Appendix B Attitude Software

RTKNav attitude determination will compute the roll, pitch, and yaw of a vehicle or other object, given that data is available from three or more fixed mounted GPS antennae. The receiver antennae must be arranged in a non-collinear fashion. The software will also require the relative positions of the antennae, which are essentially their coordinates in the local body frame of the vehicle or object. These can be obtained through the calibration procedure described in Section 1 of this appendix. In addition to the attitude, the software will also compute the relative vectors between the GPS antennae used. The following steps need to be performed:

1. Compute the coordinates of each receiver in the body frame of the vehicle.
2. Create the project, and set the relevant options.
3. Process the data.

The first step is described in Section 1 of the appendix. The second and third steps are described in Section 2 of this appendix.

Section 1 Make Body Coordinates

Purpose

The Make Body Coordinates dialog box allows the user to define the body coordinate system for the GPS antenna locations. The output of this process is a .CRD file that will be read by RTKNav. The .CRD file will contain the body coordinates of each of the antenna stations. These stations refer to the GPS antennae used solely for the multi-antenna computation. This is a calibration procedure that only needs to be performed once per installation.

The main purpose of this calibration procedure is to produce x, y, and z coordinates for each fixed mounted GPS antenna in the frame of the vessel, aircraft or vehicle. This is the body coordinate system and is required for two reasons:

- Defines where the roll, pitch and yaw angles are referenced.
- Used as distance constraint information to improve multi-antenna KAR performance.

Figure 1 shows this body coordinate system. Make Body Coordinates basically solves for the roll, pitch and heading (-ve yaw) for the calibration installation. These are the angles required to rotation the antenna stations from local level to the body frame. This procedure requires a minimum of three antenna stations.

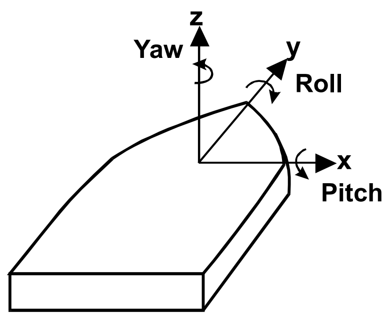


Figure 1: Body Coordinates Axis

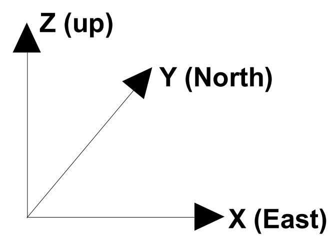


Figure 2: Local Level Coordinate System

What is needed to start?

Before running Make Body Coordinates, the following information is required:

GPS baselines: Using the standard version of GrafNav, coordinate/baseline information must be obtained for each of the fixed mounted antenna stations. The vessel/aircraft/vehicle must be approximately level (<10°) during calibration. In fact, it is best to level the vessel/aircraft/vehicle to a position to be expected during travel. The GPS baseline data is computed as follows:

Baseline Computation:
In the calibration procedure, data must be captured from each of the antenna stations simultaneously. Each baseline is processed separately with GrafNav, but it is suggested that the same base station be used throughout. It is <u>highly</u> suggested that one of the vessel/aircraft/vehicle antennae be used as the base. This procedure is greatly simplified for cases when the calibration is performed in static (stationary) mode. At least 15 minutes of data should be collected. In static mode, the GrafNav fixed solution can be used giving a very accurate baseline resolution. In kinematic mode, KAR should be used if possible. Single frequency KAR requires at least 20 minutes of data and 40 to 120 minutes are suggested. Make sure that no antenna heights are entered during processing. If very large base movements (+100m) are encountered, then GrafMov should be used.

Coordinates:
The local level or ECEF coordinates can be obtained from numerous sources. The easiest two are:

.FSS or .RSS file for static calibration. Look for the Fixed Static Solution block. The local level vector values are DE/DN/DZ: *x y z*, and the ECEF vector values are VECTOR: *x y z*. These values are with respect to the master station.

.FWD or .REV file or kinematic calibration. Be sure to use the same epoch in seconds for each of the stations. The first three values in the second row of each data block refers to the local level east, north and up values respectively.

Station names:

Assign each of the antenna stations an ID. This ID can be alpha numeric but cannot contain spaces. This will later on be assigned to each .GPB file for processing. Be sure to include the master station, its local level or ECEF coordinates will be [0,0,0] if the same master is used throughout. The first station, which is often the master station, is termed the reference station; it will be given final body coordinates of [0,0,0].

