R-
Mode
Baltic

Interreg
Baltic Sea Region

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

R(anging)-Mode Baltic

A step forward towards reliable maritime PNT data

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RNN seminar on Our dependency on GPS/GNSS,
Stockholm

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Content

R-Mode Baltic

- Introduction to R-Mode
- R-Mode Signals of Opportunity
- Project: R-Mode Baltic
- Summary

GNSS in maritime domain

Safe navigation requires backup system

R-Mode Baltic

- GNSS has become the primary source for maritime positioning, velocity and timing (PVT).
- GNSS data is used in many ship systems e.g. AIS, ECDIS, INS
- GNSS is vulnerable to unintentional and intentional interferences.

www.glasgowmaritimeacademy.com

DLR

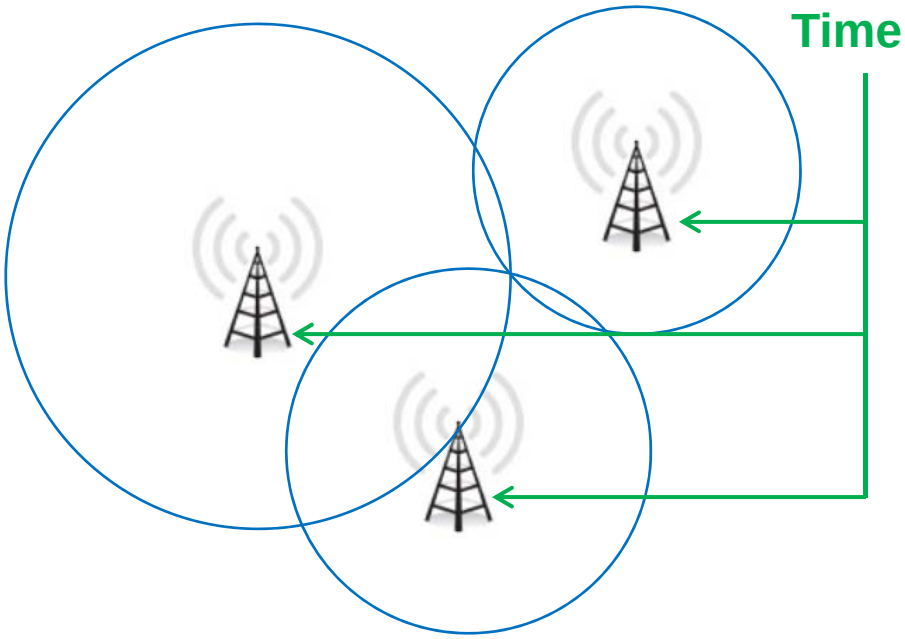
AIS

www.raymarine.com

R(anging)-Mode approach

R-Mode – civilian maritime backup system

R-Mode Baltic



Concept

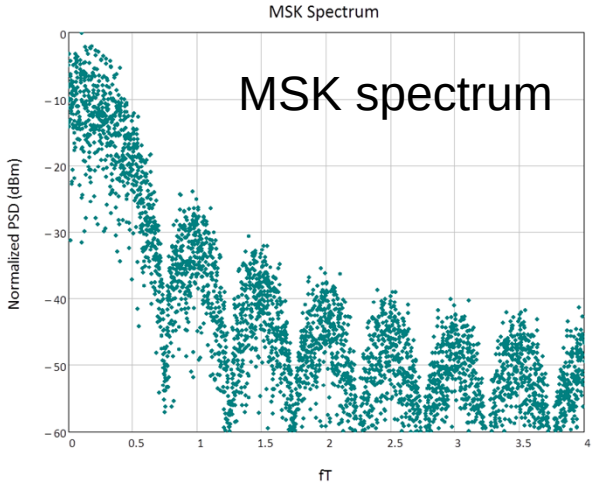
- Add ranging capability to existing maritime communication channels: MF radio beacon (300 kHz) and VHF AIS (162 MHz)
- Synchronized stations provide signals with well known transmitting time dependency.
- Range estimation based on time of arrival (TOA).
- Positioning using method of trilateration.

