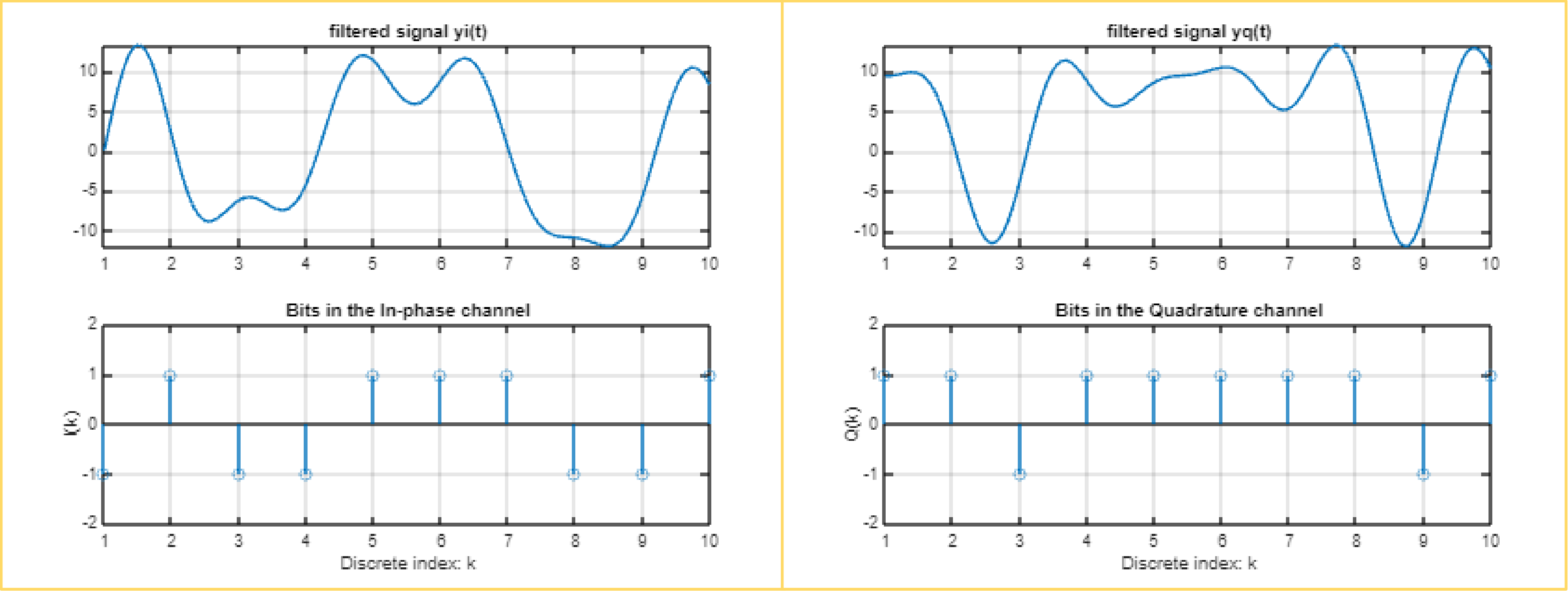
III. The expression of $y_I(t)$ and $y_Q(t)$ for the Rectpulse:





