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Technical Domain / Task Number 2 3.1.11. Monitor developments in GNSS, DGNSS, radar, resilient PNT, ePelorus, terrestrial systems, inertial and any other relevant areas etc.

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WG5 (PNT)

Information paper

R-Mode status update

# Summary

The document provides a brief update of test bed measurements performed within the ACCSEAS project early 2015 at the Dutch coast. Further it informs about ongoing R-Mode tests from a German DGPS site, located at Heligoland, in the German Bight. In addition possible future work to further deploy R-Mode as a potential terrestrial backup to GNSS will be provided.

## Background

Position fixing systems are identified as one strategic key element of e-navigation. Existing and future Global Navigation Satellite Systems (GNSS) like GPS, GLONASS and GALILEO are fundamental infrastructures for global determination of PNT data. Additionally, terrestrial services are used to improve performance or to ensure backup functionality to overcome the vulnerability of GNSS. As a contribution to the development of redundant positioning, a terrestrial backup navigation system based on ranging signals (R-Mode) transmitted from MF radio beacons and/or AIS base stations was proposed. Both systems are globally distributed and are widely used in the maritime field. Certain amendments with a moderate investment of the above systems (so-called Ranging-Mode or R-Mode) are suggested, which would allow an additional world-wide terrestrial backup in coastal waters, high densely traffic areas and for harbor approach areas. To further develop the new system idea it was decided to perform a feasibility study as well as a practical field demonstration within a transnational EU project named ACCSEAS (Accessibility for Shipping, Efficiency, Advantages and Sustainability).

One aim within the ACCSEAS project was further to implement a test bed which enable on air measurements for the proposed R-Mode using MF transmission from an IALA radio beacon station. For this purpose a prototype of an MF-DGPS R-Mode transmitter and MF-DGPS R-Mode receiver have been developed. The transmitter has been installed in IJmuiden Netherlands and the receiver has been deployed along the Dutch coast for initial on-air testing of the R-Mode concept. While positioning is not possible with only one R-Mode transmitter, the combination of a synchronized transmitter and receiver pair allows for useful testing of the R-Mode concept.

## The R-Mode Test Bed using MF DGNSS transmissions

The R-Mode Test Bed using MF DGNSS transmission within the ACCSEAS project was chartered only through early 2015; this limited what can be included as part of the test bed. However, even this limited test served as a proof-of-concept and provided a basis for further work. The following was accomplished within the timeframe of the ACCSEAS Test Bed:

* Installation of a single R-Mode transmitter at one site.
* Development and installation of a fixed R-Mode receiver to act as a monitor site.

The installation of the mentioned system components enabled the following tests:

* usability of standard MF transmitter and antenna setup for R-Mode operation
* proof of R-Mode concept using MF transmissions from IALA radio beacons
* proof co-existence of R-Mode signals and DGPS-transmission within one channel
* measure achievable accuracy figures (range and timing) in the test area
* analyze mutual influence of R-Mode and DGNSS signal

## Test Bed in Ijmuiden, Netherland

An R-Mode transmitter was installed at the Dutch coast in Ijmuiden which enabled R-Mode tests within a range of about 50 km. For the transmission of the R-Mode signals a typical MF transmitter, and MF transmitting antenna was used. Based on the 3 different solutions evaluated in the feasibility study the R-Mode transmitter was able to provide 3 signals:

* One standard MSK signal (legacy signal)
* Two CW signals (R-Mode signal)

For this purpose an R-Mode modulator was developed which enabled the transmission of standard RTCM messages used for the DGNSS service and two independent CW signals which can be adjusted concerning frequency and output. Furthermore, the transmission of the ranging signals needed a reference timing which was received from a rubidium clock.

The R-Mode receiver needed to have the capability of measuring the pseudo-range from the R-Mode transmitter. Further the R-mode receiver was able to demodulate the MSK signal and decode the RTCM messages. This data on pseudo-ranges were logged along with position and time for later analysis. For the R-Mode test bed a prototype R-Mode receiver was developed consisting of an H-field antenna, a band filter with pre-amplifier and a PC with ADC board and MATLAB software. The receiver together with a rubidium clock was installed on a lighthouse tower in Noordwijk. The distance to Ijmuiden was about 25 km.

