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e-Navigation and Future Trend in Navigation

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ABSTRACT: The International Maritime Organization (IMO) adopted the following definition of e-Navigation: "e-Navigation is the harmonised collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance berth to berth navigation and related services, for safety and security at sea and protection of the marine environment". A pre-requisite for the e-Navigation is a robust electronic positioning system, possibly with redundancy. A new radar technology emerged from the last IALA-AISM conference held in Cape Town, March 2010, where almost all the manufactures companies involved on navigation surveillance market presented –at various state of development-solid state products for VTS and Aids to Navigation indicating a new trend for this application. The paper present an overview of the systems for global navigation and new trend for navigation aids. The expected developments in this field will also be briefly presented.

1 BACKGROUND

The International Maritime Organization (IMO) [1] adopted a "Strategy for the development and implementation of e-Navigation" (MSC85-report, Annexes 20 and 21).

In particular, IMO adopted the following definition of e-Navigation:

"e-Navigation is the harmonized collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance berth to berth navigation and related services, for safety and security at sea and protection of the marine environment".

IMO has stated the driving forces and the consequential goal for their e-Navigation concept as follows: << There is a clear and compelling need to equip shipboard users and those ashore responsible for the safety of shipping with modern, proven tools that are optimized for good decision making in order to make maritime navigation and communications more reliable and user friendly. The overall goal is to improve safety of navigation and to reduce errors. However, if current technological advances continue without proper coordination there is a risk that the future development of marine navigation systems will be hampered through a lack of standardization on board and ashore, incompatibility between vessels and an increased and unnecessary level of complexity >> (IMO MSC 85, Annex 20, §2.1).

e-Navigation is therefore a vision for the integration of existing and new navigational tools, in a holistic and systematic manner that will enable the transmission, manipulation and display of navigational information in electronic format.

The paper is organized as follows. After the preparing for e-Navigation in section 2, the initial e-Navigation architecture is presented in section 3 followed by the usage of radar to validate aids to navigation including the identification of buoys by solid state VTS / navigation radars in section 4. Conclusion and future trends are reported in section 5 while references in section 6 will close the paper.

2 PREPARING FOR E-NAVIGATION

IMO has invited IALA and other international organizations to participate in its work and provide relevant input. IALA formed the e-Navigation (e-NAV) committee for the purpose of developing recommendations and guidelines on e-Navigation systems and services. The committee aims to review and develop related IALA documentation on issues such as the impact of new radar technology on radar aids to navigation, future Global Navigation Satellite System (GNSS) and differential GNSS and the impact of electronic ship-borne navigation aids on aids to navigation systems. The committee also works with other international organizations to develop the overall e-navigation concept.

Concerning radars, a clear trend emerged from the last IALA-AISM conference held in Cape Town, March 2010, where almost all the manufactures companies involved on navigation surveillance market present –at various state of development- solid state products for VTS and Aids to Navigation [2][3][4]. The trend of events set the evolution from the microwave tubes (klystrons and magnetron or travelling-wave) [5] to the solid state technologies. It starts from the IMO resolution 192(79) [6] who intend to encourage the development of low power, cost-effective radars removing (from July 2008) the requirement for S-band radar to trigger RACONS (radar beacons). Solid state radar may fulfill these wishes making use of low-power and digital signal processing techniques to mitigate clutter display that are instead associated with high-power magnetron based radars.

A full comparison magnetron versus solid state VTS radars is provided in [7] including experimental result with live data to show clutter filtering and range discrimination of the solid state LYRA 50 radar. The advantage of solid state transmitted could be summarized as long operational life and graceful degradation, coherent processing, high duty cycle, multi frequency transmission on a wide band, no high voltage supply and compact technology.

Regarding GNSS and DGNSS, an overview of the state of art is reported in [8] where also radio aids to navigation are mentioned while an innovative usage of radar to validate aids to navigation (AtoN) is described later in this paper.

In short, based on the IMO definition, three fundamental elements must be in place as pre-requisite for the e-Navigation. These are:

1 worldwide coverage of navigation areas by Electronic Navigation Charts (ENC);
2 a robust and possibly redundant electronic positioning system; and
3 an agreed infrastructure of communications to link ship and shore but also ship and ship.

3 THE INITIAL E-NAVIGATION ARCHITECTURE

In previous sections e-Navigation and its pre-requisite were presented as a concept but in order to implement such concept a technical architecture is needed. It is shown hereafter (Figure 1) where the shipboard entities, the physical link(s) and the shore-based entities are included in this representation.

