Datawell CSV file formats

Specifications for the
DWR MkIII, DWR-G, WR-SG,
and the DWR4 /ACM

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Preface

This document contains the specifications for the CSV files (comma separated values files) that contain wave data from DWR MkIII, DWR-G, WR-SG, or DWR4 /ACM buoys. This specification describes how data stored in HVA, HXV, SDT and RDT files, is converted to CSV files. The specifications are shipped with the Datawell software library as an aid to understand the files generated. The software library is used in the buoy firmware, and inside the Waves4 suite. The library will also be provided, free of charge, to our customers. This will help them to decode the data received from the buoy into data structures in the C programming language.

These specifications do not describe how to decode HXV files, this has been documented in [MKIII]. The specifications for the SDT and RDT files can be found on our website. (When using the library there is no need to know how to decode these files.) The decoding of the HVA files is documented in [DWTP].

Contents

Document Change Summary

Issue	Issue date	Reason for change
1.0.0	01/2013	Initial version
1.1.0	10/2013	Added DWR4 information and units
1.2.0	10/2014	Added new DWTP messages
1.3.0	05/2015	Added DWR4 /ACM summary message
1.4.0	12/2015	Added a new DWTP message
1.5.0	03/2017	Added new DMF and DWTP messages
1.6.0	01/2019	Added new DMF and DWTP messages

1 Conventions

In order to properly read these specifications some conventions are used. This chapter explains the conventions used.

1.1 Field conventions

The specifications define multiple messages and every message contains multiple fields. These fields are written in the text with a different font face to recognise whether the text refers to a field or not. An example of a field used in the text “The H_s is the significant wave height, H_s.” The first instance of H_s is a field, the second refers to the oceanographic parameter.

1.1.1 Units

The values of the fields are using SI units.
Lengths and heights use metres, wave periods use seconds.
NB: Temperatures are in *Kelvin*.
NB: Directions are in *radians*.

1.1.2 Directions

The directions used in this document are using the geographic convention: North = 0, East = $\pi/2$ (90°).

The north direction means the magnetic north.

The direction for the wind and the waves is the direction where they travel *from*.
The direction for the water current is the direction the water particles are travelling *to*.

NB: Directions are in *radians*.

2 MkIII CSV file formats

The data of the MkIII buoys is stored on the logger card in the RDT format and SDT format. The RDT format stores the real-time displacements. The SDT format stores the system file and the spectrum file. The buoy also transmits its data via the HF-link in the HXV format. This format contains the displacements, system file and spectrum file. Data received using the Internet communication option is also supported. These messages are received in the mini message format. Starting with version 5.4.0 of the Waves4 suite the waved program generates post-processing CSV files. These CSV files are based on the DWR4 CSV files.

2.1 Displacements

The fields of the displacements are described in *Table 1*.

Table 1. Format of the displacements

Field	Description	Unit
1	Source	-
2	Checksum	-
3	*h*	m
4	*n*	m
5	*w*	m

The Source contains a string with the source of the decoded message.

Table 2. Possible values for the Source *field*

Value	Description
RDT	The data's source was an RDT file
HXV	The data's source was an HVX file or data received from an RX-C or RX-D receiver

The Checksum contains a checksum for the field. The checksum is built from a set of values, named flags, which are OR'ed together. When a particular situation occurs the corresponding flag is set to 1 else it is set to 0. This means when no problem occurs the field is set to 0. Depending whether the source is RDT or HXV some values are not available.

Value	Description	Available in HXV	Available in RDT
0x0001	A vector was successfully repaired.	Yes	No
0x0002	A vector contains an error and could not be repaired.	Yes	No
0x0003	This is an OR of 0x0001 and 0x0002, but has its own meaning; the decoded vector only contains zeros or ones.	Yes	No
0x0004	The receiver was not synchronised.	Yes	No
0x0080	Only available when the buoy is a DWR-G. This field indicates whether the GPS receiver had an error while determining the position.	Yes	Yes
0x0100	The 'begin of message marker' has been omitted.	No	Yes
0x0200	The ID of the message is not the one expected.	No	Yes
0x0800	A CRC checksum error occurred in the message header.	No	Yes
0x1000	A CRC checksum error occurred in the message body.	No	Yes

The h contains the heave displacement.

The n contains the northern displacement.

Remark In the WR-SG this value is always 0. In the HXV and RDT file this field contains a second heave displacement, in the decoded data this second heave displacement is stored as a second displacement record.

The w contains the western displacement.

Remark In the WR-SG this value is always 0.

2.2 Messages

Table 3 gives an overview of the messages defined for the system file and the spectrum file. The sections below will give the definitions of these messages. Depending on the type of the buoy some message may not be transmitted.

Table 3. Overview of the defined messages

MsgID	Description	Status
0x300	Compressed heave spectrum message	a
0x303	Spectral parameters message	a
0x309	Compressed directional spectrum message	a
0x320	Heave spectrum message	a
0x321	Primary directional spectrum message	a
0x324	Spectral parameters message	a
0x328	Secondary directional spectrum message	a
0x380	GPS location message	a
0x381	Sea surface temperature message	a
0x383	CAT4 air temperature message	a
0x3C0	System message for the DWR-G	a
0x3C1	System message for the DWR MkIII	a
0x3C2	System message for the WR-SG	a

Status has one of the following values:

- **a** active; the message is still created by new versions of the library.
- **d** deprecated; the message is still created by new versions of the library, but about to be *retired*. The description of the message should mention whether or not there is a replacement message and the timeframe for its retirement.
- **r** retired; the message is not created by new versions of the library.

These MsgIDs are not used in the messages but are used in the filename of the decoded messages.

2.3 Common message header

All messages share a common header as described in *Table 4*.

Table 4. Format of the common message header

Field	Description	Unit
1	Source	-
2	Checksum	-
3	Message stamp	-

The `Source` contains a string with the source of the decoded message.

Value	Description
SDT	The data's source was an SDT file
HXV	The data's source was an HVX file or data received from an RX-C or RX-D receiver
TCP	The data's source was the Internet communication option of the buoy
SBD	The data's source was the SBD communication option of the buoy
SMS	The data's source was the SMS communication option of the buoy

The `Checksum` contains a checksum for the field. The checksum is built from a set of values, named flags, which are OR'ed together. When the situation occurs its flag is set to 1 else it is set to 0. This means when no problem occurs the field is set to 0. Depending whether the source is SDT or HXV some values are not available.

Value	Description	Available in HXV	Available in SDT
0x0100	The 'begin of message marker' has been omitted.	No	Yes
0x0200	The ID of the message is not the one expected.	No	Yes
0x0400	The length of the message is not the expected length.	No	Yes
0x0800	A CRC checksum error occurred in the message header.	No	Yes
0x1000	A CRC checksum error occurred in the message body.	No	Yes

The `Message stamp` contains an identification for the message.

SDT — The `Message stamp` is the timestamp at which the data acquisition for the message *started*. This is an unsigned number representing the number of seconds elapsed after 1-1-1970 in UTC time, excluding leap seconds.

Remark — By ignoring the leap seconds every day is exactly 86400 seconds long, making it easier to determine the proper date and time in UTC (including UTC's leap seconds). The only problem arises at the exact second the leap second is added. For example the 30th of June 2012 at 23:59:60 will be decoded as the 1st of July 2012 at 00:00:00.

HXV — The `Message stamp` is a sequence number of the decoded message. It only shows the order of the messages in one decoding sequence.

TCP — The `Message stamp` is the same as SDT.

SBD — The `Message stamp` is the time at which the message was decoded.

