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Environmental-friendly underwater acoustic communications and networks

S.M. Jesus, LARSys and UAN teams
(sjesus@ualg.pt)

LARSys - Laboratory of Systems and Robotics
Universidade do Algarve
www.siplab.fct.ualg.pt

September 14, 2012

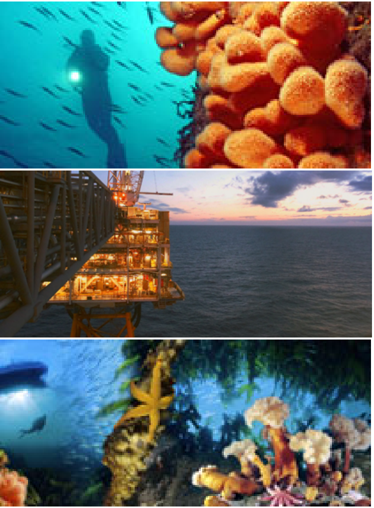
Motivation/conclusion

Q: *how do we perform underwater wireless communications that are not harmful/"pollute" the environment ?*

A1: *we don't know.*

A2: *we study the acoustic environment, the impact and then we try adapt.*

The environmental challenge



(from Statoil web site)

Marine Strategy Framework Directive (MSFD - EU 2008/56/EC):

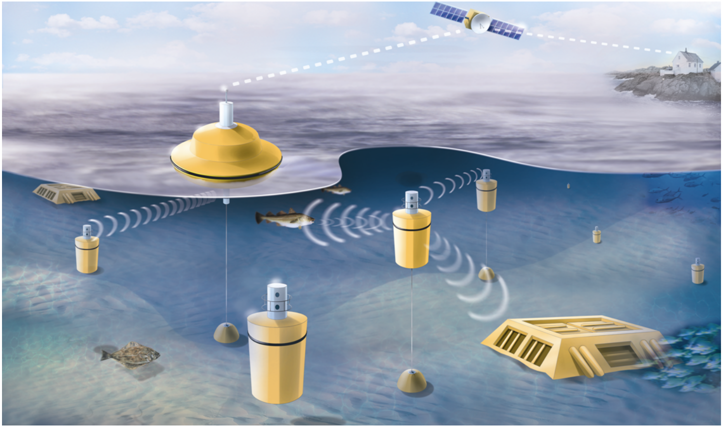
- Define "good environmental status": *the marine environment is a precious heritage that must be protected, preserved and, where practicable, restored with the ultimate aim of maintaining biodiversity and providing diverse and dynamic oceans and seas which are clean, healthy and productive*
- What is being done ?
  - AlfaSentral platform (Norway): plankton, benthic fauna, fish, marine mammals, seabirds, fishing activity, conservation areas and species
  - 25 MEuro contract Statoil - Kongsberg

The technological challenge

- **"pre-sal" technological challenge (Petrobras, Brazil)**
  - reservoir geological and seismic characterization
  - CO2 corrosion and wellbore fractures
  - large pipe (18") in 2200 m water depth
  - long range to shore
- **The Arctic challenge ahead**

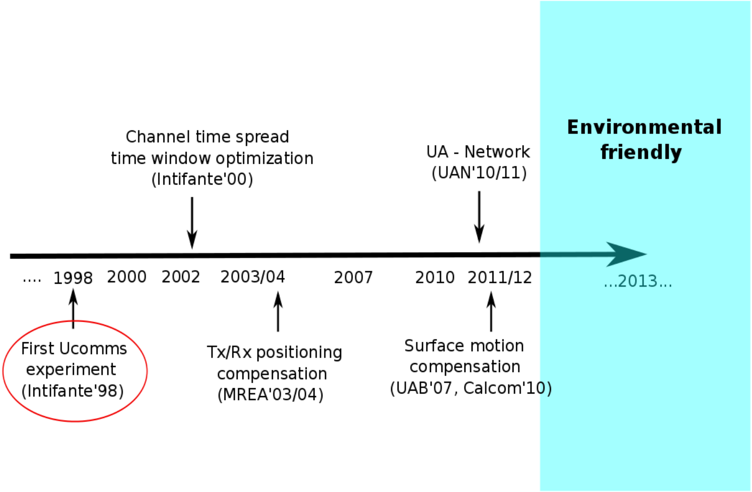
The integrated vision

Underwater wireless communications is an enabling technology for integrating critical infrastructure protection and environmental monitoring networks



