Universitat de Lleida

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Communication Services and Security
Exercise 5

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1 Problem

Let's assume we employ 4 APs at the UNII band. We use 3 spatial streams, a 1/2 coding rate, a transmission rate of 100 Mbps and a 32 QAM modulation.

1. **Which is the bit time ? Which is the symbol time for each spatial stream ?**
   Bit time is defined as as the time it takes for one bit to be ejected from a network interface controller (NIC) operating at some predefined standard speed. It is calculated divinding 1 by the transmission rate multiplied. Then as we know that the transmissionrate is 100 Mbps:

$$T_b = \frac{1}{100 * 10^6} = 0.01 \mu s \tag{1}$$

   Then the symbol time for each spatial steam taking into account the previous variables indications (M = spatial streams = 3, 1/r = code rate = 1/2 and n = is the number of bits sent per symbol = 5) is as it follows:

$$T_s = (n * \frac{M}{r}) * (T_b) = (5 * \frac{3}{2}) * (0.01 \mu s) = 75ns \tag{2}$$

2. **Assuming that the period of the transmitted signal is twice the symbol time and that its bandwidth is defined by the main lobe plus the two side lobes (right and left from the main), which is the signal bandwidth ?**

   We assume that:

$$T_b = 2 * T_s = 2 * 75 * 10^{-9} = 150ns$$

   And:

$$f_0 = \frac{1}{T_b}$$

   Then:

$$BW = 8 * f_0 = 8 * \frac{1}{T_b} = 8 * \frac{1}{150 * 10^{-9}} = 53.33MHz \tag{3}$$

3. **Propose a channel assignment for each AP considering:**
   - **all 4 APs interfere between them,**
   - **the lowest usable channel is 36,**
   - **to minimize the frequency gap between channels,**
   - **the frequency allocation for Europe** http://en.wikipedia.org/wiki/U-NII

Before assigning a channel for each AP, we know the following requirements: that the lowest usable channel must be 36. The frequency must have an European allocation, the channels must not have interferences and lastly the frequency gap between them must be minimal. Having into account the previous optained bandwith 53.33MHz, the following table summarizes the different channels allowed for Europe and their frequency:

Band	**Channel**	**Frequency (MHZ)**	**Europe**
U-NII-1	**36**	5180	Yes
U-NII-1	38	5190	No
U-NII-1	40	5200	Yes
U-NII-1	42	5210	No
U-NII-1	44	5220	Yes
U-NII-1	46	5230	No
U-NII-1	48	5240	Yes
U-NII-2A	52	5260	Yes
U-NII-2A	56	5280	Yes
U-NII-2A	60	5300	Yes
U-NII-2A	64	5320	Yes
U-NII-2B		5350–5470	Unknown
U-NII-2C	100	5500	Yes

Table 1: Frequency allocation for Europe.

Then the solution found is:

AP	**Channel**	**Frequency (MHZ)**	**Frequency + BW (MHZ)**
1	36	5180	5233,33
2	48	5240	5293,33
3	60	5300	5353,33
4	100	5500	–

Table 2: Channel assignment.

2 Problem

Consider a 802.11b Channel 1 with a 22 MHz perfect pass-band filter at transmitters and receivers. BPSK at 6 Mbps is employed. Assume the following two transmissions getting the receiver with the same power:

1. **A periodic signal (101010. . .) at channel 1**
2. **A periodic signal (100100. . .) at channel X (interferent)**

Plot the received base-band signal during two bits time considering two cases; X = 3 and X = 6 and detail the procedure to obtain the received base-band signal.

2.1 Considerations, periods and coefficients

The further calculartions will be done considering the provided information about the channel distributuion.

