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R-Mode in the Baltic Sea

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Outline



- R-Mode Baltic – A testbed for the Southern Baltic Sea
- The need for resilient PNT
- R-Mode Basics
- Results of measurements, theoretical analysis and developments (MF)
- Conclusions

Project R-Mode Baltic 2017 - 2020



Aims

- Build a R-Mode testbed in the Baltic Sea until 2020 that utilises maritime radio beacons and AIS/VDES base stations
- Show R-Mode is able to meet maritime user requirements for a backup system.

R-Mode Baltic – Work topics



KONGSBERG



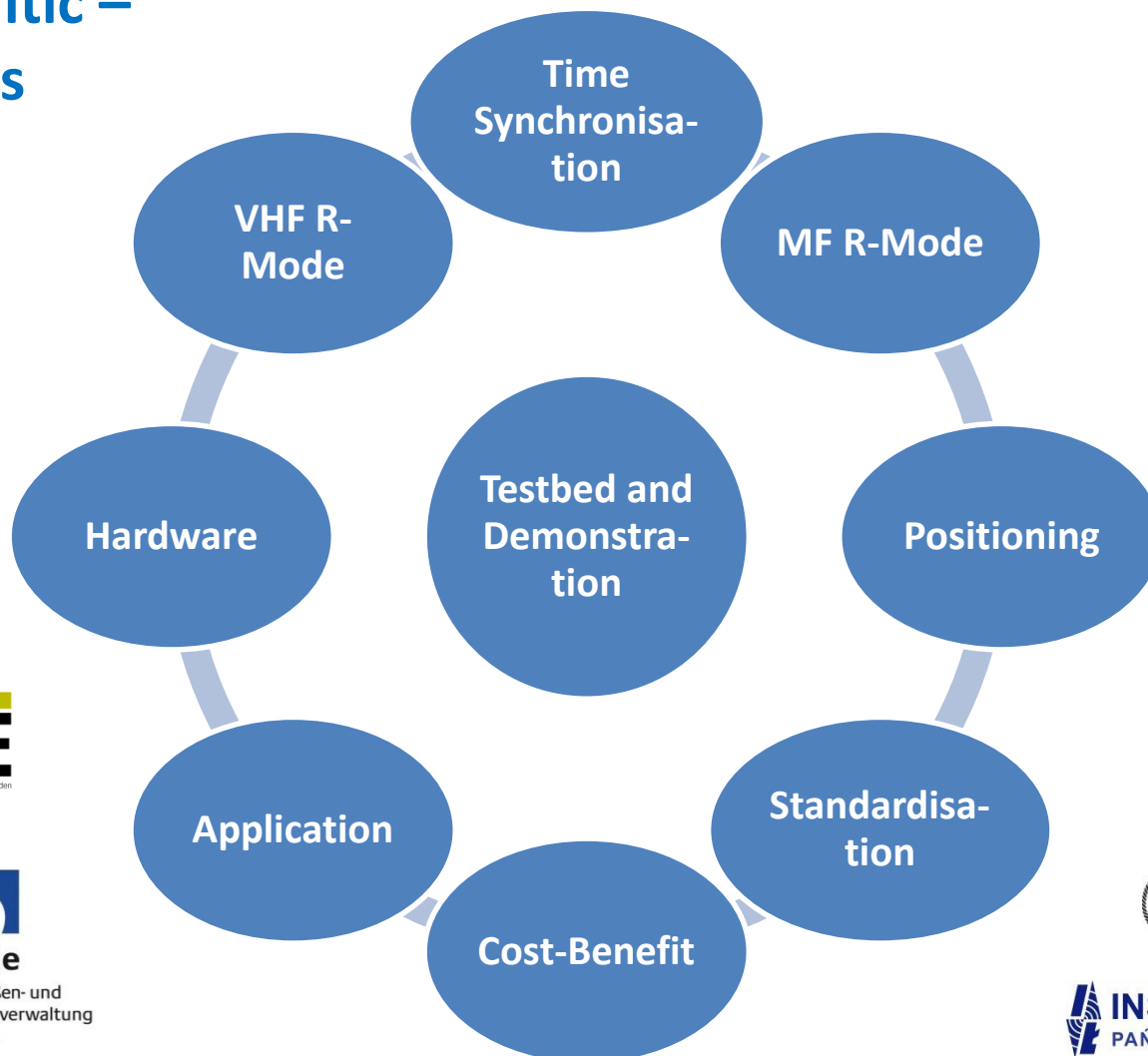
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User requirement used in the project R-Mode Baltic

The project team will setup a **back-up system** for GNSS, which in case of unavailability of GNSS should allow positioning for at least **2 hours** with:

	System level parameters				Service level parameters			
Maritime region	Absolute Accuracy	Integrity			Availability % per 30 days	Continuity % over 15 minutes	Coverage	Fix interval (seconds)
	Horizontal (meters)	Alert limit (meters)	Time to Alarm (seconds)	Integrity Risk (per 3 hours)				
Coastal	100	250	30	10^{-4}	99	N/A ²	Regional	15
Port approach and restricted waters	10	25	10	10^{-4}	99	99,97	Regional	2
Inland Waterways	10	25	10	10^{-4}	99	99,97	Regional	2

The need for resilient PNT

E-Navigation

- IMO E-Navigation

“the harmonized collection, integration, exchange, presentation and analysis of marine information on board 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.”

