eDLoran

enhanced Differential Loran

Durk van Willigen, René Kellenbach, Cees Dekker & Wim van Buuren

Reelektronika

Dutch Pilots' Corporation Rotterdam

ENC-GNSS 2014 Rotterdam

Today's navigation reality at sea

Acknowledge facts

- Majority of ships rely nearly solely on GNSS
- Galileo, GLONASS, Beidou and GPS all easy to jam
- GNSS denial effects can be tremendous

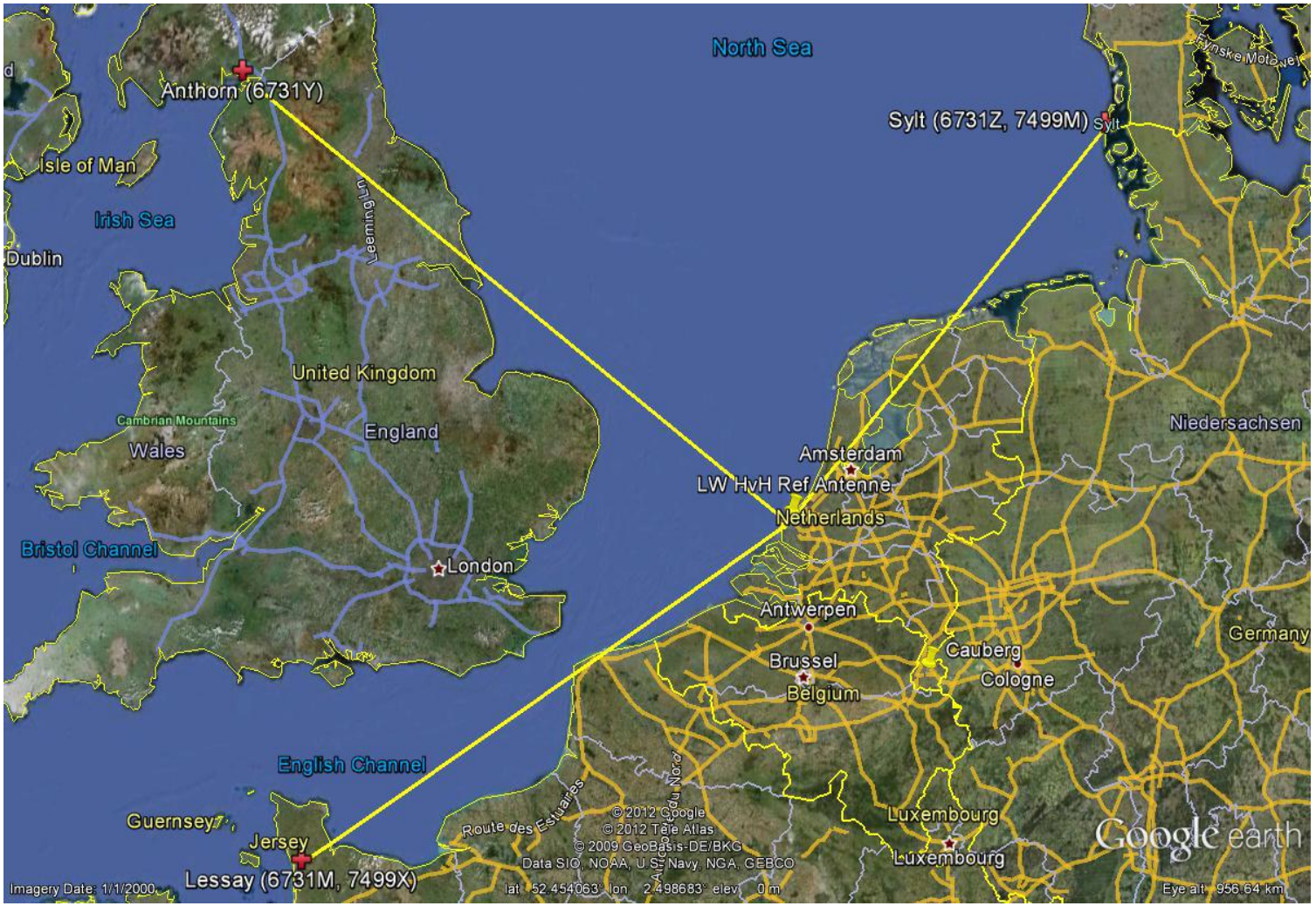
Take action

- Rotterdam pilots recognised the problem and took initiative to investigate useable backup for GNSS
- eDLoran shows strong capabilities for harbour entrance and approach operations