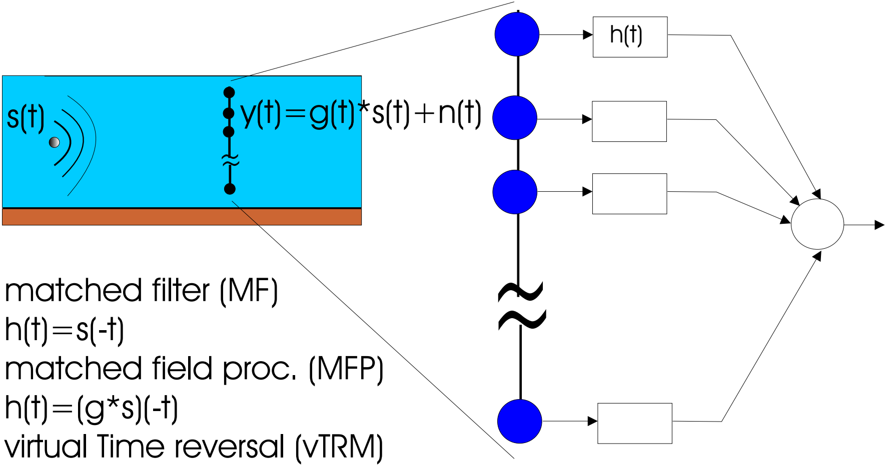
(from UAN project, FP7 # 225669)

Timeline (1)



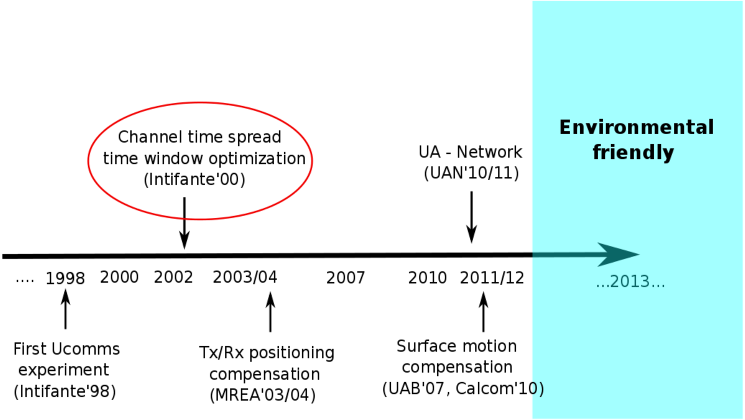
Channel time spread
time window optimization
(Intifante'00)
UA - Network
(UAN'10/11)
Environmental
friendly
.... 1998 2000 2002 2003/04 2007 2010 2011/12
...2013...
First Ucomms
experiment
(Intifante'98)
Tx/Rx positioning
compensation
(MREA'03/04)
Surface motion
compensation
(UAB'07, Calcom'10)

The matched filtering array



- matched filter (MF) h(t)=s(-t)
- matched field proc. (MFP) h(t)=(g*s)(-t)
- virtual Time reversal (vTRM) h(t)=y (-t)

Timeline (2)



