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**DYNAMIC POSITIONING CONFERENCE**
**October 9-10, 2007**

**Sensors**

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# DGNSS Position Quality Information for DP Applications

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## Introduction

Surface positioning is fundamental to DP operations within the offshore oil and gas industry. The systems are required to be simple to operate plus provide robust and stable positioning because these systems are critical to vessel operation. Typically, other reference systems such as acoustics or taut-wire are used to provide greater redundancy and minimize the reliance on one positioning system. However, the trend of developments into deeper water means that the reliance on GNSS systems becomes greater due to the restrictions on other positioning reference systems.

There have been advances in positioning technology that are now delivering position solutions with decimeter accuracy. When these are combined with systems providing a differing level of accuracy problems can occur if the weighting is not correct within the DP system. This will become more of a problem in the future with new satellite navigation systems and different position solutions available to the operator/user.

The objective of this paper is to highlight the advances in positioning technology and to describe the different position quality standards currently available. It also presents some considerations for use in DP applications.

## Advances in Positioning Technology

The offshore oil and gas industry has been using surface positioning systems for navigation and positioning since the 1960's. Initially the systems used were based on radio navigation from terrestrial based reference stations. These systems permitted the exploration and development of oil and gas fields all over the globe but technological developments and the introduction of satellite based navigation systems have seen positioning become more accessible to the wider community.

The oil and gas industry was an early adopter of satellite navigation through the use of GPS and nowadays, satellite based radio navigation using GPS is used almost exclusively for positioning in the offshore oil and gas industry. The technology can now be considered a mature and accepted technology.

Several service providers provide differential corrections that enable users to improve their GPS position providing a higher level of accuracy and repeatability. Today there are products on the market offering decimeter level accuracy. Veripos is one such service provider of augmentation data that permits users to derive a position or navigation solution to a higher level of accuracy than just the standalone GPS position generated within a receiver. The term GNSS (Global Navigation Satellite System) is often used due to the fact that multiple satellite navigation systems are and will become available. Currently GPS and the Russian system GLONASS are available but systems from Europe (Galileo) and China (COMPASS) will become available in the coming years.

A variety of different services are offered to ensure that the requirements of the user are met. This includes users who require seamless global coverage and others who only require regional coverage. Secondly, there is an accuracy requirement with certain users requiring high positional accuracy compared against users who do not require the same level of accuracy but demand high repeatability. An example of this can be seen in Figure 1 which demonstrates the difference in accuracy between a L1 DGPS solution and a high accuracy position solution. This also has implications when taking position references with different accuracy levels into a DP system as this can potentially cause problems depending on the rejection criteria used within the DP system.

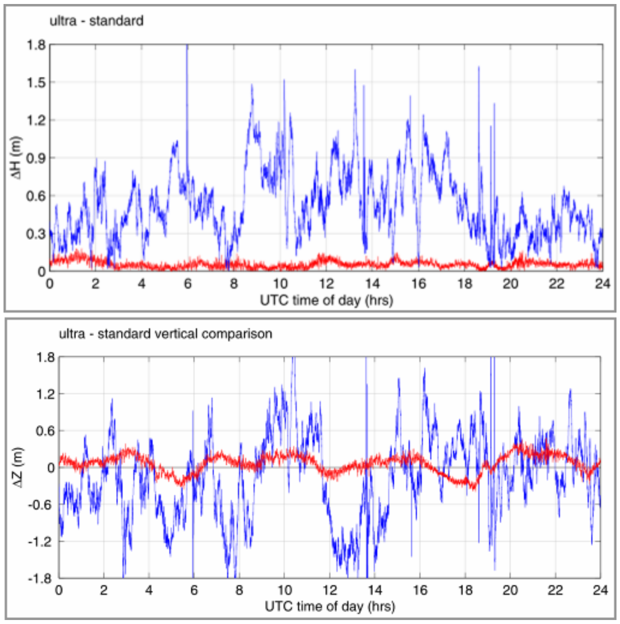


***Figure 1 – Comparison of Veripos Standard (blue) and Veripos Ultra (red)***

Finally, there are users who wish to have a 'black-box' solution compared against those who wish to have more visibility and control of the positioning process. Once the position is calculated it is normally sent to the DP system or survey system using a specific message standard such as NMEA.