Constraint information:
Information on how to define the body coordinate system is required. There are two possibilities:

Angular definition:
You can specify absolute angles within the body frame between two stations (from and to). This will define the axes. Three angles need to be specified. The body azimuth is rotation about the z-axis and defines heading. The easiest approach is to pick two stations along one axis, but this is not required. Roll and Pitch are defined by tilt values. Preferably these tilt values (Tilt-x and Tilt-y) are orthogonal and along the body x and y-axes. However, you will have to do your best. For these inputs, enter the vertical angular difference between the level plane and the vector between the 'from' and 'to' stations. See figure 3 for an example.

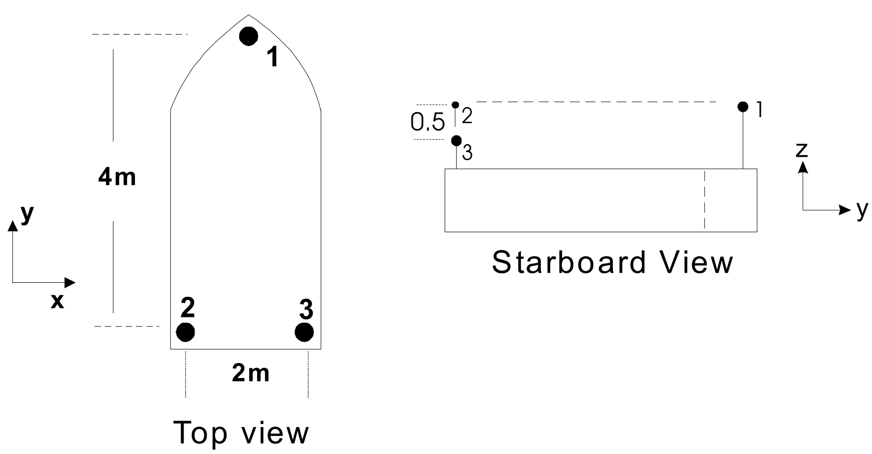


Figure 3: Angular definition

The body azimuth is defined as 90° from stations 2 to 3.

The tilt along the x-axis (Tilt-x) is defined as -14.04° from stations 2 to 3. This is computed using the formula ($\theta = \tan^{-1}[(Z_{to}-Z_{from})/HzDist]$), where HzDist is the horizontal distance (m).

The tilt along the y-axis cannot be directly observed, therefore an approximation of the tilt must be made either by using stations 3 to 1, or 2 to 1. Using 2 to 1, Tilt-y can be set to 0.0.

More details are given in the Procedure Section.

Coordinate definition:
If externally obtained (i.e. surveyed) antenna phase centre coordinates are available, then these can be used to define the body coordinate system. With a proper survey, this method may produce more accurate results than the angle-based method. Since the final coordinates of the reference station are [0,0,0], all input body coordinate measurements must be referenced to this station (i.e. the body coordinates of the reference station must be subtracted from each coordinate). Therefore, the coordinates for this reference point must be known. Minimums of three body coordinate measurements are required for stations other than the reference. In order to generate a proper seed value, one of these stations (other than the reference) must have both X and Y set. Best results are obtained with an X, Y, and Z set on one station and Z on another.

Procedure

The Make Body Coordinates dialog box is shown below. It must be filled in the following manner before the final computation can be made.

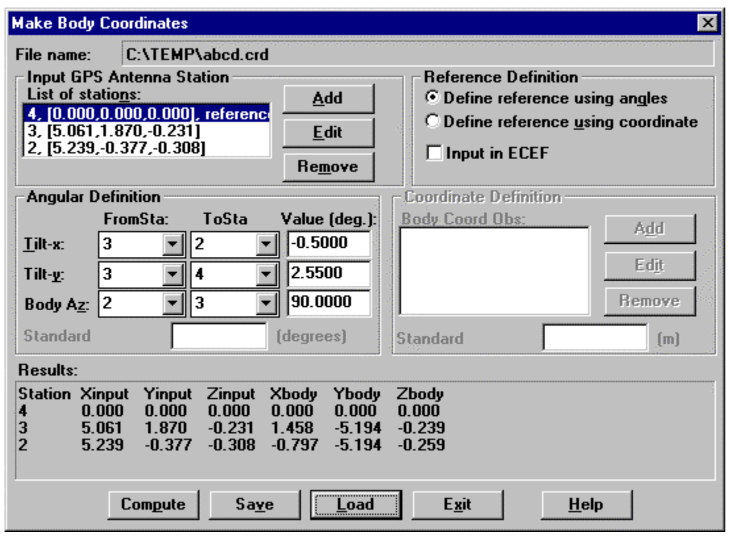


Figure 4: Make Body Coordinates Dialogue Box

Add GPS Antenna Stations:
This process adds, antenna station IDs along with their local level or ECEF coordinates. The dialog box is shown below.