Objectives

- Maintain safety at Rotterdam Harbour if GNSS is denied
- Can Loran offer 5 metres accuracy?
- Integrable with existing GNSS-RTK equipment
  - No additional workload for pilots – fully automatic operation
  - Light-weight portable equipment
  - Capable to detect GNSS jamming or spoofing
- Fully independent of Loran data channel
- Low initial- and operating costs
- Soft degradation structure

eLoran configuration at Rotterdam harbour



How does eLoran work?

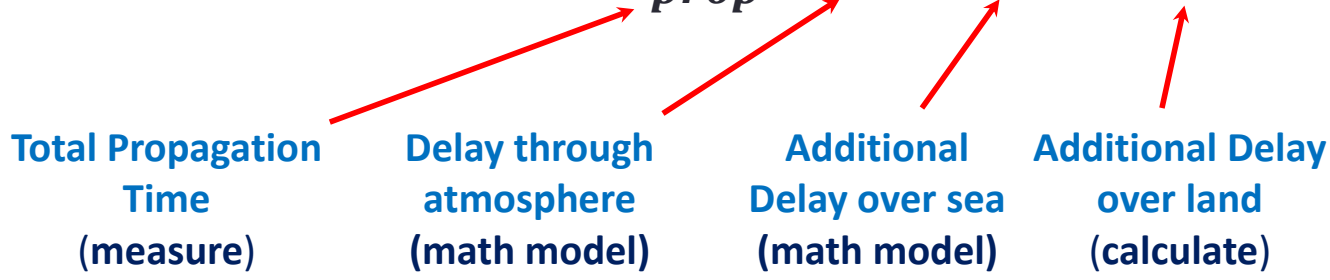
- Receiver receives 100 kHz pulses from at least three eLoran stations and measures accurately pseudo time of arrival (TOA)
- Multiply pseudo travel times by speed of light to find distances to three eLoran stations at accurately known positions
- Do some math to find the receiver's position and receiver clock offset

Simple but inaccurate solution

Three major error sources:

1. **Time of transmission not accurate within few nanoseconds**
2. **Transmitter position not stable within 1 metre**
3. **eLoran's signal propagation speed not accurately known**

Total propagation time from TX to RX $t_{prop} = \mathrm{PF} + \mathrm{SF} + \mathrm{ASF}$



So, invest in better transmitter or go <u>real</u> differential

Differential techniques needed !

- Mentioned errors are strongly correlated at a reference receiver at known reference position and pilot's receiver, so .....
- Send the measured errors at the reference site to the user's receiver to correct the errors in his receiver
- Resulting accuracy depends on correction data latency which reduces the correlation between errors and corrections
  - Temporal decorrelation
- Resulting accuracy depends also on the physical distance between the reference receiver and the pilots receiver
  - Spatial decorrelation

10-Metre barrier impregnable ?