SMS — The `Message stamp` is the time at which the message was decoded.

2.4 Mini messages

The mini messages are the messages transmitted by the MkIII using the communication options. These messages are documented in [MkIII §5.7.2]. Some messages use dedicated CSV-file other messages are integrated with the messages generated by the HXV data. *Table 5* describes how these mini messages are decoded in the various CSV files.

Table 5. Overview of the CSV output of the mini messages.

MsgID	Description	Output messages
0	Compressed heave spectrum	The spectral parameters are stored in Spectral parameters message (0x324). The bins are stored in Compressed heave spectrum message (0x300).
3	Spectral parameters	Spectral parameters message (0x303)
5	Buoy information	The GPS information is stored in GPS location message (0x380). The system information is stored in System message for the DWR-G (0x3C0), System message for the DWR MkIII (0x3C1), or System message for the WR-SG (0x3C2), depending on the type of buoy.
6	Meteorological parameters	Sea surface temperature message (0x381)
9	Compressed directional spectrum	Compressed directional spectrum message (0x309)
A	Air temperature	Air temperature message (0x30A)

2.4.1 Compressed heave spectrum message (0x300)

The compressed heave spectrum message contains 27 bins of the heave spectrum calculated by the buoy. The format for the compressed heave spectrum message is shown in *Table 6*.

Table 6. Format of the compressed heave spectrum message.

Field	Description	Unit
1	Source	-
2	Checksum	-
3	Message stamp	-
4	f_0	Hz
5	f_1	Hz
…	…	…
29	f_{25}	Hz
30	f_{26}	Hz
31	S_0	m^2/Hz
32	S_1	m^2/Hz
…	…	…
56	S_{25}	m^2/Hz
57	S_{26}	m^2/Hz

The Source is explained in section 2.3.

The Checksum is explained in section 2.3.

The Message stamp is explained in section 2.3.

The f_k is the frequency in bin *k*. Unlike the other spectral messages the frequency of the bins is not fixed. They are determined by the buoy, depending on the peak of the spectrum. Therefore the list of frequencies is stored in the file.

The S_k is the PSD in bin *k*.

2.4.2 Spectral parameters message (0x303)

The spectral parameters message contains spectral parameters calculated by the buoy. The format for the spectral parameters message is shown in *Table 7*.

Table 7. Format of the spectral parameters message.

Field	Description	Unit
1	Source	-
2	Checksum	-
3	Message stamp	-
5	H_s	m
6	T_I	s
7	T_E	s
8	T_1	s
9	T_z	s
10	T_3	s
11	T_c	s
12	T_{dw}	s
13	T_p	s
14	Q_p	-

The Source is explained in section 2.3.

The Checksum is explained in section 2.3.

The Message stamp is explained in section 2.3.

The $H_s = 4.\sqrt{(m_0)}$ is the significant wave height, H_s.

The $T_I = T_m(-2,0) = \sqrt{(m_{-2}/m_0)}$ is the integral period.

The $T_E = T_m(-1,0) = m_{-1}/m_0$ is the energy period.

The $T_1 = T_m(0,1) = m_0/m_1$ is the mean period.

The $T_z = T_m(0,2) = \sqrt{(m_0/m_2)}$ is the average wave period.

The $T_3 = T_m(1,3) = \sqrt{(m_1/m_3)}$, plays a role in the 1D Stokes drift approximation.

The $T_c = T_m(2,4) = \sqrt{(m_2/m_4)}$ is the crest period.
In the above formulae, m_n (n = -2..4) is the *n*th spectral moment.

The T_{dw} is a Datawell specific period.

The T_p is the period at the peak value of the PSD.

The Q_P is Goda's peakedness.

2.4.3 Compressed directional spectrum message (0x309)

The compressed directional spectrum message contains 27 bins of the directional spectrum calculated by the buoy. The format for the compressed directional spectrum message is shown in *Table 8*.

Table 8. Format of the compressed Directional spectrum message.

Field	Description	Unit
1	Source	-
2	Checksum	-
3	Message stamp	-
4	f_0	Hz
5	f_1	Hz
…	…	…
29	f_{25}	Hz
30	f_{26}	Hz
31	direction_from$_0$	rad
32	direction_from$_1$	rad
…	…	…
56	direction_from$_{25}$	rad
57	direction_from$_{26}$	rad
58	spread$_0$	rad
59	spread$_1$	rad
…	…	…
83	spread$_{25}$	rad
84	spread$_{26}$	rad

The Source is explained in section 2.3.

The Checksum is explained in section 2.3.

The Message stamp is explained in section 2.3.

The f_k is explained in section 2.4.1.

The Direction from$_k$ is the mean wave direction in bin *k*. This is the direction the waves are travelling *from*. The values may be interpolated as described in [MkIII §5.7.2.7].

The Spread$_k$ is the directional spread about the mean wave direction. The values may be interpolated or extrapolated as described in [MkIII §5.7.2.7].

2.4.4 Air temperature message (0x30A)

The air temperature message contains 3 sets of sea surface and air temperatures. The format for the air temperature message is shown in *Table 9*.

Table 9. Format of the air temperature message.

Field	Description	Unit
1	Source	-
2	Checksum	-
3	Message stamp	-
4	$(T_w)_{-2}$	K
5	$(T_{air})_{-2}$	K
6	CAT4 $status_{-2}$	-
7	$(T_w)_{-1}$	K
8	$(T_{air})_{-1}$	K
9	CAT4 $status_{-1}$	-
10	$(T_w)_0$	K
11	$(T_{air})_0$	K
12	CAT4 $status_0$	-

The Source is explained in section 2.3.

The Checksum is explained in section 2.3.

The Message stamp is explained in section 2.3.

The $(T_w)_n$ is the temperature of the water at the sea surface.

The $(T_{air})_n$ is the temperature of the air.

The CAT4 $status_n$ bitfield contains the flags indicating the status of the CAT4. The possible flags are shown in *Table 10*.

Table 10. Flags of the CAT4 status *bitfield.*

Bit	Decimal value[1]	Description
0	1	Error
1	2	Busy
2	4	Evaporation detected
3	8	Solar induced uncertainty
4	16	Not used [0]
5	32	Not used [0]
6	64	Not used [0]
7	128	Not used [0]

The BUSY flag is set when the device is performing a measurement cycle. This flag should always be zero when receiving the message, it is used internally in the buoy.

The ERROR flag indicates that an error occurred while getting a measurement from the device. If this flag is 1 multiple times a day there might be issues with the CAT4 antenna.

The Evaporation detected flag is set when the evaporation sensor detected evaporation. When this occurs the T_{air} may be less accurate.

[1] Multiple bitfields can be combined resulting in decimal values not listed.

The Solar induced uncertainty flag is set when the solar sensor detected a high solar intensity. When this occurs the T_{air} may be less accurate.

2.5 Spectrum messages

The wave spectrum is spread over three messages: a message for the heave spectrum, common to all buoy types, and two messages for the directional spectrum.

All spectrum messages contain 64 bins for the data at various frequencies. The frequency f_k of bin k can be calculated using the following formula:

$$f_k = \begin{cases} 0.025 + 0.005 \cdot k & \text{for } k \text{ in } [0..15] \quad \text{range } [0.025..0.1] \\ 0.1 + 0.010 \cdot (k - 15) & \text{for } k \text{ in } [16..64) \quad \text{range } (0.1..0.58] \end{cases} \cdot \text{Hz} \qquad (1)$$

2.5.1 Heave spectrum message (0x320)

The heave spectrum message contains the PSD of the heave displacements. The format for the heave spectrum message is shown in *Table 11*.

