Problem 1: Single carrier modulation

1. Demodulation the signal to find back.

1) The form of the modulated signal is:

$$y(t) = \sqrt{SNR}[A_k \cos(2\pi f_0 t) - B_k \sin(2\pi f_0 t)] + Noise$$
$$A_k = Acos(\varphi), the\ inphase\ component$$
$$B_k = Asin(\varphi), the\ quadrature\ component$$

A – Amplitude

φ – the phase determined by the 16QAM constellation diagram

2)

$$A_k: y(t) * 2\cos(2\pi f_0 t)$$

- $\cos(2\pi f_0 t) * cos\,(2\pi f_0 t) = \frac{1}{2}[cos0 + \cos(4\pi f_0 t)] = \frac{1}{2}[1 + \cos(4\pi f_0 t)]$
- $\sin(2\pi f_0 t) * cos\,(2\pi f_0 t) = \frac{1}{2}[\sin(4\pi f_0 t)]$

Then,

$$y(t) * 2\cos(2\pi f_0 t) = \sqrt{SNR}\,\{A_k\,[1 + \cos(4\pi f_0 t)] - B_k \sin(4\pi f_0 t)\} + N$$

Remove high-frequency ($\cos(4\pi f_0 t), \sin(4\pi f_0 t)$) components with a low-pass filter (with a frequency $\frac{1}{duration\ of\ a\ symbol}$), to get $\sqrt{SNR} * A_k$.

3)

$$B_k:\ y(t) * [-2\sin(2\pi f_0 t)]$$

- $\cos(2\pi f_0 t) * sin\,(2\pi f_0 t) = \frac{1}{2}[\sin(4\pi f_0 t)]$
- $\sin(2\pi f_0 t) * sin\,(2\pi f_0 t) = \frac{1}{2}[1 - \cos(4\pi f_0 t)]$

Then,

$$y(t) * [-2\sin(2\pi f_0 t)] = \sqrt{SNR}\,\{-A_k \sin(4\pi f_0 t) + B_k\,[1 - \cos(4\pi f_0 t)]\} + N$$

Remove high-frequency ($\cos(4\pi f_0 t), \sin(4\pi f_0 t)$) components with a low-pass filter (with a frequency $\frac{1}{duration\ of\ a\ symbol}$), to get $\sqrt{SNR} * B_k$.

4) Based on $A_k = Acos(\varphi), B_k = Asin(\varphi)$, can get A and φ.

2. The processing of the received signal.

In-phase Component Processing Flow

1) **Receiving the Signal:** receive the signal transmitted at a carrier frequency of 800 MHz.
2) **Spectrum Analysis:** Perform spectrum analysis on the received signal, finding that the signal has energy distributed around 0 GHz and 1.6 GHz (2 * 800 MHz).
3) **Multiplying the Signal by $2\cos(2\pi f_0 t)$**: To extract the in-phase component A_k, multiply the signal by $2\cos(2\pi f_0 t)$. This generates a new signal containing components of the original signal and a high-frequency component.
4) **Low-pass Filtering:** Pass the product signal through a low-pass filter to remove high-frequency components around 1.6 GHz, retaining only the baseband signal. After

filtering, the time-domain signal becomes clearer, mainly containing low-frequency oscillations representing different binary symbols and a small amount of noise.

5) **Reading A_k**: In the time-domain signal, read the in-phase component A_k. These values correspond to the in-phase component of the original 16QAM modulated signal.

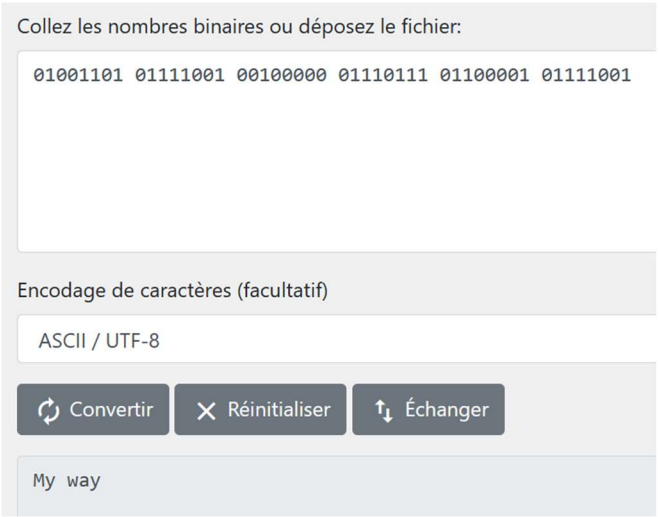
Quadrature Component Processing Flow

1) **Multiplying the Signal by $-2\sin(2\pi f_0 t)$**: To extract the quadrature component B_k, multiply the signal by $-2\sin(2\pi f_0 t)$. This generates a new signal containing components of the original signal and a high-frequency component.
2) **Low-pass Filtering:** Pass the product signal through a low-pass filter to remove high-frequency components around 1.6 GHz, retaining only the baseband signal. After filtering, the time-domain signal becomes clearer, mainly containing low-frequency oscillations representing different binary symbols and a small amount of noise.
3) **Reading B_k**: In the time-domain signal, read the quadrature component B_k. These values correspond to the quadrature component of the original 16QAM modulated signal.

3. Indicate the duration of the symbols.

(-1, 3) ->0100
(1, 1) ->1101
(-1, -1) ->0111
(3, 1) ->1001
(-3, -3) ->0010
(-3, 3) ->0000
(-1, -1) ->0111
(-1, -1) ->0111
(-1, -3) ->0110
(-3, 1) ->0001
(-1, -1) ->0111
(3, 1) ->1001

4. Name of the song.



Problem 2: OFDM signal

1. Find the spacing.

Between two neighbours' subcarriers:

- $\Delta f = \frac{1}{T}$, $T\ is\ the\ duration\ of\ an\ OFDM\ symbol\ transmitted.$
- $N = 128, the\ number\ of\ the\ subcarriers.$
- $T = \frac{N}{Fs}$
- $\Delta f = \frac{1}{T} = \frac{Fs}{N} = \frac{1.92*10^6}{128} = 15kHz$

2. Find the data rate.

1) For using 32AQM, and the message occupies only 20 subcarriers:

$$f_s = \frac{1}{T_s} = 15k\ Baud$$

2) Information bits per symbol = $20 * 5 * \frac{4}{5} = 80\ bits/symbol$

3) $R_{data} = f_s * information\ bits\ per\ symbol = 15000 * 80 = 1.2Mb/s$

3. Find the 16QAM symbols transmitted.

(-1, -3)->01010
(-3, -1) ->01111
(-3, 3) ->01100
(-1, -5) ->00011
(-3, 3)->01100
(1, 3) ->11000
(-3, 3) ->01100
(5, -1) ->10111
(-5, 1) ->00101
(-3, 5) ->00000
(-1, 1) ->01001
(-1, -5) ->00011
(-3, 3) ->01100
(1, 3) ->11000
(-3, 3) ->01100
(3, -3) ->11110
(-3, 3) ->01100
(3, 1) ->11101
(-3, 3) ->01100
(-1, -3) ->01010

4. Name of the song.