Iceland Liechtenstein Norway grants

Closing Event of the PT02 Programme

Integrated Marine and Coastal Waters Management "Achieved Outcomes"

December 6th - Lisbon

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ENDURE

Enabling Long-Term Deployments of Underwater Robotic Platforms in Remote Oceanic Locations

Luís Pessoa, INESC TEC

INESCTEC
ipma instituto português do mar e da atmosfera
MARLO

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Outline

- Motivation and Challenges
- ENDURE Objectives
- Docking mechanism
- Underwater RF Communications
- Wireless Power Transfer
- Demo
- Dissemination
- Conclusion

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Motivation

Increasing need to sense the underwater environment:

- Environmental monitoring
- Water/seabed data

Large and deep ocean -> Automation -> AUVs

- Autonomous operation ✓
- Scalable ✓
- Unlimited autonomy ✗

Need for energy solution enabling the operation of multiple AUVs in remote oceanic locations, with time unlimited missions

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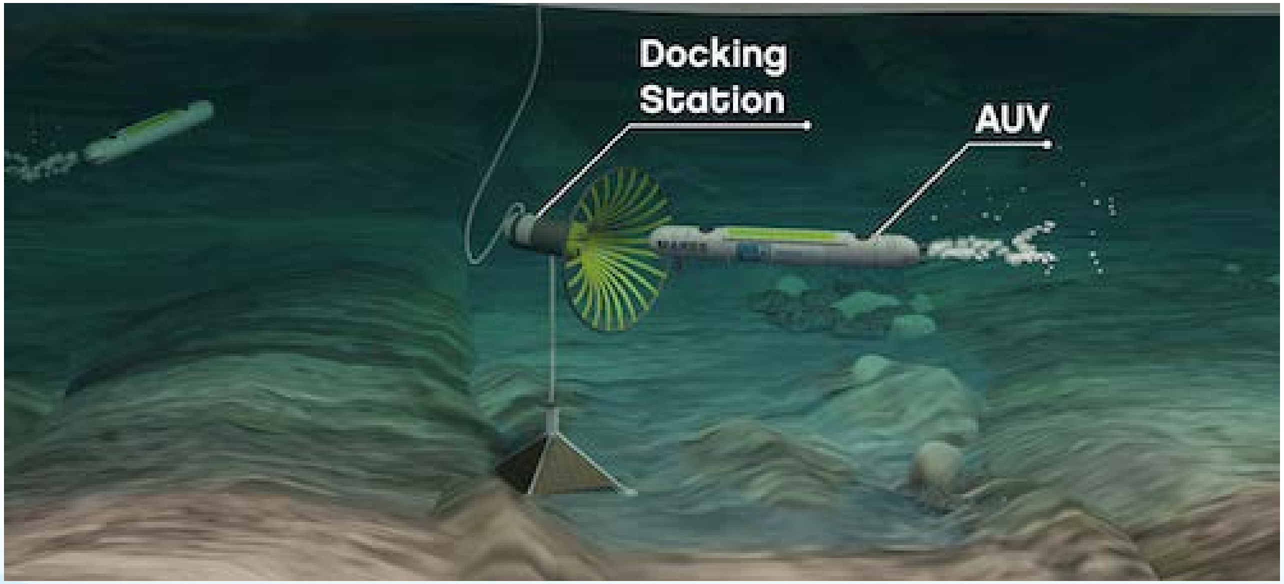
Technical Challenges

- **Docking manoeuvre**
- **Communications**
- **Power transfer**



ENDURE Project Objectives

- **Develop and demonstrate a cost-effective solution for recharging AUVs**
- Docking mechanism, based on a novel vision based AUV positioning subsystem.
- Wi-Fi based high-bandwidth short range communication subsystem, for fast data downloading.
- Wireless battery recharging subsystem, capable of tolerating misalignments.