- The GLA (UK) showed 10 metres accuracy with DLoran
- Still doesn't meet requirements of Rotterdam Pilots
- What causes that 10 metre hurdle?
- Thorough investigations indicated four major error sources

1. Technically difficult to measure signal's Total Propagation time accurate within few nanoseconds to build accurate ASF database
2. Unstable position of transmitter antenna, especially at Anthorn (UK)
3. Far too much data latency of differential correction data sent to the user's receiver through 30 bps Eurofix data channel
4. Transmitter timing accuracy

Two convenient data links available

1. **Eurofix provides a broadcast-type low-speed data channel added to the eLoran navigation pulses**
   - **Data latency can be as high as 15 minutes**
   - **Eurofix used in GLA's DLoran system**

2. **UMTS/GPRS mobile network offers much higher data speed for sending correction data to the user receiver**
   - **Data latency about 1 second**
   - **Mobile network used by eDLoran**

Measurements confusion

- Large differences observed between accurate simulation and real-life performance
- Apparently not all “noises” are atmospheric or RFI
- Transmitters generate noise of various sources
  - Loran chain network timing control
  - Transmitter timing control
  - Transmitter antenna tuning
  - Unstable antenna phase centre
- Nearly impossible to improve transmitter performance at reasonable costs

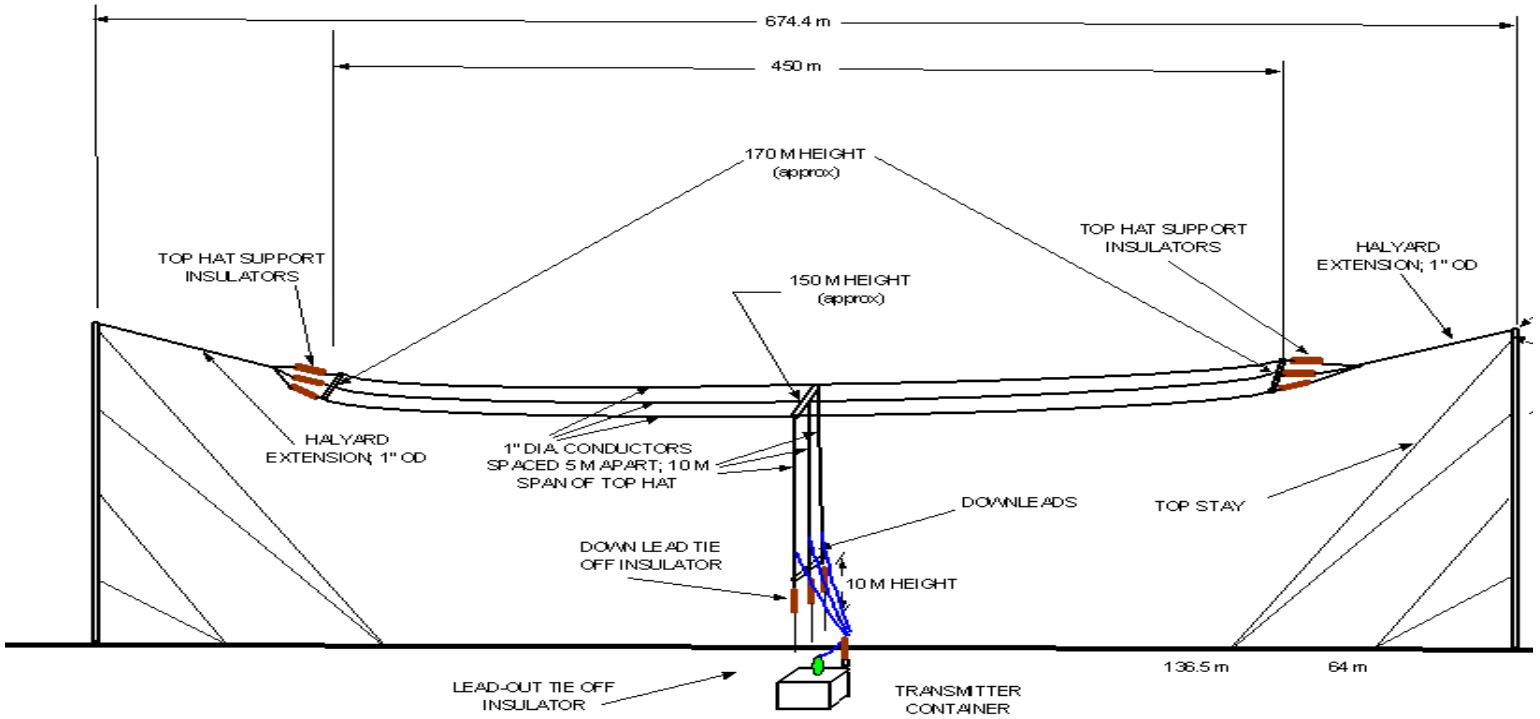
Loran transmitter antennas

- Military antenna Park at Anthorn, Cumbria, UK
- 13 masts of ≈200 metres
- Radiated Loran power 250 kW