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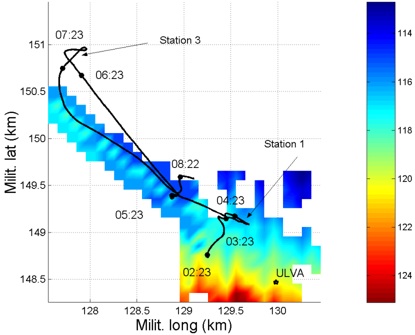
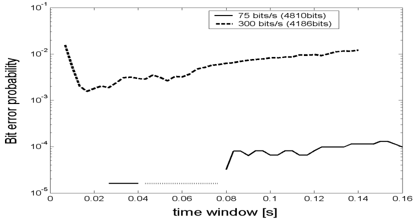
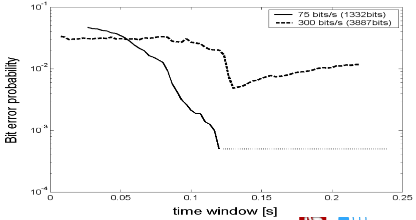
INTIFANTE'00 sea trial, Setúbal (Portugal)



station - 800 m

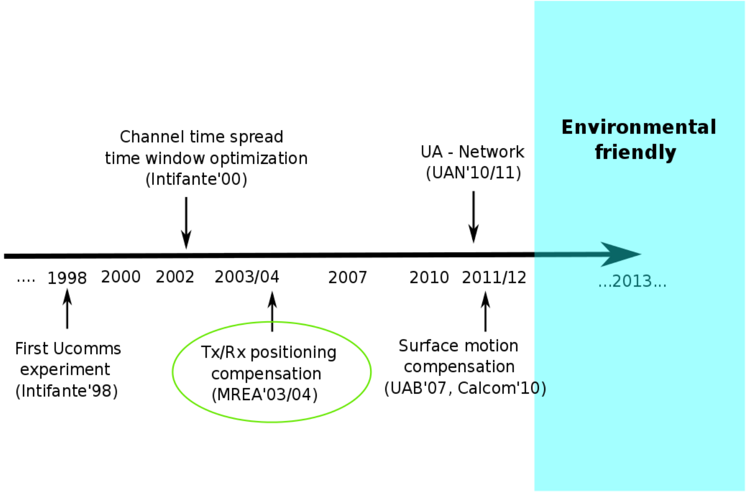


station - 3300 m



- 16hyd, 4m spacing VLA
- band 3.6 kHz

Timeline (3)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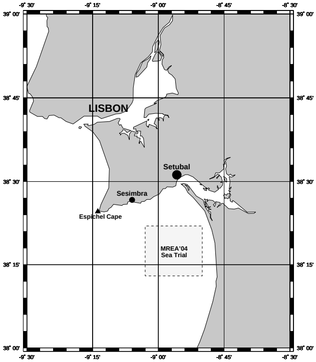
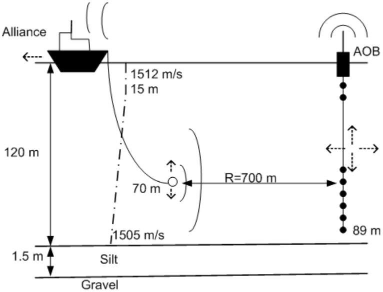
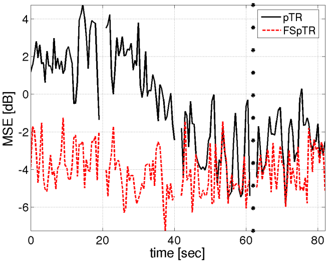
Geometric variability challenge (2)

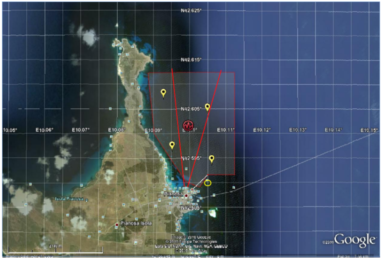
MREA'04, Setúbal (Portugal): f_c=3.6 kHz, 2PSK, 400 symb/s