On the left side is represented, for simplicity's sake, a single "ship technology environment". From the e-Navigation concept's perspective the relevant devices within the ship technology environment are the transceiver station, the data sources and the data sinks connected to the transceiver station, the Integrated Navigation System (INS) and the Integrated Bridge System (IBS). The transceiver station is shown as a single station for simplicity's sake, although there may be several transceiver stations. The entities which are involved with the specifics of the link technology are confined by the dotted line.

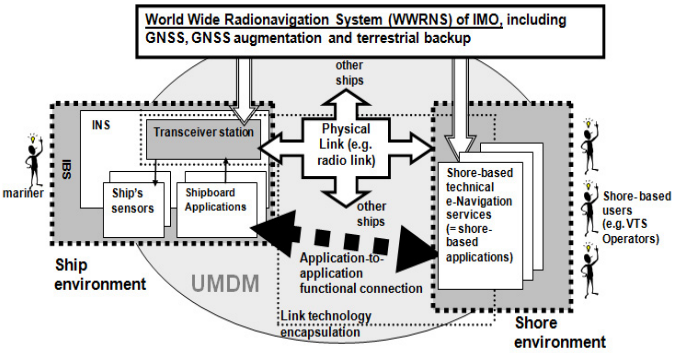

Figure 1. e-Navigation architecture Source: IALA e-NAV140 [9]

The shore-based technical e-Navigation services, in their totality and by their interactions, provide the interfaces of the shore-based user applications to the physical link(s). They also encapsulate their technology to the whole of the common shore-based e-Navigation system architecture. Encapsulation, used as an Object Oriented Programming term is 'the process of compartmentalizing the elements of an abstraction that constitute its structure and behavior; encapsulation serves to separate the contractual interface of an abstraction and its implementation'. The encapsulation principle hides the technology's sophistication from the shore-based e-Navigation system as a whole and thus reduces complexity. The entities which are involved with the specifics of the link technology are confined by the dotted line. Amongst other benefits, it allows for parallel work of the appropriate experts in the particular technology of a given physical link, provided the functional interfaces of the shore-based technical e-Navigation services are well defined.

For the precise technical structure of the shore-base technical e-Navigation services, the common shore-base e-Navigation system architecture is under development for a future IALA Recommendation.

It is also showed the World Wide Radio Navigation System (WWRNS), which includes GNSS, being presented as a system external to the e-Navigation architecture providing position and time information. The Universal Maritime Data Model was also introduced as an abstract representation of the maritime domain [9].

4 USAGE OF RADAR TO VALIDATE AIDS TO NAVIGATION

The use of an additional source of information to improve AtoN has been suggested by Barker in [10] where he consider the vessel traffic routing information providing by the Automatic Identification System (AIS) as an improvement in the AtoN assessment. On the contrary the on board radar of vessels travelling around an AtoN device could be used to assess and to check the position of the buoys/beacons resulting in an almost real-time verification of the information provided by the Aids and consequently alert for maintenance if needed. To this end, new generation VTS / navigation radars [2] provide a break-through for the task of target classification.

4.1 *Identification of buoys by solid state VTS / navigation radars*

In this section an example of application of the described system is shown.

Navigation buoys are often affected by drift or malfunctioning. A method to detect the presence of the buoy and the correct position is addressed, and data are sent to ground base station, in order to verify the position and the presence of the buoy against the navigation maps. The method described is used also for maintenance purpose, in case of failure of the device (i.e. low battery) and uses just the passive reflector positioned on the top of the buoy.

Conventional VTS / navigation radars have poor classification capabilities at long distance due to their non-coherent receiver and the limited range resolution. Navigation radars equipped with magnetrons usually are set for medium-high range, to improve safety in navigation, using medium-long pulses (i.e. 30-75 m) with the consequence of very poor discrimination in range.

New generation solid state radars permits to uncouple resolution from transmitted pulse length by using a coherent receiver and long coded pulses. High range resolution can be preserved by implementing a pulse compression algorithm in the digital processor. The radar “LYRA 50” for example can provide a range resolution of 9 m for all ranges up to 24 NM making use of long compressed pulses shown in figure 2.

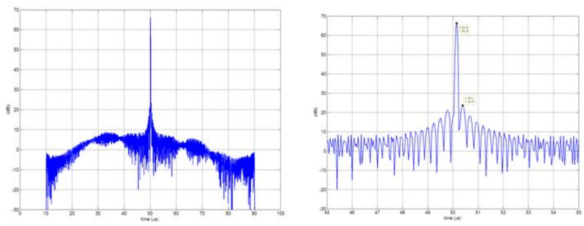

Figure 2. Example of digital a compressed pulse with close up.

