

Evaluation of AIS Reception in Arctic Regions From Space by using a Stratospheric Balloon Flight

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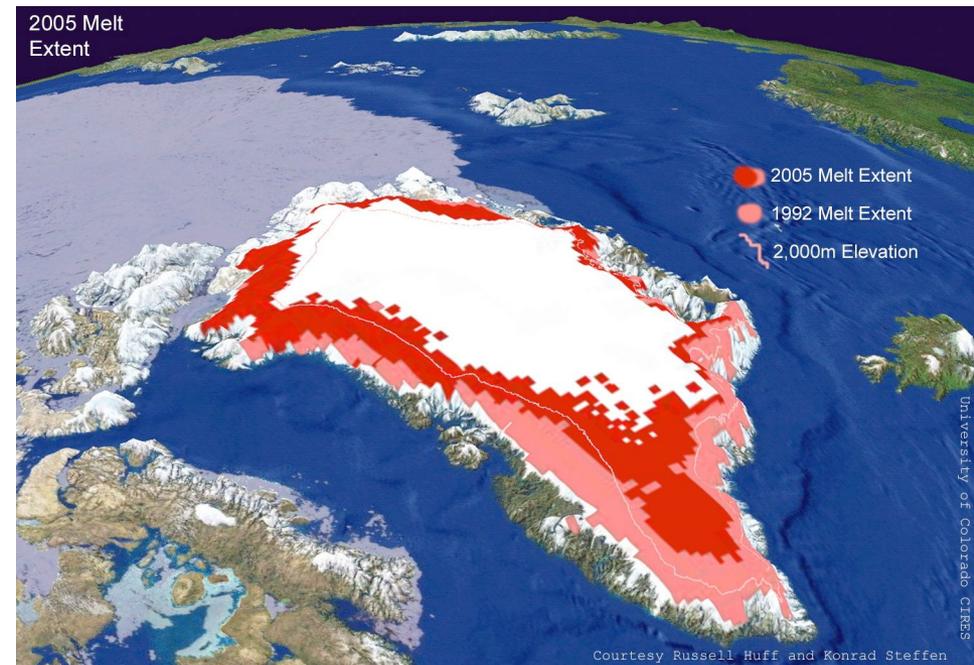
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Motivation

Proposed by the Danish Maritime Safety Administration

- In charge of the safety in Danish territorial waters
- This includes Greenland
- Practically impossible to monitor from ground
- Increased traffic
- Increased risk



Automatic Identification System (AIS)

- Broadcast position to nearby ships
- Monitored using ground stations
- Limited by line of sight
- Problems around Greenland



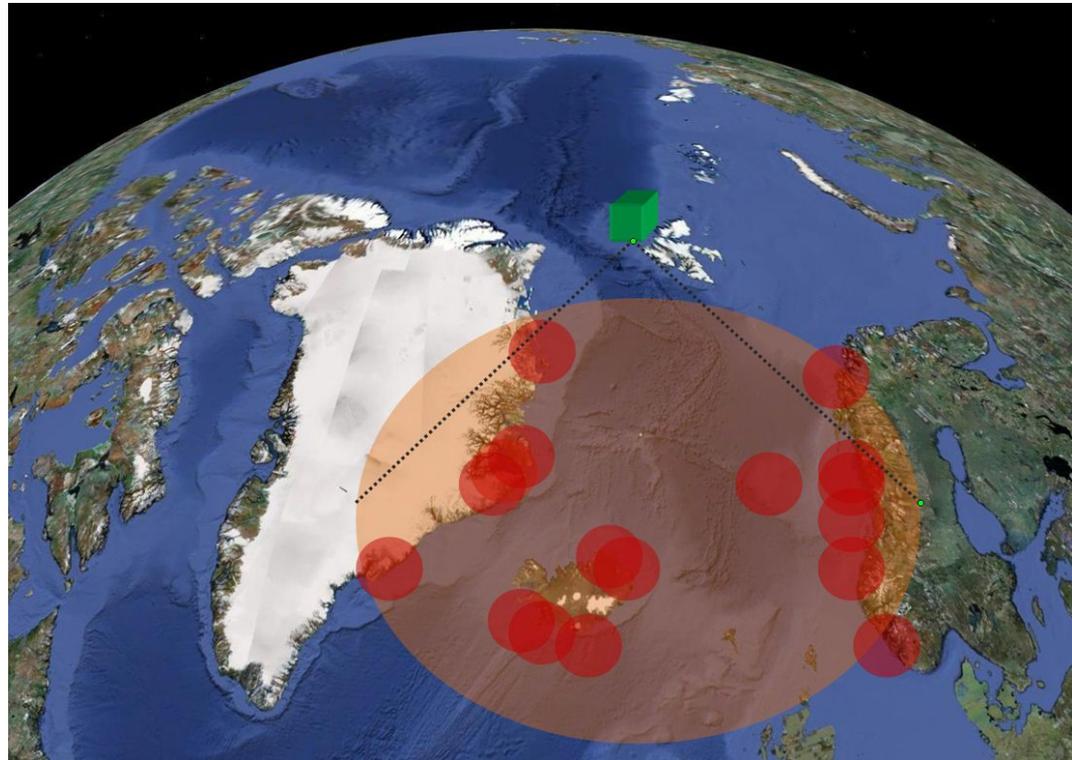
Automatic Identification System - Cont'd

