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ABSTRACT

The main goal of this work is to compare the accuracies of transmitters' geolocation results obtained by Argos system (France) and by INPE´s system, using the algorithm for geographic location of transmitters developed in Sousa et al. (2001). Location data (time and Doppler shift) were supplied by Argos control center staff, except for the satellites ephemeris. This comparison was performed using NOAA satellites, in order to verify the robustness of the location procedure compared to the supplied ARGOS results, which are claimed to have a precision of about 100-500m. The ARGOS control center uses precise orbitography transmitters data with sophisticated orbit determination of the NOAA satellites, besides having the full Doppler curve data available for processing and geo-location. On the other hand, INPE has developed a simple scheme for processing the sparse Doppler data obtained through the Brazilian network of DCPs (Data Collecting Plataforms). The ephemeris is recovered via Internet, the orbit is propagated by the SGP4 NORAD model (Hoots, 1980), and the Doppler data is modeled and processed using a robust Householder orthogonalization for the least squares processing procedure (Lawson, 1972). The results obtained using such data and two-line orbit elements, obtained at www.celestrak.com, show as expected a fair degree of consistency in terms of precision compared to results of Argos system.

1. INTRODUÇÃO

The comparison of accuracies between INPE and Argos geolocation systems (CLS, 1989; Sousa, 2000) was accomplished using location data (time and Doppler shift) and corresponding location results (latitude and longitude) provided kindly by the Argos system staff; and two fixed and known reference transmitter platforms. The geographic location of transmitting platforms was computed as shown in (Sousa, 2001) and five NOAA satellites (NOAA 11,12,14,15,16) were used.

There are two classes of location results:

a) using satellite passes containing at least one measurement with elevation higher than 11º;
b) the same passes but using only a subset of such measurements with elevation higher than 4º, to attenuate atmospheric refraction effects.

Considering the two fixed and known reference transmitter platforms the location accuracies obtained by Argos system was of 0.44km. That one for INPE system was of 1.02km and 1.18km for both classes represented above.

Statistical Analysis of both systems comparision results was shown in grafics and Tables as bellow. In the next section descriptions of both systems are presented.

2. INPE AND ARGOS SYSTEMS LOCATION DESCRIPTION

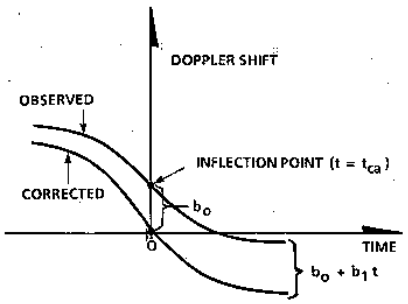
Both INPE and Argos system determine a geographic location measuring the Doppler shift of the transmitted frequency due to the relative velocity between the satellite and the transmitter (CLS, 1989; Sousa, 2000; Sousa, 2001). This velocity in vacuum conditions, denoted by $\dot{\rho}$, is given by the Doppler effect equation (Resnick, 1969):

$$\dot{\rho} = (f_r - f_t)c/f_t$$

where:

- f_r is the frequency value as received by the satellite;
- f_t is the reference frequency sent by the transmitter;
- $(f_r - f_t)$ is the Doppler shift due to the relative velocity satellite-transmitter;
- c is the speed of light.

A characteristic Doppler curve is shown in Fig. 1 where b_o and b_1 are constants associated with each Doppler curve (Aksnes, 1998).



In Argos system all UHF signals from the transmitters are received on board the satellite, which measures the Doppler shift and records its arrival time reproducing then the full Doppler curve. Those recorded measurements are played back to the ARGOS ground reception stations where the data are processed after some time delay (some hours) (CLS, 1989). In INPE´s system, the received frequency signals are relayed in real time to the ground reception stations and processed right after the satellite pass (Sousa,

2000). Thus, some data are lost, resulting in a broken Doppler curve, but gaining in location fastness.

3 COMPARING RESULTS BETWEEN INPE AND ARGOS

For the purpose of accuracy comparison between both systems, two DCPs (Data Collecting Platforms) were considered:

The DCP 109 located in French Guiana:

i) Latitude: 5.17137º N.
ii) Longitude: 307.31388º W.
iii) Altitude: 0.007m.
iv) Transmitting signals every 30s.

The DCP 113 located in French Peru:

i) Latitude: 12.09003º S.
ii) Longitude: 282.96146º W.
iii) Altitude: 0.134m.
iv) Transmitting signals every 30s.

Both DCPs have reference frequencie of 401.65MHz.

In the Section 3.1 we present Tables with the synthesis with results obtained and its analyses. And in the Section 3.2 grafics with comparison location error obtained by both systems are presented. These analyses consider five NOAA sattelites. All data were taken during November 2001.