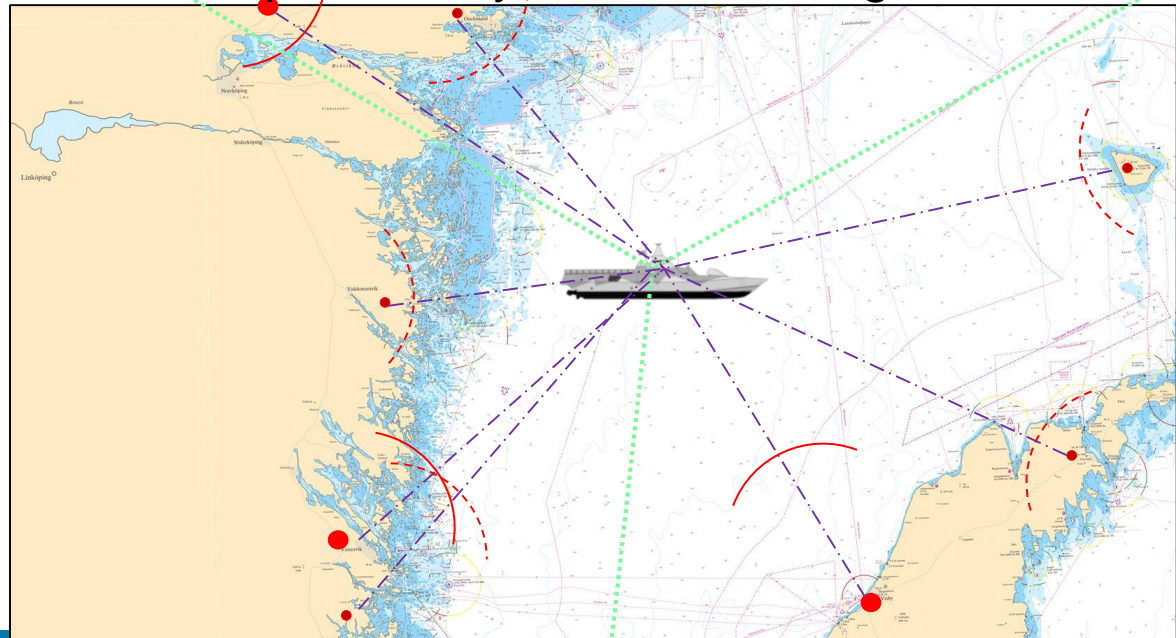
The need for resilient PNT

E-Navigation

- To be realized by the IMO Strategy Implementation Plan (adopted in 2014) by five prioritized solutions:
 - improved, harmonized and user-friendly bridge design;
 - means for standardized and automated reporting;
 - improved reliability, resilience and integrity of bridge equipment and navigation information; (Ensuring reliable and resilient PNT data is particularly important for safe navigation at sea)
 - integration and presentation of available information in graphical displays received via communication equipment; and
 - improved Communication of VTS Service Portfolio (not limited to VTS stations).

R-Mode (Ranging Mode)

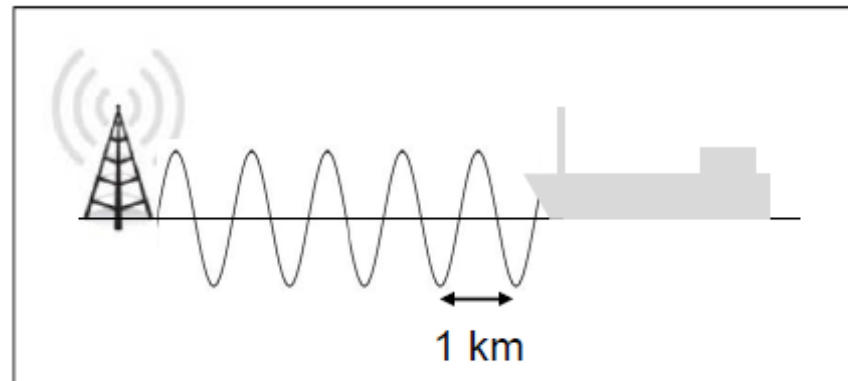
- R-Mode is based on "Signals of Opportunity", i.e. already existing transmitters/infrastructure
- Add ranging capability to the marine signal (e.g. VHF and MF)
- A receiver calculates its position by TOA and triangulation



R-Mode

- Needs very accurate clocks (atomic clocks) at the transmitting station
- Needs very good control of the transmitting chain in each transmitter station

MF MSK signal



Baltic Sea as Suitable Test Bed

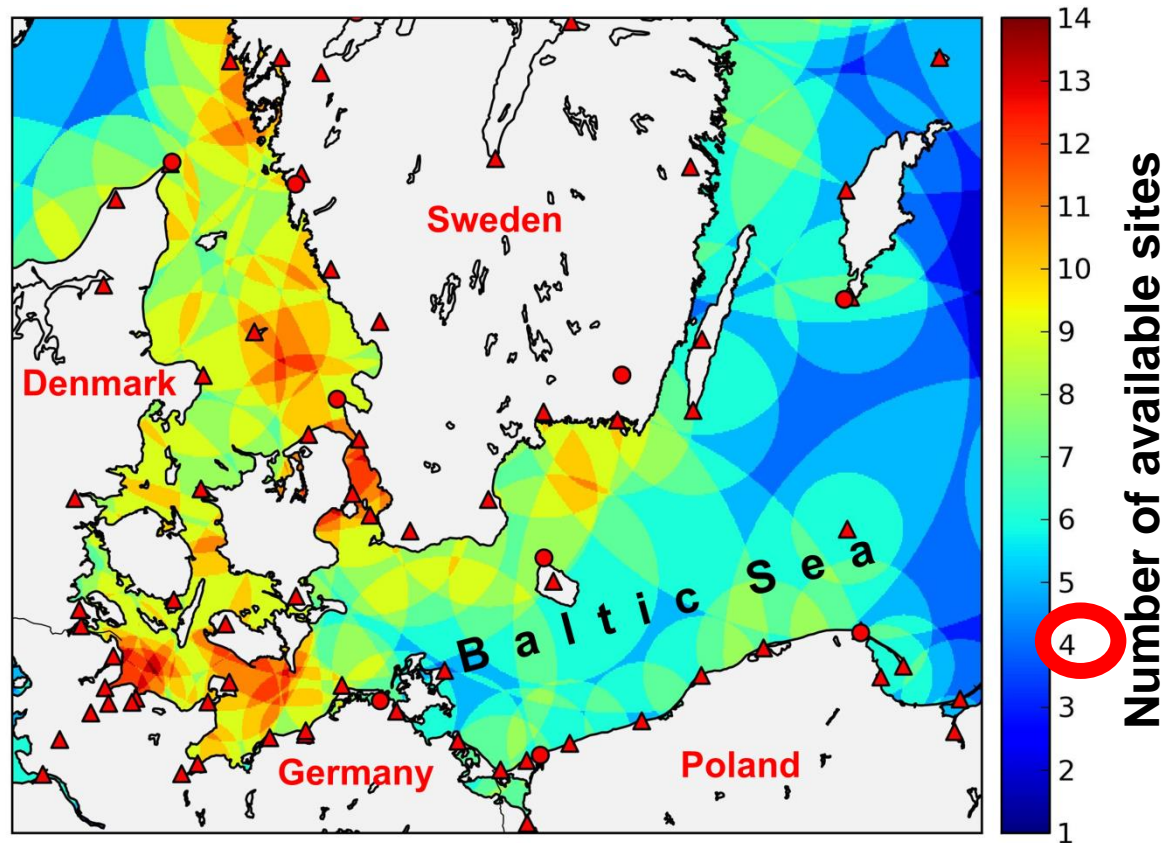
- Marginal sea surrounded by 9 states
- Important for transport of goods and persons
- Challenging conditions for maritime traffic
 - Shallow waters, narrow straights, many small islands
 - High traffic density
 - Crossing traffic routes
- Challenge: coordinate activities of all Baltic Sea states
- EU strategy for the Baltic Sea region
=> increase maritime safety

