Datawell DWR-G unit

Manual

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CE

Declaration of conformity

(According to EN ISO/IEC 17050-1:2004)

Document No.:	Datawell_DoC_DWRG_Unit_1_2
Manufacturer's name:	Datawell B.V.
Manufacturer's address:	Zomerluststraat 4 2012 LM Haarlem The Netherlands

Declares under sole responsibility that the product:

Product name:	Waverider
Trade name:	Datawell
Model:	DWR-G Unit

complies with the essential requirements of the following applicable European Directives, and carries the CE marking accordingly:

RE Directive (2014/53/EU)
ROHS Directive (2011/65/EU)

and conforms with the following product standards:

RED EN 300 220-1/EN 300 220-2
EN 300 390-1/EN 300 390-2
EN 301 489-1/EN 301 489-3
EN 55022
EN 55024
EN 61000-6-1/EN 61000-6-3

Supplementary Information:

This DoC applies to above-listed products placed on the EU market after:

June 13, 2017	**Eric Stoker**
Date	Quality Assurance Manager

Contents

1 Introduction

Thank you for choosing the Datawell DWR-G unit. The DWR-G unit is a directional wave motion sensor intended for use on existing buoys. It relies on the Global Positioning System (GPS) for its motion measurement and as such it does not require calibration ever. External power must be supplied to the unit and a wide range of input voltages is accepted. Together with the associated Datawell W@ves21 and Waves4 processing and presentation software (none included) the DWR-G unit makes a complete wave monitoring system.

After this introduction first some remarks on wave measurement with floating buoys are made. In the following chapter the core of the DWR-G unit, the GPS motion sensor, will be explained. The next chapters cover the general topics of data processing and data formats, mechanics and electronics. Then the standard features are discussed. The remaining chapters provide help, should the DWR-G unit fail to function normally.

2 Measuring waves with the DWR-G unit

Datawell is specialized in the production of complete wave measuring equipment generating high quality wave data and wave parameters for marine traffic and operations, coastal engineering and scientific institutes. Mooring lines, hull size and shape, wave motion sensors, etc. of all products are designed and integrated specifically to serve this purpose. The DWR-G unit however only consists of the heart of such measuring equipment assembled in a stainless steel housing. The accuracy of obtained data is highly dependent on the way the unit has been built into a major assembly and the way this major assembly is moored, its buoyancy, etc.

2.1 Measuring waves with floating buoys

When building a complete wave measurement system the following aspects must be taken into consideration:

- Wave lengths shorter than twice the diameter of the platform will not be measured anymore. This will result in some high frequency cut-off in the generated spectra.

- The reduced freedom of movement due to the mooring will result in a restriction mainly in the horizontal direction, not so much in vertical motion. The problems in the horizontal direction are its sign asymmetry (complete freedom of motion towards the mooring point and absolutely no motion from the mooring point beyond the mooring line length) and direction asymmetry (perpendicular to the mooring line the motion is nearly unrestricted). This will slightly affect the estimated wave heights but may yield misleading wave directions, depending on wave-, wind- and current direction.

- Another point to consider is that pitching and rolling of tall structures may introduce non-wave motion away from the centre of rotation (pseudo-motion); horizontal motion will be influenced most.

- A final point of consideration: the response of the buoy or platform to the waves and current may display resonant motion like immersion resonance, pitch/roll resonance or sheering at certain frequencies.

3 Wave motion sensor: GPS

3.1 Wave measurement principle

The GPS principle of wave measurement is explained by analogy. Apart from distance measurements between satellite and receiver, the so called GPS code phase, some GPS receivers also provide Doppler measurements. The former are used in GPS positioning, whereas the latter are indicative of satellite and receiver velocities. Now, we exploit the analogy of Doppler frequency shifts for sound waves from moving sources. As for a passing car blowing its horn, it is in principle possible to track the motion of the car by listening to the sound of the horn. The more the frequency differs from the original frequency of the horn source, the higher the speed of the car. Integrating over time then yields the motion of the car.

3.2 GPS and atmospheric or marine conditions

In line with the military and strategic intentions of the GPS system, GPS receivers and therefore the DWR-G unit will continue functioning during rain, snow or hail storms. The only problematic meteorological situation is when the GPS antenna is covered with a continuous layer of ice.

As for marine conditions, spray will also not impede the normal operation. However, GPS signals do not penetrate through a continuous layer of salt or fresh water. A breaking wave washing over the GPS antenna will result in data missing.

Apart from meteorological and marine influences, also dirt, paint on the antenna or metal constructions added by the user may block the GPS signal. If the GPS antenna has become dirty, clean it with water and soap and a soft piece of cloth.

3.3 Multipath

Multipath implies that the GPS signal arrives at the antenna along multiple paths, i.e. apart from the direct path also via one or more reflection paths. Especially metal surfaces, but also the sea, are strong reflectors. Assuming that reflected signals are weaker than the direct path signal, which is usually the case, multipath will not prevent motion measurement as such, but will rather increase the noise with several centimetres.

In anticipation of multipath the GPS antenna pattern is designed to be rather insensitive to signals from behind it. Furthermore the direct GPS signal is right-hand circularly polarized (RHCP) whereas single-reflection signals are left-hand circularly polarized. Since the antenna selects RHCP multipath signals are suppressed.

Anyway, to minimize multipath errors it is best to mount the Unit either flat on or away from horizontal metal surfaces and always away from vertical metal surfaces.

3.4 Limit on buoy velocity

The processing cannot keep up with position changes over 100 m in less than 100 s and measurements will start to fail. E.g. when a buoy is used free floating or is towed at constant velocities above 1 m/s. This will appear as sudden large oscillations in the displacement data.

3.5 Selective availability

As mentioned the GPS system originally was and still is a military system, maintained by the United States Department of Defence. As such a few features are incorporated to restrict the use of precise GPS to selected users. This is known as Selective Availability (SA). When SA is active a dither is added to the satellite GPS time thereby deteriorating the GPS position accuracy from 10 m to 100 m. Furthermore the precision of the satellite orbit information may be reduced. The information to correct for dithering is encrypted in the GPS signal. Unless one has the encryption key one cannot restore the intrinsic GPS accuracy.

On May 1, 2000 SA was officially discontinued, see www.navcen.uscg.gov/gps/selective_availability.htm. If, in the unlikely event, SA would be temporarily switched on for strategic reasons, the current GPS wave motion sensor will not work anymore! However, it will continue measuring waves immediately after SA is switched off again.

