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ANY OTHER BUSINESS

Enhanced Radar Positioning System for resilient navigation

Submitted by IALA

SUMMARY

Executive summary: The information paper provides an extended insight into a new approach towards a terrestrial radio navigation system suitable as stand-alone maritime positioning system and back-up system for today's satellite navigation systems. The Enhanced Radar Positioning System (ERPS) technology offers an inexpensive and an independent backup to GNSS to provide resilient PNT. The ERPS is based on existing, mature and robust technology. It is anticipated that this facility could be delivered to existing systems by way of software update

Strategic direction, if applicable:

Output:

Action to be taken: Paragraph 26

Related documents: Resolution A.915(22), and A.1046(27), MSC.401(95), MSC.432(98), MSC.1/Circ.1575, SN.1/Circ.329, SN.1/Circ.334, A.615(15); MSC.192(79)

Introduction

1 Within the strategy for the development and implementation of e-Navigation and the developed Strategic Implementation Plan (SIP) resilient positioning and navigation has been recognised as an indispensable prerequisite for maritime safety of life, safe transport and environmental protection.

2 Within this scope the need for resilient Positioning, Navigation and Timing (PNT) information has been recognised to support safe operation and collision avoidance of vessels, as well as for

comprehensive management of marine infrastructure such as marine aids to navigation in coastal and restricted waters.

3 Specifically, the IMO e-navigation strategic implementation plan considered existing and future Global Navigation Satellite Systems (GNSS) as a strategic key element, within the availability of navigation data from Electronic Position Fixing Systems (EPFS), to satisfy the demand for the provision of reliability, resilience and integrity to bridge equipment.

4 With respect to the vulnerability of signals from global, as well as Regional Navigation Satellite Systems (RNSS) to interference, whether intentional or not, multiple dissimilar and uncorrelated PNT sources are recommended by IMO to achieve resilient PNT.

5 Terrestrial radio navigation signals use different frequency bands, transmitter powers and message architectures and can provide similar navigation performance to GNSS while having dissimilar failure modes.

6 In accordance with the information given above, this paper introduces a proven concept of Enhanced Radar Positions System (ERPS) by using signals from racons to provide position information to the ships radar. ERPS racons provide unambiguous identification of landmarks, which can also be used for radar-based terrain mapping applications.

7 Both IMO documents, the “*Performance Standards for Multi-System Shipborne Radionavigation Receivers*” (MSC.401 as amended) as well as the “*Guidelines for Shipborne Position, Navigation and Timing (PNT) Data Processing*” (MSC.1/Circ. 1575) developed by the IMO, are seeking to provide means of resilient positioning, navigation and timing by the combination of multiple and highly dissimilar PNT sources like GNSS and explicitly demanding a terrestrial source of position data, if available - The ERPS technology qualifies to fill today's gap towards resilient PNT.

8 The IMO documents Resolution MSC.192(79) ADOPTION OF THE REVISED PERFORMANCE STANDARDS FOR RADAR EQUIPMENT and Resolution A.615(15) RADAR BEACONS AND TRANSPONDERS appear to allow ERPS with little or no revision.

Introduction to enhanced radar positioning system

9 ERPS is a simple concept in which the eRacon provides unique position information encoded in its response signal to the eRadar. The concept is similar to what navigators would do by hand, using radar target azimuth and distance to triangulate a vessel's position. eRacons are essentially normal racons modified to encode their unique identification and position into the signal response to the radars that interrogate them. The eRacon position (latitude, longitude, and elevation) is surveyed and entered as static parameters in the eRacon configuration, therefore eRacons must be located at fixed sites and not placed on buoys. The eRacon identification and surveyed position data is encoded by the eRacon using modulation in response.

10 The response is received by the eRadar and is demodulated to extract the identification and position data from the eRacon. To calculate the position, it is necessary either to have:

- A single eRacon signal together with own ship heading; or
- Signals from two or more eRacons.

11 Knowing the measured azimuth and range (distance) of the eRacon targets, and the received position (latitude and longitude) of the eRacons, eRadars calculate and report positions for their own vessels. If available, multiple eRacons are used simultaneously to improve position accuracy.