Table 11. Format of the heave spectrum message.

Field	Description	Unit
1	Source	-
2	Checksum	-
3	Message stamp	-
4	S_0	m^2/Hz
5	S_1	m^2/Hz
…	…	…
66	S_{62}	m^2/Hz
67	S_{63}	m^2/Hz

The Source is explained in section 2.3.

The Checksum is explained in section 2.3.

The Message stamp is explained in section 2.3.

The S_k is the PSD in bin k.

2.5.2 Primary directional spectrum message (0x321)

The primary directional spectrum contains the wave direction and the directional spread, both of which are based on the first-harmonic coefficients; other more specific variables are stored in the Secondary directional spectrum message (0x328) as described in section 2.5.3. The format for the primary directional spectrum message is shown in *Table 12*.

Table 12. Format of the primary directional spectrum message.

Field	Description	Unit
1	Source	-
2	Checksum	-
3	Message stamp	-
4	Direction from$_0$	rad
5	Direction from$_1$	rad
…	…	…
66	Direction from$_{62}$	rad
67	Direction from$_{63}$	rad
68	Spread$_0$	rad
69	Spread$_1$	rad
…	…	…
130	Spread$_{62}$	rad
131	Spread$_{63}$	rad

The Source is explained in section 2.3.

The Checksum is explained in section 2.3.

The Message stamp is explained in section 2.3.

The Direction from$_k$ is the mean wave direction in bin k. This is the direction the waves are travelling *from*.

The Spread$_k$ is the directional spread about the mean wave direction.

2.5.3 Secondary directional spectrum message (0x328)

The secondary directional spectrum message contains the second-harmonic coefficients and the checkfactor K. The format for the secondary directional spectrum message is shown in *Table 13*.

Table 13. Format of the secondary directional spectrum message.

Field	Description	Unit
1	Source	-
2	Checksum	-
3	Message stamp	-
4	Status n_2	-
5	$(m_2)_0$	-
6	$(m_2)_1$	-
…	…	…
67	$(m_2)_{62}$	-
68	$(m_2)_{63}$	-
69	$(n_2)_0$	-
70	$(n_2)_1$	-
	…	…
131	$(n_2)_{62}$	-
132	$(n_2)_{63}$	-
133	K_0	-
134	K_1	-
…	…	…
195	K_{62}	-
196	K_{63}	-

The Source is explained in section 2.3.

The Checksum is explained in section 2.3.

The Message stamp is explained in section 2.3.

The Status n_2 determines the status of the sign of the values of $(n_2)_k$. In older versions of the MkIII firmware the value of $(n_2)_k$, was calculated with its sign inverted. Later versions of the firmware no longer have this error.

Value	Description
0	The status could not be determined; the sign is expected to be correct.
-1	The sign was inverted and the error is corrected.
1	The sign was correct; no correction required.

The $(m_2)_k$ is the centred cosine Fourier coefficient in bin *k*.

The $(n_2)_k$ is the centred sine Fourier coefficient in bin *k*.

The check factor K_k is the ratio of the amplitude of the horizontal motion, to the amplitude of the vertical motion, in bin *k*. Its reciprocal equals the aspect ratio of the orbit of the water particles.

2.6 Spectral parameters message (0x324)

This message contains the parameters of the spectrum. The format for the spectral parameter message is shown in *Table 14*.

Table 14. Format of the spectral parameters message.

Field	Description	Unit
1	Source	-
2	Checksum	-
3	Message stamp	-
5	H_s	m
6	T_z	s
7	S_{max}	m^2/Hz

The Source is explained in section 2.3.

The Checksum is explained in section 2.3.

The Message stamp is explained in section 2.3.

The H_s is the significant wave height, H_s.

The T_z is the average wave period.

The S_{max} is the peak value of the PSD.

2.7 GPS location message (0x380)

The GPS location message contains the current location of the buoy. The format for the GPS location message is shown in *Table 15*.

Table 15. Format of the GPS location message.

Field	Description	Unit
1	Source	-
2	Checksum	-
3	Message stamp	-
4	Latitude	rad
5	Longitude	rad

The Source is explained in section 2.3.

The Checksum is explained in section 2.3.

The Message stamp is explained in section 2.3.

The Latitude is the latitude the location.

Remark A positive value for the Latitude means the location is on the northern hemisphere.
A negative value for the Latitude means the location is on the southern hemisphere.

The Longitude is the longitude of the location.

Remark A positive value for the Longitude means the location lies east of the Prime Meridian.
A negative value for the Longitude means location lies west of the Prime Meridian.

2.8 Sea surface temperature message (0x381)

This message contains the sea surface temperature and is only used with buoys equipped with the sea surface temperature sensor. The format for the sea surface water temperature message is shown in *Table 16*.

Table 16. Format of the sea surface temperature message.

Field	Description	Unit
1	Source	-
2	Checksum	-
3	Message stamp	-
4	T_w	K

The Source is explained in section 2.3.

The Checksum is explained in section 2.3.

The Message stamp is explained in section 2.3.

The T_w is the temperature of the water at the sea surface.

2.9 CAT4 air temperature message (0x383)

This message contains the air temperature and is only used with buoys equipped with the Air Temperature option. The format for the sea surface air temperature message is shown in *Table 17*.

Table 17. Format of the air temperature message.

Field	Description	Unit
1	Source	-
2	Checksum	-
3	Message stamp	-
4	CAT4 status	-
5	T_{air}	K

The Source is explained in section 2.3.

The Checksum is explained in section 2.3.

The Message stamp is explained in section 2.3.

The CAT4 status bitfield contains the flags indicating the status of the CAT4. The possible flags are shown in *Table 18*.

Table 18. Flags of the CAT4 status bitfield.

Bit	Decimal value[2]	Description
0	1	Error
1	2	Busy
2	4	Evaporation detected
3	8	Solar induced uncertainty
4	16	Not used [0]
5	32	Not used [0]
6	64	Not used [0]
7	128	Not used [0]

The BUSY flag is set when the device is performing a measurement cycle. This flag should always be zero when receiving the message, it is used internally in the buoy.

The ERROR flag indicates that an error occurred while getting a measurement from the device. If this flag is 1 multiple times a day there might be issues with the CAT4 antenna.

The Evaporation detected flag is set when the evaporation sensor detected evaporation. When this occurs the T_{air} may be less accurate.

The Solar induced uncertainty flag is set when the solar sensor detected a high solar intensity. When this occurs the T_{air} may be less accurate.

The T_{air} is the temperature of the air.

2.10 System message for the DWR-G (0x3C0)

This message contains the system message for the DWR-G. The format of the system message for the DWR-G is shown in *Table 19* .

Table 19.Format of the system message for the DWR-G.

Field	Description	Unit
1	Source	-
2	Checksum	-
3	Message stamp	-
4	Battery time remaining	s
5	Battery status	-

The Source is explained in section 2.3.

The Checksum is explained in section 2.3.

The Message stamp is explained in section 2.3.

The Battery time remaining is the estimated time until which the batteries are drained.

Remark More information can be found in [MkIII §5.10.2].
When the value is 0 it means either the batteries are (about to be) drained or it was not possible to determine the status.

[2] Multiple bitfields can be combined resulting in decimal values not listed.

The Battery status is an indication of the remaining battery time.

Remark More information can be found in [MkIII §5.10.2].
When the value is 0 it means either the batteries are (about to be) drained or it was not possible to determine the status.

2.11 System message for the DWR MkIII (0x3C1)

This message contains the system message for the DWR MkIII. The format of the system message for the DWR MkIII is shown in *Table 20*:

Table 20.Format of the system message for the DWR MkIII.

