Safe and reliable navigation of vessels in ocean, coasts and harbor areas based on GNSS and its augmentation systems

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Nautical Systems
rough sea

Source: Internet
foggy weather

Source: Internet
darkness
Challenge

We want to know where we are and we want to know if we can trust the information we get!

We have to find a way to obtain reliable information!
Accuracy vs. Preciseness

Horizontal Positioning Error

Graphical Translation for the user or operator
A Global Navigation Satellite System is a system of satellites that provides autonomous geo-spatial positioning with global coverage on earth.

It allow receivers/users to determine their location and time using signals transmitted along a line-of-sight by radio channels from satellites.
The Status Quo in GNSS

GPS (USA)
FOC since 1993

GLONASS (Russia)
FOC since 1996

GALILEO (Europe)
in development

COMPASS (China)
in development

Achievable horizontal positioning accuracy is around 5 up to 10 m
IMO A.915(22) Minimum Requirements on future GNSS

<table>
<thead>
<tr>
<th></th>
<th>Absolute Accuracy</th>
<th>Integrity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Horizontal (m)</td>
<td>Alert Limit (m)</td>
</tr>
<tr>
<td>Port</td>
<td>1</td>
<td>2,5</td>
</tr>
<tr>
<td>Automatic Docking</td>
<td>0,1</td>
<td>0,25</td>
</tr>
</tbody>
</table>
SBAS (DGNSS)

A Satellite Based Augmentation System is a system that supports wide-area or regional augmentation through the use of additional satellite-broadcast messages.

Ground stations are used to measure the satellite signals and environmental factors which may impact the signals received by the users.
The Status Quo in SBAS (DGNSS)

**WAAS (USA)**
operational since 2003

**MSAS (Japan)**
operational since 2007

**EGNOS (Europe)**
operational since 2009

**GAGAN (India)**, **SDCM (Russia)**, **SNAS (China)**,
in development

**SACCSA (South America)**, **AFI (Africa)**, **Malaysia**
feasibility studies

Achievable horizontal positioning accuracy is between 0.5 and 3 m (partly with integrity)
GNSS Error Sources

- Orbit errors and Clock errors of satellites
- Influence of atmospheric effects
  - Ionosphere 70…2000 km Altitude
  - Troposphere 0 … 70 km Altitude
- Interferences of other Radio-Systems
- Shadowing and Multipath
- Jamming
- Spoofing
GBAS (DGNSS)

A **Ground Based Augmentation System** is a system that supports **small-scale** or **local** augmentation through the use of additional **terrestrial-broadcast** messages.

One or more ground stations are used to measure the **satellite signals** and **local environmental factors** which may impact the signals received by the users.
An example for a GBAS (DGNSS)

Achievable horizontal positioning accuracy is in a range of dm up to cm (with integrity)
GBAS Integrity Monitor for GPS

Maritime GBAS Integrity Message Monitor

Single Frequency User Mode (SFUM)
CA Code L1
Station status = healthy

Accuracy Requirements
Ocean / Coastal SAR
Galileo SAR
Port
Automatic Docking

Accuracy > 1m
GPS Satellite Status

Dual Frequency User Mode (DFUM)
P Code L1 & P Code L2
Station status = healthy

Accuracy < 0.1m
GPS Satellite Status

Source: DLR
# GBAS Integrity Monitor for GNSS

The Maritime GBAS - GNSS Integrity Message Monitor

### Application Area

<table>
<thead>
<tr>
<th></th>
<th>Accuracy Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ocean / Coastal SAR</td>
<td>0.1 Positioning [m]</td>
</tr>
<tr>
<td>Galileo Sol. Port</td>
<td>0.25 Integrity [m]</td>
</tr>
<tr>
<td>Automatic Docking</td>
<td></td>
</tr>
</tbody>
</table>

### Mode Selection for Satellite Status

- **GPS Dual Frequency**
- **Galileo Single Frequency**
- **Galileo Dual Frequency**
- **Multi GNSS Single Frequency**
- **Multi GNSS Dual Frequency**

### Positioning Monitor (Positioning Error of Virtual User)

Source: DLR
Embedding of solutions into an international framework

E-Navigation (E-NAV) Strategy of the IMO

- Framework and working program bringing harmony and interoperability into maritime information systems to enhance safety and operations

- Utilisation of all electronic means to integrate these information into ship navigation systems and vessel management systems

- PNT Working work of IALA E-NAV is authorized to propose standardized solutions to fulfil these requirements
Key issues addressed by E-NAV related to GNSS

Detection of malfunctions in core elements of navigation

Provision of support information (e.g. warnings, alerts) for the mariner or operator

Harmonisation of equipment and processes

Safe, secure and efficient realisation of all processes inside the Global Maritime Traffic System
Is it possible to avoid such pictures?

75 percent of accidents are induced by human errors.

Around 50 percent of accidents have navigational causes.
Thank you for your attention