QUATTRO-G3D

Application Notes

Version 1.1

Last Revised March 10, 2011

PREFACE

Thank you for purchasing this product. The materials available in these Application Notes have been prepared by JAVAD GNSS, Inc. ("JAVAD GNSS") for owners of JAVAD GNSS products. It is designed to assist owners with the use of Quattro-G3D and its use is subject to these terms and conditions (the "Terms and Conditions").

Note: Please read these Terms and Conditions carefully.

Terms and Conditions

USE – JAVAD GNSS receivers are designed to be used by a professional. The user is expected to have a good knowledge and understanding of the user and safety instructions before operating, inspecting or adjusting. Always wear the required protectors (safety shoes, helmet, etc.) when operating the receiver.

COPYRIGHT – All information contained in these Application Notes is the intellectual property of, and copyrighted material of JAVAD GNSS. All rights are reserved. You may not use, access, copy, store, display, create derivative works of, sell, modify, publish, distribute, or allow any third party access to, any graphics, content, information or data in these Application Notes without JAVAD GNSS' express written consent and may only use such information for the care and operation of your Quattro-G3D. The information and data in these Application Notes are a valuable asset of JAVAD GNSS and are developed by the expenditure of considerable work, time and money, and are the result of original selection, coordination and arrangement by JAVAD GNSS.

TRADEMARKS – Quattro-G3D, JAVAD GNSS® are trademarks or registered trademarks of JAVAD GNSS.

DISCLAIMER OF WARRANTY – EXCEPT FOR ANY WARRANTIES IN THESE APPLICATION NOTES OR A WARRANTY CARD ACCOMPANYING THE PRODUCT, THESE APPLICATION NOTES AND THE QUATTRO-G3D ARE PROVIDED "AS-IS." THERE ARE NO OTHER WARRANTIES. JAVAD GNSS DISCLAIMS ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR USE OR PURPOSE. JAVAD GNSS AND ITS DISTRIBUTORS SHALL NOT BE LIABLE FOR TECHNICAL OR EDITORIAL ERRORS OR OMISSIONS CONTAINED HEREIN; NOR FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES RESULTING FROM THE FURNISHING, PERFORMANCE OR USE OF THESE MATERIAL OR THE QUATTRO-G3D. SUCH DISCLAIMED DAMAGES INCLUDE BUT ARE NOT LIMITED TO LOSS OF TIME, LOSS OR DESTRUCTION OF DATA, LOSS OF PROFIT, SAVINGS OR REVENUE, OR LOSS OF THE PRODUCT'S USE. IN ADDITION, JAVAD GNSS IS NOT RESPONSIBLE OR LIABLE FOR DAMAGES OR COSTS INCURRED IN CONNECTION WITH OBTAINING SUBSTITUTE PRODUCTS OR SOFTWARE, CLAIMS BY OTHERS, INCONVENIENCE, OR ANY OTHER COSTS. IN ANY EVENT, JAVAD GNSS SHALL HAVE NO

LIABILITY FOR DAMAGES OR OTHERWISE TO YOU OR ANY OTHER PERSON OR ENTITY IN EXCESS OF THE PURCHASE PRICE FOR THE QUATTRO-G3D.

LICENSE AGREEMENT – Use of any computer programs or software supplied by JAVAD GNSS or downloaded from a JAVAD GNSS website (the "Software") in connection with the Quattro-G3D constitutes acceptance of these Terms and Conditions in these Application Notes and an agreement to abide by these Terms and Conditions. The user is granted a personal, non-exclusive, non-transferable license to use such Software under the terms stated herein and in any case only with a single Quattro-G3D or single computer. You may not assign or transfer the Software or this license without the express written consent of JAVAD GNSS. This license is effective until terminated. You may terminate the license at any time by destroying the Software and Application Notes. JAVAD GNSS may terminate the license if you fail to comply with any of the Terms or Conditions. You agree to destroy the Software and application notes upon termination of your use of the Quattro-G3D. All ownership, copyright and other intellectual property rights in and to the Software belong to JAVAD GNSS. If these license terms are not acceptable, return any unused software and application notes.

