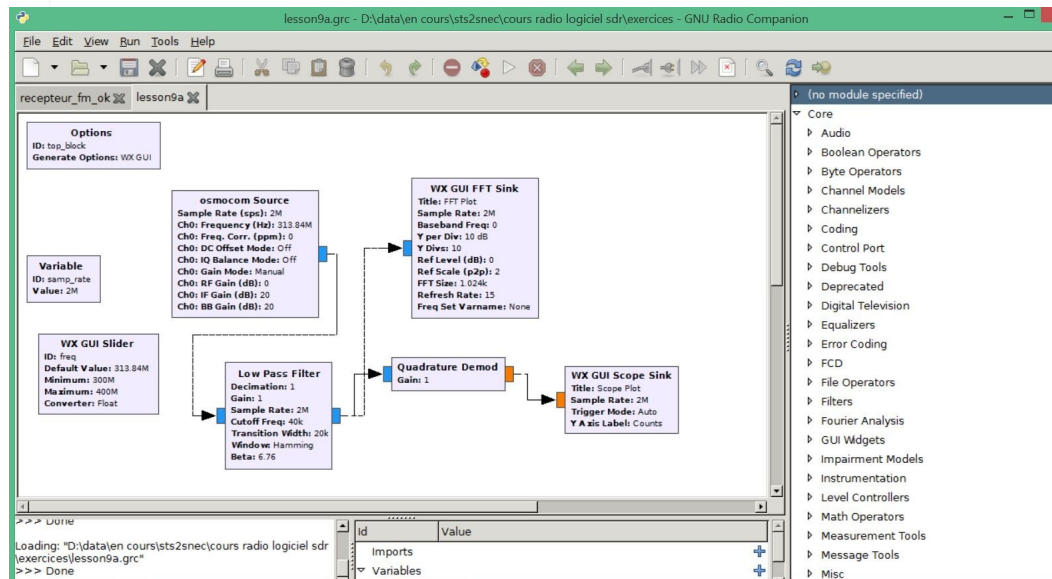


# Radio logiciel SDR + GNU Radio

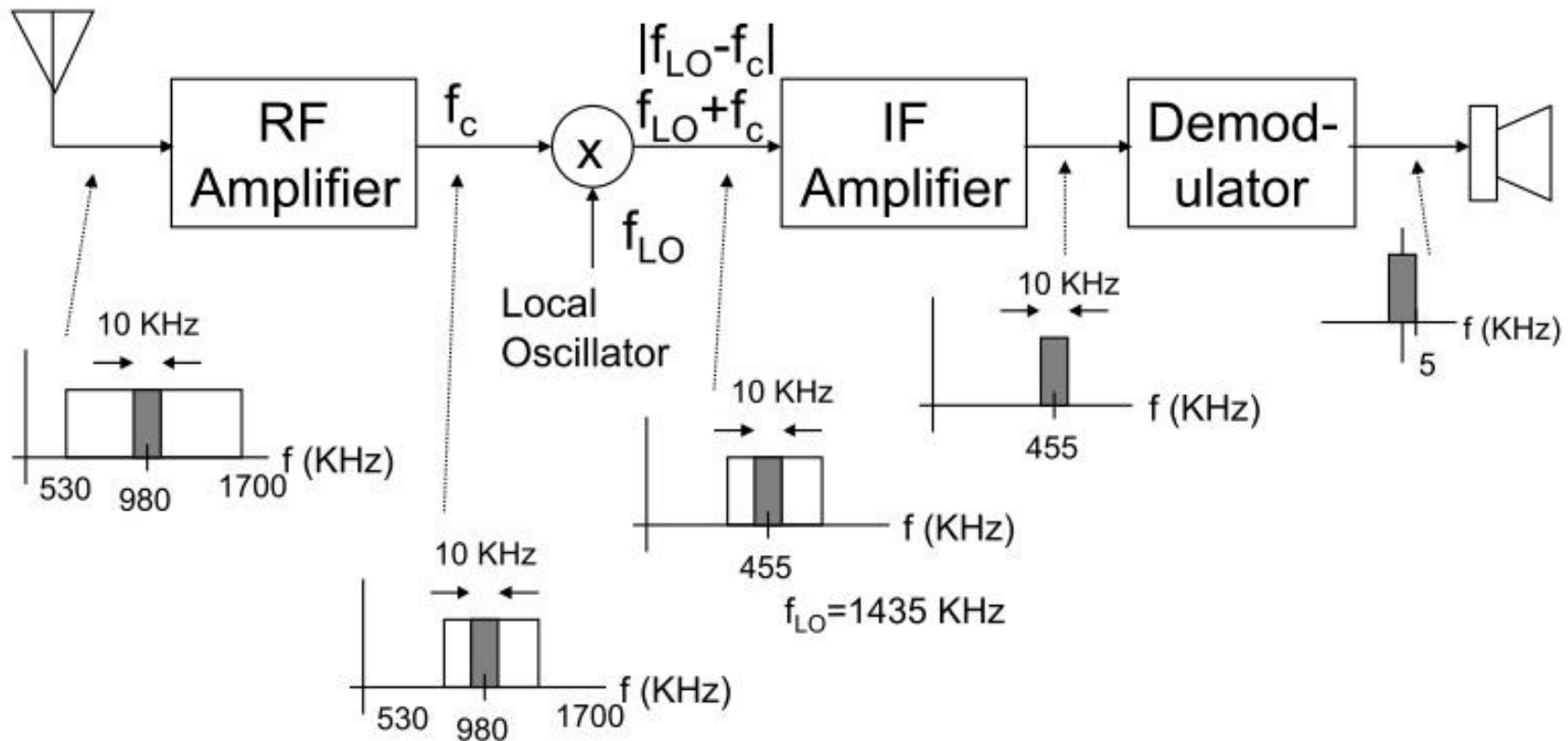


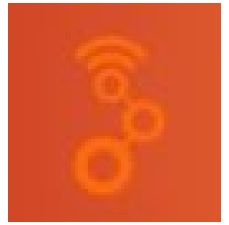
- Software Defined Radio : radio définie logicielle



