The issues with SDRs

Morgan Diepart

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Who I am

Morgan Diepart

- Research engineer for SDR-Engineering
- Also a PhD student at University of Liège
- Licensed ham radio operator ON4MOD, member of the LGE section
- Mainly interested in hardware design and firmware development

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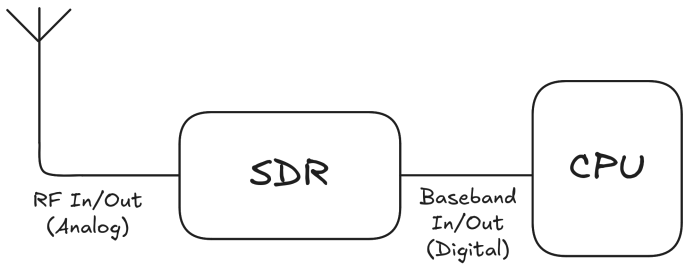
Preamble

What is an SDR

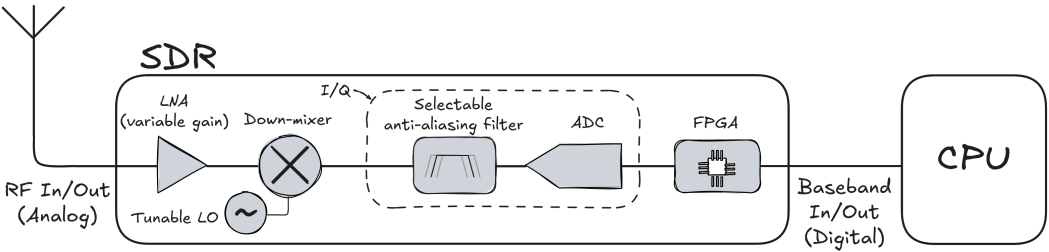


High-level diagram of an SDR

What is an SDR

RTL-SDR dongle (image source : https://www.aliexpress.com/item/1005005952682051.html)

What is an SDR



Low-level diagram of most common SDR architecture (RX)

SDR-Engineering

Who are we?

SDR-Engineering is a small company located in Crealys science park, Namur.

We develop various applications based on Software Defined Radios (SDR) for railways, drone detection, medical monitoring, ...

What do we do?

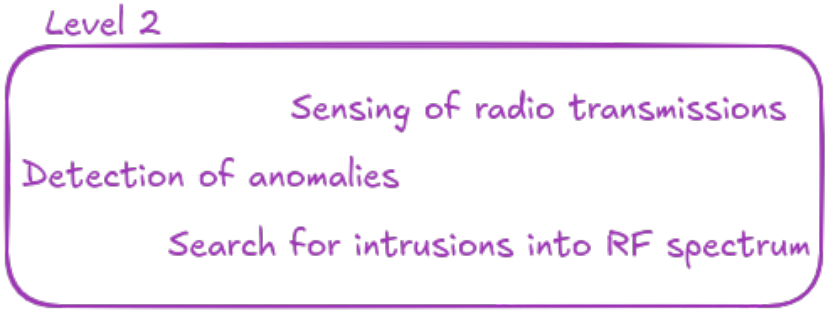
Level 1

Here are a few examples of what we can provide

What do we do?

Level 2

Here are a few examples of what we can provide



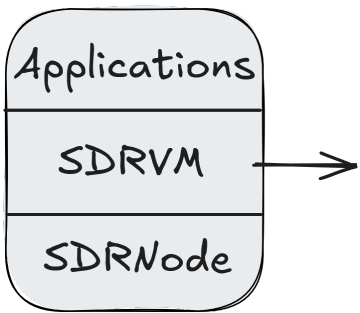
What do we do?

Level 3

Here are a few examples of what we can provide

What do we do?