## Position Quality Standards

In the offshore industry a number of recommendations and guidelines exist that offer users of satellite navigation systems quality information on the calculated position. This information can be used to determine the accuracy and integrity of the position supplied a DP system. The most well know and frequently used standards are:

1. NMEA
2. UKOOA
3. IMCA

### NMEA

The National Marine Electronics Association (NMEA) has developed a specification [1] that defines the interface between various pieces of marine electronic equipment. The standard permits marine electronics to send information to computers and to other marine equipment.

GPS receiver communication is defined within this specification. The idea of NMEA is to send a line of data called a sentence that is totally self contained and independent from other sentences. There are standard sentences for each device category and in addition NMEA permits hardware manufactures to define their own proprietary sentences for whatever purpose they see fit. All of the standard sentences have a two letter prefix that defines the device that uses that sentence type. For GPS receivers the prefix is GP and for GLONASS GL, which is followed by a three letter sequence that defines the sentence contents. All proprietary sentences begin with the letter P and are followed with 3 letters that identifies the manufacturer controlling that sentence.

NMEA consists of sentences, the first word of which, called a data type, defines the interpretation of the rest of the sentence. Each data type has its own unique interpretation and is defined in the NMEA standard. Each sentence begins with a '$' and ends with a carriage return/line feed sequence and can be no longer than 80 characters of visible text (plus the line terminators). The data is contained within this single line with data items separated by commas. The data itself is ASCII text and may extend over multiple sentences in certain specialized instances but is normally fully contained in one variable length sentence. The data may vary in the amount of precision contained in the sentence. For example time might be indicated to decimal parts of a second or location may be show with 3 or even 4 digits after the decimal point. Applications that read the data should only use the commas to determine the field boundaries and not depend on column positions. There is a provision for a checksum at the end of each sentence which may or may not be checked by the application reading the data. The checksum field consists of a '*' and two hex digits representing the exclusive OR of all characters between, but not including, the '$' and '*'. A checksum is required on some sentences.

There have been several changes to the standard but for GPS use the only ones that are likely to be encountered are versions 1.5 and 2.0 through 2.3. Version 2.3 added a mode indicator to several sentences which is used to indicate the kind of fix the receiver currently has. This indication is part of the signal integrity information needed by the FAA. The value can be A=autonomous, D=differential, E=Estimated, N=not valid, S=Simulator. Sometimes there can be a null value as well. Only the A and D values will correspond to an active and reliable sentence. This mode character has been added to the RMC, RMB, VTG, and GLL, sentences and optionally some others including the BWC and XTE sentences.
The current version of the standard is 3.01.

The hardware interface for GPS receivers is designed to meet the NMEA requirements. They are also compatible with most computer serial ports using RS232 protocols, however strictly speaking the NMEA standard is not RS232. They recommend conformance to EIA-422. The interface speed generally can be adjusted but the NMEA standard is 4800 baud with 8 bits of data, no parity, and one stop bit. All GPS receivers that support NMEA should support this speed. Note that, at a baud rate of 4800, you can easily send enough data to more than fill a full second of time.

At 4800 baud one can only send 480 characters per second. Since an NMEA sentence can be as long as 82 characters one can be limited to less than 6 different sentences. The actual limit is determined by the specific sentences used, but this shows that it is easy to overrun the capabilities if one wants rapid sentence response.

In order to connect to the GPS receiver’s output one will need a cable, but data can also be output via Ethernet or wireless connection. For general NMEA use with a GPS receiver one will only need two wires in the cable, data out from the GPS receiver and ground.

The NMEA standard is the most commonly used standard by the DP manufacturers.

## UKOOA

The UK Offshore Operator Association (UKOOA) issued guidelines in 1994 for the use of DGPS in offshore surveying [2]. These guidelines set out what is generally regarded in the offshore industry as good practice but they are not mandatory and operators are free to adopt different standards.