# Radio logiciel

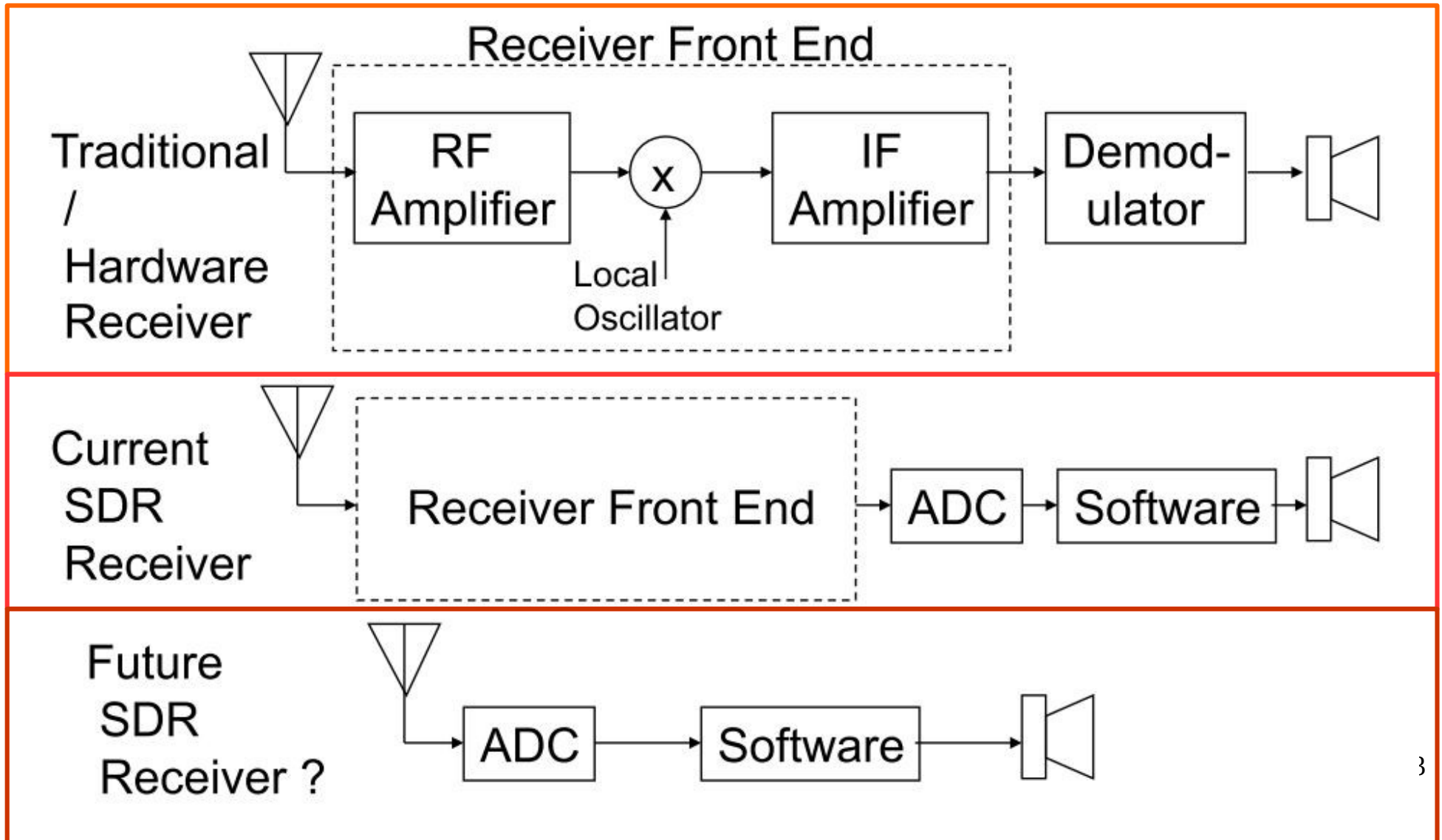
## Récepteur traditionnel





# Radio logiciel

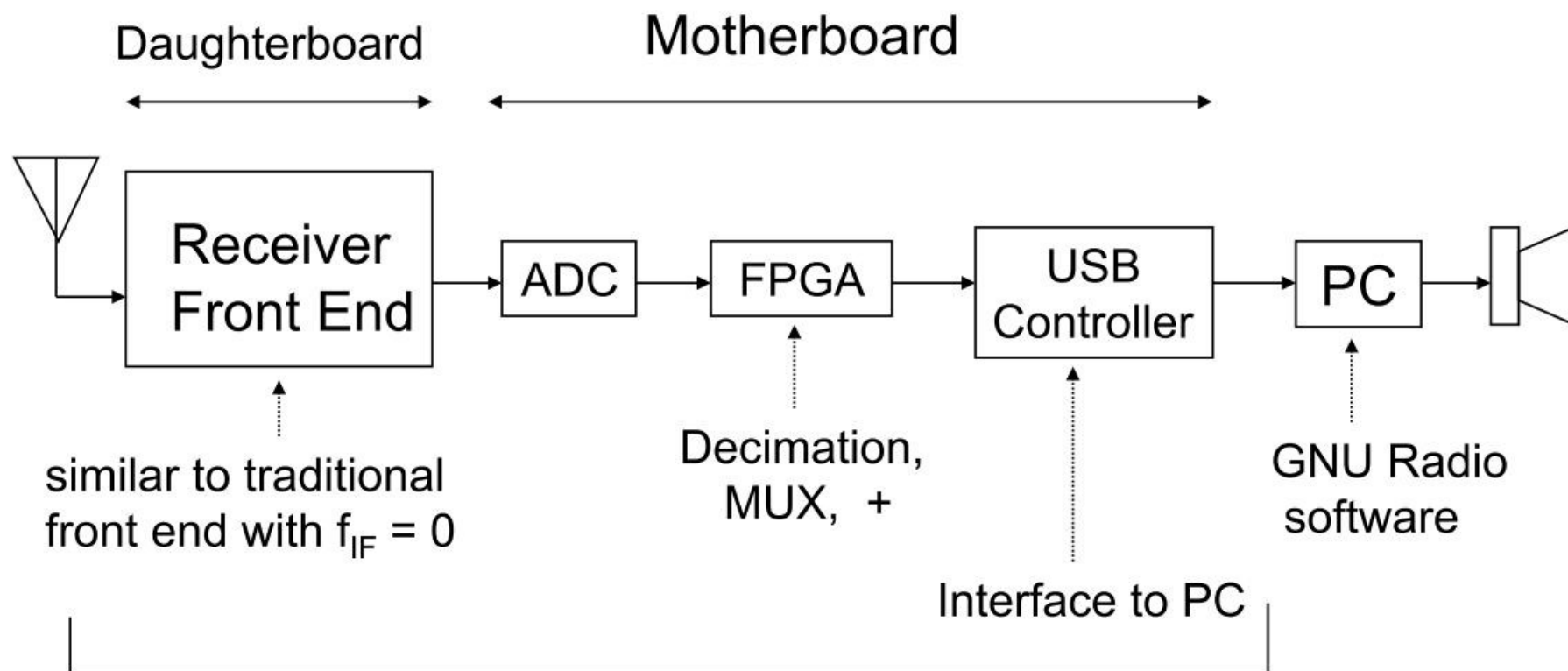
## Comparaison Traditionnel / USRP





# Radio logiciel

## *Récepteur USRP*



USRP: Universal Software Radio Peripheral



# Radio logiciel

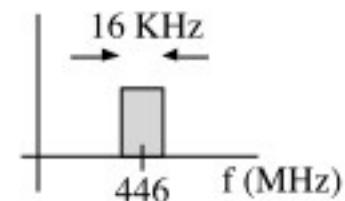
## *Représentation signaux en quadrature*

- L'USRP fournit les composantes I et Q du signal ramené à la bande de base ( $F = 0$ )
- GNU Radio travaille sur ces composantes I et Q.

The received signal,  $S(t)$ , may be represented as follows:

$$S(t) = I(t)\cos(2\pi f_c t) + Q(t)\sin(2\pi f_c t)$$

$f_c$  = carrier frequency



$I(t)$  = in-phase component

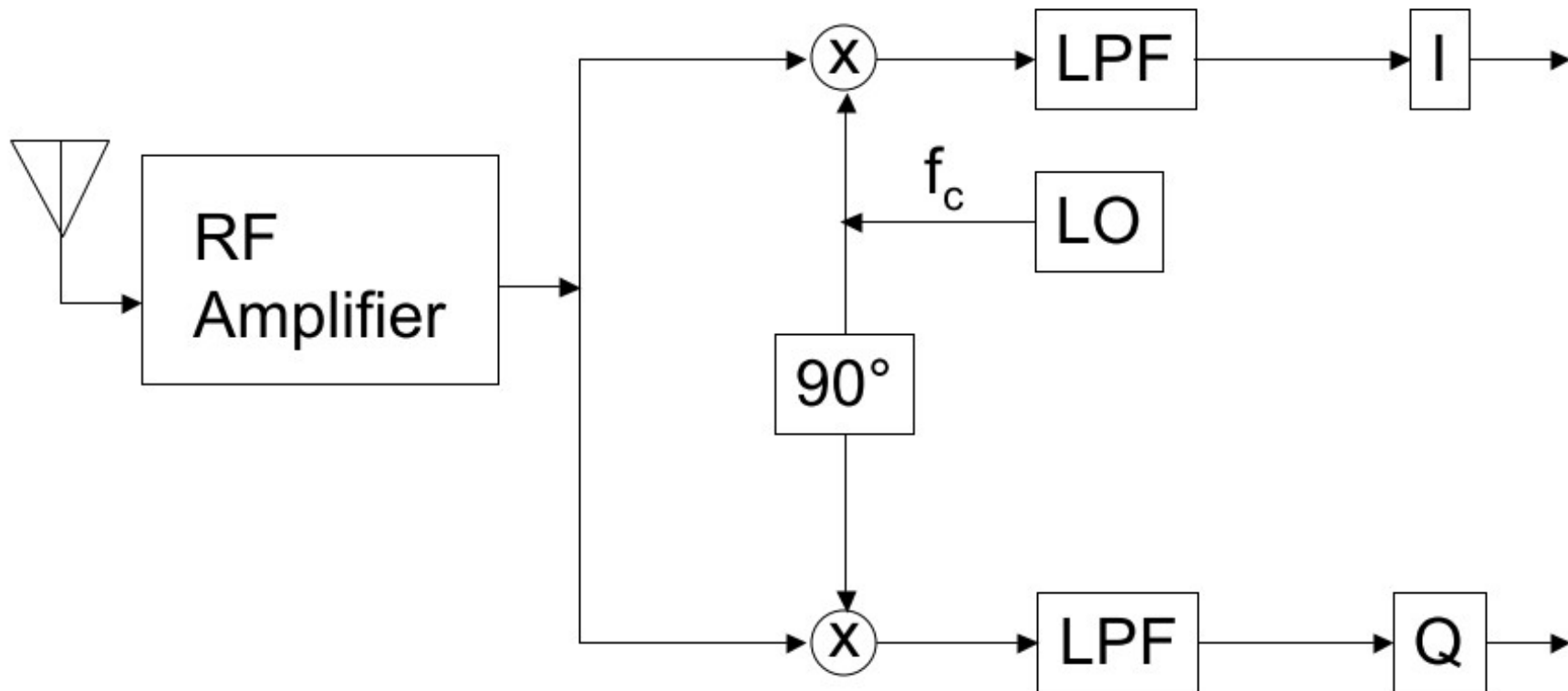
$Q(t)$  = quadrature component

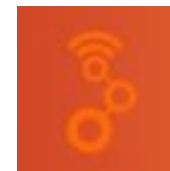
←  
←  
Contain amplitude and phase information of baseband signal



# Radio logiciel

## *Extraction de I et Q*





# Radio logiciel

## *ADC caractéristiques*

### HackRF One

- Résolution 8 bits
- $F_e = 20\text{Msps}$



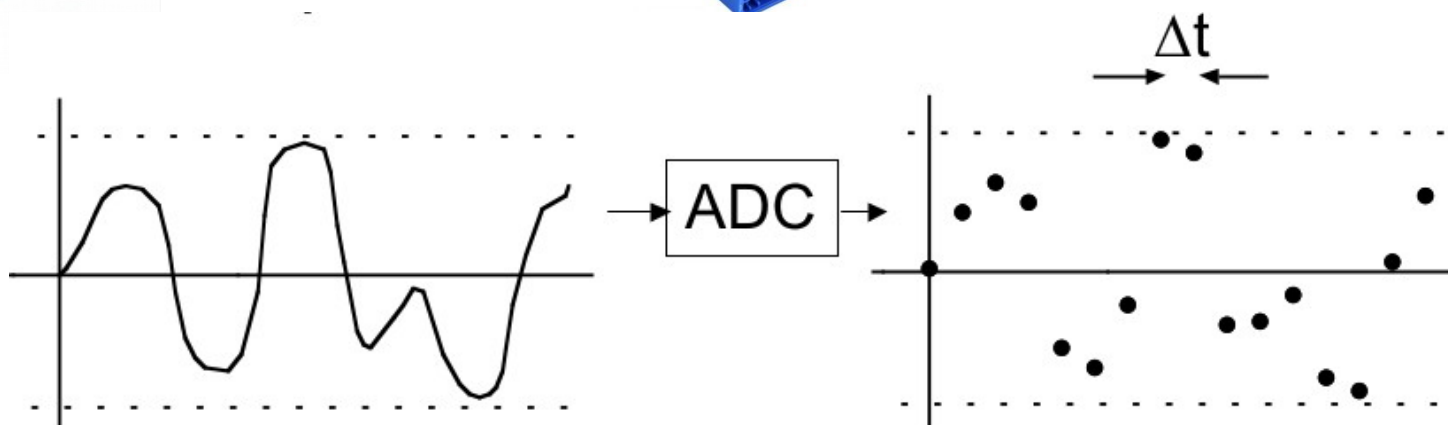
### RTL-SDR

- Résolution 8 bits
- $F_e = 2.4\text{Msps}$



### USRP Ettus

- Résolution 12 bits
- $F_e = 64\text{Msps}$

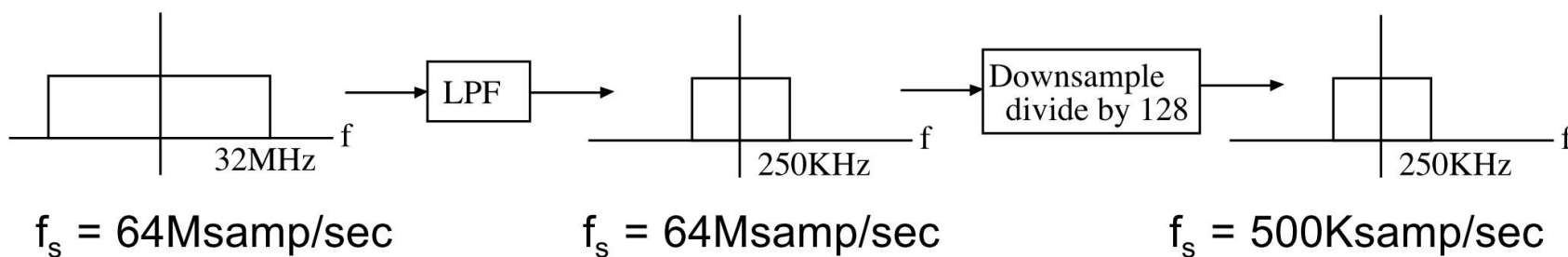




# Radio logiciel

## *Décimation – interpolation : rôle*

- La décimation permet de diminuer le nombre d'échantillon par seconde
- L'interpolation permet d'augmenter le nb d'échantillon par seconde