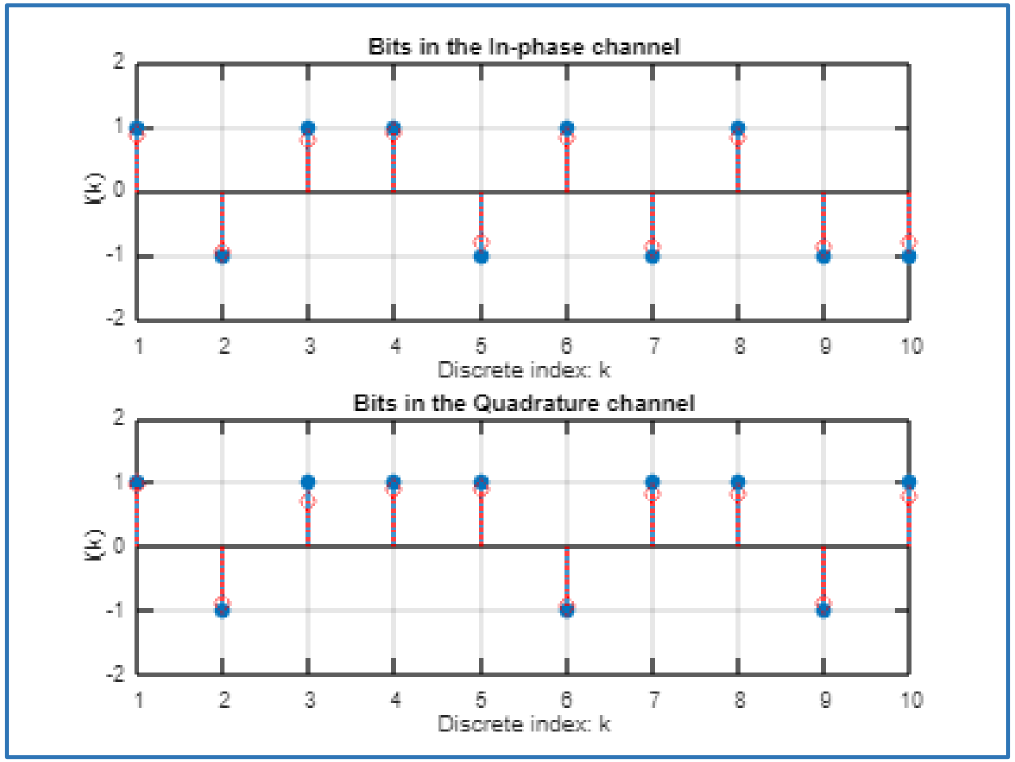
Reconstruction of the signal

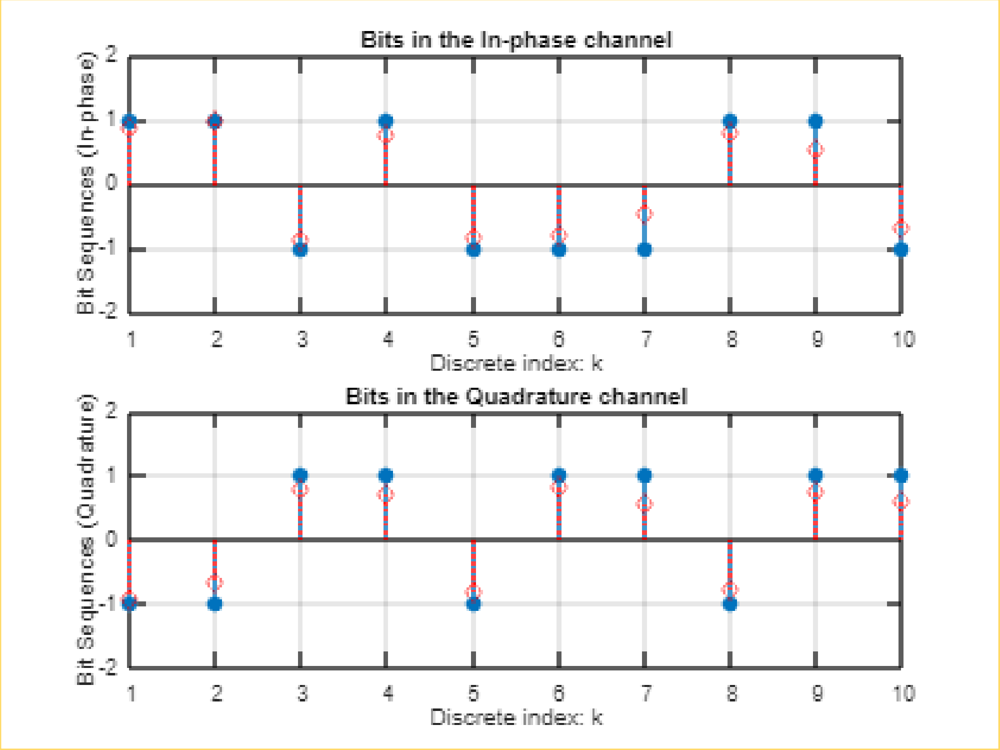
III. The expression of $y_I(t)$ and $y_Q(t)$ for the RRC:



IV. The sampling and sequence reconstruction:

RECTANGULAR PULSE



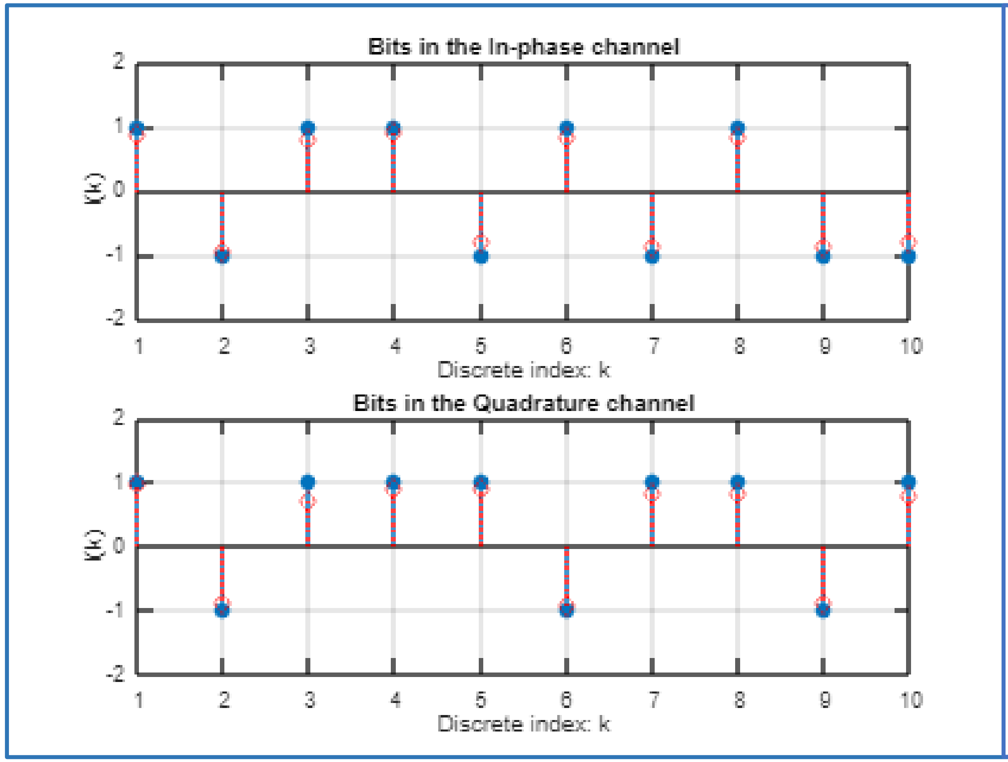


ROOT-RAISED COSINE PULSE

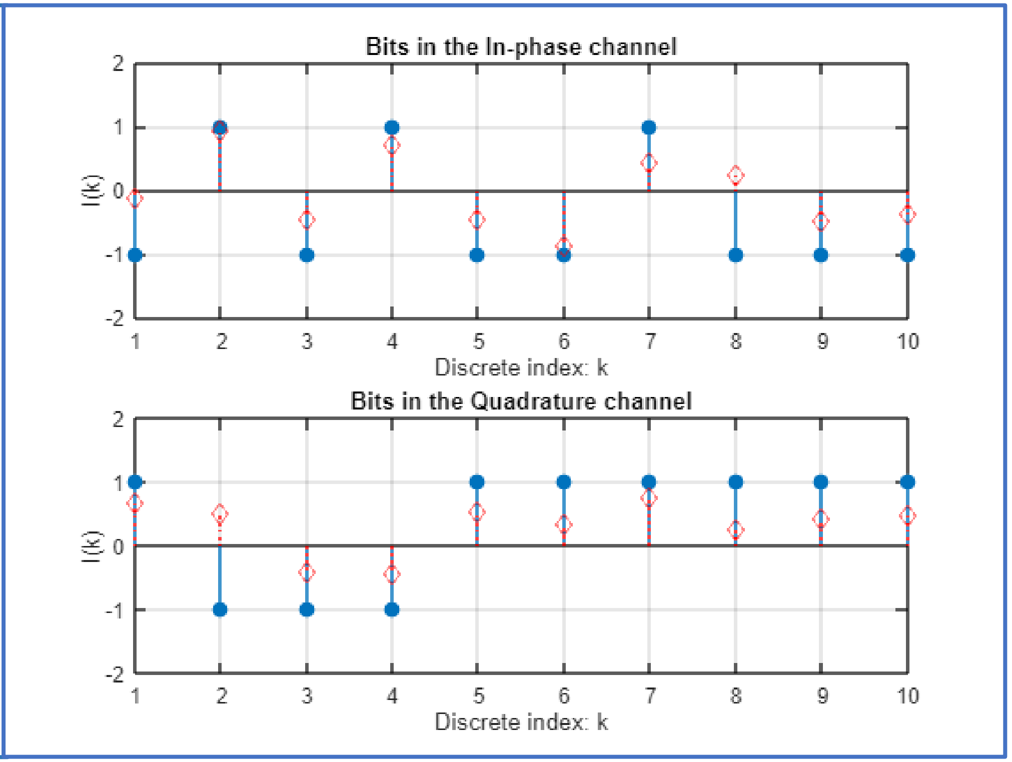
The Final signal

IV. The sampling and sequence reconstruction: the impact of the noise

$\sigma_n = 0.5$



$\sigma_n = 4$



Thank you for listening !