- ≈200 Metres Loran antenna tower at Sylt
- Radiated power 250 kW

Time of Emission of Anthorn signal?

- Transmitting process synchronised to UTC
- Error in the internal TX chain timing
- Where is the phase centre of the antenna?



Courtesy GLA

User differential Loran receiver

DLoran (GLA-UK)

- *Measure all pseudo-ranges of useful transmitters*
- *Apply pseudo-range corrections from receiver's ASF database*
- *Apply pseudo-range corrections from reference station via Eurofix*
- *Calculate position and clock offset from corrected pseudo-ranges*
- *ASF database generated with specialised equipment costly operation*

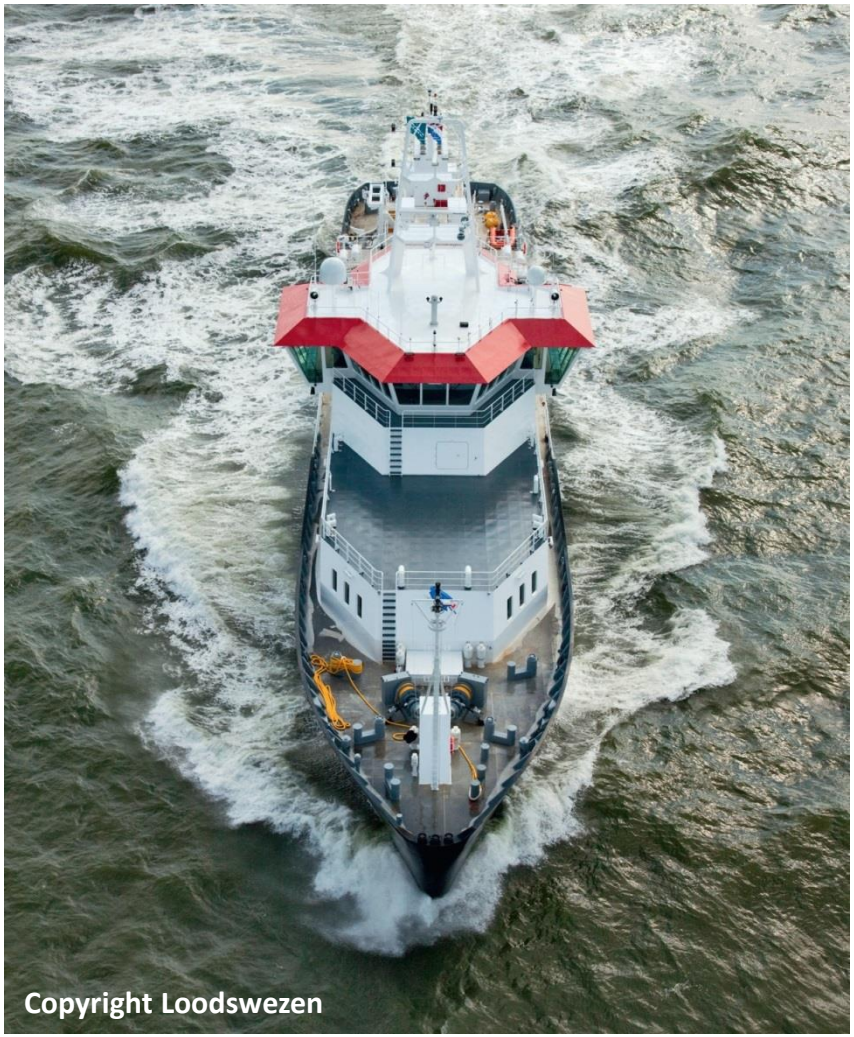
eDLoran (Rotterdam pilots-NL)