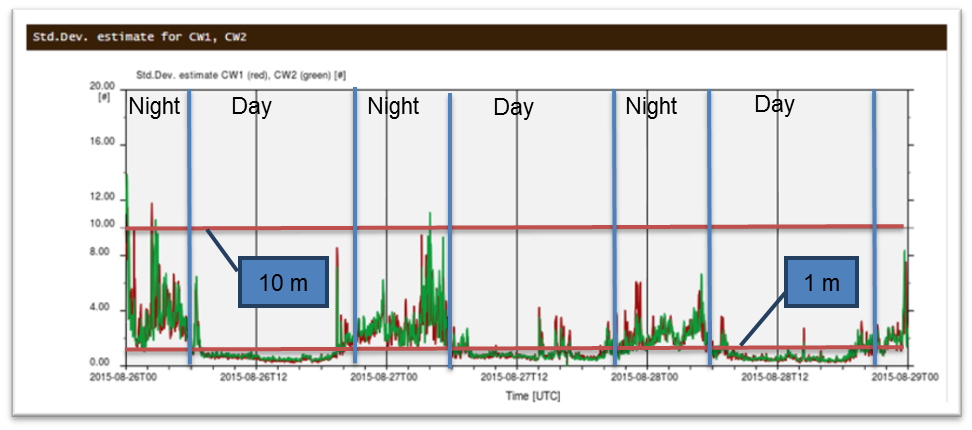
## Results from first on air tests

After the setup of the R-Mode equipment in Ijmuiden and Noordwijk a first measurement campaign was performed over a two day period (07-08 February 2015). The recorded data were analyzed with respect to signal to noise ratio and the standard deviation of the measured range. The range was based from the phase determination of the two CW signals and the beat frequency of both signals to solve the ambiguity. The resulting ranging performance of the R-Mode signal using MF transmissions was very encouraging and validated the theoretical findings of the R-Mode feasibility study. The standard deviation measured was in a range of 2-5 m. Nevertheless, it must be noted that these results were taken on a short distance of about 25 km. Further testing was required in distances between 100 and 200 km to get a full picture of the R-Mode ranging performance, also during night when sky wave interference may degrade the measurements.

## First results from MF-R-Mode tests at Heligoland in the German Bight

Hence, further tests were made feasible in the German Bight by re-locating the above equipment. These tests are currently ongoing using an operational DGPS site in Germany. Here the location Heligoland in the German Bight was chosen. This site enables a testing of the MF R-Mode ranging performance along the German coast line with distances of up to 200 km. For these measurements the same test equipment, developed during the ACCSEAS project, was used. The tests started in mid-August and will run until the end of 2015. During the tests the R-Mode receiver will be placed on different locations starting from a distance of about 70 km with a stepwise increase towards a distance of 200 km. First tests were already performed at a local workshop of the German Federal Waterways and Shipping Administration in Tönning. The distance to Heligoland is about 70 km. The results were again pretty good resulting in a day time standard deviation of the measured range of about 1m. During night, sky wave interference was measured resulting in a measured range performance of about 5 m with maximum outliers of about 10m. Figure 1 shows some results from this measurement campaign.

At present the R-Mode receiver is placed on the island of Sylt (approximately 100 km distance). First results show a comparable range error as measured from Tönning previously. A detailed analysis of the data will be conducted until the end of 2015.



## Outlook to future work

Future work about R-Mode seems to be required addressing the following topics:

1. R-Mode using MF transmissions from MF radio beacons

* measuring the influence of sky wave and other environmental variations
* measuring the influence of transmitter and receiver setup
* assessment of various R-Mode solutions (based on R-Mode feasibility study)
* Setup a testbed which enables positioning tests
* Further develop the existing R-Mode receiver to perform position calculations
* Further develop the existing R-Mode receiver towards a user friendly receiver

1. R-Mode using AIS VHF transmissions

* Setup a testbed to enable transmissions from AIS shore infrastructure
* Further develop the R-Mode receiver to use AIS transmissions
* Perform measurements

1. Test the combined solution

* Setup a testbed to enable transmissions from MF radio beacons and AIS shore infrastructure
* Further develop the R-Mode receiver to use combined MF/AIS transmissions
* Perform measurements

1. Start standardisation process

# Related documents

* e-NAV4-07-10A/B German Contribution WWRNP (the original proposal for R-, T-, and D-Modes) (2008)
* enav16\_14\_2\_41\_wg5\_draft\_recommendation\_on\_pnt\_relevant\_services\_and\_systems
* enav17\_10\_4\_5\_accseas\_final\_report\_v1
* enav17\_10\_4\_6\_accseas\_final\_conference\_report
* enav17\_10\_5\_6\_accseas\_service\_description\_msps\_multi\_source\_positioning\_system\_v1

# Action requested of the Committee

The Committee is requested to:

1. note the information provided,
2. consider a possible co-ordination of future work regarding R-Mode development

1. Input document number, to be assigned by the Committee Secretary [↑](#footnote-ref-1)
2. Leave open if uncertain [↑](#footnote-ref-2)