A GPS RECEIVER FOR USE IN SOUNDING ROCKETS

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ABSTRACT

In this paper we present the results of the use a space GPS receiver in two sounding rockets launched from Brazil, a VS30 rocket (launched from CLBI in Parnamirim/RN, with an apogee of 121 km) and a VSB30 rocket (launched from CLA in Alcântara/MA, with an apogee of 242 km) to provide a navigation solution (position and velocity) for the rocket during the flight. This GPS receiver was designed from a platform denominated "GPS Orion" proposed by Zarlink, and its software was modified so the receiver could be able to accommodate the rocket dynamics (high velocities and accelerations). The tests were partially successful, since the receiver was able to navigate during part of the flights, and the results were compatible with another receiver aboard the rocket. More tests and improvements are needed in order to have a receiver fully qualified to be used in sounding rockets.

1. INTRODUCTION

The use of a GPS system is an alternative to traditional tracking methods to rockets like C band radars, slant range systems or others. The advantages of GPS using are: costs, global coverage, service availability on a 24-hour basis and acceptable precision of positioning solution.

Although GPS receivers are very accessible and cheaper today, most of these receivers could not work appropriately in vehicles with high velocities and accelerations (high dynamics vehicles) because they are manufactured with built-in limits. These limits are: altitude < 60,000 feet (≈ 18000 m), velocity < 515 m/s, acceleration < 4g (39.2 m/s^2) and jerk motion < 20 m/s^3. For rocket use, for example, we need a special kind of GPS receiver. This kind of receiver must be free of these operational limits and must be able to provide navigational solutions in an appropriate rate to give a precise positioning of the vehicle in flight.

This paper describes an experiment to construct a GPS receiver for rocket use. The project was sponsored by the AEB (Brazilian Space Agency) with the participation of UFRN (Federal University of *Rio Grande do Norte* State), IAE (Aeronautics and Space Institute), INPE (National Institute of Space Research) and CLBI (*Barreira do Inferno* Launch Center in Parnamirim/Brazil).

The main objective of the project was to construct a GPS receiver, using commercial off-the-shelf items, capable to provide a positioning solution of a rocket during its flight. This receiver was projected to work with a GPS L1 frequency (1.57542 GHz) C/A code. The prototype of this receiver was tested in two Brazilian rockets: VS30 and VSB30.

2. RECEIVER HARDWARE DESCRIPTION

The core component of the receiver is the Zarlink's GP2000 chipset (GP2015 and GP2021) [1]. The first one is an RF Front-end small format for Global Positioning System (GPS) receivers [2]. It is similar in capabilities to GP2010 but built in a TQFP package.

The GP2021 [3] is a 12-channel C/A code baseband correlator for use in NAVSTAR GPS satellite navigation receivers. It is compatible with most 16-bit and 32-bit microprocessors, especially those by Motorola and Intel, with additional on-chip support for the ARM60 32-bit RISC processor [4]. The GP2021's On-Chip Dual UART allows two serial communication ports to the receiver.

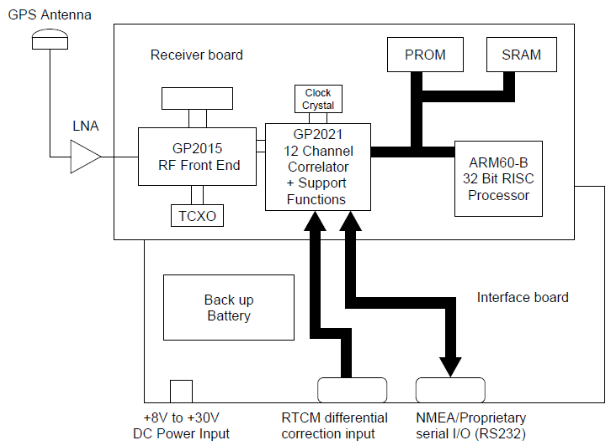

Figure 1 - GPS receiver block diagram [5]

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The microprocessor used in this receiver was an ARM60-B, also by Zarlink. It is a high performance 32 bits RISC processor with a 32-bit data and address buses.

