HEXAGON | NovAtel

APN-098

Terrain Compensation and SPAN Comparison for SMART Antenna Products

Contents

Introduction

Terrain Compensation and SPAN both use an IMU (Inertial Measurement Unit) to measure the acceleration and the rotation of the vehicle, however these NovAtel technologies use this information to provide different features to the user. Terrain Compensation and SPAN can both be used in various applications depending on what the use-case requirements are.

Terrain Compensation is a technology offered on select variants of SMART2 and SMART7[1] antenna products, which provides terrain compensated position output, inclination (roll and pitch) and acceleration in X/Y axes. To enable Terrain Compensation on supported platforms, a software model option is also required.

SPAN technology is NovAtel's GNSS+INS solution, which provides the user with deeply coupled GNSS+INS position, velocity and attitude (roll, pitch, and azimuth) output. SPAN is offered on select variants of SMART7 antenna products, and OEM7 receivers and enclosure products that have an IMU integrated and a SPAN enabled software model.

Terrain Compensation and SPAN Comparison

Table 1 outlines the key performance differences between Terrain Compensation and SPAN for SMART Antenna products.

Table 1: Terrain Compensation and SPAN - Side by Side Comparison for SMART Antennas

	SMART2-TB w/ T0 (Software Unlock)	SMART7[1] w/ T0 (Software Unlock)	SMART7-S or SMART7-SI w/ P1 (Software Unlock)
IMU Option	**Terrain Compensation**		**SPAN**
Attitude Accuracy	Roll/Pitch: <1.0° RMS	Roll/Pitch: 0.5° RMS	Roll/Pitch: 0.03° RMS / 0.06° 95% Heading: 0.1° RMS / 0.5° 95%
Required Part Number/ Software Model Option	SM2TB-***-***-***-T0-*	SM7W- / SM7I-***-***-***-T0	At least SM7S / SM7SI-***-***-***-P1
Heading Source	Course over Ground (COG) / GNSS		GNSS+INS
Position Output Reference Point	The point on the ground under the vehicle, that is projected from the antenna to the ground along the line perpendicular to the vehicle frame.		IMU Centre of Navigation or User-defined location on vehicle.
Logs Available	Position – corrected for vehicle roll and pitch (i.e. BESTPOS, GPGGA), inclination (roll & pitch) and acceleration in X/Y axes (i.e. TILTDATA)		Full SPAN solution – position, velocity, and attitude (roll, pitch, and azimuth) (i.e. INSPVA).
One-Time Setup & Calibration Procedure (Only needs to be repeated if antenna is remounted)	Set antenna height and perform Two-Stage zeroing. Save height data and level setting.		Primary antenna lever arm and default RBV rotation are pre-configured for SMART7-S/SI. Optional: Enter custom RBV rotation if SM7 has not been mounted in recommended orientation. Optional: Perform RBVCalibration.
System Start-Up - Initialization Procedure	N/A		Perform SPAN Alignment.

Max Position Update Rate	20 Hz	200 Hz (INS)
Positioning Level Available	Available with any positioning level that is supported by hardware and software model	Available with any positioning level that is supported by hardware and software model.

[1] As of March 2022, Terrain Compensation is no longer available with the SMART7 base variant (SM7), more information on this can be found here.

Terrain Compensation

Requirements for Terrain Compensation

Firmware

Terrain Compensation is supported on firmware versions ≥7.06.01 on SMART7s, and on firmware versions ≥7.06.02 on SMART2s.

Note: Two-Stage zeroing was introduced as of firmware version 7.08.01 on SMART7 and SMART2, and is the preferred method of zeroing. Single-Stage zeroing can still be performed in these firmware versions to support backwards compatibility for users.

Firmware versions <7.08.01 on SMART7 and SMART2 only support Single-Stage zeroing.

Hardware

Terrain Compensation is available on SMART2-TB, SMART7-I and SMART7-W.

Software Model

The Terrain Compensation feature is enabled in the 10th and 11th characters of the OEM7 model string. For example, if the model string is DDN-PNN-TMN-T0-G, the characters T0 identify the Terrain Compensation feature. Terrain Compensation requires INS Model 'T' and IMU Grade 0.

One-Time Terrain Compensation Setup & Calibration

Terrain Compensation requires a one-time setup and calibration to be completed before Terrain Compensation system can be used.

1. **Mount SMART Antenna**: with the SMART antenna connector facing the rear of the vehicle. It must be rigidly mounted to reduce possibility for vibration/motion, which will induce errors in the solution.

