

Appendix HGPS – Hemisphere GPS Compass Option

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This appendix describes the unique features and procedures associated with the "Hemisphere GPS Compass" navigation option.

1.1 Manual Organization

This appendix is provided as a supplement to the baseline RC4000 manual. The corresponding paragraphs in the baseline RC4000 manual are referred to when data specific to the Hemisphere GPS (HGPS) compass option are described.

Section 1 provides background with respect to the GPS compass sensor from Hemisphere.

Section 2 describes unique hardware and software configuration procedures which must be performed prior to install the Hemisphere GPS sensor.

Section 3 describes unique RC4000 operations associated with the HGPS compass.

Section 4 provides troubleshooting tips related to sensor performance.

This appendix is written from the perspective of how the GPS compass integrates and works with the RC4000 antenna controller. For further information on the CSI GPS compass itself, the user should refer to the "Vector OEM" integration and programming manuals from Hemisphere.

1.2 RC4000 Features

This option provides the RC4000 controller with the ability to sense latitude, longitude and true heading from a single GPS unit manufactured by Hemisphere.

Software Configuration: If this option is purchased, the navigation option designator will appear as "H".

Example: the software for a RC4000 purchased with the HGPS compass option, inclined orbit tracking and remote control capability would be designated RC4K-xx-HEINN.

1.3.2 System Interface Requirements

There are two different installation options for the Hemisphere GPS compass. The compass module can be installed in an external box separate from the controller, or installed directly inside of the controller. Consult the enclosure specific appendix for your controller to verify which option you have.

External GPS box:

Two GPS antennas will be attached via coax cable to TNC connectors on the external compass box. A cable will connect the external compass box to the RC4000 chassis as described in the enclosure specific appendix.

Internal GPS:

Two GPS antennas will be attached via coax cable to TNC connectors on the RC4000 chassis as described in the enclosure specific appendix.

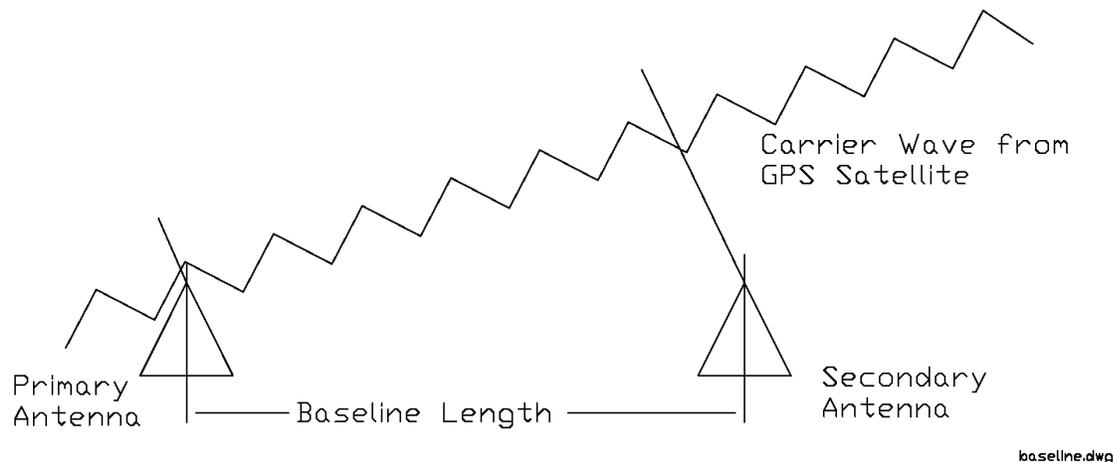
1.3 Theory of Operation - GPS Compass

The HGPS unit provides both latitude/longitude and true heading by measuring how the two GPS antennas are positioned relative to each other. The baseline RC4000 configuration gets this information from separate GPS and fluxgate compass units.

Magnetic compass units can provide less than optimal performance in various poor magnetic environments. These include proximity to metal buildings, proximity to power lines and in areas where the horizontal component of the earth's magnetic field is weak such as high latitude locations. The HGPS compass unit may provide better results in such situations since it is generating the heading solution based on signals from the constellation of GPS satellites.

