# *Test Report: Comparison of iVRU-CB-M against SPAN-CPT and SPAN-HG1700*

(excerpt)


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## CHANGE RECORD

| Date | Issue | Paragraph | Comments |
|---|---|---|---|
| 29.02.14 | 1.0 | All | New Document |
| 21.03.14 | 1.01 | 1.01 | Pictures added |
| 17.04.14 | 1.02 | all | Flight tests added |
| 09.05.14 | 1.03 | 2.3 | Flight test campaign #3 added |
| 24.05.14 | 1.04 | all | Branch from now restricted version |

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# 1 SCOPE

This report provides test results obtained from an inertial measurement system (IMS) iVRU-CB-M system from iMAR Navigation manufacturing, compared with third party IMS of type SPAN-CPT (flight #1, flight #2) and SPAN-HG1700 (flight #3) of a Canadian manufacturer.

The iVRU-CB-M is equipped with MEMS type 3 gyroscopes, 3 MEMS type accelerometers and a standard GPS L1 receiver and contains an integrated iMAR proprietary 15+ state Kalman filter, which is performing a sophisticated INS/GNSS data fusion.

The SPAN-CPT contains an comparable expensive L1L2 GNSS receiver and a cost intensive fiber optic gyro based IMU with data fusion. The SPAN-HG1700 contains the same GNSS receiver as SPAN-CPT, but a much more accurate ring laser gyro (RLG) based IMU (export restricted by ITAR regulations).

Each both systems, iMAR's iVRU-CB-M and NovAtel's SPAN-CPT or NovAtel's SPAN-HG1700, had been installed on an helicopter for several flights. The data are compared in this report.

# 2 RESULTS

Many aviation based applications require an attitude performance of better than 0.5 deg rms under flight conditions. The following flight tests show, that the results of both systems, iVRU-CB-M and SPAN-CPT, meet this performance requirement in an airborne application. Nevertheless both systems meet this level of accuracy, the cost of the iVRU-CB-M is significantly lower than the cost of the SPAN-CPT or even the SPAN-HG1700.

The iVRU-CB-M and the SPAN-CPT or the SPAN-HG1700 are mounted together on the helicopter and the GNSS data are provided from the same GNSS antenna via a splitter. The iVRU-CB-M was not provided by GNSS correction data of a ground station

The following plots show the results of the test units and the differences between them:

- The difference between iVRU-CB-M and SPAN-CPT is less than 0.2 deg rms in roll, 0.15 deg rms in pitch and better 0.5 deg rms in heading.
- The difference between iVRU-CB-M and SPAN-HG1700 is less than 0.1 deg rms in roll and 0.15 deg in pitch and better 0.35 deg rms in heading.

The data rate at the output of the iVRU-CB-M is 100 Hz, internally an advanced coning algorithm processes the inertial sensor data, which are acquired with higher data rate to provide robustness also on vibrating environment. A Notch filter bank can be activated on the output channels in case that the connected flight control system would require this (not activated in these test flights – tests show that the results are not degraded y these filters)

The iVRU-CB-M performance is described in its datasheet. The test results show, that the typical performance in real environment is better than given in the datasheet: http://www.imar-navigation.de

Today, with the availability of the iVRU-CB-M, the performance of this system is suitable in many applications, where in the past only much more expensive systems had been considered.

## 2.1 Flight Campaign #1 on Helicopter

### 2.1.1 Test Results for Attitude and Heading

This plot shows attitude and heading of both measurement systems.