SDRVM

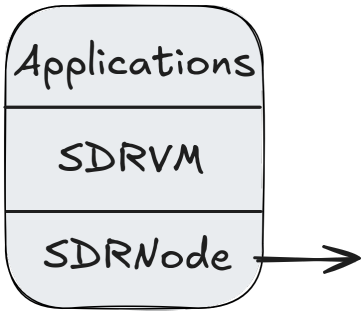


SDRVM:

- A lightweight virtual machine for the signal processing
- Free license available for Ham operators: `https://sdrvm.sdrtechnologies.fr/`

What do we do?

SDRNode



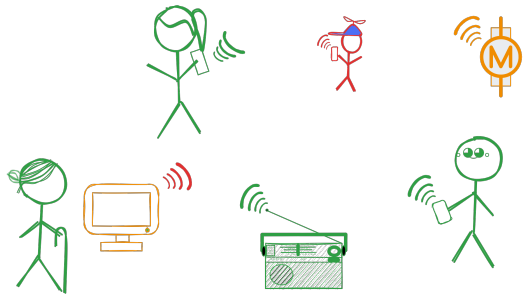
SDRNode:

- Radio transceiver based on SDR
- Various versions depending on the needs
- GPU available for parallel signal processing

The limitations of SDRs

Our use case

We will place ourselves in a spectrum-monitoring situations.



We want: a large (instantaneous) bandwidth, a high probability to intercept signals, and highly-flexible analysis of the signal (location, type, content, ...).

Our use case

It's like where is waldo...

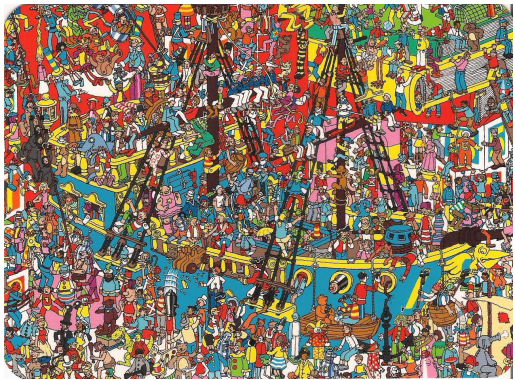


Image source: https://x.com/shutupmikeginn/status/679045081937018880

Our use case

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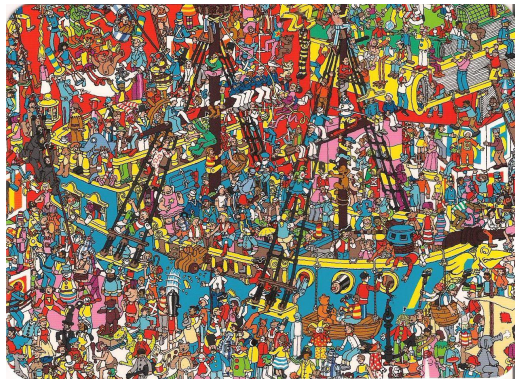
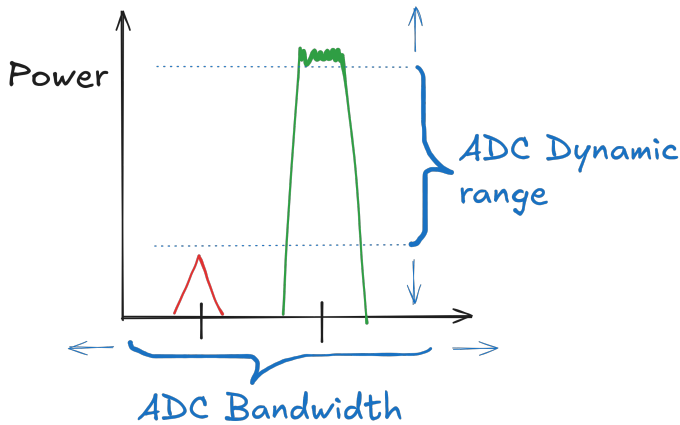


Image source: https://x.com/shutupmikeginn/status/679045081937018880

But you are not sure waldo is in the picture.