Two GPS antennas are placed a known distance apart. The GPS engine instantaneously measures the phase at both antennas of the signal from the same set of GPS satellites. Knowing the instantaneous position of the GPS satellites, the GPS engine can determine how the two antennas must be oriented with respect to each other and thus determine the heading between the two antennas.

The following simple diagram illustrates the situation of the two antennas measuring the signal phase from one GPS satellite.



The vector between the two antennas is often referred to as the baseline. One antenna will be designated as the primary antenna and the other as the secondary antenna. The true heading derived will represent the heading from the primary antenna to the secondary antenna.

The GPS compass engine can measure the instantaneous phase of the carrier at both antennas but it can't directly determine the total number of carrier waves between the antennas. The compass engine must be told the actual distance between the two antennas. Knowing the baseline length and phase information from multiple GPS satellites, the compass engine sorts through the many (possibly thousands of) combinations of orientations between the two antennas. The compass engine's algorithm eventually determines what heading must exist between the two antennas in order to fit all the data collected.

This discussion of the GPS compass algorithm is extremely rudimentary but is presented in order to highlight some critical items associated with the installation of the unit:

1) the most critical item is that the two antennas be positioned where they have unobstructed views of the sky. If the antennas don't receive signals on a direct path from the GPS satellites, the phase measured won't be representative of the true geometry of the antenna array. If the direct path to a GPS satellite is blocked, the antennas may still receive a signal reflected off of some surface (multipath) in the area of the

antennas. This reflecting surface may be buildings in the area or other structures associated with the satellite antenna system. The GPS compass algorithm can't distinguish between signals received directly or from a reflected path. It is possible that the algorithm can determine an incorrect heading solution based on multipath signals. Note that the high performance antennas supplied have a large ground plane area in order to minimize the chance of multipath reception.

The Hemisphere manual states that the antenna array must be positioned with no structures above its horizon.

2) The distance between the antennas must be carefully measured and programmed into the compass engine via the RC4000 antenna controller.

Procedures to address these items are discussed in the installation section.

2.0 INSTALLATION

This section details specific installation procedures applicable only to the HGPS compass option. Proceed with all other installation steps as described in the baseline RC4000 manual and any other applicable appendices.

The following installation steps described in the baseline manual are superseded by those described in this appendix:

GPS mounting (2.2.2)

Compass mounting (2.2.3)

Navigation sensor communication (2.3.8)

Compass calibration (2.4.1)

2.1.2 GPS Receiver Mounting

The HGPS compass option consists of a circuit card containing the GPS compass engine and two high performance GPS antennas. Coax cables will connect the GPS compass engine to the two GPS antennas. Multiple factors must be considered when positioning the 2 antennas (antenna array).

1) The two GPS antennas may be positioned between 0.2 and 2.0 meters apart. The further the antennas are placed (up to 2 meters), the better the theoretical performance of the heading solution will be. The distance between the antennas will need to be precisely measured and programmed into the MSEP parameter (see 3.3.2.9 GPS Compass Calibration).

2) The two antennas must be placed where they both have unobstructed views of the sky. Do not sacrifice either antenna's view of the sky though in order to obtain a longer baseline. No structure associated with the satellite antenna system should rise more than 10 degrees above the horizon of the GPS antenna array. This restriction also applies to external structures within the area that the antenna array will be functioning. If the 10 degree and above view cannot be achieved, the MASK parameter must be changed (see 3.3.2.9 GPS Compass Calibration).

3) Coax cables should be limited to lengths that would realize 15 dB of loss or less at GPS L1 (1.575 GHz). This limits the length of RG58 cable (0.78 dB/m) to approximately 10 m. when connector loss is included. RG8 material (0.36 dB/m) may be used to about 20m.

4) The antennas should also be placed where the vector between the two will be as close to parallel to the ground (level) as possible when the antenna controller polls the GPS engine for a heading reading. The suggestion to have the antenna array within 10 degrees of level allows the heading algorithm to disregard some possible mathematically correct heading solutions for antenna array tilts greater than 10 degrees. The engine compass will be programmed to assume this level situation exists. If level operation cannot be achieved, the LEVEL parameter must be changed (see 3.3.2.9 GPS Compass Calibration).