CONFIDENTIALITY – These Application Notes, its contents and the Software (collectively, the "Confidential Information") are the confidential and proprietary information of JAVAD GNSS. You agree to treat JAVAD GNSS' Confidential Information with a degree of care no less stringent that the degree of care you would use in safeguarding your own most valuable trade secrets. Nothing in this paragraph shall restrict you from disclosing Confidential Information to your employees as may be necessary or appropriate to operate or care for the Quattro-G3D. Such employees must also keep the Confidentiality Information confidential. In the event you become legally compelled to disclose any of the Confidential Information, you shall give JAVAD GNSS immediate notice so that it may seek a protective order or other appropriate remedy.

WEBSITE; OTHER STATEMENTS – No statement contained at the JAVAD GNSS website (or any other website) or in any other advertisements or JAVAD GNSS literature or made by an employee or independent contractor of JAVAD GNSS modifies these Terms and Conditions (including the Software license, warranty and limitation of liability).

SAFETY – Improper use of the Quattro-G3D can lead to injury to persons or property and/or malfunction of the product. The Quattro-G3D should only be repaired by authorized JAVAD GNSS warranty service centers. Users should review and heed the safety warnings in Appendix A on page 21.

MISCELLANEOUS – The above Terms and Conditions may be amended, modified, superseded, or canceled, at any time by JAVAD GNSS. The above Terms and Conditions will be governed by, and construed in accordance with, the laws of the State of California, without reference to conflict of laws.

WEEE Directive

The following information is for EU-member states only:

The use of the symbol indicates that this product may not be treated as household waste. By ensuring this product is disposed of correctly, you will help prevent potential negative consequences for the environment and human health, which could otherwise be caused by inappropriate waste handling of this product. For more detailed information about the take-back and recycling of this product, please contact your supplier where you purchased the product or consult.

Technical Assistance

If you have a problem and cannot find the information you need in the product documentation, contact your local dealer. Alternatively, request technical support using the JAVAD GNSS World Wide Web site at: www.javad.com.

APPLICATION NOTES

Introduction

Quattro-G3D has four antenna inputs. In this manual, they are denoted as A, B, C, and D. Antenna A (A1), is called master, and the others are called slaves.

Quattro-G3D receiver is designed for the following purposes:

- Determine three vectors between antennas AB, AC, and AD without any additional knowledge about relative antenna positions.
- For a mobile object with rigidly attached antennas, determine its orientation in space.
- Determine position of antenna A, in standalone or RTK mode.

This document is an addition to GREIS[1].
There is detailed description of commands specific to Quattro-G3D receiver

The processing of satellite data within the Quattro-G3D receiver is divided into two processes:

1. Fast process, which runs every `pos/msint` millisecond, is used to compute position of the master antenna, baseline vectors from master to rover antennas, rotation matrix, and angles based of known integer ambiguities.
2. Slow process, which works every 1 second, resolves the integer ambiguities.

On these processes, different requirements are imposed. The ambiguity resolution is a complicated slow process, where it is recommended to use all capabilities available in the receiver and additional knowledge about the antenna position.

In contrast to the slow process, the important requirement on the fast process is its computational performance, which determines the highest possible frequency of solution output. The quality of solutions of this process is less critical to whether GPS L2 or geometric constraints are used.

For example, in dynamic applications, it may be reasonable to use L1-L2 with the maximum number (14) of GPS satellites and to include the geometric constraints in the slow process and only L1 frequency band with maximum 7 satellites without using the constraints in the fast process.

To achieve maximal possible flexibility, these processes are controlled by different groups of parameters:

`att/fast/…` – parameters of the fast process,

`att/slow/…` – parameters of the slow process.

These sets are, in turn, divided into the two groups:

---

1. JAVAD GNSS Receiver External Interface Specification

`att/…/master/…` – parameters of the master antenna positioning engine.

`att/…/slaves/…` – parameters of the slaves antennas positioning engine.

Input data control parameters

This group of parameters specifies what measurements are used in the processing.