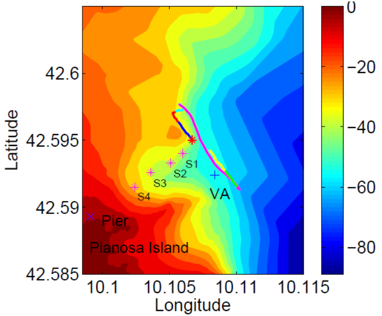






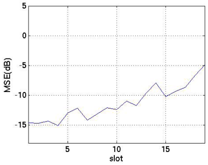
UAN10, Pianosa (Italy): variable f_c, nPSK, SD, SR

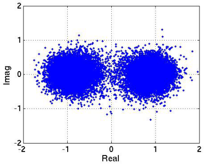




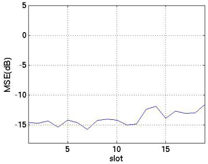
pTR + DFE

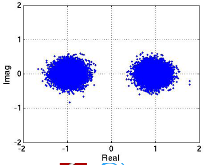
No frequency shift





With frequency shift





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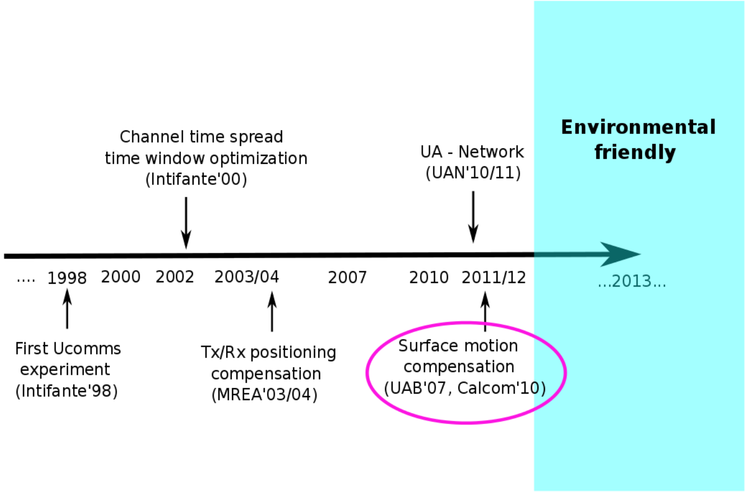
Timeline (4)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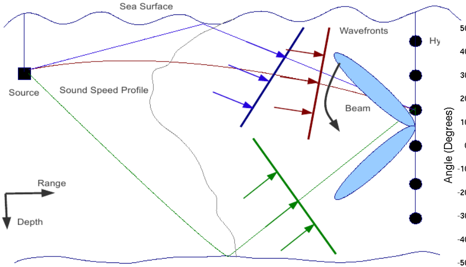
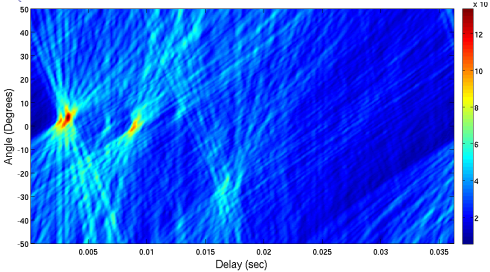
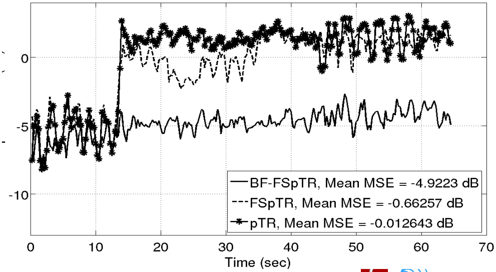
Environmental variability challenge

