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
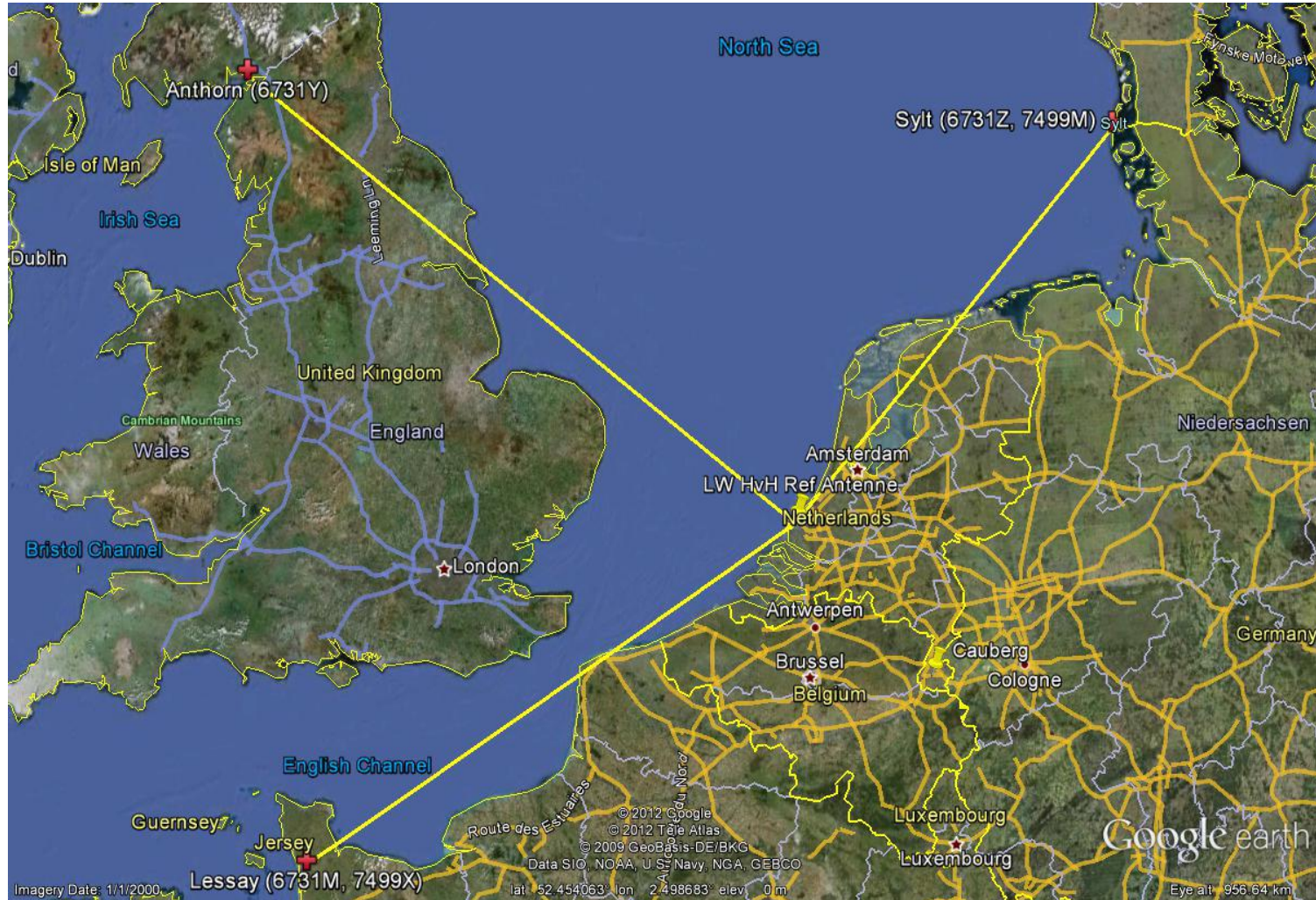
How does eLoran work?

