JAVAD

QUATTRO

Application Notes

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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.

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:

`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 slave antennas (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)

`att/fast/out/anglevell` allow to calculate the angular velocity vector (default – off)

`att/fast/out/wgsmatrix` calculate the rotation matrix for MR and mr messages with respect to WGS-84 coordinates, not the local horizon (default – off).

`att/fast/out/blangles` allow to calculate two angles, heading and pitch, of a baseline, in case of only one baseline fixed (default – off).

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.

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

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 to set up the calculation of two angles on the base of one baseline

For the case of only one fixed baseline, there is a possibility to calculate the pitch and heading of that baseline, and the possibility to add some additives to it before outputing. These additive parameters are the following:

`att/delta/ab/pi` value to add to the pitch angle of baseline AB before output, in the case when only the AB is fixed (default 0);

`att/delta/ab/he` value to add to the heading angle of baseline AB before output, in the case when only the AB is fixed (default 0);

`att/delta/ac/pi` value to add to the pitch angle of baseline AC before output, in the case when only the AC is fixed (default 0);

`att/delta/ac/he` value to add to the heading angle of baseline AC before output, in the case when only the AC is fixed (default 0);

`att/delta/ad/pi` value to add to the pitch angle of baseline AD before output, in the case when only the AD is fixed (default 0);

`att/delta/ad/he` value to add to the heading angle of baseline AD before output, in the case when only the AD is fixed (default 0)

Warning: Heading and pitch angles of a baseline are equal to the same angles of the localframe coordinates only if this baseline is parallel to OX coordinate axis of the localframe. If not, there is no way to calculate the angles of localframe precisely. Output

of the receiver in this case is the angles of the corresponding baseline plus the delta shifts described above. It's the controller responsibility to use this kind of data properly, in general, not as true pitch and heading.

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/tolerance` 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/threshold` 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 al-

lowed, 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
}
```

[mR] - All the elements of the Rotation Matrix *).

```
struct FullRotationMatrix
{
  f4 q00, q01, q02;  // components of the rotation matrix
  f4 q10, q11, q12;  // components of the rotation matrix
  f4 q20, q21, q22;  // components of the rotation matrix
```

```
  u1 cs; // Checksum
};
```

The matrix is reported with respect to Local Horizon coordinate system if the parameter att/wgsmatrix is 0 (default value). If the value of parameter att/wgsmatrix is set to 1, the matrix is reported with respect to WGS-84. If the matrix has not been estimated, the message will not appear for this epoch.

[bL] - Internal baseline vectors in WGS-84 coordinate system).

```
struct BaseLines
{
  f4 bl0[3];       // baseline vector AB in the current epoch (meters)
  f4 bl1[3];       // baseline vector AC in the current epoch (meters)
  f4 bl2[3];       // baseline vector AD in the current epoch (meters)
  f4 rms[3];       // estimated accuracy for three baseline vectors
  u1 solType[3]; // solution types for three baseline vectors
  u1 cs; // Checksum
};
```

If this message is enabled, it will appear in the message stream only if any of three internal baseline is estimated as float or fixed.

Human readable (ASCII based) messages (for firmware ver. 3.2 and newer)

Nonstandard NMEA like message for orientation angles.

nmea/ATT – Full orientation

#	Format	Description
1	%6.[0-2]F	UTC Time, in second from the beginning of the day
2	%S	String containing two symbols, 'PI' to denote Pitch,
3	%[1-2].[0-6]F	Value of pitch angle in degrees,
4	%[1-3].[0-6]F	Value of RMS estimate for pitch angle,
5	%S	String containing two symbols, 'RO' to denote Roll,
6	%[1-2].[0-6]F	Value of Roll, angle in degrees
7	%[1-3].[0-6]F	Value of RMS estimate for Roll angle,
8	%S	String containing two symbols, 'HE' to denote Heading,
9	%[1-3].[0-6]F	Value of heading angle in degrees,
10	%[1-3].[0-6]F	Value of RMS estimate for Heading angle,
11	%C	Baseline AB fixation flag: 'F'-fixed, 'N'-not fixed,
12	%C	Baseline AC fixation flag: 'F'-fixed, 'N'-not fixed,
13	%C	Baseline AD fixation flag: 'F'-fixed, 'N'-not fixed,
14	*%2X\0D\0A	NMEA format checksum

jps/AT – JPS message for full orientation in ASCII human readable format

#	Format	Description
1	%S	Three symbols ATT to denote the attitude message
2	%C	UTC time indicator 'V' – valid, 'N'- not valid
3	%6.[0-2]F	UTC Time, in second from the beginning of the day
4	%S	String containing two symbols, 'PI' to denote Pitch,
5	%[1-2].[0-6]F	Value of pitch angle in degrees,
6	%[1-3].[0-6]F	Value of RMS estimate for pitch angle,
7	%S	String containing two symbols, 'RO' to denote Roll,
8	%[1-2].[0-6]F	Value of Roll, angle in degrees
9	%[1-3].[0-6]F	Value of RMS estimate for Roll angle,
10	%S	String containing two symbols, 'HE' to denote Heading,
11	%[1-3].[0-6]F	Value of heading angle in degrees,

12	%[1-3].[0-6]F	Value of RMS estimate for Heading angle,
13	%C	Baseline AB fixation flag: 'F'-fixed, 'N'-not fixed,
14	%C	Baseline AC fixation flag: 'F'-fixed, 'N'-not fixed,
15	%C	Baseline AD fixation flag: 'F'-fixed, 'N'-not fixed,
16	%C	JPS format checksum

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:

The position during the calibration process is horizontal (pitch=0, roll =0),

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:

The antenna with IMU (GyrAnt) is oriented in parallel with local frame coordinate system.

The OX axis of the IMU is parallel to the projection of vector AB (from antenna A to B) onto the horizontal plane.

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.

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