$$\frac{64M}{500K} = 128$$

- C'est le FPGA qui réalise ces calculs



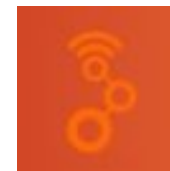


# Radio logiciel

## *Schéma d'un récepteur*

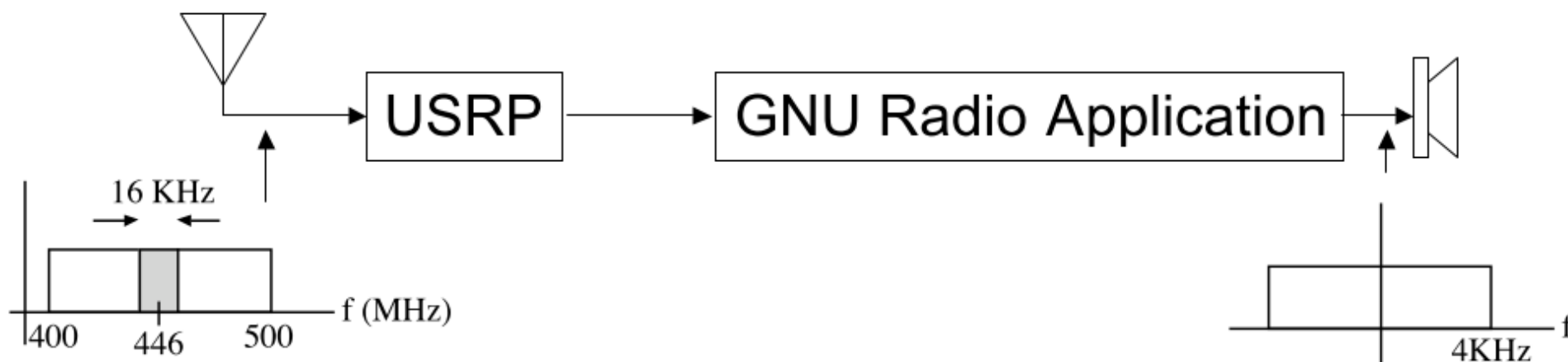


- USRP : réglage fréquence oscillateur local, gain de l'ampli HF, facteur décimation...
- GNU Radio : utilise Python pour spécifier et connecter les blocs qui démodulent et décodent.



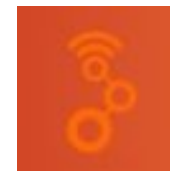
# Radio logiciel

## *Exemple d'un récepteur NBFM 400-500 MHz*



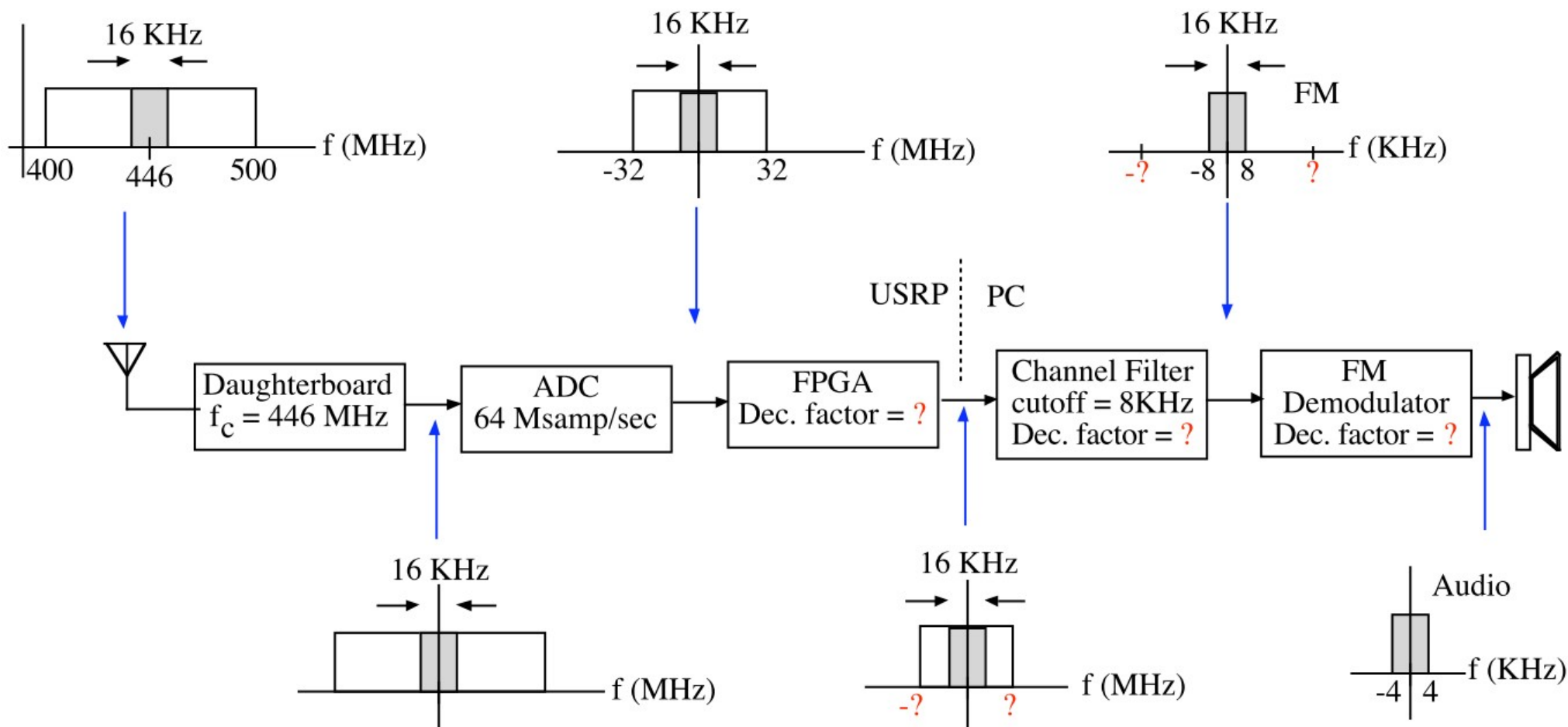
Problématique :

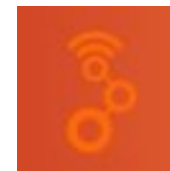
- recevoir un signal audio de 4KHz
- transmis en FM à 446MHz
- avec une bande étroite de 16KHz



