Results of Discussion on VDES R-mode

VDES Seminar & IALA ENAV WG3 Intersessional Meeting  
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# Summary of Discussions

Following presentations on R-mode provided by the Dalian Maritime University (DMU), the General Lighthouse Authorities of the UK & Ireland and representatives of the R-mode Baltic project, discussions took place in a breakout group on various aspects of AIS / VDES R-mode, as detailed below.

## Need for Resilient Positioning, Navigation & Timing (PNT)

The group understands that Global Navigation Satellite Systems (GNSS) have become the primary source of position, velocity and time data on-board maritime vessels. However, due to the relatively low signal power levels at the Earth’s surface, all GNSS are vulnerable to interference – whether from natural phenomena, such as Solar emissions, or man-made sources. Wide-band jammers are available online, capable of jamming multiple GNSS simultaneously, and incidents of unintentional GNSS jamming caused by faulty or inappropriately operated radio equipment are well documented in the literature. Using multiple complementary positioning systems reduces the probability of any such interference affecting the continuity of maritime navigation.

The need for resilient PNT is well recognised by IMO (see the e-Navigation Strategy Implementation Plan Risk Control Option 5) and the combined use of various radionavigation and augmentation systems (including, potentially, R-mode) on-board vessels is enabled by IMO Resolution MSC.401(95): *‘*Performance Standards for Multi-system Shipborne Radionavigation Receivers*’* (MSR).

## System Requirements for AIS / VDES R-mode

The group feels there is a need to compile a formal set of system requirements for AIS / VDES R-mode which could serve as the basis for system architecture and design activities.

The majority of the group appeared to be of the opinion that AIS / VDES R-mode should be capable of operating as a standalone positioning system, independent of other ship-borne systems. Some envisage R-mode primarily as a source of data for an integrated positioning receiver. The R-mode Baltic project intends to integrate R-mode into the MSR.

R-mode Baltic has defined a set of performance requirements for AIS R-mode based on the IMO performance requirements for recognition of systems in the World Wide Radio Navigation System (Resolution A.1046, WWRNS) and requirements for future GNSS (Resolution A.915). These include: horizontal positioning accuracy of 100 m (95%) for coastal navigation, 10 m (95%) for harbour approaches and inland waters, and a stretch target of 1 – 10 m (95%) for navigation in ports; and position update interval of 15 seconds for coastal navigation, 2 seconds for harbour approaches and inland waters and 1 second for navigation in ports. It was noted that A.1046 specifies a position update interval of 2 seconds for all areas.

The question was raised whether the requirements derived from A.1046 / A.915 were too stringent. The majority view appeared to be that it would be appropriate to have less stringent performance requirements for a backup system. However, the concern was also raised that failing to meet the requirements of A.1046 would prevent R-mode from being integrated into the MSR. It is understood that the question of performance requirements for a backup positioning system had been discussed within the Baltic R-mode project; however, the group was not aware of any discussion on this topic at IMO.

In particular, the need for the 1 second position update interval was questioned as this does not appear to be consistent with the expected dynamics of maritime vessels. The system design should be informed by a user mobility model (currently unavailable). Supplying speed and heading data from the ship’s INS/IMU could enable reduced R-mode update rates. The DMU R-mode team believe an update interval of 10 seconds is appropriate. The impact on the AIS / VDES datalink loading also needs to be considered. R-mode must not significantly affect the communication capability of VDES. Allocating 3 slots every 3 seconds to R-mode transmissions is considered acceptable from the datalink loading point of view (2.6% load); however, initial analysis of AIS R-mode suggests inadequate performance / range with only one-slot AIS messages (5-slot transmissions may be required). Consider also that Message 4 has to be used to allocate slots for Message 26.

A “holdover” time for the backup system also needs to be specified (the minimum duration over which the system must maintain the required performance following a GNSS outage).

## AIS vs. VDES R-mode

Views differed on whether R-mode should be implemented as part of the AIS or VDES.

The DMU researchers expressed the opinion that AIS R-mode is necessary to keep ships safe, and that implementation on the AIS channels only requires the addition of an “ASF”/propagation correction message. It was pointed out that the AIS Recommendation (ITU-R M.1371) permits transmission jitter of ±52 microseconds with respect to the synchronisation signal (equivalent to a ±15.6 km range error) and that, according to one major AIS base station manufacturer, supplying an external synchronisation signal is unlikely to improve the jitter performance. DMU confirmed they had been using custom-built hardware in their R-mode trials, specifically designed for AIS R-mode testing.

An alternative view was expressed that AIS is overused and placing additional burden on AIS is not advised. The added constraints on transmission timing and simultaneous use of the two AIS channels (one of the proposals by R-mode Baltic) is not consistent with how AIS base stations currently work. VDES is much more accommodating than AIS.

## Propagation Channel Characterisation

It was pointed out that all theoretical analyses and simulations of R-mode performance so far had been performed for an Additive White Gaussian Noise (AWGN) channel only. No considerations of multipath propagation have been made yet. It was also pointed out that the waveform bandwidths used in AIS / VDES are too small to allow detailed observation of multipath.

