# FIELD SERVICE APPLICATION NOTE 002 (FSA-002)
# DGPS-LIKE POSITIONING ACCURACIES FOR UNDERWATER VEHICLES
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From an article for Ocean News and Technology by JP Lapeyre, Dr. Joel Young, and Dr. Blair Brumley
(all from RD Instruments)

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1. Print out the document in “black and white.”
2. Go to the next page, and “zoom” to 150%. This will let you view the figures within Word, while you read the text from the printed copy. To “zoom,” use the menu bar to select View-Zoom-150% (you can use different percentages based on your monitor and preferences).

## *RD Instruments demonstrates DGPS like Positioning Accuracies for Underwater Vehicles*

*By JP Lapeyre, Dr. Joel Young, Dr. Blair Brumley RD Instruments*

The wide availability of modern Global Positioning System (GPS) receivers and differential service (DGPS) has greatly improved the navigation of surface vessels. Underwater vehicles, however, cannot take advantage of this satellite positioning capability. RD Instruments in a recent experiment has demonstrated that DGPS like precision navigation can be achieved underwater by using a BroadBand™ Doppler velocity log (DVL) in bottom track mode along with a carefully calibrated flux gate magnetic compass. In addition, RDI showed that even higher precision was possible by combining the DVL with an inertial navigation system (INS) through a technique called "intercalibration". This method combines the short term high accuracy of the INS with the long term stability of the DVL to eliminate the well known Schuler oscillations and drift of inertial systems while correcting for scale factor errors of the DVL.

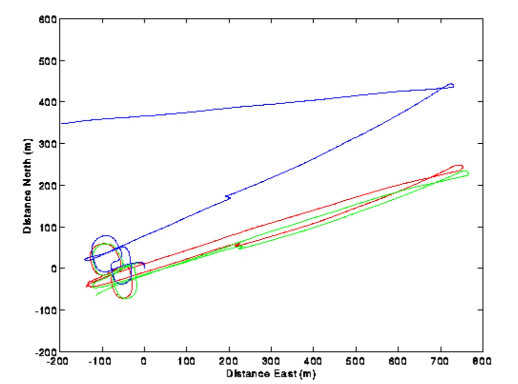


***Figure 1 -*** *Raw DGPS, DVL/Fluxgate and INS tracks*

DVLs measure a vehicle's 3D ground velocity in a vehicle centered coordinate system. The vehicle's heading as measured by the compass is used to convert the velocity into geographic coordinates. Position is determined by integration of the velocity components to calculate change in position relative to an initial point. This process is known as dead reckoning (DR). The long term accuracy of this type of navigation is limited by scale factor errors in the DVL and heading errors in the compass. Factory calibration of the RDI BroadBand DVL reduces scale factor errors to less than 0.2% of velocity. The principal compass errors are attributable to the effects of hard iron components in the vehicle. These single-cycle errors have been reduced to less than 0.1° by the intercalibration procedure developed by RDI. The predicted navigation performance of a DVL/flux gate compass system was proven in a test on Lake Miramar in San Diego.

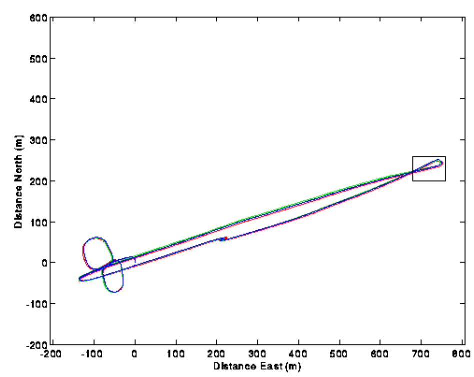


***Figure 2 -*** *DGPS & Corrected DVL tracks*

Figure 1 shows boat tracks derived from uncorrected sensors assuming a starting point at the origin. The boat did a 5-minute figure-eight maneuver simulating a typical calibration procedure followed by a 13-minute reciprocal course. The red DPGS track is the closest to the true course in this figure. The green track is the DVL DR course using an uncorrected KVH compass. Single-cycle (hard iron) compass errors cause the track to drift to the east during the figure-eight and then drift to the southeast perpendicular to the reciprocal coarse. The blue track shows the INS position (free inertial mode) starting 42 min. after initialization. The dominant error seems to be Schuler oscillation. Clearly, an unaided INS is not suitable for this type of application.

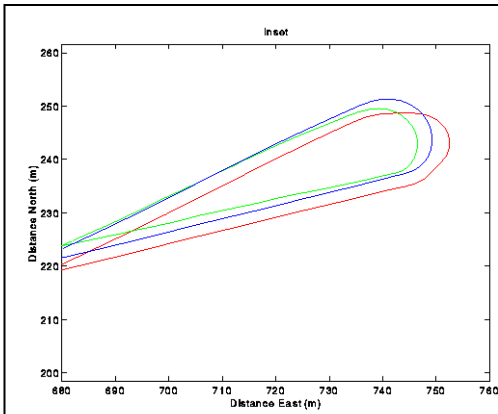


***Figure 3*** *- Detail of East End of Fig. 2*

Figure 2 shows the tracks derived from corrected sensors and Fig. 3 is a blow-up of the East end of Fig. 2. The red DGPS track is repeated from Fig. 1. The green track is again the DVL DR course but now the single-cycle (hard iron) and double-cycle (soft iron) compass errors have been removed by least-squares fit to the INS heading. The blue track is the DVL DR course using the INS heading while correcting for scale factor, alignment, and lever arm determined by least-squares fit of the discrepancy between the Doppler and INS velocities to the signatures of these errors during the figure-eight maneuver.

The DVL navigation errors using the fluxgate heading reference were reduced to an impressive 0.3% of distance traveled. The DGPS data was never used for error correction, and is for reference only. Unfortunately, the DGPS reference is not adequate to determine the performance of the intercalibrated DVL/INS system but RDI believes the performance will be less than 0.1% of distance traveled.

These results show that for many underwater applications, ROVs, and AUVs can be navigated accurately without relying on external systems such as acoustic long baseline (LBL) transponder networks which are expensive and difficult to install and accurately calibrate. Instead, sensors onboard the vehicle, possibly aided by an ultra-short baseline (USBL) system on the mother ship to take out very long term drifts, can provide precise navigation for many important applications. The savings in time and money for undersea vehicle operators will be substantial, particularly as their operations extend into deeper water. The use of an RDI DVL is even more compelling because of its ability to additionally measure altitude, depth, water temperature, flux-gate heading, pitch and roll.

*Please see RD Instruments on the WWW for details of this and other experiments at* ***http://www.RDInstruments.com.***