# Radio logiciel

## Exemple d'un récepteur NBFM 400-500 MHz

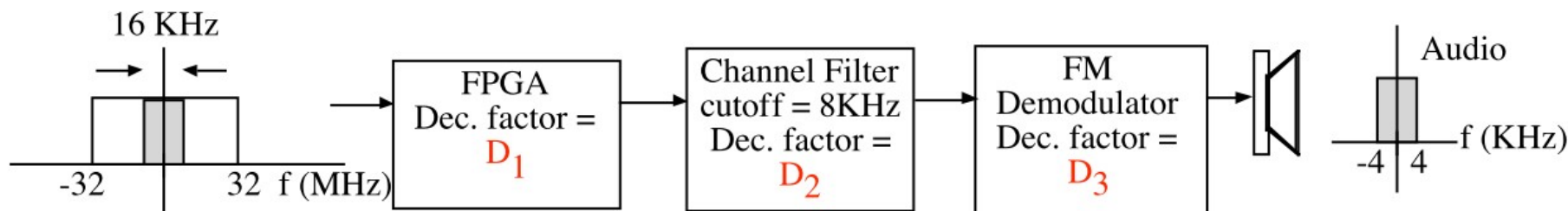




# Radio logiciel

## *Exemple d'un récepteur*

### *NBFM 400-500 MHz*

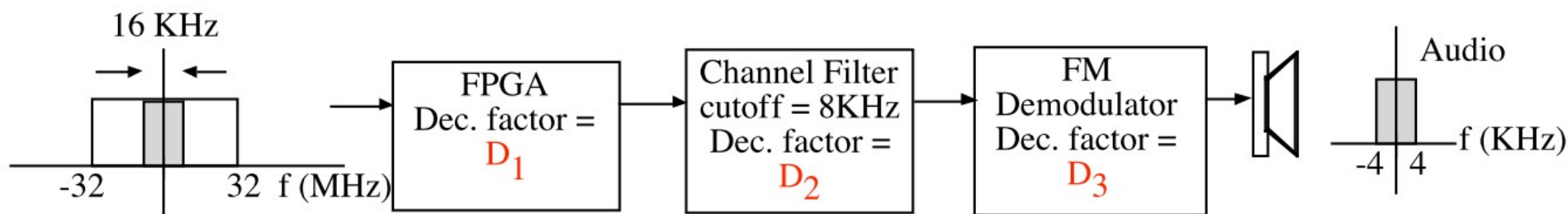


$$\text{Total Decimation factor} = 8000 = D_1 D_2 D_3$$

64Msamp/sec  $\longrightarrow$  8Ksamp/sec

# Radio logiciel

## *Exemple d'un récepteur NBFM 400-500 MHz*

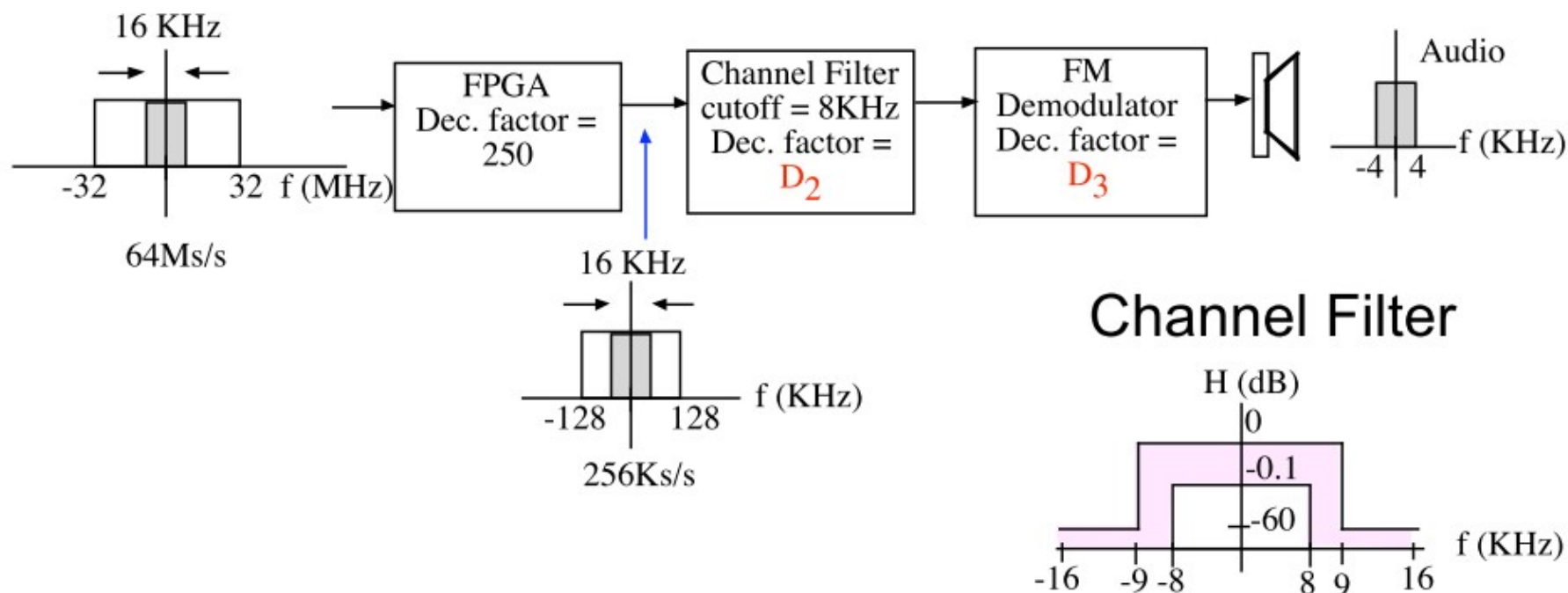


- Total Decimation factor = 8000 =  $D_1 D_2 D_3$
- Maximize the decimation in FPGA
- Maximum decimation factor in FPGA = 256
- Select  $D_1 = 250$  (factor of 8000)
- Output sample rate =  $64\text{Ms/s} / 250 = 256\text{Ks/s}$



# Radio logiciel

## *Exemple : filtre spécification*

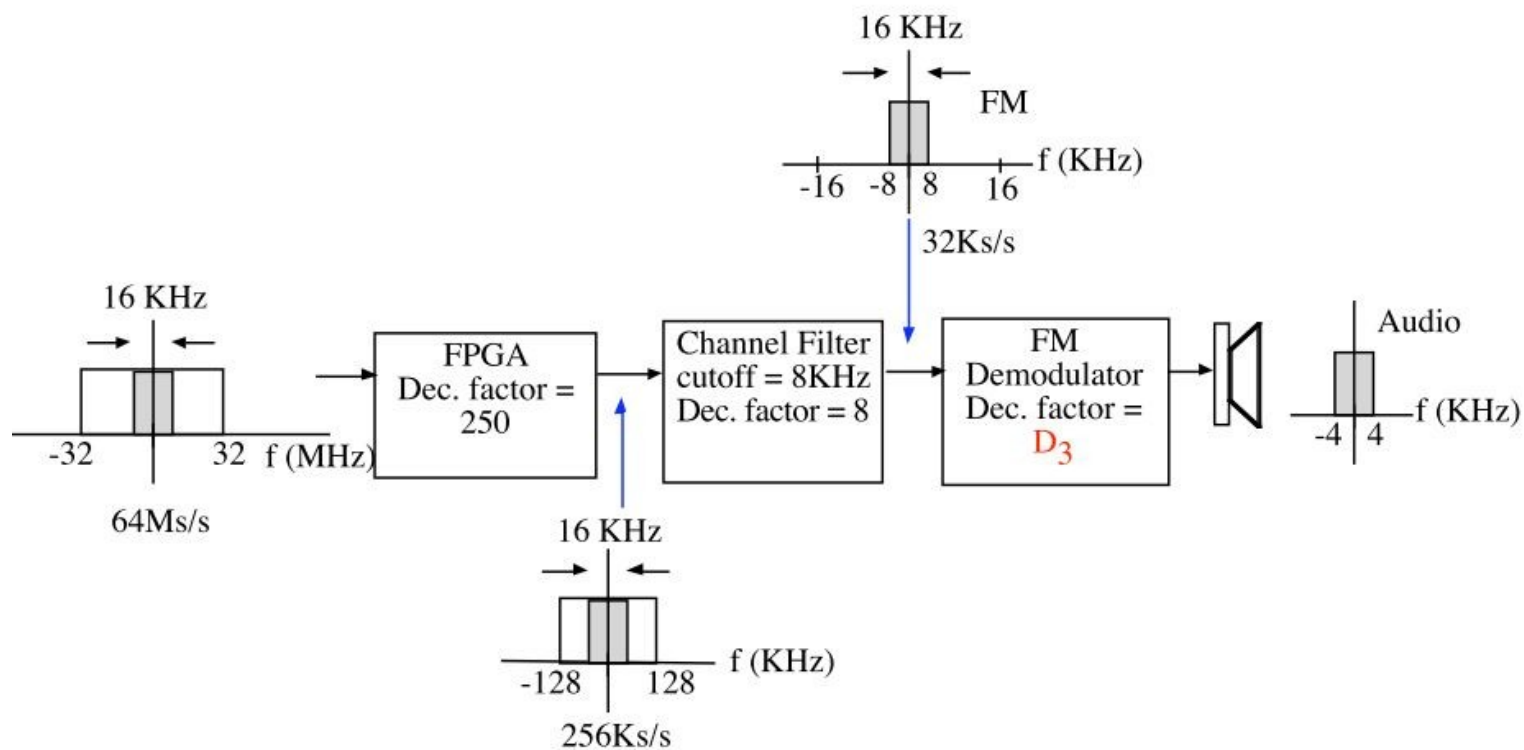


- Maximum frequency = 16 KHz  $\rightarrow$  Reduce sample rate to 32 Ks/s
- $256\text{Ks/s} / 32\text{Ks/s} \rightarrow D_2 = 8$



# Radio logiciel

## *Exemple : FM démodulation*

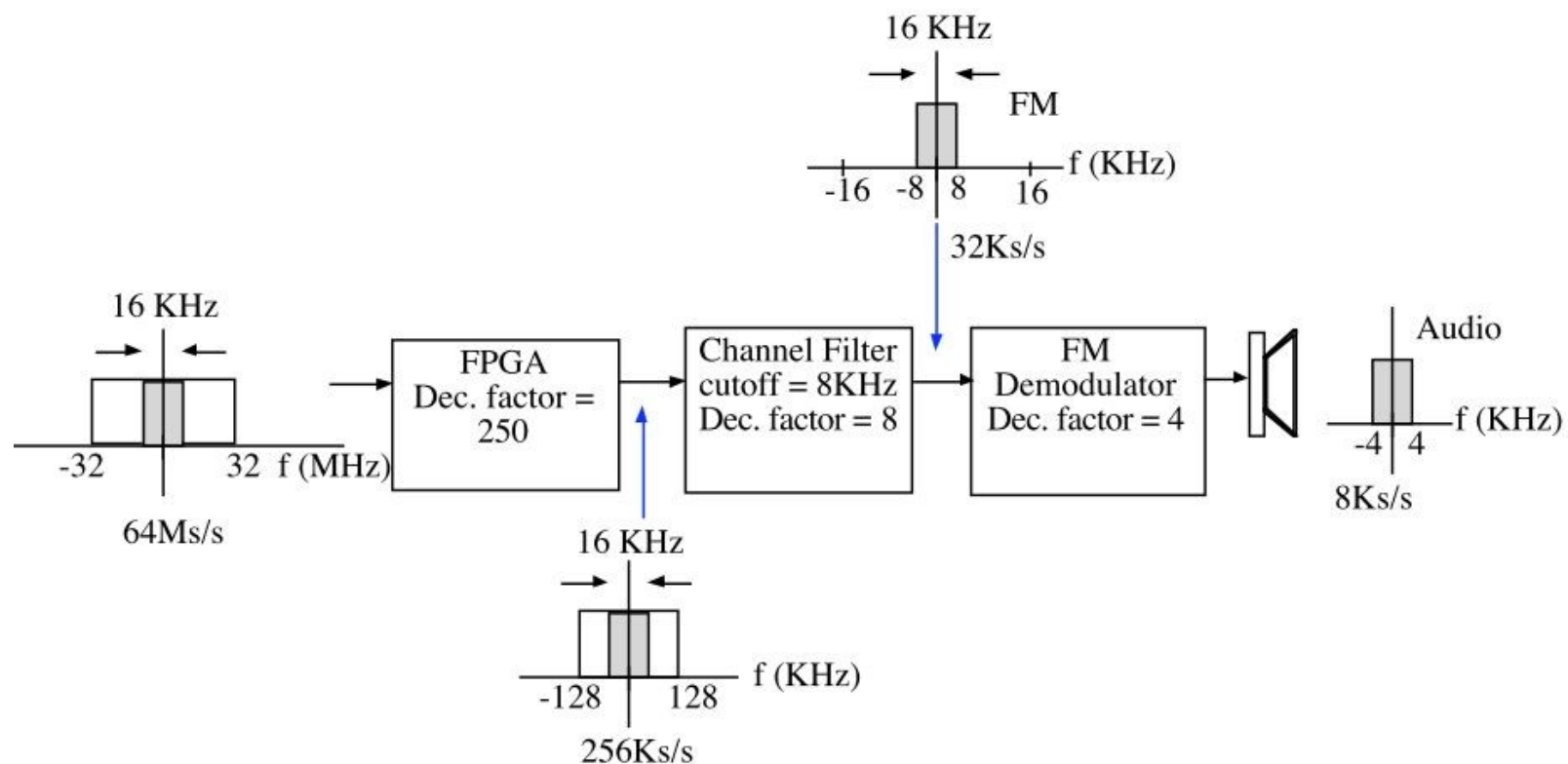


- Maximum frequency = 4 KHz → Reduce sample rate to 8 Ks/s
- $32\text{Ks/s} / 8\text{Ks/s} \rightarrow D_3 = 4$
- FM Demodulator block “extracts” audio signal from FM waveform by operating on I and Q