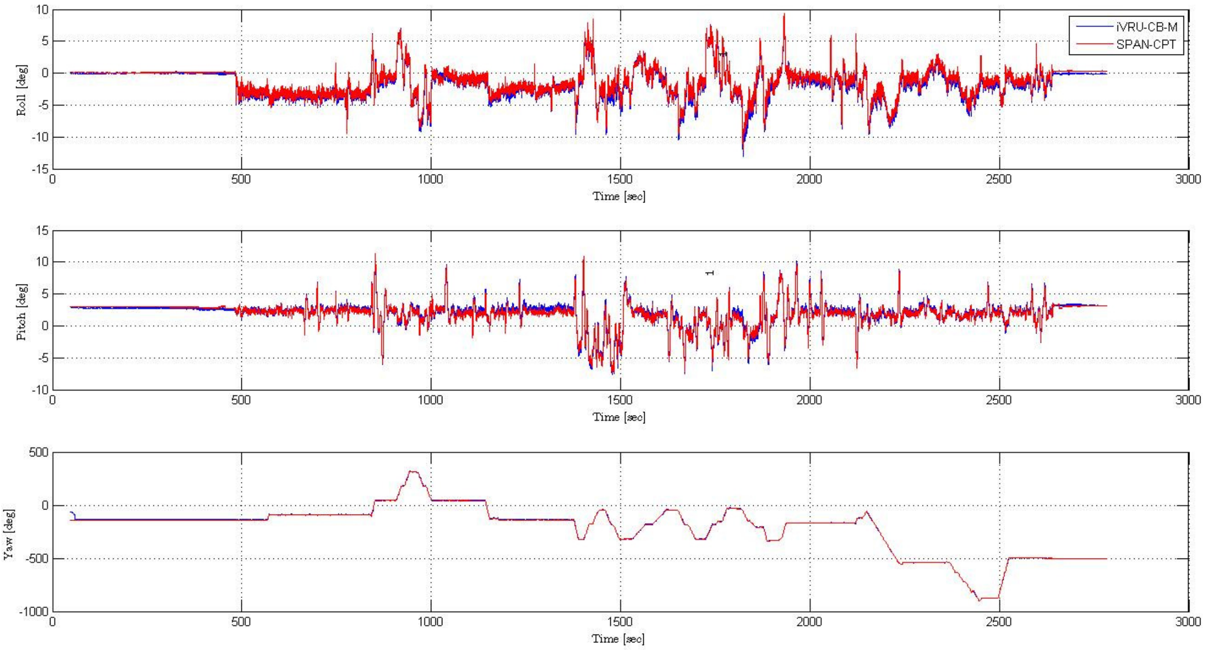



Figure 1: Attitude & Heading, blue = iVRU-CB-M, red = SPAN-CPT, flight #1

The following figure shows the difference between both systems.

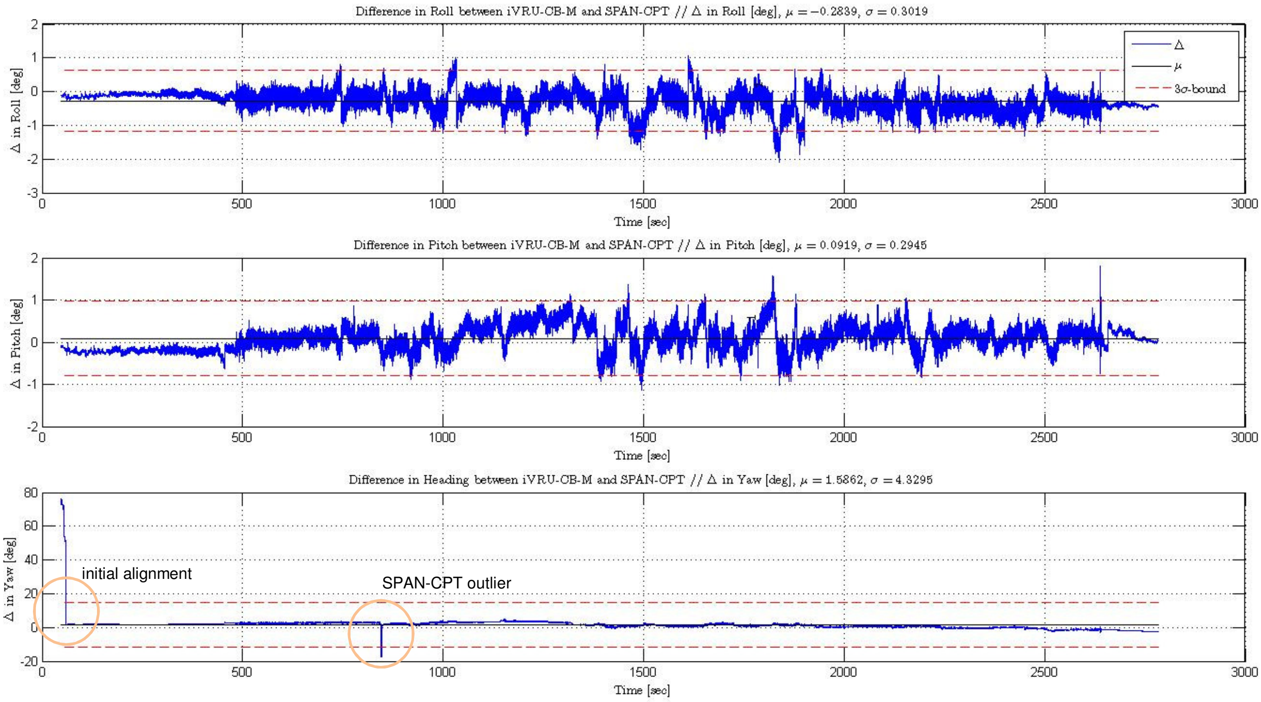



Figure 2: Difference Plot; blue = iVRU-CB-M, red = SPAN-CPT, flight #1

## 2.2 Flight Campaign #2 on Helicopter

This flight test had been more extensive, with many challenging manoeuvres, also containing constant straight level flight (the highest challenge for an INS/GNSS signal processing due to missing dynamics and therefore reduced Kalman filter observability) as well as sideward flight paths.

### 2.2.1 Test Results: Flight Path

This plot shows the East/North plot of the flight trajectory of the helicopter.