AIS specifications

- Data Rate: 9600 bit/sec, GMSK
- Two channels: 161.975 and 162.025 MHz
- Typical output power
 - Class A 12.5 W
 - Class B 2.5 W
- Typical 50 km range, limited by line of sight
- TDMA based, 2250 slots per channel per min
- HDLC encapsulated msg. with 16-bit CRC-CCITT

Extended Field of View

- Time Division Multiple Access
- Messages collision happen due to different TDMA zones in extended FOV
- Investigated using a stratospheric balloon experiment.
- Developed a transmission and collision model
- Validated on received data



AAUSAT3 Engineering model

Modified AAUSAT3 EM used for flight

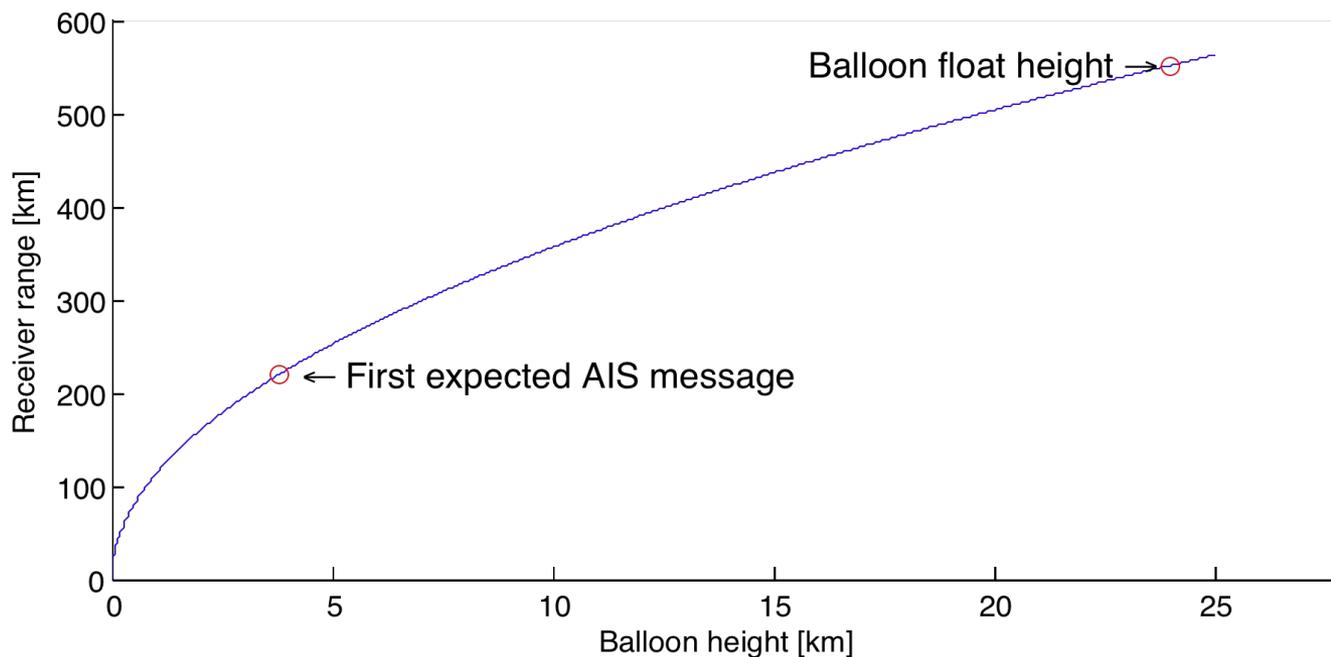
- No solar panels
- Extended battery pack
- Added active thermal control
- E-link interface to gondola