3.6 Signal loss and flag

In the example of the passing car, one will lose track of the car if one temporarily closes one's ears. Likewise if the GPS receiver temporarily loses signal, due to waves washing over or a momentarily extreme tilt, the wave velocity is temporarily unknown. As a result the wave motion may contain discontinuities. However the GPS receiver knows when signal loss occurs and will inform the user of this through setting a flag: the least significant bit of the north.

3.7 GPS motion sensor test

A GPS motion sensor consists of a GPS antenna and a GPS receiver. A patented algorithm will calculate the motion of the antenna centre.

As a GPS receiver is a complicated piece of electronics, usually malfunction means no functioning at all. However, should you want to test the GPS motion sensor, the procedure is very simple. Just leave the DWR-G unit in a place where it has a clear view of the sky (no buildings or trees in the near vicinity) and set it running. If the resulting north, west and vertical signals remain within a few centimetres approximately the sensor is alright. It may seem paradoxical to test a motion sensor by leaving it motionless. The way out of this paradox is that GPS satellites orbit the earth with velocities of 4 Km/s and any motion of the GPS receiver only forms a minor contribution. So if a motionless GPS motion sensor correctly produces a no-motion result in a highly dynamic situation then it works fine.

3.8 Filtering

Measured velocities are digitally filtered using an integrating high-pass filter with a cut-off at 0.01 Hz. Moreover, the intrinsic 2 Hz sampling is converted into 1.28 Hz north, west and vertical motions to fit the long-existing Datawell data-format. Use is made of a so-called decimation filter, which causes an extra delay.

3.9 Specifications

Table 3.1 summarizes the specifications of the GPS motion sensor in the DWR-G unit.

Table 3.1. Specifications of DWR-G unit GPS motion sensor.

Parameter	Value	
Heave, north, west		
Range	−20 m-+20 m	
Resolution	1 cm	
Accuracy	±1 cm or 0.1% of value, whichever is worse	
Period time (frequency range)	1.6 s-100 s (0.01 Hz-0.64 Hz)	
Direction		
Range	0º-360º	
Resolution	1.5º	
Accuracy	1.5º	
Reference	true north (WGS84)	
Filter		
Sampling frequency	2.0 Hz	
Digital filtering type	phase-linear, combined band-pass and single-integrating FIR filter	
Filter delay	256.0 s	
Decimation filter delay	43.0 s	
HF output buffer delay and actual HF output	5.5 s (approximately, does not apply to logger files)	
Data output rate	1.28 Hz	
Band-pass characteristics	0.0154-0.59 Hz:	0.0013 dB
	0.0132	0.009 dB
	0.0115	0.09 dB
	0.01 Hz	0.8 dB
	low frequency side	52 dB/octave (< 0.01 Hz)

4 Location and naming of components

This section presents an overview of the components of the MOSE-G1000, their name and location. It is subdivided into a mechanical and an electronics part. For now a brief description suffices, more details will follow in later chapters.

4.1 Mechanical components

The DWR-G Unit consists of a stainless steel cylindrical housing with a domed cover. On top the GPS antenna is fixed. With 4 hexagon socket screws the flanges of domed cover and cylindrical housing are bolted together. A groove in the flange with a rubber sealing ring ensures water tightness. The label on the side indicates instrument name and serial number. Electrical contact is established through a cable connector (not shown) and a connector receptacle. The base plate contains 4 holes for mounting of the unit. Figure 4.1 shows the main components.

