Module IT.2407
Homework 2: Digital Transmission Chain

2021 – 2022

Problem 1: Binary representation of a sound message

To represent the sound message by a binary stream, you need to use MATLAB. You don't need to program in MATLAB, but you need to change parameters in the file Prob1.m. Run the program section by section and not all at ones. You need to put the .m file in the same folder as the file Haydn.wav. This file is a 15.4 second stereo file sampled with a sampling frequency of 44.1 kHz and each sample Is coded into 16 bits, leading to a total file size of 2.7 Mo.

The goal of this problem is to see the effect of a bad choice of sampling period on the sound (aliasing), as well as an insufficient number of the quantization levels on the quality of the sound.

1. Read and understand the matlab code. Find the max frequency of the audio signal.
2. Change the parameter k to 4 and 16 in line 36 to increase the sampling period. Observe the spectrum of the signal and conclude on the aliasing problem.
3. Change the level of the quantization in line 56 to 16 and 64. Listen to the sound and comment on the effect of the quantization on the signal.
4. To convert the signal to binary, we use the uniform coding (line 74 to 79) and the Huffman coding (line 83 to the end). Compare the length of the stream in both cases with the original one
   Don't draw the Huffman tree yourself.

Problem 2: Single carrier modulation

A text message is transmitted using a single carrier 16QAM modulation (illustrated in Figure 1) operating on a frequency carrier 800 MHz and within a bandwidth of 1 MHz. The data rate is 2Mbps.

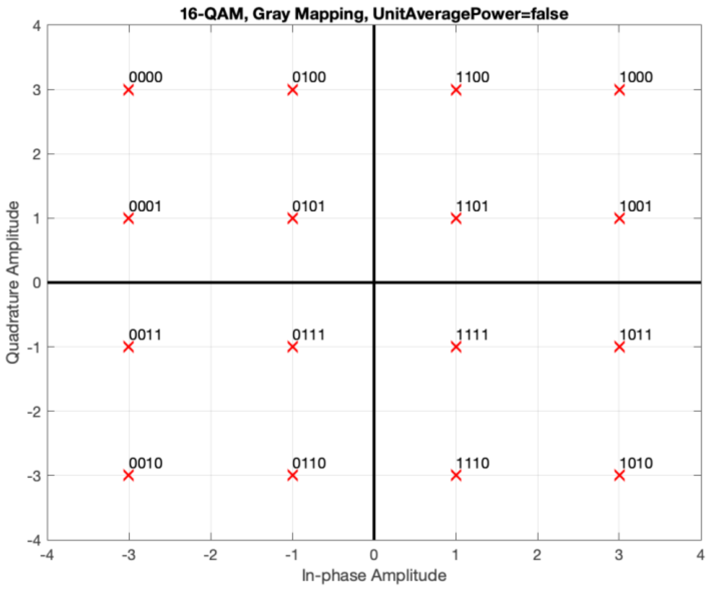

Figure 1: 16QAM constellation

The received text message over a wireless interface with SNR. = 1 dB is illustrated in Figure 2.