Baltic Sea shipping traffic



Source: HELCOM

Coverage of the Baltic Sea with VHF and MF signals



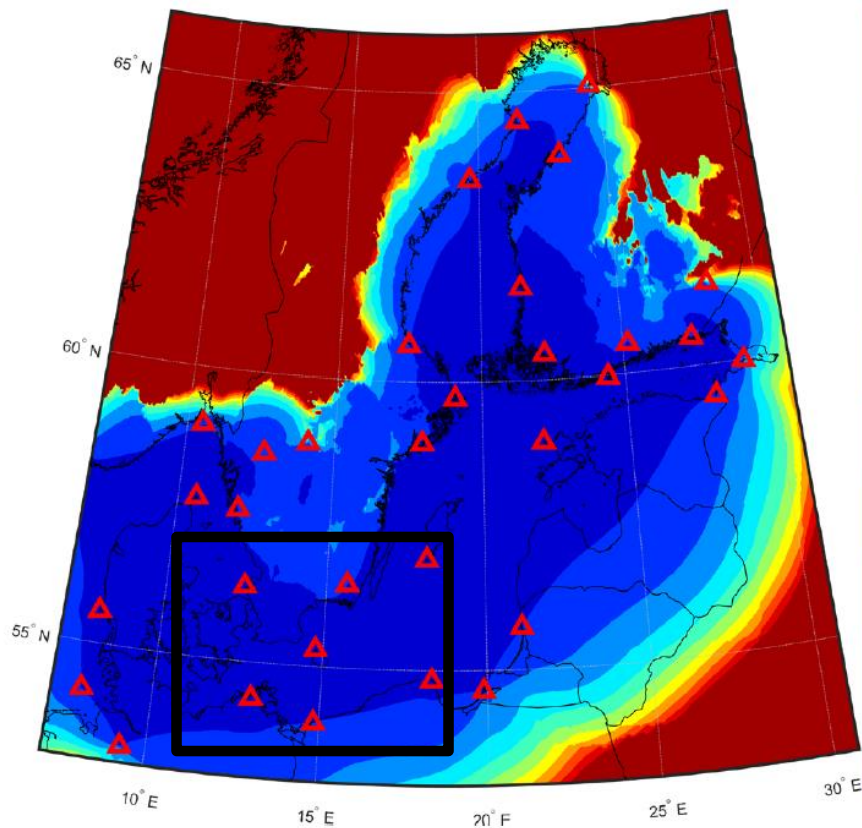
MF R-Mode



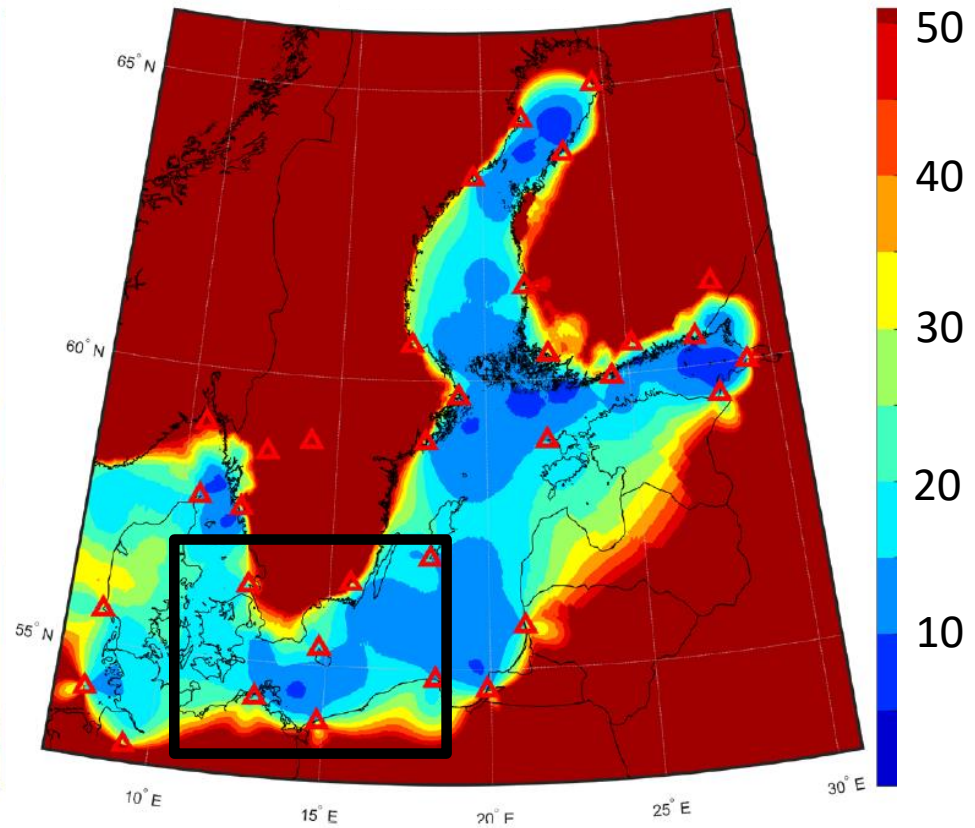
MF prediction based on propagation and interference models (GLA)

Estimated position accuracy based on coverage and HDOP predictions for the Baltic Sea

