ELEC4844/8844 Practical Class – Week 6, 2024

Complex Signals & Spectral Viewing

TASK 1

Given a linear chirp signal

$$x(t) = \cos(2\pi f_1 t + \pi\mu t^2)$$

in which f_1 = 4 kHz and μ = 100 kHz/s.

a) Generate the discrete-time signal $x[n]$ from $x(t)$ that last for 50 ms, using sampling frequency f_S = 80 kHz. Obtain the power spectral density (PSD) of $x[n]$ using its DFT $X[k]$ and the expression below (N is the number of samples in the discrete-time signal), and plot the result in decibel units.

$$\mathrm{PSD}_X\left(\frac{kf_s}{N}\right) = \frac{1}{Nf_s}|X[k]|^2$$

b) Make sure N is an odd number. Verify the spectrum $X[k]$ of the real-valued signal $x[n]$ is Hermitian, and plot the real and imaginary parts of $X[k]$.

c) Generate the analytic signal $\tilde{x}[n]$ of $x[n]$ using Hilbert transform. Obtain the PSD of $\tilde{x}[n]$, and plot the result in decibel units. For comparison, set the same display range of the plot as that of the PSD_X plotted in (a), except adding a bias of 6 dB to the vertical axis.

d) Apply frequency translation to $\tilde{x}[n]$ to obtain $\tilde{s}[n]$, which is centred at f_c = 16 kHz. Obtain the PSD of $\tilde{s}[n]$, and plot the result in decibel units. For comparison, set the same display range of the plot as that of the PSD of $\tilde{x}[n]$ plotted in (c).

e) Obtain the real-valued signal $s[n] = \mathrm{Re}\{\tilde{s}[n]\}$. Plot the spectrum of $s[n]$, and verify it is Hermitian.

TASK 2

Recall using correlation to estimate the impulse response of an LTI system (Lecture 6, p.13),

$$r_{yx}(t) = y(t) * x(-t) = h(t) * r_{xx}(t)$$

$$R_{yx}(\omega) = H(\omega)R_{xx}(\omega)$$

If $R_{xx}(\omega)$ is a constant, which can be realised using a white noise as the system input, the impulse response $h(t)$ can be estimated from the cross-correlation between the system output and the input.

a) Generate a row vector containing N = 1000 normally distributed random number $e[n]$ with zero mean and standard deviation σ = 2. Compute the autocorrelation $r_{xx}[n]$ of $e[n]$ using the MATLAB function <u>xcorr</u>. Plot it out using <u>stem</u> centred at the origin n = 0.

b) Compute the DFT $R_{xx}[k]$ of $r_{xx}[n]$. Plot the magnitude of $R_{xx}[k]$ in both linear and dB units. Calculate the mean $E(R_{xx}[k])$ of $R_{xx}[k]$, and verify $E(R_{xx}[k]) = N\sigma^2$.

c) For the following two systems, using the correlation method to estimate their respective impulse response, and compare the results with the actual impulse responses.

$$y[n] + 0.5y[n-1] = x[n]$$

$$H(z) = \frac{2.24 + 2.49z^{-1} + 2.24z^{-2}}{1 - 0.4z^{-1} + 0.75z^{-2}}$$

TASK 3

a) Refer to textbook Exercise 3.13 (p.90), use the RTL-SDR device and MATLAB script "…\spectrum\sweep\rtlsdr_rx_specsweep.m" to sweep the RF spectrum from 25MHz to 1.75GHz and explore the obtained spectrum for your local area.

Find out from the code how to set up an RTL-SDR object using the comm.SDRRTLReceiver function, and run the object using the step function.

b) Write your own MATLAB code to use the RTL-SDR device. Set the central frequency to 96.9 MHz, the gain to 40 dB, and the sampling rate f_s = 2.8 MHz to record one block of signal containing N = 4096 samples. Obtain its power spectral density (PSD) using DFT as expressed below

$$\mathrm{PSD}_X\left(\frac{kf_s}{N}\right) = \frac{1}{Nf_s}|X(k)|^2$$

Plot the PSD in decibel unit for the frequency range from $-f_s/2$ to $f_s/2$.

c) Display the PSD of the recorded signal use either periodogram or dsp.SpectrumAnalyzer function in MATLAB, and compare to the result obtained in (a). **Note**: By default, dsp.SpectrumAnalyzer uses Hann window.