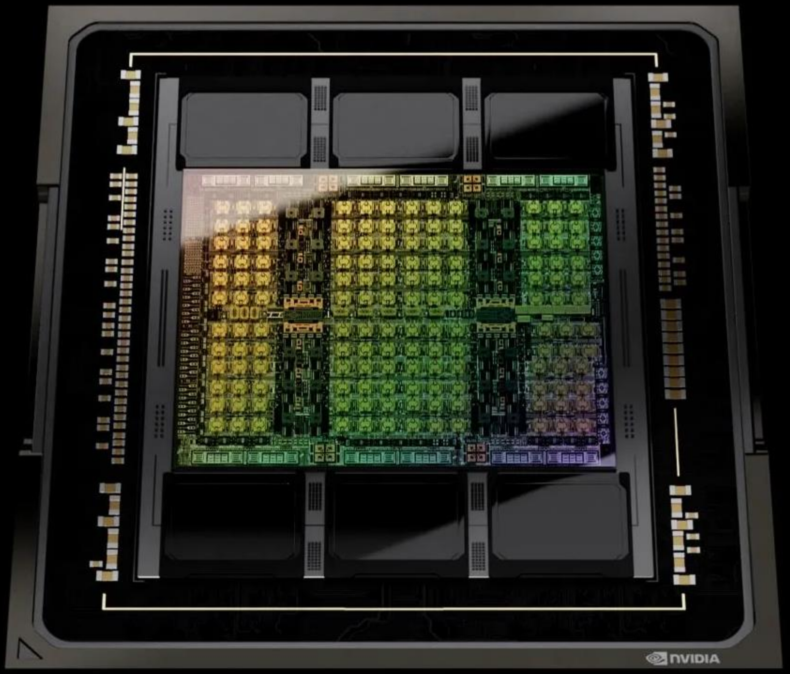
Using GPU for real-time SDR Signal processing

libGKR4GPU



Sylvain - F4GKR

Intro & Outline

- Author : Sylvain Azarian – F4GKR
  - Founder of « SDR-Technologies » , small French company around Paris
  - Former staff of ONERA (Radar Dept) and Director of SONDRA Lab in Paris-Saclay Univ.
  - Involved in Amateur Radio organizations (President of IARU R1 since 2020)

- Outline of the talk
  - Motivation
  - DDC in SDR: why it does need “some” CPU cycles
  - Using GPU: does it bring anything ?
  - The “libgkr4gpu” : what is it like ?
  - Q&A

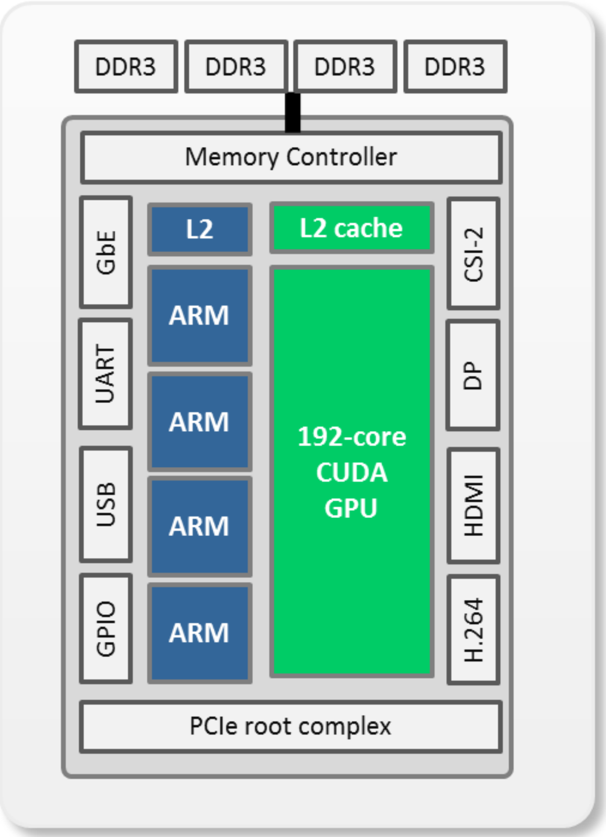
Background

- The story started while working in Radar & Signal Processing (at ONERA), when the Tegra K1 Soc was released
  - Radar processing, digital beamforming generate heavy processing needs and a « more compact » solution were required
- I was tasked to explore GPU-based solutions

- GPU for SDR is now the « core business » of the company funded in 2017

ONERA
THE FRENCH AEROSPACE LAB

What looked promising ?



326 GIGA FLOPS for 5 WATTS !!!!!!!!!!!!

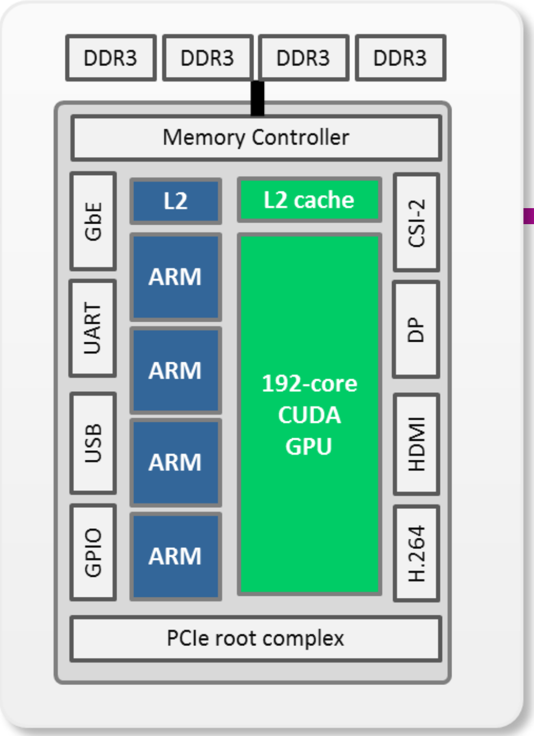
- 4 Core ARM Cortex-A15
- 192 CUDA cores
- Linux ☺

The 99€ question :
Can this bring **anything** to real-time continuous signal processing ?