Accumulate data from the GPS calibration and assign IDs to each of the fixed antenna stations.

For each station, press Add to key in the station name and Antenna phase centre coordinate values (local level or ECEF) determined from the GPS Survey. Make sure that the reference station is added first.

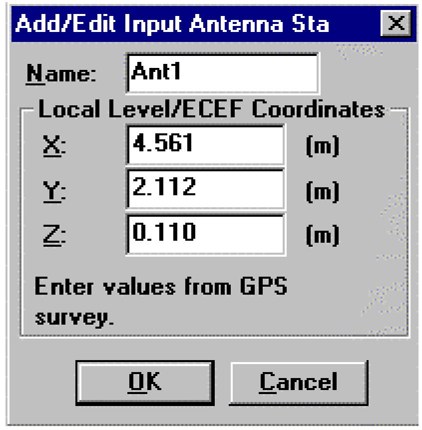
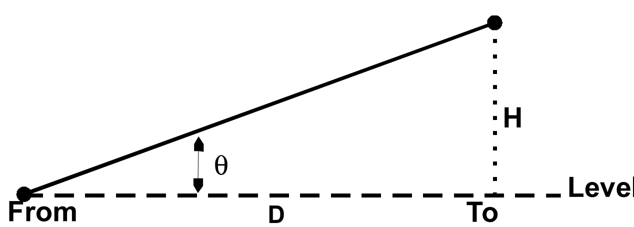


Figure 5: Add/Edit Input Antenna Station

Axes Definition:
There are two methods that can be used to define the axis: the angle based method, and the coordinate based method. If the coordinates of the antennae were entered in an ECEF frame, then check the *Input in ECEF* box.

Angle Observation Method (only):
Select two stations suitable for the definition of levelness along the x-axis (Tilt-x). Set the 'To' and 'From' station IDs. Enter the value of the angle (in degrees) between the level plane vector between from and to station. A positive value is required if the 'To' station is above the 'From' station while a negative value is required if the To station is below. See Figure 4.



θ=atan(H/D)
Figure 6: Angle Observation Method

The same procedure is repeated for Tilt-y. Define the horizontal axes by entering a body azimuth between two stations. 0° would be the +ve body y-axis and 90° would be the +ve body x-axis. See Figure 5.

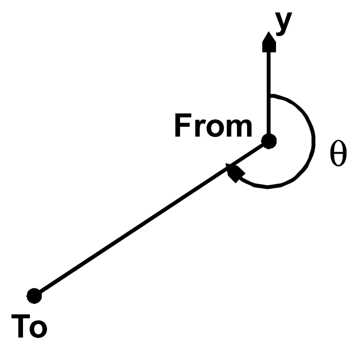


Figure 7: Angle
Observation Method

Coordinate Observation Method:
Using known body coordinate values, coordinate observations can be added. Compute the body coordinates for two or more stations in addition to the reference station. Subtract the body coordinate values of the reference station to obtain relative coordinate values. Add body coordinate observations one value at a time by pressing the Add button. Ideally, X, Y and Z should be added for one station and Z for another. Values should not be added for the reference station.

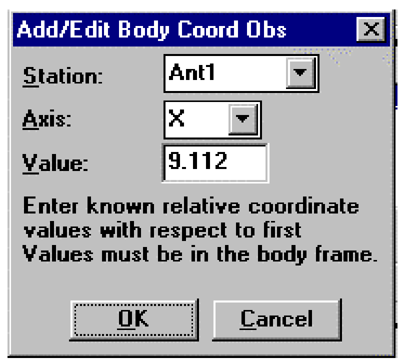


Figure 8: Coordinate Observation Method

Compute Body Coordinates:
Press the Compute button. If the solution worked, a window will appear which shows the roll, pitch and heading values required to transform the input local level antenna stations into the body frame. If ECEF is originally entered, then the ECEF to local level is taken into account with the latitude and longitude values. The angles are expressed as the rotation from body -> local level.

Otherwise, an error message will appear. For convergence or inversion errors, you may have to alter some of the input values to try another definition type. Check over all input numbers, or add more observations.

The body coordinates will appear in the results window. Check to make sure that they make sense. Save the body coordinates to the .CRD file by pressing the Save button. Enter a meaningful file name.

RTKNav attitude determination uses only one moving baseline option. The Moving Baseline Processing in the Moving Baseline Options dialog box must be on. RTKNav attitude determination does not use the Azimuth Determination option, and so it should be ignored. The user can view the Moving Baseline Options dialog box by selecting the Moving Baseline command from the Options menu.