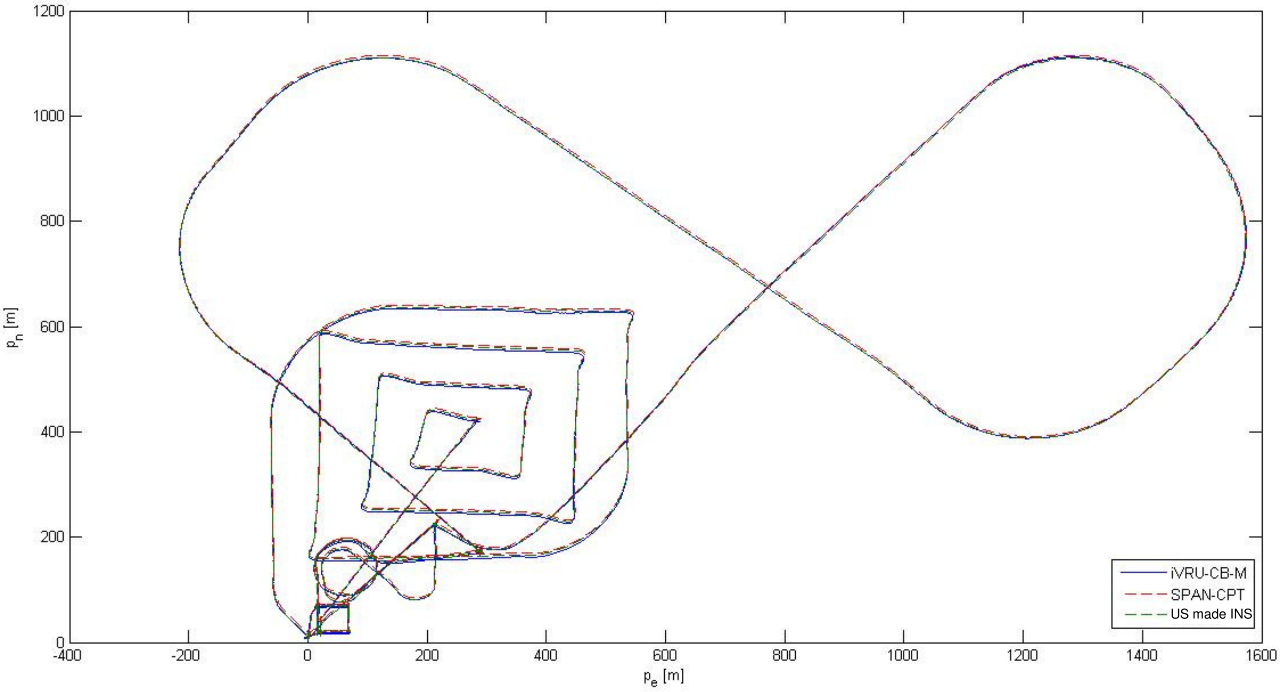



**Figure 3: Position Plot, flight #2**

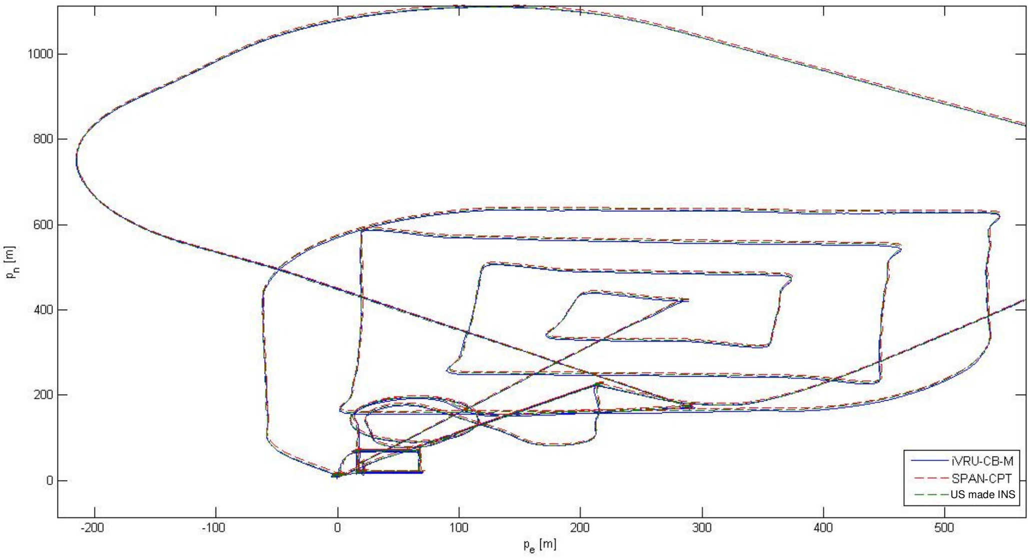



**Figure 4: Zoom of Position Plot, flight #2**

The iVRU-CB-M uses an L1 GPS receiver and was aided by standard GPS (no usage of correction data), while the SPAN-CPT contains internally an L1L2 GPS/GLONASS receiver and required online RTK correction data during the flight. On request the iVRU-CB-M can process RTCM104 correction data (DGPS, EGNOS / WAAS).