Stratospheric Balloon Flight Data



FOV during flight

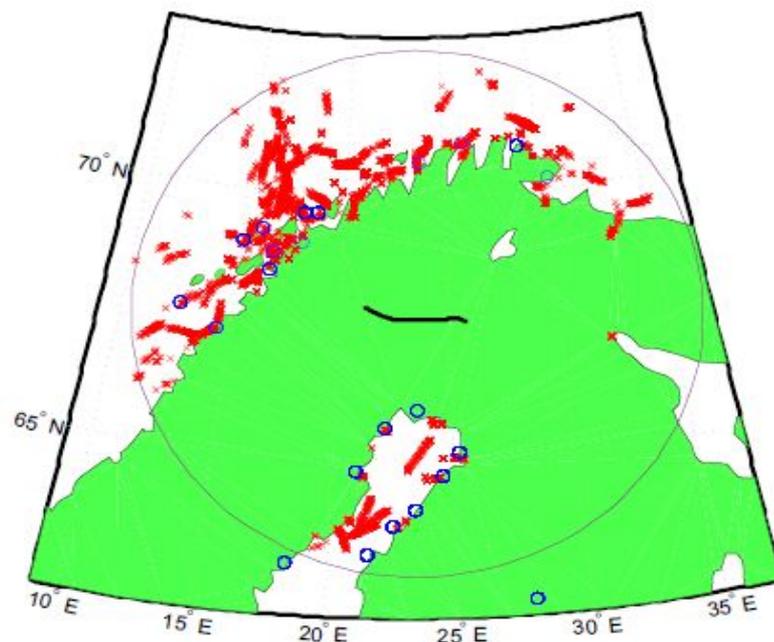


Stratospheric Balloon Flight Data

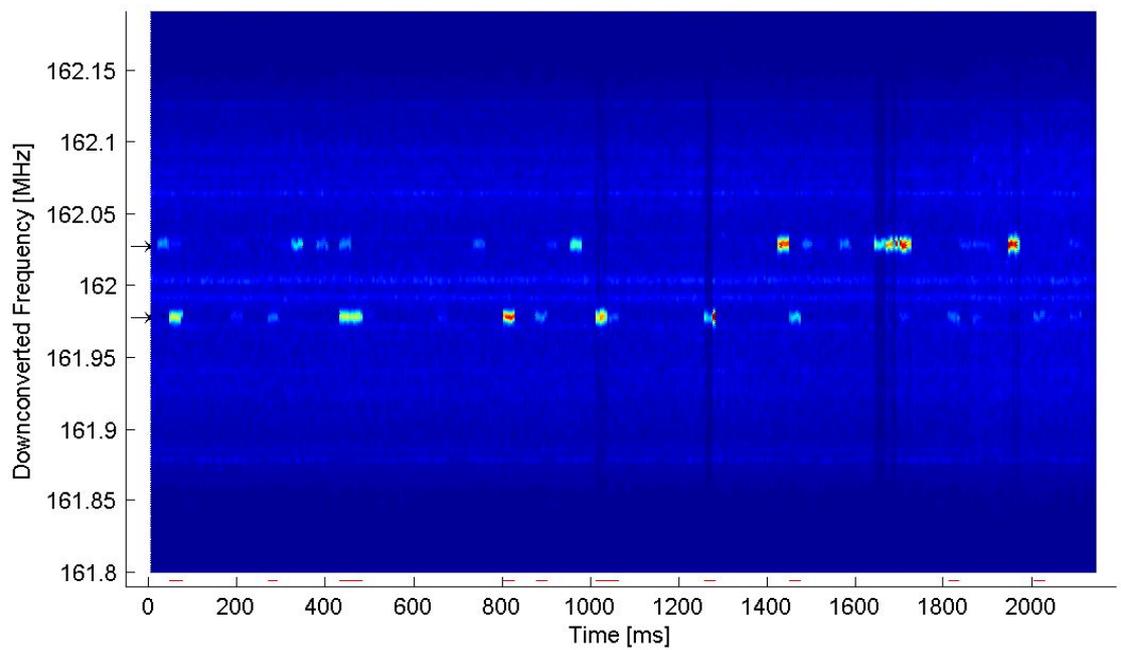
- 2 hour float in 24 km height
- 550 km theoretic line of sight