Data processed in the slow process:

`att/slow/master/maxgps` – maximum number of GPS satellites used by the master antenna (0 -GPS is not used, default - 14)

`att/slow/master/maxglo` – maximum number of GLONASS satellites used by the master antenna (default - 7)

`att/slow/slaves/maxgps` – maximum number of GPS satellites used by the slave antennas (0 -GPS is not used) (default - 14)

`att/slow/slaves/maxglo` – maximum number of GLONASS satellites used by the slaveantennas (0 - do not use GLONASS) (default - 0)

`att/slow/master/l2` – turns on or off use of L2 in the processing of the external baseline (default - 'on')

`att/slow/slaves/l2` – turns on or off use L2 in the attitude processing (default - 'on').

`att/slow/slaves/range` – turns on or off use Pseudo-range measurement for attitude determination (default - 'on').

Data processed in the fast process:

`att/fast/master/maxgps` – maximum number of GPS satellites used by the master antenna (0 - do not use GPS) (default - 14)

`att/fast/master/maxglo` – maximum number of GLONASS satellites used by the master antenna (0 - do not use GLONASS) (default - 7)

`att/fast/slaves/maxgps` – maximum number of GPS satellites used by the slave antennas (0 - do not use GPS) (default - 14)

`att/fast/slaves/maxglo` – maximum number of GLONASS satellites used by the slave antennas (0 - do not use GLONASS) (default - 0)

`att/fast/master/l2` – allows to use L2 on external baseline processing: default - on.

`att/fast/slaves/l2` – allows to use L2 on attitude processing: default - on.

Inertial measurements:

`att/fast/slaves/imu` – allows to use inertial measurement unit data for angle calculation (default - off)

`att/fast/slaves/imuacc` – allows to use accelerometer measurements to calculate orientation in almost static conditions. (default - off)

Additional information about the antenna position

This group of parameters tells the receiver if antennas are rigidly mounted on a mobile object.

`att/fast/slaves/constraints` – use of the geometrical constraints in the fast process (default is 'off', because the constraints should be defined prior to using them)

`att/slow/slaves/constraints` – use of the geometrical constraints in the slow process for fixing ambiguities at the attitude determination step (default- off)

Parameters to control the output data for the receiver

`att/fast/out/master` – turns on RTK positioning with respect to an external base (default - on)

`att/fast/out/slaves` – turns on the master-slaves baseline calculation (default - on)

`att/fast/out/angles` – turns on output of the rotation matrix and angles (default - off, because the calibration parameters are to be set before turning on)

Engine reset commands

`set,att/slaves/reset,on` – resets the attitude determination engine

`set,att/master/reset,on` – resets the external base positioning engine

Control of the self-calibration procedure.

The calibration procedure is used to determine geometrical parameters of the rigid antenna setup before determining the orientation.

`set,att/tune,on` – causes the receiver to start the self-calibration procedure,

`set,att/tune,off` – stops the calibration procedure.

`print,att/tune` – is used to determine weather the receiver is in the calibration mode. Prints 1 if calibration is on, and 0, otherwise.

`att/naver` – the number of seconds before automatic calibration stops (if not stopped manually, the calibration procedure ends up automatically in `att/naver` seconds).

Calibration parameters of the attitude engine

The following parameters may either be automatically determined by calibration process or input manually. Remember that clearing NVRAM or starting the calibration will erase the previous settings for these parameters.

1. Length of the baselines between the antennas used for master-slave integer ambiguity resolution.

`att/length/ab` – distance in meters between antennas A and B

`att/length/ac` – distance in meters between antennas A and C

`att/length/ad` – distance in meters between antennas A and D

`att/length/bc` – distance in meters between antennas B and C

`att/length/bd` – distance in meters between antennas B and D

`att/length/cd` – distance in meters between antennas C and D

2. Vectors between the antennas in the object local coordinate frame, which are used to restore the rotation matrix and angles of the local frame.