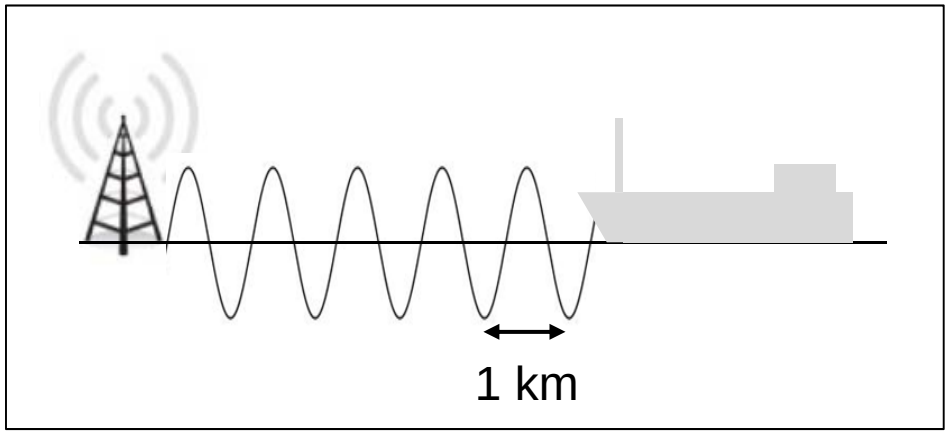
Signal of opportunity: MF radio beacon

Current System

R-Mode Baltic

- GNSS augmentation service which provides code differential corrections and integrity information
- Maritime standard for navigation in coastal areas
- Defined in IALA R-121 and RTCM SC104
- Frequency: 283.5 – 315 kHz
- Channel bandwidth Europe: 500 Hz
- Neighbouring stations differ in transmitting frequency
- Service area: up to 300 km
- MSK-Signal: Carrier is modulated with data stream of up to 200 bit/s
- Wave propagation: ground wave