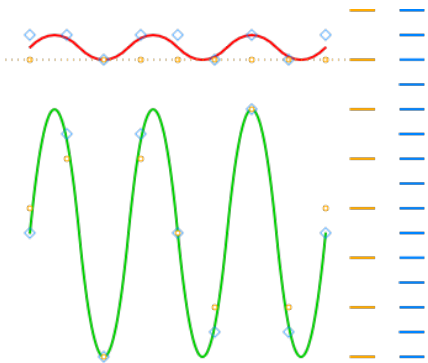
Our needs

As such, we need a system which is wide-band, but most of all, is able to detect weak signals



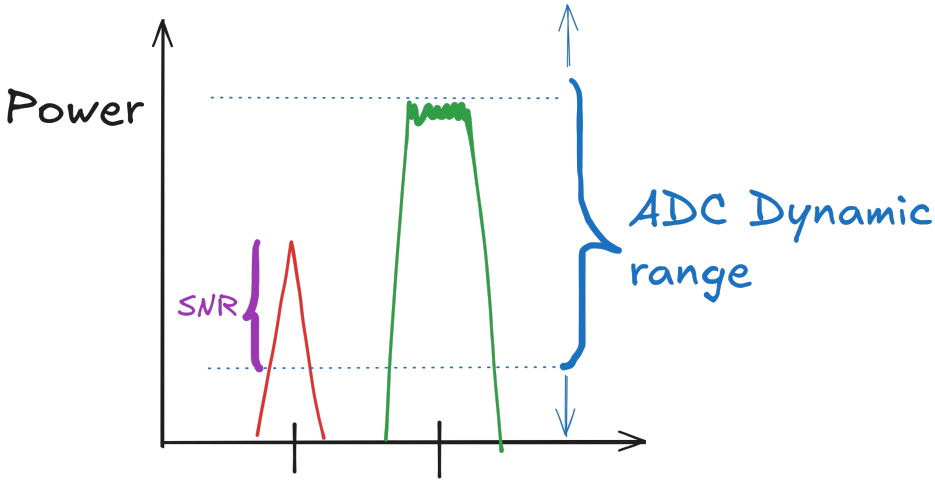
The dynamic range

The dynamic range is the difference between the most powerful and the least powerful signal that a radio can reliably receive.



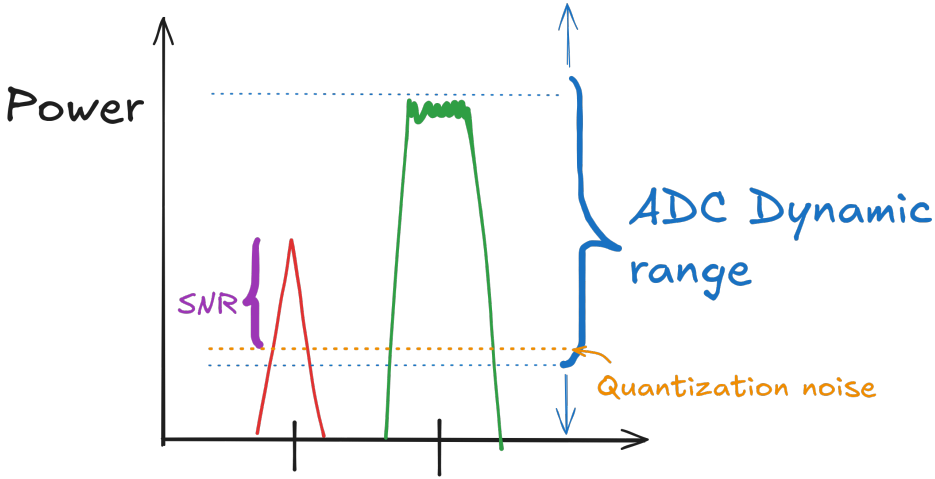
Maximum dynamic range of an ADC compared to the number of bits