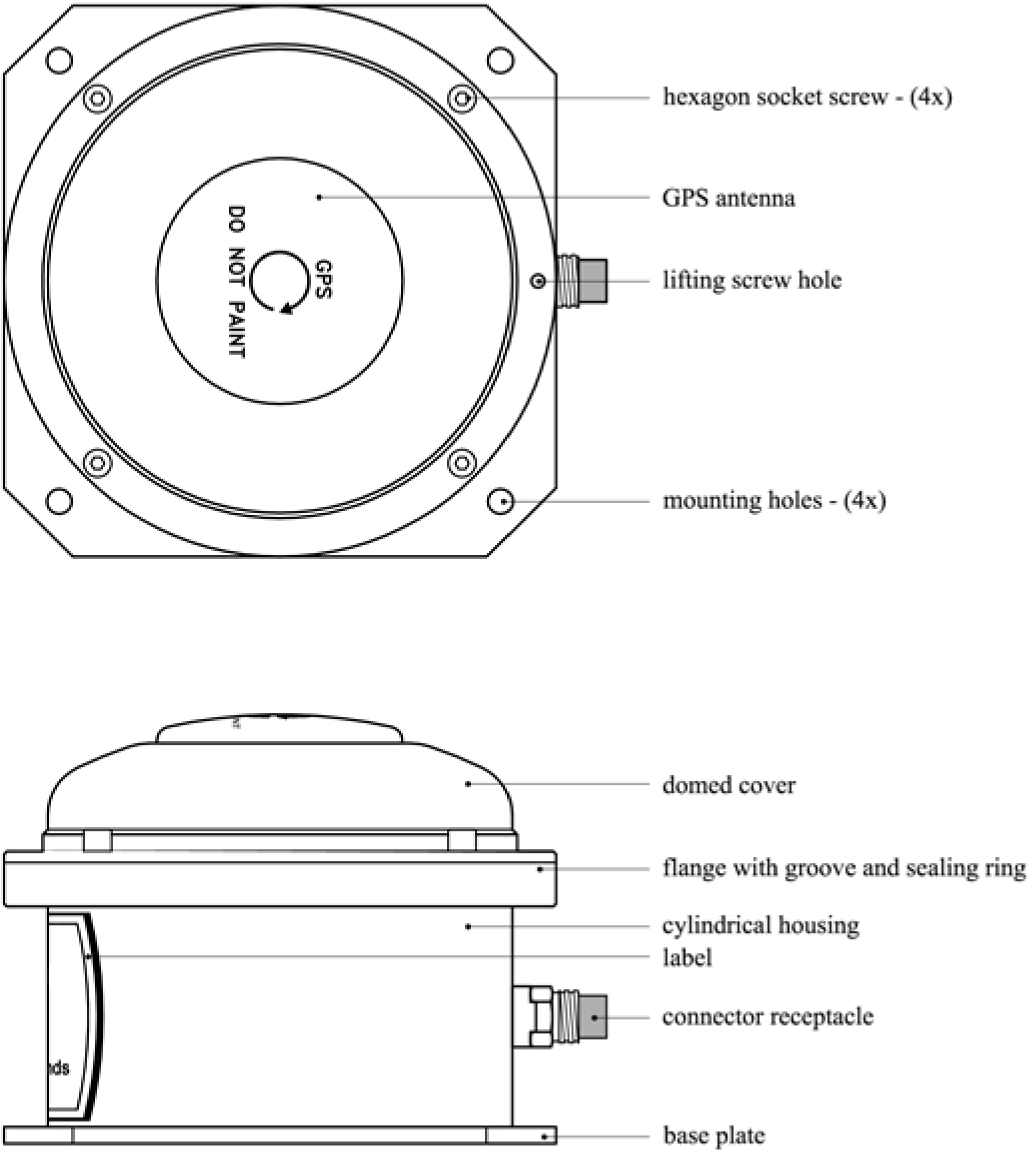

Figure 4.1. Components of the DWR-G Unit

4.2 Electronic components

The electronics unit is made up of an aluminium frame with printed circuit boards (PCB). Figure 4.2 schematically shows the location of the printed circuit boards; the interconnecting ribbon cables and coaxial cable are not shown. At the heart of the electronics unit you find the microprocessor PCB. It receives data from the GPS receiver (GPS PCB), processes it and sends motion data to the serial communication PCB. This PCB also serves as internal power supply.

The stack of aluminium PCB carrying plates is held together by three threaded bars with Nyloc nuts. At the bottom of the stack three stubs are welded to the base plate. The aluminium plates are separated by three spacers. A bag of drying agent is attached to the top plate with two holding clips. Two holes with rubber protectors in the top plate act as a strain relief on the GPS antenna coaxial cable. A small clip underneath the top plate (not shown) completes the strain relief. The coaxial cable can be disconnected on the side of the domed cover by unscrewing the GPS antenna connector.

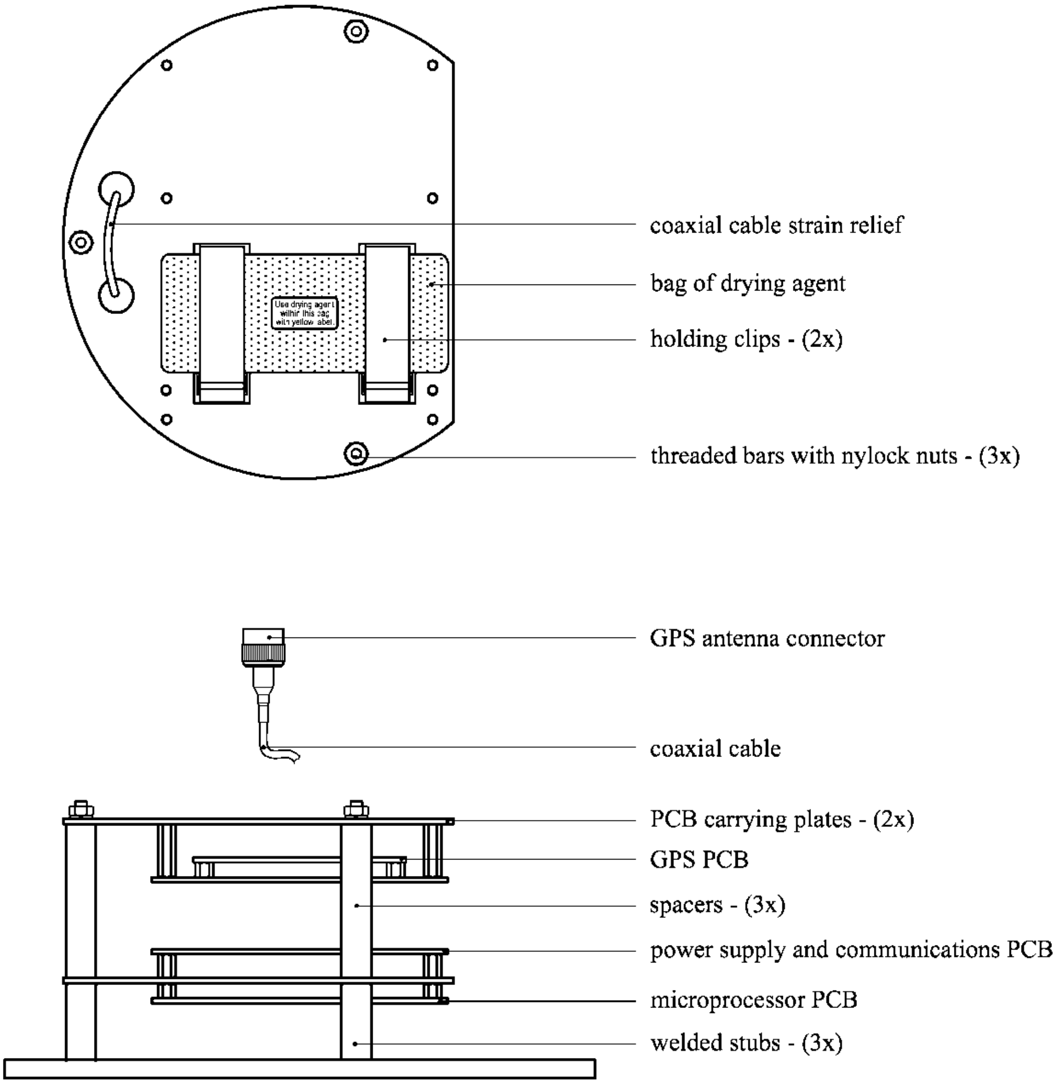

Figure 4.2. Schematic drawing of the electronics unit and its constituting components

5 Mechanics

The DWR-G Unit is made of stainless steel AISI316. It remains watertight even when submerged and is corrosion resistant. It is designed to withstand the marine environment.

5.1 Opening and closing

Before you open the DWR-G Unit, rinse it with fresh water to avoid migration of salt and dirt into the screw holes, sealing ring groove or the interior. Unscrew the 4 M6 hexagon socket screws. In case of under pressure screw one of them into the threaded hole to lift the domed cover. Due to an extra-long GPS antenna coaxial cable the domed cover can be lifted from the cylindrical housing. However, take care to unscrew the GPS antenna connector for a full separation, see Figure 5.1. Close the unit only after removing dirt from the circular groove and inspecting the rubber sealing ring for cuts. A clean groove and intact sealing ring are essential for water tightness.