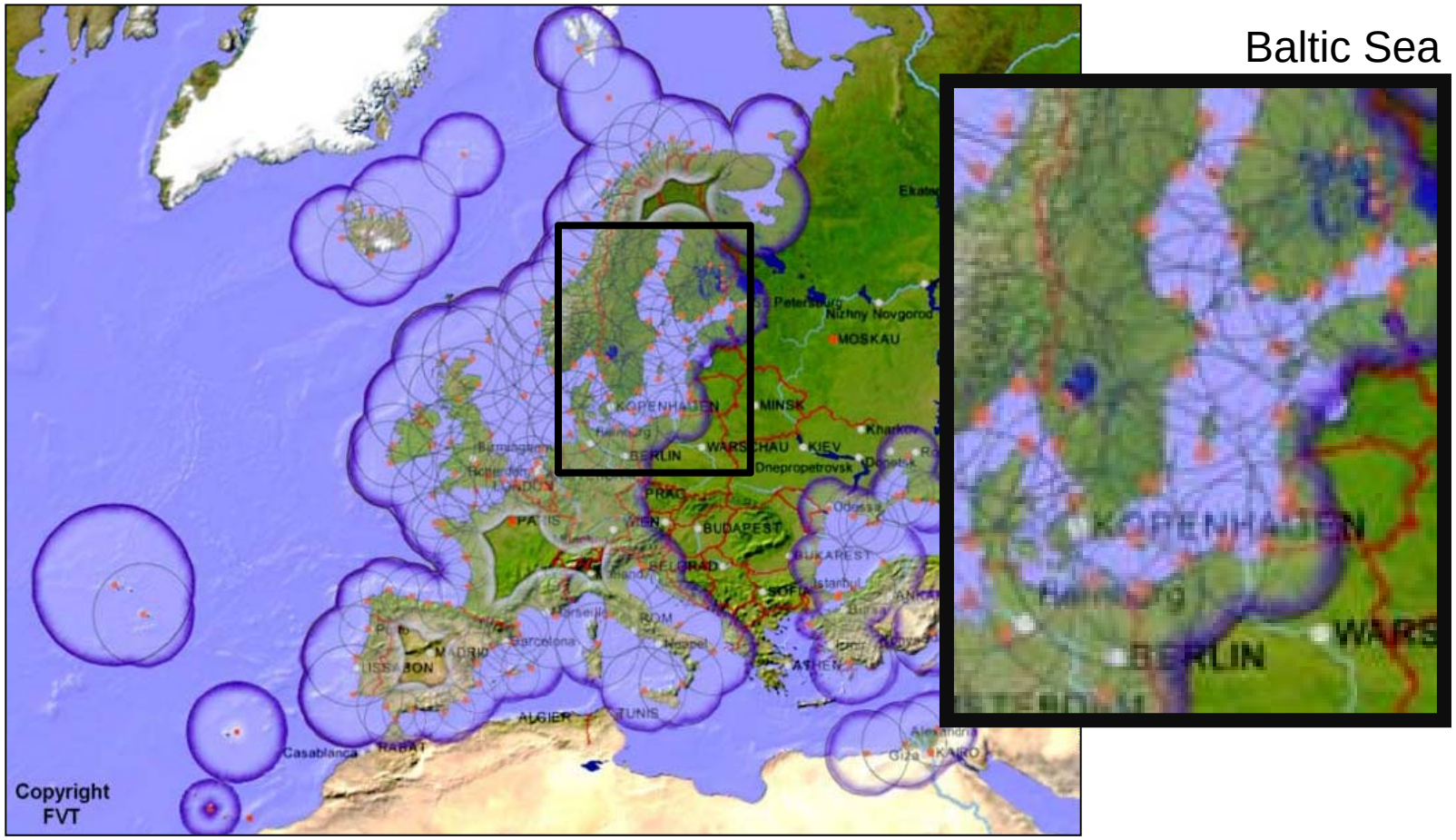




Signal of opportunity: MF radio beacon

Cumulative service area of up to 150 MF beacons in West-Europe

R-Mode Baltic



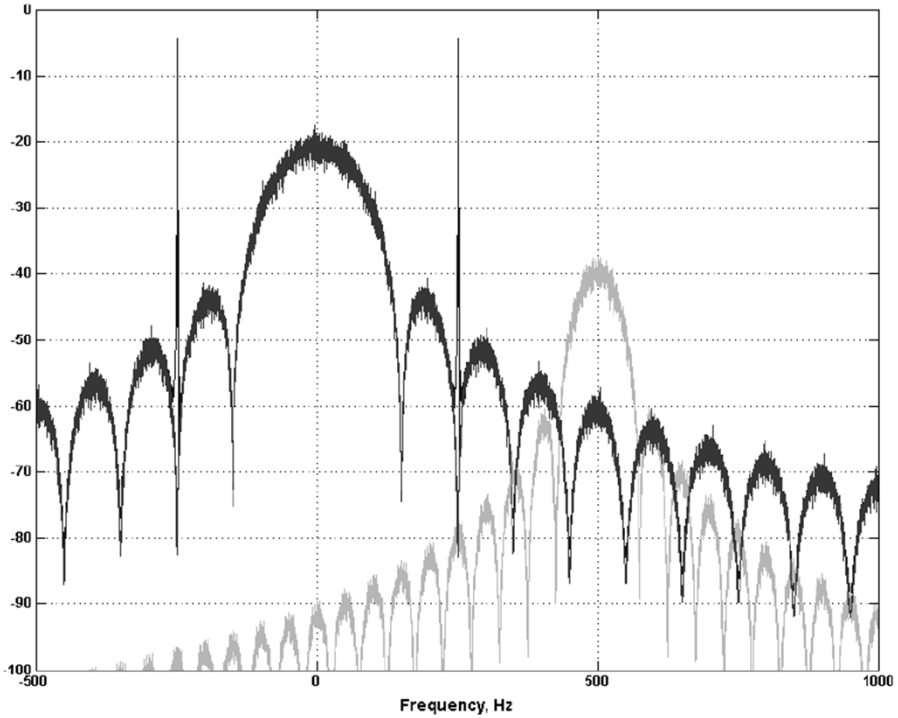
Overlap of station service areas along coastline support R-Mode concept

Signal of opportunity: MF radio beacon

In literature discussed approaches of R-Mode implementation

R-Mode Baltic

- **Goal**: Add ranging capability without disturbance of legacy DGNSS receiver
- Literature survey in ACCSEAS project results in 4 groups of implementation methods
  - Modification of the data content
  - Direction selection => receiver-side antenna modification
  - Add an additional data channel
  - Modification of the data rate
- Most promising approaches
  1. Add a new RTCM message and increase data rate to 200 bps
  2. Add CW signal(s) to the existing MSK signal



