## ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

School of Computer and Communication Sciences

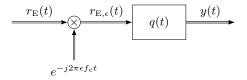
Handout 16 Solutions to Assignment 10 Modern Digital Communications
December 4, 2024

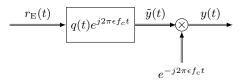
For the first 2 exercises, please see the provided MATLAB/Python code which is self-explanatory. Comparing the estimators, we observe (as expected) that the MMSE outperforms the LS.

SOLUTION 3.

1.  $r_{E,\epsilon}(t) = \sqrt{2}r(t)e^{-j2\pi f_c t - j2\pi f_c \epsilon t} = \sqrt{2}r(t)e^{-j2\pi f_c t}e^{-j2\pi f_c \epsilon t} = r_E(t)e^{-j2\pi \epsilon f_c t}.$  (1)

2. One can work out the calculations in the time domain and show that the systems in the two figures below are indeed equivalent.





Instead of that, we give here a more intuitive solution which uses the frequency domain. The output of the filter in the first figure is, in the frequency domain,

$$y_{\mathcal{F}}(f) = r_{\mathcal{E},\mathcal{F}}(f + \epsilon f_c) \cdot q_{\mathcal{F}}(f).$$
 (2)

The output of the filter in the second figure is, in the frequency domain,

$$\tilde{y}_{\mathcal{F}}(f) = r_{\mathcal{E},\mathcal{F}}(f) \cdot q_{\mathcal{F}}(f - \epsilon f_c).$$
 (3)

Clearly

$$y_{\mathcal{F}}(f) = \tilde{y}_{\mathcal{F}}(f + \epsilon f_c). \tag{4}$$