These guidelines are now slightly dated in parts. However they introduce several useful suggestions for quality monitoring. For example the guideline states [2]:

*“To assist DGPS operators and client representatives to monitor the quality of the DGPS system in real-time the following information should be continuously available:*

- *Pseudo-range residuals of all SV's and observation weight values used*
- *Unit variance*
- *Number of satellites in view and number used in solution*
- *Redundancy of least squares solution*
- *DOP values (HDOP, PDOP and VDOP)*
- *Latency of differential correction data*
- *Position comparisons derived from different reference stations*
- *Derived antenna height with respect to "known" height*
- *Monitor station information, especially position error measured at the monitor station. All data should be time tagged*
- *Maximum external reliability figure and observation carrying it"*

Following that the UKOAA guidelines present a set of test statistics and quality measures. It provides a conclusive list of quality measures which are recommended for use with DGPS. The final recommendation in the guideline states [2]:

*"It is essential to assess the precision and reliability of each position in order to ensure the quality of the DGPS measurements. Thus is recommends that the following processing steps be implemented:*

- *w-test for outliers carried out for each position fix*
- *F-test for unit variance carried out for each position fix*

*When no more outliers are identified in any fix, precision and reliability measures will be calculated:*

- *Precision: a posteriori error ellipse*
- *Reliability: external reliability (positional MDE using a power of test of 80%)"*

The UKOOA guidelines states that for rigorous QC, the covariance matrix that is generated by the least squares computation is used to generate test statistics and quality measures.

The guideline recommends the following test statistics:

1. w-test — used to detect outliers
2. F-test — to verify the model which is being used to account for 'errors' in the DGPS observations

The guideline recommends the following quality measures:

1. Error Ellipse — an approximate graphical representation of the positional standard deviation in two dimensions
2. External Reliability — the effect of the maximum MDE (marginally detectable error) on the computed position

These recommendations are particularly aimed at survey users but could equally be applied to DP applications particularly when high accuracy positioning systems are used. The UKOOA guidelines are somewhat dated due to fact that other mathematical approaches for determining position have been implemented. However, the principal of the guideline remains valid that quality monitoring is important so that the user has confidence that the position calculated is accuracy and reliable.

## IMCA

The International Marine Contractors Association (IMCA) issued in 1997 guidelines on using DGPS as a position reference in DP control systems [3]. The purpose of the document was to provide information to

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the suppliers and operators of DGPS and DP systems regarding the best practice for improving the DGPS reliability in DP applications.

The main objectives of the guideline were [3]:

*"i) to assist optimum DGPS use and improved reliability;*
*ii) to make some realistic proposals for improved DGPS use in DP i.e.*
- *to propose the use of a standard DGPS interface to DP control systems;*
- *to improve the use of DGPS Quality Control (QC) indicators in DP activities;*
- *to recognize the importance of DGPS training for DP Operators.*

*iii) to provide a basis on which DP classification authorities may formally approve (not merely accept) DGPS as a DP position reference;*
*iv) to provide a means of bridging the gap between theoretical DGPS documentation and DP vessels' procedures and quality systems;*
*v) to distil current best practices into guidance on the optimum use of DGPS in DP activities, and therefore further improve DP users' confidence in DGPS."*

Within the guideline a new message format was proposed in an attempt to provide a consistent approach for interfacing DGPS systems to DP control systems. The proposed message format was based on the NMEA standard as there is some scope for including additional information in the free fields of the GGA telegram. Within these free fields it was proposed that a DGPS Quality Indicator (DQI) was included along with text providing a description of the system being used.

| DQI | Status of Solution (see note 1) | Precision (see note 2) | Comments (see note 3) |
|---|---|---|---|
| 0 | Failed Solution | N/A | - |
| 1 | Uncorrected | N/A | Solution obtained but no differential |
| 2 | Corrected position but no redundancy | N/A | Minimum DGPS solution |
| 3 | Corrected position; Redundancy of 1 | Poor | Poor Dilution of Precision (DOP)/geometry |
| 4 | Corrected position; Redundancy of 1 | <10m | Adequate DOP/geometry |
| 5 | Corrected position; Redundancy of >1 | <10m | Ability to reject outlier; Poor DOP/geometry |
| 6 | Corrected position; Redundancy of >1 | <10m | Ability to reject outlier; Gradual improvement in geometry/DOP |
| 7 | Corrected position; Redundancy of >1 | <4m | Ability to reject outlier; Gradual improvement in geometry/DOP |
| 8 | Corrected position; Redundancy of >1 | <2m | Ability to reject outlier; Gradual improvement in geometry/DOP |
| 9 | Corrected position; Redundancy of >1 | <0.5m | Ability to reject outlier; Gradual improvement in geometry/DOP |