ACCSEAS : Feasibility study MF

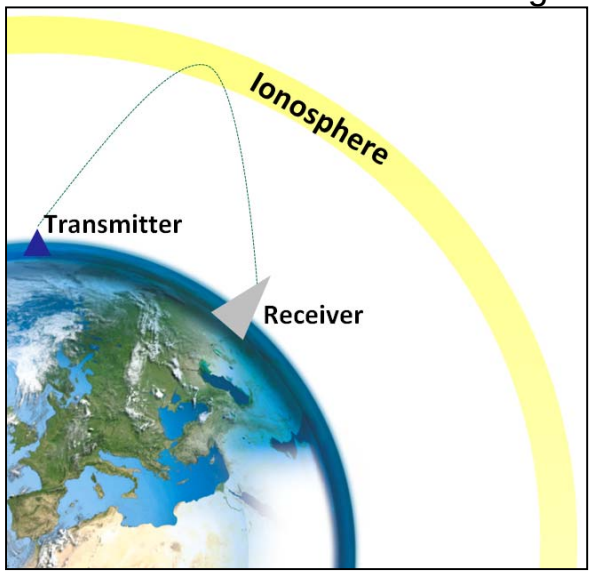
Signal of opportunity: MF radio beacon

Challenges

R-Mode Baltic

- Interference of wanted signal at night with sky wave
- Influence of Additionally Secondary Factors (ASF) on signal propagation
- Solving ambiguities