DMU provided some details about the “ASF”/propagation correction system used in their trials. It is understood that the system uses one transmitter and a pair of receivers to estimate what appears to be changes in signal propagation speed. Weather data was also collected during the trials and a mathematical model was developed allowing the propagation conditions to be predicted based on environmental data.

The question was raised of how many reference stations would be required. DMU used three base stations and one reference station in their trials.

Some group members commented that the magnitude of the corrections produced by the DMU trial system was larger than would be expected based on theory and experience from related measurement campaigns (tropospheric effects are expected to be in the order of tens of meters). It was hypothesised that the changes in propagation delay observed by the DMU could have been caused by changing tropospheric refractivity, or possibly effects related to the sea surface roughness.

## Waveform Design

Waveform bandwidth is a crucial parameter for ranging. The greater the bandwidth, the better the ranging performance.

R-mode Baltic is considering three options for the ranging waveform:

1. Simultaneous use of two AIS channels for increased bandwidth;
2. Standard VDES waveforms;
3. Simultaneous use of VDES and AIS waveforms / channels.

The possibility of using ordinary AIS/ASM transmissions was discussed (unknown data sequence vs. fixed, known, data sequence). R-mode Baltic is using a known data sequence. If the data is unknown then the receiver must be able to perfectly decode the message – this is challenging in low SNR conditions and would result in shorter station ranges for R-mode. DMU have done some research into tracking AIS messages without decoding the data, relying on a known training sequence (VDES, not AIS).

A proposal was made to consider using the AIS/VDES guard bands in R-mode waveform design. Ranging signals could be placed in the 50 kHz guard band between VDE-TER and ASM. R-mode Baltic also proposed adding two CW signals at the edges of the AIS channels.

## Equipment Considerations

There appeared to be agreement that the burden associated with R-mode should be on the shore infrastructure, not on the ship’s transceiver.

R-mode will definitely require changes to the shore infrastructure. Base stations will have to be accurately synchronised. Nanosecond-level transmission timing accuracy is required.

Concerns were voiced about the impact of R-mode on VDES throughput.

## Standardisation

Discussion took place on the need to change existing standards. It is the group’s view that it is not desirable to make changes in the AIS standard. It is clear R-mode requires both transmitters and receivers that do not exist today. A substantial change in the behaviour of AIS base stations would be required to accommodate R-mode. VDES will be used to change the AIS “box”; R-mode must be added to VDES rather than the AIS. Adding R-mode to AIS could send a confusing message as IALA has also been saying that the AIS channels are getting overloaded.

The idea of R-mode came from the ACCSEAS project. It was envisaged to be included in the IMO MSR standard (Resolution MSC.401(95)).

## Regulatory Matters

It was pointed out that VDES has allocation as a maritime mobile service, not as a radionavigation service. The group believes that the appropriate change to Radio Regulations could be considered under the e-Navigation WRC-23 agenda item.

# Proposed Next Steps / “Road Map”

The R-mode Road Map developed by the IALA ENAV/ENG PNT WG was reviewed and a number of proposed next steps with respect to VDES R-mode were identified, as summarised below.

1. Business case for VDES R-mode?
2. Research
   1. User mobility model
   2. Maritime VHF propagation channel characterisation
      1. Signal time of flight biases and variability (spatial / temporal)
      2. Multipath characterisation
   3. Performance bounds for ranging
      1. AWGN channel
      2. Multipath fading channel
   4. Synchronisation techniques
   5. High-stability clock
      1. Base station
      2. User equipment
3. System development
   1. Review \ consolidate the system requirements for VDES R-mode
      1. Standalone positioning system vs. a component of a multi-system solution
      2. Coverage requirements
      3. Performance requirements
      4. “Holdover” time (the minimum duration over which the system must maintain the required performance following a GNSS outage)
      5. Security
      6. Cost of base station equipment, user equipment and operation
   2. System architecture development
      1. Literature review (ACCSEAS, DMU, R-mode Baltic)
      2. Ranging method
      3. Need for reference stations – informed by results from B., C.3.1
   3. Detailed design
      1. Ranging waveforms
      2. Positioning algorithm (TOA, TDOA, AOA, RSS)
      3. Assess against requirements, if necessary repeat process to optimise system
   4. Testing
      1. Testbed development
      2. Test campaign
      3. Assess against requirements, if necessary repeat process to optimise system
4. Standardisation
   1. Update VDES specification based on results of C.
5. Regulatory matters
   1. Radionavigation service allocation for VDES channels

# Proposed Action Items for ENAV22 (8th-12th October 2018)

1. Review the system requirements for VDES R-mode identified by IALA ENAV/ENG PNT WG;

Note: IALA ENG PNT WG will not have met before ENAV22. Jan S. to liaise with Alan Grant (PNT WG Chair) ahead of ENAV22 to provide preliminary input on this.

1. Review the system requirements specification for AIS R-mode produced by the R-mode Baltic project (see the ‘R-mode Baltic - Baseline and Priorities’ document).
2. Consolidate system requirements for VDES R-mode.