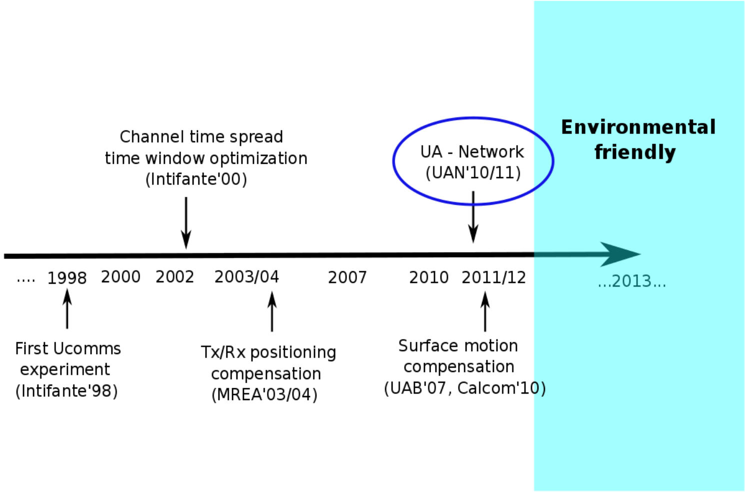




- BPSK
- carrier 6.25 kHz
- 1000 bits/s
- 50×0.1 s chirps for channel estimation
- 100 s data packets



Timeline (5)



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The networking challenge

How to mitigate channel variability effects:

1. predict communication performance based on actual environmental conditions
2. **adapt network node position** for optimized ucom performance (or to establish connection to remote nodes)
3. simpler nodes (fixed/mobile) means less autonomy and processing power
4. concentrate complexity
   - take advantage of channel diversity
   - introduce noise / array gain

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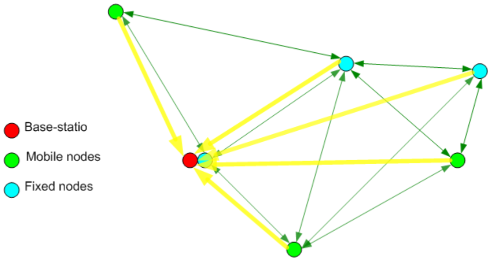
5 Kongsberg cNode Mini Transponder

Networking mode

- node discovery
- multirate Cymbal protocol
- multihop



Transparent mode

- network inhibition
- node to VLA transmission
- nPSK modulated sequences

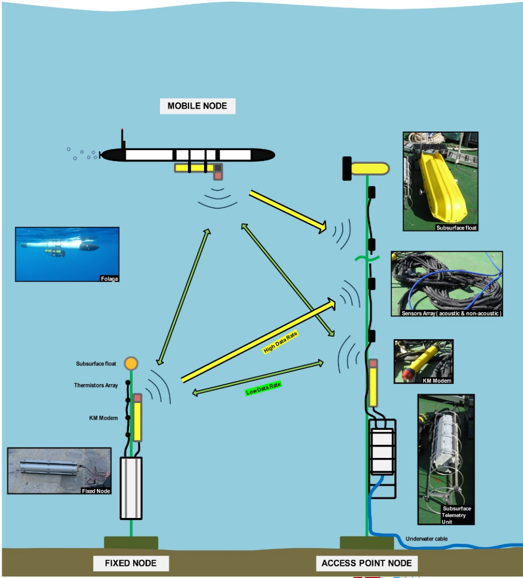
UAN approach (2)

System complexity

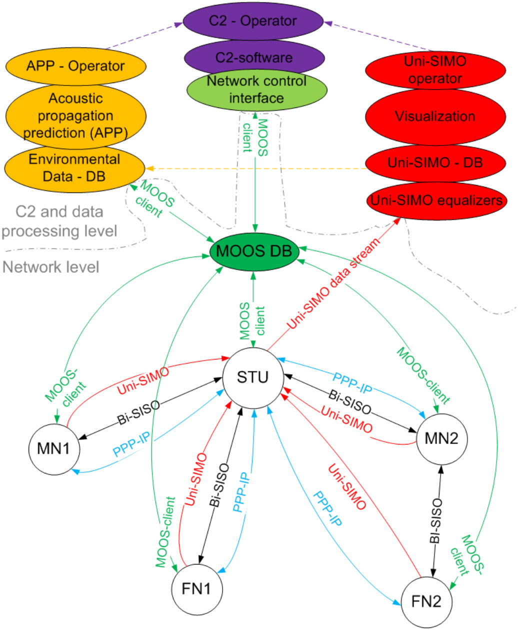
vs.