Field	Description	Unit
1	Source	-
2	Checksum	-
3	Message stamp	-
4	Battery time remaining	s
5	Battery status	-
6	O_v	m/s^2
7	O_x	m/s^2
8	O_y	m/s^2
9	μ_o	rad
10	μ_i	rad

The Source is explained in section 2.3.

The Checksum is explained in section 2.3.

The Message stamp is explained in section 2.3.

The Battery time remaining is explained in section 2.9.

The Battery status is explained in section 2.9.

The O_v is the vertical accelerometer offset.

The O_x is the x-axis' accelerometer offset.

The O_y is the y-axis' accelerometer offset.

The μ_o is the average orientation of the buoy during the last thirty minutes.

The μ_i is the average inclination of the earth magnetic field of the buoy during the last thirty minutes.

2.12 System message for the WR-SG (0x3C2)

This message contains the system message for the WR-SG. The format of the system message for the WR-SG is shown in *Table 21*:

Table 21.Format of the system message for the WR-SG.

Field	Description	Unit
1	Source	-
2	Checksum	-
3	Message stamp	-
4	Battery time remaining	s
5	Battery status	-
6	O_v	m/s^2

The Source is explained in section 2.3.

The Checksum is explained in section 2.3.

The Message stamp is explained in section 2.3.

The Battery time remaining is explained in section 2.9.

The Battery status is explained in section 2.9.

The O_v is explained in section 2.11.

2.13 Waved post-processing messages

Table 22 gives an overview of the messages generated by the waved program. This program is part of the Waves4 suite. The messages are generated by post-processing the data received. The output of these messages is identical to the output of their associated DWR4 message.

Table 22. Overview of the defined messages

MsgID	Associated DWR4 message	Status
0x224	Spectral parameters message (0xF24)	a
0x225	Directional Spectral parameters message (0xF25)	a
0x229	Upcross wave height quantiles message (0xF29)	a
0x22A	Upcross wave period quantiles message (0xF2A)	a

Status has one of the following values:

- **a** active; the message is still created by new versions of the library.
- **d** deprecated; the message is still created by new versions of the library, but about to be *retired*. The description of the message should mention whether or not there is a replacement message and the timeframe for its retirement.
- **r** retired; the message is not created by new versions of the library.

These MsgIDs are not used in the messages but are used in the filename of the messages.

3 DWR4 CSV file formats

The data of the DWR4 buoys is stored on the logger card in BVA format. The buoy also transmits its data via the HF-link in the HVA format. This format contains the same data as the BVA format, but in an ASCII format instead of a binary format. The Datawell library contains a tool to convert BVA files to HVA files.

3.1 Displacements

The displacements files generated with the library and with waved (in the Waves4 suite) have a slightly different format.

3.1.1 Library output

The fields of the displacements, as generated by the library, are described in *Table 23*.

Table 23. Format of the displacements

Field	Description	Unit
1	Status	-
2	*h*	m
3	*n*	m
4	*w*	m

The Status contains the heave displacement. The value is one of the following:

- **i** The data in the displacement vector was invalid.
- **b** The data in the displacement vector was valid, but due to the amount of errors, the vector could not be repaired.
- **r** The data in the displacement vector was valid, and contained some errors that are repaired.
- **g** The data in the displacement vector was valid, and contained no errors.

The *h* contains the heave displacement.

The *n* contains the northern displacement.

The *w* contains the western displacement.

3.1.2 Waved output

The fields of the displacements, as generated by waved, are described in *Table 24*.

Table 24. Format of the displacements

Field	Description	Unit
1	Timestamp	s
2	Status	-
3	*h*	m
4	*n*	m
5	*w*	m

The Timestamp is the timestamp of the vector, including microseconds.

Remark — At the moment the timestamp is the timestamp the vector was received in UTC time. In theory it is possible to determine the time the vector was measured, but that has not been implemented yet.

By ignoring the leap seconds every day is exactly 86400 seconds long, making it easier to determine the proper date and time in UTC (including UTC's leap seconds). The only problem arises at the exact second the leap second is added. For example the 30th of June 2012 at 23:59:60 will be decoded as the 1st of July 2012 at 00:00:00.

The `Status` contains the heave displacement. The value is one of the following:

- **3** The data in the displacement vector was invalid.
- **2** The data in the displacement vector was valid, but due to the amount of errors, the vector could not be repaired.
- **1** The data in the displacement vector was valid, and contained some errors that are repaired.
- **0** The data in the displacement vector was valid, and contained no errors.

The *h* is explained in section 3.1.1.

The *n* is explained in section 3.1.1.

The *w* is explained in section 3.1.1.

3.2 Messages

Table 25 gives an overview of the messages defined for the HVA files. The sections below will give the definitions of these messages. Depending on the type of the buoy some message may not be transmitted.

Table 25. Overview of the defined messages

MsgID	Description	Status
0xF20	Heave spectrum message	a
0xF21	Primary directional spectrum message	a
0xF22	Secondary directional spectrum message	r
0xF23	Spectrum synchronisation message	a
0xF24	Spectral parameters message	a
0xF25	Directional spectral parameters message	a
0xF26	Online upcross wave statistics message	a
0xF27	Low frequency heave spectrum message	a
0xF28	Secondary directional spectrum message	a
0xF29	Upcross wave height quantiles message	a
0xF2A	Upcross wave period quantiles message	a
0xF80	GPS location message	a
0xF81	Sea surface temperature message	a
0xF82	Acoustic current meter message	a
0xF83	CAT4 air temperature message	a
0xFB0	DWR4 /ACM summary message	a
0xFC0	System message for the GPS-DWR4	a
0xFC1	System message for the DWR4	a
0xFC2	System message for the WR4	r
0xFC3	Battery life expectancy message	a

0xFC4	CAT4 version information message	a
0xFE1	Communication option message configuration	a
0xFE2	Communication option message configuration request	a
0xFE3	Request logged message	a

Status has one of the following values:

- **a** active; the message is still created by new versions of the library.
- **d** deprecated; the message is still created by new versions of the library, but about to be *retired*. The description of the message should mention whether or not there is a replacement message and the timeframe for its retirement.
- **r** retired; the message is not created by new versions of the library.

3.3 Common message header

All messages share a common header as described in *Table 26*.

Table 26. Format of the common message header

Field	Description	Unit
1	Timestamp	-
2	Datastamp	-

The Timestamp is the timestamp at which the data acquisition for the message *started*. This number represents the number of seconds elapsed after 1-1-1970 in UTC time, excluding leap seconds.

Remark By ignoring the leap seconds every day is exactly 86400 seconds long, making it easier to determine the proper date and time in UTC (including UTC's leap seconds). The only problem arises at the exact second the leap second is added. For example the 30th of June 2012 at 23:59:60 will be decoded as the 1st of July 2012 at 00:00:00.

The Datastamp is an internal number used to identify the buoy, and based on the combination of Hatch UID and Hull UID.

3.4 Spectrum messages

The wave spectrum is spread over three messages: a message for the heave spectrum, common to all buoy types, and two messages for the directional spectrum. The separation of the directional spectrum keeps the size of the messages relatively small. This reduces the amount of data lost, if a transmission error occurs. It also allows the more important directional spectrum to be transmitted more often.

