# Study of the use of a SDR Passive RaDAR for the safe outdoor operation of an atmospheric LiDAR

F. Peyrin[1], J.-M. Friedt[2]
[1] OPGC, UMS 833 CNRS, Univ. Clermont Auvergne, Aubière, France
[2] FEMTO-ST, UMR 6174 CNRS, Univ. Franche-Comté, Besançon, France

March 28, 2019

**Abstract**

Our project aims to evaluate the potential of the Software Defined Radio technology associated to GNU Radio ecosystem in order to propose new and pragmatic solutions when applied to scientists needs, thus bridging the gap between engineering and research points of view. Here, we study the ability for a passive RaDAR to detect aircrafts and allow safe operation of a LiDAR.

## 1 Introduction

The OPGC [1] is an Observatory of Earth Sciences dedicated to Volcanology and Physical Meteorology. Among instruments implemented, a LiDAR helps to characterize the composition of the atmosphere in aerosol particles.

The LiDAR activity requires compliance with international air traffic regulation [2]. Due to strong Laser emission, the potential ocular hazard for the pilots must be cancelled by stopping the Laser emission while an aircraft is flying over the critical zone of the LiDAR. Usually, air traffic safety is provided by a X-band pulsed radar determining the presence (position, altitude, speed) of any aircraft entering the vicinity of the LiDAR.

On the one hand, a first alternative solution has been developed based on acquiring and processing ADS-B frames transmitted by the IFR aircrafts [3]. On the other hand, we also study and present here the potential of a passive RaDAR solution based on J.-M. Friedt previous work [4] using an existing non-cooperative source.

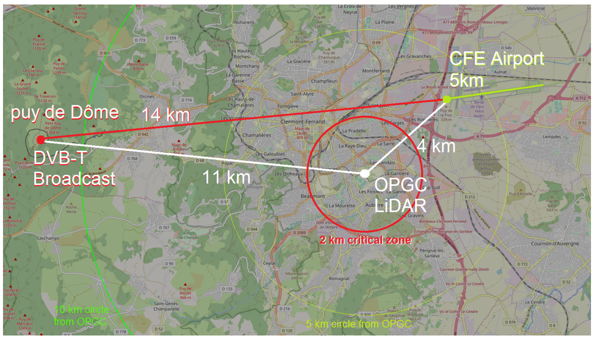


Figure 1: LiDAR location and critical zone.

We used GNU Radio to acquire and save DVB-T signal (Fig. 2) echoed by the moving distant target.

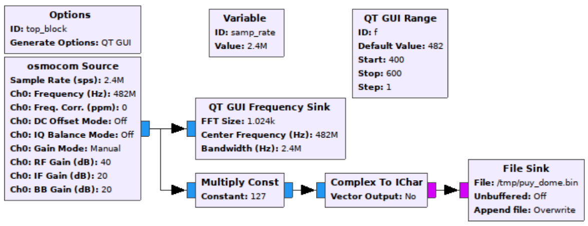


Figure 2: GNURadio code for DVB-T acquisition

## 2 Experimental setup

Experimental setup involves the reception of echoes of the local Terrestrial Digital Video Broadcasting (DVB-T) source reflected by cabin's aircrafts. The LiDAR and receiver are located (Fig.1) on the roof of the OPGC, 420 m above sea level, 4 km away from the airport and 11 km from the Puy de Dôme, 1465 m asl., where is located the DVB-T emitter.

The receiver hardware configuration was based on a RTL-SDR USB stick that features the Realtek RTL2832U chipset and the R820T2 tuner specifically designed for use in SDR mode. We used this broadband receiver coupled to a UHF yagi antenna to acquire DVB-T broadcast at 482 MHz.

Then, using MATLAB (MatWorks), we post-processed these data by autocorrelation to find the transmitted signal, delayed in time, so shifted in frequency by Doppler shift.

## 3 Results

Several tests have been processed (available at [5]). Among these, a measurement at a bistatic distance of 10 km (Fig.3), which is sufficient compared to the critical zone, suggests the ability to detect aircraft flying up to ten thousand meters above our LiDAR.