2.1.3 Compass Mounting

External Compass:

The compass should be mounted such that the RF cables are within the length specification discussed above.

Internal Compass:

Since the compass function is contained within the HGPS compass unit, no additional mounting beyond that described in 2.1.2 are required.

2.3.8 Navigation Sensor Communication

After connecting the GPS antennas to the GPS Compass, verify that the units are communicating by observing data flow via the GPS Serial Port Diagnostics screen described in 3.3.2.6.

2.4.1 Compass Calibration

In order for the compass engine to perform properly, several items describing the installation of the GPS antenna array will need to be programmed:

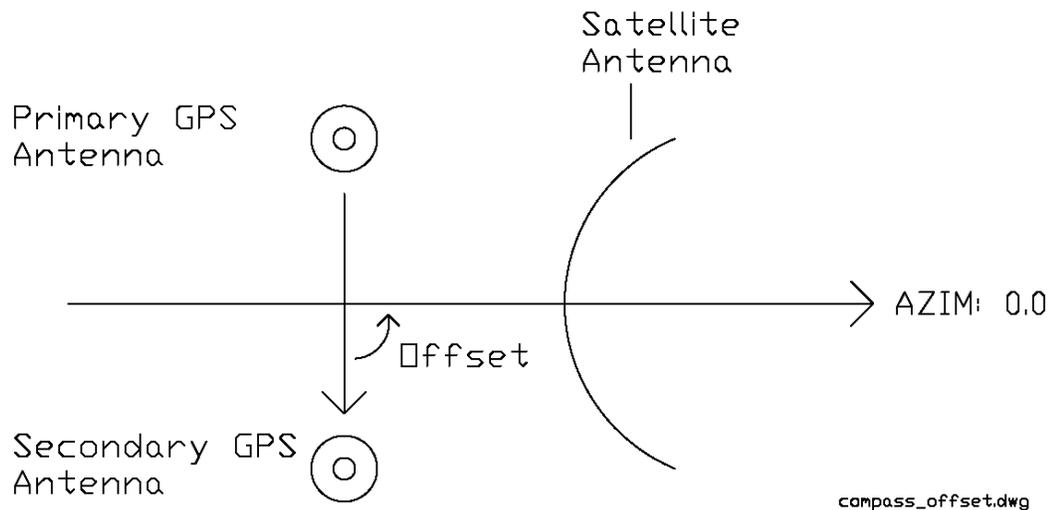
1) The distance between the center of the two antennas will need to be measured to within several millimeters. This value must then be entered into the MSEP parameter at the GPS Compass Calibration screen (3.3.2.9).

NOTE: it may be difficult to determine the center of the round GPS antennas. Measuring between the edges of the antennas may prove easier.

2) If the level operation situation described in the GPS mounting section does not exist, the LEVEL parameter (3.3.2.9) must be set to NO.

3) If permanent obstructions 10 degrees above the antenna array's horizon exist, the MASK parameter (3.3.2.9) must be set.

4) The relationship between the direction the antenna array is pointing and the satellite antenna's azimuth reference direction (AZIM 0.0) must be described to the controller. In the example figure below, the azimuth reference direction is 90 degrees counterclockwise from the direction of the GPS antenna array. Enter a value of -90.0 in the Compass Offset item on the AZIMUTH CALIBRATION screen (3.3.1.2.3 in baseline manual).



5) If the GPS antenna array is mounted such that the satellite antenna must be moved to a certain position before determining heading, the COMPASS item in the SYSTEM DEFINITION screen (3.3.1.2.1 in baseline manual) must be set to the "antenna mount" value. If this situation exists, the RC4000 will know to move the satellite antenna to the deploy position before attempting to read a heading from the GPS compass.

COMPASS CHECKOUT

After programming the various settings, the performance of the GPS compass should be confirmed. With the GPS antenna array oriented in a fairly well known true heading (account for local magnetic variation if using a magnetic compass as reference), put the RC4000 into the GPS Compass Heading maintenance screen (3.3.2.7).