ADC Dynamic range



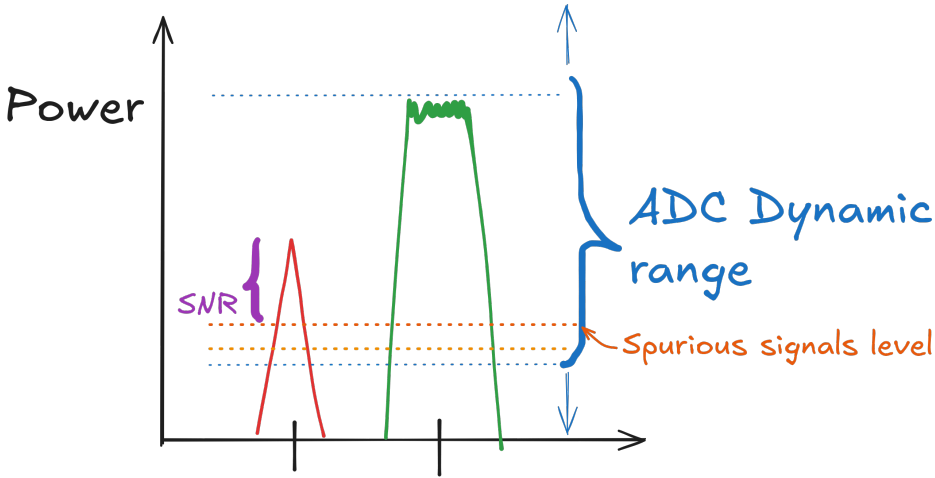
Dynamic range of an ADC (spectrum view)

ADC Dynamic range



Dynamic range of an ADC with quantization noise

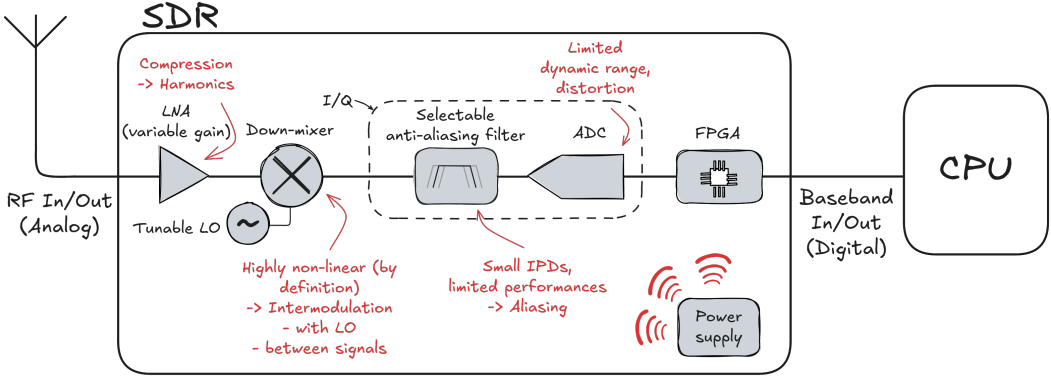
ADC Dynamic range



Dynamic range of an ADC with quantization noise and spurious signals

Where do the problems come from?

There are many sources of noise in an SDR...



Main sources of noise in an SDR

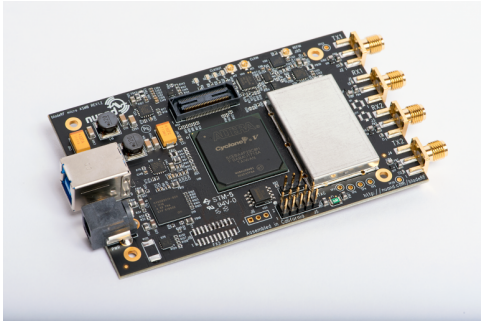
What to do then?

Here are a few ideas:

- Reduce the gain
  $\Rightarrow$ yes but, what about our low-power signals ?
- Use better components
  $\Rightarrow$ yes but, linearity often comes at the cost of more current consumption
- Use a better ADC
  $\Rightarrow$ yes but, does it even exist?
- Attenuate the higher-power signals (and increase the gain to improve the SNR of low-power signals)
  $\Rightarrow$ Ok, but how?