Visualization MF reflection at night



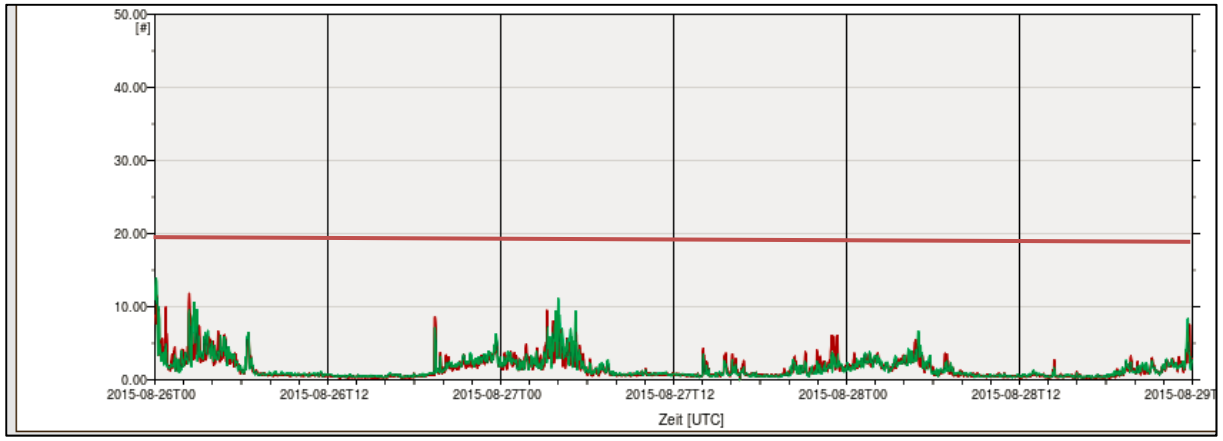
Results WSV 2015/16

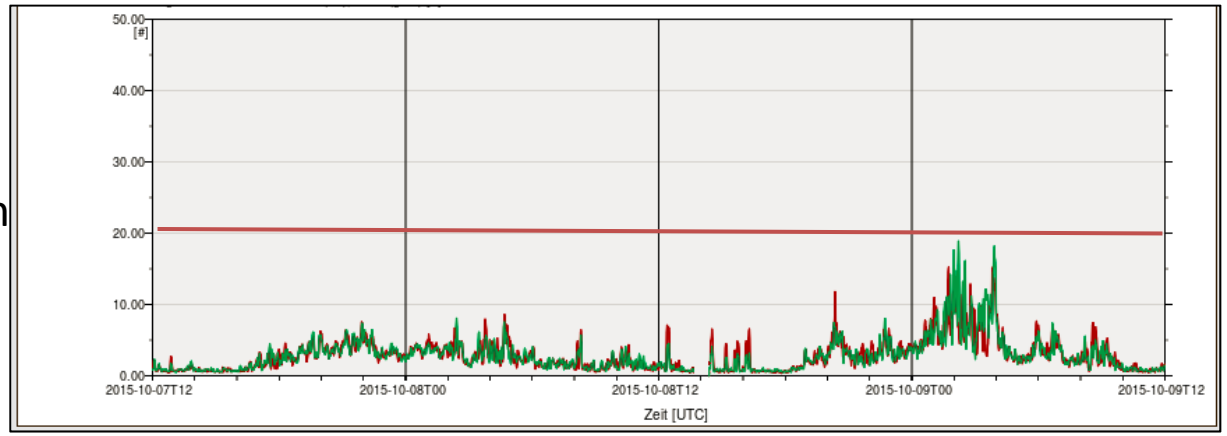
MF R-Mode

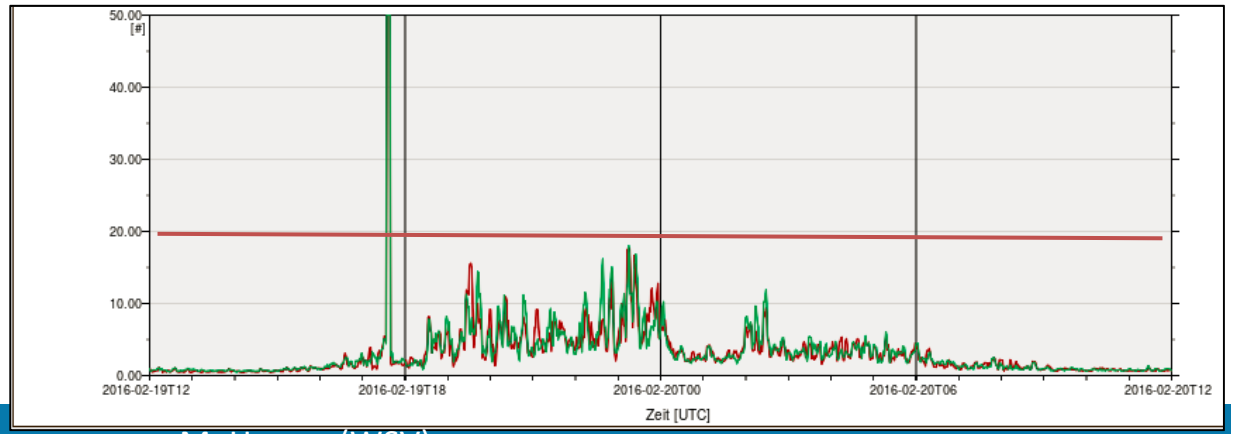
- Tönning Distance 70 km
  - Day: 1σ range error < 1m
  - Night: 1σ range error < 10 m
- List (Sylt) Distance 100 km
  - Day: 1σ range error < 1.5 m
  - Night: 1σ range error < 20 m
- Kiel Canal Distance 130 km
  - Day: 1σ range error < 1.5 m
  - Night: 1σ range error < 20 m

➢ Theoretical analysis ACCSEAS confirmed

➢ Sky wave interference starts at 70 to 100 km distance







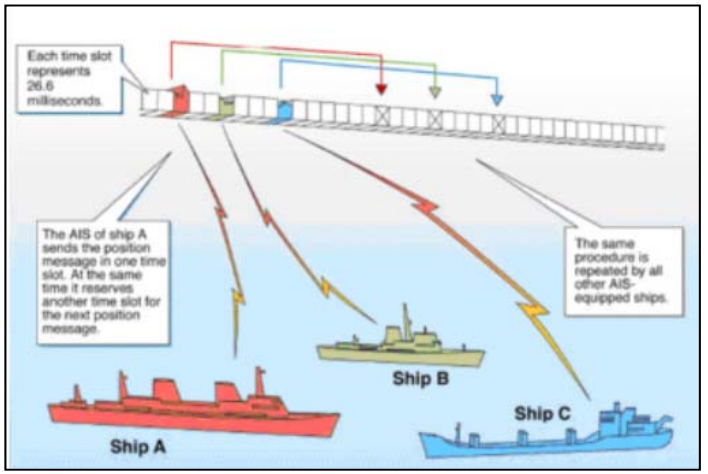
M. Hoppe (WSV)

