

# A Software Defined Radio Approach to Ground Operations of Small Satellites.

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## ABSTRACT

*In order to reduce costs on the ground segment for small satellites projects, Software Defined Radio (SDR) technology is advantageous as it reduces the amount of hardware components while adapting for different modulation schemes, link budget requirements while supporting different satellites. This work briefly presents this proposal and discusses some of the issues it entails. The SDR technology uses a processor, a special receiver and software that plays the main parts of the receiver (mixer, filters, amplifiers, modulators, demodulators, etc.) to listen to radio, television and almost all transmission modes, whether digital or analog. A first trial with this configuration was implemented to receive signals sent from a Brazilian picosatellite named Tancredo-1 and obtain the engineering value of the telemetries sent by the same. For this purpose, specific software was developed, named UbaTM - Decoder for obtaining the raw value of each of the telemetries, perform the operations necessary for the conversion to engineering value and present them friendly on a screen to the user. A series of support software packages is presented so that one can pipeline various operations, which can lead to ground stations automation.*

**Keywords:** *Software Defined Radio. Ground Stations. Small Satellites. Automation.*

## 1. Introduction

The development of projects regarding to pico and nanosatellites, also called sometimes of small satellites, the type CubeSat/TubeSats in the university environment has grown in Latin America significantly in the last decade. In 2002, there were fewer than two active projects and currently this number exceeds 20 projects [1]. Besides that, in Brazil was a significant increase in the development of such satellites on the one hand with the NanoSatC-BR1 [2], the AESP-14 [3], and Serpens [4] already released and other projects like ITASAT still in development [5].

The cost of these small projects is always a limiting factor, so the object of study in this paper is how to use the SDR technology aiming cheapen and facilitate access to communication link with small satellites in this way is intended to train qualified people in the future and base a solid space industry in Latin America.

This work has the general objective to propose and implement an SDR-based solution (Software-Defined Radio) for earth stations of small satellites to maximize cost-benefit. This work is organized as follows. Section 2 discusses what it is about the SDR technology and how it works. Section 3 presents how this technology can be used in the context of small satellite. Section 4 describes a case study for projects just like the Tancredo-1 picosatellite. Section 5 concludes this paper with general comments and possible future directions.

## **2. Motivation for Using SDR Technology**

The main motivation of this work to employ SDR ground stations components into small satellites was to improve performance and data acquisition of the satellites as well as reduce the cost of development and implementation of ground stations, replacing the robust components in hardware let the costly and less adaptable to the missions of small satellite stations.

Cubesats / tubesats platforms are development projects with educational and professional purposes. The aim is to design, create, assembly and operate small satellites, developed by students of universities and research groups which do not precludes trainings for qualified human resources.

Space mission exploration of these small satellites requires one to acquire or build ground stations that give the necessary support to their operation. Therefore an engineering solution with good cost-benefit is desirable and here is the opportunity to use SDRs [6].

Often CubeSats/TubeSats work in L Band (VHF and UHF) and S Band. Thus, the amateur radio community can be of great help in this development, because it makes frequent use of SDRs and are composed of an established and organized sector for many years.

The use of SDR in amateur radio was primarily due to the low cost and the availability of its technology. SDRs were generally also incorporated into the market to provide better performance, noise reduction and digital filtering. Using SDR technology functions such as modulation, demodulation, filtering, encoding, decoding, etc are done by a software component. They could be implemented on a general purpose processor, on a DSP (Digital Signal Processing), FPGA (Field-programmable Gate Array), microcontroller, for example.

The software flexibility provided by SDRs comes from its ability to change its operation allowing the update of new and better features and better performance rate without any need to change constantly the Hardware [7].

The SDR employs an RF front-end followed by an analog-to-digital converter in a hardware card as shown in Figure 1 which samples signals and send them to a host computer. The rest of the processing is done solely in software using the SDR algorithm implemented on the host computer. This allows for a greater operational capacity and reduces the cost with other equipment. As an example one can refer to FUNcube

Dongle [8] and the GAUSS Ground Dongle [9].