- ***Calculate position from measured un-corrected pseudo-ranges***
- ***Apply position corrections from receiver's ASF database***
- ***Apply last-second position corrections optimised for user's location from server via public mobile telecom network***
- ***Pilots contribute daily to refine ASF database without special equipment***

MS Polaris

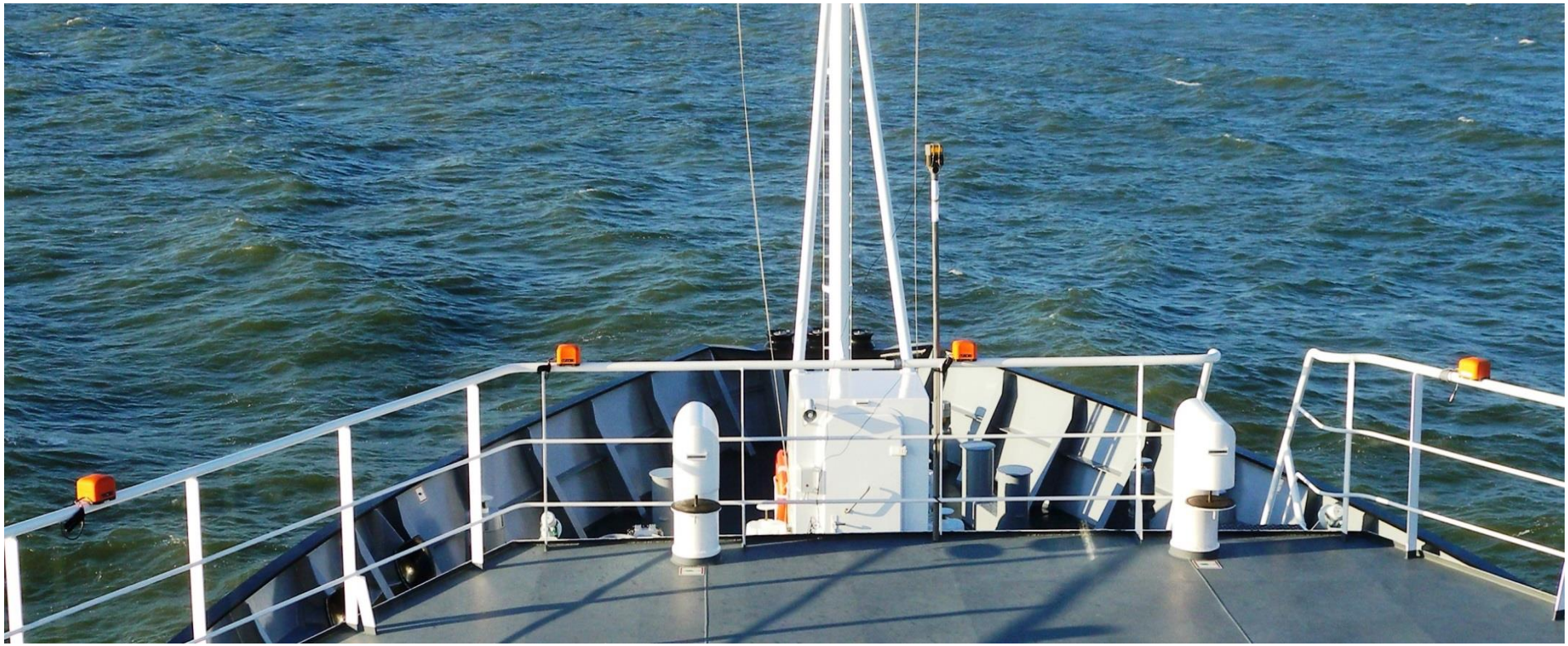
- Pilot Station Vessel
- Length 80 metres
- Christened by Queen Beatrix on 10-Oct-2012

http://www.fotorondleiding.nl/pollux/pollux.html



eDLoran receiver (14x14x10 cm)