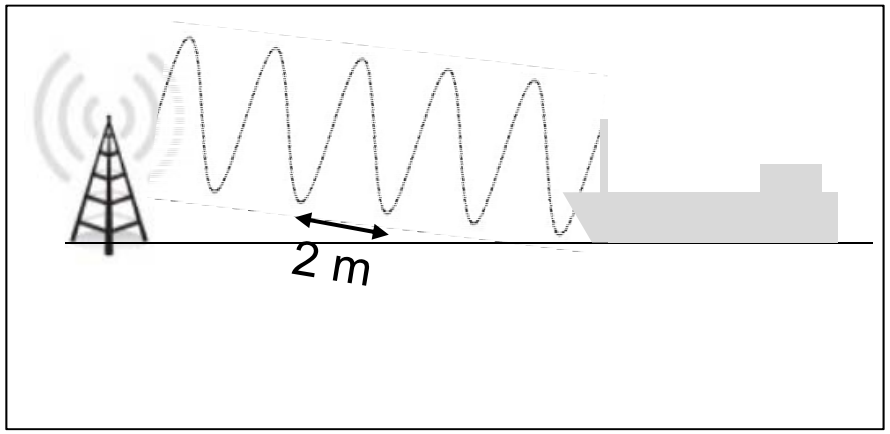
Signal of opportunity: VHF AIS

Current system

R-Mode Baltic

- Automatic Identification System (AIS) is a packed based digital communication system between ships and ship and shore (e.g. VTS).
- Main purpose provide dynamic and static ship information to reduce collision risk.
- Frequency: 161.975 MHz, 162.025 MHz
- Per channel 2250 slots per min
- Slot assignment using TDMA method
- Wave propagation along line of sight
- Communication distance depends on antenna height
- GMSK modulation with 9.6 kbps
- Defined in ITU-R M-1371





Signal of opportunity: VHF AIS

AIS stations Germany, Denmark, and Netherlands

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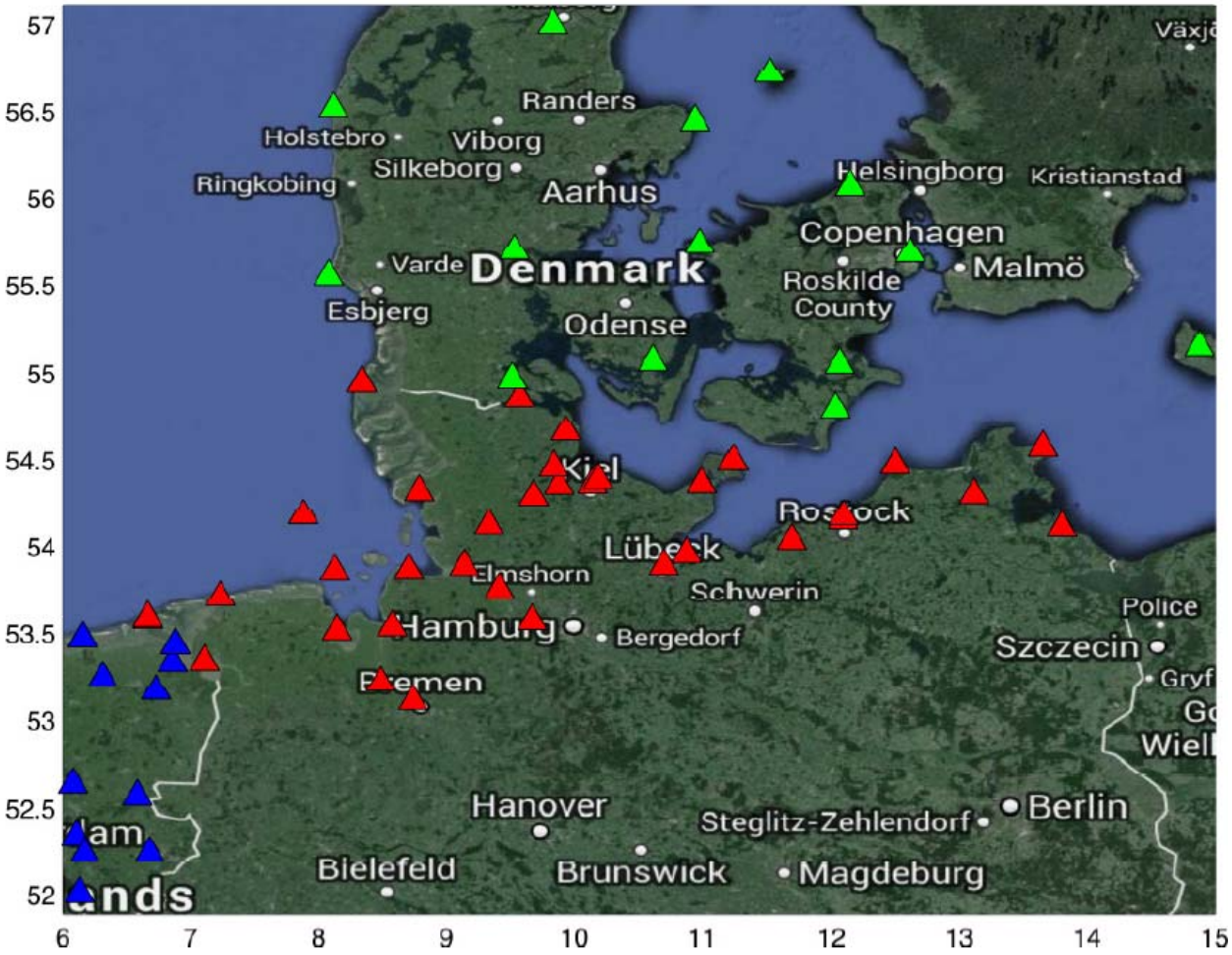