3.1 Statistical Analysis

In Tables 1 and 2 we gathered the location mean error considering the five NOAA satellites, the fixed DCPs, orbit ephemeris (two-line elements) obtained via Internet (www.celestrak.com), and the two location systems (Argos and INPE).

The expression that describes the location error (tri-dimensional) in kilometers it is given as:

$$Error(km) = \left\| r_{ref} - r_{cal} \right\|$$

where $\left\| r_{ref} - r_{cal} \right\|$ is the norm of the difference between the DCP reference position vector (r_{ref}) and the calculated position vector (r_{cal}).

TABLE 1 - Synthesis of the results for Transmitter DCP #109

Comparing Argos/INPE - DCP 109				
Satellite	Satellite Passes	Mean Location Error (km)		
		Argos	INPE	INPE: h>4º
NOAA 11	16	0.56±0.5	1.17±0.6	1.47±1.1
NOAA 12	23	0.31±0.2	1.23±0.9	1.20±0.8

NOAA 14	27	0.25±0.2	0.95±0.5	0.92±0.5
NOAA 15	23	0.51±0.5	1.48±0.7	1.49±0.8
NOAA 16	20	0.38±0.3	1.62±1.1	1.49±1.1
Mean		**0.40±0.34**	**1.29±0.76**	**1.3±0.8**

TABLE 2 - Synthesis of the results for Transmitter - DCP #113

Comparing Argos/INPE - DCP 113				
Satellite	Satellite Passes	Mean Location Error (km)		
		Argos	INPE	INPE: h>4º
NOAA 11	38	0.46±0.3	1.23±0.5	1.30±0.9
NOAA 12	40	0.41±0.4	1.12±1.3	0.92±0.4
NOAA 14	35	0.46±0.3	1.13±1.3	1.06±1.3
NOAA 15	35	0.61±0.4	1.34±0.9	1.20±0.7
NOAA 16	32	0.44±0.2	0.83±0.3	0.84±0.3
Mean		**0.48±0.32**	**1.13±0.92**	**1.06±0.7**

From Table 1 we can see that the mean location error of DCP 109 is 0.40±0.34km for Argos system, and 1.29±0.76km and 1.30±0.80km (when minimum elevation h is higher than 4º) for INPE´s system. This implies that the (1-σ) errors mostly range between 0.08km and 0.74km for Argos and 0.5km to 2.1km for INPE. From Table 2 the location error of DCP 113 is very similar to results of Table 1.

3.2 Graphic Analysis

Now there are presented the graphic analysis latitude and longitude errors of both systems (Argos and INPE). All the resuls are from November 2002.

The triangle symbols are related to INPEs system location results reffered of each NOAAs sattelite passes and PCDs. The circle symbols represente the Argos location results.

The x and y axis are concerned to the satellite passes and to the distance to reference in km respectively.

Figure 2 as follow shows location error results of both PCDs (109 and 113) using NOAA 11 satellite.

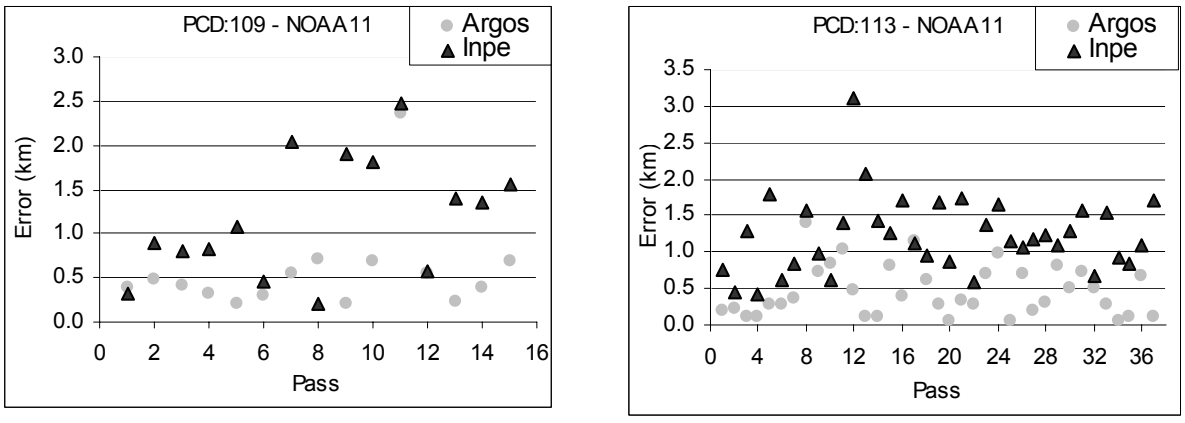


Fig. 2 - Location error of PCDs 109 and 113 using NOAA 11.