All spectrum messages contain 100 bins for the data at various frequencies. The frequency f_k of bin k can be calculated using the following formula:

$$f_k = \begin{cases} 0.025 + 0.005 \cdot k & \text{for } k \text{ in } [0..46) & \text{range } [0.025..0.25] \\ -0.20 + 0.010 \cdot k & \text{for } k \text{ in } [46..79) & \text{range } [0.26..0.58] \\ -0.98 + 0.020 \cdot k & \text{for } k \text{ in } [79..100) & \text{range } [0.60..1.00] \end{cases} \cdot \text{Hz} \qquad (2)$$

3.4.1 Heave spectrum message (0xF20)

The heave spectrum message contains the PSD of the heave displacements. The format for the heave spectrum message is shown in *Table 27*.

Table 27. Format of the heave spectrum message.

Field	Description	Unit
1	Timestamp	-
2	Datastamp	-
3	Number of segments used	-
4	S_0	m^2/Hz
5	S_1	m^2/Hz
…	…	…
102	S_{98}	m^2/Hz
103	S_{99}	m^2/Hz

The Timestamp is explained in section 3.3.

The Datastamp is explained in section 3.3.

The Number of segments used is the number of segments (using 512 samples) which are used to determine the spectrum. Normally it uses 17 segments with 50% overlap, but if an accelerometer clips (due to accelerations > 1 g) the segment will be discarded. The same occurs when a gap cannot be repaired.

The S_k is the PSD in bin *k*.

3.4.2 Primary directional spectrum message (0xF21)

The primary directional spectrum contains the wave direction and the directional spread, both of which are based on the first-harmonic coefficients; other more specific variables are stored in the Secondary directional spectrum message (0xF28) as described in section 3.4.4. The format for the primary directional spectrum message is shown in *Table 28*.

Table 28. Format of the primary directional spectrum message.

Field	Description	Unit
1	Timestamp	-
2	Datastamp	-
3	Number of segments used	-
4	Direction from$_0$	rad
5	Direction from$_1$	rad
…	…	…
102	Direction from$_{98}$	rad
103	Direction from$_{99}$	rad
104	Spread$_0$	rad
105	Spread$_1$	rad
…	…	…
202	Spread$_{98}$	rad
203	Spread$_{99}$	rad

The Timestamp is explained in section 3.3.

The Datastamp is explained in section 3.3.

The Number of segments used is explained in section 3.4.1.

The Direction $from_k$ is the mean wave direction in bin *k*. This is the direction the waves are travelling from.

The $Spread_k$ is the directional spread about the mean wave direction.

3.4.3 ~~Secondary directional spectrum message (0xF22)~~

This message has been replaced with Secondary directional spectrum message (0xF28). The contents of both messages are the same, but the sign of the n_2 is the opposite.

The secondary directional spectrum message contains the second-harmonic coefficients and the checkfactor *K*. The format for the secondary directional spectrum message is shown in *Table 29*.

Table 29. Format of the secondary directional spectrum message.

Field	Description	Unit
1	Timestamp	-
2	Datastamp	-
3	Number of segments used	-
4	$(m_2)_0$	-
5	$(m_2)_1$	-
…	…	…
102	$(m_2)_{98}$	-
103	$(m_2)_{99}$	-
104	$(n_2)_0$	-
105	$(n_2)_1$	-
	…	…
202	$(n_2)_{98}$	-
203	$(n_2)_{99}$	-
204	K_0	-
205	K_1	-
…	…	…
302	K_{98}	-
303	K_{99}	-

The Timestamp is explained in section 3.3.

The Datastamp is explained in section 3.3.

The Number of segments used is explained in section 3.4.1.

The $(m_2)_k$ is the centred cosine Fourier coefficient in bin *k*.

The $(n_2)_k$ is the centred sine Fourier coefficient in bin *k*.

The check factor K_k is the ratio of the amplitude of the horizontal motion, to the amplitude of the vertical motion, in bin *k*. Its reciprocal equals the aspect ratio of the orbit of the water particles.

3.4.4 Secondary directional spectrum message (0xF28)

The secondary directional spectrum message contains the second-harmonic coefficients and the checkfactor *K*. The format for the secondary directional spectrum message is shown in *Table 30*.

Table 30. Format of the secondary directional spectrum message.

Field	Description	Unit
1	Timestamp	-
2	Datastamp	-
3	Number of segments used	-
4	$(m_2)_0$	-
5	$(m_2)_1$	-
…	…	…
102	$(m_2)_{98}$	-
103	$(m_2)_{99}$	-
104	$(n_2)_0$	-
105	$(n_2)_1$	-
	…	…
202	$(n_2)_{98}$	-
203	$(n_2)_{99}$	-
204	K_0	-
205	K_1	-
…	…	…
302	K_{98}	-
303	K_{99}	-

The Timestamp is explained in section 3.3.

The Datastamp is explained in section 3.3.

The Number of segments used is explained in section 3.4.1.

The $(m_2)_k$ is the centred cosine Fourier coefficient in bin *k*.

The $(n_2)_k$ is the centred sine Fourier coefficient in bin *k*.

The check factor K_k is the ratio of the amplitude of the horizontal motion, to the amplitude of the vertical motion, in bin *k*. Its reciprocal equals the aspect ratio of the orbit of the water particles.

3.5 Spectrum synchronisation message (0xF23)

In the Mk4 it will be possible to determine the exact range of vectors over which the spectrum was calculated. This message can be used to determine the range. This message also makes it possible to determine which segments were used to calculate the spectrum. To better understand this message the DWTP specifications [DWTP] should be used. The format for the spectrum synchronisation message is shown in *Table 31*.

Table 31. Format of the spectrum synchronisation message.

Field	Description	Unit
1	Timestamp	-
2	Datastamp	-
3	List of used segments	-
4	Number of samples in record	-
5	Vector	-

The Timestamp is explained in section 3.3.

The Datastamp is explained in section 3.3.

The List of used segments is explained in the DWTP specifications [DWTP].

The Number of samples in record is explained in the DWTP specifications [DWTP].

The Vector is a combination of h_{n-1}, n_{n-1}, w_{n-1}, h_n, n_n, and w_n as explained in the DWTP specifications [DWTP].

3.6 Spectral parameters message (0xF24)

This message contains the parameters of the spectrum. The format for the spectral parameter message is shown in *Table 32*.

Table 32. Format of the spectral parameters message.

Field	Description	Unit
1	Timestamp	-
2	Datastamp	-
3	Number of segments used	-
5	H_s	m
6	T_I	s
7	T_E	s
8	T_1	s
9	T_z	s
10	T_3	s
11	T_c	s
12	R_p	-
13	T_p	s
14	S_{max}	m^2/Hz

The Timestamp is explained in section 3.3.

The Datastamp is explained in section 3.3.

The Number of segments used is explained in section 2.5.1.

The $H_s = 4.\sqrt{(m_0)}$ is the significant wave height, H_s.

The $T_I = T_m(-2,0) = \sqrt{(m_{-2}/m_0)}$ is the integral period.

The $T_E = T_m(-1,0) = m_{-1}/m_0$ is the energy period.

The $T_1 = T_m(0,1) = m_0/m_1$ is the mean period.

The $T_z = T_m(0,2) = \sqrt{(m_0/m_2)}$ is the average wave period.

The $T_3 = T_m(1,3) = \sqrt{(m_1/m_3)}$, plays a role in the 1D Stokes drift approximation.

The $T_c = T_m(2,4) = \sqrt{(m_2/m_4)}$ is the crest period.
In the above formulae, m_n (n = -2..4) is the nth spectral moment.

The R_P is $1/Q_p$, where Q_p is Goda's peakedness.

Remark: For typical ocean spectra $0 \leq R_P \leq 1$. For non-typical ocean spectra the value of R_P could get greater than 1 and thus result in a NaN in this field.
The value used is R_P instead of Q_p in order to make it easier to compare with the bandwidth parameters ε and ν.