The next plot shows the measured angular rates by three systems: iVRU-CB-M, SPAN-CPT and an classified US made system (the name is deleted in the public version of this report). The plot shows, that the iVRU-CB-M provides the highest bandwidth while the US made seems to contain a strong lowpass filtering. So the iVRU-CB-M provides the shortest latency, which is a strong advantage for using it also for dynamic control, e.g. on UAVs.

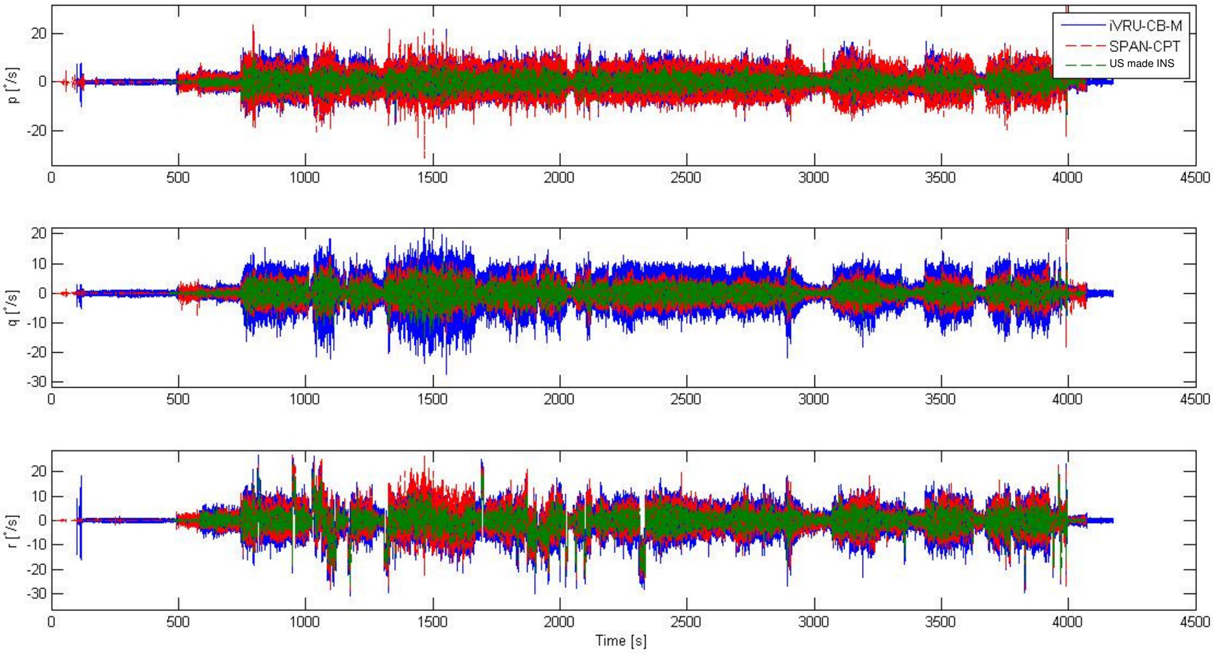



**Figure 5: Angular Rate, flight #2**

The following plot shows roll, pitch and heading, obtained from iVRU-CB-M and SPAN-CPT.