The programming model

```
// Kernel definition
__global__ void VecAdd(float* A, float* B, float* C)
{
    int i = threadIdx.x;
    C[i] = A[i] + B[i];
}

int main()
{
    ...
    // Kernel invocation with N threads
    VecAdd<<<1, N>>>(A, B, C);
    ...
}
```

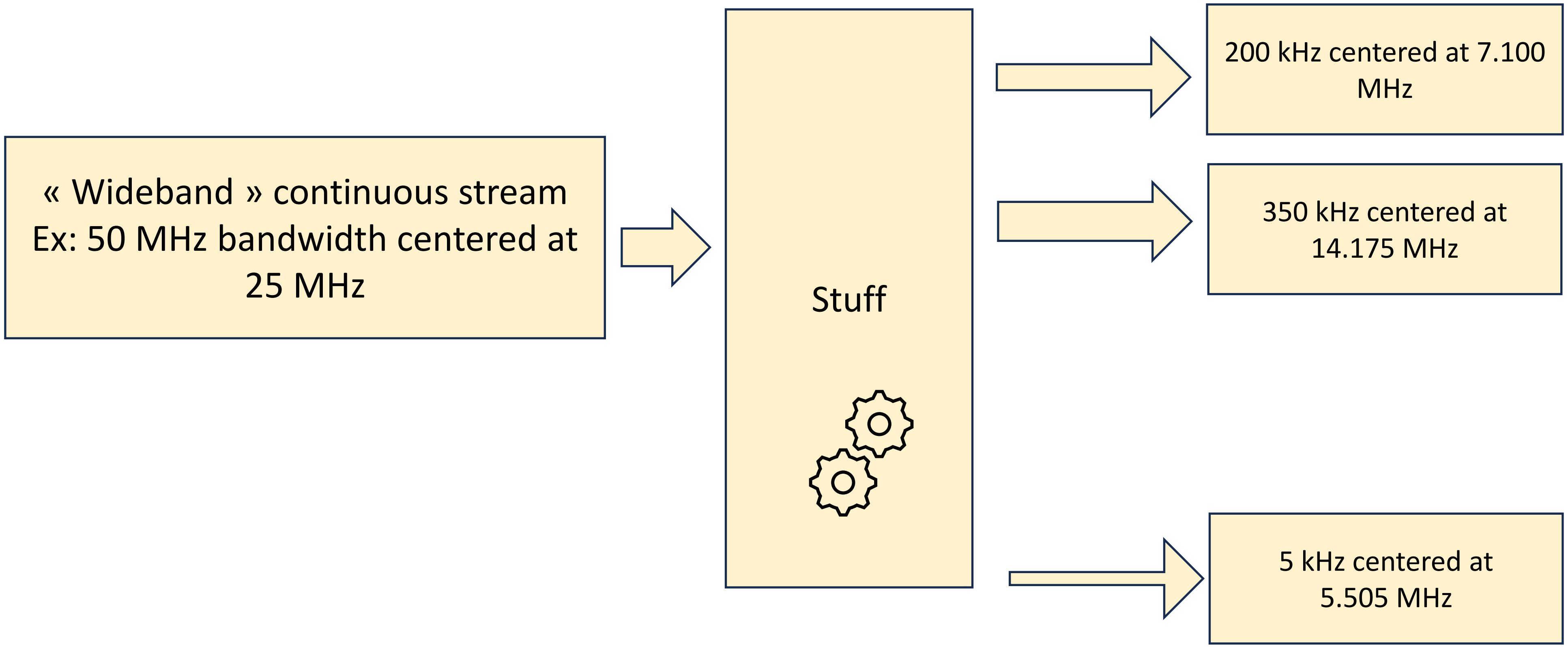


Examples of CPU consuming DSP blocks

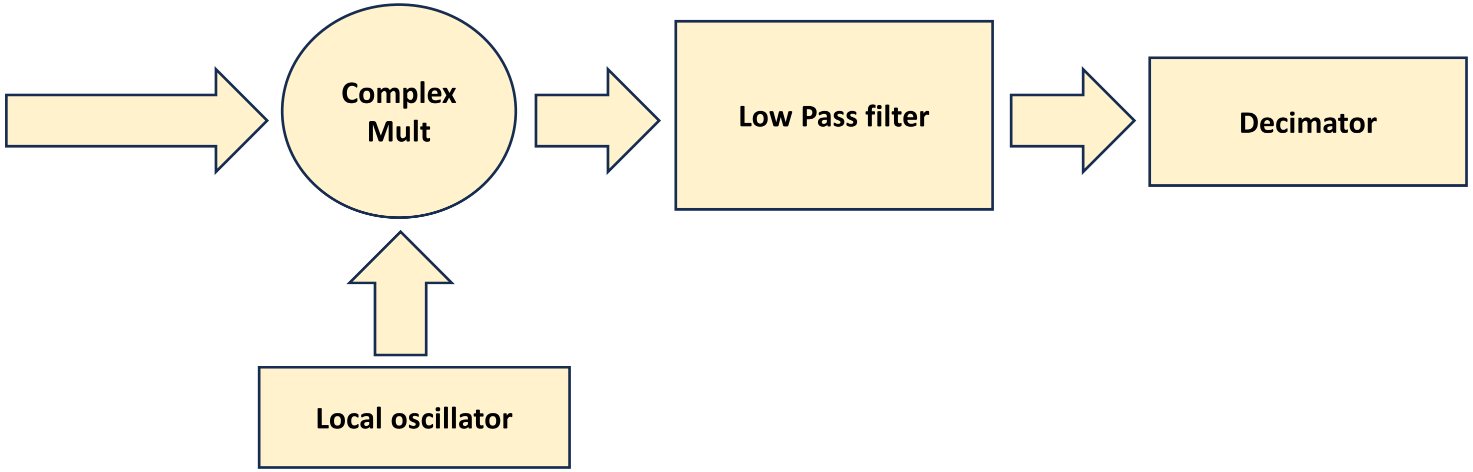
