GNSS-RTK Dynamic Checking of Positioning and Navigation Systems onboard Marine Seismic Vessels in Venezuela.

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1. Introduction

Checking of positioning and navigation systems on marine seismic vessels is a complex task that aims to determine the current state, the proper functioning and performance of the different instruments and systems. Checking (verification) of these systems is performed before, during and after a marine seismic survey, to ensure the accuracy of the coordinates of the sources and receivers during the seismic survey. DGPS and RGPS positioning systems, and Gyrocompass (guidance systems) of ships are mainly verified using this process.

In 2008 PDVSA (Petróleos de Venezuela S.A.) developed in Venezuela a methodology to check positioning and navigation systems and instruments of seismic survey ships, based on GNSS-RTK geodetic measurements, which was named GNSS-RTK Dynamic checking. It was developed with the aim of getting greater accuracy and minimizing run times normally involved in the checking process based on static measurements of high precision optical-electronic instruments (total stations). This study describes the methodology of the GNSS-RTK Dynamic Checking, and the results of this technique in marine seismic projects carried out in Venezuela.

This technique proves to be more accurate than the traditional techniques (static calibration). Its main advantage is the faster performance and reliability of measurements that are unalterable and readily auditable at any time. In addition, this technique allows the checking of different instruments over time (time series), no matter whether the ships are in motion or not. This makes easier the complex logistics process. The results of GNSS-RTK Dynamic Checking reported mean radial error of ±0.7° for Gyrocompass systems, the DGPS systems reported mean radial error of ±0.5m, and the RGPS reported mean radial error of ±0.7m.

2. Description of Positioning and Navigation Systems onboard Marine Seismic Vessels

The geodetic positioning is fundamental to execute marine and land seismic survey projects. The seismic vessels uses several positioning and navigation systems, firstly to determine and control (in real time) the position of the vessel and secondly to determine the 3D position and orientation of sources and receivers array (guns-floats and streamers) (Fig.2a). Several types of systems are used and combined for onboard positioning and navigation: DGPS, RGPS, Gyrocompass, Acoustic and Laser ranging, Echo sounding, Digicourse + Digispeed, and Sound Velocity Profiling. DGPS and RGPS master systems use antennas mounted about ±1m from the vessel reference point VRP (Fig.2b).

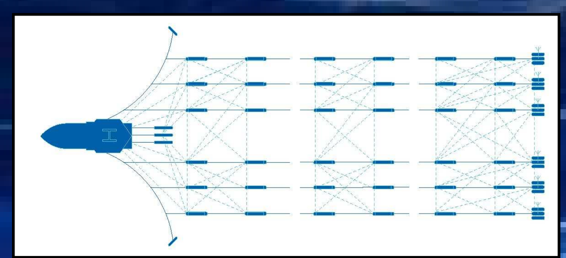


Fig.2a

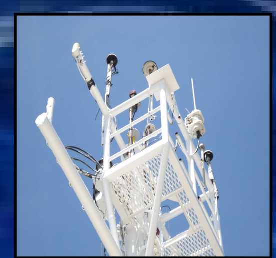


Fig. 2b

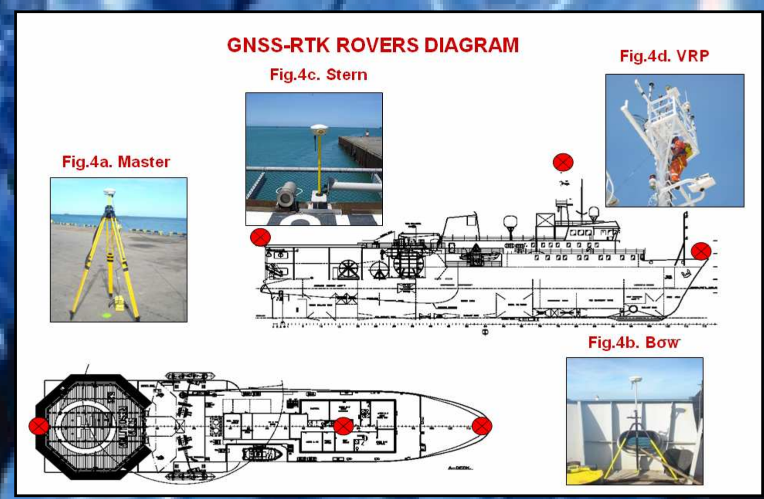
In this reasearch, the vessel is composed by three DGPS systems, one RGPS system and two Gyrocompasses. There are two types of DGPS systems onboard, C-Nav 2050M (primary and secundary) and StarFix HP (tertiary). RGPS BuoyLink Seamap pods are used on the tail-buoys as well as the source sub-array. Gun sub-array, tailbuoy and workboat positioning is provided by a Seamap RGPS system using real time kinematic processing to provide a final centimeter accuracy positioning solution. The vessel has a Sperry Marine Navigat X MK1 gyroscope with a static error < 0.1° secant latitude, and a dynamic error < 0.4° secant latitude. Additionally has a Tokimec Inc TG-5000.