12 There is no dependency on GNSS. The vessels' own positions can be calculated without external data. Calculated positions can be transmitted to the connected navigation systems, such as ECDIS and other bridge equipment, through standard NMEA sentences. ERPS uses WGS84 datum. ERPS technology seeks to add a layer of resiliency to ports and waterways by diversifying position

information inputs to the navigation system with accurate, reliable, and real-time positioning systems independent of GNSS.

13 ERPS is suitable for use in port approach, coastal waters navigation areas and inland waterways. Due to the need to have at least one eRacon in view, ERPS is unsuitable for use in Ocean waters. ERPS can be useful for navigation around or across windfarms and oil fields.

PNT system performance requirements¹⁴ The following table demonstrates actual measured ERPS performance compared to typical requirements:

	Port approach and coastal waters	ERPS Test Bed Results to Date
Accuracy (95% Horizontal Navigation System Error (HNSE))	10 m	25.3 m
System Integrity*	Within 10s	Not included in test bed
Signal Availability	99.8%	87.9% actual during testing
Continuity	99.97% (over 15 min)	Not included in test bed

*Integrity warning of system malfunction, non-availability or discontinuity should be provided to users within 10s.

Port approach and coastal waters requirements are from IMO Resolution A.1046 operational Requirements.

ERPS Test Bed Data are from IALA G1147 *The Use of Enhanced Radar Positioning Systems* Table 1, Dynamic Trial and Best Available.

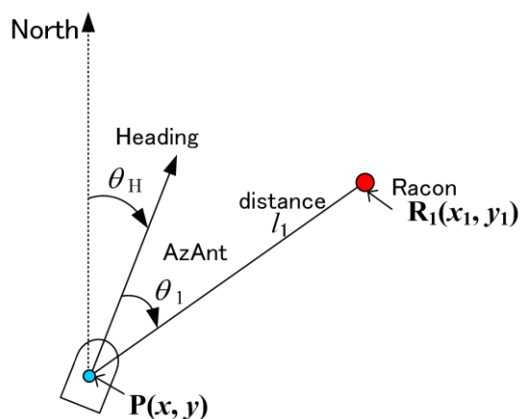
ERPS Technology

15 Knowing the measured azimuth and range of the eRacon targets, the speed and heading of their own vessels. their own antenna elevation and rotation characteristics, along with the received positions (latitude and longitude) of the eRacons, eRadars calculate and report positions for their own vessels.

16 ERPS can be used in various use cases to derive a position as described below:

One eRacon Solution

$$\begin{cases} x = x_1 - l_1 \cos(\pi/2 - \theta_H - \theta_1) \\ y = y_1 - l_1 \sin(\pi/2 - \theta_H - \theta_1) \end{cases}$$

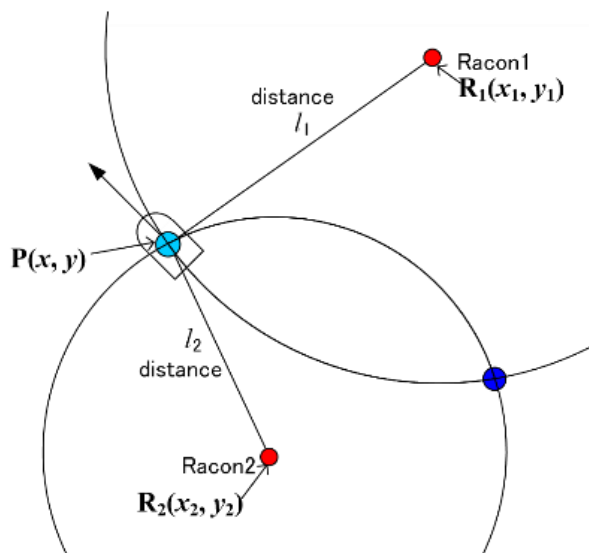


One eRacon Solution

In this case, the eRadar sees only one eRacon, but can use its own true heading to calculate a position solution.