- Extracting narrow band signal from stream: DDC (Digital Down-Converter)
- Interpolation / Decimation
- Clock recovery
- Synchronization & pattern detection

What do we want to achieve

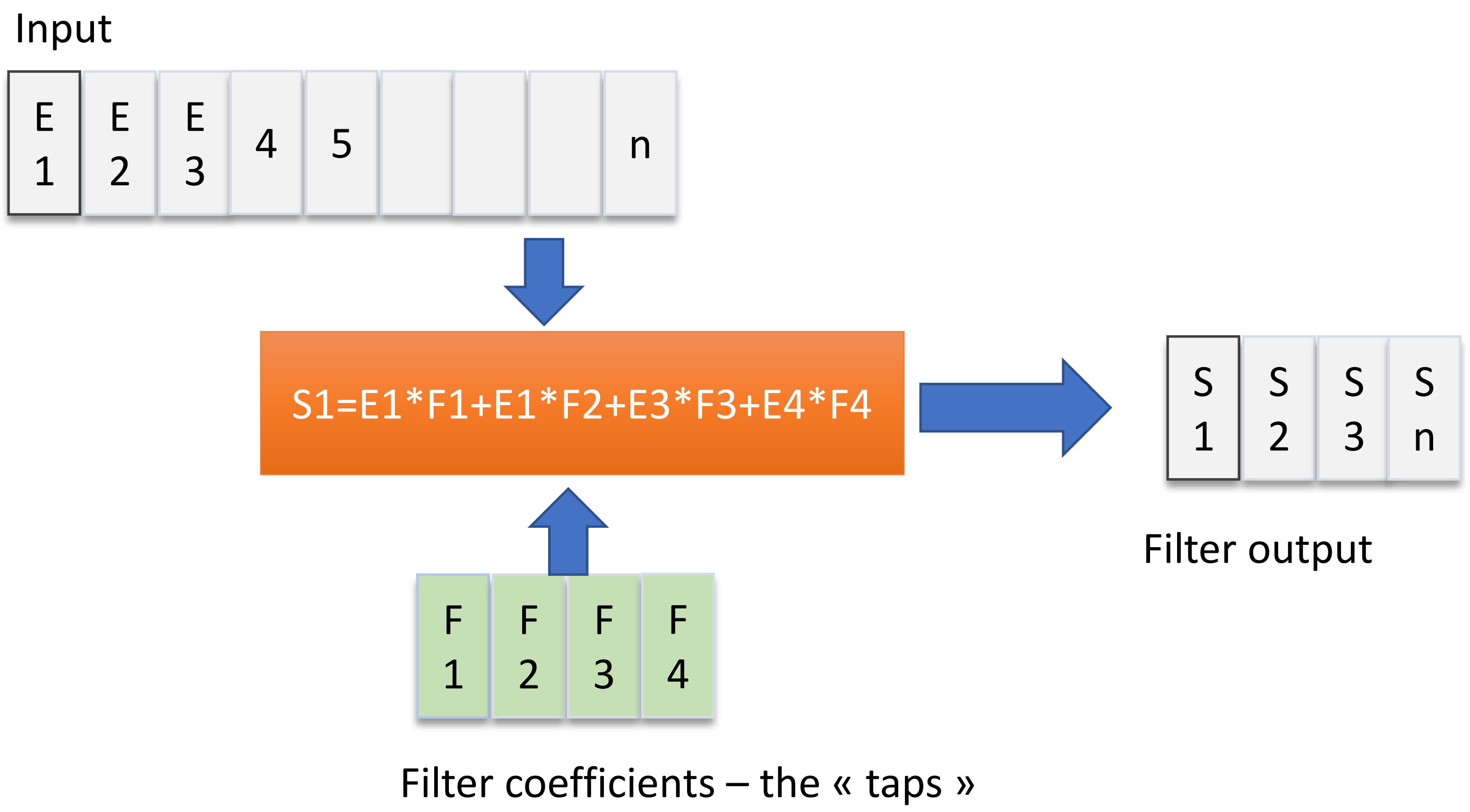
Have multiple sub bands from one single input, with different specifications (bandwidth, oversampling, …)



How do we do this ? [for one channel]



Low-Pass Filter : the convolution



Where is the issue ?

