ORDRE DES INGÉNIEURS DU QUÉBEC

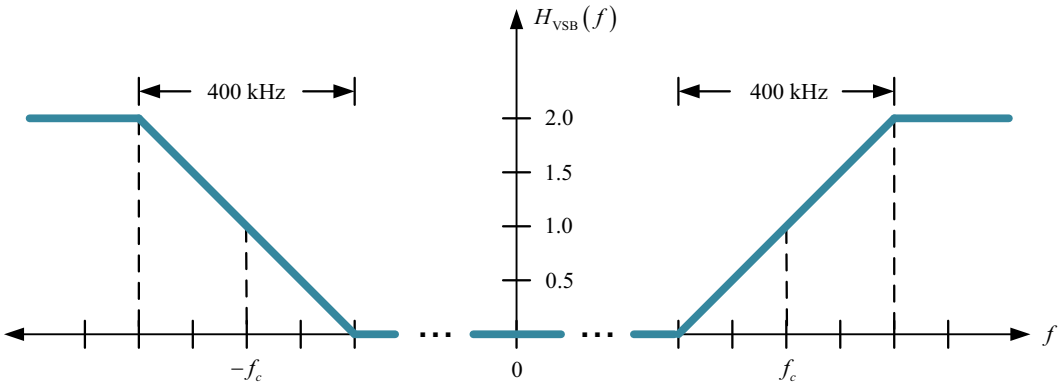
NOVEMBER 2012 SESSION

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

07-ÉLEC-A3 Signals and Communications

Question 1 : **(20 points)**

Message $m(t) = 2\cos(2 \times 10^5 \pi t) + 5\cos(6 \times 10^5 \pi t)$. $m(t)$ is transmitted using vestigial sideband modulation (VSB) with a carrier frequency of 10 MHz and $A_c = 1$. The amplitude response of the VSB filter is shown below.



a) Give the expression of amplitude spectrum $M(f)$ indicating clearly the values of each spectral component. *(5 points)*

b) Write the expression of the VSB signal spectrum du $S_{\text{VSB}}(f)$ indicating the spectral components. *(5 points)*

c) Give the expression of the power spectral density $\mathcal{P}_{\text{VSB}}(f)$ of the VSB signal with the spectral components. *(5 points)*

d) What is the average power of the signal VSB, P_{VSB} ? *(5 points)*

Question 2 : **(20 points)**

In FM broadcasting, the RF carrier is in the frequency range :

$$88.1 \text{ MHz} \leq f_c \leq 107.9 \text{ MHz}$$

The bandwidth dedicated to each radio station is 200 kHz. IF frequency f_{IF} is 10.7 MHz. Baseband messages have a bandwidth $B = 15$ kHz and the maximum frequency deviation $\Delta f_{\text{max}} = 75$ kHz.

a) Is this narrowband or wideband FM modulation ? *(5 points)*

b) Using Carson's rule, evaluate the effective transmission bandwidth B_T of each radio station. *(5 points)*

c) Draw the block diagram of a superheterodyne receiver for demodulation of FM signals. Describe clearly and briefly each component, from received RF signal to the demodulated message. *(5 points)*

d) We want to select the signal coming from a radio station operating at carrier frequency $f_c = 106.3$ MHz. What is the frequency of the receiver's local oscillator ? *(5 points)*

Question 3 : **(20 points)**

We want to transmit 24 analog signals, $m_1(t), \cdots, m_{24}(t)$ of 100 kHz bandwidth each using PCM modulation.

a) What is the minimum sampling frequency for each of these 24 signals such as to be able to recover them at the receiver ? *(5 points)*

b) These 24 signals are time division multiplexed (TDM). Sketch the MRT time frame indicating clearly the location and duration of the multiplexed samples. *(5 points)*

c) If we use an uniform quantizer with $L = 2^{24}$ levels, what will be the bit rate R_b of the multiplexed PCM signal ? *(5 points)*

d) To modulate the multiplexed PCM signal in bandpass, we use 16 level PSK modulation (16-PSK) and a raised-cosine filter with roll-off factor $\alpha = 0.35$. What is the bandwidth of the modulated signal ? *(5 points)*

Question 4 : **(20 points)**

Message $m(t) = \cos(200\pi t) + \cos(1200\pi t)$ is transmitted using frequency modulation with a carrier of 140 kHz and a deviation constant $D_f = 10$ [radians/volt-second]. The modulated signal power is $P = 50$ [Watts] (normalized to 1 Ω).

a) Write the expression frequency modulated signal $s_{\mathrm{FM}}(t)$ indicating the numerical values. *(5 points)*

b) What is the maximum frequency deviation $\Delta f_{\max}$? *(5 points)*

c) What is the maximum phase deviation $\Delta\Theta_{\max}$? *(5 points)*

d) Write the expression of the instantaneous frequency $f_i(t)$. *(5 points)*

Question 5 : **(20 points)**

Message $m(t)$, with bandwidth $B = 200$ kHz, is modulated using DSB modulation (suppressed carrier) and transmitted over an additive white gaussian noise channel. The noise power spectral density is $\frac{N_0}{2} = 10^{-12}$ [W/Hz]. Channel propagation loss is 70 dB. The signal to noise ratio at the receiver output $\left(\frac{S}{N}\right)_{\text{output}}$ should be at least 50 dB.

a) What is the bandwidth, B_T, of the transmitted signal ? *(4 points)*

b) What is the noise power $P_{n_{\text{input}}}$ at the receiver's input ? *(4 points)*

c) What is the signal to noise ratio $\left(\frac{S}{N}\right)_{\text{input}}$ at the receiver's input ? *(4 points)*

d) What is the minimum signal power $P_{s_{\text{input}}}$ at the receiver's input ? *(4 points)*

e) What is the minimum signal power $P_{s_{\text{transmitter}}}$ at the transmitter's output ? *(4 points)*