channel capacity

- gateway: complex master node
- slave nodes
  - Folaga mobile nodes
  - fixed nodes with environmental sensors



UAN approach (3)



- **Network components**
  - STU: master node (AP)
  - MNx: mobile nodes
  - FNOx: fixed nodes
  - MOOS: midlleware data base
  - C2: control and command
- **Network layers:**
  - Bi-SISO: bidirectional modem low level communication
  - Uni-SIMO: unidirectional modem to array communication
  - PPP-IP: IP layer
  - MOOS-client: message communication over IP

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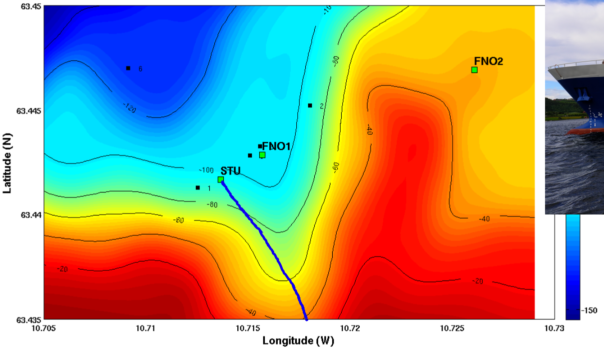
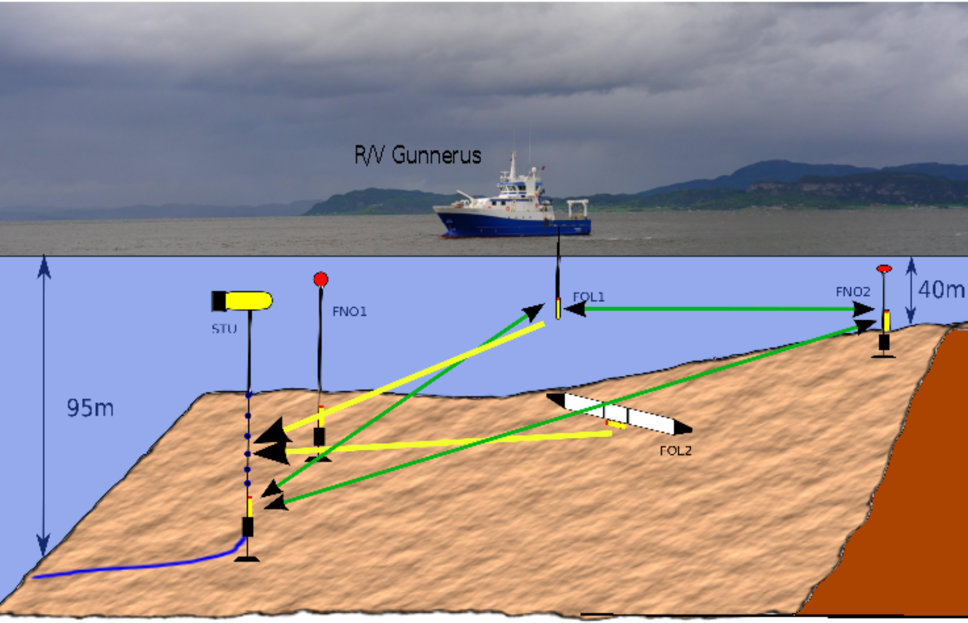
UAN11 sea trial, Strindfjorden (Trondheim, Norway) (1)