ENDURE Project Main Figures

- 3 Partners (1 from donor country)
- 256655€ Cost
- 218157€ Grant from EEA
- Timeframe: 18 months
- Outcome: #2 Improve monitoring of marine waters
- Output: Capacity on fixed or mobile unmanned oceanic and coastal monitoring operations increased

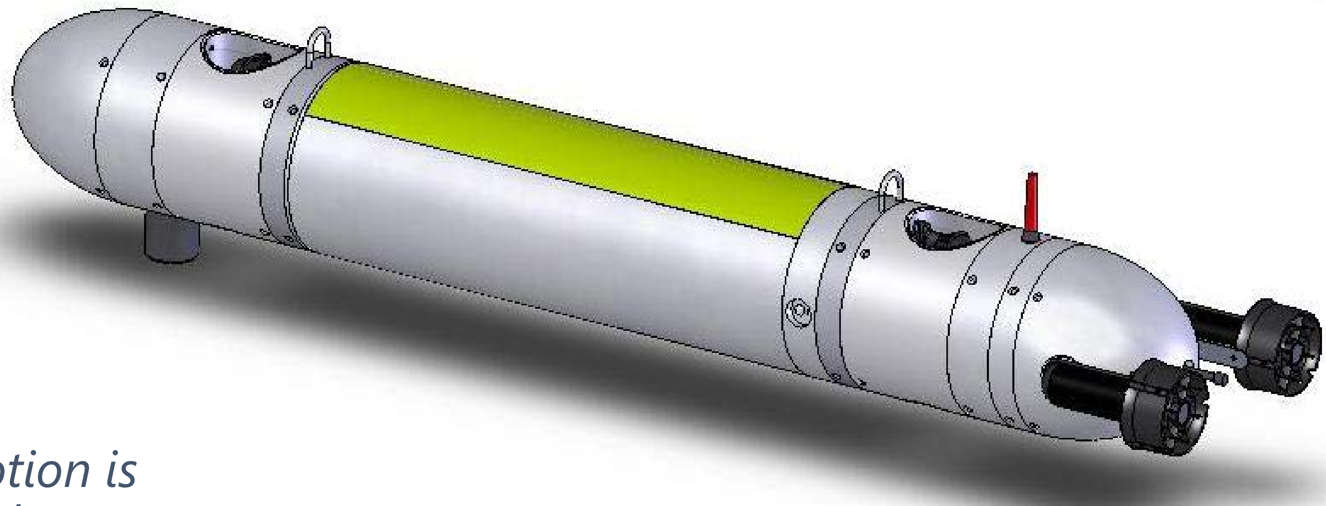
Docking mechanism

Docking station – general requirements

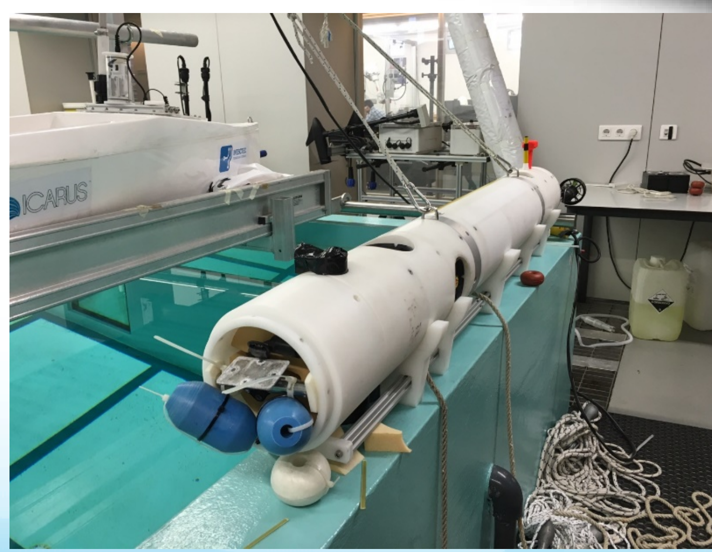
- Acoustic system for long range approach
- Visual target for short range positioning and guidance
- Short range wireless communications with AUV
- Video camera to document AUV operations
- Wireless power transfer system
- Locking mechanism to hold the AUV in place
- Cabled connection to shore/surface: communications and power (minimum 30m)
- Depth and attitude sensors
- Lights
- Weight in air less than 30kg
- 10 bar pressure hulls

Considered AUV: MARES

- **AUV current configuration**
  - 1.8m long
  - 5 Degrees of Freedom
    - *(lateral motion is now possible)*

