HARMONIC CONSTANTS
Product Specification

Edition 1.0

Contents

1. Introduction

1.1 General

The tide is a periodical movement in the level of the surface of the sea or ocean, due to the gravitational attraction between the Earth, Moon and Sun. By collating and analysing tidal data it is possible to derive harmonic constants that can be used in the prediction of sea levels.

The Harmonic Constants Product Specification sets out the rules which have to be followed when transferring tidal harmonic data.

1.2 Definitions

Harmonic analysis — The mathematical process by which the observed tide or tidal current at any place is separated into basic harmonic constituents.

Harmonic Constituents — One of the harmonic elements in a mathematical expression of the tide-producing force, and in corresponding formulae for the tide or tidal stream. Each constituent represents a periodic change of relative position of the Earth, Sun and Moon.

Harmonic Constants — The amplitude (H) and phase lag (g) of each harmonic constituent of the tide or tidal stream at any place, in a specific time zone.

Species of Tide

Long Period — Includes all tidal oscillations with periods ranging from 1 to 2 days through to 19 years.

Diurnal — A tidal cycle with a period lasting approximately a day, on average 24 hours 50 minutes.

Semidiurnal — A tidal cycle roughly occupying half a day, on average 12hours 25 minutes.

2. General Information

2.1 Observation of the Tide

Observations of sea level are made by automated tide gauges over a period of time at specific locations. The two main tidal features recorded are the tidal range, measured as the height between successive high and low levels and the period, the time laps between one high (or low) level and the next high (or low) level. Tidal analysis of the data collected produces calculated constants which can be used to compute predicted sea-levels. Analysis of the data also provides researchers with information on changes in Mean Sea Level which is used for impact analysis. In reality these calculated constants can only be approximate as the observation period often varies from a year to a month. These observations are also subject to errors induced by natural meteorological occurrences. The principal factors being atmospheric pressure and the winds acting on the sea surface to create storm surges.

2.2 Harmonic Analysis

In general, a simple Harmonic term can be expressed in the form:

$$X(t) = H_n \cos(\sigma_n t - g_n)$$

Where
- X = Value of the variable quantity at time t
- H_n = Amplitude of oscillation
- g_n = Phase lag
- σ_n = Angular speed
- t = Time

The amplitudes and phase lags are the parameters determined by analysis which define the tidal regime for the place of observation.

Note: A full list of Harmonic Constituents with their respective Speeds and Extended Doodson Numbers (XDO) is given in Annex B.

3. Header Information

3.1 Port Name
Full port or tidal station name with no abbreviations, this is a mandatory field.

3.2 Country
IHO Country code, this is a mandatory field.

3.3 Position
A Latitude and Longitude position of observation station quoted as DDD-MM.MM together with the correct suffix dependant on the hemisphere (N-S) and the direction from the Greenwich Meridian (E-W), this is a mandatory field.

3.4 Time Zone
The difference in hours and minutes to Universal Time (UT) using standard International Maritime convention (e.g. Greece -0200; Belize +0600), this is a mandatory field.

3.5 Units
The unit of measure used to specify the Amplitude (H), this is a mandatory field.

3.6 Observation
The start and end dates of the observation period quoted as YYYY-MM-DD, this is a mandatory field.

3.7 Comments
Any useful comments and remarks that will assist processing of the data, this is not a mandatory field.

4. Data Record

4.1 Constituent Name
As specified in Annex B, no variations are allowable, this is a mandatory field.

4.2 Phase Angle (g)
The phase lag of a tidal constituent at a particular place in degrees, this is a mandatory field.

4.3 Amplitude (H)
The amplitude of a tidal constituent for a given place in metres, this is a mandatory field.

4.4 Speed
The speed of a constituent has been calculated from relevant astronomical theory, this is a mandatory field.

4.5 Extended Doodson Number (XDO)
A seven-digit numerical and alphabetical system devised as a convenient way of expressing the Harmonic Constituents in order of speed, this is not a mandatory field but is highly desirable.

5. Accuracy

5.1 Calculation

The overall accuracy of the derived constants is intrinsically linked to the length of the observation period. By increasing the observation period we can gather more measurements therefore reducing the inherent error in the derived values.