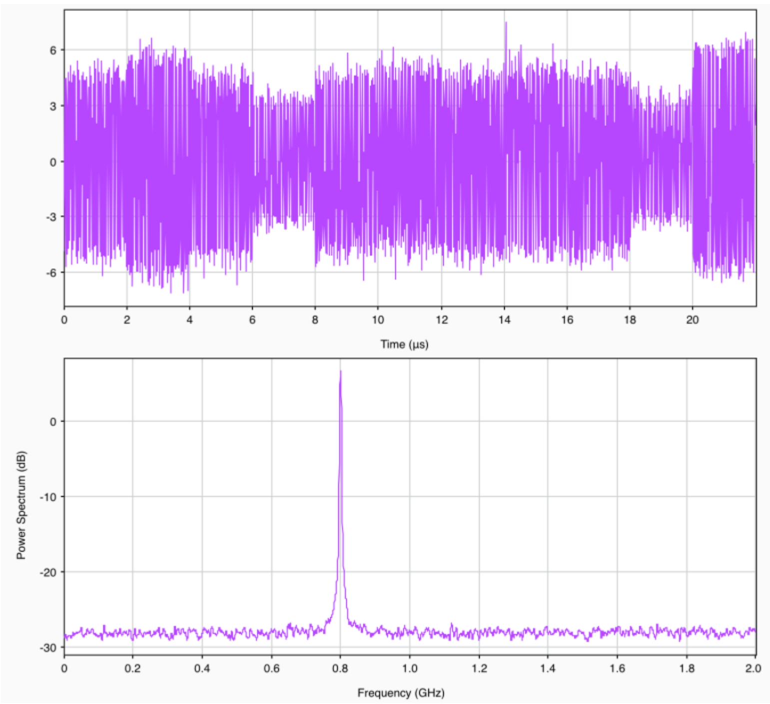

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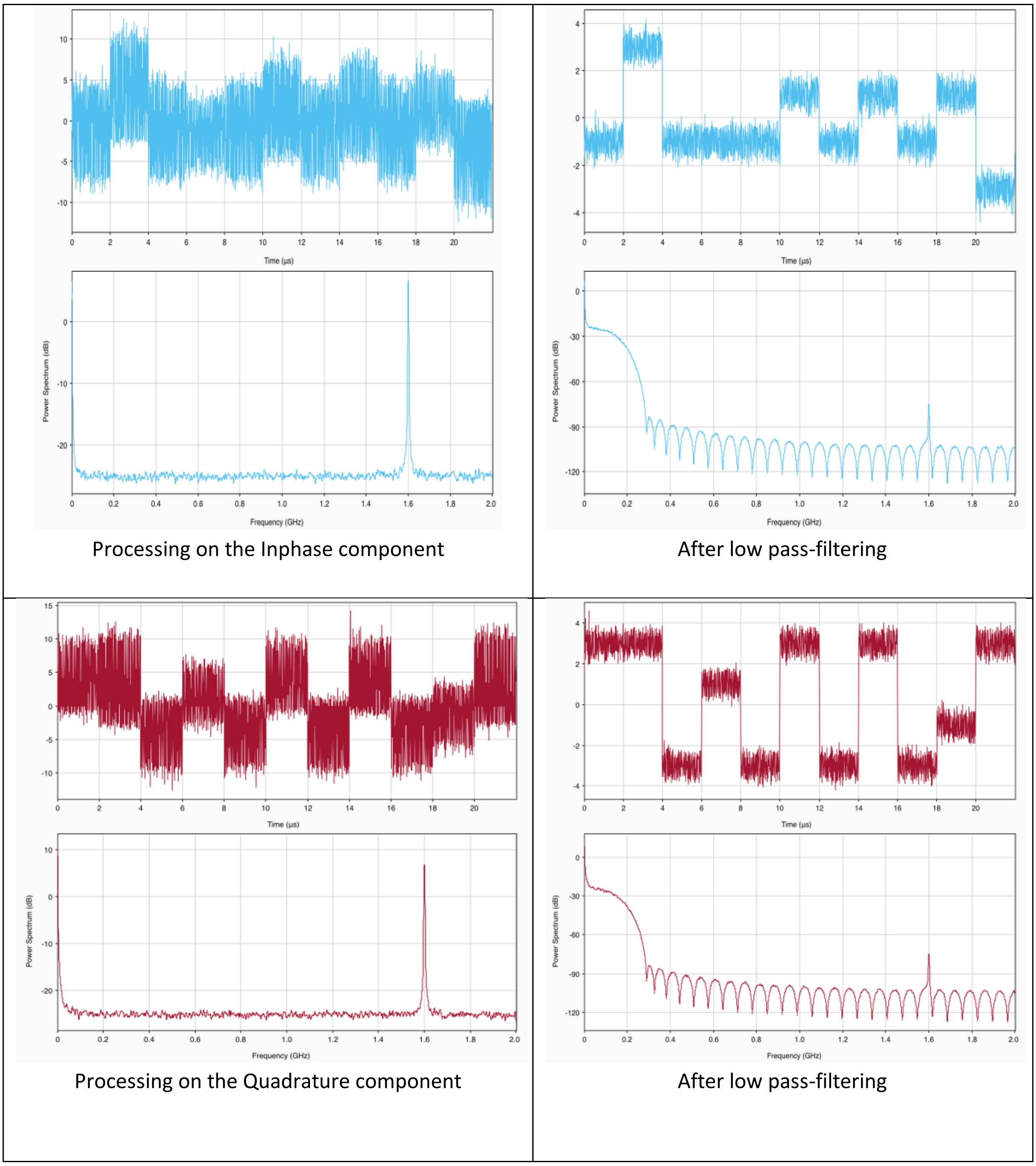
Figure 2: Received Signal