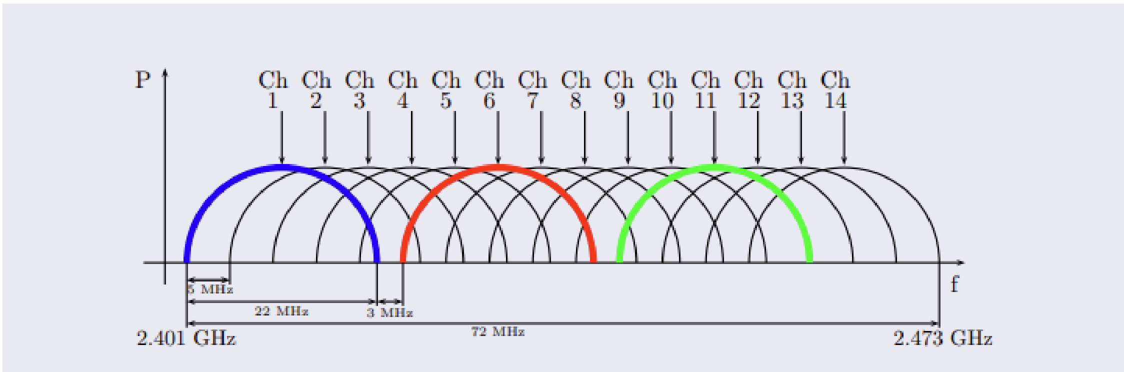

Figure 1: Channel distribution.

The following Figure plots the the previous described periodic signals.

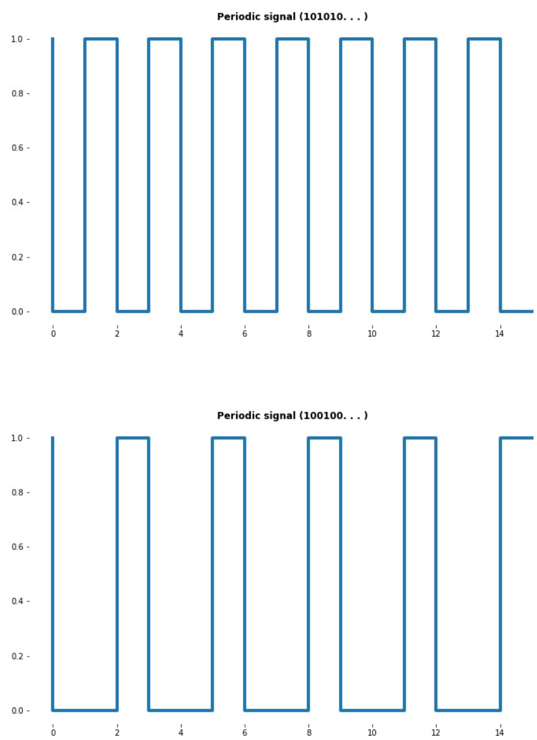

Figure 2: Periodic signals.

In further steps this signals will be refered as Signal 101 and Signal 100. Next, the signal period was calculated:

$$\mathrm{T}_b = \frac{1}{100*10^6}$$

$$\mathrm{T}_{100} = 2 * T_b$$

$$\mathrm{T}_{101} = 3 * T_b$$

Then considering the following formulas for coefficients computation:

$$a_0 = \frac{2}{T}\int_T^0 s(t)\,dt$$

$$a_n = \frac{2}{T}\int_T^0 s(t) * cos(\frac{2\pi nt}{T})\,dt$$

$$b_n = \frac{2}{T}\int_T^0 s(t) * sin(\frac{2\pi nt}{T})\,dt$$

Finally with the previous periods and coefficients, we calculated the Fourier coefficients for each signal:

- **Signal 101**

$$a_0 = \frac{2}{T}\frac{T}{3} = \frac{2}{3}$$

$$a_n = \frac{2}{T}(\int_0^{\frac{T}{2}} 1 * cos(\frac{2\pi nt}{T})\,dt + \int_{\frac{T}{2}}^{T} 0 * cos(\frac{2\pi nt}{T})\,dt) = \frac{2}{T}\int_0^{\frac{T}{2}} 1 * cos(\frac{2\pi nt}{T})\,dt$$

$$b_n = \frac{2}{T}\int_0^{\frac{T}{2}} s(t) * sin(\frac{2\pi nt}{T})\,dt = 0$$

- **Signal 100**

$$a_0 = \frac{2}{T}\frac{T}{2} = 1$$

$$a_n = \frac{2}{T}(\int_0^{\frac{T}{3}} 1 * cos(\frac{2\pi nt}{T})\,dt + \int_{\frac{T}{3}}^{T} 0 * cos(\frac{2\pi nt}{T})\,dt) = \frac{2}{T}\int_0^{\frac{T}{3}} 1 * cos(\frac{2\pi nt}{T})\,dt$$

$$b_n = \frac{2}{T}\int_0^{\frac{T}{3}} s(t) * sin(\frac{2\pi nt}{T})\,dt = 0$$

Considering that the bandiwht is 22MHz, the number of coefficients to compute for the base signal are

