ORDRE DES INGÉNIEURS DU QUÉBEC

NOVEMBER 2017 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 : **(30 points)**

In a 4G cellular system, a 20 MHz bandwidth signal is transmitted at a carrier frequency of 2.496 GHz. The base station sends the signal using an isotropic antenna over a cell of 2.5 km radius.

a) Determine the mobile receiver antenna gain, $G_{RX,dB}$ in dB, required to obtain a maximum attenuation a_{max} of 80 dB in the cell.

b) If the mobile receivers are uniformly distributed in the cell, then the average attenuation (in linear) can be expressed as :

$$a_{ave} = \frac{1}{\pi d_{max}^2} \int_0^{2\pi} \int_0^{d_{max}} a(r) r dr d\varphi$$

where d_{max} is the maximum distance maximale and $a(r)$ is the attenuation as a function of distance r, expressed in meters, between the base station and a mobile receiver. What is the receive antenna gain, $G_{RX,dB}$ in dB, needed to get an average attenuation of 80 dB ?

Question 2 : **(20 points)**

A signal is sampled at 384 000 samples per second. The samples are encoded as 32-bit words.

a) Knowing that the signal to quantizing noise ratio for a sinewave over the whole dynamic range is $SQNR = \frac{3}{2}L^2$, L being the number of quantizing levels, what is the numerical value of the signal to quantizing noise ratio in dB, i.e. $SQNR_{dB}$?

b) What is the resulting bit rate R_b ?

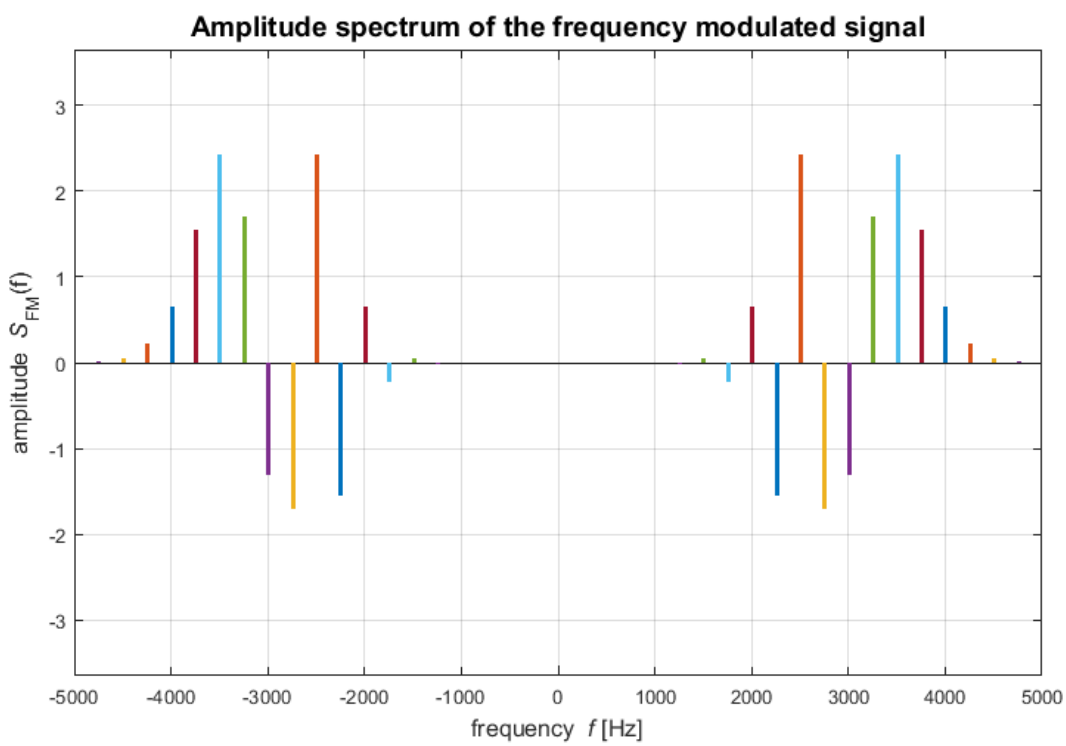
Question 3 : **(10 points)**

We want to sample $s(t)$ uniformly in time signal to represent it in digital form. What is the maximum time interval T_s between samples such as to be able to perfectly reconstruct the signal ?

$$s(t) = 10\cos^2(4800\pi t) + 5\sin\left(1600\pi t + \frac{7\pi}{11}\right)$$

Question 4 : **(20 points)**

An FM signal is modulated with message $m(t) = A_m \cos(2\pi f_m t)$. The measured amplitude spectrum, $S_{FM}(f)$, is shown below :



a) What is the carrier frequency f_c ?

b) What is the message frequency f_m ?

c) What is the FM modulation index β_f ? Is it a narrowband or a wideband signal ?

d) Using Carson's rule, estimate the transmission bandwidth, B_T, of the FM signal.

e) Write the expression of the modulated signal $s_{FM}(t)$ as a function of time, indicating the numerical values.

f) What is the power, P_{FM}, of this FM signal ?

Question 5 : **(20 points)**

A source generates a binary sequence at a rate of $R_b = 180$ Mbits/s. The sequence is bandpass modulated at a carrier frequency of $f_c = 9.8$ GHz using 256-PSK modulation and filtered with a raised-cosine filter.

a) Is it possible to transmits these 256-PSK symbols at the carrier frequency with a $B_T = 24$ MHz bandwidth ? Justify your answer. If so, what is the roll-off factor α ?

b) What is the minimum transmission bandwidth with the 256-PSK modulation if we can vary the roll-off factor α ?

Bessel function (for $0 \leq n \leq 10$)

n	$J_n(0)$	$J_n(1)$	$J_n(2)$	$J_n(3)$	$J_n(4)$	$J_n(5)$	$J_n(6)$	$J_n(7)$	$J_n(8)$	$J_n(9)$	$J_n(10)$
0	1	0.7652	0.2239	-0.2601	-0.3971	-0.1776	0.1506	0.3001	0.1717	-0.0903	-0.2459
1		0.4401	0.5767	0.3391	-0.0660	-0.3276	-0.2767	-0.0047	0.2346	0.2453	0.0435
2		0.1149	0.3528	0.4861	0.3641	0.0466	-0.2429	-0.3014	-0.1130	0.1448	0.2546
3		0.0195	0.1289	0.3091	0.4302	0.3648	0.1148	-0.1676	-0.2911	-0.1809	0.0584
4		0.0025	0.0340	0.1320	0.2811	0.3912	0.3516	0.1578	-0.1054	-0.2655	-0.2196
5			0.0070	0.0430	0.1321	0.2611	0.3621	0.3479	0.1858	-0.0550	-0.2341
6			0.0012	0.0114	0.0490	0.1310	0.2458	0.3392	0.3376	0.2043	-0.0145
7				0.0025	0.0152	0.0534	0.1296	0.2336	0.3206	0.3275	0.2167
8					0.0040	0.0184	0.0565	0.1280	0.2235	0.3051	0.3179
9						0.0055	0.0212	0.0589	0.1263	0.2149	0.2919
10						0.0015	0.0069	0.0235	0.0608	0.1247	0.2075
11							0.0020	0.0083	0.0256	0.0622	0.1231
12								0.0027	0.0096	0.0274	0.0634
13									0.0033	0.0108	0.0290
14									0.0010	0.0039	0.0120
15										0.0013	0.0045
16											0.0016