Received AIS messages from:

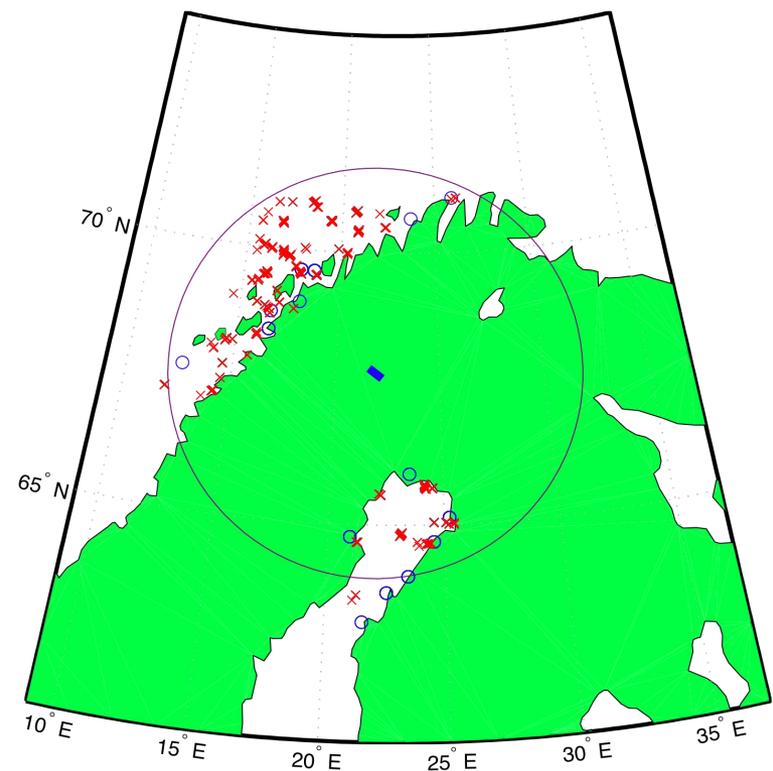
- 339 ships
- 24 ground stations
- Average 12 ships per TDMA zone



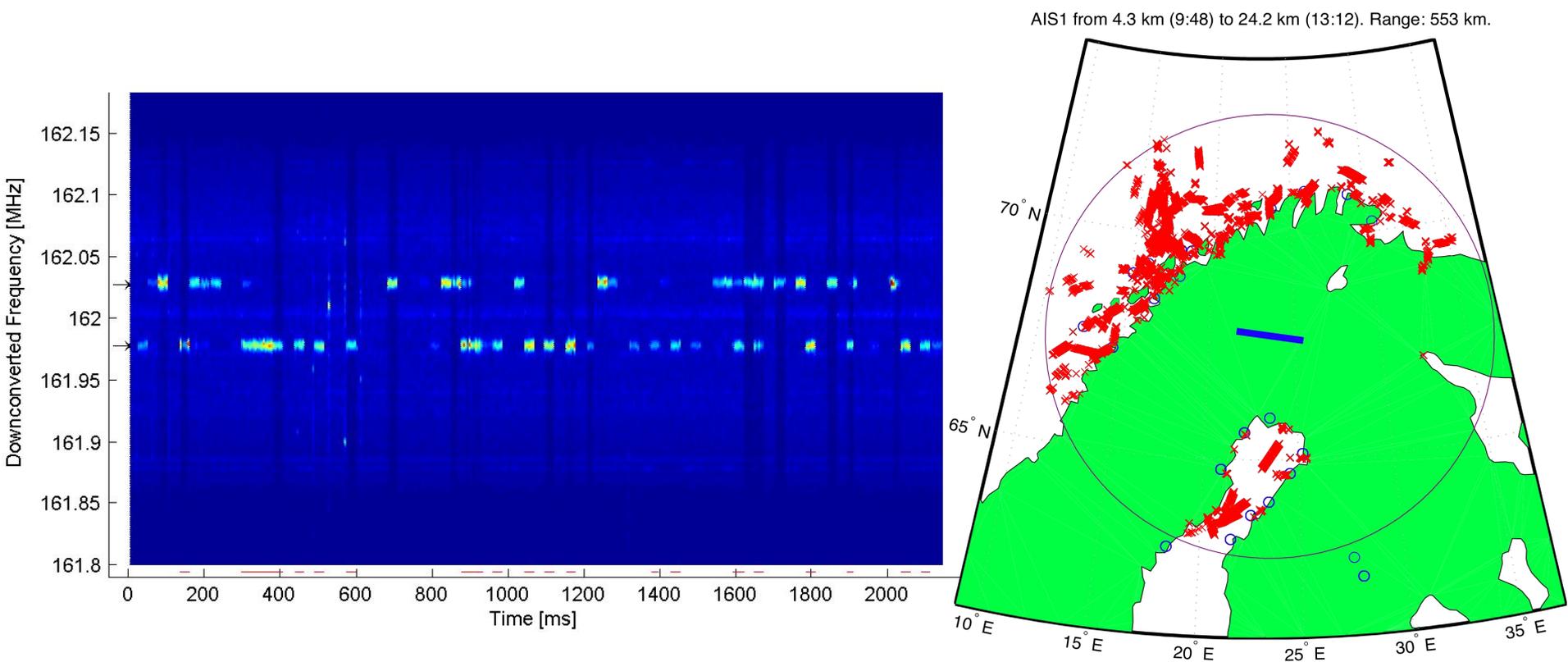
Spectrum of AIS frequencies at 420 km FOV