$$\frac{22}{3} = 7$$

Result obtained after:

$$F_{101} = 6MHz$$

$$F_{100} = \frac{1}{2 * T_b} = \frac{F_0}{2} = \frac{6}{2} = 3MHz$$

2.2 Calculations

The calculations were made using python libraries, the following portion of code summarizes how te coefficients a and b were obtained for the base signal:

```
period = 2
channel1 = int(2401 + 22/2)

# A Coefficient
ax = []
ay = []

# Adding central one
ay.append(cosIntegral(t, T1, 0, period))
ax.append(channel1)

for n in range(1,4):
  ay.append(cosIntegral(t, T1, n, period)/2)
  ay.append(cosIntegral(t, T1, n, period)/2)
  ax.append(channel1 + n*3)
  ax.append(channel1 - n*3)

# B Coefficient
by = []
bx = []

# Adding central one
by.append(sinIntegral(t, T1, 0, period))
bx.append(channel1)

for n in range(1,4):
  by.append(sinIntegral(t, T1, n, period)/2)
  by.append(sinIntegral(t, T1, n, period)/2)
  bx.append(channel1 + n*3)
  bx.append(channel1 - n*3)
```

Figures 3 and 4 show the signals obtained after modulation and demodulation whithout interference for both signals. The period time was extended, as a consequence the signals patterns is easier observed.

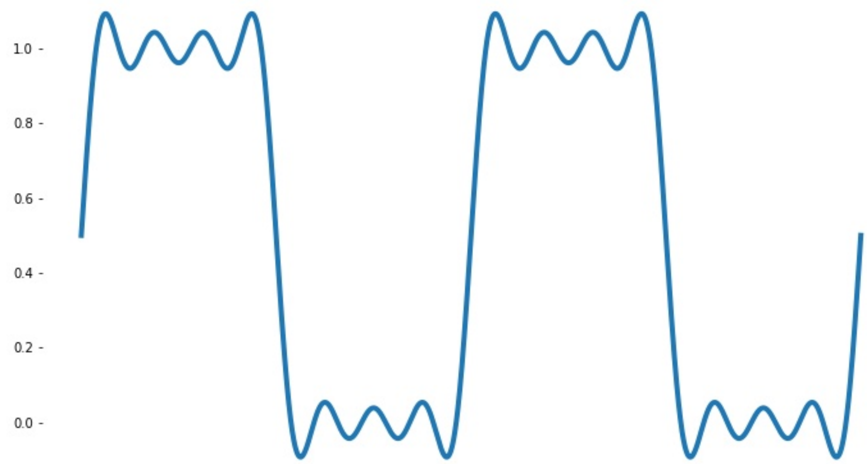

Figure 3: Signal 101 without interference.

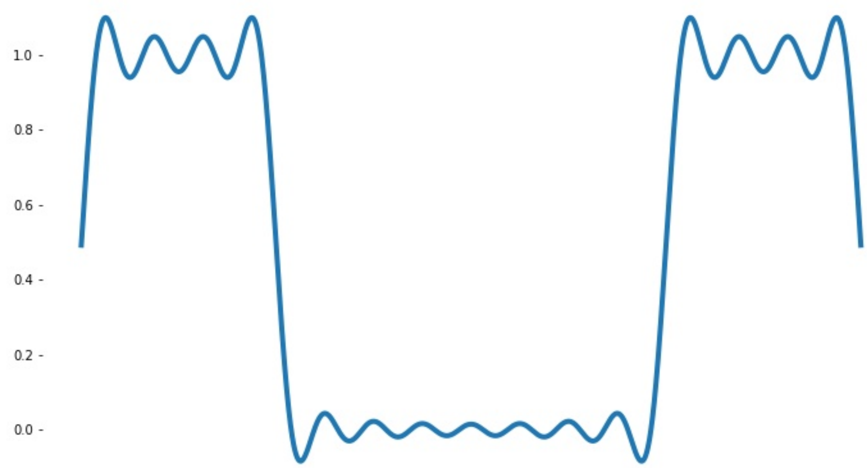

Figure 4: Signal 100 without interference.

