VN-100 Velocity Compensation

Velocity / Airspeed Aiding for AHRS Applications

Application Note

Abstract

This application note describes how the VN-100 can be used in non-stationary applications which require an accurate attitude estimate while a vehicle is in constant motion. In these dynamic environments external velocity aiding is required to compensate for the additional vehicle acceleration present. This document describes the type of applications which require this external aiding and the correct procedure for providing the necessary velocity measurements.

Document Information

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1 AHRS Fundamentals

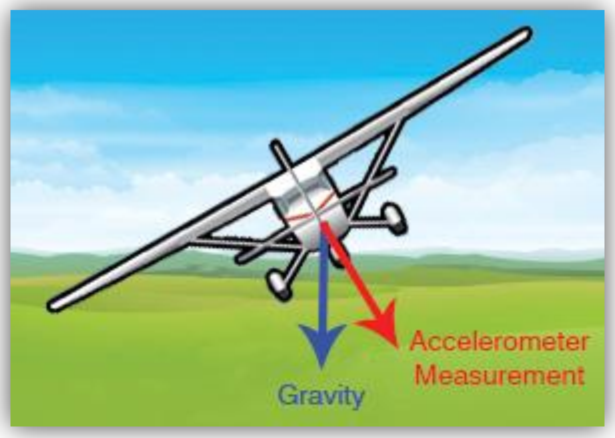
An Attitude Heading Reference System (AHRS) is a sensor system that estimates the attitude of a vehicle based upon the combined measurements provided by a 3-axis gyroscope, accelerometer, and magnetometer. An AHRS sensor typically utilizes a Kalman filter to compute the 3D orientation of the vehicle based upon the vector measurements provided from the accelerometer and the magnetometer. The accelerometer measures the effect of both gravity and any acceleration due to body motion. The magnetometer measures the influence of both the earth's magnetic field and the influence of any nearby magnetic fields created by nearby ferromagnetic objects. The gyroscope provides an accurate short term measurement of the relative change in the orientation of the sensor however it is not capable of providing a measurement of the orientation itself. The absolute accuracy of the heading, pitch and roll solution for an AHRS is ultimately derived from the accuracy of the vector measurements provided by the accelerometer and magnetometer.

1.1 AHRS Assumptions

Without any form of external compensation an AHRS does not have by itself any means of knowing how it is moving relative to the fixed Earth. As such it does not have any means of knowing what the actual acceleration of the body is. Since the accelerometer measures the effect of both gravity and the acceleration due to motion, the standard AHRS algorithm has to make the assumption that the long-term acceleration due to motion is zero. With this assumption in place the AHRS know has sufficient information to estimate the pitch and roll based upon the measurement of gravity provided by the accelerometer. This assumption works very well for applications where the sensor does not experience any long-term acceleration such as when it is used indoors or when used on a large marine vessel. Applications that do experience long-term accelerations due to motion however will experience a significant error in the pitch and roll solution due to the fact that the assumption of zero body acceleration in the AHRS algorithm is constantly being violated.

The most common case where this acceleration becomes a significant problem for an AHRS is when it is used on an aircraft operating in a banked turn. In straight and level flight the AHRS will provide an accurate measurement of attitude as long as the long-term accelerations are nominally zero. When the aircraft banks and enters a coordinated turn however, a long-term acceleration is present which due to the centripetal force created by traveling along a curved path. This apparent force is what makes you feel as if you are being pushed to the side when you drive around a corner in a car.

Figure 1 - Measured Acceleration in Coordinated Turn



When an aircraft is in a banked turn the accelerometer will measure gravity plus this centripetal acceleration which will result in a measurement vector that acts perpendicular to the wings of the aircraft as shown in Figure 1. This will result in the AHRS estimating a roll angle of zero while the aircraft is in fact in a banked turn and thus has a significant actual roll angle relative to the horizon.

If the AHRS however can obtain some knowledge of this actual motion relative to the fixed Earth then it is possible for it to subtract out the effect of the centripetal acceleration, resulting in an accurate estimate of attitude. By providing the AHRS with the known velocity or airspeed it is possible for the AHRS to estimate the centripetal acceleration term based upon this velocity and the known body angular rates.

Figure 2 - AHRS with Velocity Compensation

The above figure accurately depicts quality of attitude solution provided by three separate types of attitude estimators while operating in a coordinated turn. The flight display on the far left represents the actual attitude which is derived from the flight simulator. Moving from left to right are three separate types of attitude estimators shown in order based upon the accuracy of their derived solution. The most accurate solution is proved by the Inertial Navigation System (INS). This type of estimator incorporates the position and velocity measurements from a GPS along with the accelerometer, and gyroscope in an optimal fashion to simultaneously estimate attitude and the position and velocity of the vehicle. It provides the most accurate attitude estimate since it makes no assumptions regarding the accelerometer measurements.

2 Measurement Sources for Velocity Aiding

In order to properly account for the centripetal acceleration the user will need to supply the VN-100 with an external measurement of the velocity of the vehicle. The velocity of the vehicle can be provided in one of two different reference frames Body or Inertial.

2.1 Body Velocity Measurement (Speedometer or Airspeed)

A body velocity measurement consists of a measurement of the velocity with respect to the sensor's measurement axes. Examples of body velocity measurements would be a speedometer on an automobile or an airspeed measurement on an aircraft. In most cases the velocity is only measured out the forward axis of the vehicle and it is assumed that the velocity in directions perpendicular to the forward axes remains zero. In some cases such as when an angle of attack and sideslip angle are also measured it might be possible to get a full 3D velocity measurement in the sensor's body reference frame. See section 3.1.1 for more details on how to handle these two separate cases when providing the actual measurements to the VN-100.