AIS1 from 4.3 km (9:48) to 13.9 km (10:23). Range: 419 km.



Spectrum of AIS frequencies at 550 km FOV

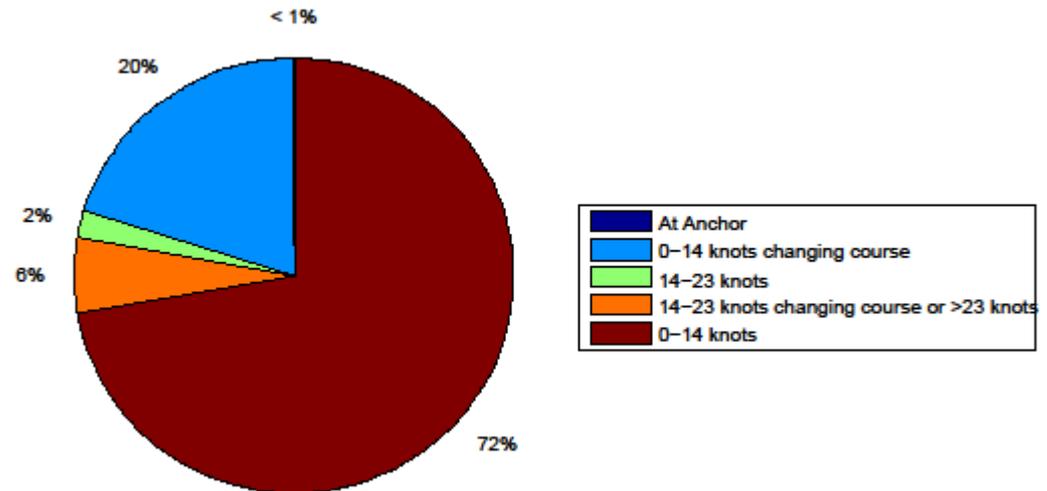


Dynamic conditions and the reporting intervals

- AIS transponder Class A reporting intervals

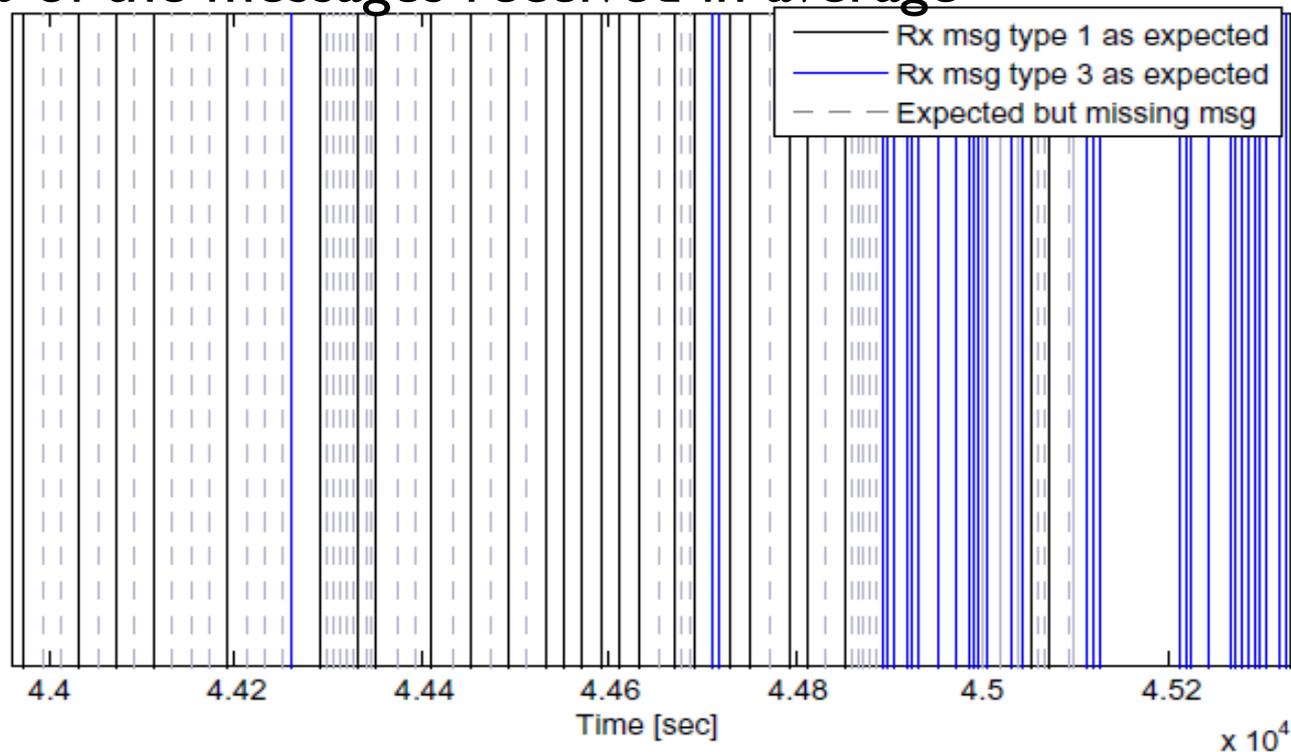
Ships dynamic conditions	Reporting interval
Ship at anchor or moored	3 min
Ship 0-14 knots	10 s
Ship 0-14 knots + cc	3 1/3 s
Ship 14-23 knots	6 s
Ship 14-23 knots + cc	2 s
Ship > 23 knots	2 s

- Dynamic conditions of ships received by AISI during balloon flight



AIS message interpolation

- Estimating number of lost messages
- From 17000 → 106000 AIS messages
- 16 % of the messages received in average



Theoretic transmission behaviour

Assumptions:

- The ships transmissions are uniformly distributed, based on an average reporting interval
- If only one message is transmitted in one slot, it is assumed to be a successful transmission
- If more than one message is transmitted in the same slot, they are presumed lost