2.2.1 Base Signal - Channel 1

Figure 5 shows the coefficients of the Signal 101 modulated. The signal channels are represented with the blue slight lines. The Figure 6 is a complementary figure which distinguishes between a and b coefficients.

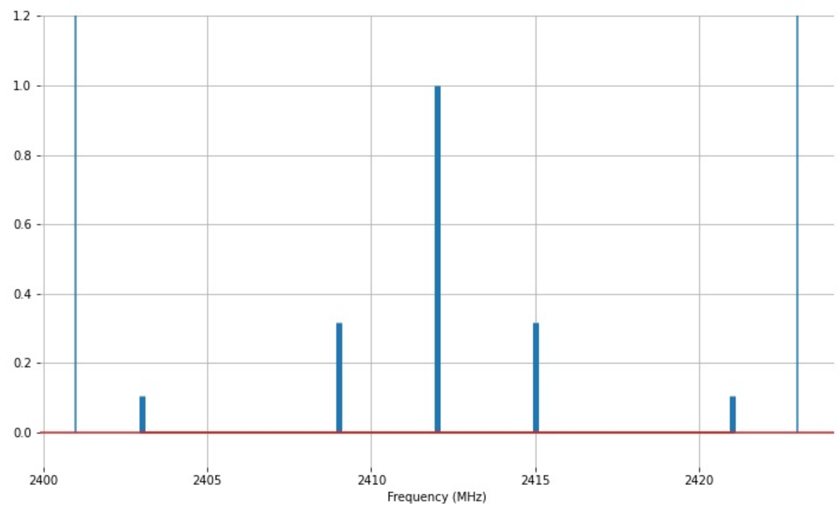

Figure 5: Coeff Original Signal 101 Modulated.

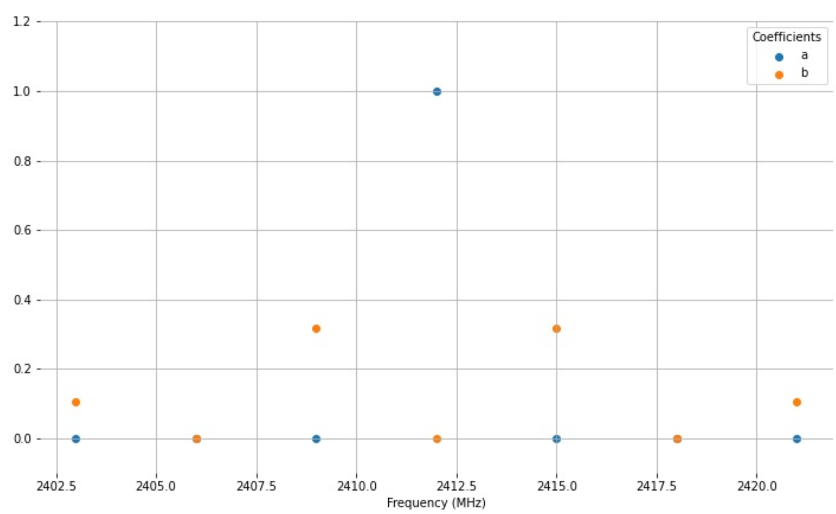

Figure 6: Coeff Original Signal 101 Modulated (a,b coeffs).

2.2.2 Secondary Signal - Channel 3

Figure 7 shows the coefficients of the Signal 100 modulated in channel 3. The signal channels are represented with the blue slight lines. The Figure 8 is a complementary figure which distinguishes between a and b coefficients.

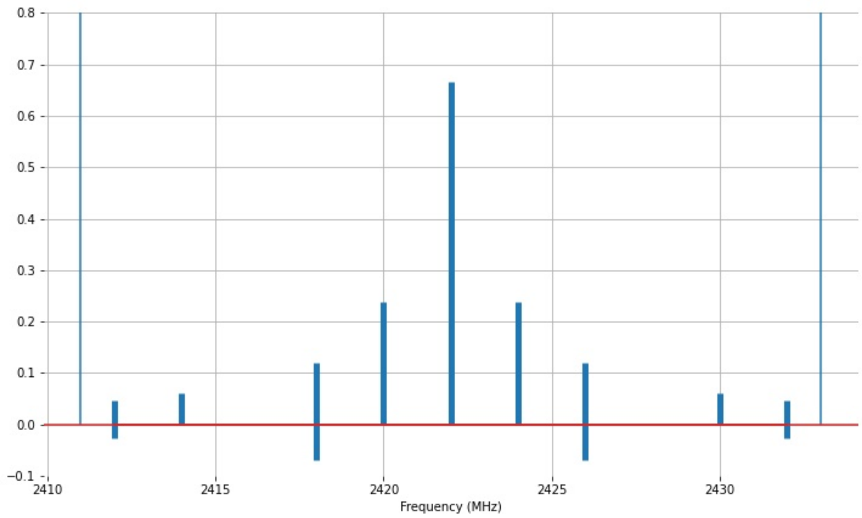

Figure 7: Coeff Interferent Signal 100 Modulated.