The T_p is the period at the peak value of the PSD.

The S_{max} is the peak value of the PSD.

3.7 Directional Spectral parameters message (0xF25)

This message contains the parameters of the spectrum. The format for the spectral parameter message is shown in *Table 33*.

Table 33. Format of the spectral parameters message.

Field	Description	Unit
1	Timestamp	-
2	Datastamp	-
3	Number of segments used	-
4	H_s	m
5	T_I	s
6	T_E	s
7	T_1	s
8	T_z	s
9	T_3	s
10	T_c	s
11	R_p	-
12	T_p	s
13	$S_{\max}$	m^2/Hz
14	θ_p	rad
15	σ_p	rad

The Timestamp is explained in section 3.3.

The Datastamp is explained in section 3.3.

The Number of segments used is explained in section 3.4.1.

The H_s is explained in section 3.6.

The T_I is explained in section 3.6.

The T_E is explained in section 3.6.

The T_1 is explained in section 3.6.

The T_z is explained in section 3.6.

The T_3 is explained in section 3.6.

The T_c is explained in section 3.6.

The R_P is explained in section 3.6.

The T_p is explained in section 3.6.

The S_{max} is explained in section 3.6.

The θ_p is the mean wave direction at S_{max}. It is the direction *from* which the waves arrive. The value 0 corresponds to North, π/2 or 90° with East. All values refer to *magnetic* North.
Remark	If more than one bin contains the value of S_{max} the one in the bin with the lowest frequency is used to determine θ_p.

The (directional) σ_p is the spread of the mean wave direction at S_{max}.
Remark	If more than one bin contains the value of S_{max} the one in the bin with the lowest frequency is used to determine σ_p.

3.8 Online upcross wave statistics message (0xF26)

This message contains the online upcross wave statistics. The format for the online upcross wave statistics message is shown in *Table 34*.

Table 34. Format of the online upcross wave statistics message.

Field	Description	Unit
1	Timestamp	-
2	Datastamp	-
3	H_{max}	m
4	$T_{H_{max}}$	s
5	T_{max}	s
6	$H_{T_{max}}$	m
7	H_{avg}	m
8	T_{avg}	s
9	$H_{s_{rms}}$	m
10	N_w	-
11	N_c	-
12	ε	-
13	Coverage	%

The Timestamp is explained in section 3.3.

The Datastamp is explained in section 3.3.

The H_{max} is the height of the highest measured upcross wave.

The $T_{H_{max}}$ is the period of the wave used to determine H_{max}.

The T_{max} is the measured upcross wave with the longest period.

The $H_{T_{max}}$ is the height of the wave used to determine T_{max}.

The H_{avg} is the average wave height of the measured upcross waves.

The T_{avg} is the average wave period of the measured upcross waves.

The $H_{s_{rms}}$ is the H_s determined by the root mean square of the height of the waves. It is an approximation of the $H_{1/3}$.

The N_w is the number of the measured upcross waves.

The N_c is the total number of wave crests, both the positive and negative crests.

The ε is the bandwidth parameter of the measured upcross waves.

The Coverage is the percentage of the samples that are covered in the measured upcross waves.

3.9 Low frequency heave spectrum message (0xF27)

Reserved.

3.10 Upcross wave height quantiles message (0xF29)

The online upcross wave height quantiles message is the table of wave height quantiles, complemented by the main wave-statistical parameters. The calculation of these parameters is based on the sorted list of upcross waves. The quantiles are a set of relevant percentiles. The format of the upcross wave height quantiles message is shown in *Table 35*.

Table 35. Format of the upcross wave height quantiles message.

Field	Description	Unit
1	Timestamp	-
2	Datastamp	-
3	Coverage	%
4	N_w	-
5	ε	-
6	H_{max}	m
7	$T_{H_{\mathrm{max}}}$	s
8	$H_{1/10}$	m
9	$T_{H_{1/10}}$	s
10	$H_{1/3}$	m
11	$T_{H_{1/3}}$	s
12	H_{avg}	m
13	T_{avg}	s
14	$(H_q)_0$	m
…	…	…
36	$(H_q)_{22}$	m

The Timestamp is explained in section 3.3.

The Datastamp is explained in section 3.3.

The Coverage is explained in section 3.8.

The N_w is explained in section 3.8.

The ε is explained in section 3.8.

The H_{max} is explained in section 3.8.

The $T_{H_{\mathrm{max}}}$ is explained in section 3.8.

The $H_{1/10}$ is the average crest-to-trough height of the highest 1/10 of the zero-upcross waves.

The $T_{H_{1/10}}$ is the average zero-upcross period of the highest 1/10 of the zero-upcross waves.

The $H_{1/3}$ is the average crest-to-trough height of the highest 1/3 of the zero-upcross waves.

The $T_{H_{1/3}}$ is the average zero-upcross period of the highest 1/3 of the zero-upcross waves.

The H_{avg} is explained in section 3.8.

The T_{avg} is explained in section 3.8.

The $(H_q)_k$ is the wave height for which a percentage p_k of all wave heights is below that value. The percentage p_k is given by:

Index k	0	1	2	3	4	…	18	19	20	21	22
Percentage p_k	1	3	5	10	15	…	85	90	95	97	99

Note that in this table there is no index for the 100% height. This height is the H_{max}.

3.11 Upcross wave period quantiles message (0xF2A)

The online upcross wave period quantiles message is the table of wave period quantiles, complemented by the main wave-statistical parameters. The calculation of these parameters is based on the sorted list of upcross waves. The quantiles are a set of relevant percentiles. The format of the upcross wave period quantiles message is shown in *Table 36*.

Table 36. Format of the upcross wave period quantiles message.

Field	Description	Unit
1	Timestamp	-
2	Datastamp	-
3	Coverage	%
4	N_w	-
5	ε	-
6	T_{max}	s
7	$H_{T_{max}}$	m
8	$T_{1/10}$	s
9	$H_{T_{1/10}}$	m
10	$T_{1/3}$	s
11	$H_{T_{1/3}}$	m
12	T_{avg}	s
13	H_{avg}	m
14	$(T_q)_0$	s
…	…	…
36	$(T_q)_{22}$	s

The Timestamp is explained in section 3.3.

The Datastamp is explained in section 3.3.

The Coverage is explained in section 3.8.

The N_w is explained in section 3.8.

The ε is explained in section 3.8.

The T_{max} is explained in section 3.8.

The $H_{T_{max}}$ is explained in section 3.8.

The $T_{1/10}$ is the average zero-upcross period of the longest 1/10 of the zero-upcross waves.

The $H_{T_{1/10}}$ is the average crest-to-trough height of the longest 1/10 of the zero-upcross waves.

The $T_{1/3}$ is the average zero-upcross period of the longest 1/3 of the zero-upcross waves.

The $H_{T_{1/3}}$ is the average crest-to-trough height of the longest 1/3 of the zero-upcross waves.

The T_{avg} is explained in section 3.8.

The H_{avg} is explained in section 3.8.

The $(T_q)_k$ is the wave period for which a percentage p_k of all wave periods is below that value. The percentage p_k is given by:

Index k	0	1	2	3	4	…	18	19	20	21	22
Percentage p_k	1	3	5	10	15	…	85	90	95	97	99

Note that in this table there is no index for the 100% period. This period is the T_{max}.

3.12 GPS location message (0xF80)

The GPS location message contains the current location of the buoy. The format for the GPS location message is shown in *Table 37*.

Table 37. Format of the GPS location message.