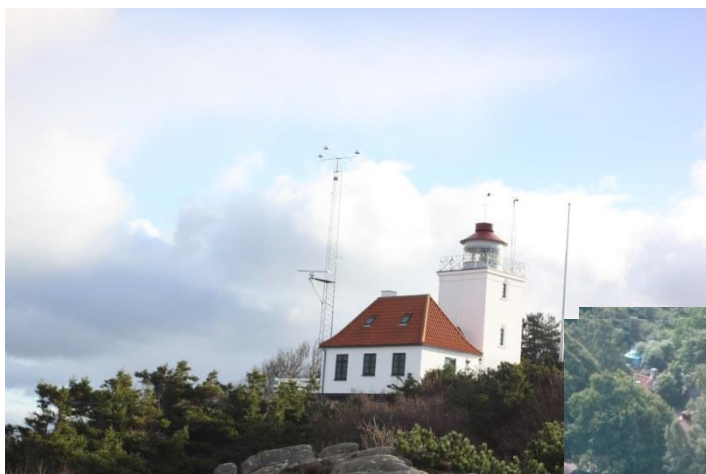
Day-time hours, 95% accuracy [m]



Night-time hours, 95% accuracy [m]



Radio beacon side inspection



Hammerodde



Holmsjö



Rozwie

Tests performed



- Approach: replace modulator
- Measure spectra in near field
- Observe influence on monitor station
- Antenna impedance measurement



Conclusion radio beacon side inspection

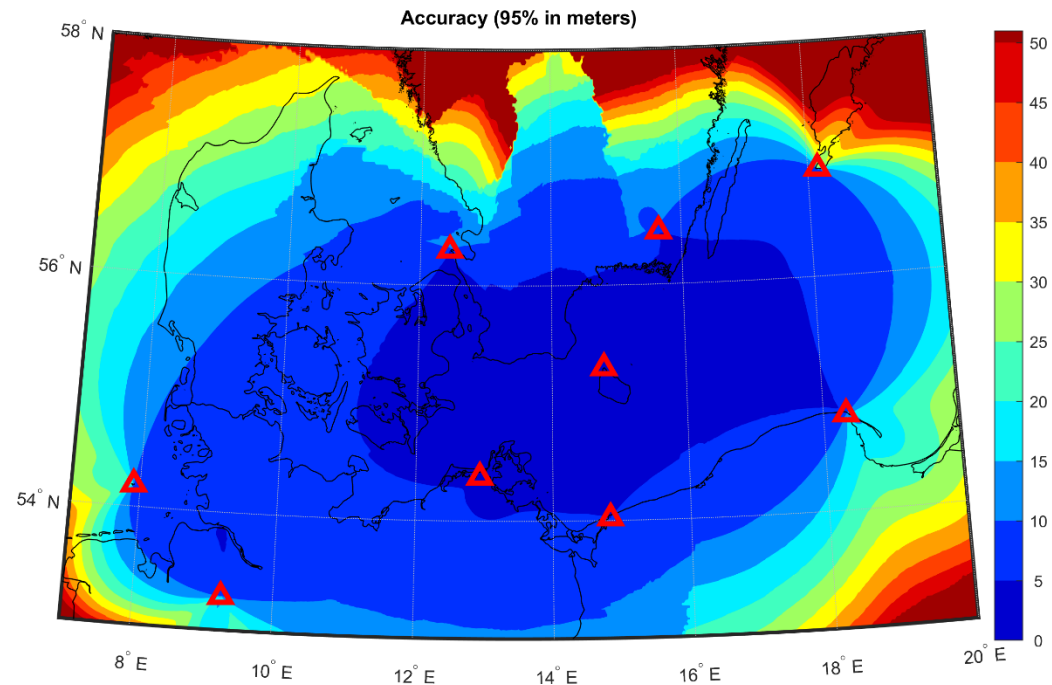
- All antennas work for R-Mode
- No changes were observed from the monitors
- Non linear amplifiers are not suitable
 - **Upgrade of Danish, Swedish and German stations is possible by modulator exchange**
 - **Polish stations need a linear transmitter**



MF R-Mode Testbed Implementation

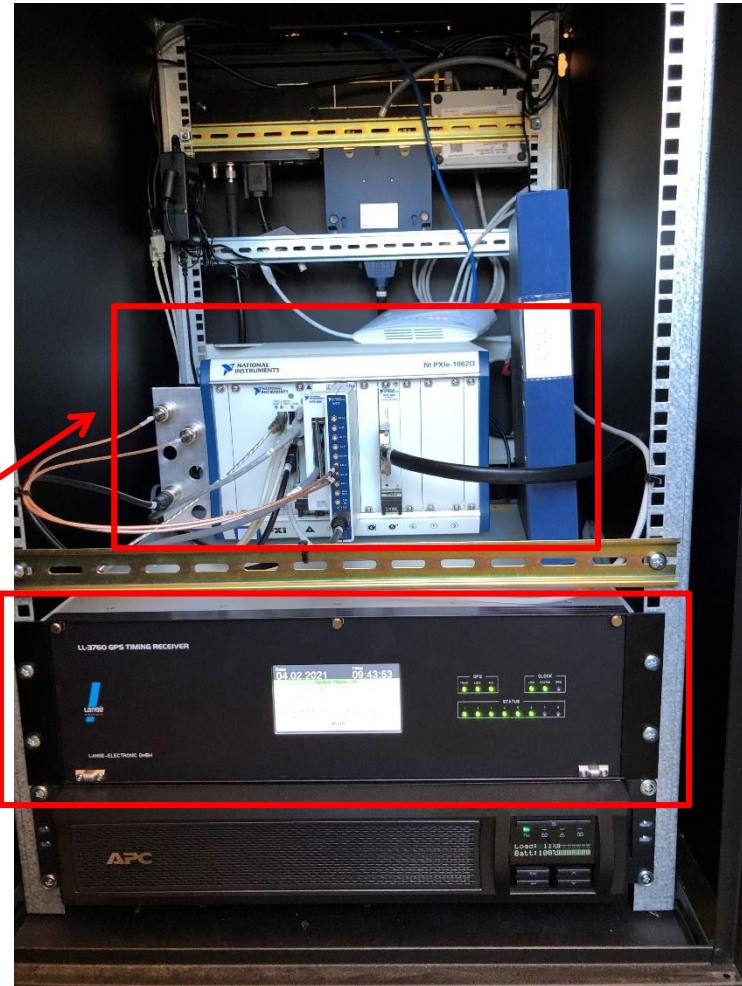


- Swedish and German maritime administration purchased MF R-Mode modulators and clocks
- First installations started in October 2019
- In total we have 9 R-Mode enabled MF transmitters