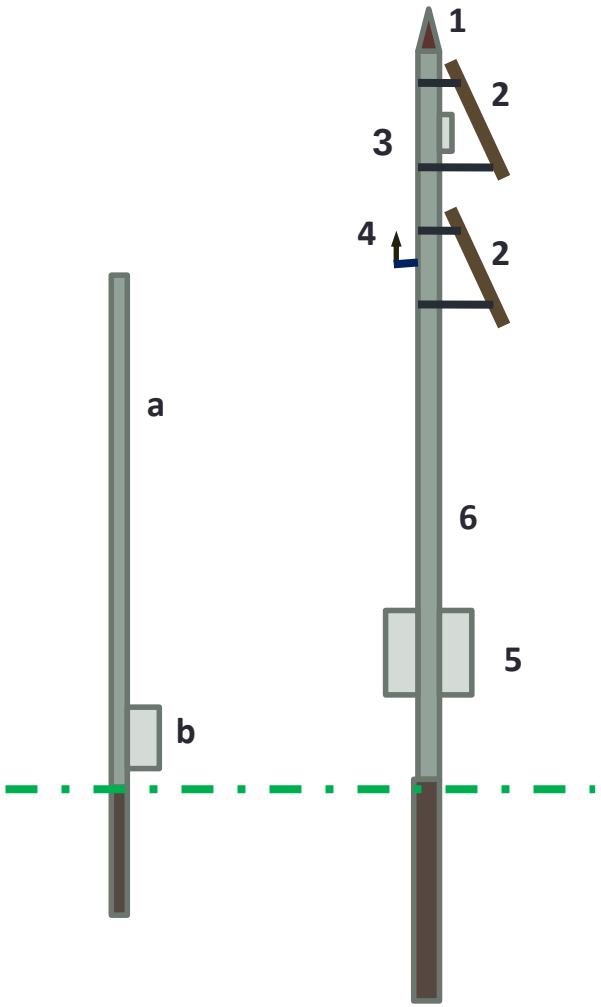
eDLoran test antenna park



From left to right: GNSS MPU, GNSS HDG, GNSS Position, eDLoran Position

eDLoran Reference Stations

Test reference station (2 m)