`att/localframe/ab/x` – X coordinate of baseline vector AB in the local coordinate frame

`att/localframe/ab/y` – Y coordinate of baseline vector AB in the local coordinate frame

`att/localframe/ab/z` – Z coordinate of baseline vector AB in the local coordinate frame

`att/localframe/ac/x` – X coordinate of baseline vector AC in the local coordinate frame

`att/localframe/ac/y` – Y coordinate of baseline vector AC in the local coordinate frame

`att/localframe/ac/z` – Z coordinate of baseline vector AC in the local coordinate frame

`att/localframe/ad/x` – X coordinate of baseline AD in the local coordinate frame

`att/localframe/ad/y` – Y coordinate of baseline AD in the local coordinate frame

`att/localframe/ad/z` – Z coordinate of baseline AD in the local coordinate frame

Offset angles

If the automatically determined coordinate frame differs from the actual one, the following parameters can be used to adjust the solution.

`att/delta/pi` – additional offset for pitch angle (default 0)

`att/delta/ro` – additional offset for roll angle(default 0)

`att/delta/he` – additional offset for heading angle(default 0)

Parameters of the IMU

`att/gyro/scale/x` – scale factor for OX gyroscope (default 1)

`att/gyro/scale/y` – scale factor for OY gyroscope (default 1)

`att/gyro/scale/z` – scale factor for OZ gyroscope (default 1)

`att/acc/scale/x` – scale for OX accelerometer (default 1)

`att/acc/scale/y` – scale for OY accelerometer (default 1)

`att/acc/scale/z` – scale for OZ accelerometer (default 1)

`att/gyro/integ/limit` – maximal interval of gyroscope integration in case of no available GPS signal

Numerical parameters of the RTK engine

The parameters listed below allow one to fine-tune the receiver for some specific situations. Most users will probably use the default values. Setting of an incorrect value without clear understanding of its purpose may lead to degradation of the receiver performance.

General parameters

`att/elev` – minimal elevation angle (in degrees), the default value is 7

`att/tol` – geometrical constraint tolerance level, default 0.06

Weather parameters used for troposphere model

`att/wth/pressure` – atmosphere pressure, default 1010

`att/wth/temperature` – outside air temperature, default 20

`att/wth/humidity` – humidity, default 90

Ionosphere model parameters:

`att/iono/use` – switch for the ionosphere model, default: on

`att/iono/factor` – ionosphere scale factor, default 4.

SNR usage:

`att/snr/use` – allows to use SNR information, default: on

`att/snr/treshold` – minimal SNR of usable satellite, default: 30

Logging raw data for postprocessing

It is possible to log satellite raw data for the postprocessing needs simultaneously from all antennas to a single port or internal file.

To allow raw satellite data from all antennas to go to port a (`dev/ser/a`), the following command can be used:

`set,out/ant/dev/ser/a,{y,y,y,y}`

In the case of logging to internal memory (cur/file/a), one may use the command

`set,out/ant/cur/file/a,{y,y,y,y}`

This command makes all raw data messages coming to the above-mentioned media, such as SI,RC,… , longer, so that they contain all specified data, like satellite index, pseudo-range, etc. from all four antennas. To separate data from different antenna, there is a special message AN. This message is similar to SI, but each field contain the antenna symbol 'a', 'b', 'c', or 'd'. Messages AN and SI altogether determine from which antenna and satellite a particular measurement has been received.

Satellite tracking control

In case, when one or several antenna is not connected to the receiver, it is better to turn off the satellite tracking by the corresponding antenna. The following command allows to do this:

```
set,lock/ant,{flag,flag,flag,falg}
```

where 'flag' equals to 'y' if tracking for the corresponding antenna is allowed, and 'n' if disabled. For example, if the receiver is connected to two antennas only, the rest antennas are to be disabled. In this case, the command appears as follows:

```
set,lock/ant,{y,y,n,n}
```

To enable back tracking of all the antenna (default mode), issue

```
set,lock/ant,{y,y,y,y}
```

If only two antennas are connected, no attitude solution will be produced, but only an RTK precision vector from one antenna to another.

JPS format binary messages for orientation.