Field	Description	Unit
1	Timestamp	-
2	Datastamp	-
3	Latitude	rad
4	Longitude	rad

The Timestamp is explained in section 3.3.

The Datastamp is explained in section 3.3.

The Latitude is the latitude the location.

Remark A positive value for the Latitude means the location is on the northern hemisphere.
A negative value for the Latitude means the location is on the southern hemisphere.

The Longitude is the longitude of the location.

Remark A positive value for the Longitude means the location lies east of the Prime Meridian.
A negative value for the Longitude means location lies west of the Prime Meridian.

3.13 Sea surface temperature message (0xF81)

This message contains the sea surface temperature and is only used with buoys equipped with the sea surface temperature sensor. The format for the sea surface water temperature message is shown in *Table 38*.

Table 38. Format of the sea surface temperature message.

Field	Description	Unit
1	Timestamp	-
2	Datastamp	-
3	T_w	K

The Timestamp is explained in section 3.3.

The Datastamp is explained in section 3.3.

The T_w is the temperature of the water at the sea surface.

3.14 Acoustic current meter message (0xF82)

This message contains the information of the acoustic current meter. The format of the acoustic current meter message is shown in *Table 39*.

Table 39. Format of the acoustic current meter message.

Field	Description	Unit
1	Timestamp	-
2	Datastamp	-
3	ACM firmware version	-
4	Speed	m/s
5	Direction to	rad
6	σ_{speed}	m/s
7	$\sigma_{direction\ to}$	rad
8	$RSSI_{T_1}$	dBr (dB relative)
9	$RSSI_{T_2}$	dBr (dB relative)
10	$RSSI_{T_3}$	dBr (dB relative)
11	T_w	K
12	ACM status	-
13	μ_w	m/s
14	σ_w	m/s

The Timestamp is explained in section 3.3.

The Datastamp is explained in section 3.3.

The ACM firmware version is string containing the firmware version used in the acoustic current meter.

The Speed is the mean current speed.

The Direction to is the mean current direction. Current direction is defined as direction the water particles are moving towards.

The σ_{speed} is the standard deviation of the mean current Speed

The $\sigma_{direction\ to}$ is the standard deviation of the mean current Direction to.

The $RSSI_{T_n}$ is the average received signal strength of transducer T_n.

Remark The RSSI value gives an indication of the strength of the acoustic echo received by the transducers. The higher this value, the better.

The T_w is the temperature of the water at the sea surface.

The ACM status bitfield contains the flags indicating the status of the current meter. The possible flags are shown in *Table 40*.

Table 40. Flags of the ACM status *bitfield.*

Bit	Decimal value[3]		Description
0	1		BUSY
1	2		ADC OK
2	4		INVALID MATRIX
3	8		Not used [0]
4	16		Not used [0]
5	32		Not used [0]
6	64		Not used [0]
7	128		Not used [0]

The BUSY flag is set when the current meter is performing a measurement cycle. This flag should always be zero when receiving the message, it is used internally in the buoy.

The ADC OK flag indicates that the ADC had no errors while processing its data. If the flag is 0 the values of the measurement might be less accurate. If this flag is 0 multiple times a day there might be issues with the acoustic current meter.

The INVALID MATRIX flag indicates that the calibration matrix is invalid. If this flag is 1 there is a serious issue with the acoustic current meter.

The μ_w is the mean vertical component of the current velocity.

The σ_w is the standard deviation of the vertical component of the μ_w.

[3] Multiple bitfields can be combined resulting in decimal values not listed.

3.15 CAT4 air temperature message (0xF83)

This message contains the information of the CAT4 air temperature option. The format of the CAT4 air temperature message is shown in *Table 41*.

Table 41. Format of the CAT4 air temperature message.

Field	Description	Unit
1	Timestamp	-
2	Datastamp	-
3	T_{air}	K
4	CAT4 status	-
5	T_{white}	K
6	T_{black}	K
7	T_{metal}	K
8	$T_{grooved}$	K

The Timestamp is explained in section 3.3.

The Datastamp is explained in section 3.3.

The T_{air} is the air temperature.

The CAT4 status bitfield contains the flags indicating the status of the CAT4. The possible flags are shown in *Table 42*.

Table 42. Flags of the CAT4 status *bitfield.*

Bit	Decimal value[4]	Description
0	1	Error
1	2	Busy
2	4	Evaporation detected
3	8	Solar induced uncertainty
4	16	Not used [0]
5	32	Not used [0]
6	64	Not used [0]
7	128	Not used [0]

The BUSY flag is set when the device is performing a measurement cycle. This flag should always be zero when receiving the message, it is used internally in the buoy.

The ERROR flag indicates that an error occurred while getting a measurement from the device. If this flag is 1 multiple times a day there might be issues with the CAT4 antenna.

The Evaporation detected flag is set when the evaporation sensor detected evaporation. When this occurs the T_{air} may be less accurate.

The Solar induced uncertainty flag is set when the solar sensor detected a high solar intensity. When this occurs the T_{air} may be less accurate.

The T_{white} is the temperature measured by the white sensor.

[4] Multiple bitfields can be combined resulting in decimal values not listed.

The T_{black} is the temperature measured by the black sensor.

The T_{metal} is the temperature measured by the metal sensor.

The $T_{grooved}$ is the temperature measured by the grooved sensor.

3.16 DWR4 /ACM summary message (0xFB0)

This message contains a summary of the information of a DWR4 /ACM buoy. The format of the DWR4 /ACM summary message is shown in *Table 43*.

Table 43. Format of the DWR4 /ACM *summary message.*

Field	Description	Unit
1	Timestamp	-
2	Datastamp	-
3	H_s	m
4	T_1	s
5	T_z	s
6	T_p	s
7	θ_p	rad
8	σ_p	rad
9	$H_{max} / H_{s_{rms}}$	-
10	Latitude	rad
11	Longitude	rad
12	Battery life expectancy	s
13	T_w	K
14	Speed	m/s
15	Direction to	rad

The Timestamp is explained in section 3.3.

The Datastamp is explained in section 3.3.

The H_s is explained in section 3.6.

The T_1 is explained in section 3.6

The T_z is explained in section 3.6.

The T_p is explained in section 3.6.

The θ_p is explained in section 3.7.

The σ_p is explained in section 3.7.

The $H_{max} / H_{s_{rms}}$ is the ratio of the maximum wave height H_{max} and the significant wave height H_s.
Remark This value is expected to be circa 1.75, and typically between 1.5 and 2.

The Latitude is explained in section 3.10.

The Longitude is explained in section 3.10.

The Battery life expectancy is explained in section 3.18.

The T_w is explained in section 3.13.

The Speed is explained in section 3.14.

The Direction to is explained in section 3.14.

3.17 System messages

The system message contains information regarding the buoy itself and several 'health' parameters. The message contains no oceanographic data. Every type of buoy – DWR4 and GPS-DWR4 – has its own system message, but they share some fields. These shared fields are listed in *Table 44*.

Table 44. Common part of the format of the system messages omitting the HF link message header

Field	Description	Unit
3	Firmware version number	-
4	Hatch UID	-
5	Hull UID	-
6	Uptime	-
7	Energy used from batteries	J
8	Energy to boostcaps	J
9	Hatch electronics temperature	K
10	Battery voltage	V
11	Batteries per section	-
12	Number of battery sections	-
13	Initial energy in a battery	J

The Firmware version number is string containing the firmware version used in the buoy.

The Hatch UID is a unique ID for the buoy's hatch generated by a chip.

The Hull UID is a unique ID for the buoy's hatch generated by a chip.

The Uptime is the number of seconds elapsed since the buoy has been turned on.