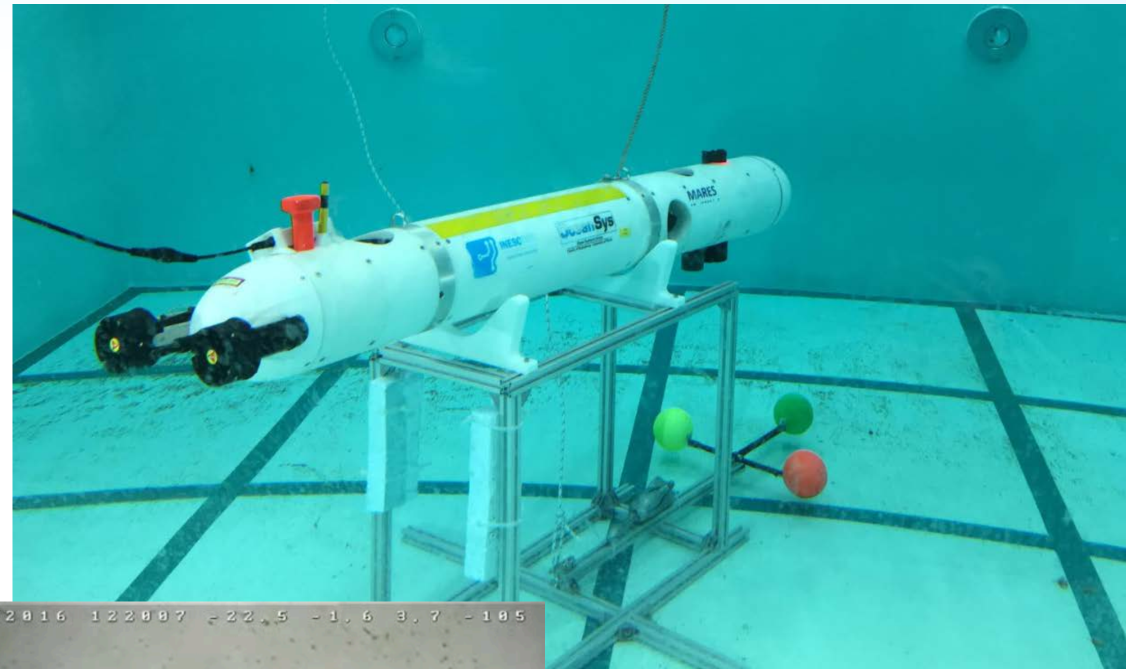


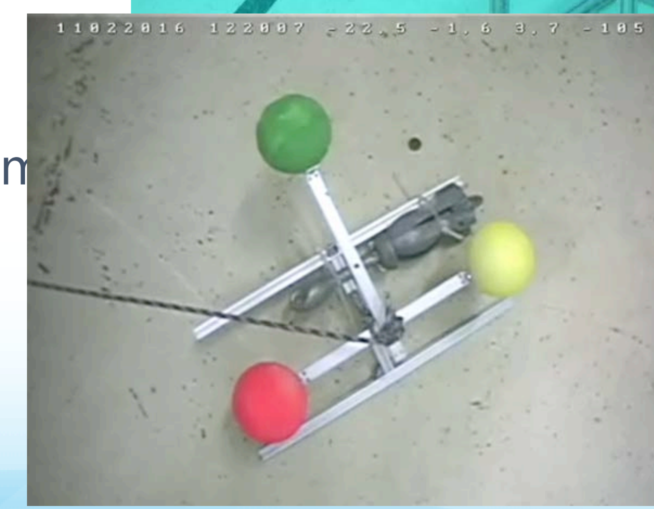
- **Sensing**
  - Attitude + depth
  - Acoustic ranging
  - Camera



Approach for docking

- 1. Search docking station
- 2. Visually track the docking station (visual markers)
- 3. Position and align wrt to the docking station
- 4. Approach the docking station from above