AR - orientation angles (with respect to local horizon coordinate frame)

```
struct
{
u4 time;
    f4 pitch,roll,heading;
    f4 rmsPitch,rmsRoll,rmsHeading;
    u1 flag,
    u1 cs
}
```

MR - orientation matrix (local frame - local horizon coordinate frame)

```
struct
{
u4 time;
    f4 q00,q01,q02,q12;
    f4 rms[3];
u1 type[3];
    u1 flag,
    u1 cs
}
```

mr - orientation raw data (local frame - WGS84) and baselines AB, AC, and AD

```
struct
{
u4 time;
     f4 q00,q01,q02,q12;
     f4 rms[3];
u1 type[3];
     u1 flag;
     f4 AB[3];
     f4 AC[3];
     f4 AD[3];
     u1 cs
}
```

AV - angular velocity WGS 84

```
struct
{
u4 time;
     f4 av[3]
     f4 rms;
     u1 flag;
     u1 cs
}
```

Human readable (ASCII based) messages (for firmware versions 3.2 and higher)

Nonstandard NMEA like message for orientation angles.

```
nmea/ATT,Time,
    'PI',                           two symbols for readability,
    Pitch,                          value of pitch angle,
    Pitch RMS,                      RMS estimate for pitch,
    'RO',                           two symbols,
    Roll,                           value of roll angle,
    Roll RMS,                       RMS estimate for roll,
    'HE                             'two symbols,
    Heading,                        value of heading angle,
    Heading RMS,                    RMS estimate for heading
    Baseline AB fixation flag:      'F'-fixed, 'N'-not fixed,
    Baseline AC fixation flag:      'F'-fixed, 'N'-not fixed,
    Baseline AD fixation flag:      'F'-fixed, 'N'-not fiexd,
    *Checksum                       NMEA like checksum
```

AT - Attitude information in ASCII format.

```
jps/AT
    {
    'ATT'                              - message title-three symbols,
    UTC time indicator,                V' - valid, 'N' - not valid,
    UTC time,                          time of orientation measurement,
    'PI',                              two symbols for readability,
    Pitch,                             value of pitch in degrees,
    RMS pitch,                         RMS estimate for pitch,
    'RO',                              symbols for readability,
    Roll,                              value for Roll in degrees,
    RMS roll,                          RMS estimate for Roll,
    'HE                                'symbols for readability,
    Heading                            value for Heading in degrees,
    RMS heading,                       RMS estimate for heading,
    Baseline AB fix status,            'F' - fixed 'N' - not fixed,
    Baseline AC fix status,            'F' - fixed 'N' - not fixed,
    Baseline AD fix status:            'F' - fixed 'N' - not fixed,
    JPS checksum
    }
```

IMU-related messages

IM (Inertial Measurements) from the IMU converted into physical units with compensated misalignments, scale factors, and temperature drift.

```
struct
{
    F4 accelerations [3] (m/sec)
    F4 angular velocities [3] (rad/sec)
    U1 cs
}
```

IS (Inertial Sensors) raw measurements from the IMU with temperature drift compensation, but without misalignment and scale factor compensation (in analog-digital converter units)

```
struct
{
    U4 temperature
    U4 accelerations [3]
    U4 angular velocities [3]
    U1 cs
}
```

STEP-BY-STEP APPLICATION EXAMPLES

Example 1. Setting up determination of three independent baselines

In this simple setup, all antennas can move arbitrarily relative to one another. This setup corresponds to default parameter values, so it can be set up by resetting of all the parameters to the default values:

```
init,/dev/nvm/a
```

If for the same reason, resetting all the parameters is not acceptable/ one may put the following commands to enter this mode

```
set,,fast/out/angles,off              (turn off  the calculation of orientation)
set,,pos/mode/cur,pd                   (turn on phase differential mode)
set,,att/slow/slaves/constraints,off   (turn off geometrical constraints from the slow process)
set,,att/fast/slaves/constraints,off   (turn off geometrical constraints from the fast process)
```

The binary representation of results, namely three baseline vectors, can be obtained from the mr binary message. No angles of rotation are calculated in this mode, and no calibration procedure is needed.