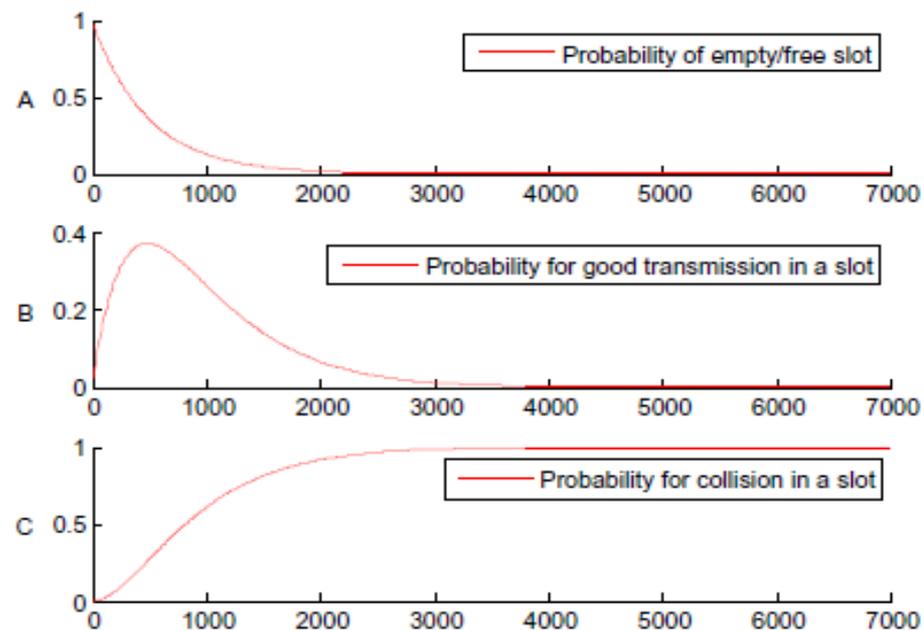
The number of packets transmitted in a slot with:

k is number of messages in a timeslot, n is number of ships within FOV, and p is transmitting probability:

$$\binom{n}{k} \cdot p^k \cdot (1 - p)^{n-k}$$

Slot-based approach

- 2250 slots per minute per channel
- Shown with 6.55 s transmission interval

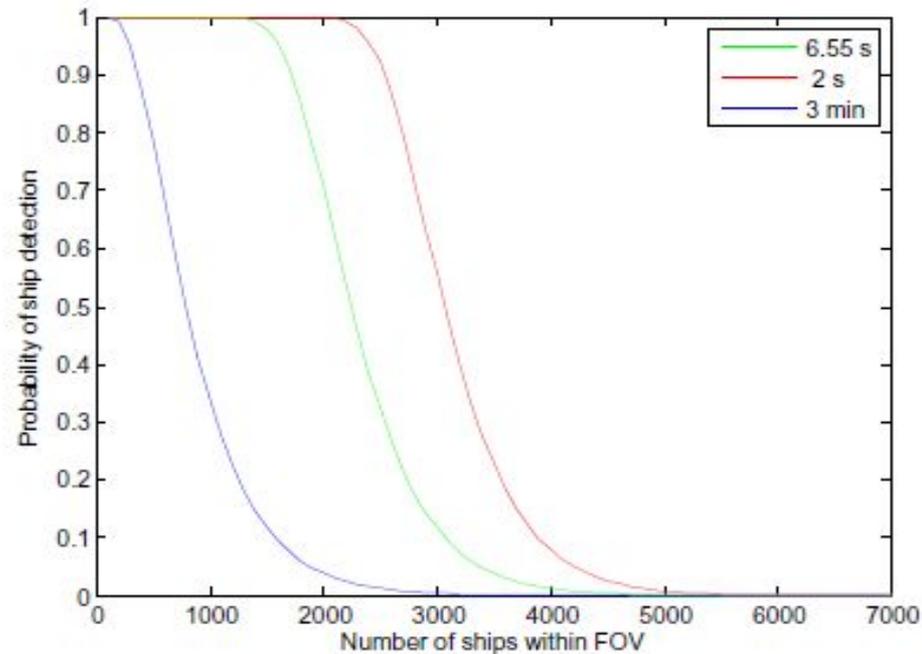


Probability of ship detection

Evaluated in a 10 min time interval.