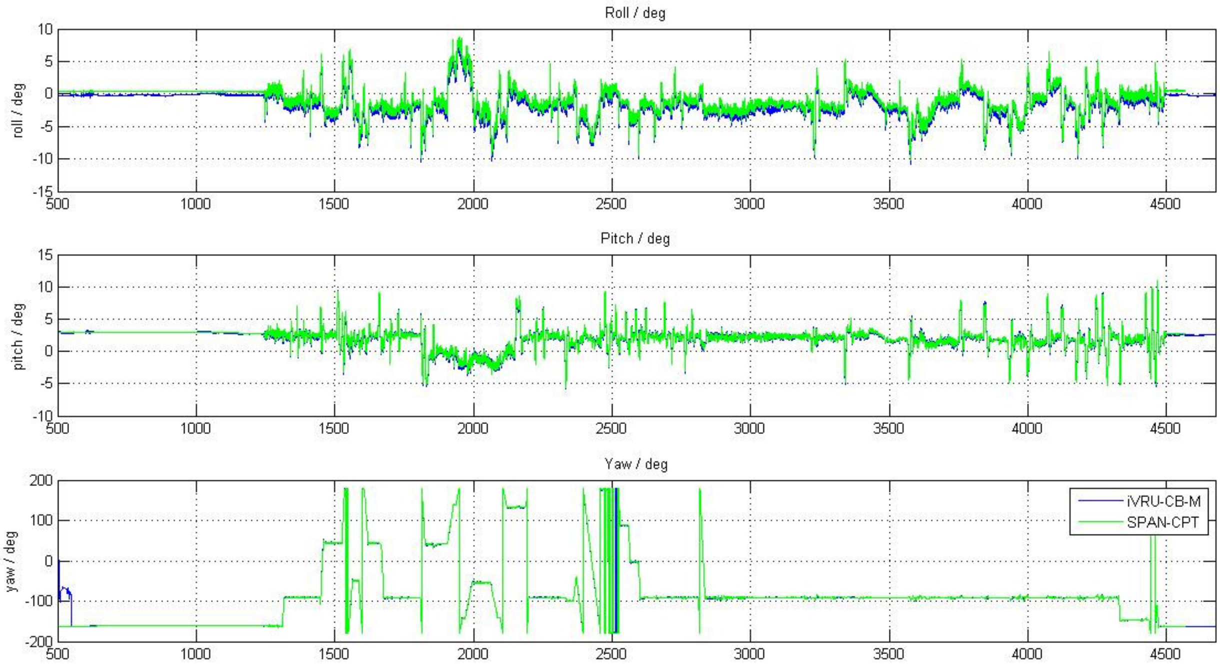
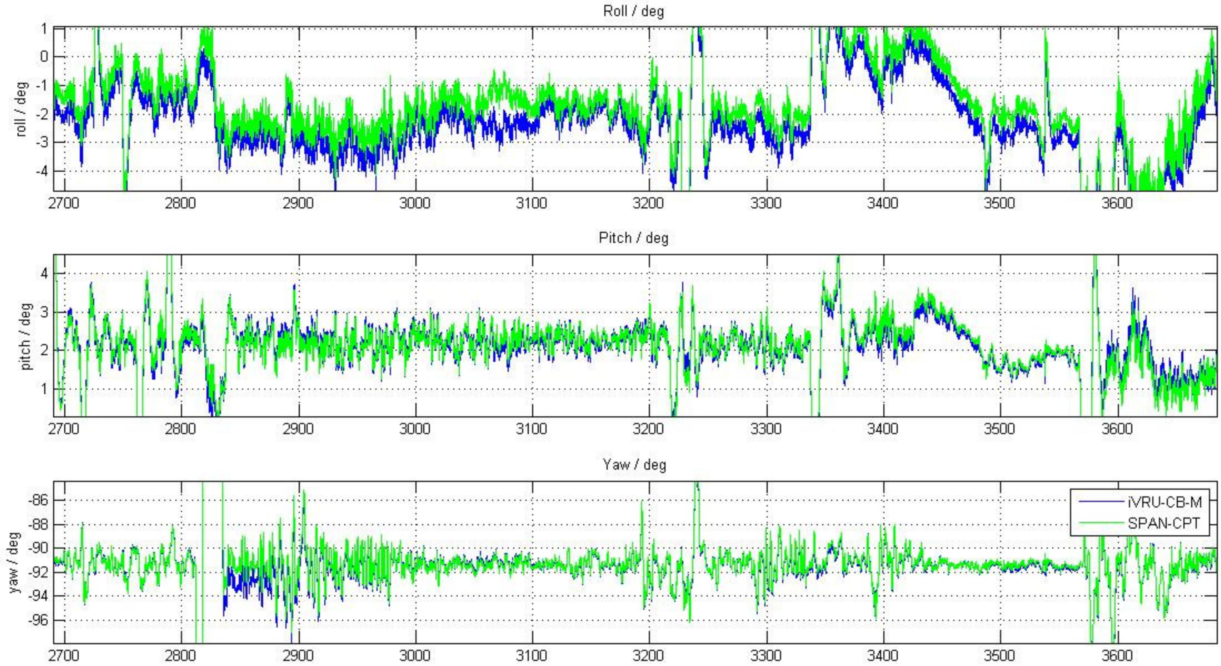
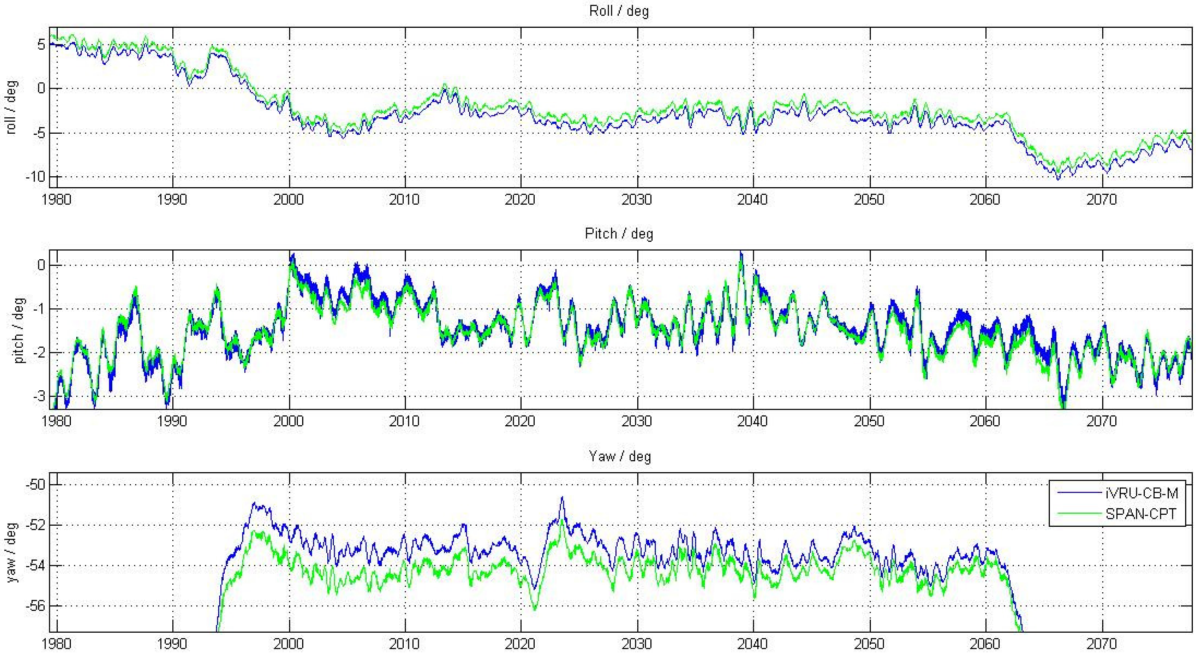