« Harris approximation »

$$N_{taps} = \frac{Atten}{22 * B_T}$$

Atten is the desired attenuation in dB,

B_T is the normalized transition band $B_T = \frac{F_{stop} - F_{pass}}{F_s}$,

F_{stop} and F_{pass} are the stop band and pass band frequencies in Hz and

F_s is the sampling frequency in Hz.

Low-pass filter might need a lot of taps

For example, we want a SSB output IQ stream from a 50 MHz continuous stream

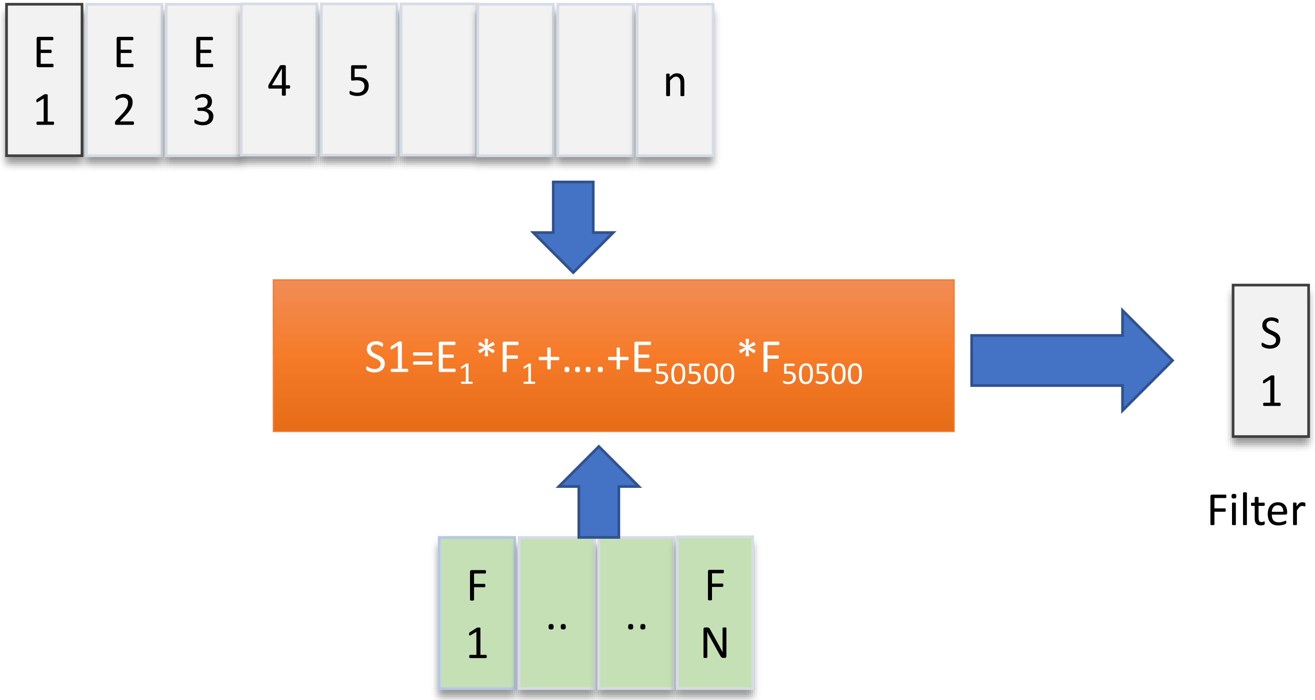
- Our signal is 3300 Hz wide, stop-band for example 6kHz
- We need at least 60 dB of attenuation for unwanted signals

$$B_T = \frac{6000 \ - 3300}{50\ MHz} = 0{,}000054$$

$$N_{taps} = \frac{60}{22 * 0{,}000054} = \frac{60}{0{,}001188} = 50\ 500\ taps$$

So what ????