Example 2. Setting up attitude determination of a mobile object

In this setup, the antennas are assumed to be rigidly mounted on a mobile object in the following manner:

> A (connector A1) is on the rear.
>
> B (connector A2) in the front. To perform the self-calibration procedure, it is also required that the longitudinal axis of the object be parallel to the projection of vector AB onto the OXY constructive plane.
>
> C is on the left,
>
> D is on the right.

To determine geometry of the object, the self-calibration procedure is applied. The procedure requires placing the immovable object in horizontal position under the open sky.

The self-calibration procedure will reconstruct the coordinate system associated with the mobile object (localframe) using the following rules:

1. The position during the calibration process is horizontal (pitch=0, roll =0),
2. The projection of vector AB onto the local horizon determines the direction of OX axis of the object.

If these assumptions are not satisfied, one can determine the calibration parameters manually or use `att/delta/pi`, `att/delta/ro`, `att/delta/he` to adjust the automatically determined coordinate system to fit the actual setup.

Turn on the receiver and the phase differential mode:

```
init,/dev/nvm/a            (clear nvram, if needed)
set,pos/mode/cur,pd        (turns on the phase differential mode)
```

Output and decode 'mr' message or read ' jps /AT' (ASCII string). The fields q00,...,q12 will not be determined, because no local frame is set at this moment, but baselines are to be defined.

Wait until all three vectors b10, b11 and b12 get fixed (type=4 in "mr" or "F" in AT).

If, for example, b12 is not determined, check the corresponding antenna connection.

If no even float output appears, check you option "attitude determination" (OCTO), which must be 'full attitude' (2)

Check the calibration time by sending

```
print,,att/naver
```

and adjust if needed.

After getting all three baselines fixed, turn on calibration: `set,att/tune,on`

wait several minutes (5 - 40) and turn it manually off: `set,att/tune,off`

The receiver will stop calibration automatically after `att/naver` seconds, or you can stop it manually at any time. If, during the period of calibration, all three baselines were fixed for some time, the output will be written to NVRAM.

Check the results of calibration by printing the calibration parameters

```
print,att/length/ab
  ......
print,att/localframe/ab/x
  .......
```

If the results are adequate to the actual geometry,

everything is ready to start calculating an angles: `set,att/fast/out/angles,on`

and using the geometrical constraints in slow process: `set,att/slow/slaves/constraints,on`

In case of output frequency less then 20 Hz it is recommended to use constants on fast process: `set,att/fast/slaves/constraints,on`

All this may be done without any corrections from an external base. The results of attitude determination are available through the AR, MR, AT, mr or nmea/ATT messages.

Example 3. Setting up attitude determination using GNSS and Inertial sensors

In this example, it is proposed that four antennas are rigidly mounted on a mobile object, and one among the antennas is GyrAnt - the integrated GNSS/Inertial sensor. This setup can improve the angular precision in case of short (less then 1m) baselines and in high dynamic conditions.

It is also proposed that the following conditions hold:

1. The antenna with IMU (GyrAnt) is *oriented* in parallel with *local frame* coordinate system.
2. The OX axis of the IMU is parallel to the projection of vector AB (from antenna A to B) onto the horizontal plane.
3. CAN or RS-422 interface of GyrAnt is connected directly to Quattro-G3D receiver and the corresponding port of the receiver is set up to receive the inertial sensor data (see GREIS for more details on commands to configure a port input).

For such setup, first of all there is a need to set the GNSS only attitude determination, as described in the example 2.

If the GNSS only solution is successfully determined, it is useful to check, that the inertial measurements come to the receiver. To do this, message IS can be enabled by command:

> `em,,jps/IS`   (enable the message IS with inertial sensors raw data).

If, after the command, the receiver starts to delivers this message with continually changing data, then the IMU is connected properly. If so, the IS message can be turned off:

> `dm,,jps/IS`   (disable IS)

After that, the integrated GNSS/IMU solution can be obtained by using the following command:

> `set,att/fast/slaves/imu,on`   (turn on the IMU integration)

Remember, that the IMU can completely destroy the solution if an error of its orientation is greater than 30 degrees.

JAVAD