Two eRacon Solution

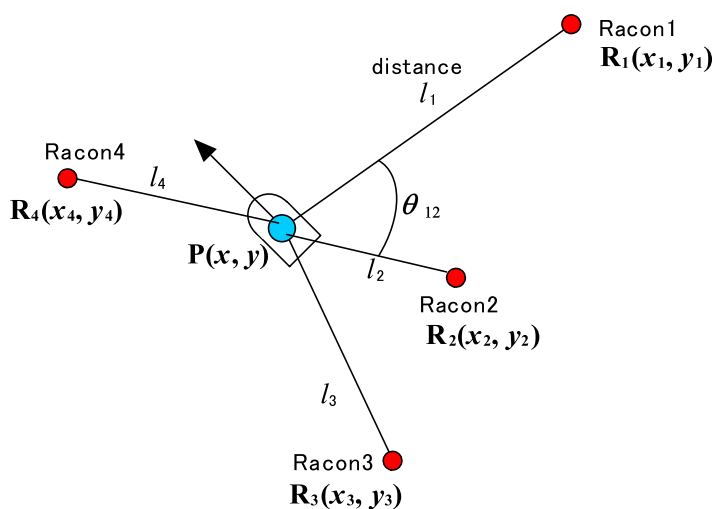
$$\begin{cases} (x - x_1)^2 + (y - y_1)^2 = l_1^2 \\ (x - x_2)^2 + (y - y_2)^2 = l_2^2 \end{cases}$$



Two eRacon Solution

With two eRacons, the radar calculates a position solution that is independent of the heading of the vessel. To note, this example shows the use of Pythagoras' Theorem with target ranges to calculate two possible solutions. Target azimuths are used to discriminate between the two solutions.

Two of Three or more eRacon Solution



Two of Three eRacon Solution

With more than two eRacons, the eRadar choose the two that provide the best solution (please refer to geometry discussion section 18, below). Once the two best are selected, then a position solution

can be calculated similarly to the two-eRacon example. In this example, possible good solutions might use Racon 1 and Racon 4, Racon 4 and Racon 3, Racon 1 and Racon 2, Racon 2 and Racon 3, or Racon 1 and Racon3. Using Racon 4 and Racon 2 shows worst case geometry.

Installation

17 eRacons can be installed at any location that would normally be chosen for a racon. eRacons will appear as normal racons when interrogated by non-ERPS radars. Sites should be chosen per existing racon recommendations and guidelines.

18 Position solutions are dependent on geometry among the eRadar and eRacons. The problem is similar to Horizontal Dilution of Precision (HDOP) for GNSS systems. Wikipedia gives this definition: "Dilution of precision (DOP), or geometric dilution of precision (GDOP), is a term used in satellite navigation and geomatics engineering to specify the Error propagation as a mathematical effect of navigation satellite geometry on positional measurement precision." HDOP is specific to the horizontal position solution.

19 To improve geometry, additional eRacon sites may be needed to give better geometry to a higher number of likely eRadar positions.

Conclusion

20 Resilient PNT is considered as a high-level goal for safety of life at sea, safe transport and an important step towards environmental protection. Today, PNT information are provided from global and regional navigation satellite systems. These suffer from the same vulnerabilities and as a result the PNT information lacks integrity and resilience.

21 Resilience and high-level integrity can be obtained by taking advantage of navigation data from multiple sources with uncorrelated errors. The ERPS technology qualifies as a gap-filling opportunity to provide resilient PNT and high-level integrity assessments. The Organization identified the need for resilient PNT in its e-Navigation Strategy and RCO 5 of the aligned strategic implementation plan.

22 Various implementations and research projects demonstrate the performance of ERPS being able to provide a positioning accuracy of 25.3 meters in coastal waters and is a candidate for a GNSS backup as well as for a solely terrestrial positioning system.

23 ERPS is a terrestrial radio navigation system. As such serving as the desired terrestrial component described in the IMO Performance Standard for Multi-System Shipborne Radionavigation Receivers" (MSC.401 as amended). Within the concept of the "Multi-System Shipborne Radionavigation Receivers" Performance Standard and in support of additional integrity assessments, as described by the "Guidelines for Shipborne Position, Navigation and Timing (PNT) Data Processing" (MSC.1/Circ. 1575), the inauguration of ERPS regional services can be considered as a significant step into resilient PNT availability in coastal areas, and demanding waters.

24 It is estimated that hardware features needed to support ERPS may already be included in the current design of many racons and radars and some devices might be able to be repurposed by software update.

25 It is expected that position accuracy will improve as error sources and corrections for them become better understood.

Actions requested of the Sub-Committee

26 The Sub-Committee is invited to note the information provided on the Enhanced Radar Positioning System.