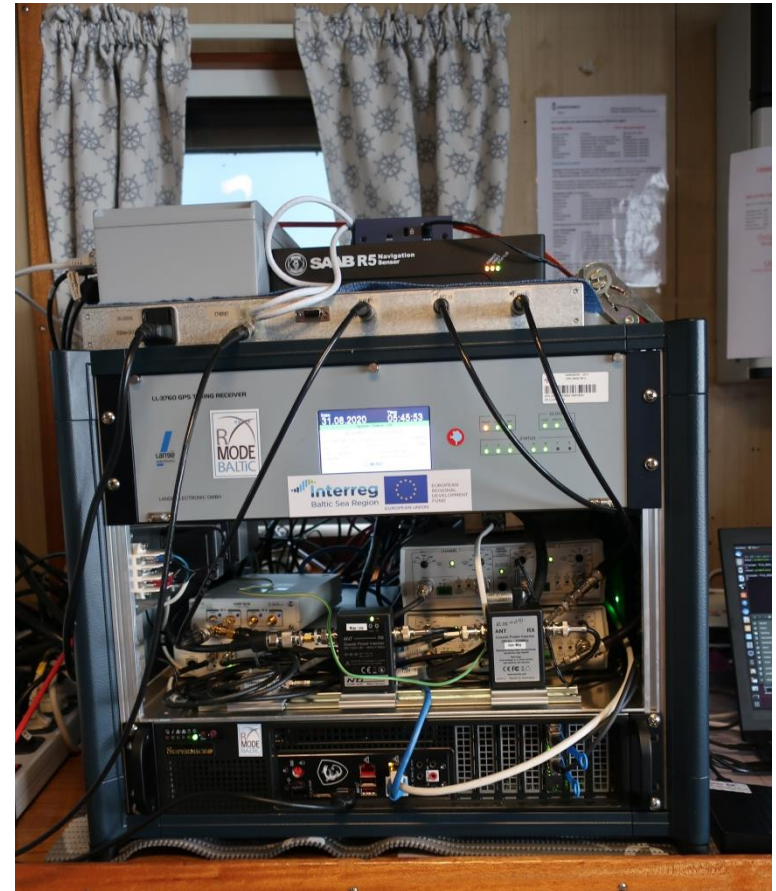


MF R-Mode Testbed Implementation

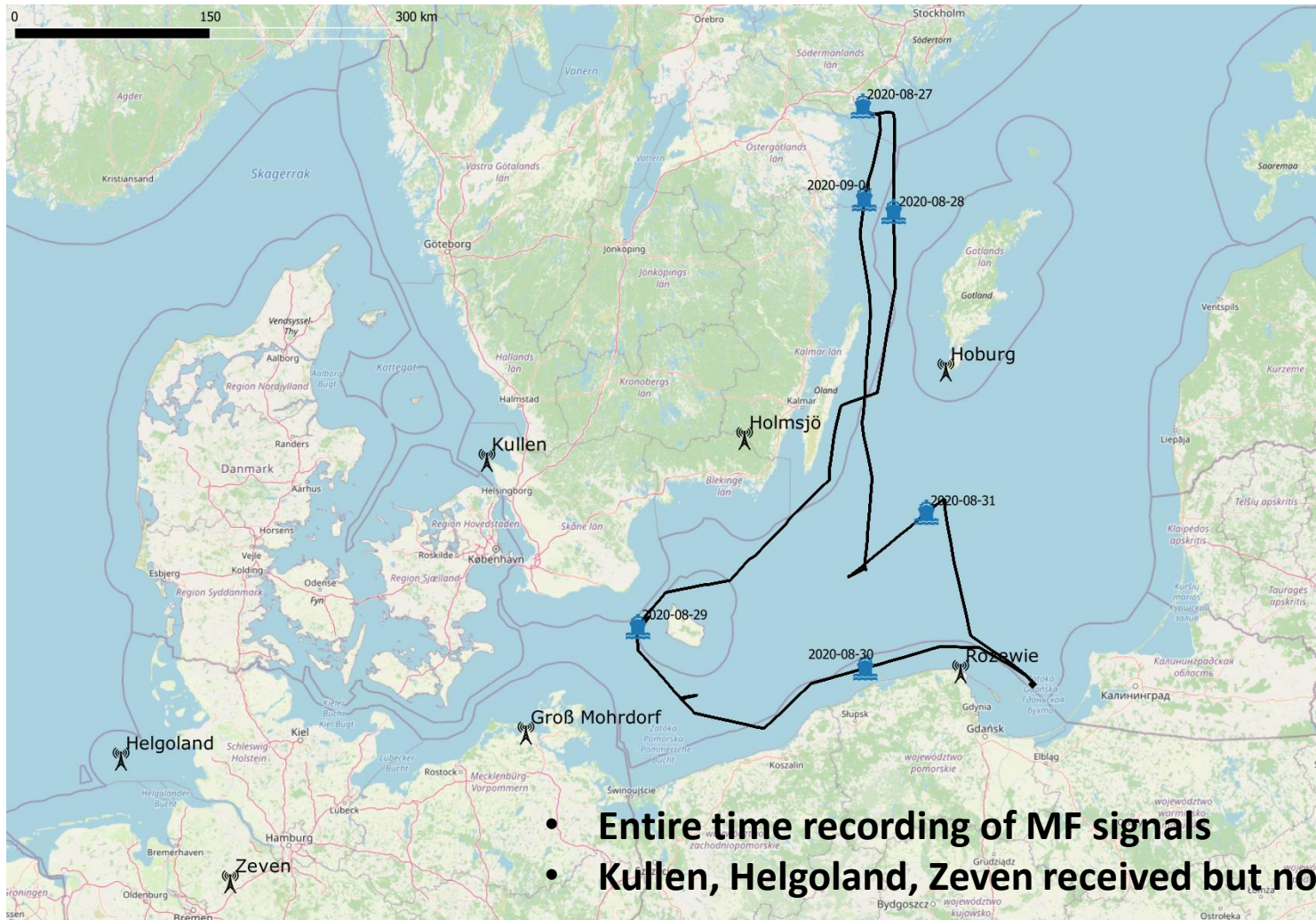
- Overlay two signals for ranging on the MSK signal
- Built by Novator Solutions, Stockholm on specifications from the project
- Generic computer and digital to analogue board for MSK signal generation
- Atomic clock for time