**Figure 6: RPY Plot, flight #2**

The zoom into the RPY plot shows the high confidence of the data. The constant offset is caused by mounting misalignments of the systems.




## Figure 7: RPY Comparison – Zoom, flight #2




## Figure 8: RPY Comparison – Zoom, flight #2

The next figure shows the advantage of the high bandwidth of the iVRU-CB-M. The SPAN-CPT is not able to follow the approx. 10 Hz vibration on the helicopter while the iVRU-CB-M shows the expected impact of the main rotor blades on the pitch.

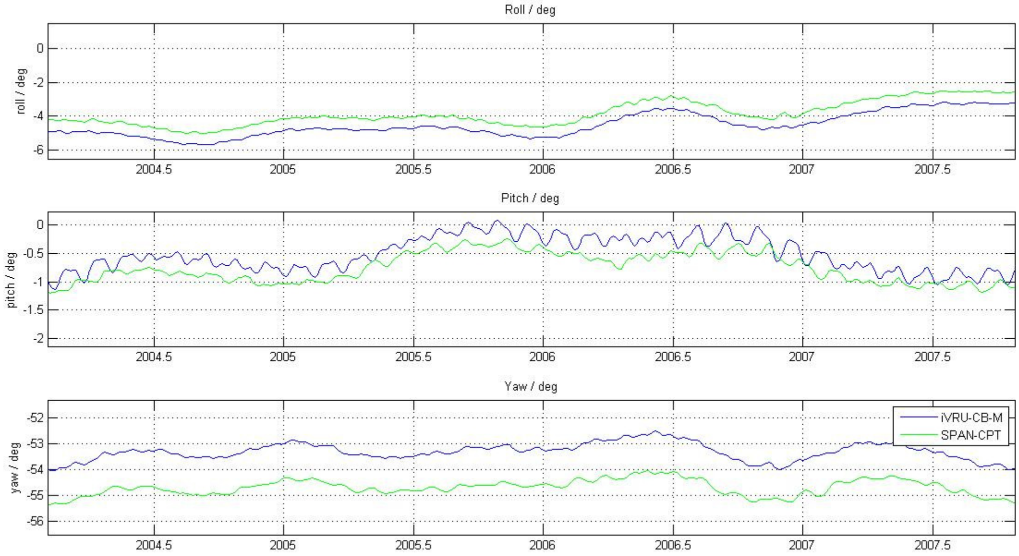



**Figure 9: Detection of the Rotor Frequency by iVRU-CB-M, flight #2**

The following plot shows also the results of a statistical calculation as a comparison between iVRU-CB-M and SPAN-CPT. The iVRU-CB-M was operated with a standard low-cost L1 GPS receiver (µBlox) while the SPAN-CPT contained a costly L1L2 RTK GNSS receiver with dual-antenna and with RTK aiding being distributed from the ground station via RF transmission. The iVRU-CB-M was aided with a 1 Hz external HDT message for heading update, derived from a dual-antenna GNSS heading system. This aiding heading is recommend for applications, where long periods without flight dynamics are expected (e.g. during observation operations of helicopters or long straight line flight operations).

The deviations are < 0.2 deg rms in roll, < 0.15 deg rms in pitch and < 0.5 deg rms in heading. The absolute deviations (mean value) are caused by mounting misalignment angles.