Docking sta

Ethernet + power cables

Dry
com

Wireless Power Transfer inductor

Video camera

Electromagnets

Lights + active beacons

Acoustic transducer

Docking experiments: video

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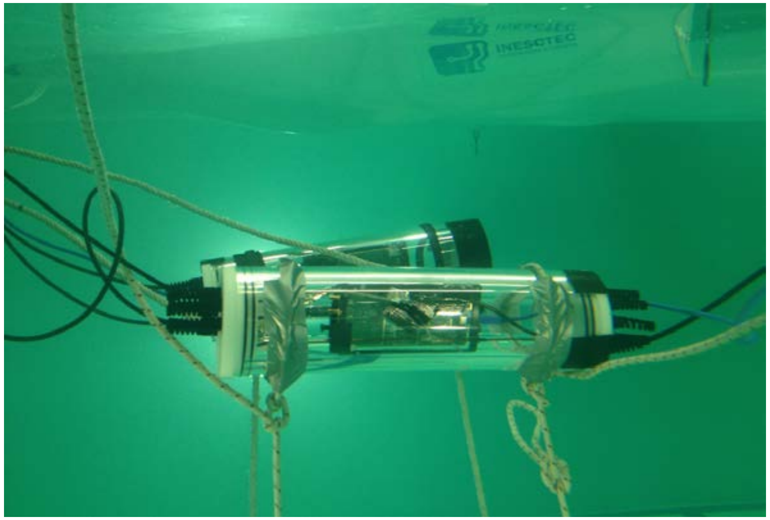
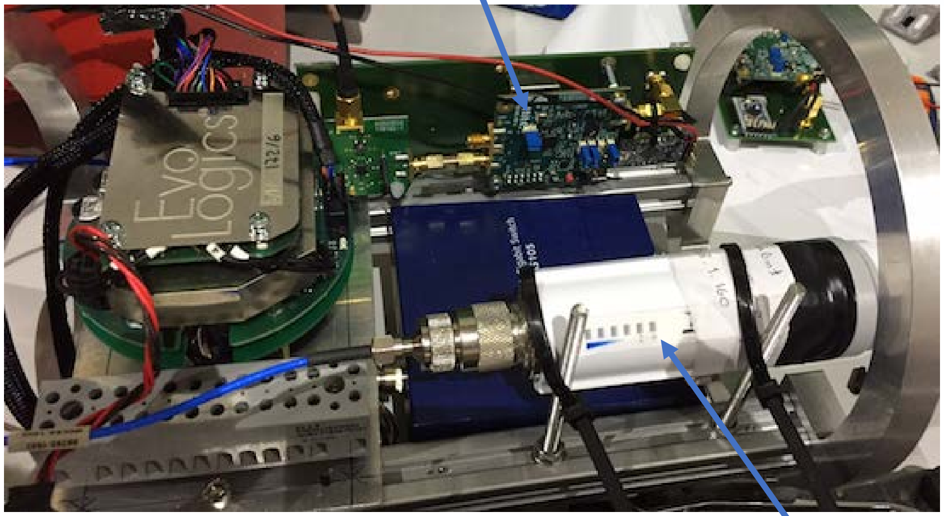
Underwater RF Communications

Short range communications





- Propagation of RF waves in seawater is well suited for short-range broadband communications

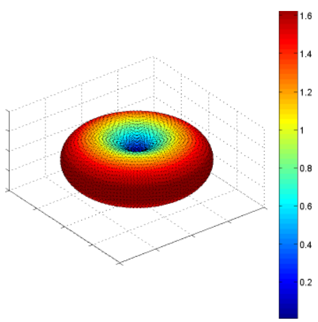
  - A 100 MHz carrier suffers a 30 dB attenuation for each 10 cm of propagation

- Based on Wi-Fi radios using sub-GHz frequencies (using up-downconversion hardware)

Simulated radiation patterns

- Seawater changes the radiation pattern
- Must be taken into account at the design stage