Test with Fyrbyggaren in August 2020



Route Fyrbyggaren: 27.08. – 01.09.2020

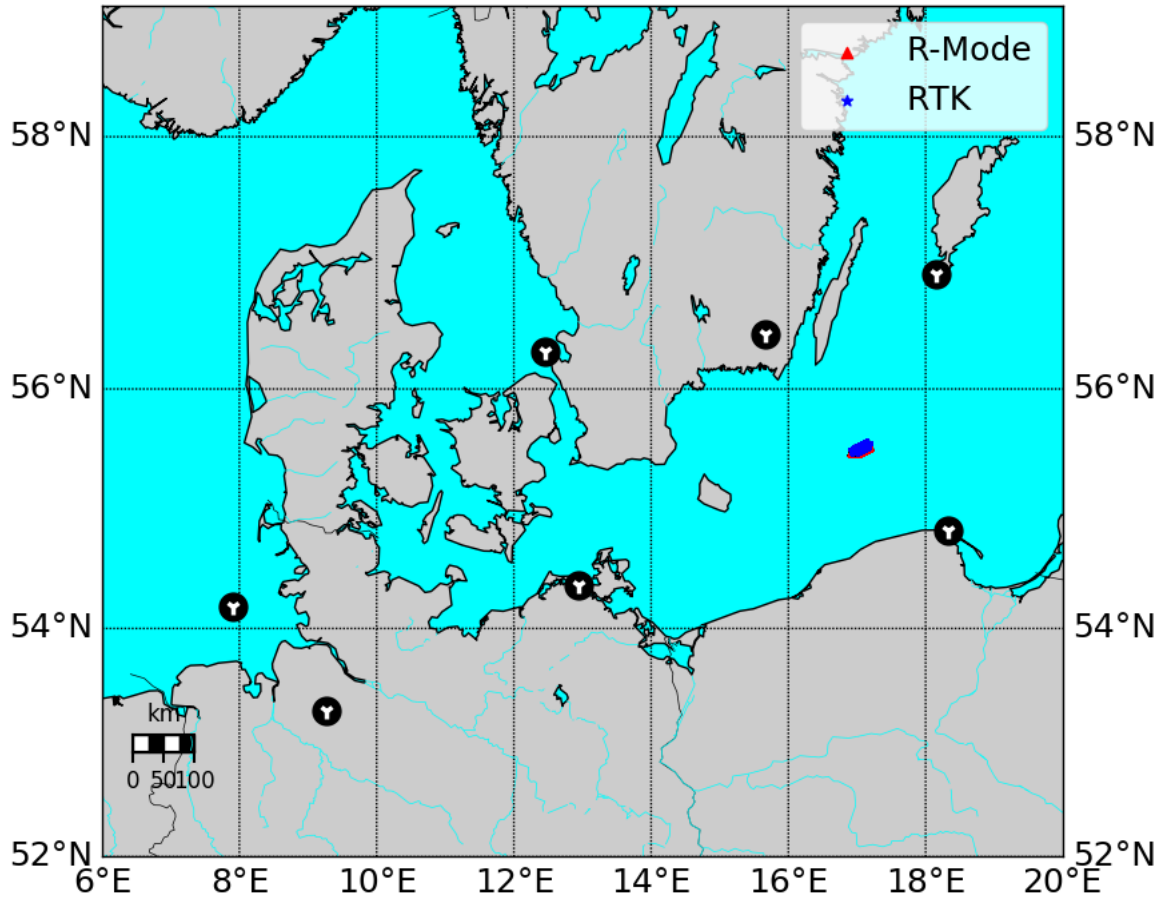


- Entire time recording of MF signals
- Kullen, Helgoland, Zeven received but not usable