Observe that the instantaneous and average true headings are close to the expected value.

If possible, allow this mode to operate for several hours and observe the maximum and minimum true headings. Over the course of several hours, the GPS constellation of satellites will continuously change and present different geometries to the compass algorithm. If the max and min are within a degree of each other, the GPS compass is probably working well.

NOTE: during this checkout we are observing the raw true heading of the GPS antenna array. Any compass offset discussed in item 4 above will not be applied to the values shown in the GPS Compass Heading maintenance screen.

3.0 DETAILED OPERATION

With the HGPS compass option properly installed, the operation of the RC4000 will be almost exactly as described in the baseline user's manual with just a few exceptions noted below.

3.2.2.3 LOCATE mode

Upon entering LOCATE mode, the RC4000 will try to automatically obtain latitude, longitude and heading as described in the baseline manual. Since the GPS compass provides true heading there is no need for the RC4000 to calculate an estimate of the local magnetic variation. A flashing "MAGVAR" will therefore not appear after the lat/lon has been obtained and the system clock has been synchronized to GPS time.

3.3.2 Maintenance Items

Items 6, 7 and 9 of the MAINTENANCE mode are different reflecting the use of the GPS compass engine.

1-VOLTS	2-DRIVE	3-TIME	MAINT
5-LIMITS	6-GPS COM	7-GPS HDG	8-MOVETO
9-CMP CAL	0-SHAKE		
			.-SYS INFO

3.3.2.6 GPS Serial Port Diagnostics

As described in the baseline manual, this screen will reflect the raw data being received from the GPS unit. The data seen will be slightly different from that described in the baseline manual:

- no \$PGRMT sentence will be present as this is a proprietary message from the Garmin GPS
- the \$GPRMC sentence should still appear at a 1 hz. rate but will contain additional characters for time, latitude and longitude. The following is an example \$GPRMC message from the HGPS unit:

```
$GPRMC,133544,V,3856.0856,N,09444.8377,W,000.0,000.0,080499,003.6,E*7B
```

Also compared to the Garmin unit, when the CSI is reporting that no current navigation solution is available ("V" in the sentence vs. "A"), no data will be displayed between the comma delimiters. In this case the sentence will appear something like:

```
$GPRMC,,V,,,,,*,*66
```

- the \$GPGGA will appear at a 0.2 hz rate vs. 1 hz for the Garmin unit.
- additionally the \$GPHDT sentence supplying the GPS engine's estimate of true heading will be provided at a 1 hz. rate. This sentence will typically not appear until a valid navigation (lat/lon) solution has been achieved by the GPS engine. The following is an example sentence:

```
$GPHDT,123.4,T*5A
```

As with the \$GPRMC and \$GPGGA sentences, if no valid true heading is currently being derived, the sentence will show no data between the comma delimiters (\$GPHDT,,, *4C).

3.3.2.7 GPS Compass Heading

This mode allows the user to observe the true heading generated by the HGPS compass over a period of time. The ability to monitor the true heading over time should help in predicting the performance of the HGPS compass installation and calibration.

GPS COMPASS			
HDT: 88.5	MAX: 88.9	P:0.000	SEC: 1315
AVG: 88.4	MIN: 88.0	R:0.000	CNT: 1300
			BLN: 15

SEC: , CNT: , BLN:

These fields provide statistics on the \$GPHDT sentence received from the GPS compass.

The SEC field shows the number of seconds that the mode has been active.

The CNT field shows the number of valid \$GPHDT sentences received. When the RC4000 is getting true heading data from the CSI unit, this number should increase at a similar rate as the SEC field since the GPS unit is programmed to output \$GPHDT at a 1 Hz. rate.

The BLN field shows the number of \$GPHDT sentences received that didn't have heading data in them. This indicates that the GPS unit has developed a lat/lon solution but is unable to develop a correct heading solution.

HDT:, AVG:

The HDT field shows the latest value received from the \$GPHDT sentence.

The AVG field shows the average heading value since the mode started.

MAX:, MIN:

These fields show the maximum and minimum heading values received since the mode started. When working properly, the spread of values should be no more than 1 or 2 degrees. Shorter baseline lengths will yield wider value swings than longer baseline lengths.