# Radio logiciel

## *Exemple : schéma final*



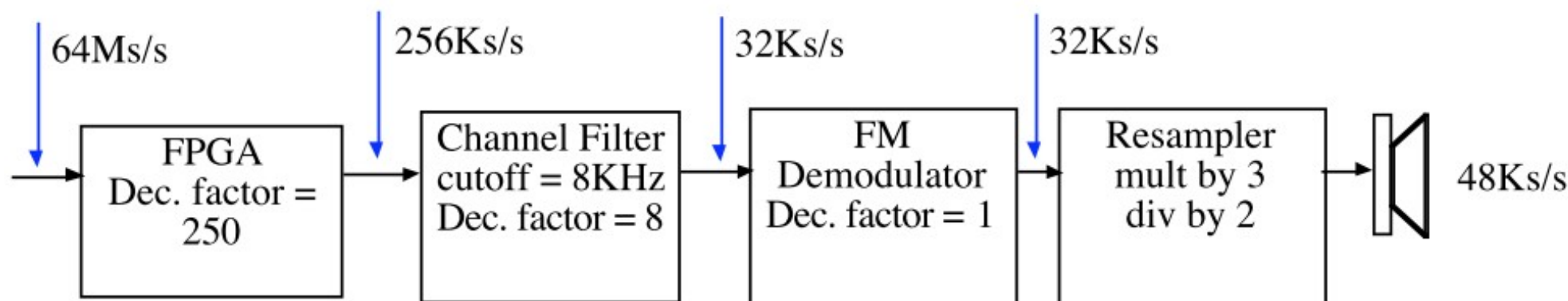
- Total decimation ratio =  $250 \cdot 8 \cdot 4 = 8000$
- Problem: The audio card requires an input sample rate  $\geq 44.1$  Ks/s
- Solution: Use a Resampler to increase the output sample rate





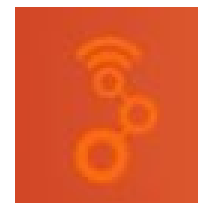
# Radio logiciel

## *Exemple d'un récepteur NBFM 400-500 MHz complet*



- Audio Card requires a sample rate  $\geq 44.1$  Ks/sec. Use 48 Ks/sec.
- Modify FM Demodulator to have a decimation factor of 1 (no change)
- Increase the sample rate to 48 Ks/sec with Resampler (x 3/2)

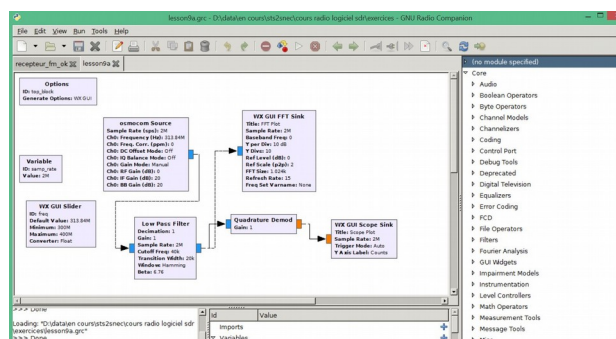
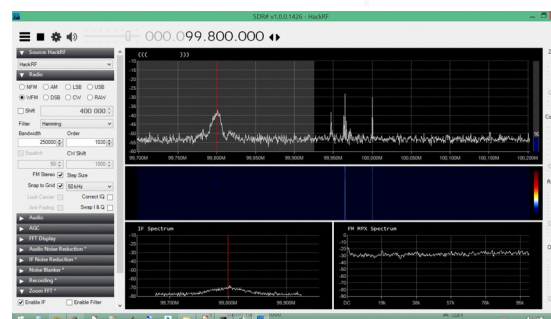
# Radio logiciel *Installation*



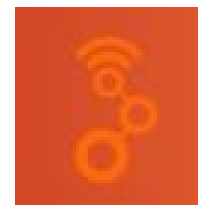
- Installation DRIVERS Hardware :
  - ✓ Clé TNT RTLSDR
  - ✓ HackRFOne



- Installation des logiciels :
  - ✓ SDRSharp
  - ✓ GNU Radio



# GNU Radio *Installation*



- Télécharger le fichier "gnuradio3.7.10.1\_win64.msi" sur [stssnsb.free.fr](http://stssnsb.free.fr)
- Installer le logiciel
- Installer le driver pour la clé USB et/ou HackRF One

OU

- Live DVD directement sous Linux sans installation

# Radio logiciel

## *Drivers Windows*



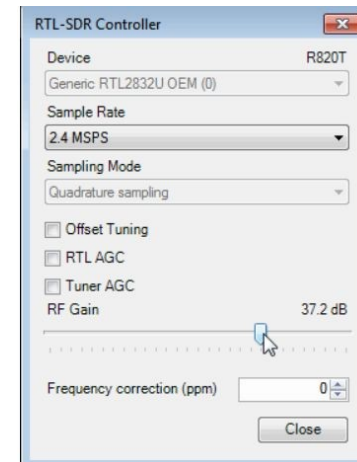
- Télécharger Zadig.exe sur <http://zadig.akeo.ie>(  
<http://www.rtl-sdr.com/tag/zadig/>)
- Lancer l'exécutable
- Cocher "List all devices"
- Choisir la clé TNT ou HackRFone
- Vérification : Gestionnaire de périphérique (aucun pb doit apparaitre)

# Radio logiciel

## Test avec SDRSharp



- Télécharger SDRSharp
- Choisir le hard à tester : RTL-SDR ou HackRF
- Choisir le "Device"
- Choisir la largeur de bande à analyser
- Régler le gain
- Lancer la lecture...



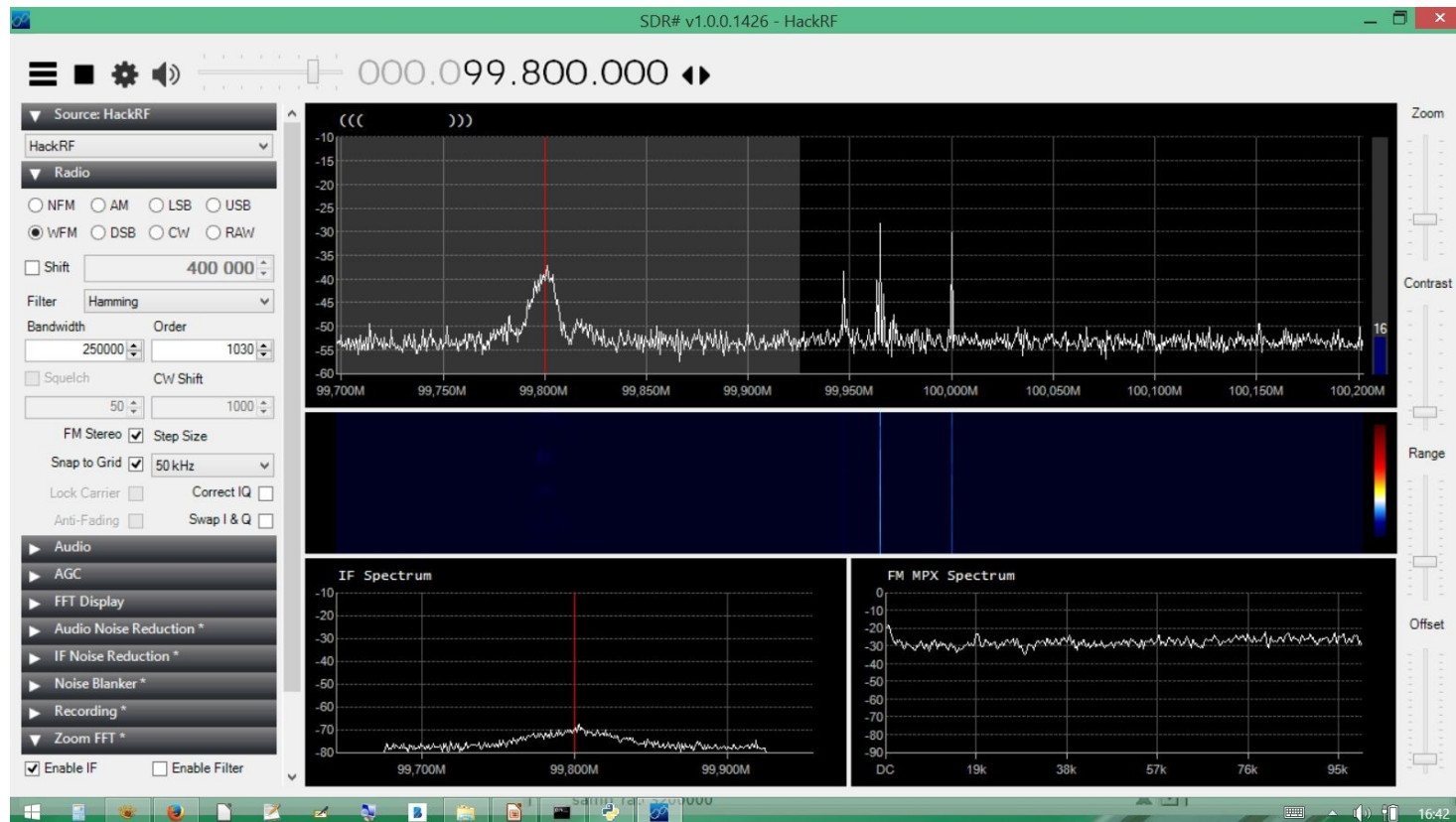


# Radio logiciel

## *Test avec SDRSharp*

**Si test OK alors continuer**

**Sinon voir driver**



# GNU Radio

## Premier diagramme



Type de widget :  
Qt ou Wt

The screenshot shows the GNU Radio Companion (GRC) interface. The main workspace is empty, with a toolbar at the top containing various icons for file operations, editing, and execution. On the left, there are two panels: 'Options' and 'Variable'. The 'Options' panel shows 'ID: top\_block' and 'Generate Options: QT GUI'. The 'Variable' panel shows 'ID: samp\_rate' and 'Value: 32k'. On the right, there is a 'Blocks' panel with a tree view of available blocks, including 'Core', 'Audio', 'Boolean Operator', 'Byte Operators', 'Channel Models', 'Channelizers', 'Coding', 'Control Port', 'Debug Tools', 'Deprecated', 'Digital Television', 'Equalizers', 'Error Coding', 'FCD', 'File Operators', 'Filters', 'Fourier Analysis', 'GUI Widgets', 'Impairment Mode', 'Instrumentation', 'Level Controllers', 'Math Operators', 'Measurement Tools', and 'Message Tools'. At the bottom, there is a 'Log' panel showing the welcome message and block paths, and a 'Variables' table.