31.08.2020 5:00 – 6:43 UTC



R-Mode versus GNSS RTK

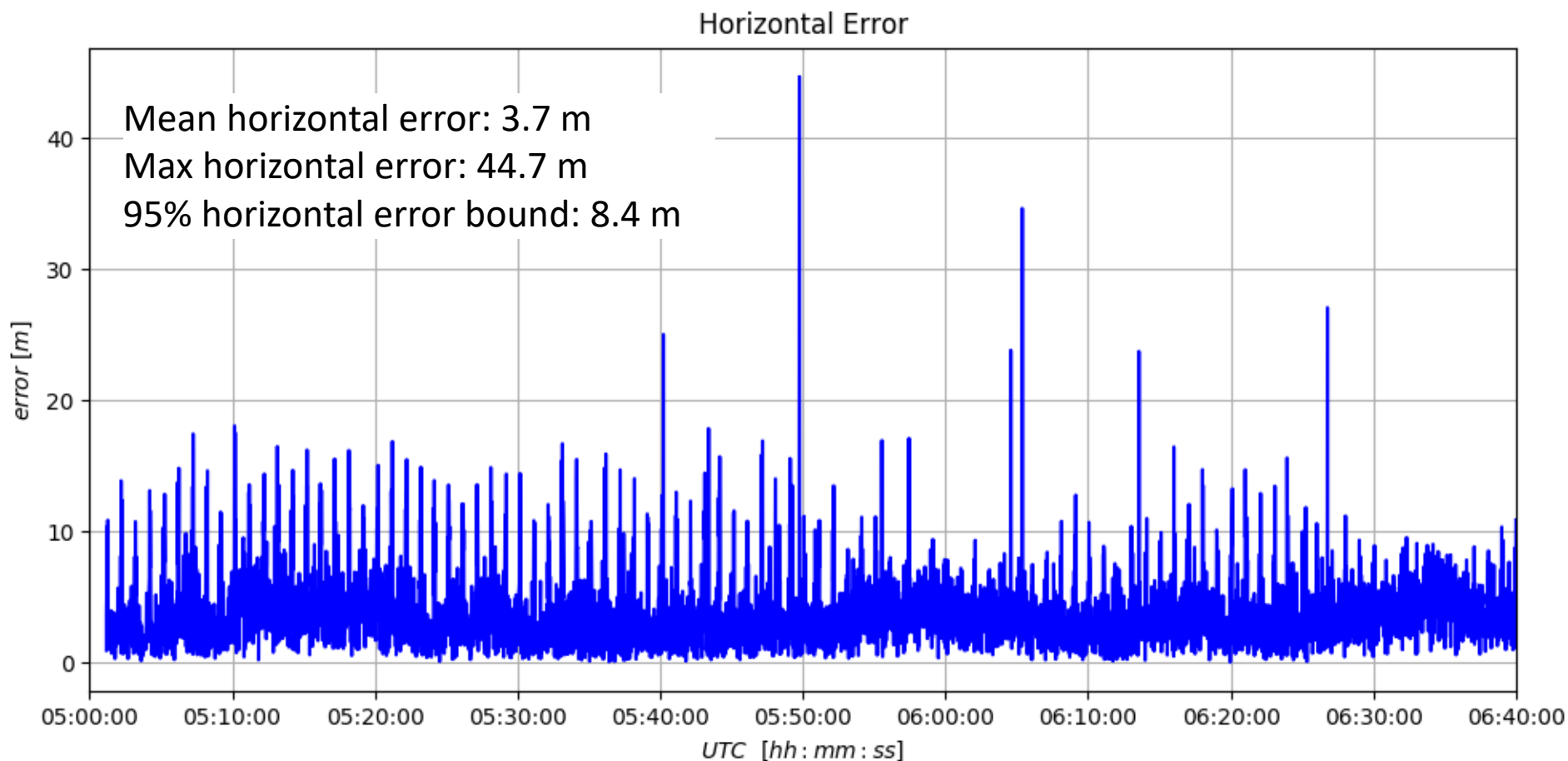


Considering signals from

- Holmsjö
- Hoburg
- Rozewie

31.08.2020 5:00 – 6:43 UTC

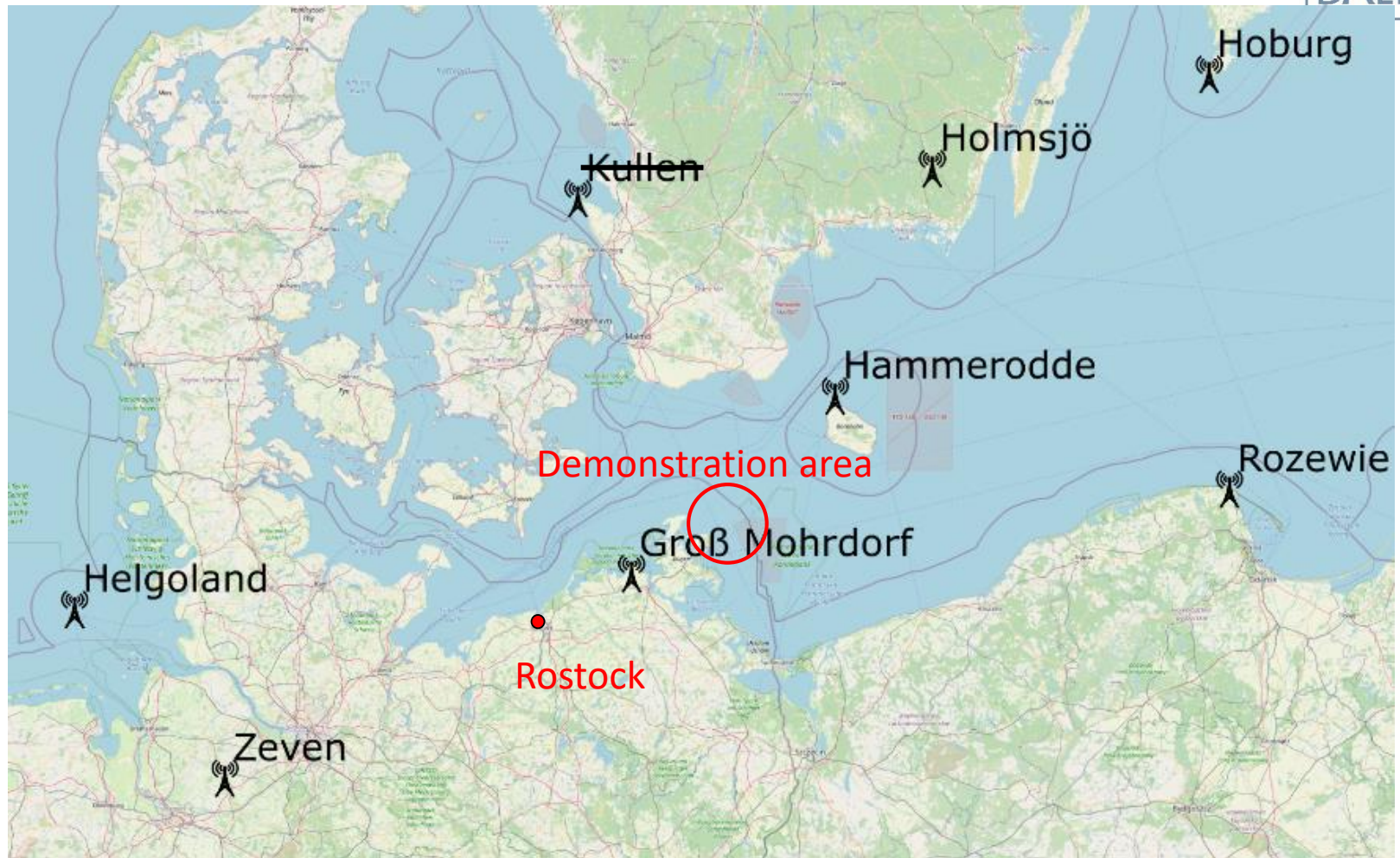
2D Positioning error



Test with Deneb February 2021

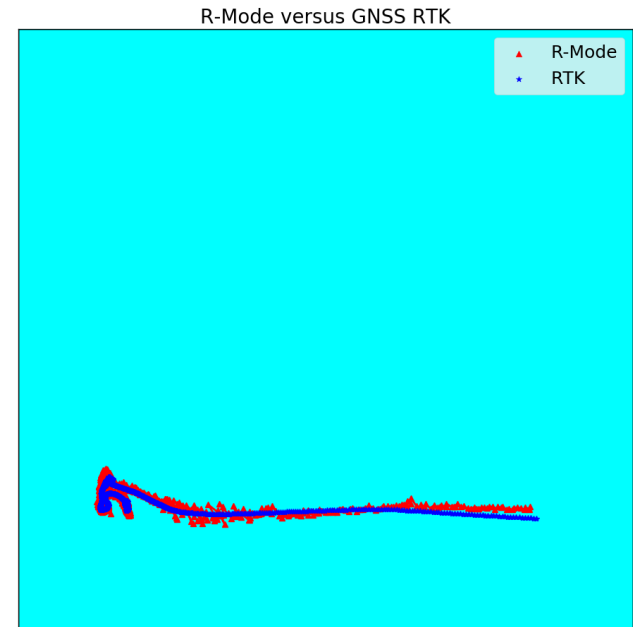
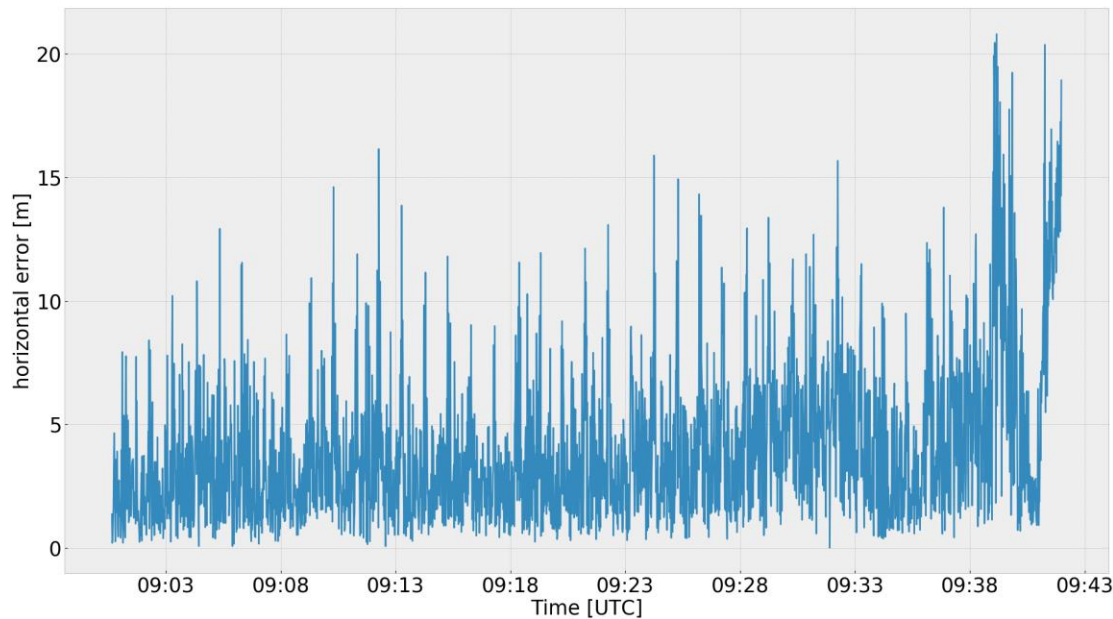


MF transmitter sites



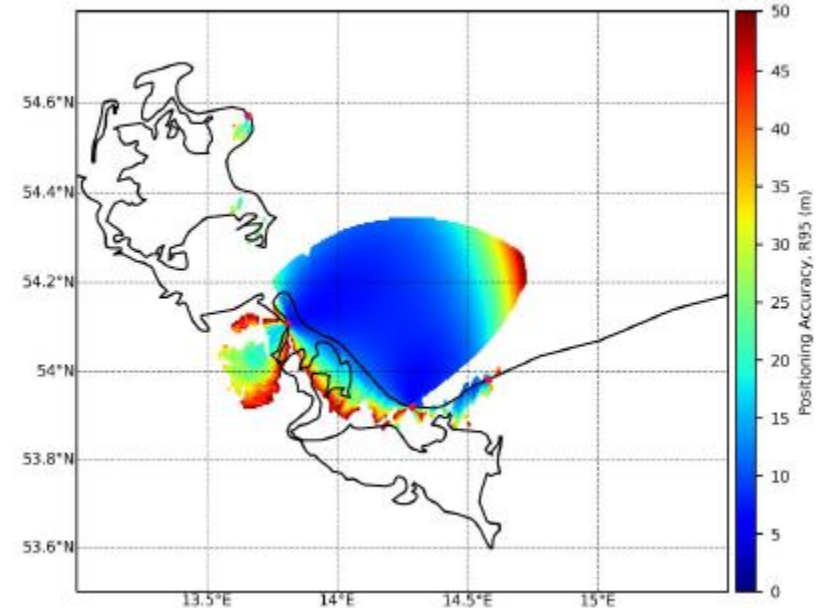
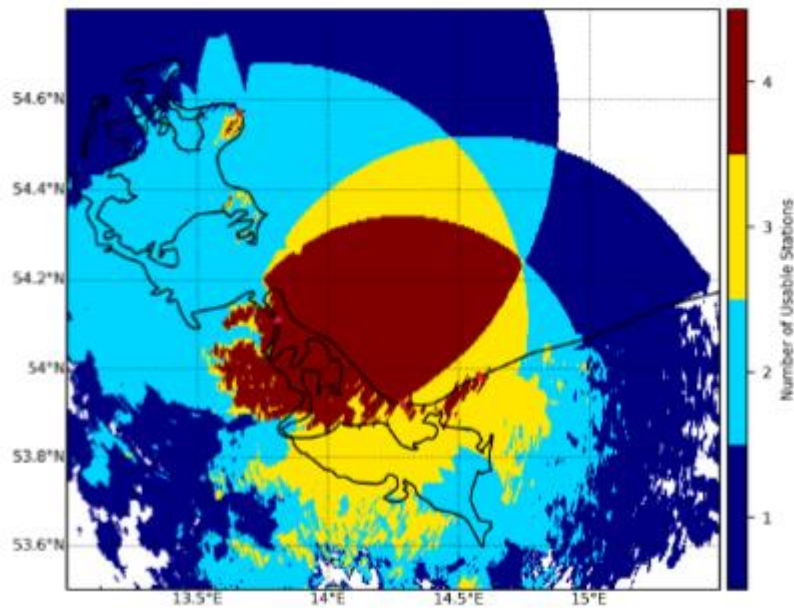
Quasi static – slow movement (9.00 – 9.42 UTC)

- Mean position error: 4.0 m
- 95th position error: 10.3 m
- Max position error: 20.8 m



VDES R-Mode Coverage Prediction Area 1

Between Germany and Poland to be done in 2021



Conclusions

- IMO set out requirements for resilient PNT and R-Mode is a candidate for e-Navigation
- Baltic Sea is a suitable region for a combined MF and VDES R-Mode testbed.
- Theoretical analysis shows, user requirement can be fulfilled at day-time.
- Tests has shown that R-Mode is candidate for resilient PNT
- R-Mode will be further developed during 2021 in “R-Mode Baltic 2”
- Project video:
<https://www.youtube.com/watch?v=2CWWKhSR0C4>



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