Input : 50 500 values at 50 MSPS



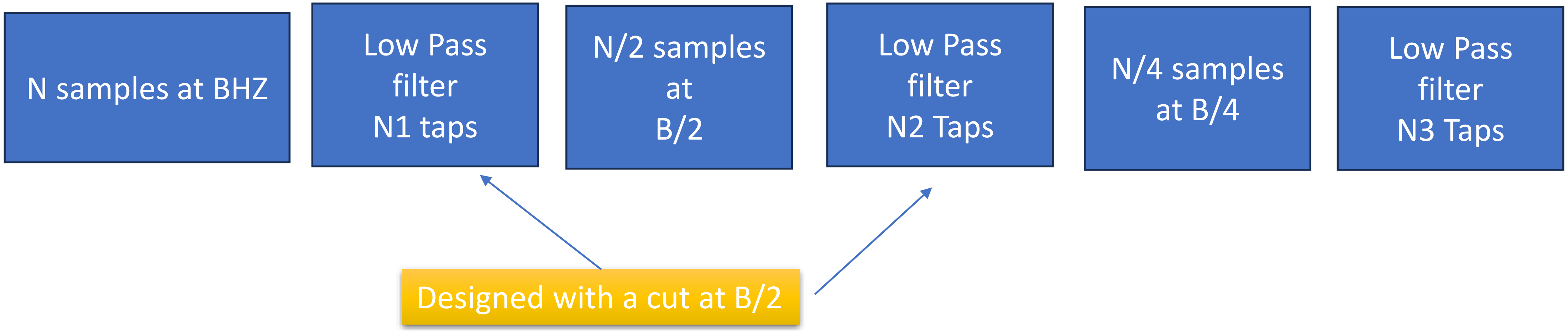
Filter output : **1** value

50500 coefficients

We must do this for **every sample**… that is 50 000 000 times per second

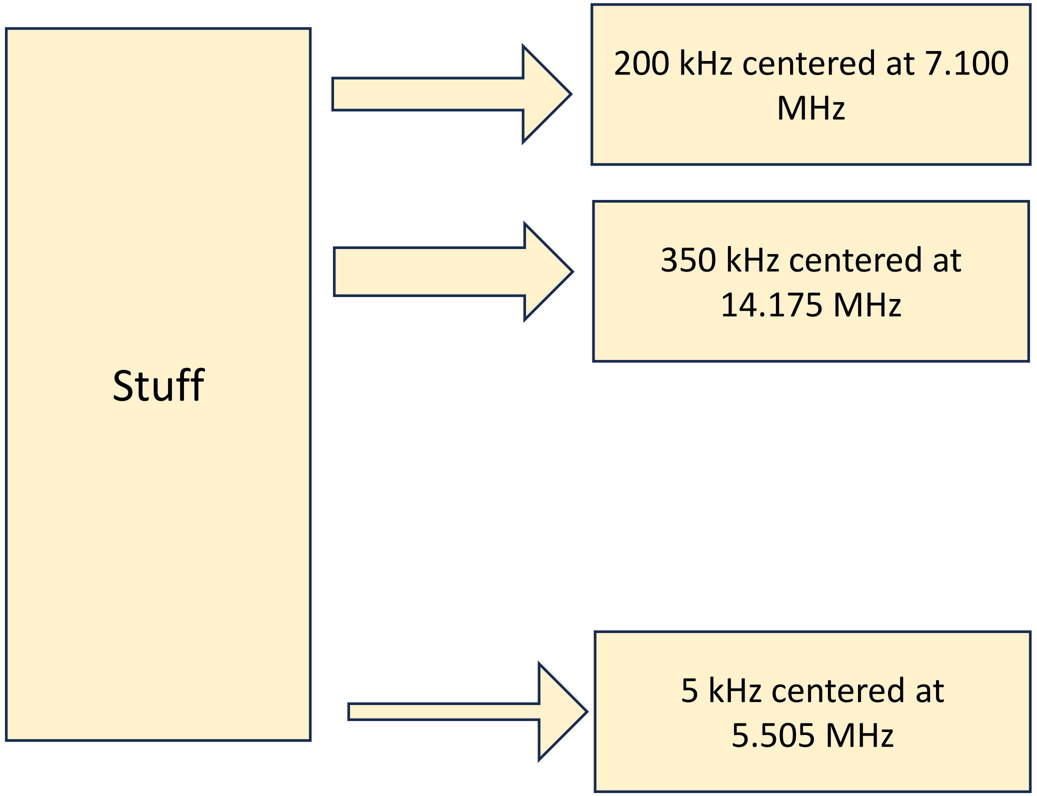
What are the solutions ?

- Divide by two, decimate, divide by two, decimate, divide by two, decimate....



- Half-band LPF = 50% of the coefficients are … 0
- Each block deletes 50% of samples
- The number of taps is increased as the throughput is reduced : N1 < N2 < N3 …

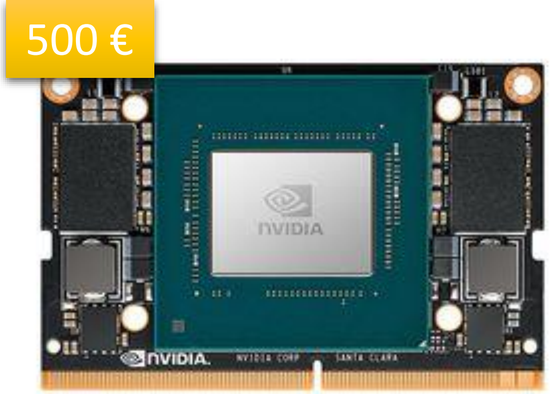
But… ?



We can hardly reuse the "divide by 2 cascade", because the center frequency of the different channel is different

Can GPU help ?