Id	Value
Imports	
Variables	
samp_rate	32000

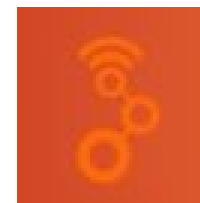
Annotations in orange callouts point to specific elements:

- "Générer" points to the 'Generate Options' button in the toolbar.
- "Run" points to the 'Run' button in the toolbar.
- Blocs disponibles points to the 'Blocks' panel on the right.

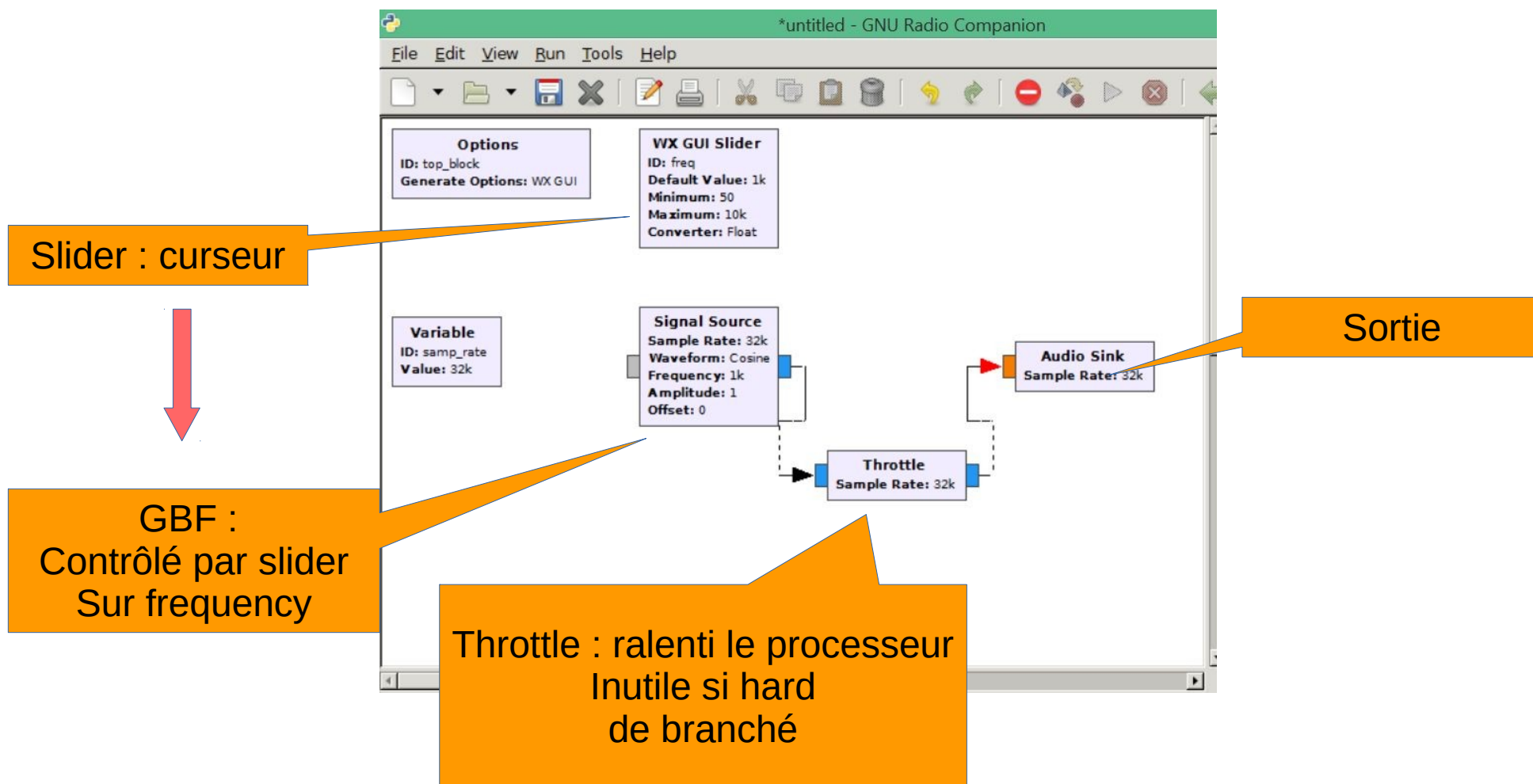
Fréquence  
échantillonnage

# GNU Radio

## Premier diagramme



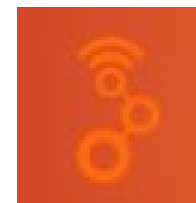
- Générateur de signaux audio :



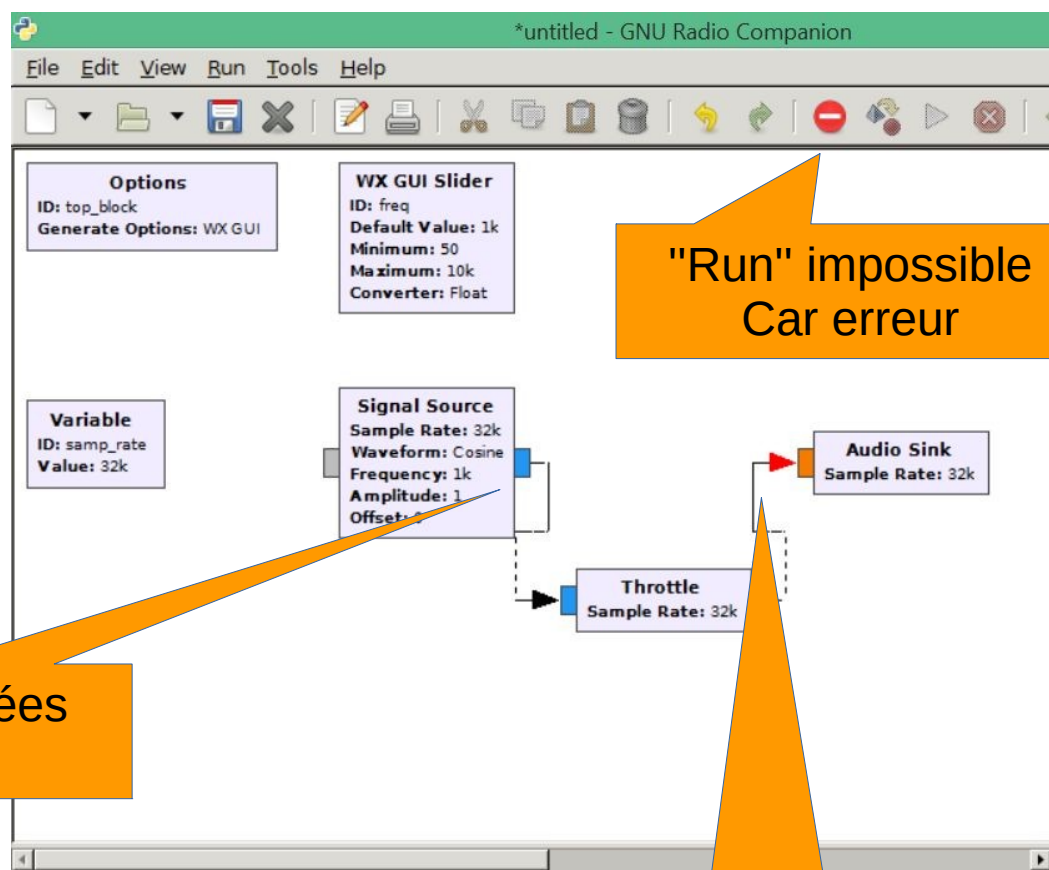


# GNU Radio

## Premier diagramme



- Générateur de signaux audio :