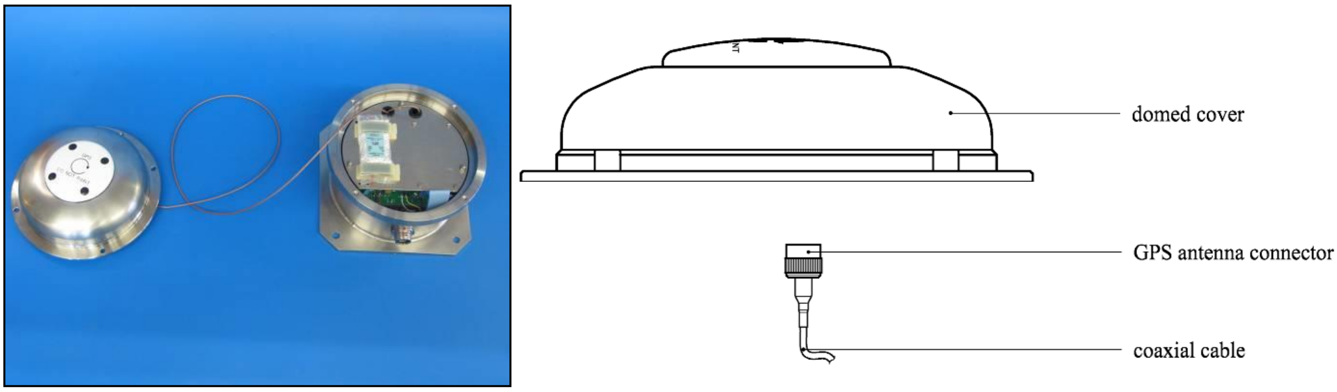

Figure 5.1. Unscrew the GPS antenna connector from the domed cover for a full separation.

5.2 Weights, dimensions and mounting

For mounting or transport please refer to the weight and dimensions in Table 5.1 and 5.2.

Table 5.1.Weights and dimensions

Parameter	Value
Weight	5 Kg
Overall height	160 mm
Base plate	200 mm x 200 mm
Mounting holes centre distance	160 mm x 160 mm
Mounting holes diameter	9 mm

5.3 Connector receptacle, feedthrough and cabling

The DWR-G Unit is fitted with a watertight connector receptacle. A length of cable with pre-mounted cable connector is included. The connector screws on the receptacle only in one orientation. Both receptacle and cable-connector are open face watertight. The cable itself is shielded and has a weather-resistant polyurethane cover. Its diameter is given in Table 5.2.

Table 5.2. Cable diameters.

	cable diameter (mm)	cable included
DWR-G Unit	9.5	yes

5.4 Drying agent bag

To protect the electronics inside from condensing water vapour a bag of drying agent is attached to or packed next to the electronics unit. Perforated plastic sealing bags are used to delay moisture saturation when the unit is open. The colour of the humidity indicator should be blue. If the colour has turned pink, the drying agent bags without plastic sealing bag should be dried at a maximum temperature of 110 ºC for 12 hours. After drying, put the drying agent bag back into the plastic sealing bag. Do not leave the unit open unnecessary.

6 Electronics unit

6.1 Accessing the electronics unit

In general no access to the electronics unit is required. All connections are made on the outside. Nevertheless to access the electronics unit carefully raise the domed cover. Remember to unscrew the TNC connector between the coaxial cable and the GPS antenna (!). Remove the 3 Nyloc screws. Now the aluminium PCB carrying plates can be taken out as far as the ribbon cables and soldered wires allow.

6.2 Power and serial connector

A shielded cable must be used and is supplied with the DWR-G Unit. The cable shield must be connected to chassis ground. To avoid ground loops it must be grounded on one side only, i.e. on the user-end side since the shield is interrupted on the connector end.
Please refer to Table 6.1 for wiring instructions of power supply and RS232 serial communications. For connector pin numbering see Figure 6.1.

Table 6.1. Wiring scheme for power supply and RS232 serial communication

PCB	Connector pin number	Cable wire color
GND_in (ground)	1	black
10-30 V (supply)	3	red
RXD (connect to TXD)	2	white
TXD (connect to RXD)	4	green
0 V (signal ground)	5	orange
		blue
		white/black

Figure 6.1. Connector pin numbering on cable (male).

6.3 Power supply and consumption

The DWR-G Unit accepts any input voltage in the range 10-30 V. The efficiency slightly depends on the voltage supplied. The power supply to the DWR-G Unit is galvanically insulated. Table 6.2 summarizes the power consumption.

Table 6.2. Power consumption of the DWR-G Unit

Model	Power consumption
DWR-G Unit	1.0 W (10-30 V)

6.4 Environmental

All electronics will operate in a temperature range from −10 ºC to +55 ºC.

7 Communication

7.1 Serial interface

The DWR-G Unit uses a RS232 serial interface. The baud rate is fixed at 9600 baud. Characters consist of 8 data bits, 1 start bit, 1 stop bit and no parity bits. No flow control is used.
The RS232 interface standard uses a single unbalanced signal referenced to a ground. RS232 communication is limited to cable lengths of only a few meters. The RS232 serial communication is galvanically insulated.

The cable included with the DWR-G Unit contains a shield. Especially for longer cable lengths, the shield must be connected to local ground on one side only. The cable shielding is not connected on the DWR-G Unit end, so it should be connected to local ground on the user end.

To communicate with a PC a RS232-to-USB converter may be required.

7.2 Output message format

The DWR-G Unit outputs the data in HXV format. This format is also used in the Waverider buoys. For more detailed information about the HXV format, refer to chapter 9. This subsection explains the hexadecimal output format briefly.

HXV format
Shown below is an example of HXV data:

```
001C,49F4,0060,0381,0AB7
001D,766C,8090,0980,A134
001E,7FFF,80E0,0300,1689
```

A line of HXV data consists of five groups of four characters separated by commas. Each line is terminated by a carriage return. The general layout of a line of HXV data is:

```
SSNN,VVVV,VVVV,VVVV,VVVV<CR>
```

The meanings of each of the fields are:
SS = status (see below)
NN = line number cyclically counting from “00” to “FF”
VVVV = 16 bits of received data
<CR> = carriage return

The status bits always have the following value:
“00” = no errors, data is OK

8 Data processing

Consistent with the long-existing Datawell format, the DWR-G unit generates raw north, west and vertical displacements at a rate of 1.28 Hz. The raw data are available on the RS232 interface. Also processed data (wave spectrum) is available in the hexadecimal data string. The processing method is the topic of this chapter.

