Application Note

SPAN with ALIGN

HEXAGON AUTONOMY & POSITIONING DIVISION
CONFIDENTIAL AND PROPRIETARY DATA

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Introduction: Use of ALIGN in SPAN

First added as a feature to the SPAN-CPT in 2010, NovAtel's dual antenna heading solution, ALIGN, has proven to be valuable in improving the heading solution of the SPAN GNSS (Global Navigation Satellite Systems) + INS (Inertial Navigation Systems) product line.

GNSS and INS are complementary technologies. While GNSS is absolute and noisy, INS is relative and smooth. Any independent source of information, such as by adding ALIGN to your SPAN solution, provides one more way to help improve your navigation solution.[1]

GNSS + INS Overview

GNSS are constellations of satellites providing signals that enable GNSS users to determine their position and time. GNSS computed positions are accurate in an absolute sense. In certain environment, GNSS can be challenged such as in 'urban canyons' or in tunnels where there is no direct line of sight to GNSS satellites. The combination of GNSS and INS addresses this challenge on availability with further additional benefits.

An INS is made up of an IMU (Inertial Measurement Unit) and a navigation processor. The IMU includes three gyroscopes (which measure changes in angle) and three accelerometers (which measure changes in velocity). Each gyroscope is fixed at a 90-degree angle to the other two, forming a coordinate frame. The same applies to the accelerometers. By summing the changes in velocity, combined with the direction (attitude), the INS estimates velocity and integrating the velocity yields position. This way, INS makes available to the user position, velocity and attitude.

Because the changes measured by the INS are relative, a starting point is needed. GNSS can easily provide the starting position and velocity. For attitude, INS makes use of the 'strong' signal of gravity for estimating roll and pitch. The harder component of attitude is heading, as described in ALIGN improvements to the INS solution.

ALIGN Overview

ALIGN is NovAtel's dual antenna-based precise positioning and heading technology. Combining two receivers, an ALIGN enabled system can generate the heading angle between two antennas to an accuracy of 0.2 degrees when the antennas are separated by a meter. This GNSS-based heading is computed relative to true North and is available on an ALIGN enabled SPAN system.

[1] For more in-depth information about GNSS and SPAN, see our book on GNSS.

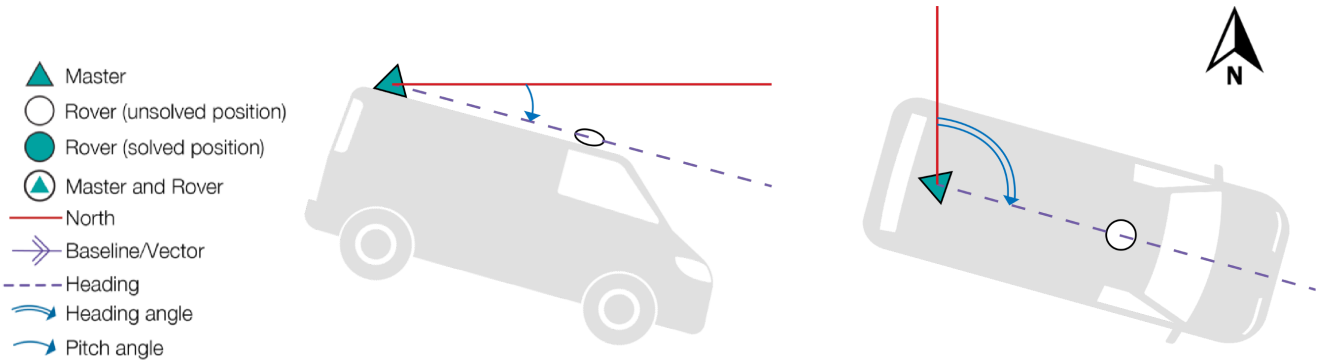

Figure 1: Heading from two receivers on one vehicle

For more information on dual antenna products from NovAtel, visit our website here.

ALIGN improvements to the INS solution

The process to determine heading in INS is difficult. In high grade systems, the gyroscopes are sensitive enough to detect the spin of the Earth[2], allowing the system to independently determine true North. From the initial alignment phase of the INS system, changes in heading are continually used in the solution to estimate the current heading in attitude. In systems that are equipped with lower grade IMUs, an external source or input may be required to provide the initial alignment.

For SPAN systems with lower grade IMUs, initial alignment can be achieved through:

- User input (SETINITAZIMUTH or EXTERNALPVAS command), or
- Kinematic alignment (requiring motion), or
- ALIGN solution.

If the lever arm (distance from the IMU to the antenna) is known to both antennas of an ALIGN enabled receiver, the difference of the ALIGN heading, compared to the heading axis of the INS, can be computed. This information allows the transfer of the dual antenna heading to the INS, providing an initial alignment for the attitude solution.

[2] If the gyroscope has a drift and noise total that is significantly less than 15 degrees/hour, the rotation of the Earth can be detected, and heading determined autonomously.