Other important components are the GPS band-definition SAW filter and a sub-miniature 10MHz Temperature Compensated Crystal Oscillator (TCXO). The general block diagram of the receiver is shown in Fig. 1. A photo of the receiver is shown in Fig. 2.

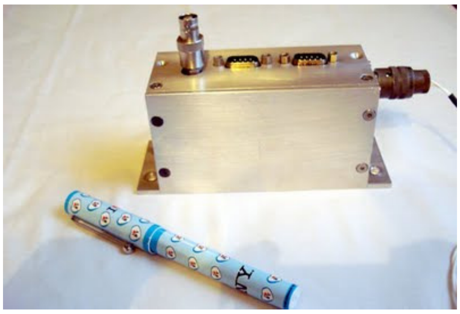

Figure 2 - GPS receiver

3. SOFTWARE DEVELOPMENT

The development system used to design and test the GPS software was that of Mitel's, GPS Architect. Zarlink was formerly Mitel Corporation.

The full GPS Architect System contains:
. A main board mounted in a plastic case;
. An active antenna with magnetic mount and cable;
. GPS software;
. A software license agreement;
. An ARM Toolkit;
. An user guide documentation;
. Power supply;
. Two serial cables to connect the GPS Architect to a PC.

The main board of the GPS Architect is built with the GP2000 chipset, the same of the receiver. This issue allows test and validates the software before it could be installed in the receiver.

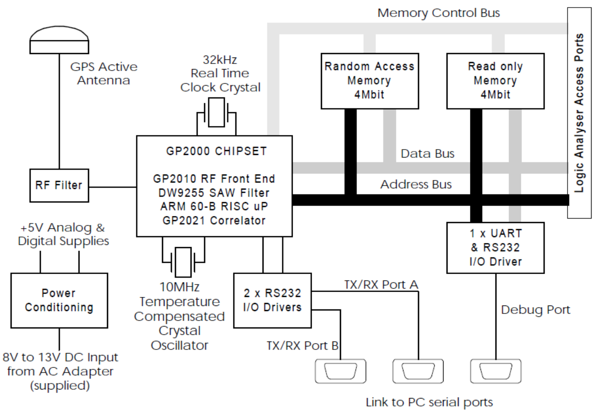

Figure 3 – The GPS Architect main board block diagram [6]

The block diagram of the GPS Architect main board is shown in Fig. 03. Its photo is shown in Fig. 04.

Figure 4 – The GPS Architect main board [6]

4. MISSION PROFILES

The GPS receiver described in this paper was used in two campaigns, *Angicos* and *Maracati II*. The main goal of the *Angicos* Campaign, with a VS30 rocket flight launched from the CLBI, was to collect data from Argentina's CONAE (National Commission for Space Activities) payload. In that payload there was another GPS receiver built by CONAE. Payload was, then, recovered from the sea.

The VS30 rocket is a Brazilian sounding rocket by IAE (Space and Aeronautics Institute). The VS30 mission profile (Fig. 05) has a 121 km apogee with about 100 sec of microgravity flight.

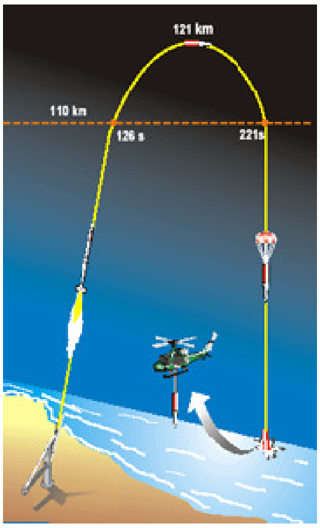

Figure 5 - Angicos mission profile

Maracati II was a campaign that allowed Brazilian academic experiments to access microgravity environment through a VSB30 rocket flight. It was launched from CLA, in Alcântara/Brazil, and reached the apogee at an altitude of 242 km, with 400 sec of microgravity. The payload was also recovered. The DLR (German Space Agency) participated with IAE in this campaign. Also, in a payload of VSB30, there was another GPS receiver by DLR (German Aerospace Center).