So that the calculated data is not misinterpreted as of a higher quality it is important to restrict the precision of the calculated g and H values to reflect the length of observation. The table below shows how many decimal places each derived constant should be quoted to with respect to the length of observation.

Time	Phase Angle (g)	Amplitude (H)
≥ 1 Year	X.X	X.XXX
< 1 Year or ≥ 3 x 30 days	X.X	X.XXX
< 3 x 30 days	X	X.XX

6. Extended Doodson Number (XDO)

6.1 Introduction

The XDO refers to a seven digit numbering system devised by Dr. A. T. Doodson in the 1920's as a convenient way of expressing the Harmonic Constituents in order of speed, which then in turn becomes a useful way of obtaining the phase and speed of any constituent within a computer environment. Each number represents a *multiplier* which is applied to the individual speeds of the Orbital Elements:-

The numbering system effectively 'runs-out' after the ninth-diurnal, therefore an alphabetical system continues through the tenth to fourteenth- diurnal.

The XDO, both numerical and alphabetical, is shown in the full list of IHO Harmonic Constituents (Annex B)

6.2 Computation of the Astronomical Argument (*E*) - Use of Extended Doodson Number (XDO)

1. The value of *E*, at 00hr, for any constituent can be derived from the values for Orbital Elements. For example the phase of the constituent known as R_2 can be expressed as:

$$h - p' + 180°$$

2. In practice it has been found convenient to include an additional term (*h–s*). The multiplier for this term is the species to which the constituent belongs. R_2 is a semi-diurnal constituent so the multiplier for this term is 2. Simple algebra means that *E* of R_2 can now be expressed as :

$$2(h–s) + 2s – h – p' + 180°$$

3. If the coefficients for the term (*h* - *s*), for each of the Orbital Elements in turn and for the number of right angles to be applied, are written in sequence, *E* of R_2 can be expressed as :

Parameter	*(h–s)*	*s*	*h*	*p*	*N*	*p′*	90°
Coefficient	+2	+2	-1	0	0	-1	+2

4. To avoid the use of negative numbers 5 is normally added to each coefficient, except the first. *E* of R_2 now becomes:

Parameter	*(h–s)*	*s*	*h*	*p*	*N*	*p′*	90°
Coefficient	2	7	4	5	5	4	7

5. In the 1920s, Dr. Doodson realised that the first three digits of this number (274 in the case of R_2) were a convenient way of tabulating harmonic constituents in order of speed and he called this the Doodson Number. What he could not have foreseen was that the full number forms a convenient shorthand for obtaining the phase and speed of any constituent within programs on electronic computers. The full number is referred to as the Extended Doodson Number (XDO).

6. Comparatively recently, electronic computers have enabled the use of constituents which overflow the above system and the UK Hydrographic Office has replaced it with an alphabetical system in which Z represents 0, the letters A to P represent coefficients of 1 to 15 respectively while R to Y represent -8 to -1. Substituting the values in Para 2.7, the XDO for R_2 now becomes :

Parameter	*(h - s)*	*s*	*h*	*p*	*N*	*p′*	90°
Coefficient	B	B	Y	Z	Z	Y	B

7. Tidal Harmonic Constant Data File Format

7.1 Header Record

Field	Name	Description
1-2	Name	Port or tidal station name
2-3	Country	IHO Country code
3-4	Latitude N - S	DDD-MM.MM
4-5	Longitude E - W	DDD-MM.MM
5-6	Time Zone	+/-HHMM Maritime Convention
6-7	Observation Start	YYYY-MM-DD
7-8	Observation End	YYYY-MM-DD
8-9	Comment	Comment or remarks

7.2 Harmonic Constants Record

Field	Name	Description			
1-2	Sa	Phase Angle of Sa constant in degrees	Amplitude of Sa in meters	Speed of Sa in degrees per mean solar hour	XDO value Numerical or alphabetical
2-3	Ssa	Phase Angle of Ssa constant in degrees	Amplitude of Ssa in meters	Speed of Ssa in degrees per mean solar hour	XDO value Numerical or alphabetical
3-4	Sta	Phase Angle of Sta constant in degrees	Amplitude of Sta in meters	Speed of Sta in degrees per mean solar hour	XDO value Numerical or alphabetical