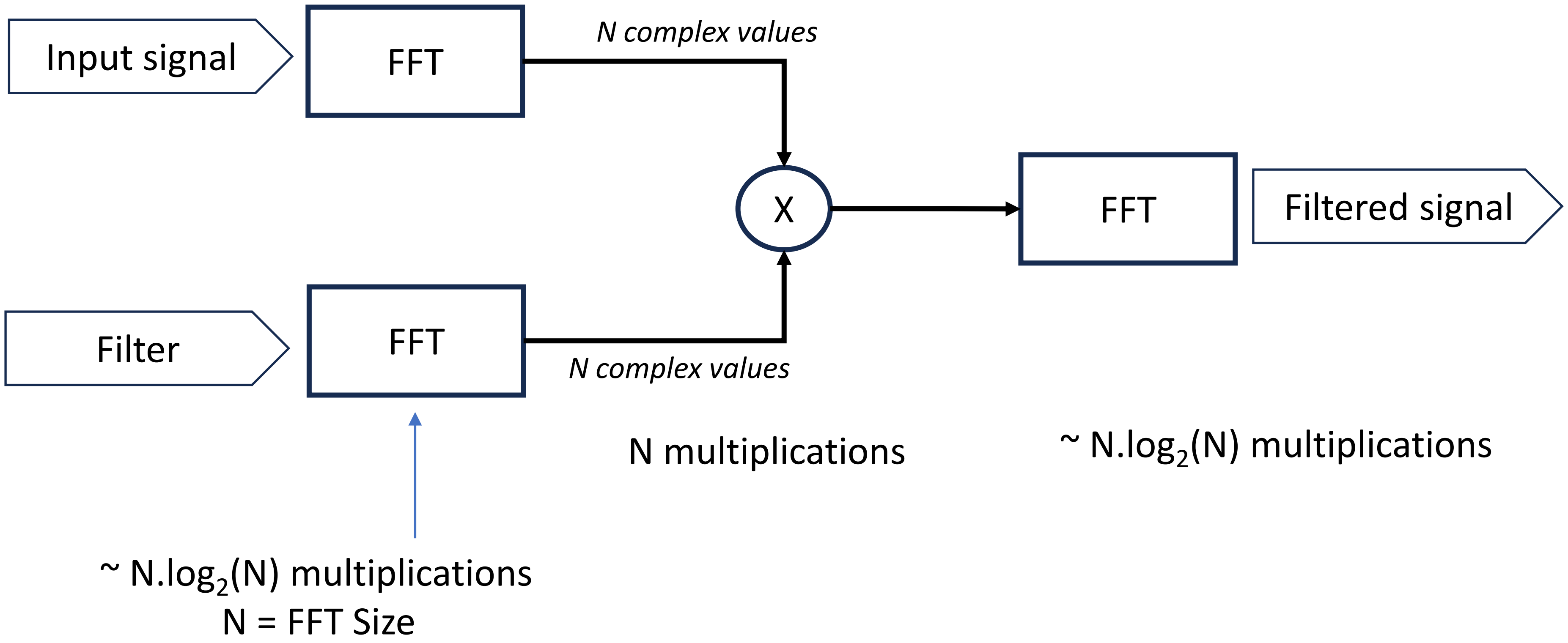
- NVIDIA **Jetson Xavier NX**
  - GPU with 384 cores – 16 GB
    - FFT Size : 524 288 (2^{19}) : 0.31 milli secs
    - FFT Size : 8 388 608 (2^{23}) : 7.15 milli secs



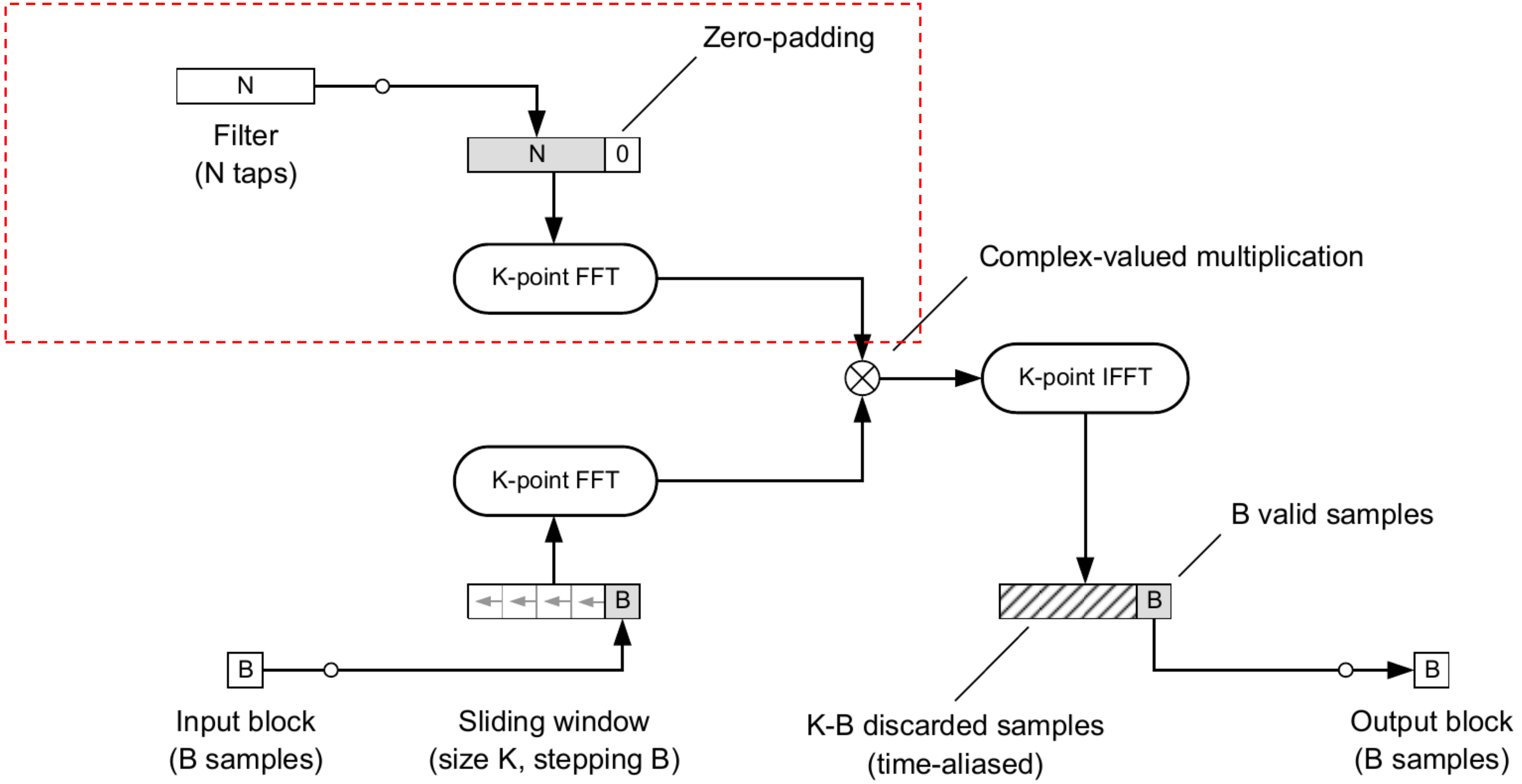
- NVIDIA **A100** :
  - GPU with 6912 cores – 80 GB
    - FFT size = 2^{23} : **0.17** milli secs (!)
    - FFT size = 2^{30} : 23.3 milli secs