2.2 Inertial Velocity Measurement (GPS)

An inertial velocity measurement consists of a measurement of velocity with respect to the Earth's fixed reference frame. An example of inertial velocity measurements would be measurements based upon GPS. In the case of GPS the velocity is either provided in the North, East, Down (NED) frame or in the Earth Centered Earth Fixed (ECEF) frame. In either case the 3D velocity components are all independent of the orientation of the sensor.

3 Procedure for Velocity Aiding on the VN-100

There are two actions that will need to be taken by the user in order to properly configure and use velocity compensation on the VN-100. First the user must configure the type of velocity measurement (Body or Inertial) that is used in the configuration register. Second the velocity measurements themselves need to be provided to the velocity measurement register.

3.1 Configuration

Before you begin to use the velocity compensation feature on the VN-100 you will need to properly setup the velocity compensation by writing to the Velocity Compensation Configuration Register (Register 51). The layout of this register is shown in the VN-100 User Manual and is shown in the figure below for reference.

Figure 3 - Velocity Compensation Control Register

Velocity Compensation Control				
Register ID :	51	Firmware : v1.1.140.4		Access : Read / Write
Comment :	Provides control over the velocity compensation feature for the attitude filter.			
Size (Bytes):	8			
Example Serial Read Register Response:	$VNRRG,51,1,0.1,0.01*5A			
Byte Offset	**Name**	**Number Format**	**Unit**	**Description**
0	Mode	U1	-	Selects the type of velocity compensation performed by the VPE. See Figure 4 for available modes.
4	VelocityTuning	F4	-	Tuning parameter for the velocity measurement.
8	RESERVED	F4	-	This field is reserved for future use. This field should always be set to 0.01.

Figure 4 - Mode Options

Value	State	Description
0	OFF	No velocity compensation performed.
1	SCALAR	Scalar velocity measurement along sensor X-axis.
2	BODY	3D velocity measurement in body frame.
3	INERTIAL	3D velocity measurement in inertial frame.

Firmware versions v1.1.140.4 to v1.1.143.0 only supports the scalar velocity measurement (Mode 1). Firmware version v1.1.144.0 and up support all three modes (Scalar, Body, & Inertial).

3.1.1 Configuring the VN-100 to accept a scalar velocity measurement

To setup the VN-100 to accept a scalar velocity measurement, send the following command to the VN-100.

Figure 5 - Example Configuration Command for Register 51

Interface	Write Register – Setup Velocity Compensation Configuration Register
Serial	$VNWRG,51,1,0.1,0.01*5F
SPI	

3.2 Providing Measurements

Velocity measurements are provided to the VN-100 by writing to the Velocity Compensation Measurement Register (Register 50). The register is shown below for reference.

Figure 6 - Velocity Compensation Measurement Register

Velocity Compensation Measurement				
Register ID :	50	**Firmware :** v1.1.140.4		**Access :** Read / Write
Comment :	Input register for a velocity measurement to be used by the filter to compensate for acceleration disturbances.			
Size (Bytes):	12			
Example Serial Read Register Response:	$VNRRG,50,37.2,0,0*42			
Byte Offset	**Name**	**Number Format**	**Unit**	**Description**
0	VelocityX	F4	m/s	Velocity in the X-Axis axis.
4	VelocityY	F4	m/s	Velocity in the Y-Axis axis.
8	VelocityZ	F4	m/s	Velocity in the Z-Axis axis.

The velocity measurement must be provided in the correct reference frame determine by the Mode field in the Velocity Compensation Control Register (Register 51).

For Mode 1(Scalar measurement mode) the VN-100 will compute the vector length of the provided 3D velocity vector and use this for velocity compensation. If you have a scalar measurement you can set only the X-axis and set the Y & Z to zero.

3.3 Tuning for Higher Performance

In most situations the default tuning parameters for the velocity compensation will provide adequate results without the need for manual adjustment. In the event that you have a case where you need improved performance, there are tuning parameters provided in the Velocity Compensation Control Register (Register 50) that provide a means to adjust the behavior of the compensation algorithm.

3.3.1 Velocity Tuning

The velocity tuning field in the Velocity Compensation Control Register (Register 51) provides a means to adjust the uncertainty level used for the velocity measurement in the compensation estimation filter. The default value is 0.1. A larger value places less trust in the velocity measurements, while a smaller number will place more trust in the velocity measurement. If your velocity measurement is noisy or unreliable increasing this number may provide better results. If you have a very accurate velocity measurement then lowering this number will likely produce better results.

3.4 Velocity Measurement Rate

The performance of the velocity compensation will be affected by both the accuracy of the velocity measurements and the rate at which they are applied. To ensure adequate performance the velocity should be provided at a rate higher than 1Hz. Best performance will be achieved with update rates of 10Hz or higher.

If you stop sending velocity measurement updates for any reason, the velocity compensation will continue indefinitely using the last received velocity measurement. If you want to stop using while the vehicle is still in motion, be sure to turn off the velocity compensation using the Mode field in the Velocity Compensation Control Register (Register 51).

4 Conclusion

With external velocity compensation the VN-100 AHRS is capable of providing an accurate orientation even during periods of prolonged acceleration. Measurements can be provided to the sensor in either the inertial or body frame and at any rate above 1Hz.

If you have any questions regarding the velocity compensation feature on the VN-100 or need assistance determining whether the feature is required in your application, please contact our technical support team.

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