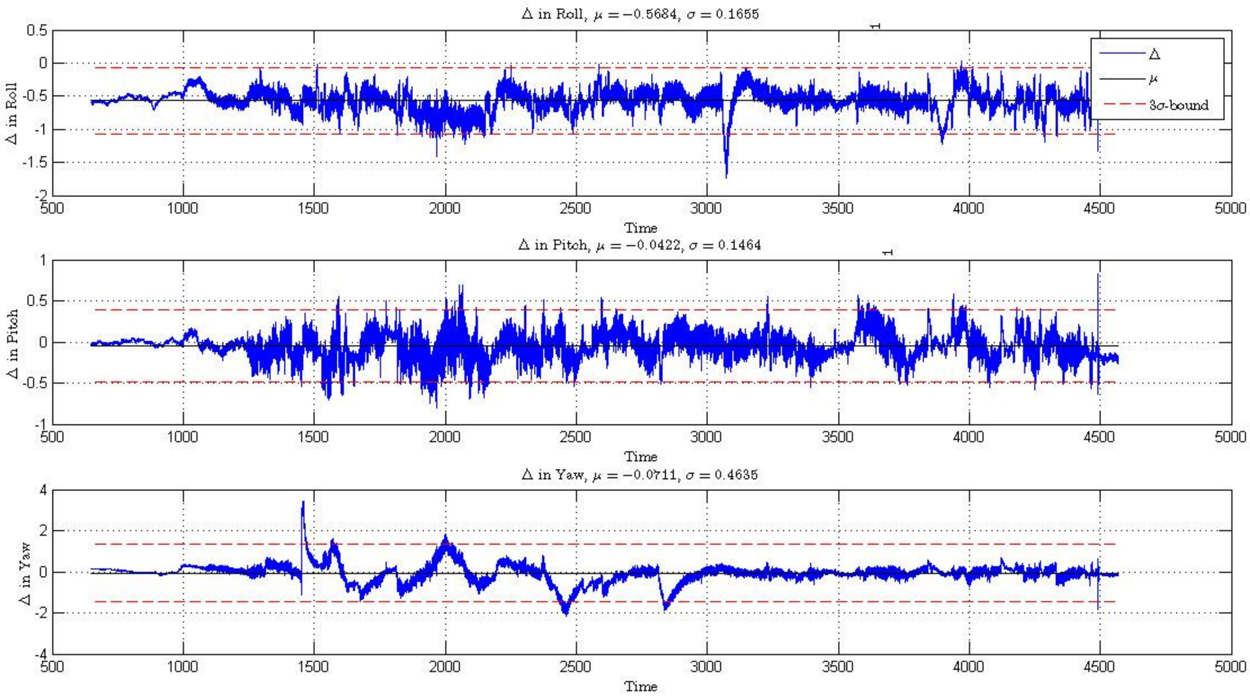



**Figure 10: Difference in roll/pitch/yaw between iVRU-CB-M and SPAN-CPT (angles in [deg], time in [sec])**

## 2.3 Flight Campaign #3 on Helicopter

This flight test had been comparable to flight test #2, but as inertial measurement systems we operated a MEMS based iVRU-CB-M (the same as before) and a SPAN-HG1700 ring laser based IMS (this RLG based system, which is class of iMAR's FOG based iIMU-FSAS, is much more accurate than the SPAN-CPT fiber optic gyro based IMS). The SPAN-HG1700 is of class 1 deg/h, for iVRU-CB-M see iMAR's datasheet: http://www.imar-navigation.de

The following plots show again the high accuracy of the iVRU-CB-M. The Notch filters, which are available on the iVRU-CB-M to eliminate the rotor frequencies on the output channels (2 independently selectable Notch frequencies with each one selectable bandwidth) had not been activated, because we wanted to demonstrate the full bandwidth of the iVRU-CB-M system. These Notch filters can be activated if the aircraft's flight control system (FCS) would require this.

The first figure shows the flown trajectory.