Figure 1 - SDR hardware adapter. [10]

### 3. Infrastructure Options for Affordable SDR-Based Tracking

The implementation of a cost-effective solution for SDR-based tracking of small satellites involves a series of hardware and software elements, which interconnected with each other, provide the function of reception and decoding of the signals sent by the satellite.

Some of the points presented hereafter are just some software options available mainly for the downlink monitoring where some are suitable for a casual satellite tracking but are not quite adequate to be integrated into a ground station system that needs sometimes to function autonomously.

#### 3.1. Hardware Options for Tracking Satellites

The hardware part of this infrastructure may be simply as: (1) Laptop, (2) Funcube Dongle Pro Plus show in Figure 2 or similar SDRs and, (3) RF Antenna.



Figure 2. Funcube Dongle Pro Plus connected to computer <http://www.funcubedongle.com/>

For the RF part of the project, one can employ many solutions and one pointed in this work is a MoxonZBZ antenna [11] with two elements in VHF and four elements in UHF.

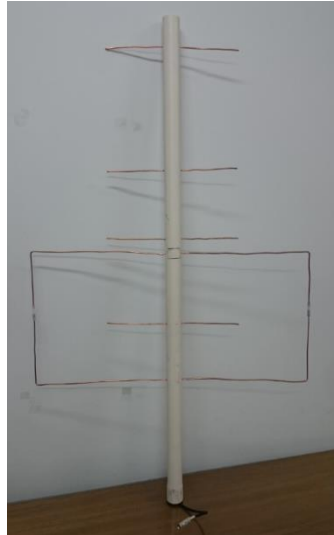


Figure 3. Antenna VHF and UHF fabricated for receive the satellite signals.

### 3.2. Software Options for Tracking Satellites

There is a great many of software packs available for various platforms from desktop to mobiles. This work calls attention to some which are available free of charge making them suitable for projects that run on a budget, namely: Heavens-Above, Orbitron, SDR Sharp, SoundModem.

The Heavens-Above app on Android [12], shown in Figure 4, has a list of satellites, including those dedicated to radio amateur, with information about them and their passes.

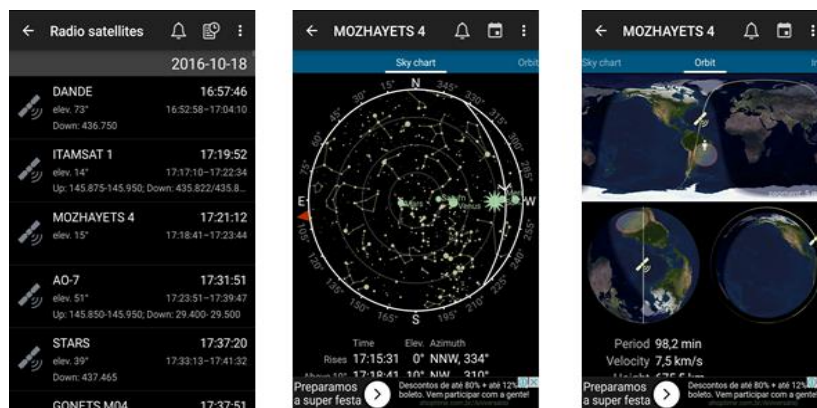


Figure 4. Various Heavens-Above app screens on passing-by satellites [12]

Orbitron is a well-known software to track satellites, shown in Figure 5, providing real time and simulated position and pointing antennas according to their azimuth and elevation [13].