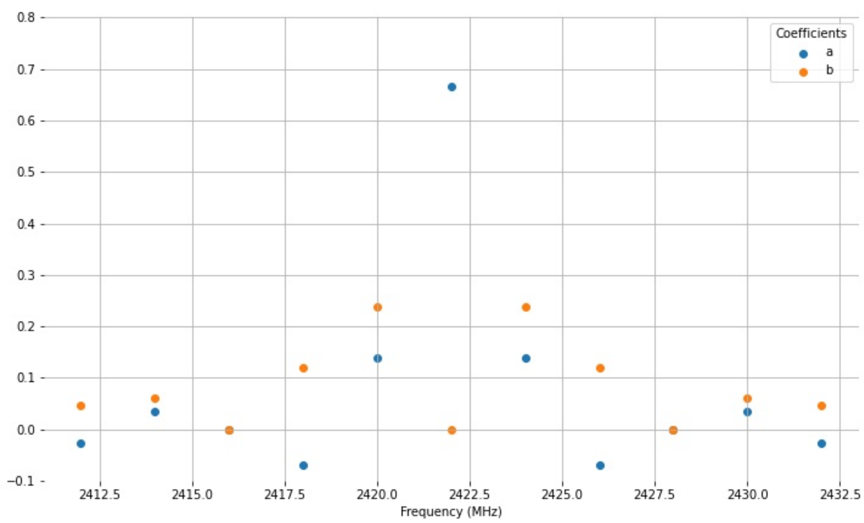

Figure 8: Coeff Interferent Signal 100 Modulated (a,b coeffs).

Figure 9 shows in a more clarifying form applied to our signals, what we have seen previously in the Figure 1. Between channel 1 and channel 3 there are some interferences. The signal channels are represented with the corresponding slight lines.

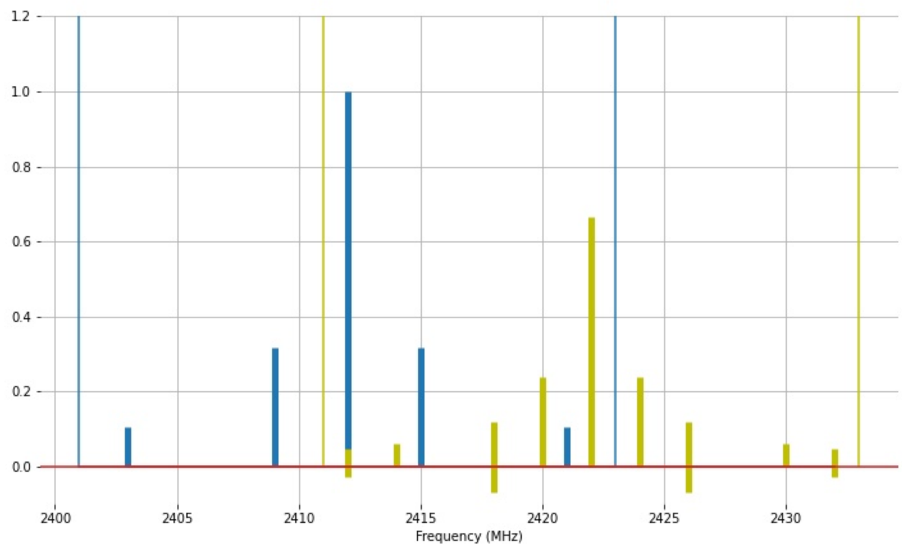

Figure 9: Coeffs Interferent Signal 101 (Blue) Singal 100 (Yellow) Modulated.