NOTE: If the antenna array is pointing towards North (0.0), the max and min values may be deceiving since a value like 359.9 may only indicate an actual swing of 0.2 from a 0.1 reading. It will typically be best to have the antenna array pointing away from North when running a long term test of the heading solution.

P:,R:

The P field shows the latest pitch value received from the compass.

The R field shows the latest roll value received from the compass.

3.3.2.9 GPS Compass Calibration

This mode allows the user to program several variables associated with a particular installation of the HGPS compass.

MSEP:1.000	MASK:10	CSI CAL
LEVEL:1		
TILT:0		<MODE>SAVE&EXIT

Asterisks will be shown in all fields when the controller is not communicating with the compass. When the compass is communicating with the controller, all of the values will be populated with the current values stored in the compass.

MSEP:

ANT SEPARATION <0.200-2.000>METERS

Enter the distance between the installed antennas. Accuracy to within several millimeters is required.

LEVEL:

LEVEL OPERATION <0>NO <1>YES

The programmed value for this item as the GPS compass is supplied will be "YES", indicating that the antennas are guaranteed to be positioned in a plane within 10 degrees of horizontal.

If level operation cannot be guaranteed, it may take longer to generate a heading solution and there is a greater possibility of generating an incorrect solution.

TILT :

TILT AIDING <0>NO <1>YES

The programmed value for this item as the GPS compass is supplied will be "NO". To be able to program as "YES", the enclosure must be positioned in the same plane and in the same direction as the antenna array.

NOTE: RCI does not recommend at this time to set this value to YES.

MASK:

ELEV CUTOFF MASK <5-20>DEGREES

The programmed value for this item as the GPS compass is supplied will be 10 degrees. It is recommended that the antenna array be positioned so that both antennas have a clear view of the sky. The 10 degree default value represents the idea that the signal from any GPS satellite that is less than 10 degrees high will probably be experiencing degradation due to atmospheric refraction effects.

Masking more of the sky eliminates the use of more of the GPS satellite constellation and increases the chance that no heading solution may be generated.

4.0 Troubleshooting

NO COMMUNICATION

The GPS engine needs to be programmed to the correct settings to work with the RC4000 controller. The engine will come from RCI programmed to the correct settings. This programming is accomplished via the Window's program "PocketMaxPC version 2.0" supplied by Hemisphere.

If the GPS engine must be reprogrammed the following tables are included to document the desired settings. Note that the PocketMaxPC software will be looking for a "Hemisphere Vector" device at 4800 baud.

GPS VALUES

DiffMode: SBAS	Elevation Mask: 5	COAST: 1800
This Baud: 4800	Other Baud: 9600	
	This Port	Other Port
\$GPGGA	5 sec	OFF
\$GPGLL	OFF	OFF
\$GPGSA	OFF	OFF
\$GPGST	OFF	OFF
\$GPGSV	OFF	OFF
\$GPRMC	1 Hz	OFF
\$GPRRE	OFF	OFF
\$GPVTG	OFF	OFF
\$GPZDA	OFF	OFF
Bin 95	OFF	OFF
Bin 96	OFF	OFF

NOTE: The RC4000 software was developed to work with a GPS engine containing ARM firmware vesion 1.5D DSP firmware version 46.

HDG VALUES

Tilt Aidina: unchecked	Pitch: checked	Roll: unchecked
Gvro Aidina: unchecked	Negative Tilt: unchecked	FLIPBRD: unchecked
Magnetic Aidina: unchecked	Level Operation : checked	Heading Tau: 0.5
Heading Rate Tau : 2.0	COG Tau: 0	Speed Tau: 0
Heading Bias: 0	Pitch/Roll Bias: 0	MSEP: 0.5
	This Port	Other Port
\$GPHDT	1 Hz	OFF
\$GPROT	OFF	OFF
\$PSAT.HPR	OFF	OFF

INCORRECT HEADING

- reprogram the baseline length to confirm it is stored correctly in the GPS compass
- check that any azimuth offset is described correctly to the RC4000
- run the GPS Heading maintenance function