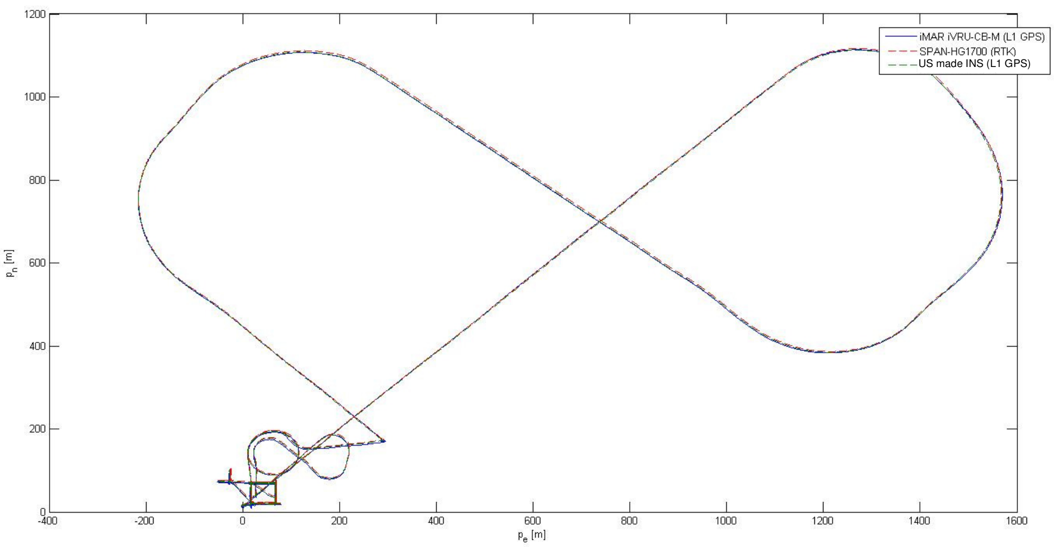
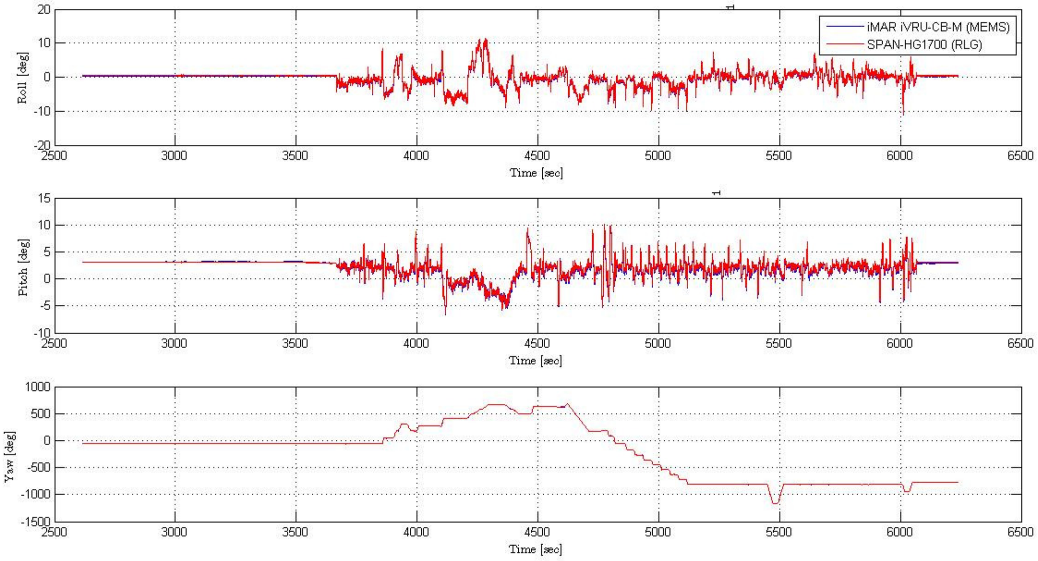



**Figure 11: Trajectory of helicopter flight #3**

The next figure shows the angles roll, pitch and yaw of both systems, iVRU-CB-M (MEMS) and SPAN-HG1700 (RLG).




## Figure 12: Attitude and Heading during flight #3

The following figure shows the difference between the MEMS IMS and the RLG IMS. It can be found that the standard deviation between both is very small, i.e. only 0.1 deg in roll, 0.15 deg in pitch and 0.35 deg in yaw.

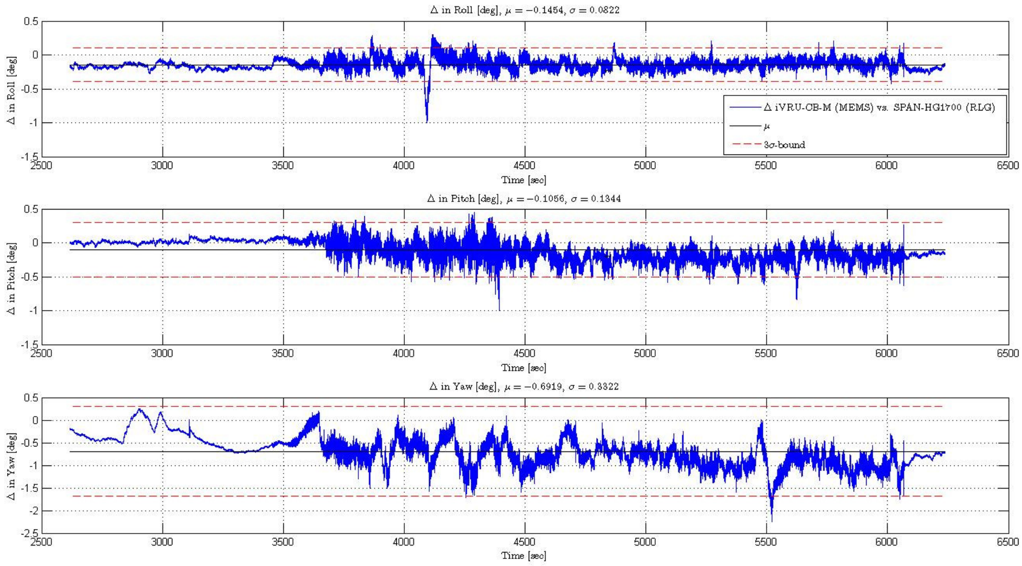



**Figure 13: Difference between iMAR's iVRU-CB-M and SPAN-HG1700 (US/Canadian Manufacturer, ITAR restricted) during flight #3**