Examples

Here are a few examples illustrating what we discussed.

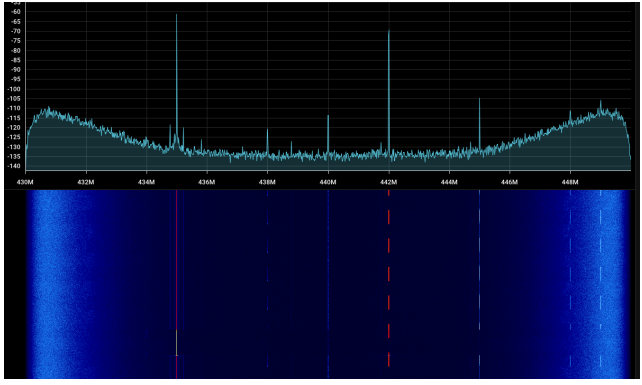


BladeRF 2.0 Micro (image source: https://www.nuand.com/bladerf-2-0-micro/)

ADC is 12 bits (the maximum dynamic range is thus 72 dB).

Examples

Intermodulation

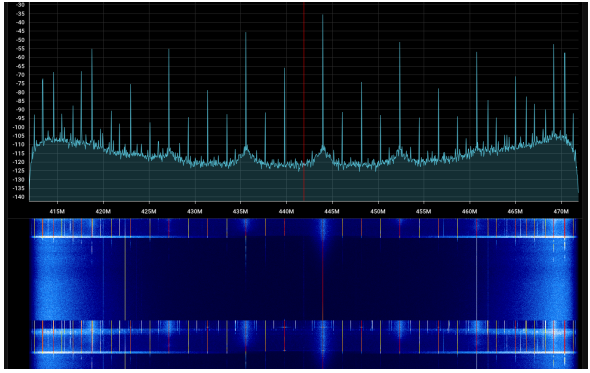


Intermodulation products created inside the BladeRF with signals at -56 dBm

Files `01-intermod_minus56dbm.mkv`, `02-intermod_moving.mkv`, `03-intermod_moving_powerful.mkv`.

Examples

Saturation



Saturation of the BladeRF at around -30 dBm

File `04-saturation_bladerf.mkv`

Quick summary

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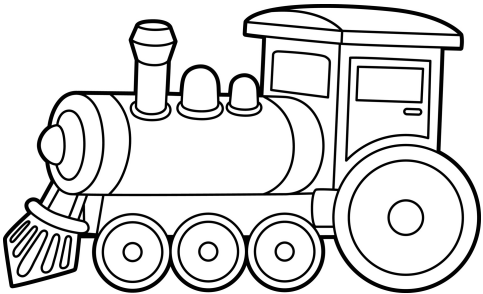
Different parts of the SDR creates different kinds of noise.

The main problem stays the overall dynamic range of the system

The dynamic range of the receiver is difficult to improve

Ongoing research

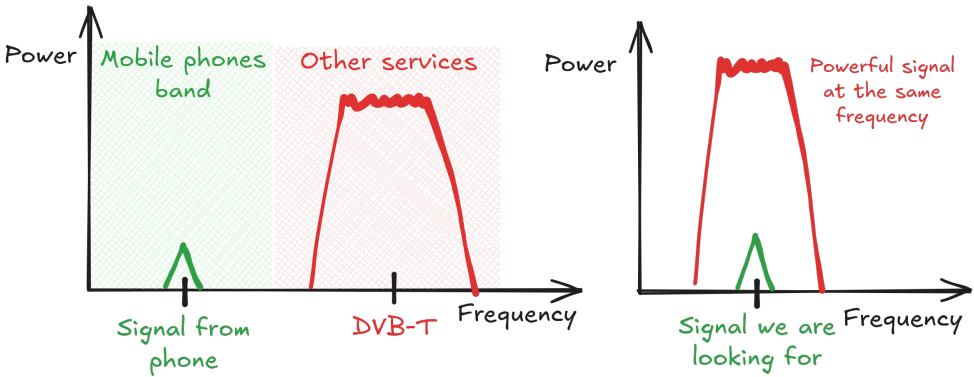
Taking a few examples



A train (image source: https://www.vecteezy.com/)