The long uncompressed pulse has a time length of 30 μs (4.5 km) and an instantaneous bandwidth of 22 MHz. Due to the digital pulse compression the resulting pulse is severely deformed: it presents one high peak lasting only 60 ns (9 m) and a series of much weaker peaks (side lobes) lasting all together 60 μs (9 km); however the side lobes are more than 40 dB lower with respect to the main one and their contribute to the received signal is usually negligible.

Range profile can be associated to a radar report and stored for classification purpose by the radar data processor. Buoys can be considered small object for a radar having range extension less than 1 m which produce a narrow peak signal in the radar receiver, whose width equal to the range resolution. Small vessels usually generate a broader peak and sometimes even different discriminated peaks when the length of the vessel is greater than twice the resolution.

An addition contribute to the classification process of the target can be derived by analysis of the amplitude of the echoes. A study on the variation of the amplitude of the target echo over different scans has been conducted by the authors using live radar data (examples are shown see figures 3, 4 and 5).

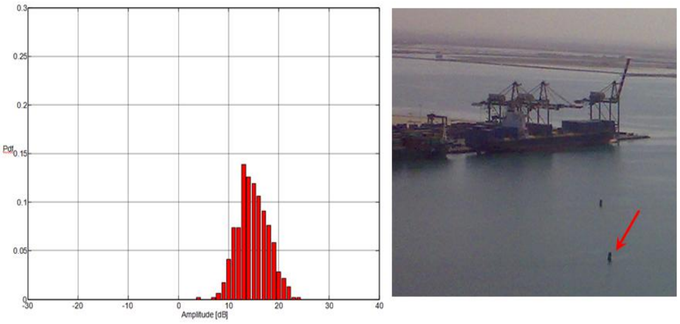

Figure 3. Example of amplitude distribution from an buoy (live data).

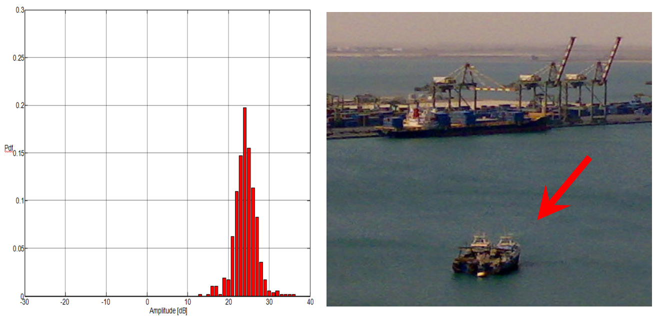

Figure 4. Example of target echoes amplitude distribution from a small anchored boat (live data).

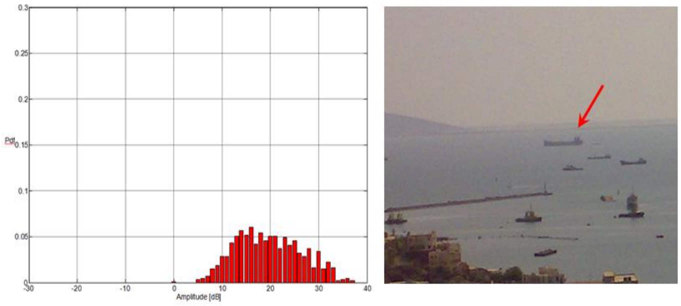

Figure 5. Example of target echoes amplitude distribution from a tanker (live data).

5 CONCLUSION AND FUTURE TREND

For someone in the short term e-Navigation should remain a theoretical concept but it is indubitably an overall concept to which all marine users have to deal with from now on.

Electronic positioning system is a prerequisite for the e-Navigation and position fixing using GNSS is prevailing amongst commercial and leisure users. By the way radars and traditional Aids to Navigation (AtoN) will continue to be required, at least for redundancy and/or terrestrial backup to satellite systems, or in many military scenarios. Co-operation between complementary systems such as radar and AtoN should become stronger and stronger to assessing the data and improving reliability for more informed decisions.

These analysis should be used to improve the filtering and the recognition of buoys, not only based on the expected position data: the recognition process is helpful to distinguish the radar echo of a buoy from other fixed targets such as ships in stand-by or outcropping rocks.

Further work may include studies on the range extension of the radar echoes.

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