The Energy used from batteries is the amount of energy used from the batteries. This is a perpetual wrapping counter.

The Energy to boostcaps is the amount of energy received from the solar cells is stored in the boostcaps. Like Energy used from batteries it is a perpetual wrapping counter.

The Hatch electronics temperature is the temperature of the hatch cover electronics and gives a rough estimation of the temperature inside the buoy hardware.

Remark This temperature is not the acceleration sensor's temperature and can not be used to determine the temperature of the acceleration sensor. When interested in the temperature of the acceleration sensor use T_{sensor} instead.

The Battery voltage is the voltage of the batteries.

The Batteries per section is the number of batteries in a section in the buoy.

The Number of battery sections is the number of battery sections in the buoy.

The Initial energy in a battery is the amount of energy in a single battery as installed in the buoy.

3.17.1 System message for the GSP-DWR4 (0xFC0)

Reserved.

3.17.2 System message for the DWR4 (0xFC1)

This message contains the system message for the DWR4. The format of the system message for the DWR4 is shown in *Table 45*.

Table 45.Format of the system message for the DWR4.

Field	Description	Unit
1	Timestamp	-
2	Datastamp	-
3	Firmware version number	-
4	Hatch UID	-
5	Hull UID	-
6	Uptime	s
7	Energy used from batteries	J
8	Energy to boostcaps	J
9	Hatch electronics temperature	K
10	Battery voltage	V
11	Batteries per section	-
12	Number of battery sections	-
13	Initial energy in a battery	J
14	O_v	m/s^2
15	C_v	-
16	O_x	m/s^2
17	O_y	m/s^2
18	C_x	-
19	C_y	-
20	μ_o	rad
21	σ_o	rad
22	μ_i	rad
23	σ_i	rad
24	μ_H	T
25	σ_H	T
26	C_{pitch}	-
27	C_{roll}	-
28	T_{sensor}	K

The Timestamp is explained in section 3.3.

The Datastamp is explained in section 3.3.

The Firmware version number is explained in section 3.17.

The Hatch UID is explained in section 3.17.

The Hull UID is explained in section 3.17.

The Uptime is explained in section 3.17.

The Energy used from batteries is explained in section 3.17.

The Energy to boostcaps is explained in section 3.17.

The Hatch electronics temperature is explained in section 3.17.

The Battery voltage is explained in section 3.17.

The Batteries per section is explained in section 3.17.

The Number of battery sections is explained in section 3.17.

The Initial energy in a battery is explained in section 3.17.

The O_v is the vertical accelerometer offset.

The C_v is the number of times the output of the vertical accelerometer reached its maximum value during the last thirty minutes.

The O_x is the x-axis' accelerometer offset.

The O_y is the y-axis' accelerometer offset.

The C_x is the number of times the output of the x-axis accelerometer reached its maximum value during the last thirty minutes.

The C_y is the number of times the output of the y-axis accelerometer reached its maximum value during the last thirty minutes.

The μ_o is the average orientation of the buoy during the last thirty minutes.

The σ_o is the standard deviation of the orientation of the buoy during the last thirty minutes.

The μ_i is the average inclination of the earth magnetic field of the buoy during the last thirty minutes.

The σ_i is the standard deviation of the inclination of the earth magnetic field of the buoy during the last thirty minutes.

The μ_H is the average length of the earth magnetic field vector during the last thirty minutes.

The σ_H is the standard deviation of the length of the earth magnetic field vector during the last thirty minutes.

The C_{pitch} is the number of times the pitch angle reached its maximum value during the last thirty minutes.

The C_{roll} is the number of times the pitch angle reached its maximum value during the last thirty minutes.

The T_{sensor} is the temperature of the acceleration sensor.

3.17.3 ~~System message for the WR4 (0xFC2)~~

Reserved.

3.18 Battery life expectancy message (0xFC3)

The format for the battery life expectancy message is shown in *Table 46*.

Table 46. Format of the battery life expectancy message.

Field	Description	Unit
1	Timestamp	-
2	Datastamp	-
3	Battery life expectancy	s

The Timestamp is explained in section 3.3.

The Datastamp is explained in section 3.3.

The Battery life expectancy is the estimated time until which the batteries are drained.

3.19 CAT4 version information message (0xFC4)

The CAT4 version information message contains the information of the hardware and software used in the CAT4 module. The contents of the message are static for a buoy during its deployment. The format for the CAT4 version information message is shown in *Table 47*.

Table 47. Format of the CAT4 version information message.

Field	Description	Unit
1	Timestamp	-
2	Datastamp	-
3	Instrument ID	-
4	Instrument serial number	-
5	CAT4 slave firmware version	-
6	CAT4 master firmware version	-

The Timestamp is explained in section 3.3.

The Datastamp is explained in section 3.3.

The Instrument ID is the Datawell ID for the instrument type.
Remark The value in this message will be 77, but that may change in the future.

The Instrument serial number is the Datawell serial number of the instrument.

Remark The combination of Instrument ID and Instrument serial number uniquely identifies a piece of equipment.

The CAT4 slave firmware version is the firmware version used in the slave of the CAT4 module.

The CAT4 master firmware version is the firmware version used in the master of the CAT4 module.

3.20 Buoy communication messages

These messages are used in bi-directional communication with the buoy. They are used to configure the settings of the buoy or its communication options.

3.20.1 Communication option message configuration (0xFE1)

The format for the communication option message configuration message is shown in *Table 48*.

Table 48. Format of the communication option configuration data message.

Field	Description	Unit
1	Timestamp	-
2	Datastamp	-
3	Configuration message ID	-
4	Interval	-
5	Offset	-

The Timestamp is explained in section 3.3.

The Datastamp is explained in section 3.3.

The Configuration message ID is the same as a MsgID, it is used to identify which message's configuration is handled.

The Interval lookup table contains the transmission interval of a message. The possible values are listed in *Table 49*.

Table 49. Lookup values of the Interval *lookup table.*

Value	Description
1	Transmit the message once every 24 hours.
2	12 hours
3	8 hours
4	6 hours
5	4 hours
6	3 hours
7	2 hours
8	Every 1.5 hours
9	Every hour
10	Every 30 minutes
11	20 minutes

Value	Description
12	10 minutes
13	5 minutes
63	Transmit the message every time new data is available
64	Never transmit the message
128	This value is special in that it does not modify the settings of the interval, instead it directly transmits the available requested message. After the transmission the original interval remains. Due to this behaviour this value can only be sent to the buoy, and won't be returned by the buoy.
255	NaN

The Offset is the offset in periods of thirty minutes.

3.20.2 Communication option message configuration request (0xFE2)

The format for the communication option message configuration request message is shown in *Table 50*.

Table 50. Format of the communication option configuration request message.

Field	Description	Unit
1	Timestamp	-
2	Datastamp	-
3	Configuration message ID	-

The Timestamp is explained in section 3.3.

The Datastamp is explained in section 3.3.

The Configuration message ID is explained in section 3.20.1.

3.20.3 Request logged message (0xFE3)

The format for the communication option message configuration request message is shown in *Table 51*.

Table 51. Format Format of the request logged message message.

Field	Description	Unit
1	Timestamp	-
2	Datastamp	-
3	Request message ID	-
4	Request timestamp	-

The Timestamp is explained in section 3.3.

The Datastamp is explained in section 3.3.

The Configuration message ID is explained in section 3.20.1.

The Request message ID is the same as a MsgID, it is used to identify which message is requested.

The Request timestamp is like a Timestamp as explained in section 3.3. It is the timestamp of which message to retrieve from the logger.