The different steps resulting from the processing of the signal are illustrated in Figure 3.



Processing on the Inphase component

After low pass-filtering

Processing on the Quadrature component

After low pass-filtering

Figure 3: Processing of the received signal at the demodulator

1. Recall how the demodulation is made to find back the signal.
2. Comment the processing of the received signal illustrated in Figure 2 at the reception.
3. Indicate the duration of the symbols and find back the 16QAM symbols.
1. Find the name of the song that was transmitted on the wireless interface. using the ascii decoder accessible on https://www.rapidtables.org/fr/convert/number/binary-to-ascii.html
   Important: Set the field Encodage de caractères (facultatif) to ASCII (THIS IS NOT DONE BY DEFAULT)
   Who is the singer of this song?

Problem 3: OFDM signal

We consider an OFDM system operating on the frequency 800 MHz. The total bandwidth of 1.4 MHz of is divided into N = 128 sub-carriers with spacing Δf. The total duration of the OFDM symbol carrying N symbols modulated with a 16QAM constellation is equal to T = N/Fs with Fs being the sampling frequency Fs = 1.92 MHz.
The OFDM signal corresponds to a text message (in Figure 1) coded using an ASCII code, with an error correction code corresponding to a parity check code such that $(b_0, b_1, b_2) \rightarrow (b_0, b_1, b_2, b_0 \oplus b_1 \oplus b_2)$
We recall that this OFDM signal with duration T. is:

$$\mathrm{x_e}(\mathrm{t}) = \sum_{k=1}^{128} (A_k\, cos(2\pi f_k t) - B_k sin(2\pi f_k t))\, rect(t, T)$$

with $f_1 = 800$ MHz and A_k and B_k correspond to the I and Q amplitude of the 16QAM symbols. The coded text message **occupies only 24 subcarriers**, and all other sub-carriers are left empty (meaning $A_k = B_k = 0$, for $25 \leq k \leq 128$). The 16QAM constellation that maps the binary bit is illustrated in Figure 1.

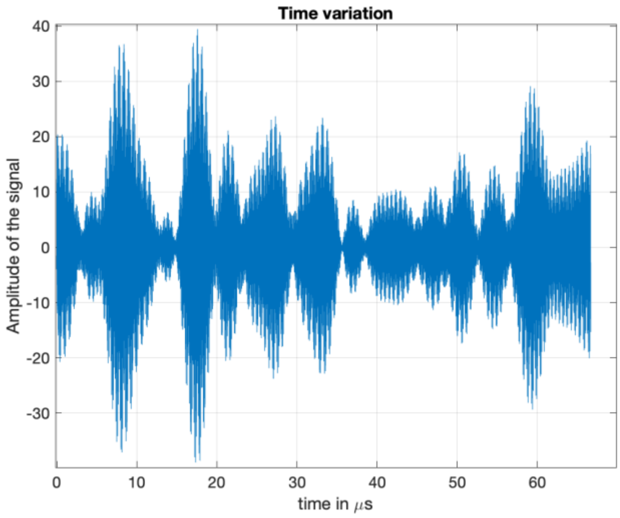


Figure 4: Time variation of OFDM signal

The spectrum analysis of this signal multiplied by 2 is a complex number. The real component of the Fourier Transform of 2 $\mathrm{x_e}(\mathrm{t})$ is given in Figure 5:

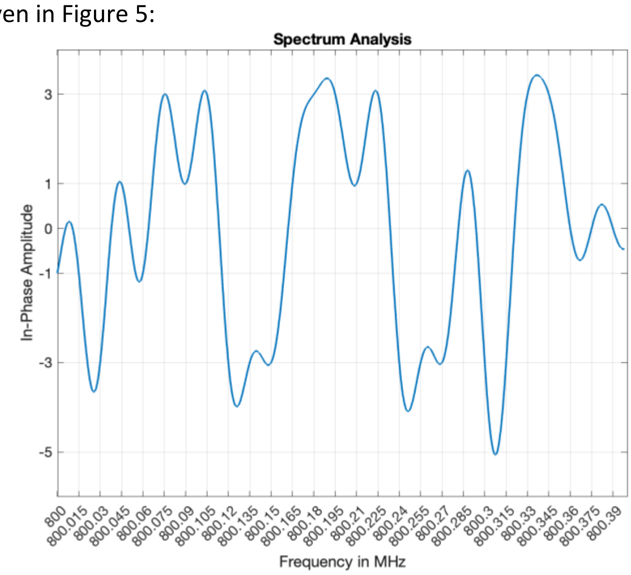


Figure 5: Real component of the Fourier Transform of 2xe(t)

And its imaginary component is given in Figure 6:

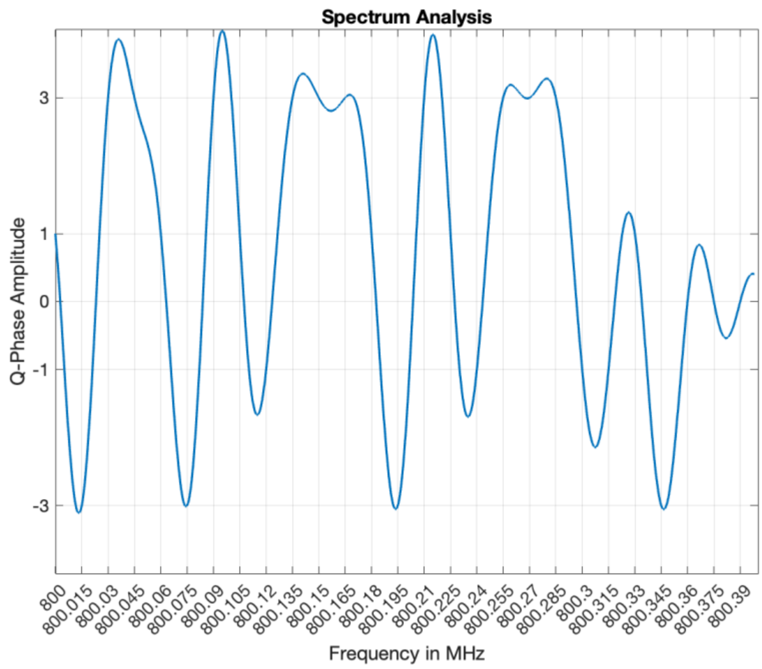


Figure 6: Imaginary part of the Fourier Transform of 2xe(t)

2. Find the spacing between the sub-carriers that guarantees orthogonal sub-carriers?
3. Find the data rate of this signal.
4. Using the spectrum analysis, find the 16QAM symbols transmitted in this message, and the corresponding binary message.
5. Remove the redundancy bits and find back the name of the song transmitted in this message using the ascii decoder accessible on https://www.rapidtables.org/fr/convert/number/binary-to-ascii.html
   Important: Set the field Encodage de caractères (facultatif) to ASCII (THIS IS NOT DONE BY DEFAULT)
   Who is the singer of this song?