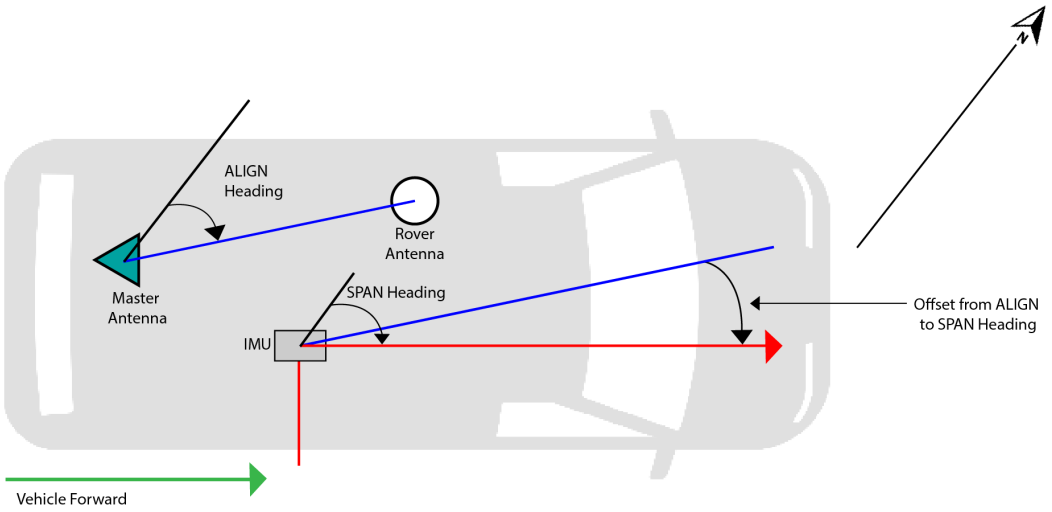

Figure 2: Typical setup showing SPAN Heading provided in the vehicle frame and ALIGN heading provided from two antennas

The most difficult attitude component to determine in a GNSS + INS solution is heading (azimuth) because the rotation of the Earth is small compared to the noise and errors in gyroscope measurements. Also, roll and pitch can be determined with greater ease, as they depend on the very strong 'signal' of gravity. Adding an ALIGN solution improves the ongoing performance of the SPAN system by providing constant information about heading from an outside source.

Advantage of SPAN with ALIGN

To improve the heading accuracy, SPAN uses the complementary attributes of ALIGN. Independent of the heading determined by the INS, the heading solution provided by ALIGN can help to continuously estimate the errors in the inertial measurements and refine the solution. In the latest release of SPAN firmware, the difference between the ALIGN heading vector and the SPAN heading is now constantly estimated and refined, allowing the system to make better use of the heading update. Also, the ALIGN solution is now used when the system is in a turn, increasing the availability and usefulness of the external heading update.

As with all systems that involve multiple inputs, the system is greater than the sum of the parts. The ALIGN solution is only one component of the SPAN heading. While the ALIGN solution is very accurate (improving with increased antenna separation), the additional need to mathematically transform the ALIGN solution into the INS computational frame, along with the GNSS measurement noise in the ALIGN solution, requires careful weighting of the additional information in the SPAN solution.

The more information from independent sources that is input into the SPAN filter, the more the solution will improve. ALIGN solution is only used when there is confidence that the solution is good and a number of checks have passed[3]. It is important to remember that the ALIGN heading does not replace the INS heading but augments and facilitates it. To get the best possible INS results, move the system through some dynamics (turns, accelerations, and decelerations) to help the system determine error and help improve the result. More turns help the system 'see' the error in the offset from the ALIGN solution to the INS heading, allowing the system to make better use of the ALIGN heading information.

[3] Including ALIGN in an RTK Narrow Integer, verified solution.

Low dynamic situations (slow velocities, few turns) are a challenge for inertial navigation systems. This is especially true for integrations with lower cost IMU systems. Lower dynamics reduce the ability of the navigation filter to estimate the errors in the system because there are fewer independent observations. Adding ALIGN to your system provides an additional, independent observation source of the most difficult to estimate parameter (heading) of a GNSS + INS system.

The figure below shows how ALIGN helps in very low dynamic situations. This dataset is from a test situation that is challenging for a lower grade IMU. The error was estimated relative to a navigation–grade, post-processed inertial reference.