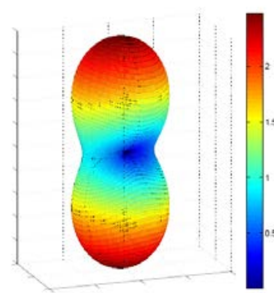
Dipole radiation pattern



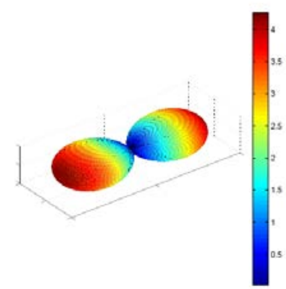
Fresh water

Sea water

Loop radiation pattern

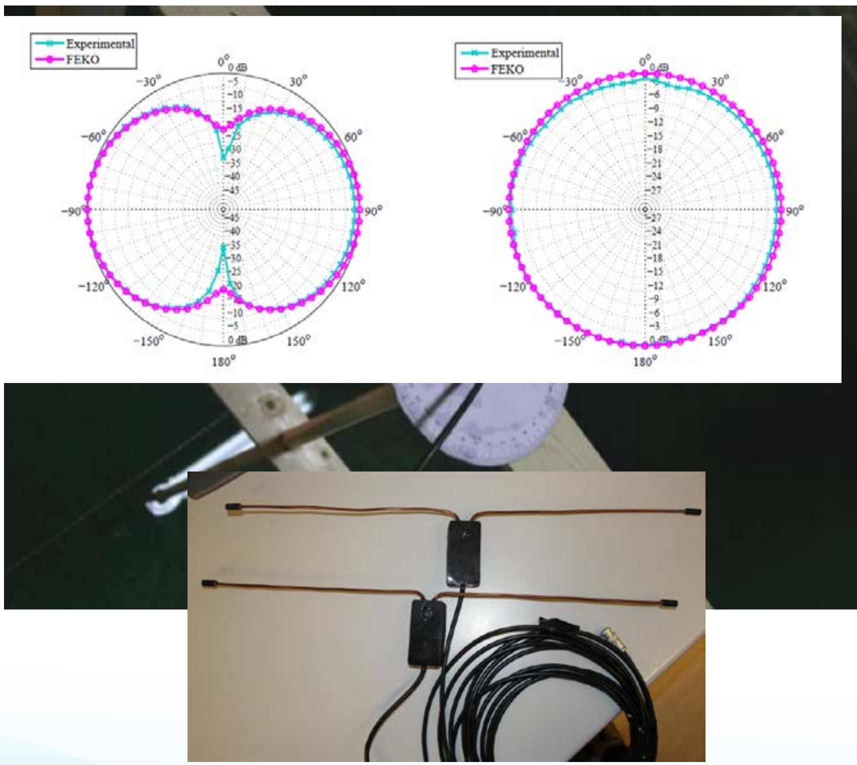


Fresh water

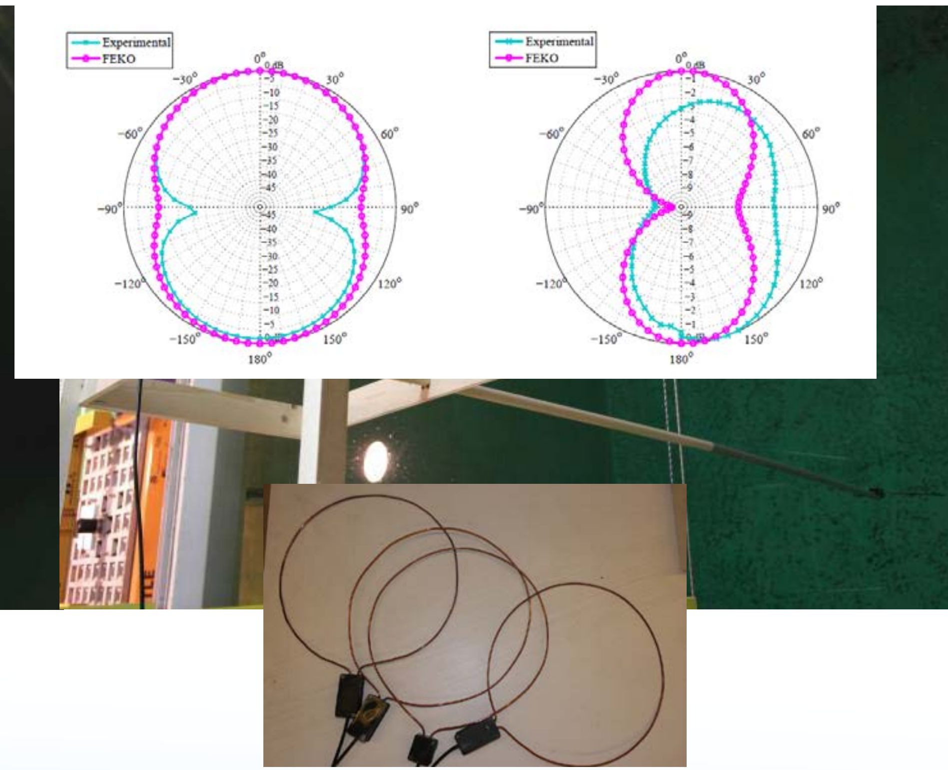