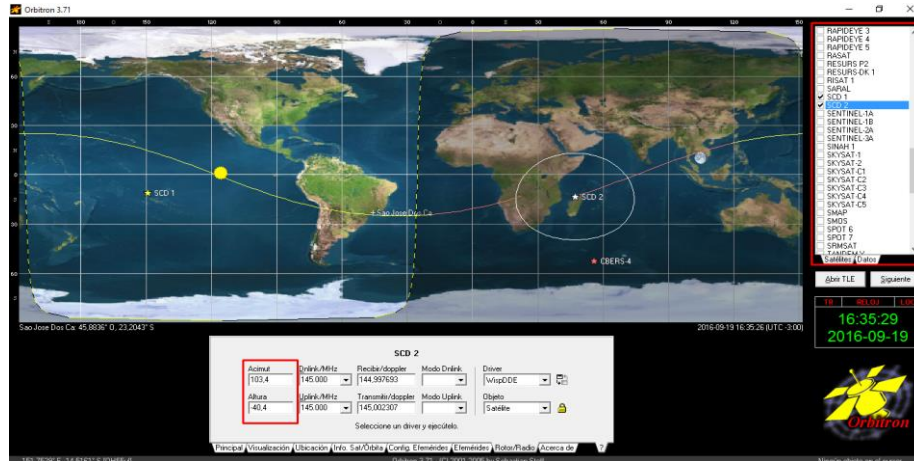


Figure 5. Orbitron screenshot with satellite tracking information [13].

SDR Sharp by AIRSPY [14] is an application that replaces conventional physical radios, shown in Figure 6, allows you to listen to the signals sent by the satellite.

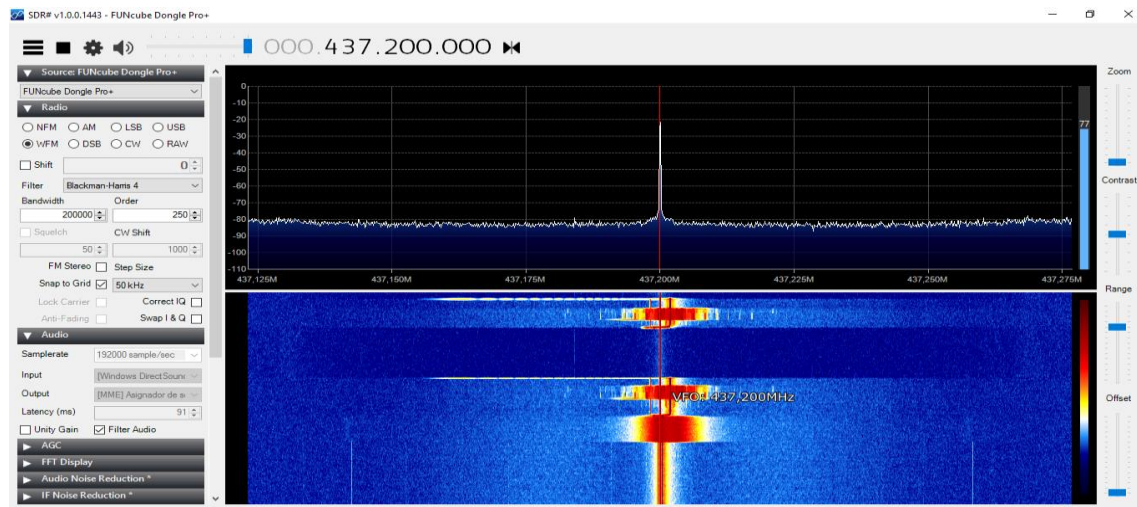


Figure 6. SDR Sharp screen with spectrum of received signal. [14]

SoundModem v.95 by UZ7HO [15] is a software that converts the satellite signals into ASCII information encoded, shown in Figure 7. Basically, it listens to the signal received by the radio via the computer microphone, in this case an SDR.