- In harbour, 3 min
- Above 23 knots, 2 s
- Measured average, 6.55 s

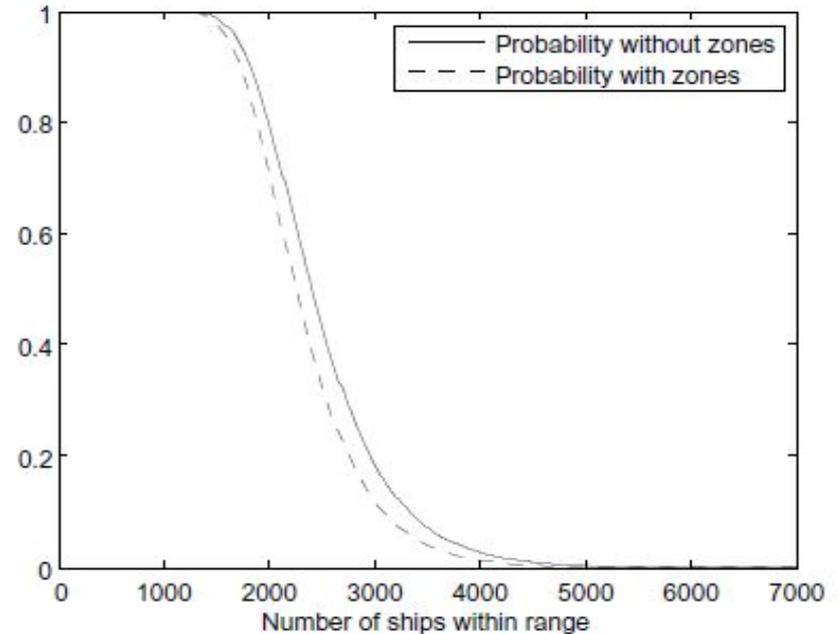
Above 1200-1500 ships in FOV degrades probability of detecting.



The Influence of TDMA Zones

- SO-TDMA ensures collision free transmissions within the zone
- Additional parameter: m – number is zones within FOV
- The number of packets transmitted in a slot:

$$\binom{m}{k} \cdot p_z^k \cdot (1 - p_z)^{m-k}$$



Verifying the interpolation method

- Data from a AIS GND station
- Interpolated Ground station data
 - 50.5% AIS msg. received
- Unfeasible to receive 100%
- Even in good conditions

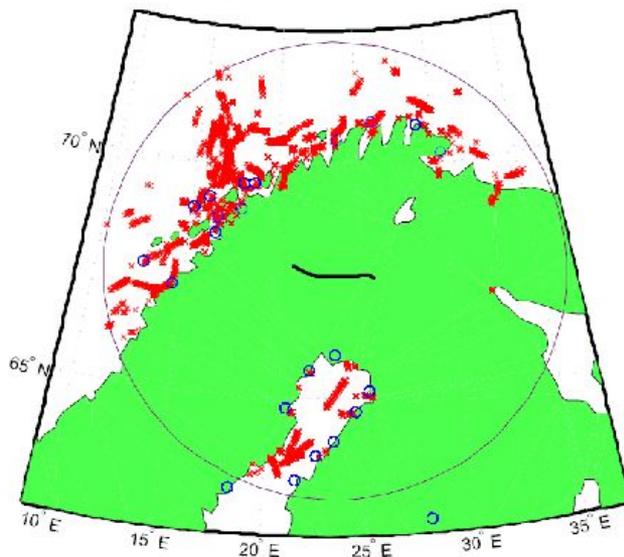


Comparison with ground station data

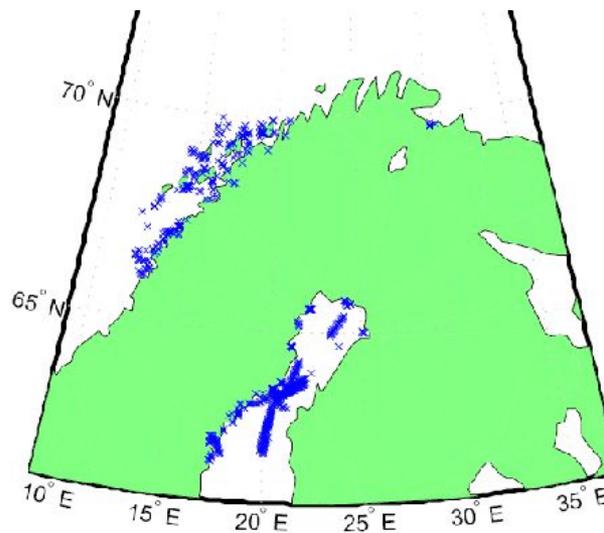
Reference data from the HELCOM database

- 151 unique MMSI numbers
- Balloon flight only listened to one AIS channel

Balloon flight
Unique ships: 339



HELCOM database
Unique ships: 309



Conclusion

Balloon flight measurements:

- 339 ships and 24 ground stations
- 12 ships in each TDMA zone
- Ship reporting interval of 6.5 s
- Received 15.9 % of the messages

Conclusion:

- Developed transmission and collision model and verified on balloon flight data
- Satellite antenna design must limit FOV to contain 1200-1500 ships for reliable detection of all ships during each pass.