Notes: 1. Prerequisite is a successful solution with a valid statistical test
2. Confidence regions are 95%
3. Assumes improving DQI; if DQI value is worsening, read gradual deterioration

***Table 1 - Proposed DQI Values***

The DQI was intended to be used by the DP system to determine whether the position was acceptable. It was designed to be simple to prevent overloading the DPO with too much information. Table 1 shows the proposed DQI values which are based on a single integer value that should allow the operator to determine whether the DGPS is operating correctly producing a position that is both reliable and to the required precision.

Through using the DQI information, an indication of whether the position is improving or deteriorating is available which could provide a countdown to system rejection that would permit suitable action to be taken in advance. Information on quality is important as more reliance is being placed on DGNSS, particularly as the industry moves into deep water activities coupled with the fact that there are many systems providing differing levels of accuracy. Therefore, having information on position quality is important so that the DP system can apply appropriate model weight if the DQI value if the system can use the information.

As the document is a guideline, similar to UKOOA, it is not intended to be used as a specification so it has been left to the discretion of the supplier, operator or user whether or not to follow the guideline. The guideline does not appear to have been widely adopted by both DGPS providers and DP manufacturers.

## Position Output Strings

For the majority of DP systems the most common interface used is the NMEA standard with the following sentences the most frequently used. A full definition of the sentences can be found in the NMEA standard [1].

***GGA*** – time and position fix related data which includes basic quality information, which is limited to 'Fix Quality', 'Number of Satellites in Use', 'HDOP' and 'Age of Differential GPS Data'.

***GLL*** – provides 2D position data.

***VTG*** – provides the actual course and speed relative to the ground.

***GST*** – provides error statistics of the position fix. These statistics are derived from the position calculation process.

***ZDA*** – provides time and time zone information.

***GSV*** – provides information about the number of satellites in view, satellites ID numbers, elevation, azimuth and SNR value. Note that the GSV sentence only allows a maximum of four satellites per transmission. The total number of sentences being transmitted and the number of the sentences being transmitted are indicated in the first two fields.

***GSA*** – provides details on the nature of the position fix. It includes the numbers of the satellites being used in the current solution plus a range of DOP (dilution of precision) values.

As discussed earlier, IMCA proposed a new output string for use by DP systems. This output is based on the NMEA GGA sentence and utilizes the free fields in the sentence. The structure of the NMEA GGA sentence is set out below along with an example.

$GPGGA,hhmmss.ss,llll.llll,a,yyyyy.yyyy,a,X,xx,xx.x,xxx.x,M,xxx.x,M,xx.x,xxxx*hh<CR><LF>
$GPGGA,123519,4807.0378783,N,01131.0054784,E,1,08,0.9,545.4,M,46.9,M,0777*47

GGA sentence defined:

| | |
|---|---|
| GGA = Global Positioning System Fix Data | |
| hhmmss.ss | UTC of position |
| llll.llll | latitude of position |
| a | N or S, latitude hemisphere |
| yyyyy.yyyy | longitude of position |
| a | E or W, longitude hemisphere |
| X | GPS Quality indicator |
| xx | number of satellites in use |
| xx.x | horizontal dilution of precision |
| xxx.x | antenna altitude above mean-sea-level |
| M | units of antenna altitude, meters |
| xxx.x | Geoidal height |
| M | units of geoidal height, meters |
| xx.x | age of differential GPS data |
| xxxx | Differential reference station ID, 0000 to 1023 |
| *hh<CR><LF> | checksum, carriage return and line feed |

The proposed IMCA message is referred to as the 'NMEA UKOOA/IMCA DGPS DP Interfacing Format' and is structured as follows with the main changes from the GGA format highlighted in red.