- **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 $t_{prop} = \mathrm{PF} + \mathrm{SF} + \mathrm{ASF}$

Total Propagation Time (measure)

Delay through atmosphere (math model)

Additional Delay over sea (math model)

Additional Delay over land (calculate)

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**
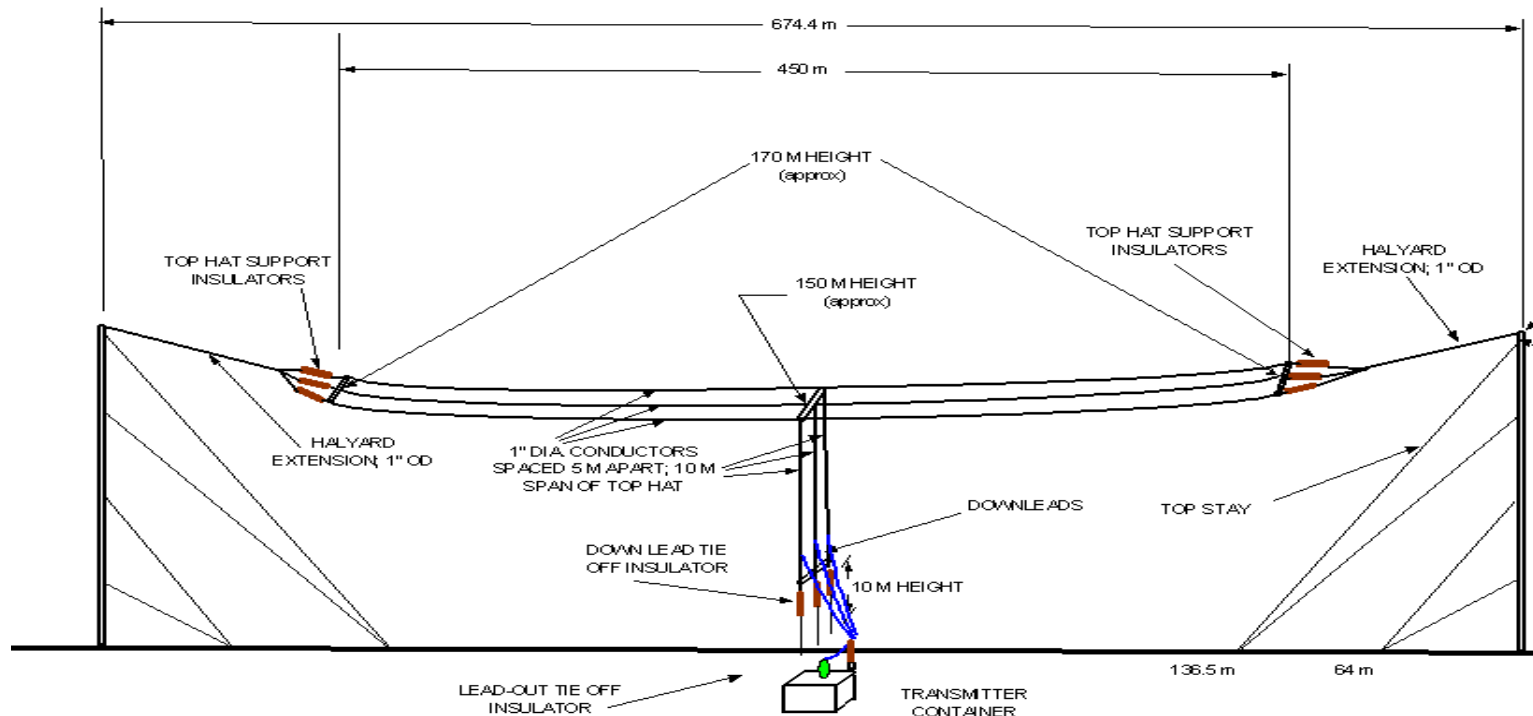
Loran transmitter antennas