In both the CLBI and the CLA there are two tracking C-band radars and an S-band telemetry ground station. The data collected by the radar and by the telemetry were used in comparison with the positioning data provided by the GPS receiver. Since each payload had another GPS receiver, we expected to be able to compare the data provided by all these means with the data provided by the receiver under test.

5. SOME PARTIAL RESULTS

The positioning data provided by the GPS receiver were available at a 1Hz data rate. The NMEA sentences supplied by the receiver were GSV, GSA, GGA and RMC.

5.1. RESULTS FROM THE ANGICOS CAMPAIGN

On this flight the telemetry data collected cover the first 72 seconds of flight. On the other side, this data covered all booster phase and the beginning of ballistic phase. During this entire time the GPS receiver was on a 3D fix status with at least 9 satellites being used for fix navigation data.

5.1.1. COMPARISON TO THE SECOND GPS RECEIVER

In Fig. 6 we can see the comparison between the parameter altitude (sentence GSA) provided by both receivers. At the end of the booster phase the Argentina GPS stopped sending data to the PCM telemetry encoder, so we could only compare the first 25 sec. of flight. As we can see, the curve provided by the data from Brazilian GPS was more stable and smooth.

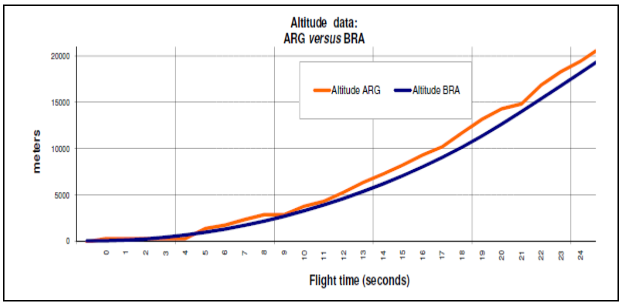

Figure 6 - ARG versus BRA altitude data

5.1.2. COMPARISONS BETWEEN GPS AND RADAR TRAJECTORIES DATA

Since the GPS data from the Argentina GPS receiver were not available after 25s of flight, we used the tracking position provided by the radar to verify the operation of the receiver under test.

Because of this, all the geodetic data from the GPS receiver had to be converted to ECEF coordinates just like the radar data. On the other side, this changing made it easier to calculate the differences (in meters) between the GPS and the radar data. It also made it simpler to calculate the rocket average speed and acceleration. As a sample, we can see in Fig. 7 both trajectories on a 3-axis chart.

In the Fig. 8 we have a graphic with the differences between the GPS receiver and the radar positioning data. In fact, there are some small errors at the trajectory provided by the radar that will not be discussed in this article. Since the purpose of this first flight was only to validate the receiver in flight conditions, we can consider all Δ-values as the GPS error of positioning and the positioning points provided by the radar as our reference.

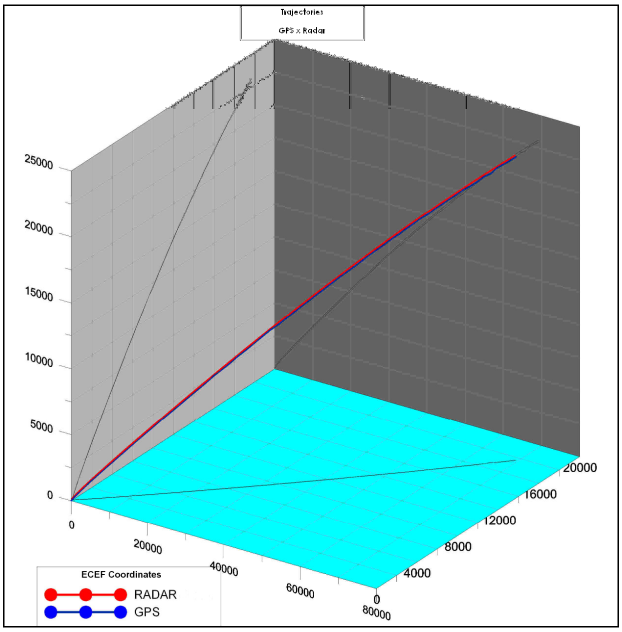

Figure 7 - GPS and Radar data trajectories

The points not recovered from the telemetry data are shown in a dashed line. The positioning data of these points were calculated by linear interpolation. In this graphic we see some oscillations at the end of the available data because of the data oscillations in the radar data. On the other side, even with these variations we can see that the average values of errors on each axis are less than 28m.