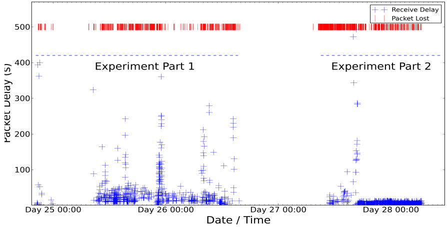


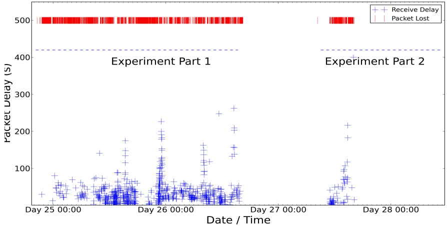
UAN11 sea trial, Strindfjorden (Trondheim, Norway) (2)



Networking issues: master to fixed node 2

- data rate 200 bps, occasionaly 500 bps
- up to 500s packet delay
- 40 and 42% data loss
- most data was received with delays 3 to 20s
- packets actually received, but link broken for the ack





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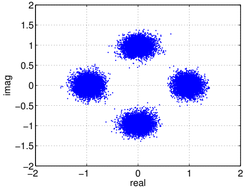
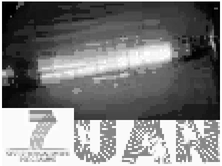
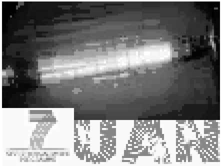
Network transparent signals: FS-pTR + DFE

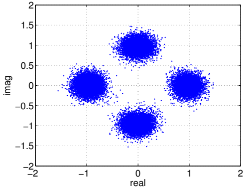
Folaga 2 May 27, 2011, MSE = -15.7, BER=0

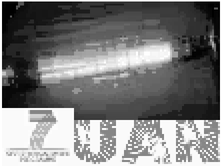


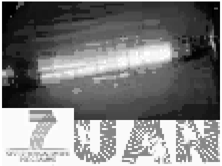




R/V Gunnerus (moving): May 27, 2011, MSE = -14.8, BER=0

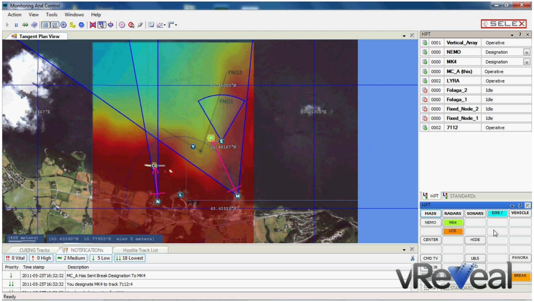


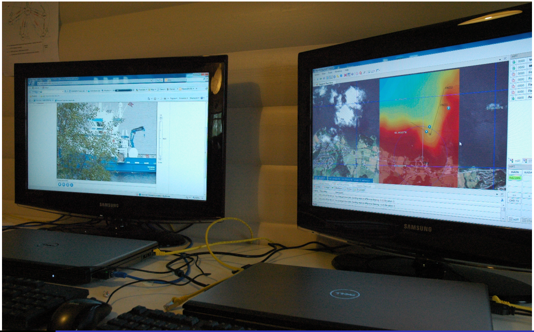




UAN11 sea trial, Strindfjorden (Trondheim, Norway) (5)

1. demonstration at sea of a full network up to the application layer
2. concurrent SISO (networking) and SIMO (network transparent) messaging
3. control and command running for several hours in a intruder interception task
4. grabb environmental information from nodes





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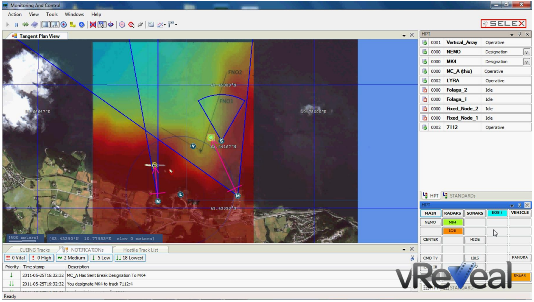