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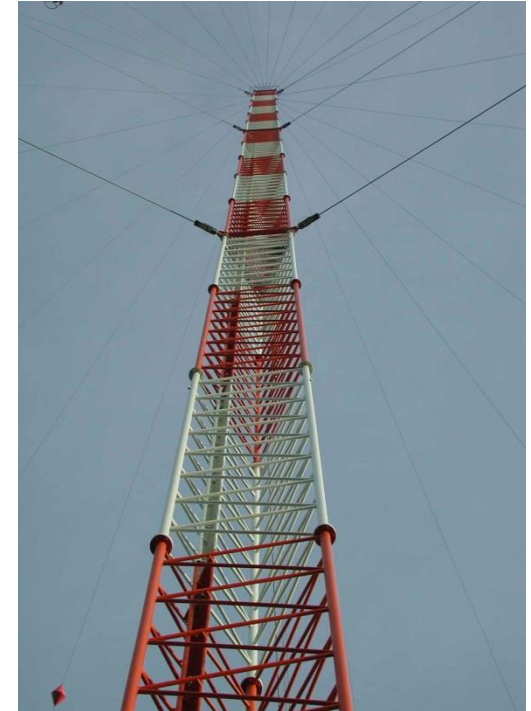
- **≈200 Metres Loran antenna tower at Sylt**
- **Radiated power 250 kW**

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
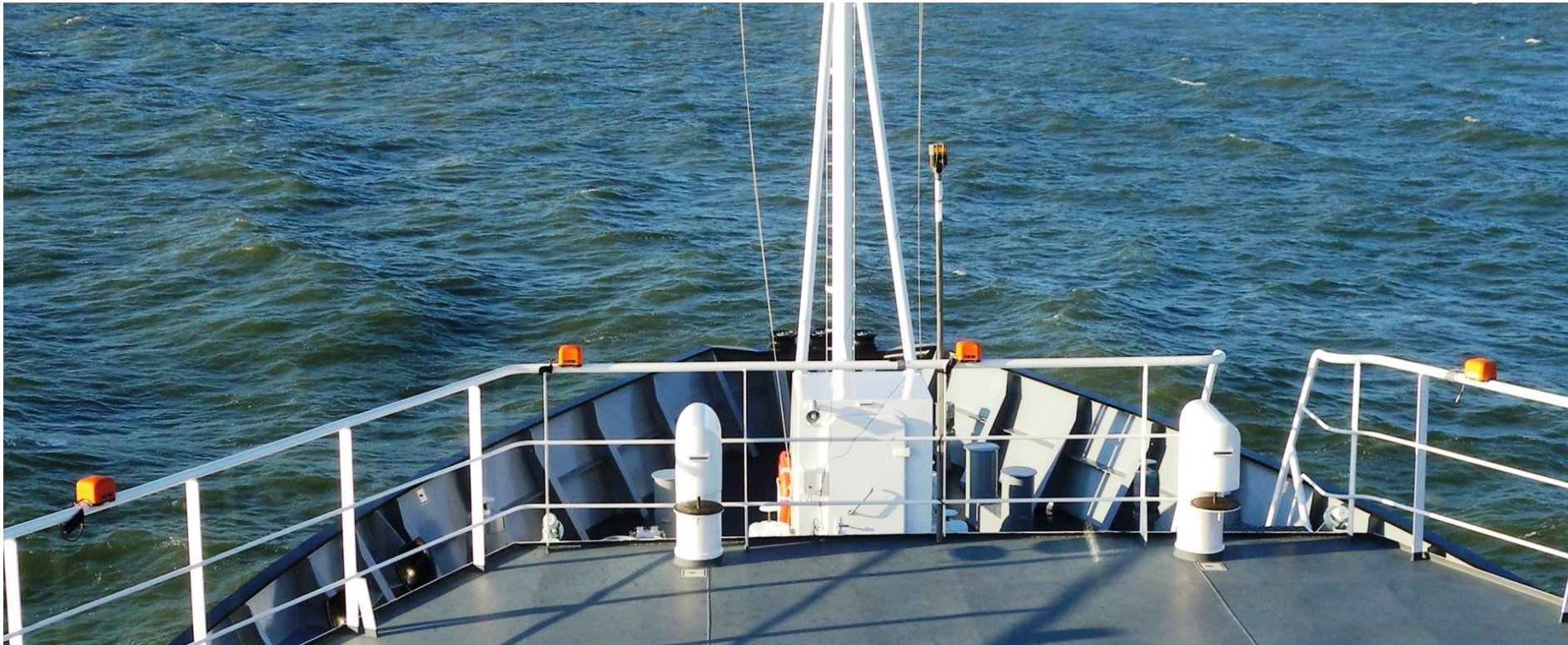