$DPGGA,hhmmss.ss,llll.llll,a,yyyyy.yyyy,a,x,xx,xx.x,uxxx.x,M,uxxx.x,M,xx.x,xxxx*hh <CR><LF>
$DPGGA,123519,4807.0378,N,01131.0054,E,9,08,0.9,545.4,M,46.9,M,DGPR*47

DPGGA sentence defined:

| | |
|---|---|
| DPGGA = NMEA UKOOA/IMCA DGPS DP Interfacing Format | |
| hhmmss.ss | UTC of position |
| llll.llll | latitude of position |
| a | N or S, latitude hemisphere |
| yyyyy.yyyy | longitude of position |
| a | E or W, longitude hemisphere |
| X | DGPS Quality Indicator (DQI) |
| xx | number of satellites used in solution |
| xx.x | horizontal dilution of precision |
| u | Sign of Altitude above or below Mean Sea Level (MSL)/Geoid |
| xxx.x | antenna altitude above mean-sea-level |
| M | units of antenna altitude, meters |
| u | sign of Geoidal Separation |
| xxx.x | Geoidal height |
| M | units of geoidal height, meters |
| xx.x | age of differential GPS data |
| xxxx | DGPS System Identifier (text) e.g. DPGR = DGPS Radio-based link |
| *hh<CR><LF> | checksum, carriage return and line feed |

For survey and seismic applications many companies have their own defined strings that need to be implemented by the DGNSS suppliers in order to provide an interface with the navigation software used. Additionally, many DGNSS suppliers have defined their own proprietary output formats that provide quality information regarding the position solution. Typically these output messages contain information as defined by the UKOOA guideline.

Utilizing proprietary messages can be problematic because they are not necessarily a published standard and are thus subject to change. However, once the message decode has been incorporated into software or hardware platforms it is unlikely to change in order to minimize future interfacing problems.

Veripos has implemented two different proprietary messages which contain a wide range of quality information on the calculated position solution. The output messages are named Veripos UKOOA and Veripos UKOOA2 format. Table 2 presents the Veripos UKOOA message format.

| | Bit No. | Content | Unit |
|---|---|---|---|
| A1 | 1 | Start Character | - |
| I4 | 2….5 | Length of Message | - |
| A5 | 6…11 | Software Version | - |
| A6 | 12…17 | System Name | - |
| I2 | 18...19 | Record Identifier | - |
| I4 | 20…24 | GPS Week Number | - |
| F7.1 | 25…33 | UTC Time of Fix | Sec |
| F3.1 | 34…38 | Age of Record | Sec |
| F4.1 | 39…44 | Latency | Sec |
| F6.6 | 45…57 | Latitude | DM |
| A1 | 58 | Latitude Hemisphere Specifier (N or S) | - |
| F7.6 | 59…72 | Longitude | DM |
| A1 | 73 | Longitude Hemisphere Specifier (E or W) | - |
| F3.3 | 74…80 | Altitude Above MSL | M |
| F5.2 | 81…88 | Geoid Separation | M |
| F3.3 | 89…95 | PDOP | - |
| F3.3 | 96…102 | HDOP | - |
| F3.3 | 103…109 | VDOP | - |
| I2 | 110…111 | Fix Status (Single Freq. 0=No or Bad Fix, 1=Alt. Aiding, 2=Alt Hold, 3=3D Fix) (Dual Freq. 4=No or Bad Fix, 5=Alt. Aiding, 6=Alt Hold, 7=3D Fix) | - |
| F3.3 | 112…118 | Internal Reliability | M |
| F4.3 | 119…126 | External Reliability (m) (Largest Position MDE at the Configured Level – Typical 80%) | M |
| F2.2 | 127…131 | Unit Variance | $m^2$ |
| F3.3 | 132…138 | Variance Latitude | $m^2$ |
| F4.3 | 139…146 | Covariance Lat/Long | $m^2$ |
| F3.3 | 147…153 | Variance Longitude | $m^2$ |
| F3.3 | 154…160 | Variance Height | $m^2$ |
| F3.2 | 161…166 | 95% Error Ellipse semi-major axis (m) | M |
| F3.2 | 167…172 | 95% Error Ellipse semi minor axis (m) | M |
| F4.1 | 173…178 | Orientation of Semi-major axis of error | D |
| A2 | 179…180 | F Test (P=Pass, F=Fail) | - |
| I3 | 181…183 | No of SVs Used at the Mobile | - |
| {I2*n} | Variable | Satellite PRN Numbers of Satellites used in Fix | - |
| I2 | | Number of Reference Stations used for this Fix(00 - 99) | - |
| {I4*n} | Variable | IDs of the Reference Stations used in the Fix | - |
| A1 | | End Character | - |
| ¬ | | Carriage Return | - |
| ^ | | Line Feed | - |