In oceanography the use of Fourier spectra of the vertical displacements to represent the wave conditions is wide-spread. The power spectral density PSD thus obtained quickly shows what wave amplitudes occur at what frequencies. The first part of this chapter is devoted to this straightforward Fourier spectrum calculation. In the second part we will deal with a more sophisticated Fourier analysis that also incorporates the horizontal motion. Now also information on wave direction, direction spread, wave ellipticity, etc. becomes available.

8.1 Wave height spectrum

The internal wave spectrum is calculated as follows. At a sampling rate of f_s = 1.28 Hz, every 200 seconds a total number of N=256 heave samples h_k are collected

$$h_k = h(k\Delta t),\ k=0\ldots N\text{-}1 \tag{4.1}$$

where $\Delta t=1/f_s$ is the sampling time. A fast Fourier-transform (FFT) is applied to obtain a spectrum in the frequency range 0 to $f_s/2$ = 0.64 Hz, having a resolution of f_s/N = 0.005 Hz. Aliasing is avoided by applying a low-pass filter to the data.
The FFT yields Fourier coefficients according to:

$$H_l = H(f_l) = \sum_{k=0}^{N-1} w_k h_k \exp(2\pi i\, kl/N) \quad f_l = l/N\Delta t \quad l = 0\ldots N-1 \tag{4.2}$$

with $i = \sqrt{(-1)}$. The w_k indicate the window coefficients. Datawell applies a cosine-shaped window over the first and last 32 samples, according to

$$w_k = w_{255-k} = \frac{1}{2}\left(1-\cos\left(\frac{k\pi}{32}\right)\right) \quad k = 0\ldots 31 \tag{4.3a}$$

$$w_k = 1 \qquad \text{otherwise} \tag{4.3b}$$

For normalization all window coefficients must be divided by

$$w_{norm} = \sqrt{f_s \sum_{k=0}^{N-1} w_k^2} \tag{4.4}$$

The power spectral density is obtained from the Fourier coefficients

$$PSD(f_0) = |H_0|^2 \tag{4.5a}$$

$$PSD(f_l) = |H_l|^2 + |H_{N-l}|^2 \quad l = 1\ldots N/2-1 \tag{4.5b}$$

$$PSD(f_{N/2}) = |H_{N/2}|^2 \tag{4.5c}$$

where frequencies range from 0.0 Hz to 0.64 Hz in steps of 0.005 Hz. Actually, there is one more step, all coefficients are smoothed according to

$$\overline{PSD_l} = \frac{1}{4}PSD_{l-1} + \frac{1}{2}PSD_l + \frac{1}{4}PSD_{l+1} \tag{4.6}$$

To limit the number of frequencies low frequency coefficients ($f_l \leq 0.1$ Hz) are left as they are, while only every other smoothed coefficient on the high frequency side($f_l > 0.1$ Hz) is kept in the spectrum file. Finally, 8 consecutive spectra covering 1600 s are averaged and used to compute the half-hourly wave spectrum. Each half-integral hour (1800 s) a new cycle starts.

8.2 Wave direction spectrum

So far only the vertical displacements have been processed to give the wave power spectral density. When north and west displacements are included into the processing, much more wave information can be obtained. Starting from the time-series of north, west and vertical (*n*, *w*, *v*) displacements, the three associated Fourier series may be calculated. Each Fourier series consists of a number of Fourier coefficients, which in turn consist of a real and imaginary part. Thus six Fourier components per frequency *f* are obtained α_{nf}, β_{nf}, α_{wf} , β_{wf} , α_{vf} and β_{vf} or in vector notation:

$$A_{nf} = \alpha_{nf} + i\beta_{nf} \tag{4.7a}$$

$$A_{wf} = \alpha_{wf} + i\beta_{wf} \tag{4.7b}$$

$$A_{vf} = \alpha_{vf} + i\beta_{vf} \tag{4.7c}$$

Building on this, co- (*C*) and quadrature-spectra or quad-spectra (*Q*) may be formed, e.g. (we shall omit the frequency subscript hereafter)

$$C_{nw} = \overline{A_{nf}} \cdot \overline{A_{wf}} = \alpha_{nf}\ \alpha_{wf} + \beta_{nf}\ \beta_{wf} \tag{4.8}$$

$$Q_{vn} = \overline{A_{vf}} \times \overline{A_{nf}} = \alpha_{vf}\ \beta_{nf} - \beta_{vf}\ \alpha_{nf} \tag{4.9}$$

In total 9 components arranged in a 3x3 matrix will be obtained for both co- and quad-spectra. However, not all components need to be calculated. By definition we have

$$Q_{nn} = Q_{ww} = Q_{vv} = 0 \tag{4.10}$$

Furthermore, *Q* represents rotation. To give an example, a wave rolling eastward will have a rotation component directed to the north (right-handed screw) and hence $Q_{vw} \neq 0$ and $Q_{wv} \neq 0$. The rotation in the waves is particularly clear for breaking waves in the surf zone. A rotation component directed vertically would represent eddy currents which are not part of the physics of waves, therefore we also have

$$Q_{wn} = Q_{nw} = 0 \tag{4.11}$$

Thus, one obtains:

$$\begin{pmatrix} C_{ww} & C_{wn} & C_{wv} \\ C_{nw} & C_{nn} & C_{nv} \\ C_{vw} & C_{vn} & C_{vv} \end{pmatrix} \tag{4.12}$$

and

$$\begin{pmatrix} 0 & 0 & Q_{wv} \\ 0 & 0 & Q_{nv} \\ Q_{vw} & Q_{vn} & 0 \end{pmatrix} \tag{4.13}$$

Given these components a whole set of informative wave parameters such as: wave direction, direction spread, wave ellipticity can be obtained. Before discussing their meaning in more detail, first, all formulas will be given.