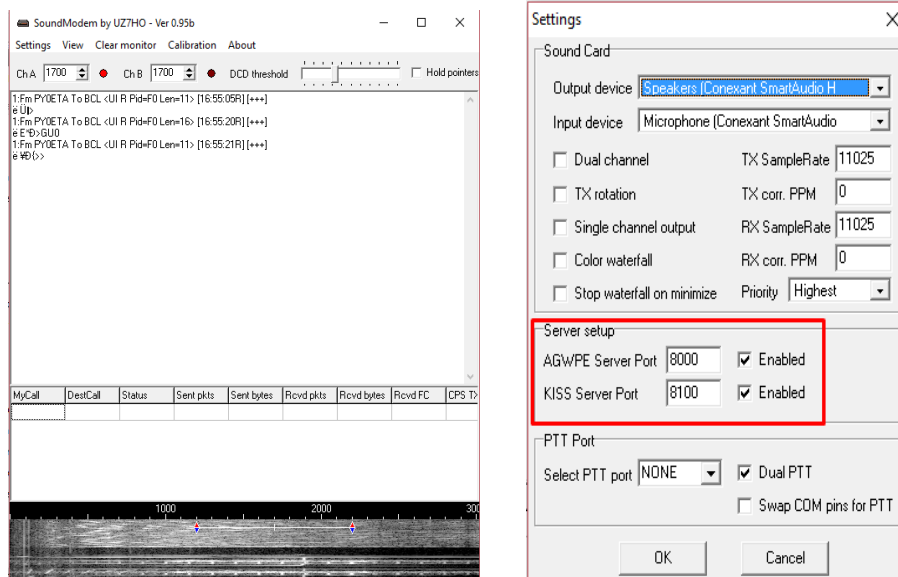


Figure 7. SoundModem application converting raw data into ASCII [15].

In conjunction with the software mentioned above under "General Software" and supported by another piece of software such as AGW Online Kiss v. 2.4.4 by DK3WN [16]. This software converts information from SoundModem into raw values as shows in Figure 8. The telemetries values sent by any satellite are obtained and visualized in raw value.

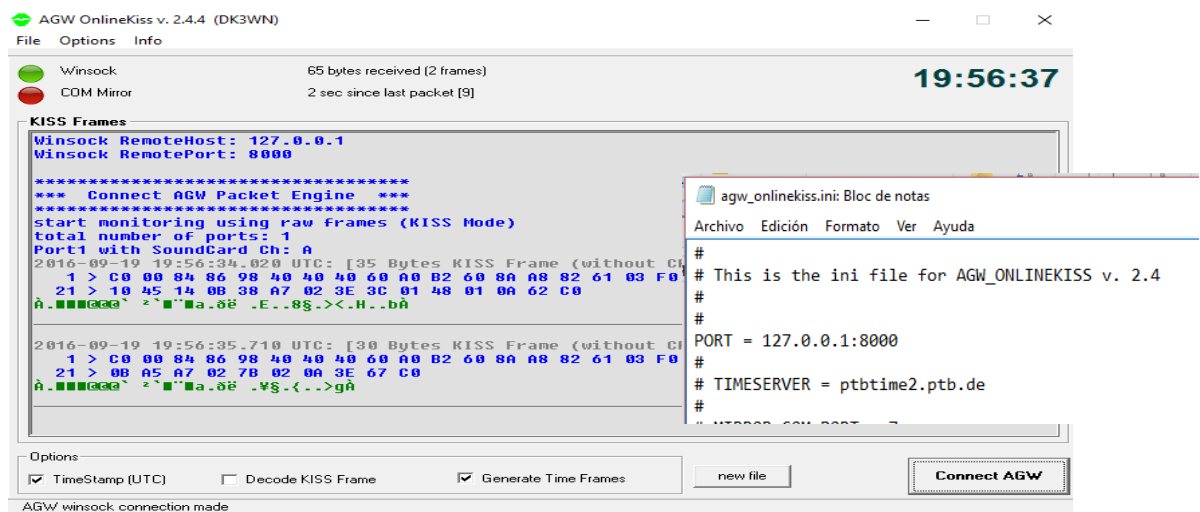


Figure 8. AGW Online Kiss program with raw values and configuration file [16]

#### 4. Interoperability Issues in the Tracking Software and a Case Study

Interoperability issues appear when one tries to track a satellite and has to put together all aforementioned software packages in order to get telemetries for example. From this scenario, there are two possible types: one part is from the received sound input to the output and the other is between application network ports. More precisely these are detailed hereafter:

- The sound output of the SDRSharp, becomes the signal input of the SoundModem program for the conversion of sound into ASCII encoded information and,
- ASCII encoded information provided by SoundModem is sent via a communication port, either on a local or a remote machine (IP address). This depends whether the satellite being tracked communicates with one of two applications specified for each mode, which are explained in the next section.