After the modulation of both signals as shown in the previous Figure, the next step was to unify them as one signal and demodulate them applying the following formula:

$$\frac{a_0}{2} + \sum_{n=1}^{\infty} \left[a_n * cos(\frac{2\pi nt}{T}) + b_n * sin(\frac{2\pi nt}{T}) \right]$$

Figure 10 shows the obtained plot for the previous equation result of the primary signal obtained by the receptor when the secondary signal is on channel 3. The statement requirement of plotting two bits time was extended to achieve a more clear image of the plotted pattern.

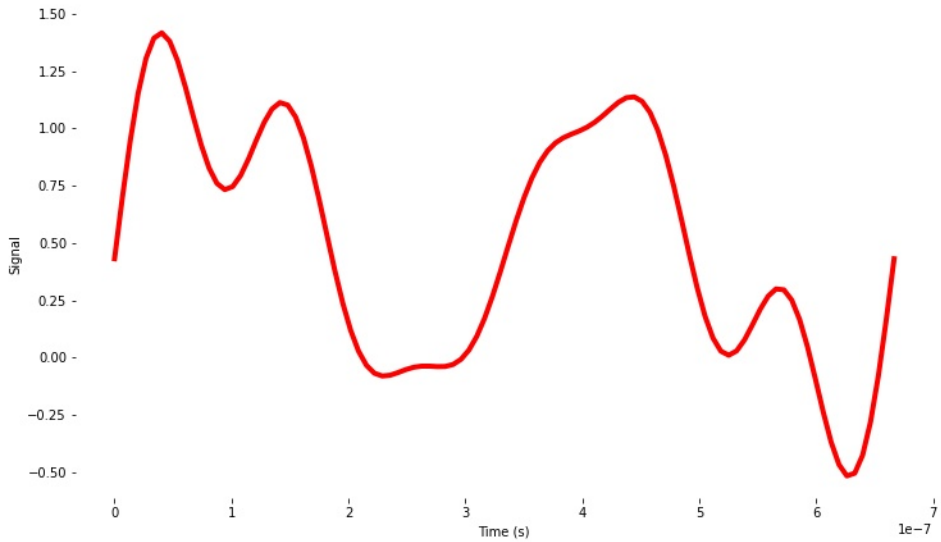

Figure 10: b' results with interference in channel 3.

2.2.3 Secondary Signal - Channel 6

Figure 11 shows the coefficients of the Signal 100 modulated in channel 6. The signal channels are represented with the blue slight lines. The Figure 12 is a complementary figure which distinguishes between a and b coefficients.

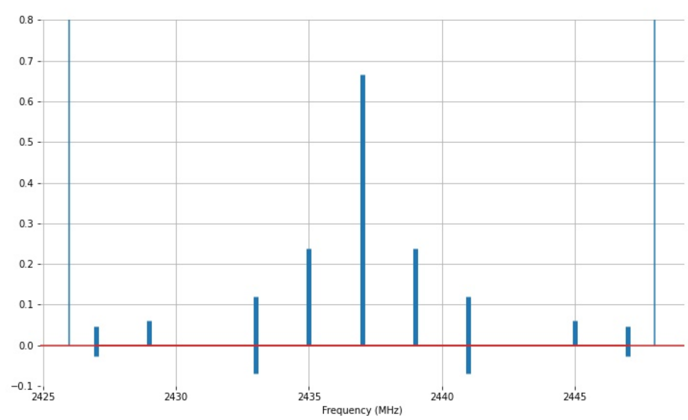

Figure 11: Coeff Interferent Signal 100 Modulated.