2. **Enable Terrain Compensation and Enter Antenna Height**: using the TILTFILTER command. The height (in metres) must be measured on a hard-packed level surface from the ground to the bottom of the SMART antenna. The measurement accuracy should be within 2.5 to 5.0 cm.

3. Zero (Level) Terrain Compensation Sensor: Two-Stage zeroing is preferred. To level the TILTZERO command is used.

4. Save Height and Zeroing Setting: To save the Terrain Compensation height setting and the zeroing setting, issue the TILTZERO SAVE command.

5. Save the Overall Configuration: with the SAVECONFIG command.

Important Note: When performing zeroing it is recommended that the vehicle has no added ballast or weights, or attached implements which could all negatively affect the zeroing. The vehicle should also have the correct tire pressure, as this affects the height of the vehicle.

One-Time Terrain Compensation Setup & Calibration should be repeated if there are changes to the tires or baseline tire pressure, or if the antenna has been re-mounted.

System Start-Up – Terrain Compensation

After One-Time Terrain Compensation Setup & Calibration has been completed, for subsequent system start- ups (power cycle), the Terrain Compensation height and level settings do not need to be reconfigured.

Terrain Compensation is ready for use as soon as the SMART antenna has computed its initial GNSS position and sufficient vehicle motion >1 km/hr has been detected, as vehicle motion is required to compute and obtain terrain-compensated positions.

The user can monitor Bit 7 of the Extended Solution Status (Field 20) in the BESTPOS log to determine if Terrain Compensation corrections have been applied to the position output for that epoch. The TILTDATA log can also be monitored to observe the instantaneous horizontal accelerometer measurements, as well as the filtered inclination values computed based on the movement of the vehicle.

Terrain Compensation Output & Benefits

The Terrain Compensation feature corrects for errors in position caused by the roll and pitch of the vehicle. The SMART Antenna senses the vehicle's roll and pitch angle and, with the user-entered "height above ground", compensates the position output to give the position under the vehicle rather than at the antenna.

If terrain compensation is enabled, the SMART Antenna determines the roll and pitch angles and corrects the position data before it is output.

In the example shown in Figure 1, the roll angle is 10 degrees, so the position correction that needs to be applied is 61 cm. In the example shown in Figure 2, the pitch angle is 8 degrees, so the position error that needs to be applied is 49 cm.

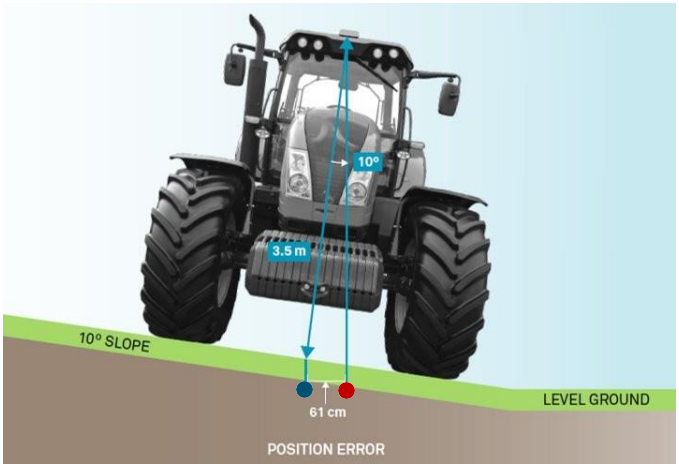

Figure 1: Terrain Compensation – Vehicle Roll

- Erroneous vehicle position (uncorrected for roll of vehicle), without Terrain Compensation, projected onto ground.
- True vehicle position (corrected for roll of vehicle) using Terrain Compensation.

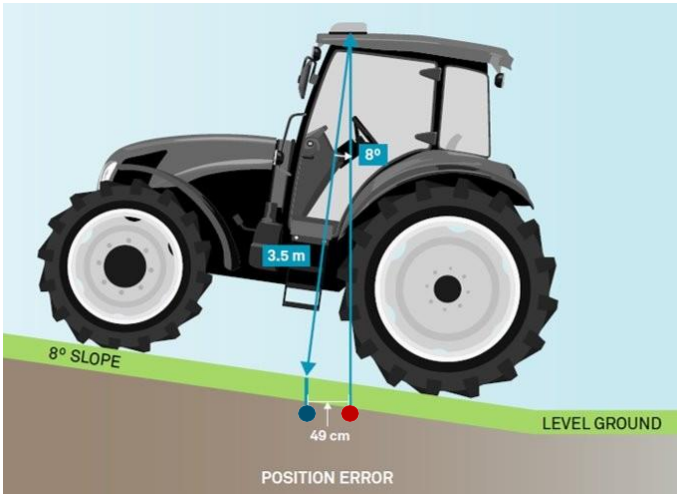

Figure 2: Terrain Compensation - Vehicle Pitch

- Erroneous vehicle position (uncorrected for pitch of vehicle), without Terrain Compensation, projected onto ground.
- True vehicle position (corrected for pitch of vehicle) using Terrain Compensation.