source: ACCEAS feasibility study AIS

Signal of opportunity: VHF AIS

In literature discussed approaches of R-Mode implementation

R-Mode Baltic

- **Goal**: Add ranging capability without disturbance of legacy AIS receiver
- Possible approaches discussed in literature
    1. Existing AIS: Use predictable message 4 or binary message 8 (up to 5 slots) of the existing base station AIS messages.
    2. CW Aiding: Adding continuous wave (CW) signals in other VHF channels. Three or more are needed to resolve ambiguities.
    3. Spread Spectrum: Transmitting direct sequence spread spectrum signals, akin to GNSS pseudolites. Ranging signal would use more VHF bandwidth.
    4. DTOA: Transmit messages from two neighboring stations at the same time.
    5. Use VDE with more data channels with partially higher bandwidth.

Project R-Mode Baltic

Interreg Baltic Sea Region

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- **Goal**: Implementation of the worldwide first R-Mode testbed
- 12 partners from 4 countries
- 4 administrations, 3 research institutes, 2 big and 3 small enterprises
- Duration: 10/2017 – 09/2020
- DLR project leader
- Associated partners from
  - UK, Denmark, Finland, France, Norway, Lithuania, Germany
- Funded by EU Interreg Baltic Sea Region Programme - budget: 3.4 Million €

Project partner

DLR
KONGSBERG
WSV.de
Wasserstraßen- und Schifffahrtsverwaltung des Bundes
INSTYTUT ŁĄCZNOŚCI
PAŃSTWOWY INSTYTUT BADAWCZY
URZĄD MORSKI W GDYNI
SWEDISH MARITIME ADMINISTRATION
RI.SE
Research Institutes of Sweden
Gutec AB
- electromagnetic design
- components and systems
BSH
BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE
SAAB
POLAND NavSim TECHNOLOGY
navXperience

Project challenge: R-Mode requirements

R-Mode Baltic

- Provide specification of requirements for R-Mode a terrestrial backup system to GNSS.

- *User requirements - shipborne equipment*
  - should be conform with user need for resilient PNT receiver
  - can provide PNT information to a range of shipborne navigational equipment as well as to e-Navigation operational services
  - should be able to provide RAIM

- *Service providers requirements - land based infrastructure*
  - No interference with legacy apparatus and communication signals
  - Provide GNSS independent timing
  - mitigation of technical and economic implementation costs