3. GNSS-RTK Dynamic Checking (methodology)

This technique was developed by PDVSA, and it is based on GNSS-RTK (kinematic) measurements on points (benchmark) of the vessel, and its offsets from the origin Vessel Reference Point (VRP) are well known (Fig.3a). Three (3) points are simultaneously measured on the vessel, in the bow, stern and VRP. It is not necessary having the vessel static (Fig.3b). The GNSS-RTK results (coordinates - time series) are combined and reduced in order to correlate with the simultaneous observations recorded for each positioning and navigation systems, DGPS, RGPS and Gyrocompass. The residuals or differences calculated allow to know the health status of all the system involved.

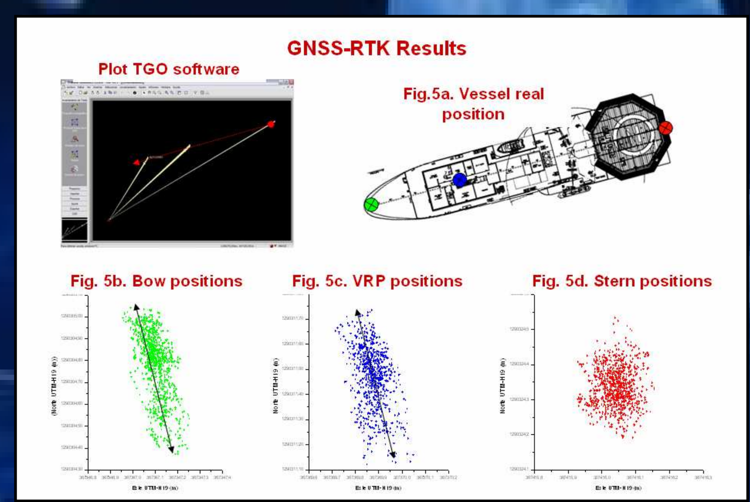
4. GNSS-RTK, Real Time Kinematic measurements

GNSS-RTK measurements were made with four (4) Trimble R8 receivers owned by PDVSA. A GNSS-RTK Master receiver was installed on a reference station (Fig. 4a) whose coordinates are well known and belong to the National Geodetic Control Network, REGVEN. Its accuracy is better than ±0.05m. Three (3) GNSS-RTK Rovers receivers were installed simultaneously on the vessel, specifically in the bow, stern and VRP (Fig. 4b, 4c, 4d). The GNSS-RTK data was collected at 1 second of record interval, and simultaneously with the DGPS and Gyrocompass systems. The maximum distance from the RTK master was 4000m.



5. GNSS-RTK Results (coordinates - time series)

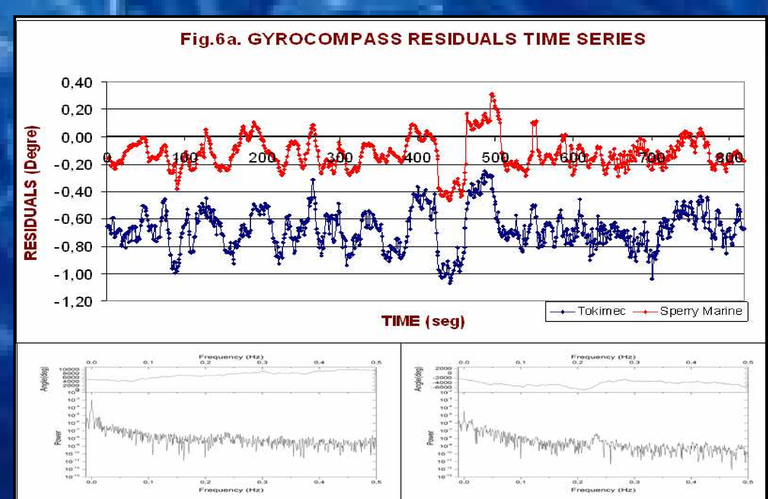
The GNSS-RTK results were basically three (3) coordinates time series 4D (time, east, north and height) at 1 second (Fig.5a). GNSS-RTK positions showed that the vessel was moving from NW to SE direction, conciding with the orthogonal orientation compared to the vessel azimuth (measurement by gyrocompass), due to currents and wind for that moment (Fig.5b, 5c). The stern station does not show a similar behavior because this part of vessel has a pivot behavior because of the weight of the load in this part (Fig.5d). The average of these movements were about ±2m. In general, these movements are those that primarily affect the results of conventional measurements for static calibration.