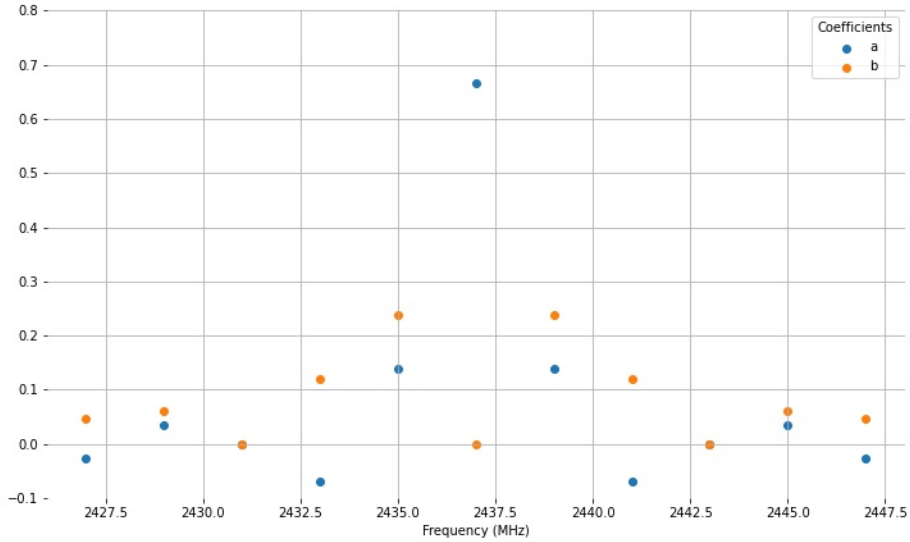

Figure 12: Coeff Interferent Signal 100 Modulated (a,b coeffs).

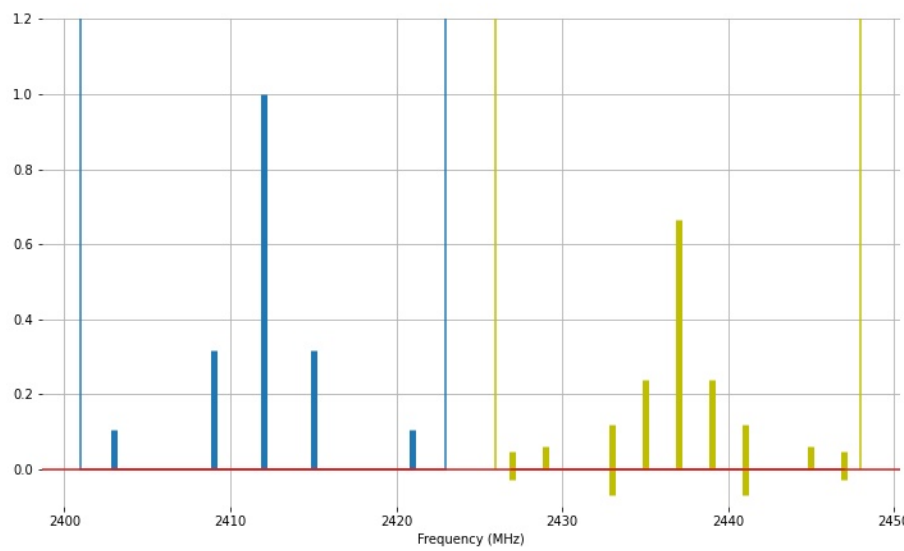

Figure 13: Coeffs Interferent Signal 101 (Blue) Singal 100 (Yellow) Modulated.

Figure 13 shows in a more clarifying form applied to our signals, what we have seen previously in the Figure 1. Between channel 1 and channel 6 there aren't interferences. The signal channels are represented with the corresponding slight lines. As we can see in the Figure 14, as a consequence of no interference between this channels, the received base band signal is equal as in the Figure 3.

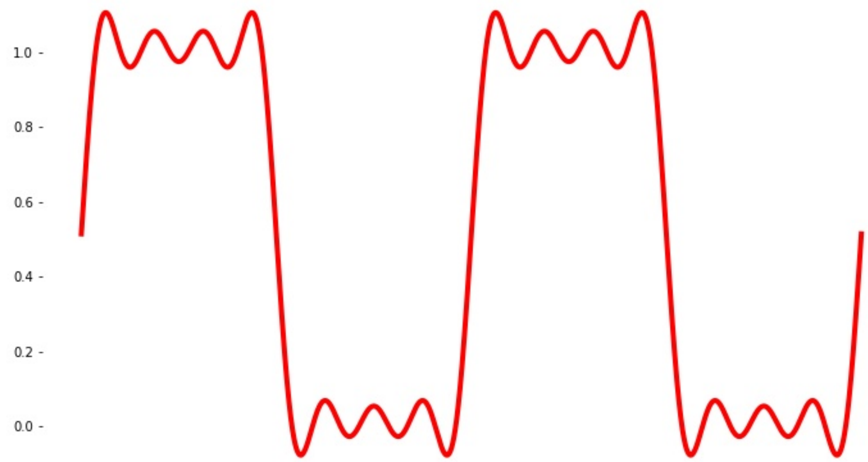

Figure 14: b' results with interference in channel 6.