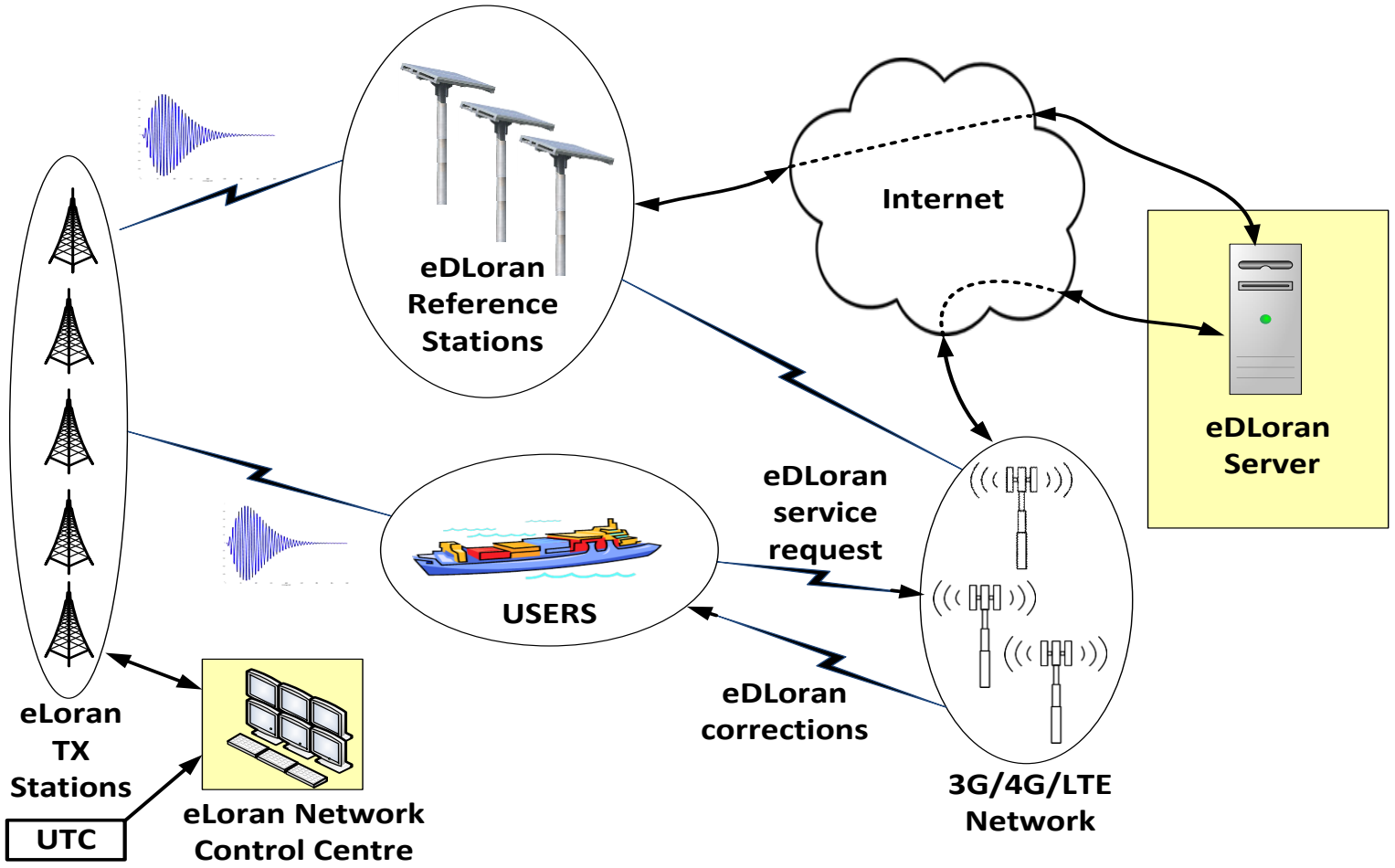
Fixed reference station (4-5 m)