6. Gyrocompass Checking

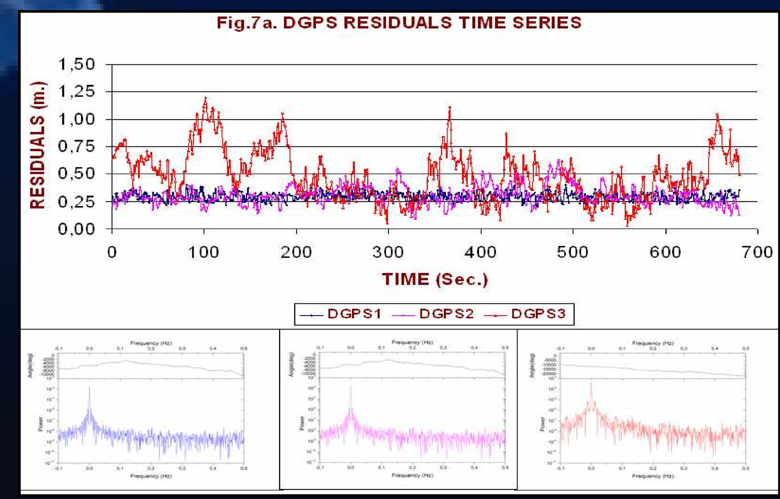
From the coordinates time series measured by GNSS-RTK at bow and stern, were synchronized both series, then, were calculated instant azimuths as time series. These azimuths time series were synchronized and compared with those measured by the Gyrocompasses (Sperry Marine and Tokimec). Both GNSS-RTK (rover) and Gyrocompass measured at the same time and recording interval.

The residuals of Sperry Marine system reported a mean of -0.12° ±0.12° and Tokimec system reported a mean of -0.68° ±0.14°. Both gyrocompasses showed a normal behavior with a constant differences between them about 0.55° in a period of 820 sec. These systems have a very similar behavior in time and frequency, by FFT's spectral analysis (Fig.6a, 6b, 6c).



7. DGPS Checking

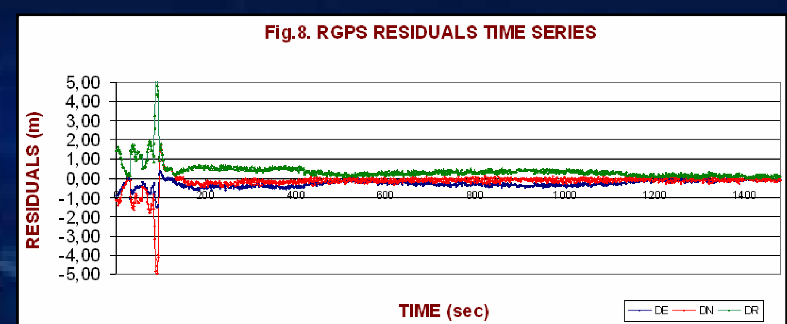
The coordinates (time series) measured by several DGPS systems located near the VRP were geometrically referenced to VRP position by trigonometric models, applying its knowed offsets and azimuths (measured by GNSS-RTK). The new coordinates of the several DGPS systems (referenced to VRP) were synchronized and compared with the coordinates measured by GNSS-RTK at the VRP. Both, GNSS-RTK (VRP) and the different DGPS systems measured at the same time and recording interval.



The mean residuals of DGPS systems were about 0.30m ±0.04m, 0.31m ±0.09m and 0.50m ±0.22m for C-Nav (primary), C-Nav (secondary) and StarFix (tertiary) respectively. All systems showed a normal behavior in a period of 820 sec. These systems have a very similar behavior in time and frequency, by FFT's spectral analysis (Fig.7a, 7b, 7c, 7d).

8. RGPS Checking

Each one of the RGPS pods (rover) were installed on a reference station in ground with well known coordinates. Those measurements were executed in 30 minutes. The coordinates of the several RGPS pods (referenced to VRP by RGPS master) were synchronized and compared with the coordinate's reference station. Were checked 16 RGPS pods, the mean residuals were about ±0.70m ±0.10m (Fig.8).



RGPS	ΔE(m)	ΔN(m)	ΔR(m)		RGPS	ΔE(m)	ΔN(m)	ΔR(m)
0264-0508	-0,378	-0,253	0,583		0320-0601	-0,081	0,003	0,221
0265-0508	-0,279	-0,172	0,388		0368-0604	-0,504	-0,167	0,582
0362-0604	-0,311	0,405	0,633		0355-0604	-0,064	0,096	0,185
0807-0586	0,063	0,053	0,160		0319-0601	-0,247	-0,125	0,331
0388-0607	0,121	-0,087	0,270		0352-0604	0,070	-0,117	0,153
0507-0535	0,002	0,034	0,110		0324-0601	0,079	-0,102	0,153
0507-0538	0,099	-0,112	0,234		0342-0604	0,126	-0,129	0,207
0340-0604	No record data				0331-0604	No record data		

9. Conclusions

PDVSA has developed an own, innovative, robust, highly reliable and also much faster and cheaper than traditional methodologies technique to check the positioning and navigation systems.

The GNSS-RTK Dynamic Checking technique does not require having the vessel in a static mode, which minimizes logistic and measurement time. The technique can be done at any time and is not dependent of weather conditions.

The data is fully auditable and it is essentially binary GNSS data. Additionally, the quality does not depend of the human observers.

The technique lets analyze in detail the behavior of the system over time continuously (discrete time series of high frequency).

The results of GNSS-RTK Dynamic Checking reported mean residuals of ±0.7° for Gyrocompass systems, the DGPS systems reported mean residuals of ±0.5m, and the RGPS reported mean residuals of ±0.7m.

The GNSS-RTK Dynamic Checking technique evidenced by the results, that is accurate, rapid and cheaper compared to the static calibration.