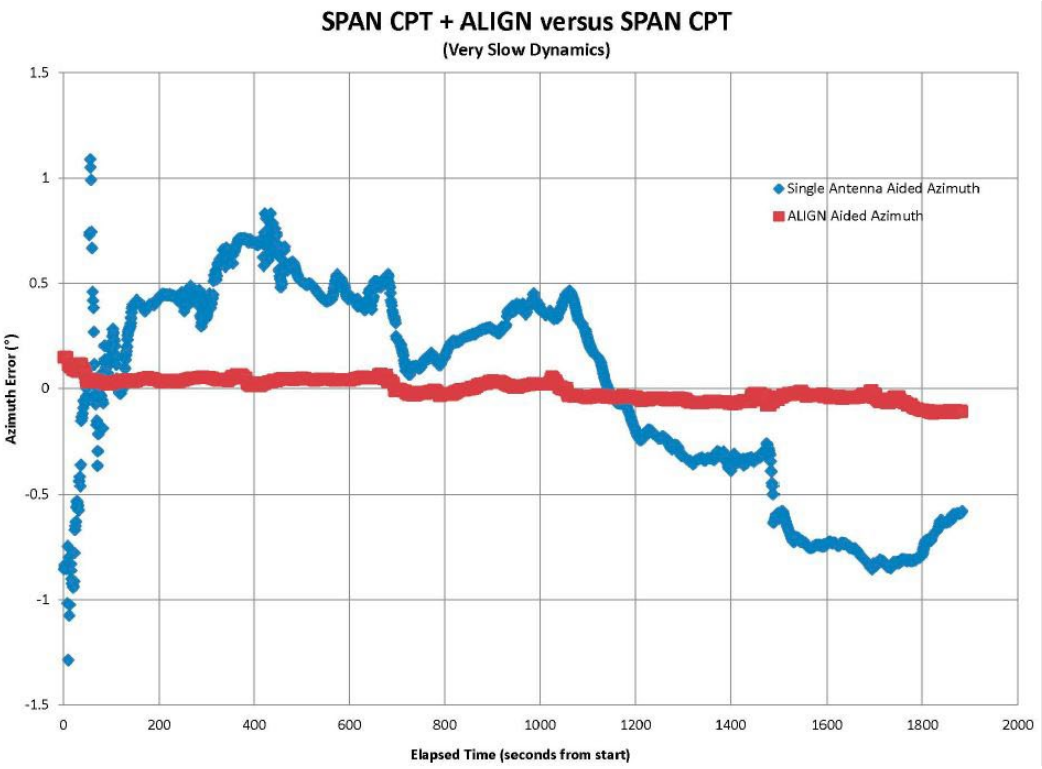

Figure 3: ALIGN in low dynamic solutions

ALIGN can be added to an existing single antenna SPAN setup by the addition of an ALIGN-capable receiver with its own antenna. ALIGN parameters will need configured for the SPAN receiver using the INSALIGNCONFIG command as shown below using Ethernet communication between the two receivers. This setup allows utilising the ALIGN vector solution in SPAN operation. For the “ANT2” SETINSTRANSLATION entry, the lever arm is measured from the SPAN IMU’s centre of navigation (CoN) to the phase centre of the rover ALIGN receiver’s antenna.

Rover ALIGN-capable receiver (with e.g. Z-model for ALIGN capability):

```
INTERFACEMODE ICOM5 NOVATEL NOVATEL OFF
ICOMCONFIG ICOM5 TCP 192.168.5.10:3005
```

SPAN receiver to use the above rover ALIGN receiver for ALIGN input into its SPAN operation. Commands that need to be added on this receiver are shown in bold:

```
INTERFACEMODE ICOM5 NOVATEL NOVATEL OFF
ICOMCONFIG ICOM5 TCP :3005
MOVINGBASESTATION ENABLE
SETINSTRANSLATION ANT1 0.5 0.5 0.5 1 1 1   >> Presumably pre-existing on this SPAN receiver.
SETINSTRANSLATION ANT2 1.5 1.2 0.5 0.5 0.5 0.5
SETINSROTATION RBV 0 0 0                   >> Presumably pre-existing on this SPAN receiver.
ALIGNMENTMODE AIDED_TRANSFER
INSALIGNCONFIG ICOM5 ICOM5 230400 2
```

The SPAN receiver is now able to use ALIGN in its SPAN operation with an additional ALIGN rover receiver. ALIGN vector becomes possible with the configuration above.

Heading in ALIGN and INS

In the INSPVA and INSATT logs, the heading is always the heading from the INS. The HEADING log provides the ALIGN heading between the two antennas. These headings are different because the ALIGN heading is between the two antennas, while the INS heading is determined from the results of the IMU input into the SPAN system.

Because these two headings come from different sources, they behave differently. The INS heading will be smoother from epoch to epoch but will likely wander more in low dynamic situations where the error sources are hard to estimate. The heading derived from the ALIGN system will not wander, but will have sharper, discrete jumps as new measurements are made.

Be sure to use the information, available in the INSSTDEV or INSATTX logs to assess the quality of the solution.

Value of ALIGN in SPAN

While ALIGN benefits all SPAN systems, the effect of that benefit is most noticeable with lower grade IMUs, such as the SPAN-CPT, as well as with installations where dynamics do not allow for kinematic or coarse alignment, e.g. marine applications. The ALIGN solution helps to curb the drift that the inertial solution will experience (especially when the system has not had a significant amount of convergence time following coarse alignment). Remember that more turns and velocity changes provide a better chance for the system to improve its accuracy.

Support

To help answer questions and/or diagnose any technical issues that may occur, the NovAtel Support website is a first resource.

Remaining questions or issues, including requests for test subscriptions or activation resends, can be directed to NovAtel Support.

Before contacting Support, it is helpful to collect data from the receiver to help investigate and diagnose any performance-related issues. A list of appropriate troubleshooting logs can be found on the OEM7 Documentation Portal (the LOG command with the recommended trigger and data rate is included with each log).

The data can also be collected using NovAtel Application Suite.

Documentation

For any questions on logs and commands, please visit the OEM7 Documentation Portal.