Figure 3 shows location error results using NOAA 12 satellite:

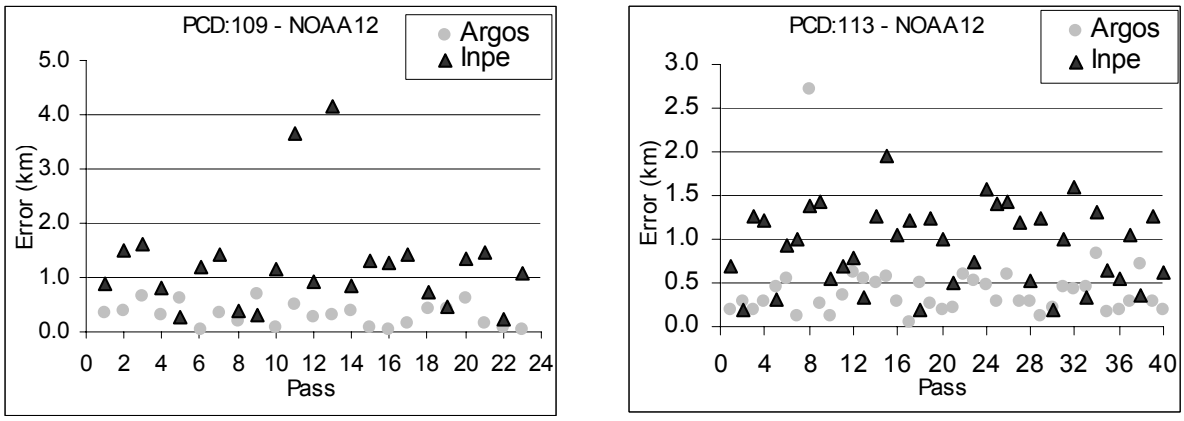


Fig. 3 - Location error of PCDs 109 and 113 using NOAA 12.

Figure 4 shows location error results using NOAA 13 satellite:

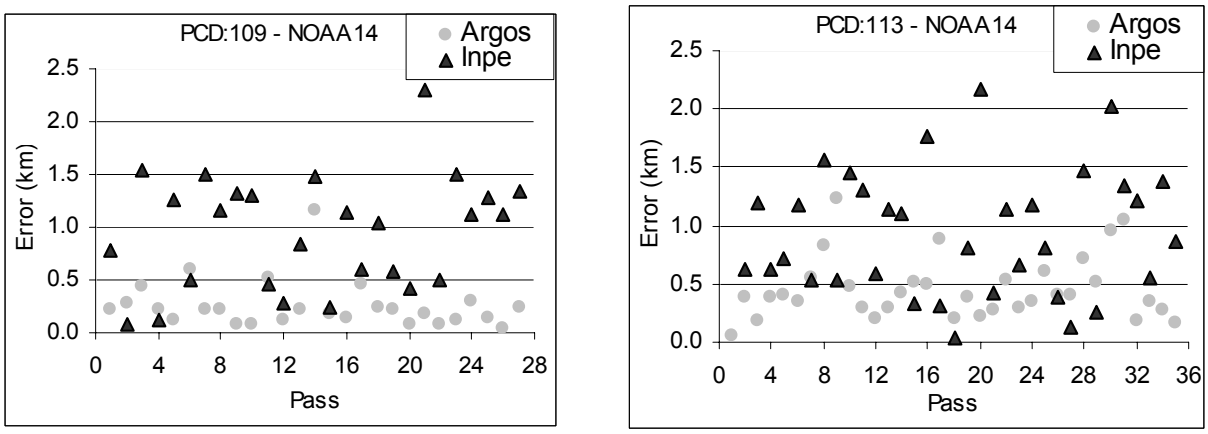


Fig. 4 - Location error of PCDs 109 and 113 using NOAA 14.

Figure 5 shows location error results using NOAA 13 satellite:

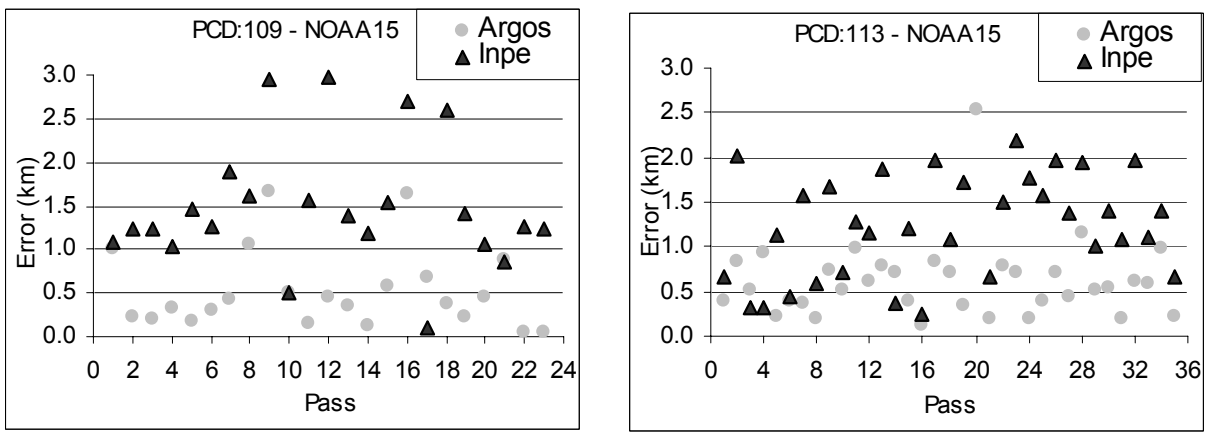


Fig. 5 - Location error of PCDs 109 and 113 using NOAA 15.

Figure 6 shows location error results using NOAA 13 satellite:

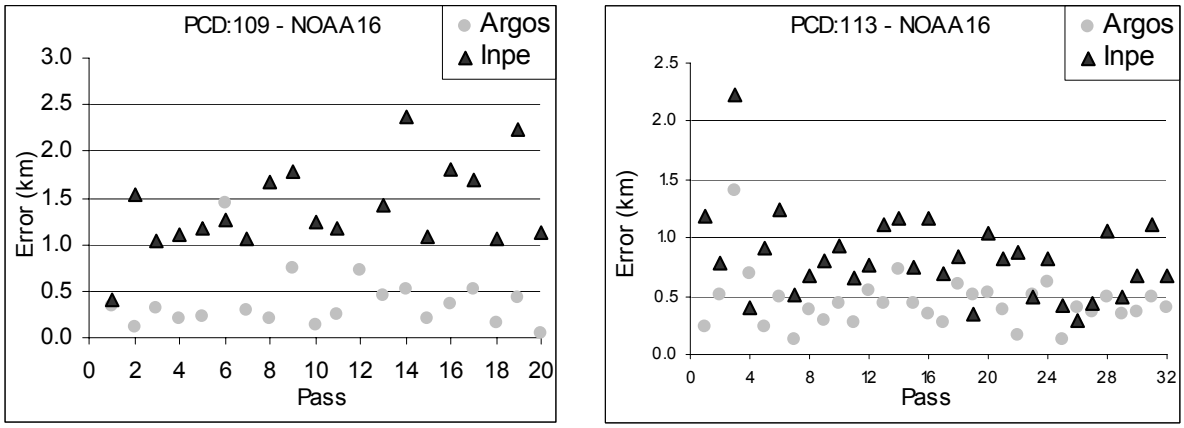


Fig. 6 - Location error of PCDs 109 and 113 using NOAA 16.

Observing the Figures above, we note that the supplyed Argos location error were smaller then that calculated from INPEs system. This probability happened because the satellite orbit elements generated by Argos system have a more sofisticated results than that one obtained by inpe trought *internet* (NORAD model). Even so we can note that in some cases INPEs system results were better than Argos results.

4 CONCLUSION

This paper showed geo-location results for two precises and known PCDs using five diferents NOAAs satellites. The location mean error was of 0.44km for Argos system as total mean accordind to the Tables 2 and 3. The location mean error for INPEs system was of 1.21km considering elevation smaller than 4º and 1.18km discarding the last.

The non-approach between Argos and INPEs systems results is probably due the orbit elements precision obtained by Argos and that obtained via internet. Even so they are suitable to the geo-location applications.

The precision results obtained by INPEs system using brazil satellites can be find in (Sousa, 2001).

5. ACKNOWLEDGEMENTS

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6 REFERENCES

1. Aksnes, K.; Andersen, H. P.; Haugen, E. "A precise multipass method for satellite Doppler positioning." Celestial Mechanics, v. 44, p. 317-338, Sept. 1998.
2. CLS - Service Argos: guide to the Argos System. Toulouse, September 1989.
3. Hoots, F. R. and Roehrich, R. L. "Models for propagation of NORAD element sets." Aerospace Defense Command, Peterson, AFB, Co., Spacetrack no. 3, Dec., 1980.
4. Lawson, C. L. and Hanson, R. J. "Solving least Squares Problems." Englewood Cliffs, Prentice, 1972.
5. Resnick, R. "Introdução à relatividade especial." New York, Wiley, 1968
6. Sousa, C. T. "Geolocalização de transmissores com satélites usando desvio Doppler em tempo quase real". (in Portuguese) PhD dissertation, São José dos Campos, INPE, 2000.
7. Sousa, C. T.; Kuga, H. K.; Setzer, A. W. "Geolocation of transmitters using real data, Doppler shifts and Least Squares." Book by: Hans Peter Roser; Arnoldo Valenzuela; Rainer Sandau, in "Small Satellites for Earth Observation", Berlin, Wissenschaft un Technik Verlag, 2001, v. 1, p. 327-330.