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eDLoran receiver (14x14x10 cm)

eDLoran test antenna park

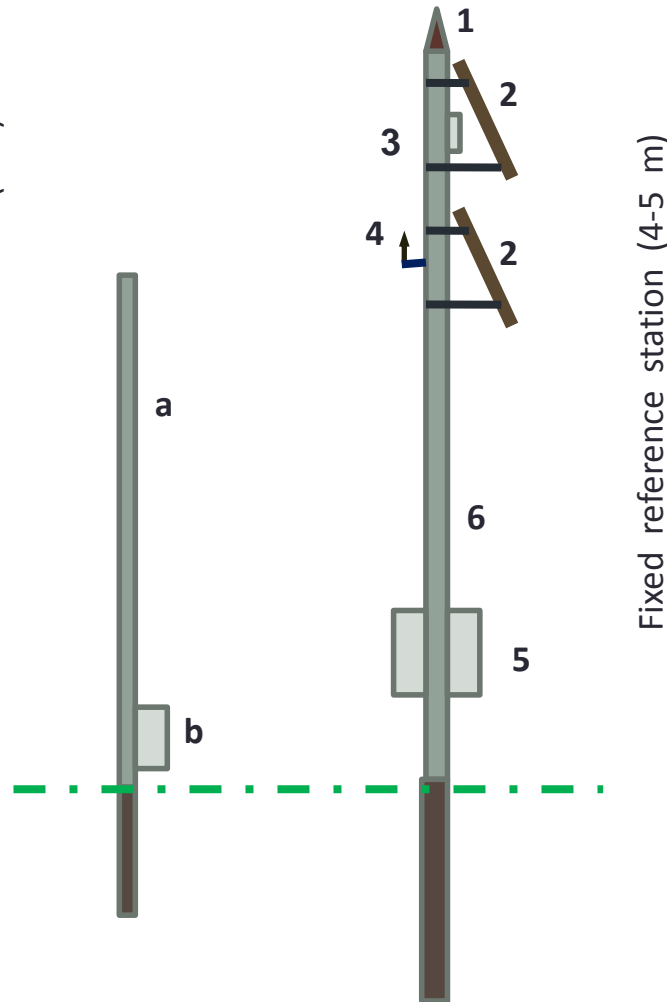**From left to right: GNSS MPU, GNSS HDG, GNSS Position, eDLoran Position**