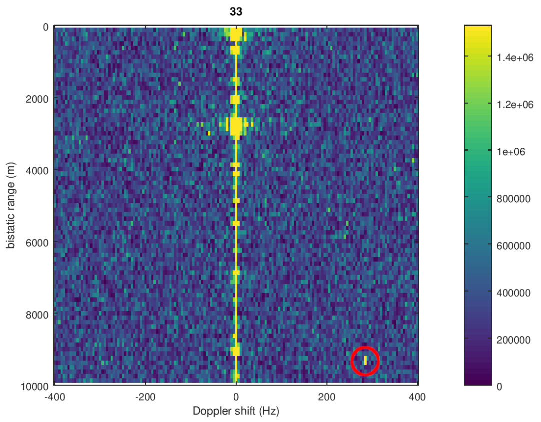


Figure 3: Remote detection (a.u.) of the target, circled with red, at a bistatic distance of 10 km, i.e. an aircraft at a distance of 5 km in a configuration where source, receiver and target are aligned.

The DVB-T emitter provides promising results that need to be confirmed with a suitable hardware, i.e. two synchronized receivers fed by directional antennas, one pointing to the transmitter (reference signal) and an other one pointing to zenith to detect eventual mobile targets (surveillance channel). Separating the reference and monitoring channels improves the signal-to-noise ratio and, more importantly, eliminates artifacts related to autocorrelations of signals due to multiple targets.

The main limitation currently observed is the processing time of the acquired signals. In the absence of any optimization (arbitrary choice of 221 processed points, for a Doppler shift analyzed by steps of 5 Hz between -400 and +400 Hz), and post-processing the acquired data with an interpreted language (GNU / Octave), two minutes are needed to process every second of recording. Without considering a processing shorter than the acquisition time, the main effort, in addition to the experimental setup, must focus on the reduction of this computation time, highly parallelizable and optimizable in terms of choice of the parameters of analysis. Towards the aim of real time processing, shifting part of the processing chain from general purpose Central Processing Units (CPUs) to FPGA parallel computing units is being developed [6].

## 4 Conclusion, Perspectives

This study highlights the potential of the SDR concept in regard to our applications. While detecting ADS-B with a dongle could already give an inexpensive solution for air traffic safety during LiDAR activity, the passive RaDAR implementation could be complementary for operational purpose if hardware is upgraded and calculation time is lowered.

More generally, SDR implementation may also be helpful for further Earth Science Experiments driven at the OPGC, in particular when applied to remote sensing instruments. For example, Software Defined Radio could also be dedicated to passive or active RaDAR concepts involved in characterization of atmospheric clouds or volcanic ash plumes. The main technical objectives are to improve the ergonomics and the mobility of instruments on the field, to improve the spatial and temporal resolutions (size and movement of the targets), to reach a greater modularity (emission-reception, directions, frequencies ...), and to optimize the overall cost of development and maintenance of these new systems. This ongoing study will be focused on free and open source ecosystem such as GNURadio.

## References

[1] at http://wwwobs.univ-bpclermont.fr/

[2] *Doc 9815 AN / 447 2003 of the International Civil Aviation Organization, 2003* at https://www.skybrary.aero/bookshelf/books/3849.pdf

[3] *Tests of the ADSB-SDR technique to detect aircrafts - An alternative to radar solution for air traffic safety during Lidar activity, F. Peyrin et P. Freville, 2018* at https://www.researchgate.net/publication/329874059_Tests_of_the_ADSB-SDR_technique_to_detect_aircrafts_-_An_alternative_to_radar_solution_for_air_traffic_safety_during_Lidar_activity/

[4] *RADAR passif par intercorrélation de signaux acquis par deux récepteurs de télévision numérique terrestre, J.-M Friedt, 2018* at http://jmfriedt.free.fr/passive_radar.pdf

[5] *RADAR passif pour la sécurité d'opération d'un LiDAR, F. Peyrin et J.-M Friedt, Experiment Findings, 2018* at https://www.researchgate.net/publication/331929425_RADAR_passif_pour_la_securite_d%27operation_d%27un_LiDAR/

[6] J.-M Friedt, W. Feng, S. Chrétien, G. Goavec-Merou, M. Sato, *Passive radar for measuring passive sensors: direct signal interference suppression on FPGA using orthogonal matching pursuit*, accepted SPIE Multimodal Sensing and Artificial Intelligence: Technologies and Applications (München, 2019)