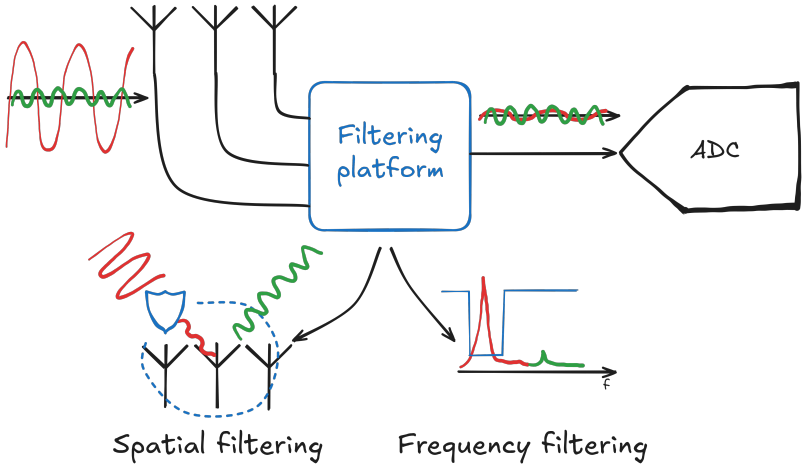
A person lost in the forest?

Problems



Two main categories of problems

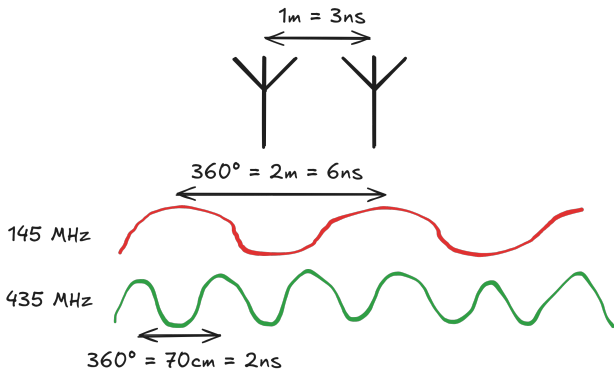
How to solve these issues?



The goal of this work

How to solve these issues?

How to do beamforming over a wide frequency band?



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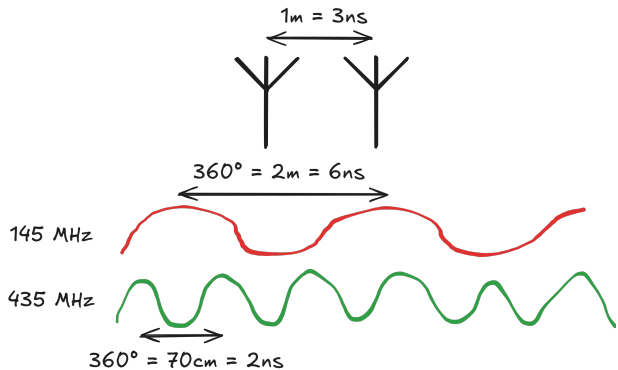
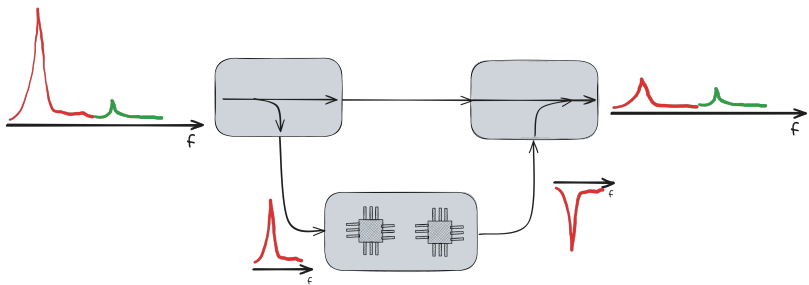


The answer might be True-Time-Delay techniques.