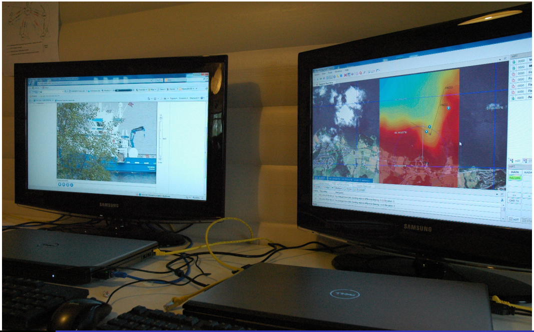

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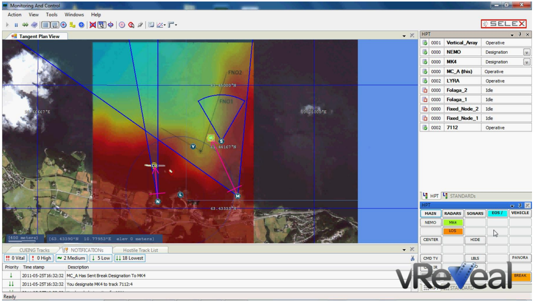

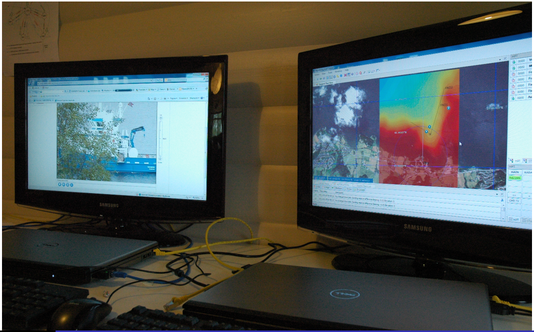

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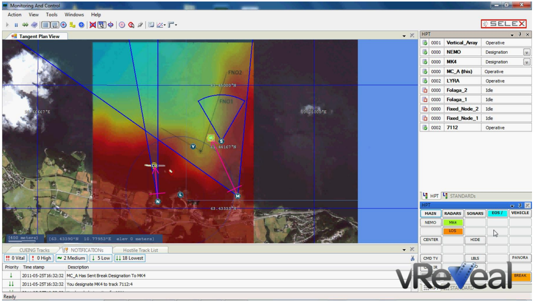

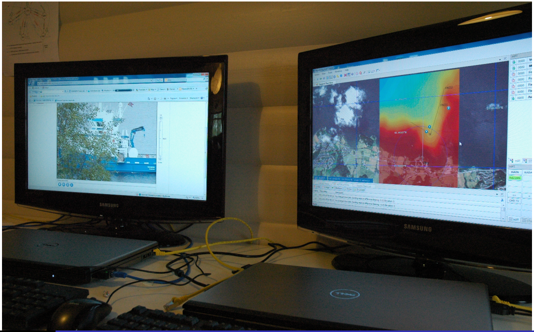

Environmental-friendly

- **characterize the coastal ecosystem soundscape**
  - **time periodicities and variability:** day/night, lunar cycles, year, season...
  - **correlations with other ocean effects:** tidal variations, temperature variability, current system,...
  - **frequency band:** effective at least in 1 - 10 kHz*
  - **correlation and statistics in time and space**
- **correlate with species**
  - abundance, activity, health, location
  - type (resonating sea urchin, snapping shrimp, coquille St. Jacques, "breathing" sea grass, ...)
- **usage for ucomms ?**
  - correlate with ucomms performance
  - adapt levels, levels, biological noise becomes biological (interference) signal

* work by Di Iorio, Gervaise, Chauvaud et al. from GiPSA-Lab, LEMAR, and others

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Underwater Acoustic Network[1] (2008-2011)

www.ua-net.eu

A. Silva, J.P. Gomes, S. Ijaz,
U. Vilaipornsawai, F. Zabel and C. Martins

R. Massimmelli and M. Cresta

T.A. Reinen and A. Lie

A. Caiti, A. Munafo and G. Dini

I. Karasalo and T. Oberg

T. Husoy and M. Pettersen

[1] funded by the 7th Framework Program, contract 225669.