The following logs provide terrain compensated positions and can be output at a rate up to 20 Hz:

- **BESTPOS** log
- **BESTXYZ** log
- **BESTUTM** log
- **GPGGA** log
- **GPGGALONG** log
- **GPGLL** log
- **GPRMC** log
- **PGN129025** NMEA log
- **PGN129027** NMEA log
- **PGN129029** NMEA log

The user can output the acceleration in X/Y axes and the pitch and roll of the vehicle (inclination in the X/Y axes) with the TILTDATA log.

The Terrain Compensation operation can be enabled or disabled via the TILTCOMPENSATIONCONTROL command, so that the position corrections computed by the Terrain Compensation filter will or will not be applied to output positions. The user can monitor Bit 7 of the Extended Solution Status (Field 20) in the BESTPOS log to determine if Terrain Compensation corrections have been applied to the position output for that epoch.

Important Note: Vehicle motion >1 km/hr is required to compute and obtain Terrain-Compensated positions. If the vehicle speed drops below this threshold the position output is no longer terrain compensated, so the position output reference point will move to the antenna phase centre.

SPAN

Requirements for SPAN

Firmware

SPAN is supported on all OEM7 firmware versions.

Hardware

SPAN is available on SMART7-S and SMART7-SI variants.

Software Model

The SPAN features enabled on a receiver are identified in the 10th and 11th characters of the OEM7 model string. For example, if the model string is FFN-RNN-TBN-P1, the characters P1 identify the SPAN features. SPAN on SMART7 requires INS Model 'P' and IMU Grade 1. For more information on SPAN model characters, refer to SPAN Models and Features.

One-Time SPAN Setup & Calibration

SPAN requires a one-time setup and calibration to be completed before a new SMART7 SPAN system can be operated.

1. **Mount Equipment:** Mount the SMART7-S/SI in the recommended orientation, with the front of the SMART7 facing the direction of forward motion for the vehicle and the connector facing the rear of the vehicle. The SMART7 must be rigidly secured to the vehicle to avoid errors caused by vibration and motion.

2. **Configure RBV Rotation:** If the SMART7 has been mounted in the recommended orientation, the factory default SETINSROTATION settings can be used (SETINSROTATION RBV 180 0 90). If the SMART7 has been mounted in a different orientation, enter the rotation from the IMU body frame to the vehicle frame (RBV) with the SETINSROTATION command

3. **Save Configuration**: with SAVECONFIG command so the SPAN configuration persists through a power cycle.

4. **Complete RBV Calibration (Recommended)**: For the SMART7 to provide the best performance, the rotation offset of the IMU body to the Vehicle frame (RBV) should be known as accurately as possible. It is recommended that a Body to Vehicle Frame rotation calibration routine be completed so the SPAN system can determine and compensate for any installation misalignment angles. Refer to Importance of RBV Calibration for details on why it is important and for step-by-step instructions.

5. **User Translation and Rotation (Optional)**: If desired, the user can configure an additional 'user' translation to a desired output location on the vehicle, using SETINSTRANSLATION USER, which shifts the position and velocity information in the INSPVA, INSPOS, INSVEL, INSATT, and INSSPD logs, along with their short

header and extended versions. This can be useful for positioning an alternate point on the vehicle or other piece of equipment on the vehicle, instead of where the SMART7 has been mounted (IMU centre of navigation).

Similarly, the user can optionally configure a 'user' rotation using the SETINSROTATION USER command to shift the attitude information in the INSPVA, INSPOS, INSVEL, INSATT, and INSSPD logs, along with their short header and extended versions.

Note: The One-Time SPAN Setup & Calibration needs to completed once for new SMART7 SPAN installations and only needs to be repeated if the SMART7 is remounted.

System Start-Up - SPAN Initialization

After One-Time SPAN Setup & Calibration has been completed, each time the SMART7 is powered on, SPAN alignment must be completed to initialize the INS filter. The type of SPAN alignment techniques available depends on the hardware used. SMART7 supports:

- Kinematic alignment: Requires vehicle motion to estimate the heading from the GNSS velocity vector and inject it into the SPAN filter as the initial system heading.
- Dual antenna alignment: Requires dual antenna installation.
- INS Seeding alignment: Requires the alignment information from a previous power up to quickly perform an alignment.