Project challenge: R-Mode station time synchronisation

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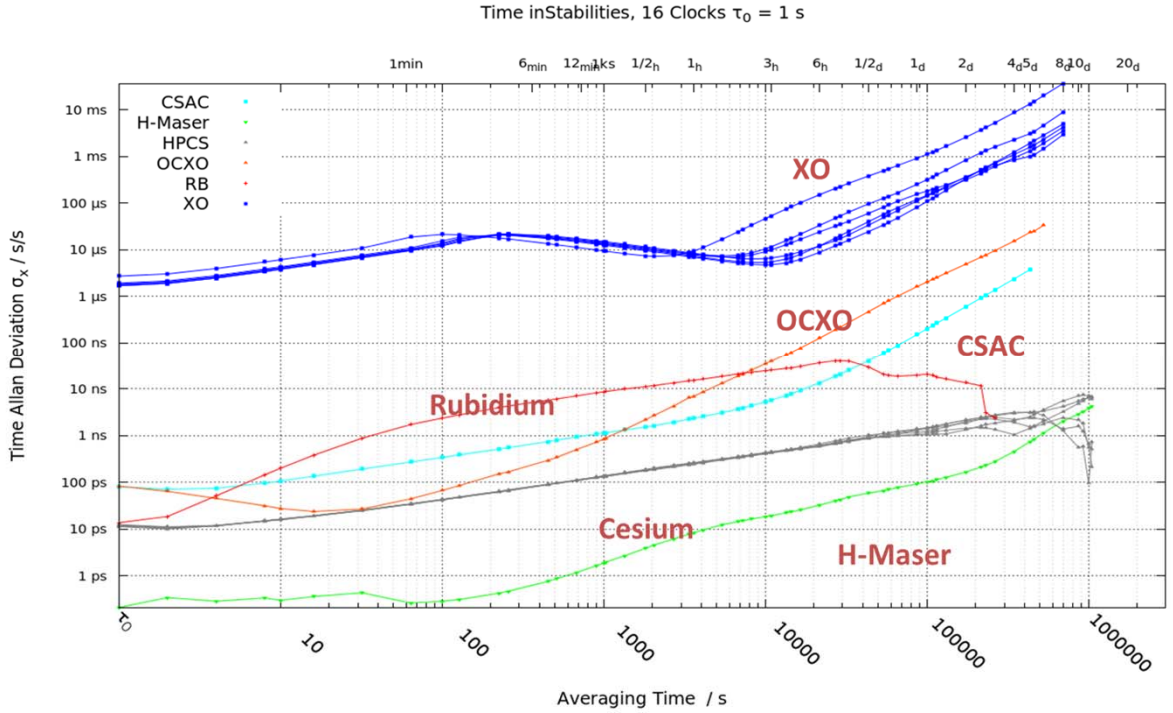
- Error of 10 ns at R-Mode transmitter causes an error of 3 m in range estimation.
- Depending on requirements on station timing accuracy selection of suitable local clock and link for synchronization. Conduct tests.



Project challenge: Signals of opportunities

R-Mode Baltic

- MF radio beacon
  - Identification of main errors
  - Sky wave mitigation
  - Consider alternatives to current R-Mode implementation
  - Develop concept for mitigation of local effects

- VHF AIS base station
  - Signal design/optimization and development of ranging algorithms
  - Identification of main errors sources
  - Channel load
  - Formulated stringed requirement for improved AIS standard (ITU-R M.1371-5 d)

Project challenge: Ranging and positioning

R-Mode Baltic

- Consider optimal positioning methods
- Positioning based on MF + AIS ranging
- Assessment of error propagation from potential sources to R-Mode based position

Project challenge: R-Mode standardization

Analyzation of existing standards, proposed changes or draft new standards should be provided at least in the following domains:

On-board [IMO, IEC, RTCM, etc.]	Radio link [ITU]	Shore Site [IALA]
•Performance Standards •Performance Requirem. •Test and Type approval • Output data protocols (61162) • Input data protocols for ASF, dR-Mode, Timing, etc.	• Standard for DGNSS transmissions in radio beacon band ITU-R M.823-3 • Standard for AIS in the VHF Band ITU-R M.1371-5	• Recommendations (e.g. R-121, R135, R-129, etc. • Guidelines (1112) • New R-Mode Guideline

Summary

R-Mode Baltic

- R-Mode has the potential to be a maritime backup system for positioning.
- There are at least two R-Mode Signals of Opportunity with need for further investigation.
- Challenges of R-Mode will be addressed in the R-Mode Baltic project.
- Research and development results will be made available for further usage.
- Project R-Mode Baltic will implement an R-Mode testbed within Baltic Sea until 2020.

Thank you for your attention!

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