Convolution… and FFT

This works for 1 single block of N samples long

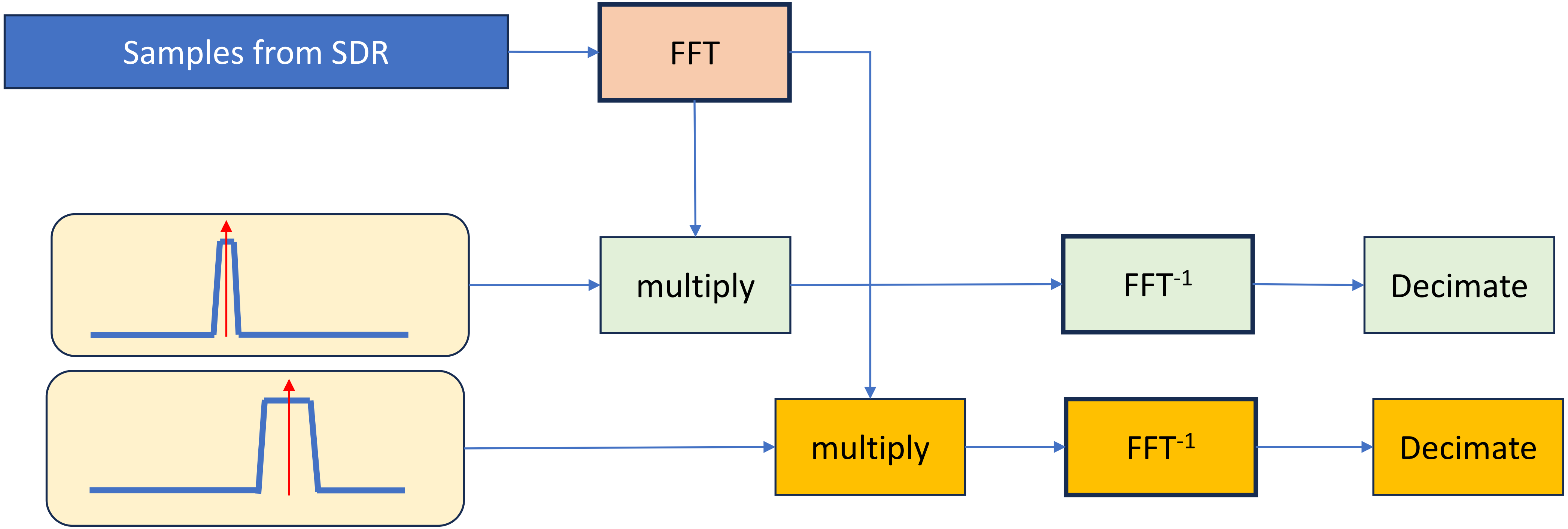


The Overlap-Save method



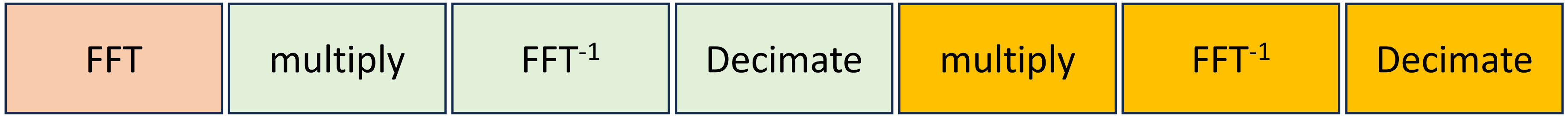
Source: https://thewolfsound.com/fast-convolution-fft-based-overlap-add-overlap-save-partitioned/