"Run" impossible  
Car erreur

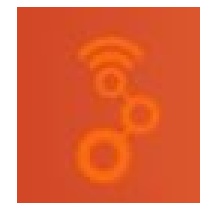
Flux de données  
typées

! Erreur de type

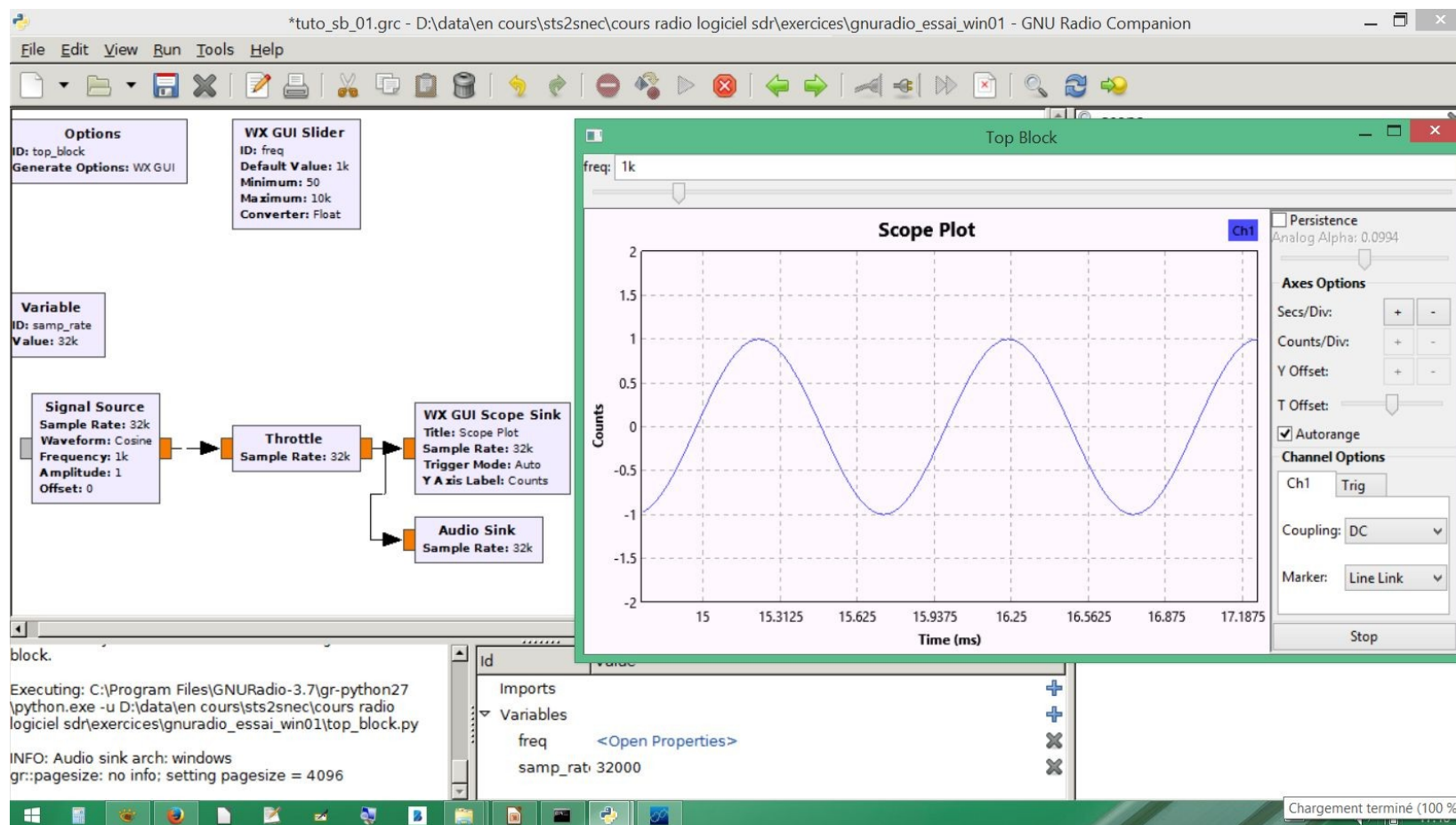


# GNU Radio

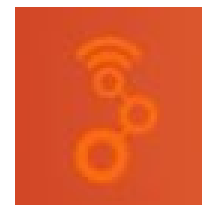
## Premier diagramme



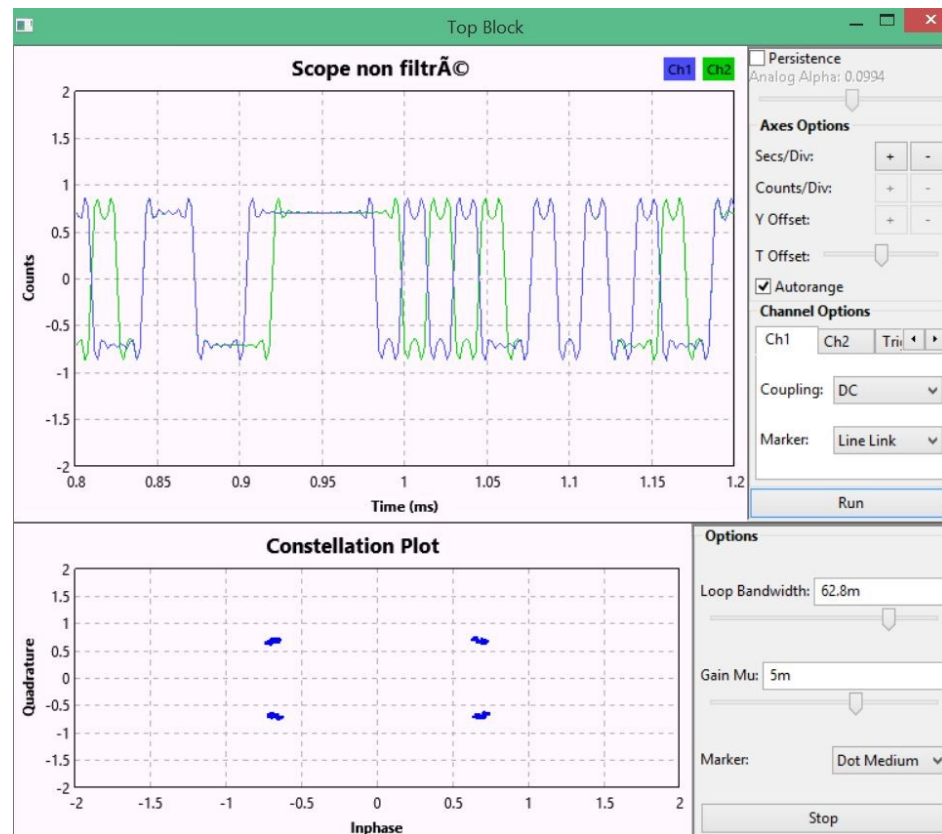
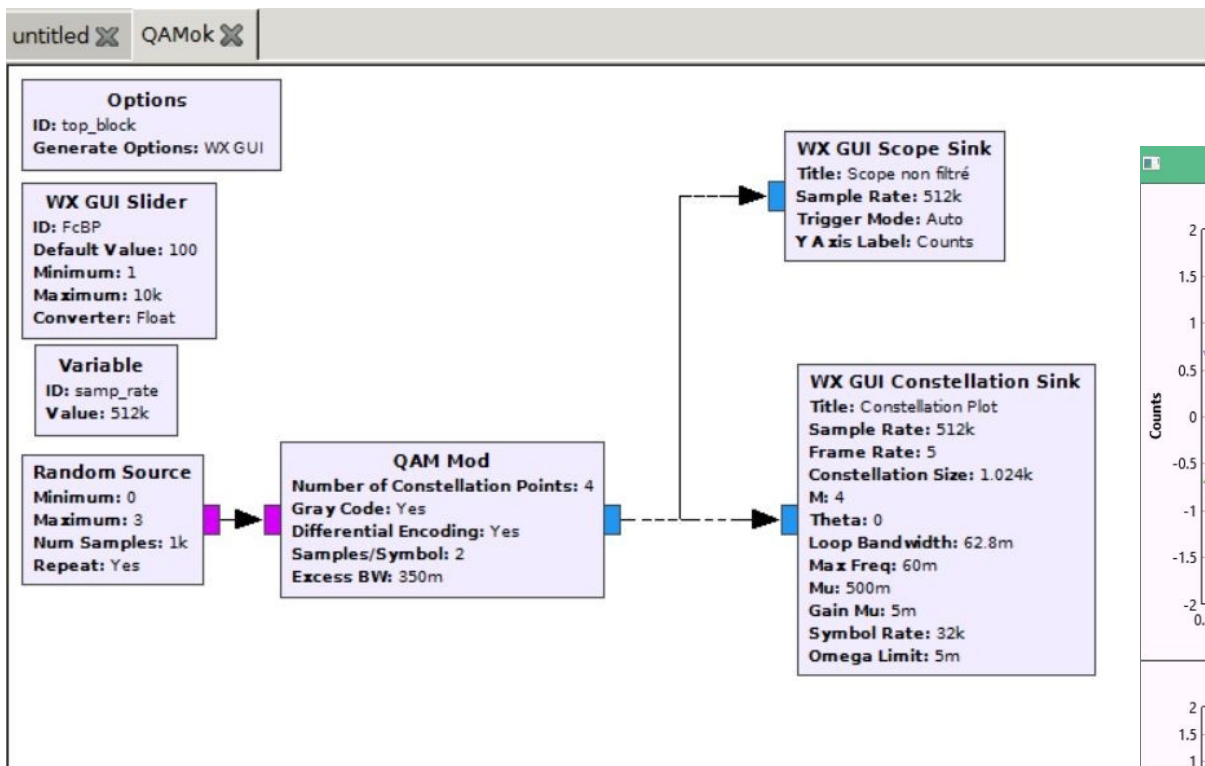
- Générateur de signaux audio :



# GNU Radio QAM simple



- Simulation :



# GNU Radio QAM Tx + HackRF



- Émission de données en QAM :

The screenshot displays the GNU Radio interface for a QAM Tx setup. The flow graph on the left includes a Random Source, QAM Mod block (4 constellation points, differential encoding), and an osmocomb sink. The osmocomb sink parameters are: Sample Rate (sps): 512k, Ch0: Frequency (Hz): 274M, Ch0: Freq. Corr. (ppm): 0, Ch0: RF Gain (dB): 10, Ch0: IF Gain (dB): 20, Ch0: BB Gain (dB): 20.