$$a_1 = \frac{Q_{nv}}{\sqrt{(C_{nn} + C_{ww})C_{vv}}} \tag{4.14}$$

$$b_1 = \frac{-Q_{wv}}{\sqrt{(C_{nn} + C_{ww})C_{vv}}} \tag{4.15}$$

$$a_2 = \frac{C_{nn} - C_{ww}}{C_{nn} + C_{ww}} \tag{4.16}$$

$$b_2 = \frac{-2C_{nw}}{C_{nn} + C_{ww}} \tag{4.17}$$

These are the first four Fourier coefficients of the normalized directional distribution $G(\theta, f)$

$$G(\theta, f) = \frac{1}{\pi}\left\{\frac{1}{2} + a_1 \cos\theta + b_1 \sin\theta + a_2 \cos 2\theta + b_2 \sin 2\theta + ...\right\} \tag{4.18}$$

alternatively cast as

$$G(\theta, f) = \frac{1}{\pi}\left\{\frac{1}{2} + m_1 \cos(\theta - \theta_0) + m_2 \cos 2(\theta - \theta_0) + n_2 \sin 2(\theta - \theta_0) + ...\right\} \tag{4.19}$$

where

$$\theta_0 = \arctan(b_1, a_1) \tag{4.20}$$

$$m_1 = \sqrt{a_1^2 + b_1^2} \tag{4.21}$$

$$m_2 = a_2 \cos 2\theta_0 + b_2 \sin 2\theta_0 \tag{4.22}$$

$$n_2 = -a_2 \sin 2\theta_0 + b_2 \cos 2\theta_0 \tag{4.23}$$

The *m*- and *n*- coefficients are known as the centred Fourier coefficients [Kuik88] or the second harmonic of the directional energy distribution recalculated to the mean wave direction.

Wave direction

$$D = \theta_0 = \arctan(-Q_{wv}, Q_{nv}) \tag{4.24}$$

Directional spread

$$S = \sqrt{2 - 2m_1} \tag{4.25}$$

Wave ellipticity or 1/*K* where *K* is the check factor

$$\varepsilon = 1/K = \sqrt{\frac{C_{vv}}{C_{nn} + C_{ww}}} \tag{4.26}$$

Power Spectral Density

$$PSD = C_{vv} \tag{4.27}$$

In the present context parameters a_i and b_i are just helpful intermediate variables. In terms of this more intricate Fourier analysis we again arrive at the power spectral density. Its value and meaning already have been mentioned.

Wave ellipticity indicates the shape of the wave. For wavelengths much smaller than the depth, waves describe circular orbits and the ellipticity is near 1. However, if the wavelength becomes comparable to or larger than the depth, the vertical displacements are smaller than the horizontal ones and the ellipticity is smaller than 1. The variation of the ellipticity with wave frequency is indicative of the local depth. Historically, Datawell refers to its reciprocal as check factor.

Wave direction and spread speak for themselves. By a close look at the simultaneous north and west motion the wave direction can be determined. For clarity the Datawell wave direction is the direction *from* which the waves arrive. Both are expressed in radians.

In this analysis we have followed the analysis in [Long63].

9 Data format

The DWR-G Unit uses the same data format as transmitted via HF by our Waverider buoys. This message is called the real-time format. The Datawell real-time format refers to the long-existing hexadecimal vectors with vertical, north and west displacements and words ultimately forming the spectrum and system files.

9.1 Datawell real-time format

The real-time format is organized at four levels

(1) Vectors of 64 bits with real-time data together with cyclical data
(2) Blocks of 18 vectors assembling cyclical data with spectral and system data
(3) Spectral data of 16 blocks complete a spectrum file
(4) System data of 16 blocks complete a system file

More precisely one or two samples of the real-time data are framed in one 64-bit vector, but the 64-bit vectors also contain fractions of cyclical data. After collecting 18 vectors all fractions of cyclical data form a complete block of cyclical data. Similarly, one cyclical data block contains a fraction of a complete spectrum and system file, which require 16 blocks or 288 vectors to assemble. The full set of cyclical data in 16 blocks makes up a system file and a spectrum file.

Below all four levels are explained in detail. Timing and the derived compressed spectrum are also discussed in the following subsections.

9.1.1 Real-time displacements

Each 64-bit vector is subdivided into three parts

- cyclical data (sync word or system file word or spectral data words)
- real-time displacements (one vertical, north and west sample or two vertical samples)
- parity bits for transmission error detection and correction

The parity bit algorithm uses a Galois code table to encode 63 bits of a vector. In the receiver these bits are processed to check data integrity and correct for transmission errors. All displacements are given as 12 bit signed integers in cm. The most significant bit (MSB) is the sign bit, MSB = 1 means negative. Table 9.1 shows the organization of the 64-bit vector. On the DWR-G unit the least significant bit (LSB) of the north is used as a GPS flag (0 = ok, 1 = error).

Table 9.1. Organization of real-time displacements in 64-bit vector.

Cyclic data	Real-time displacements (1 cm/bit)*			Parity bits
spectrum/system	vertical	north**	west	see text
16 bits	12 bits	12 bits	12 bits	12 bits
Bits 63-48	bits 47-36	bits 35-24	bits 23-12	bits 11-0

*MSB is sign, 1 means negative

**LSB is GPS flag

9.1.2 Spectrum file or full wave spectrum

One level further up the cyclic data contained within 18 vectors forms one block. The cyclical data is organized as shown in Table 9.2. One block provides information on spectral parameters at 4 frequencies. The parameters are:

- frequency f
- relative power spectral density *RPSD*
- K check factor (reciprocal of the wave ellipticity)
- mean direction from D
- direction spread S
- centred Fourier coefficients (m_2 and n_2), see Equations (4.22) and (4.23).

Table 9.2. Organization of cyclic data in a block of 18 vectors.
16 blocks constitute a spectrum file or full wave spectrum.
The vector number on the left is not transmitted.

No	Cyclic data word (16 bits)		
1	sync word (hex 7FFF)		
2	system file word number 4 bits		system file word 12 bits
3	S_{LSB}(n) 2 bits	frequency index n 6 bits	direction D(n) 8 bits
4	M_{2LSB}(n) 2 bits	N_{2LSB}(n) 2 bits	rel. power spectral density RPSD(n) 12 bits
5	spread S(n) 8 bits		M_2(n) 8 bits
6	N_2(n) 8 bits		check factor K(n) 8 bits
7-10	n+1, same as n		
11-14	n+2, same as n		
15-18	n+3, same as n		

The sync word is repeated every 18 vectors. Its pattern is not likely found elsewhere. S_{LSB}, M_{2LSB} and N_{2LSB} represent the two LSB's of spread, M_2 and N_2, respectively. 16 blocks of 16 vectors (omitting the sync word and system file word number and the system file word itself) make up a complete spectrum file or a full wave spectrum ranging over 64 frequency values. However, the spectral parameters in the cyclic data must be transformed first.

