ORDRE DES INGÉNIEURS DU QUÉBEC

NOVEMBER 2019 SESSION

Open-book examination
Programmable calculators, communicating calculators and personal computers are not allowed
Duration : 3 hours

16-EL-A3 Signals and Communications

Question 1 : **(20 points)**

Consider the following signal :

$$s(t) = a\cos\left[2\pi f_c t + b\cos(2\pi f_1 t) + c\cos(10\pi f_1 t)\right].$$

a) Determine its phase deviation $\Delta\theta(t)$ (radians).

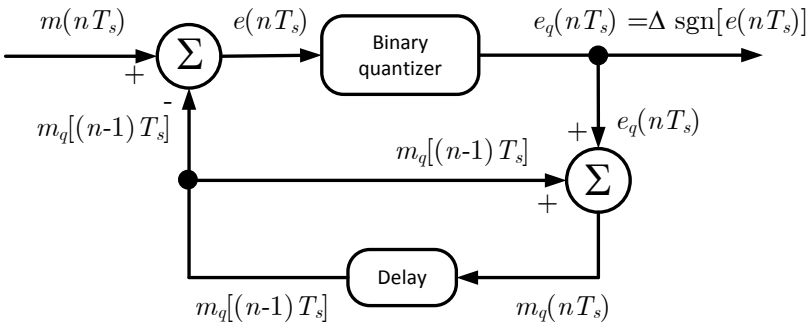
b) Determine its maximum phase deviation $\Delta\theta(t)$ (radians).

c) Determine its instantaneous frequency $f_{\text{inst}}(t)$ (Hertz).

d) Determine its maximum frequency deviation $\Delta f_{\max}$ (Hertz).

Question 2 : **(20 points)**

We want to modulate signal $m(t) = 2\times 10^{-4}\cos(8\times 10^5\pi t)$ [volt] using the Delta modulator shown below with a stepsize of $\Delta = 4\times 10^{-6}$ [volt].



a) What is the minimum sampling frequency f_s needed to avoid slope overload ?

b) Draw the bloc diagram of Delta demodulator, indicating clearly all the components and corresponding signals.

Question 3 : **(20 points)**

A digital system generates data at a rate of 24 megabits per second. This signal is FSK modulated and transmitted over an additive white gaussian noise (AWGN) channel of power spectral density $S_N(f) = \frac{N_o}{2} = 10^{-19}$ Watts per Hertz. The received FSK signal amplitude (without noise) is 80 microvolts in a 50 Ω impedance. **Note :** $Q(z)$ function can be approximated by : $Q(z) \approx \frac{1}{\sqrt{2\pi}z} \exp\left(-z^2/2\right)$.

a) What is the FSK signal energy per bit E_b ?

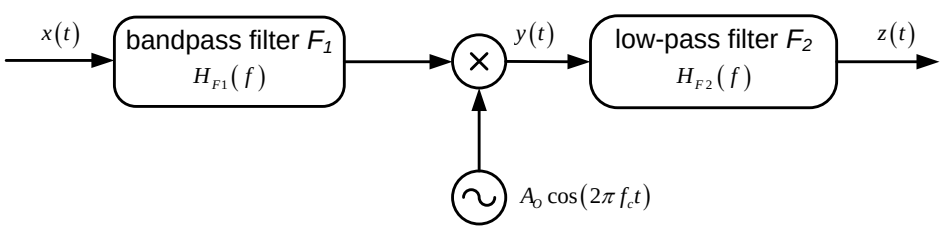
b) Determine the average error probability $P_{\text{FSK-noncoh}}$ if one uses a non-coherent FSK receiver.

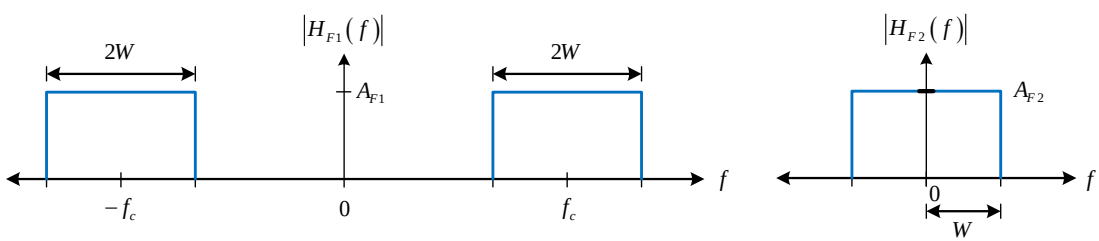
c) What is the average error probability $P_{\text{FSK-coh}}$ if we use a coherent FSK receiver instead.

d) Compare the results obtained with the 2 receivers.

Question 4 : **(20 points)**

The signal $x(t)$ at the circuit input illustrated below consists of gaussian noise with zero mean and power spectral density $S_x(f) = N_0/2$ [W/Hz].





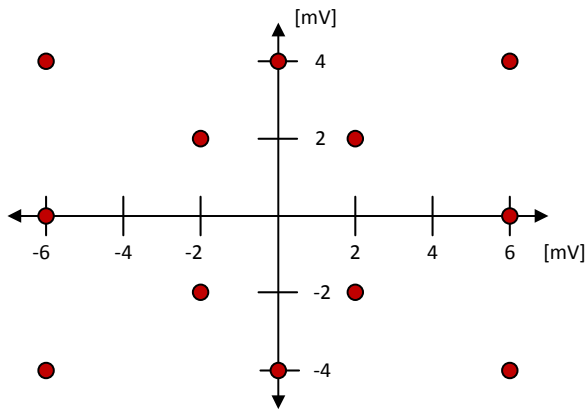
a) Compute the power spectral density $S_z(f)$ at the output of low-pass filter F_2.

b) Determine the autocorrelation function $R_z(\tau)$ of the signal at the output of low-pass filter F_2.

c) What is the signal power P_z at the output of this filter ?

Question 5 : **(20 points)**

Consider the signal constellation below.



a) Write in table form, the coordinates (volts) and corresponding energy (joules) for each symbol, assuming a $Z = 75\Omega$ impedance and symbol duration $T_s = 2$ ms.

b) Compute the average energy per symbol E_s (joules [J]) for this signal constellation.