As a case study, a configuration was sought to receive the telemetry signals and obtain the engineering value of the telemetries sent by the Brazilian satellite Tancredo-1, recently launched in January 2017. After sorting out all operability issues mentioned earlier, the output port from the AGW Online Kiss has to be connected to SoundModem and finally its output to a telemetry decoder.

For this, a specific software was developed, which is responsible for obtaining the raw value of each of the telemetries, perform the operations necessary for the conversion to engineering value and present them on a screen to the user, in such a way that the information about the satellite is made in an easy and understandable way for anyone. The name of the software is UbaTM - Decoder by PY2SDR v.1.0 to convert to engineering value and display the information sent by the Tancredo-1 satellite.

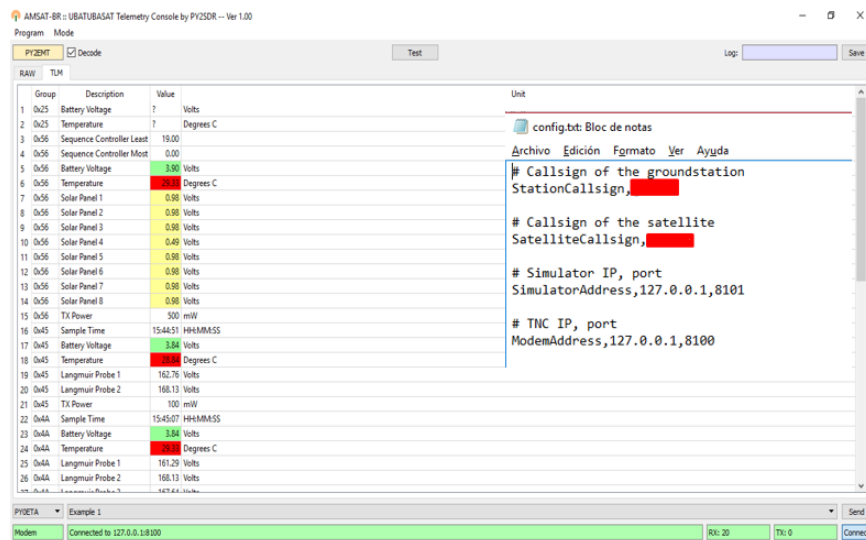


Figure 9. UbaTM Decoder with engineering valued telemetry and configuration file.

## 5. Conclusion and Research Outlook

This work's motivation is lowering costs for monitoring mainly the downlink of smallsats projects which mostly run on a budget constraint. Therefore it presented the use of software tools and few hardware elements that facilitate the assembly of a simple ground station to receive and decode the signal that is sent by a satellite. The material presented is simply one solution that was used for monitoring telemetry signal from a picosatellite named Tancredo-1 as a case study and a proof of concept.

Project participants become this aware of the information flow starting from the RF signal acquisition up to the decoded engineering-valued telemetry. Still they are able to reduce tracking costs in large percentage compared to solution based on fixed stations currently available on the market depending on their cost-benefit analysis. In order to provide reliability, there is a need for further development in the software arena.

The software packages mentioned in this work in conjunction with the hardware elements allows telemetry decoding. Part of this chained processing is satellite independent and only the final stream when the engineering values of telemetries are derived one has to know the configuration and the structure of each of telemetry data.

Since the solution employed does not work "as is" for most satellites in orbit further development is needed so future work will concentrate on more flexible SDR framework such as GNUradio.

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