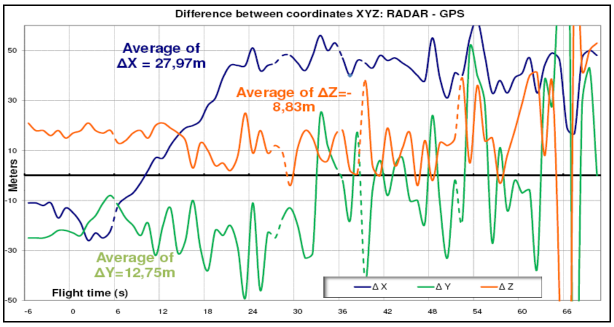

Figure 8 - GPS positioning “errors"

If we consider all individual XYZ errors as a new vector we could call this an "error vector". By calculating the mode of each vector, the value gives us a more representative number about our positioning error. As we can see in Fig. 9, maximum error occurs at the end of the booster phase (about 24 sec.) and decreases after that. Minimum value is at the beginning of flight (about 1,2 m). The mean value is about 32 m.

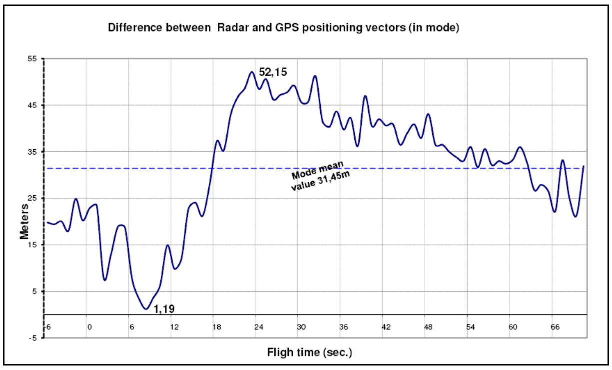

Figure 9 - Mode of error vectors (in meters)

The rocket average velocity calculated by the GPS receiver and the radar data is shown in Fig. 10. At the end of the booster phase the average speed was 1360 m/s on the X axis.

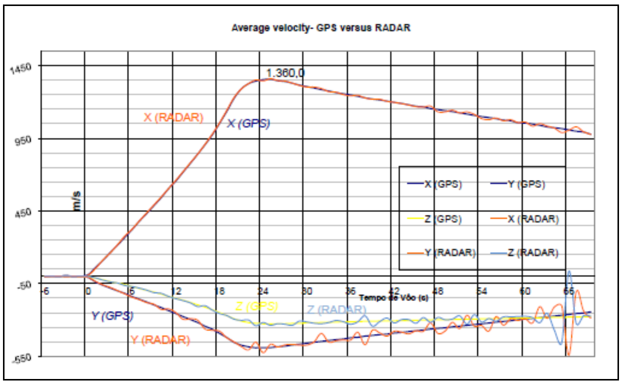

Figure 10 - Average speed on all axis (GPS x Radar)

With respect to acceleration, the maximum value calculated was about 90 m/s^3 on the X axis at the end of the booster phase (Fig. 11).

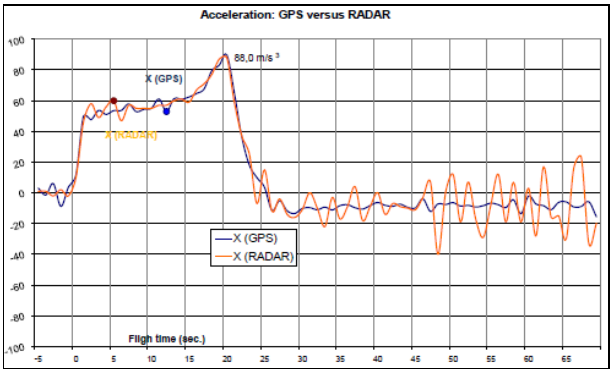

Figure 11 - Acceleration on X axis (GPS x Radar)

Although the problem with the telemetry encoder that caused data loss after 72 seconds of flight, the receiver worked perfectly after the recovering of payload on the *Angicos* campaign. The same hardware was used in the *Maracati II* campaign.