Two plots are shown in the Top Block:

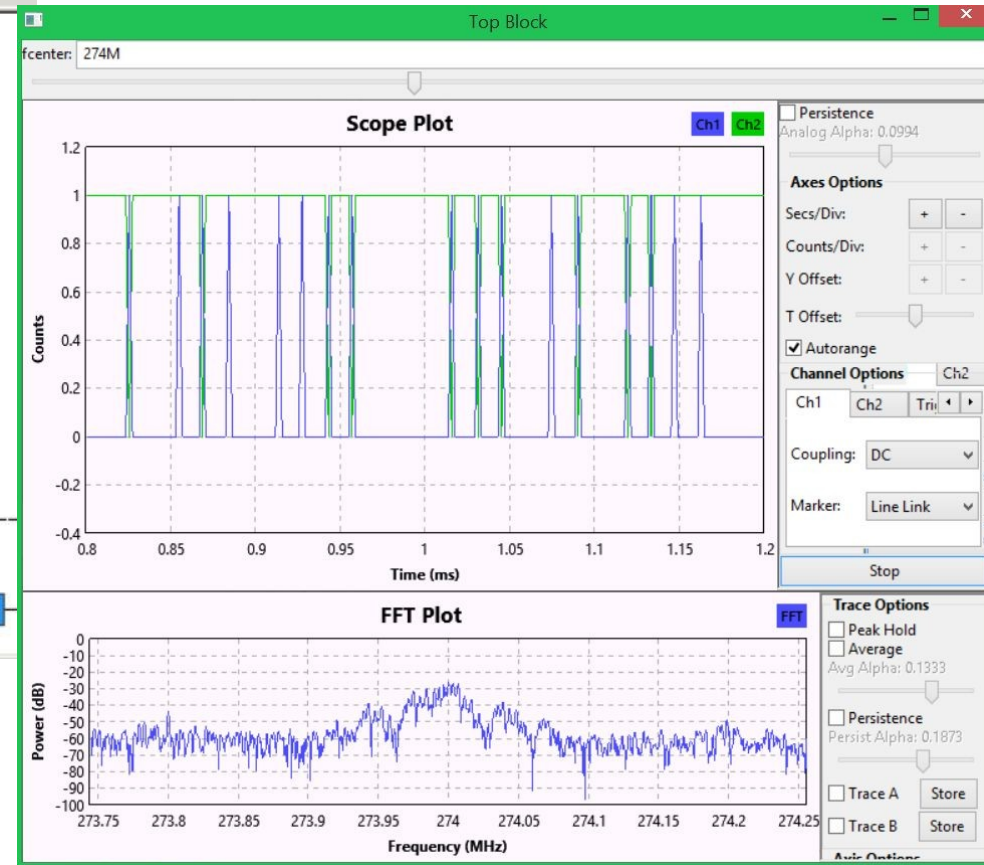
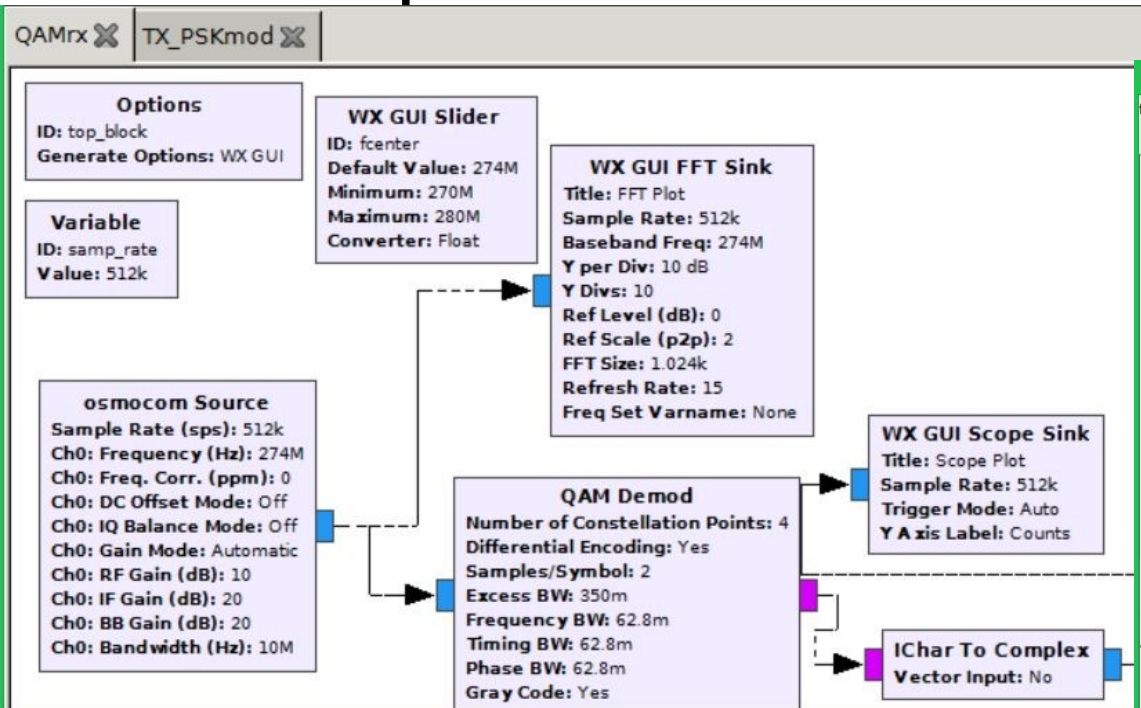
- Scope non filtré:** A time-domain plot showing the raw QAM signal. The Y-axis is labeled 'Counts' and ranges from -2 to 2. The X-axis is 'Time (ms)' from 0.6 to 1.4. Two channels (Ch1 and Ch2) are visible as overlapping waveforms.
- Constellation Plot:** A scatter plot showing the constellation points in the I-Q plane. The Y-axis is 'Quadrature' and the X-axis is 'Inphase', both ranging from -2 to 2. Four distinct clusters of points are visible, representing the 4-QAM constellation.

Control panels for both plots are visible on the right, including persistence settings, axes options, and channel options.

# GNU Radio QAM RX + RTL-SDR

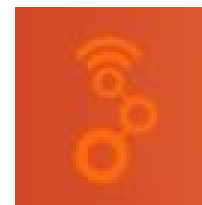


- Réception de données en QAM :

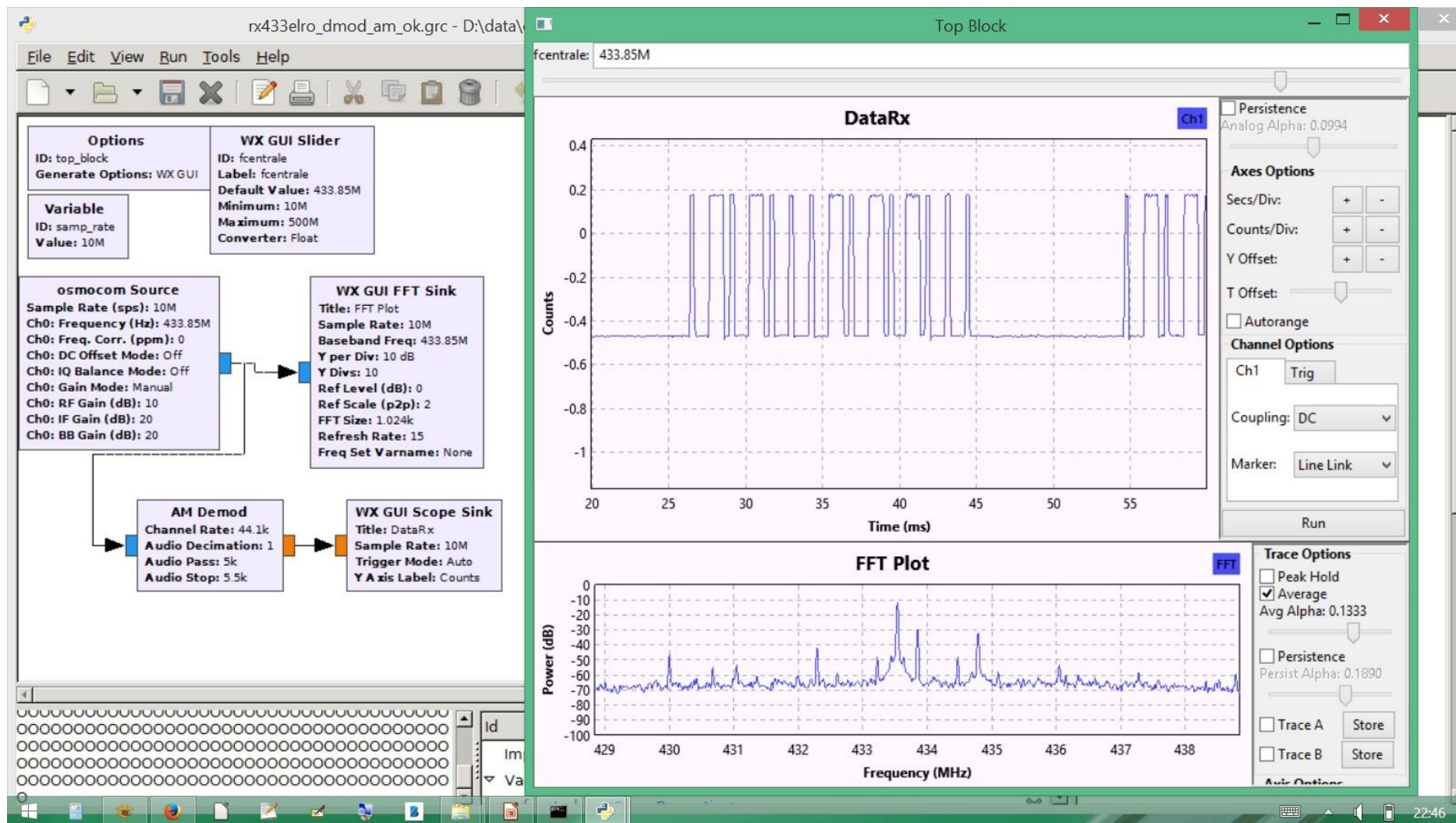


# GNU Radio

## Récepteur AM



- Réception du ELRO 433MHz en AM avec HACKRF





# Radio logiciel

## *Références...*



- [Stssnsb.free.fr](http://Stssnsb.free.fr) – rubrique : télécharger/sn2/sdr
- [https://wiki.gnuradio.org/index.php/Main\\_Page](https://wiki.gnuradio.org/index.php/Main_Page)
- <https://wiki.gnuradio.org/index.php/GNURadioCompanion>
- <http://www.rtl-sdr.com/tag/zadig/>
- <http://www.rtl-sdr.com/rtl-sdr-quick-start-guide/>
- <https://greatscottgadgets.com/hackrf/>
- <https://www.passion-radio.com/fr/>
- [http://www.ece.uvic.ca/~elec350/grc\\_doc/ar01s12s07.html](http://www.ece.uvic.ca/~elec350/grc_doc/ar01s12s07.html)
- [https://www.csun.edu/~skatz/katzpage/sdr\\_project/sdr/](https://www.csun.edu/~skatz/katzpage/sdr_project/sdr/)

MERCI