Table 9.3 explains how the various cyclic data fields translate to the respective spectral parameters. The intermediate point of n = 15 is an exception with a frequency interval running from 0.0975 to 0.105 Hz and with a Δf of 0.0075 Hz.

Table 9.3. Translation equations for spectral parameters in spectrum file.

Parameter	Equation	Remarks
Frequency	$f_n = 0.025\text{ Hz} + n\Delta f$ $f_n = 0.11\text{ Hz} + (n-16)\Delta f$	$\Delta f = 0.005$ Hz, n = 0…15 $\Delta f = 0.01$ Hz, n = 16…63
Direction	$D = \mathrm{D}\ 360^{\circ}/256$	0° = north, 90° = east
Relative power spectral density	$RPSD = \exp(-\mathrm{RPSD}/200)$	max 1, multiply by power density in system file
Spread	$S = 0.4476\ (\mathrm{S} + \mathrm{S}_{LSB}/4)$	degrees
m_2	$m_2 = (\mathrm{M}_2 + \mathrm{M}_{2LSB}/4-128)/128$	centred Fourier coefficient (cosine)
n_2	$n_2 = (\mathrm{N}_2 + \mathrm{N}_{2LSB}/4-128)/128$	centred Fourier coefficient (sine)
Check factor (reciprocal wave ellipticity)	$K = \mathrm{K}/100$	K = 1/ε, K = 1 for waves in deep water

9.1.3 System file

All system file words of 16 blocks are combined into one system file. A complete system file consists of 16 words from 16 consecutive blocks. It takes 16×18 = 288 vectors to acquire one system file. Table 9.4 below shows the significance of the system file data. Bits in the 12-bits word are numbered 0 through 11 with bit 11 MSB and bit 0 LSB. LSB and MSB subscripts of Long, Lat and Inc mean least/most significant bits.

Table 9.4. Organization and significance of the system file data.

System file word no (4 bits)	System file word (12 bits)	Significance
0	bits 11-8: $T_p = 0$ bit 7: $M = 1$ bit 6: $T = 0$ bit 5: F bit 4: $C = 1$ bits 3-0: T_n	always 0 (DWR-G unit) always 1 (MkII transmission format) always 0, figure of merit of GPS position solution 1 = GPS position fix, 0 = no solution available or old position always 1 = GPS position module OK T_n transmission number (1-8)
1	bits 11-0: Hrms	H_{rms} = Hrms/400 H_{rms} root mean square wave height = $\sqrt{m_0}$, $H_s = 4\sqrt{m_0}$, units m
2	bits 11-8: reserved bits 7-0: fz	f_z = fz,/400 units Hz $T_z = 1/f_z$, T_z mean time between zero-up crossings, units Hz
3	bits 11-0: PSD	PSD_{max} = 5000 exp(−PSD/200) PSD_{max} peak power spectral density, units m^2/Hz
4	bit 11: reserved bit 10 reserved bits 9-0: Tr	T_r = Tr/20 − 5 T_r reference temperature, units ºC (internal check) always 0 (DWR-G unit)
5	bit 11: reserved bit 10 reserved bits 9-0: Tw	T_w = Tw/20 – 5 T_w water temperature, units ºC always 0 (DWR-G unit)
6	bits 11-4: t_{ol} bit 3: reserved bits 2-0: B	t_{ol} operational life* units weeks B battery status bits*
7	bit 11: *sign* bits 10-0: Av0	A_{v0} = Av0/800 *sign* sign bit, 0 = pos, 1 = neg A_{v0} vertical accelerometer offset, units m/s^2 always 0 (DWR-G unit)
8	bit 11: *sign* bits 10-0: Ax0	idem x-axis accelerometer offset always 0 (DWR-G unit)
9	bit 11: *sign* bits 10-0: Ay0	idem y-axis accelerometer offset always 0 (DWR-G unit)
10	bit 11: *sign* bits 10-0 Lat_{MSB}	$Lat = 90(Lat/2^{23})$ *sign* sign bit 0 = north, 1 = south *Lat* Latitude, units degrees
11	bit 11-0: Lat_{LSB}	
12	bit 11: *sign* bits 10-0 $Long_{MSB}$	$Long = 180(Long/2^{23})$ *sign* sign bit 0 = east, 1 = west *Long* Longitude, units degrees
13	bit 11-0: $Long_{LSB}$	
14	bits 11-8: reserved bits 7-0: O	O = 360(O/256) O buoy orientation, units degrees always 0 (DWR-G unit)
15	bits 11-8: Inc_{LSB} bits 7-0: Inc_{MSB}	$I = (90/128)\ (Inc_{MSB} - 128 + Inc_{LSB}/16)$ I inclination of earth magnetic field, units degrees always 0 (DWR-G unit)

*has no meaning for DWR-G unit

9.1.4 Timing

During half an hour 8 spectra of a 200 s data interval each are collected and averaged. At the end of the half-hour over which the calculations are executed, all (directional) spectral parameters are available. The transmission of one spectrum file takes 225 s. During the next half hour the spectrum file is transmitted 8 times for redundancy. Table 9.5 gives an overview of the timing of vectors, blocks and files.

Table 9.5. Timing at all levels of data.

Unit	Size	Time
Vector	64 bits	0.78125 s (1/1.28 Hz)
Block	18 vectors	14.0625 s
File	16 blocks (288 vectors)	225 s
Full cycle	8 repeated files	30 min

10 GPS position

With GPS (Global Positioning System) the position of a host buoy adrift can be tracked. Latitude and longitude are updated once every half hour and transmitted to the user 8 times in one half hour. The position accuracy is about 10 m (0.3”). Position integrity is monitored by the GPS receiver. Only if the receiver flags the position as valid, will the position be updated and transmitted. Otherwise a zero position will be retransmitted.