5.2. RESULTS FROM THE MARACATI II CAMPAIGN

In *Maracati II*, the GPS receiver obtained navigation solutions for only one sample. This happened because of an operational power discontinuity, some minutes before launch. However, the receiver successfully got new satellite signals during the flight and allocated them into its correlator channels, as it is shown in Fig. 06. Even with the severe dynamics that VSB30 was subjected to, as it is shown in Fig. 12, the GPS receiver worked properly.

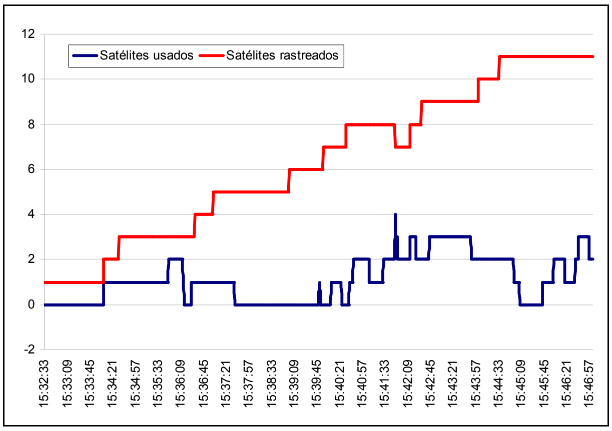

Figure 12 Satellites tracked and used in the Maracati 2 campaign

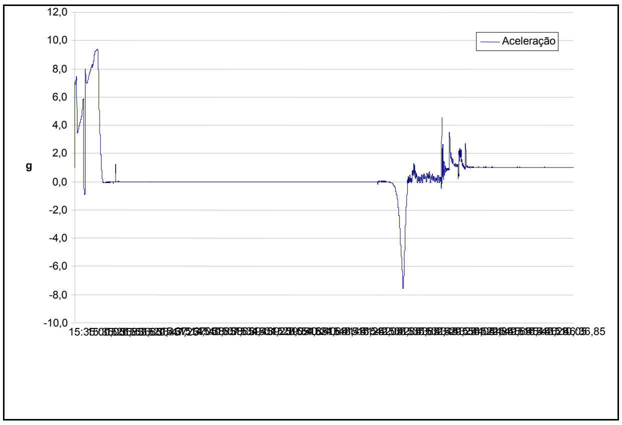

Figure 13- VSB30 acceleration profile on the Maracati 2 campaign

The VSB30's altitude obtained by the Brazilian GPS receiver is compared to the German data in Fig. 14. The spot shown occurred in sample 15:41:49,77 UTC.

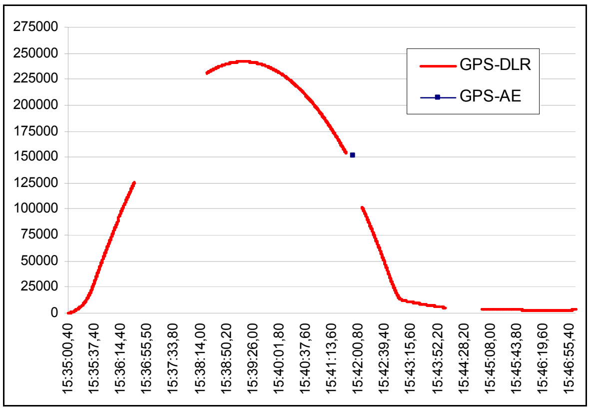

Figure 14– Altitude: Brazilian x German GPS receivers (on the Maracati II campaign)

6. CONCLUSIONS

Although all results are partial, the receiver worked properly in high dynamic conditions. New tests will be provided to qualify the receiver. New modifications will be implemented to allow the receiver to be used in small satellites.

7. REFERENCES

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