***Table 2 - Veripos UKOOA Format***

The Veripos UKOOA format follows the recommendations from the UKOOA guideline [2] providing statistical measures to allow the user to determine the precision and reliability of the position solution through values such as the error ellipse and internal/external reliability. The primary objective of the Veripos output message is to provide an output format that contains all the main proprietary information that is required by the majority of navigation systems and DP systems. It is designed to allow the transfer of information to produce statistical testing when required.

This is one example of a proprietary message and different DGNSS suppliers and users have defined their own proprietary messages. This makes using these messages difficult because they are not defined by a recognized industry body.

## Consideration for DP Applications

The NMEA standard provides a good interface standard for DP systems allowing the transfer of positioning information as well as basic system status and quality information. The majority of DP systems use the NMEA standard, in particularly the GGA sentence, as a means of transferring position information into the DP system. With advances in positioning techniques there is a movement towards higher accuracy positioning systems and subsequently additional information on the solution quality, particularly statistical information, should be made available and used by the DP system.

For example if a DP system uses a basic voting system which treats the 3 GNSS position references with equal weight. If one system is a high accuracy system (accuracy approximately 0.2m) and the other two are L1 DGPS (accuracy approximately 1-3m) then it is entirely conceivable that the high accuracy system could be rejected by the DP system. The only way to ensure that this does not happen is to provide quality information regarding the calculated solution and allow the DP to adjust the weighting scheme to reflect the accuracy and reliability of the solutions.

To achieve this, it may require additional quality information to be passes to the DP system in order that it can process and weight the position solution correctly. At present there is no standard or message format that has been universally adopted with the message type varying between DP systems and in particular some of the older legacy DP systems still require old format message types such as Syledis format.

As the positioning technology advances with the advent of new satellite constellations and modernization of the current satellite navigation systems coupled with new augmentation services it is clear that there is going to be a diverse range of positioning solutions available to the user. It is conceivable that a user could be using up to 4 satellite navigation systems. This means that not only a position will be required by the DP system but something to allow the system to know how the solution was derived and the solution quality.

## Conclusions

It is evident that there is a multitude of different output strings available for use in DP systems. With the advances in positioning technology it is becoming clear that there is a lack of status and quality information being made available to the DP systems to permit better modeling and weighting of the position solutions. The issue is important with the reliance on GNSS for DP operations and with advances in future positioning technology it is going to become ever more important that some standards are defined to allow quality information to be made available to the DP system.

The published IMCA standard is still valid but may need to be updated to reflect recent improvements in satellite navigation performance particularly once the new GNSS signals become available as there will inevitably new solutions available to users. With different DGNSS suppliers and DP manufacturers it seems sensible to define a new standard that can be universally adopted to provide the necessary GNSS system status and quality information required by the DP system. This will help with better modeling of the position sensors to be carried out within the DP system which should provide more robust and reliable positioning for DP operations. The IMCA and UKOOA documents are guidelines and are not intended to be used as a specification so it has been left to the discretion of the supplier, operator or user whether or not to follow the guideline. With such a safety critical aspect then perhaps the guidelines should be reviewed or re-written in consultation with the key players in the DP industry so that they become specifications for both DGNSS supplier and DP system manufacturers.

## References

[1] **National Marine Electronics Association**, *NMEA 0183 Interface Standard version 3.01 & 0183-HS High Speed Addendum version 1.0.*

[2] **UKOOA**, 1994, *Quality Measures for Offshore Differential GPS.*

[3] **IMCA**, 1997, *Guidelines on the User of DGPS as a Position Reference in DP Control Systems*, IMCA document M 141, October 1997.