10.1 Principle

The Global Positioning System consists of 32 satellites orbiting the earth and allowing GPS receivers to calculate their position at anytime and anywhere on the earth. To see how GPS works let us look at its original name: NAVigation through Synchronized Timing And Ranging (NAVSTAR). It says that GPS satellites and receivers all refer to a single time. Each satellite transmits a unique repeating bit pattern (code signal) that is linked to the GPS timing. GPS receivers receive these patterns. With the unique pattern the receiver can identify the satellite source. The difference between the moment of reception and the moment of transmission of the bit pattern, the travel time, multiplied by the speed of light determines the range between the specific satellite and receiver. As the satellites also transmit orbit information, the so called ephemeris, the GPS receiver can calculate the position of the satellite at the moment of transmission. If the ranges to at least three satellites are known the GPS receiver can also calculate its own three-dimensional position on earth. This would be the case if the GPS receiver would exactly know what time it is. In practice, the GPS receiver time is offset from the exact GPS time. To solve for the additional offset time, the receiver clock error, a minimum of four visible GPS satellites is required for positioning.

11 Installation

This chapter summarizes the points of attention when installing the DWR-G Unit.

11.1 Initial tests

Before installing the unit in its final location it is recommended that you test the unit. This will also help you getting acquainted with the DWR-G Unit. Simply set it running while providing a clear view of the sky for the GPS antenna. Connect the DWR-G Unit to a PC running a Terminal application and/or Waves21 software to check the communications.

11.2 Installation

The final location for installation must be chosen with care. As the motion measurement relies on GPS satellites, a clear view of the sky is required. An elevated position is therefore preferred. A few thin antenna whips at a distance are not a problem, but e.g. solar panels on a buoy or a nearby chimney on a vessel are. The elevation is however limited by possibly unwanted pitch-roll motion and high GPS antenna accelerations. In addition reflection of GPS signals must be considered.

For mechanical mounting and electrical connections consult chapters 5 and 6. Note that the cable included with the DWR-G Unit has a high resistance to torsion. It is suggested to connect the cable to the instrument before tying down the cable. In this way the cable connector is easily screwed on and off without excess torsion forces. Furthermore it is recommended that the DWR-G Unit is oriented in such way that the connector receptacle and cable connector are not likely to hit the water and waves, e.g. when mounted on a buoy.

The shielding of the cable included with the DWR-G Unit should be connected to local ground on the user end. It is not connected to local ground at the instrument end.

The user must take precautions to prevent lighting striking the unit.

12 Maintenance

The DWR-G unit requires no calibration ever and hardly any maintenance. Nevertheless we advise you to inspect all parts when you have the opportunity, to avoid future problems.

12.1 Consumables

12.1.1 Bags of drying agent

In a hermetically sealed DWR-G unit the bags with drying agent will protect the electronics from short-circuiting due to condensing water vapour. As such the bags require no maintenance. However, whenever the DWR-G unit is opened the bags will take up moisture and need to be replaced. Section 5 explains how.

12.2 Inspection

12.2.1 GPS antenna

Dirt on the GPS antenna may block the signal. When dirty, clean the antenna with water, soap and a soft piece of cloth.

12.3 Calibration

As the DWR-G unit ultimately relies on the GPS wavelength which is maintained by the GPS control authorities, calibration of the DWR-G is not required ever.

13 Trouble Shooting

A GPS receiver is a complex though reliable system. As a consequence a GPS receiver either works perfectly or does not work at all, which makes life simple. However, there are a few things to check before boldly replacing a seemingly faulty GPS receiver.

If you don’t get a new GPS position or if your GPS wave signal is zero all the time, your GPS antenna, coaxial cable or connectors may be broke or loose. Also verify that the GPS antenna is clean.

When in doubt about the health of the GPS wave sensor, please conduct a stationary test. Place the DWR-G unit and GPS antenna on a spot with a clear view of the sky and observe the output. If your displacements remain within a few centimetres the GPS motion sensor works just fine. Note that with GPS satellites moving at 4 Km/s, DWR-G Unit/GPS antenna motion becomes a negligible factor and a stationary test is as good as a 20 m high real wave test.

14 Repair

If your DWR-G unit does not function correctly and, although you may have tracked down the problem with help of the *Trouble shooting* chapter, you are not able to solve the problem, the malfunctioning unit (part) should be send to Datawell Service. This chapter will explain where to turn for help and what information must be provided that Datawell may swiftly remedy your problems.

14.1 Assistance and training

Datawell offers you to hire a service and repair specialist to train your personnel. If you just purchased a wave measuring system you are entitled to one day of assistance and training for free. Ask our Sales Department or Service Department.

14.2 Contact

To contact Datawell Service, you can use the following address or numbers. If you ship the DWR-G Unit or parts of it please use the same address.

Datawell BV
Voltastraat 3
1704 RP Heerhugowaard
The Netherlands

Phone +31-(0)72-534 5298
Fax +31-(0)72-572 6406
Email servdept@datawell.nl

If you use airfreight please use following address:

DATAWELL bv
c/o DHL Global Forwarding
PRESTWICKWEG 1
1118LC SCHIPHOL-SE
AMSTERDAM AIRPORT
THE NETHERLANDS
Notify: DATAWELL BV
TEL: +31-(0)72-534 5298

14.3 Serial numbers

If you have any questions regarding your DWR-G Unit or if you encounter problems and you wish to contact Datawell, please keep the serial number at hand.

15 Contacts and Questions

For brochures, quotations and orders please contact Datawell Sales.
For technical questions, support, training and advice, please contact Datawell Service.

15.1 Addresses

Please mail documents to

Sales
Datawell BV
Voltastraat 3
1704 RP Heerhugowaard
The Netherlands

Units and parts should be shipped to

Service
Datawell BV
Voltastraat 3
1704 RP Heerhugowaard
The Netherlands

15.2 Telephone and fax numbers

Datawell Sales & Service

Phone	+31-(0)72-534 5298
Fax	+31-(0)72-572 6406

15.3 Email-addresses

Datawell Sales
sales@datawell.nl

Datawell Service
servdept@datawell.nl

15.4 Website

Our website www.datawell.nl will inform you of new Datawell products and developments.

15.5 FAQ

Datawell maintains a Frequently Asked Questions list with answers about products and services. Go to the Datawell website www.datawell.nl and click <Support>, <FAQ>.

15.6 Datawell Bulletin

About twice a year Datawell composes an e-mailing on new products and services. If you want to subscribe to this Datawell Bulletin e-mailing, please contact Datawell Sales.

16 Literature

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