Adding output channels



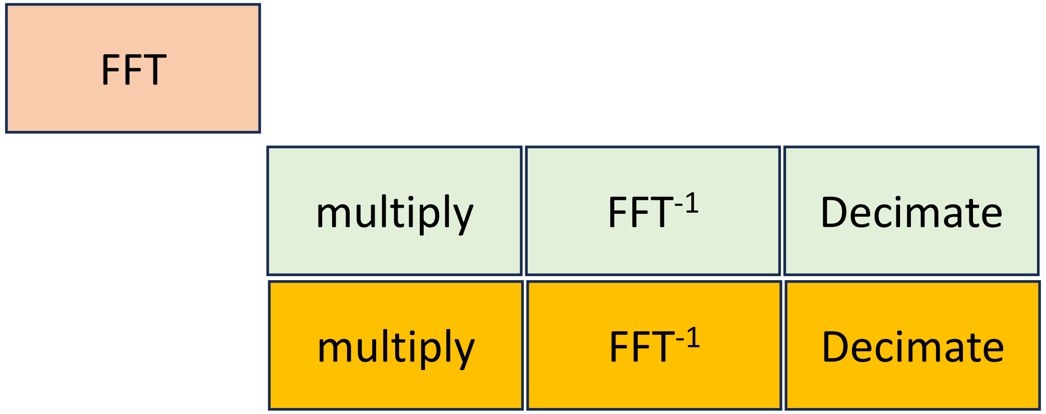
A nice feature from NVCC and NVIDIA devices

By default, kernels (CUDA code) are run sequentially…



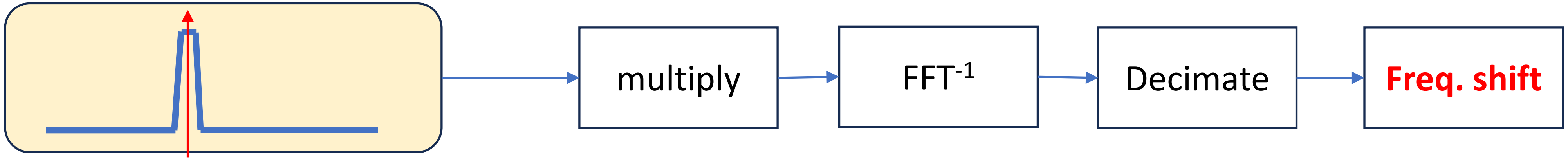
This enables the different GPU processing streams to run concurrently :

```
nvcc --default-stream per-thread
```



Small « issue » we need to fix

➲We want our output band « centered »



➲We need to frequency shift the signal…

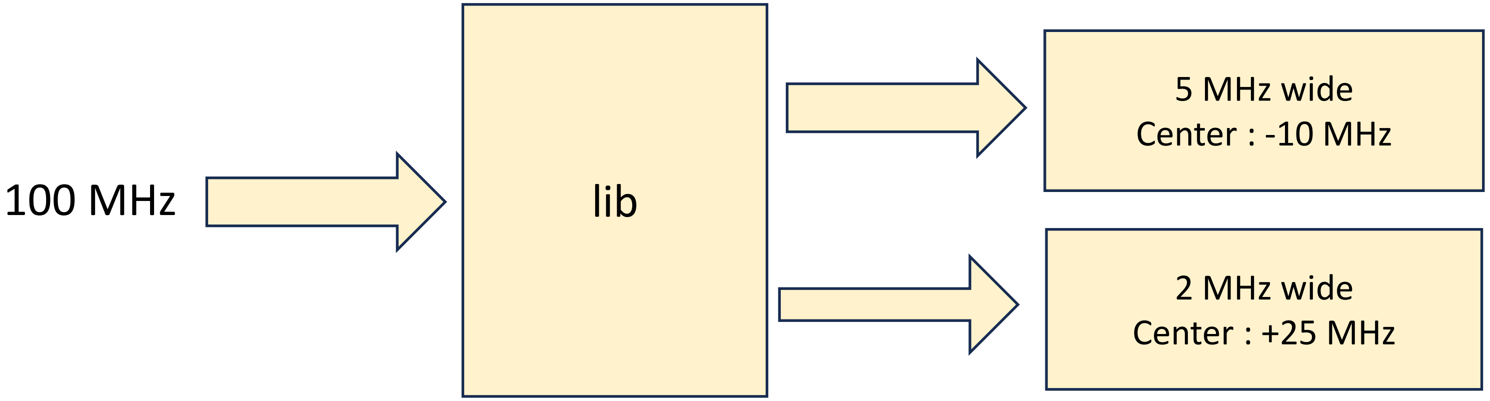
The easiest is to do this after the decimation step : we will use less multiplications
BUT we must compensate for the aliasing (look in the code ☺)

The « libGKR4GPU »

https://github.com/f4gkr/**libgkr4gpu**/

- Accepts « any » number of output channels (limit: GPU ram)
- Accepts « on the fly » addition, deletion of channels
- Thread safe
- No external dependency (except CUDA)
- Any channel can be retuned
- C "++" and CUDA, works **ONLY** with NVIDIA GPU, Desktop or Jetson family

A quick look at the performances



Filters: 7200 Taps

CPU	GPU	FFT Size	1 channel	2 channels
Intel® Core™ i7-9700K CPU @ 3.60GHz × 8	GeForce RTX2060	512*1024	608 Mega samples/sec	530 Mega samples/sec
Jetson Xavier NX	Jetson	256*1024	130 Mega samples/sec	70 Mega samples/sec
Jetson Xavier NX	Jetson	512*1024	156 Mega samples/sec	117 Mega samples/sec
Jetson Xavier NX	Jetson	1024*1024	143 Mega samples/sec	103 Mega samples/sec

Looking for speed

- Size of FFT and Filter length : depends on # of Cuda Cores
- Moving data from Host to GPU is expensive
- Gathering samples from SDR via USB through LibUSB is expensive

- The most important: the CPU is available for other tasks !

That's all folks

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