a: polyester mast, including
- Loran antenna
- UMTS/GPRS antenna

b: Loran receiver, including
- micro computer
- UMTS/GPRS module
- battery

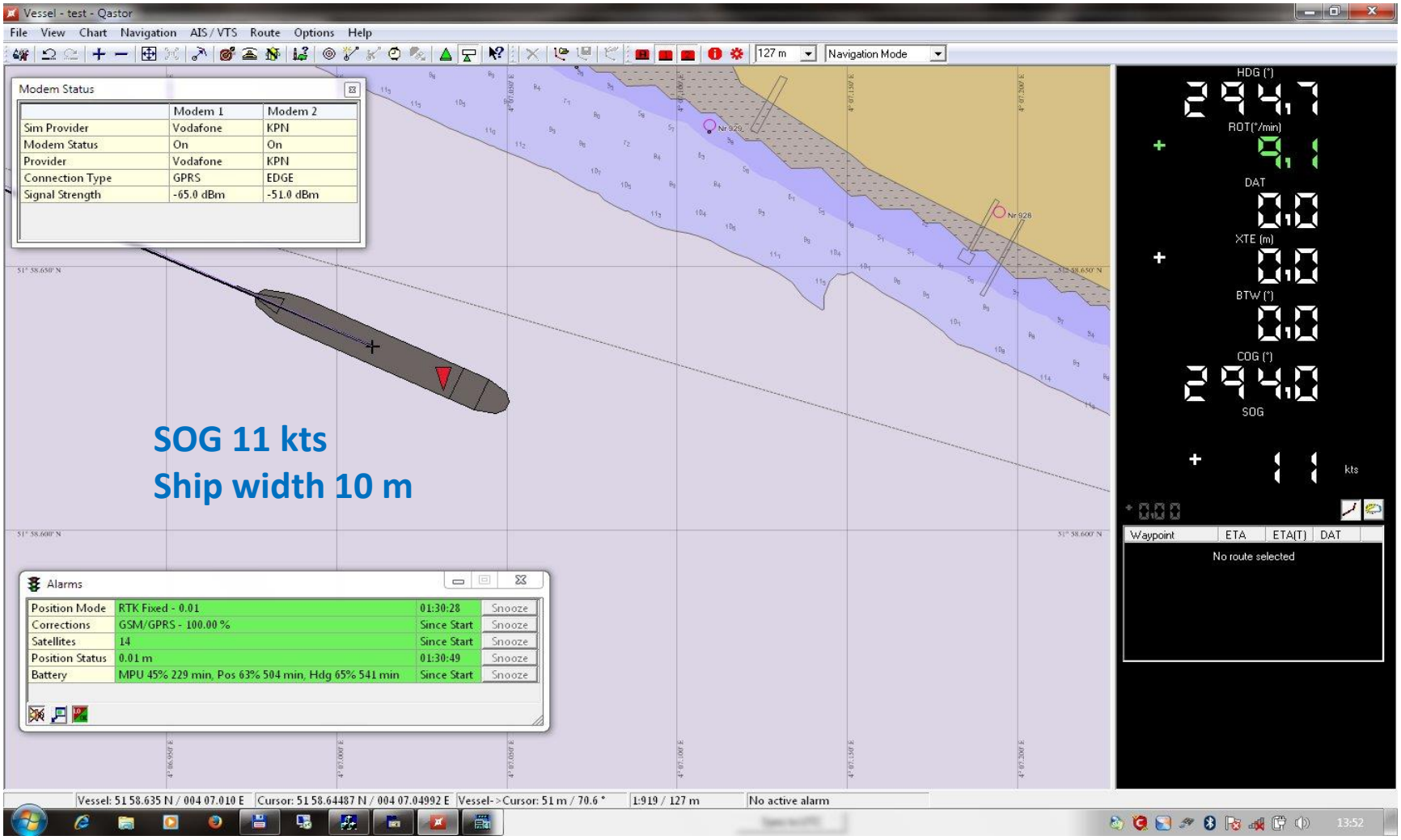
1: eLoran antenna
2: solar cells
3: Loran receiver, including
- UMTS/GPRS module
- micro computer
4: UMTS/GPRS antenna
5: buffer battery
6: metal mast

eDLoran Concept



By courtesy of Babcock International Group

GPS-RTK & eDLoran on Qastor (QPS)



eDLoran Measurements @ Hook of Holland

Achieved pilot's objectives

- Safety can be maintained at Rotterdam Harbour if GNSS is denied
- eDLoran demonstrated < 5 metres accuracy
- Integrable with existing GNSS-RTK equipment
  - No additional workload for pilots – fully automatic operation
  - Light-weight portable equipment
  - Capable to detect GNSS jamming or spoofing
- Fully independent of Loran data channel
- Multiple reference stations weapon against terrorism
- Permanent monitoring of possible jamming and spoofing

Economic achievements

- **No need to replace older Loran-C or Chayka stations with proven track record => *major cost saver***
- **eDLoran can be used anywhere where Loran/Chayka and 3G/4G/LTE network are available**
- **No agreements with Loran providers needed**
- **Installing eDLoran reference stations is fast, simple and cost effective**
- **No limitation in number of reference stations**
- **Legacy Loran receivers can be used as no Loran Data Channel needed**

Thank you for your attention

We are grateful for the support from:
- **the crew of MS Polaris and tenders**
- **Loodswezen Rotterdam-Rijnmond**
- **AD Navigation**

www.reelektronika.nl

www.loodswezen.nl