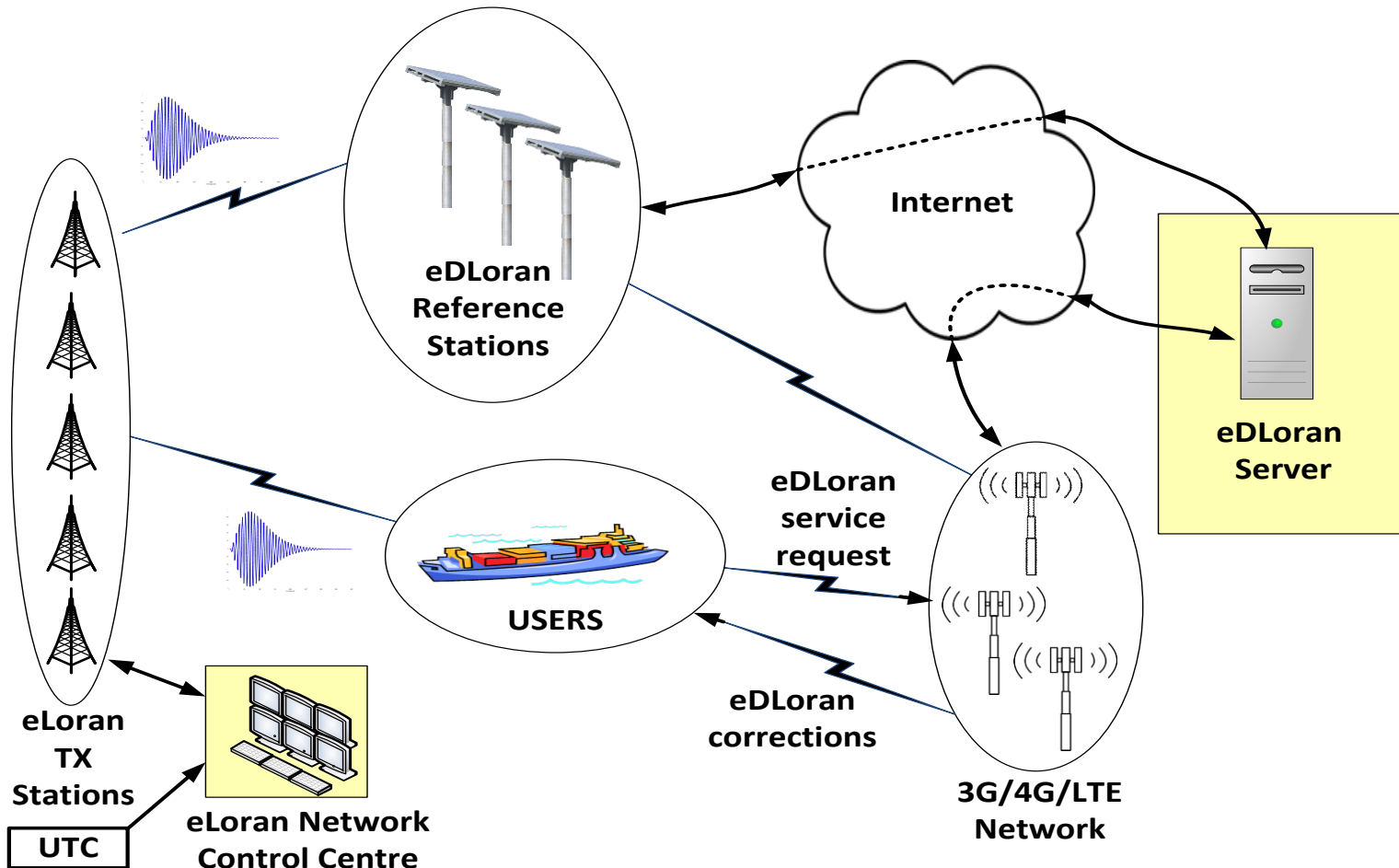# eDLoran Reference Stations

Test reference station (2 m)

