ELEC4844/8844 Practical Class – Week 10, 2024

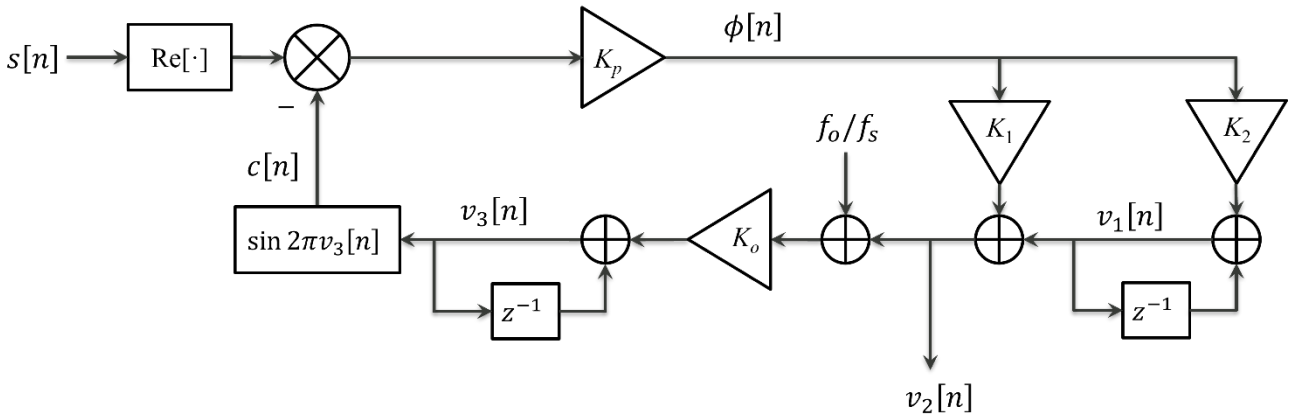
Phase Locked Loop

TASK

The supplied file "data_practical_W10.mat" contains an RF signal $s[n]$ acquired by the RTL-SDR device at sampling rate f_s (=$1/T_s$) = 1.2 MHz for 10 seconds. The RTL-SDR device was tuned to f_c = 96.75 MHz.

a) It is known there exists a local FM radio station at 96.9 MHz. Use MATLAB function periodogram (or pwelch) to plot the centred two-sided power spectral density of $s[n]$, confirming that it is likely from this FM radio station.

b) The signal can be FM-demodulated using a Type-2 phase locked loop according to the following diagram:



Calculate the parameters of the loop filter K_1 and K_2 based on the following equations

$$\eta = \frac{B_n T_s}{\zeta + \frac{1}{4\zeta}}, \qquad K_1 = \frac{4\zeta\eta}{K_o K_p (1+2\zeta\eta+\eta^2)}, \qquad K_2 = \frac{4\eta^2}{K_o K_p (1+2\zeta\eta+\eta^2)},$$

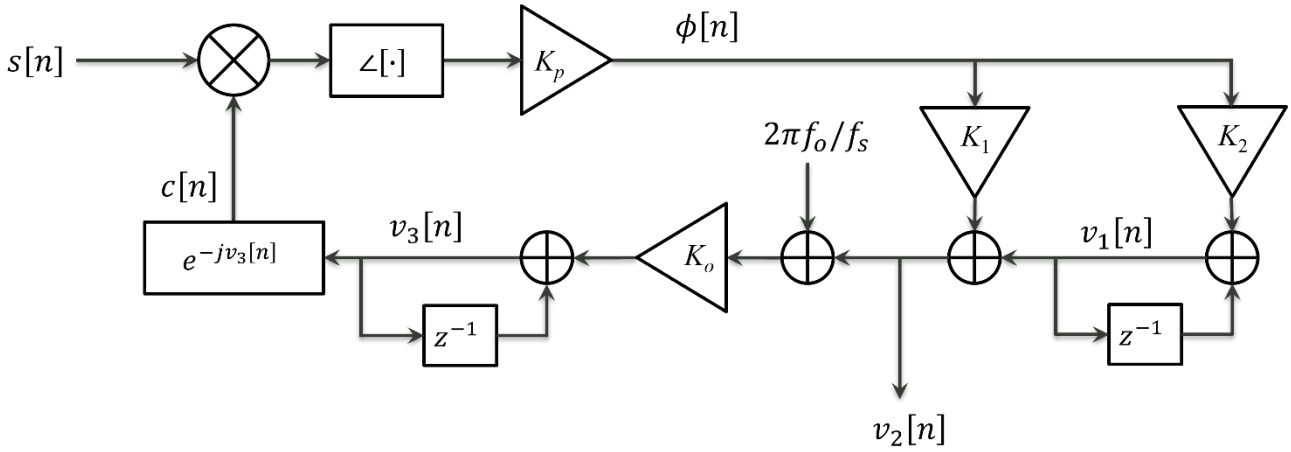
and with gain of phase detector K_p = 1, gain of NCO K_o = 1, noise bandwidth B_n = 50 kHz, and damping ratio ζ = 1. In addition, set f_o = 100 kHz.

c) Derive the updating equations for the internal registers $\phi[n]$, $v_1[n]$, $v_2[n]$, $v_3[n]$, and $c[n]$. Build the model in MATLAB or Simulink, and perform the FM demodulation.

Plot the obtained $v_2[n]$ as a function of time, which is the demodulated FM signal.

d) Convert the sampling rate of the demodulated signal to 48 kHz. Plot it as a function of time and play the audio.

e) The PLL above tracks the real part (i.e. in-phase component) of the received RF signal. But since the RTL-SDR device receives quadrature signal in the complex format, it is also possible to track the complex-valued $s[n]$ directly, using a Type-2 PLL as shown in the following diagram:



Modify the updating rules for $\phi[n]$, $v_1[n]$, $v_2[n]$, $v_3[n]$, and $c[n]$ accordingly, and use the same PLL parameters to simulate the model for FM demodulation. Note that the location of the coefficient 2π has changed.

Plot the demodulated FM signal $v_2[n]$, downsample it to 48 kHz, and play the audio.