How to solve these issues?

How to do frequency filtering over a large bandwidth with adjustable filter width?



Decoupling the most powerful signals before the SDR

How to solve these issues?

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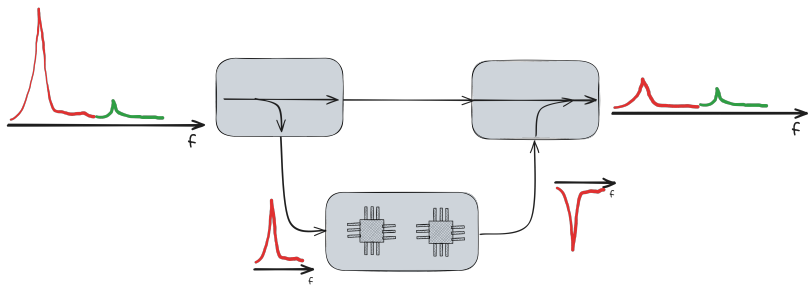


Decoupling the most powerful signals before the SDR

The answer might be based on active noise cancellation techniques

Conclusion

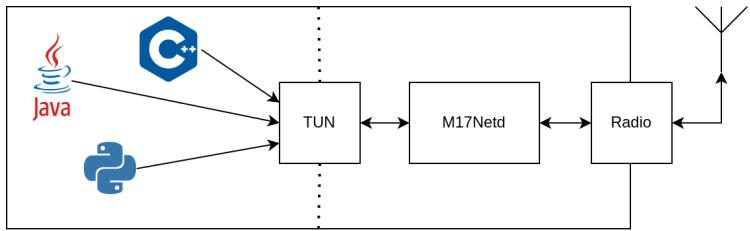
The final goal is a platform that can be embedded in drones.

The work started in october 2024 (for 4 years).

This project is financed by the SPW Économie Emploi Recherche through the Win4Doc program (grant n°2410122)

Bonus: M17Netd

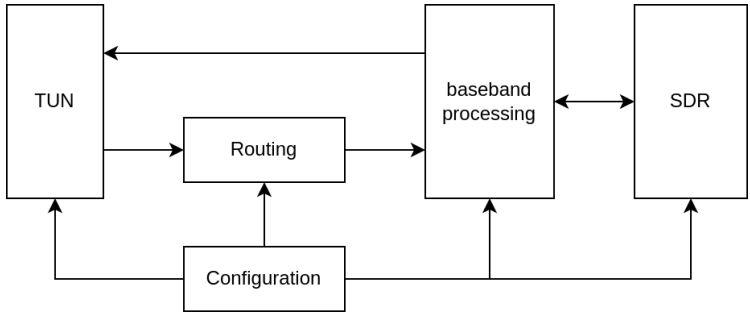
M17Netd



Principle of M17Netd

It allows to create IP links over M17.
Current implementation works on an SDRNode

M17Netd



Architecture of M17Netd

The bitrate is about 0.5 kB/s (or 4000 b/s). Enough to communicate remotely with a relay.

This project is open-source!

M17Netd uses the M17 protocol

M17Netd uses OpenRTX demodulator for M17

The project's source code can be found at :
`https://github.com/mdiepart/M17Netd`

Demo

Establishing an SSH connection over M17 using M17Netd?

File `05-demo_ssh.mkv`.

What's next?

Some of the future goals for M17Netd include:

- Support for Soapy to support many SDR devices
- Writing a better M17 library
- Supporting OpenRTX devices as node devices

Thank you

Don't hesitate to ask questions about SDRs, SDR-Engineering, my thesis, M17Netd, or whatever you feel like asking.

Contact me: m.diepart@sdr-engineering.be