SPAN Output & Benefits

The SPAN solution can be observed by logging INS type logs such as INSPVA. When SPAN is enabled, it provides the following benefits:

- GNSS & INS solution at a high output rate (up to 200 Hz) for all IMU/Receiver combinations:
  - Position (Latitude, Longitude, Height)
  - Velocity (North, East, Down components)
  - Attitude (Roll, Pitch, Azimuth) after alignment for deeper integration with steering systems
- GNSS solution is supported by INS in places where GNSS is completely denied or partially blocked/degraded (tree line, buildings, foliage etc.)
- Terrain compensated position
- Smooth solution epoch to epoch
- Detailed information about the updates used in the INS filter each epoch, which is output in the INSUPDATESTATUS log or the Extended Solution Status word found in several SPAN logs such as INSPVAX and INSATTX.
- Once initialized (SPAN alignment), SPAN continues to output the SPAN solution even when at slow speeds or when the vehicle is stationary.

Use the INSCOMMAND command to enable or disable INS. When INS is disabled, no INS position, velocity or attitude is output (however IMU data is still available). Also, INS aiding of tracking reacquisition is disabled. If the command is used to disable INS and then re-enable it, the INS system has to go through its alignment procedure (equivalent to issuing a RESET command).

Which technology is best for my application?

Refer to Table 2 for general guidance on which technology (Terrain Compensation or SPAN) is recommended based on the application requirements.

Table 2: Solution recommendations based on application requirements.

Application Requirements	Terrain Compensation	SPAN
Application requires terrain compensated position because the vehicle is operating on uneven/sloped terrain.	✔	✔
Application involves a slow-moving vehicle, where >20 Hz position and velocity solution output is not required	✔	✔
Application involves a higher speed vehicle, where a high accuracy solution with update rates >20 Hz is required		✔
Application requires low rate (≤ 20Hz) roll and pitch output	✔	✔
Application requires high rate (≤ 200 Hz) attitude (roll, pitch, azimuth) output for integration into steering/vehicle control		✔
Application requires GNSS+INS fused azimuth		✔
Application requires heading/azimuth output, even when at very low speeds or the vehicle is stationary, and is not using a dual antenna ALIGN solution		✔
Application requires Terrain Compensated position at speeds <1 km/hr		✔
Application requires solution availability even during short periods of degraded or unavailable GNSS where there may not be enough satellites to compute a GNSS-only solution (tree lines, heavy foliage, buildings, etc.)		✔
Application requires the ability to enable INS Profiles, such as the Agriculture INS profile to benefit from simplified configuration and enhanced performance.		✔

Appendix A: Additional Resources

Commands and Logs

Commands

- TILTFILTER
- TILTZERO
- TILTCOMPENSATIONCONTROL
- SETINSROTATION
- SETINSTRANSLATION
- INSCOMMAND

Logs

- BESTPOS
- INSPVA
- TILTDATA

References

Terrain Compensation Technical Overview

SMART7 with SPAN Operation Overview

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. In those cases, collect the following list of logs (the LOG command with the recommended trigger and data rate is included):

```
LOG RXSTATUSB onchanged
LOG ALMANACB onchanged
LOG RAWEPHEMB onchanged
LOG GLORAWEPHEMB onchanged
LOG TRACKSTATB ontime 1
LOG SATVIS2B ontime 60
LOG BESTPOSB ontime 1
LOG RANGEB ontime 1
LOG RXCONFIGA once
LOG ITDETECTSTATUSB onchanged
LOG VERSIONA once
LOG PORTSTATSB ontime 10
```

For Terrain Compensation systems, also include the following logs:

```
LOG RAWIMUSXB onnew
LOG TILTFILTERA
LOG TILTDATAB ONTIME 1
```

Note: RAWIMUSX is encrypted on Terrain Compensation models but can be decoded by NovAtelCustomer Support.

For SPAN systems, also include the following logs:

```
LOG RAWIMUSXB onnew
LOG INSUPDATESTATUSB onnew
LOG INSPVAXB ontime 1
LOG INSCONFIGA onchanged
```

The data described above can be collected using the NovAtel Application Suite.

Contact Hexagon | NovAtel

support.novatel@hexagon.com 1-800-NOVATEL (U.S. and Canada) or 1-403-295-4900
For more contact information, please visit novatel.com/contact-us

Documentation

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

Contact Hexagon | NovAtel

support.novatel@hexagon.com 1-800-NOVATEL (U.S. and Canada) or 1-403-295-4900
For more contact information, please visit novatel.com/contact-us