a

b

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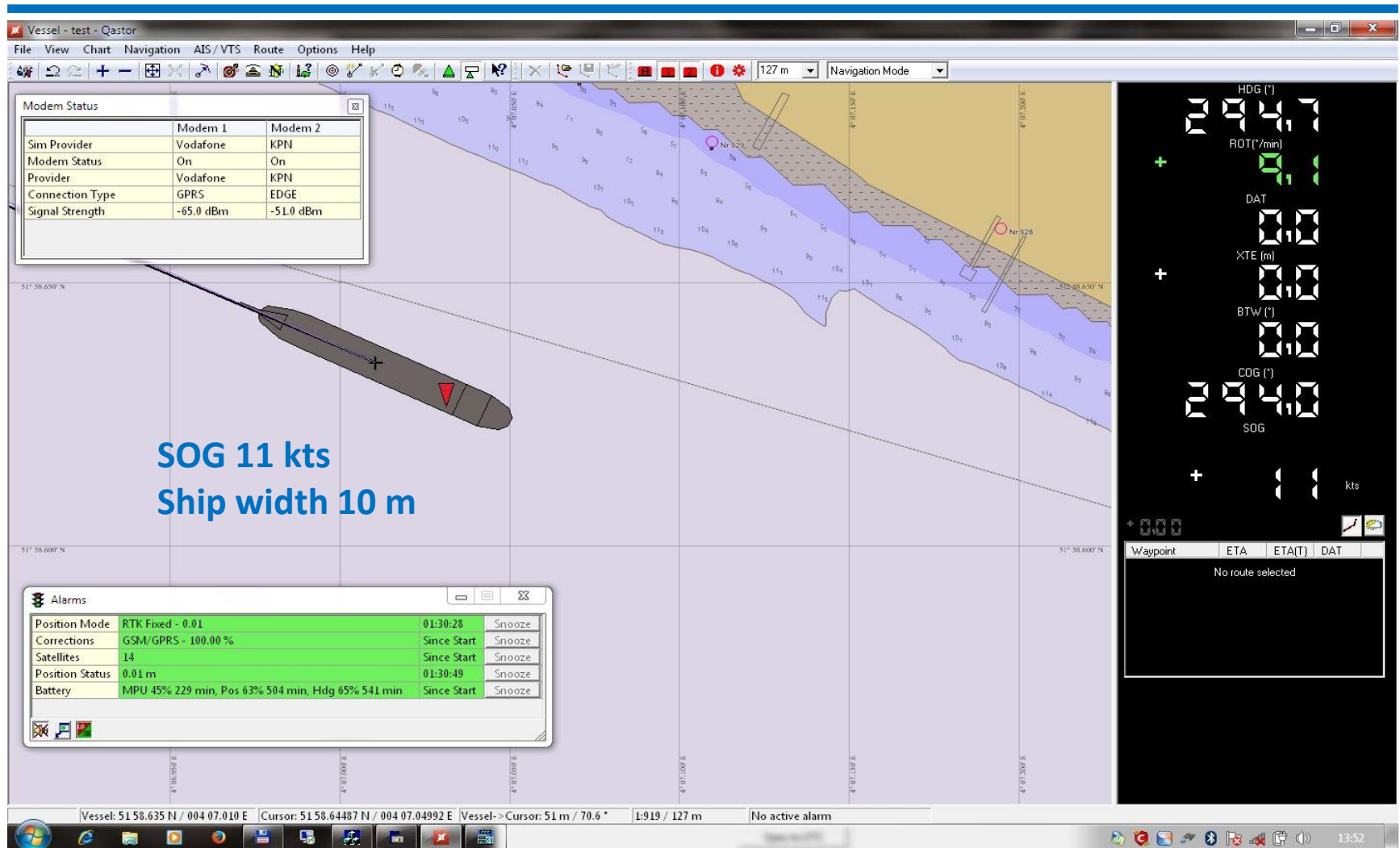
1: eLoran antenna
2: solar cells
3: Loran receiver, including
   - UMTS/GPRS module
   - micro computer
4: UMTS/GPRS antenna
5: buffer battery
6: metal mast

a: polyester mast, including
   - Loran antenna
   - UMTS/GPRS antenna
b: Loran receiver, including
   - micro computer
   - UMTS/GPRS module
   - battery

eDLoran Concept

eDLoran Reference Stations

Internet

eDLoran Server

eLoran TX Stations

UTC

eLoran Network Control Centre

USERS

eDLoran service request

eDLoran corrections

3G/4G/LTE Network

By courtesy of Babcock International Group

GPS-RTK & eDLoran on Qastor (QPS)

SOG 11 kts
Ship width 10 m

eDLoran Measurements @ Hook of Holland

Red = raw eLoran
Blue = 10m wide GPS-RTK
White = eDLoran

144 m

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Google earth

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