Sea water

Measurements in laboratory tank: Antenna radiation pattern

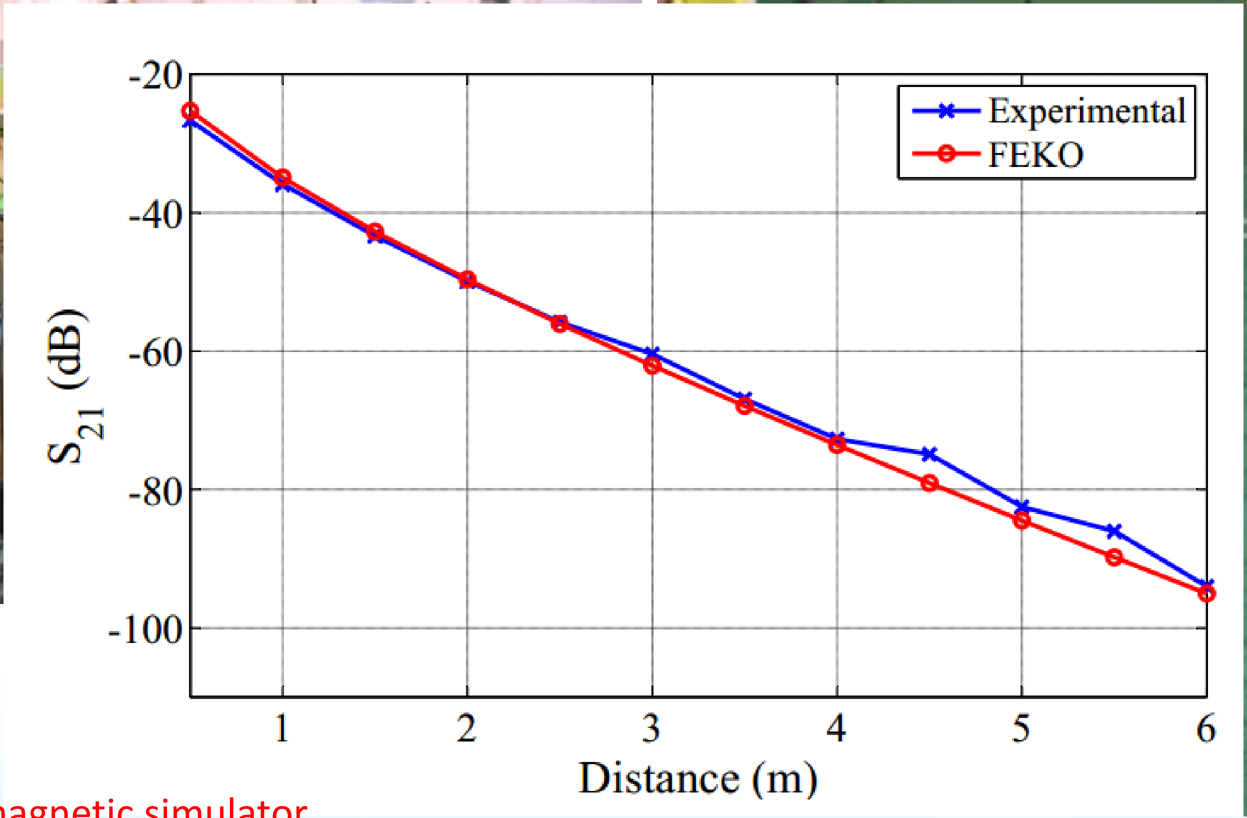


Dipole antenna



Loop antenna

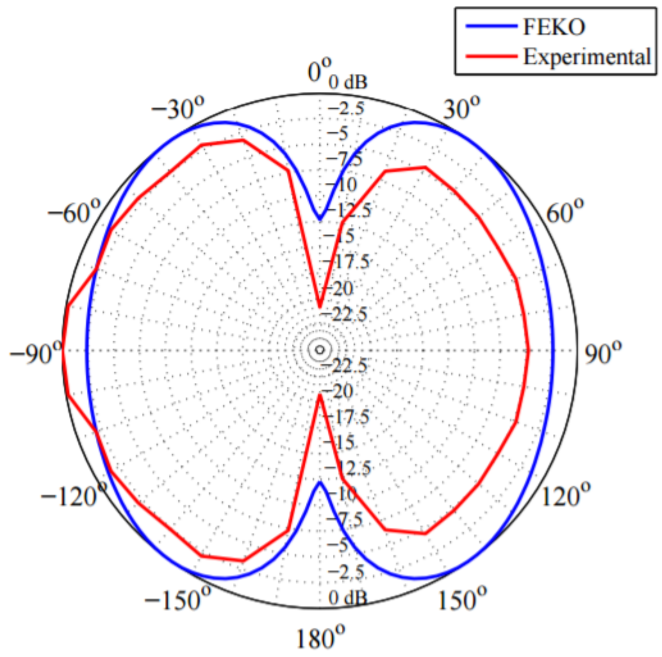
Measurements in laboratory tank: Distance between antennas

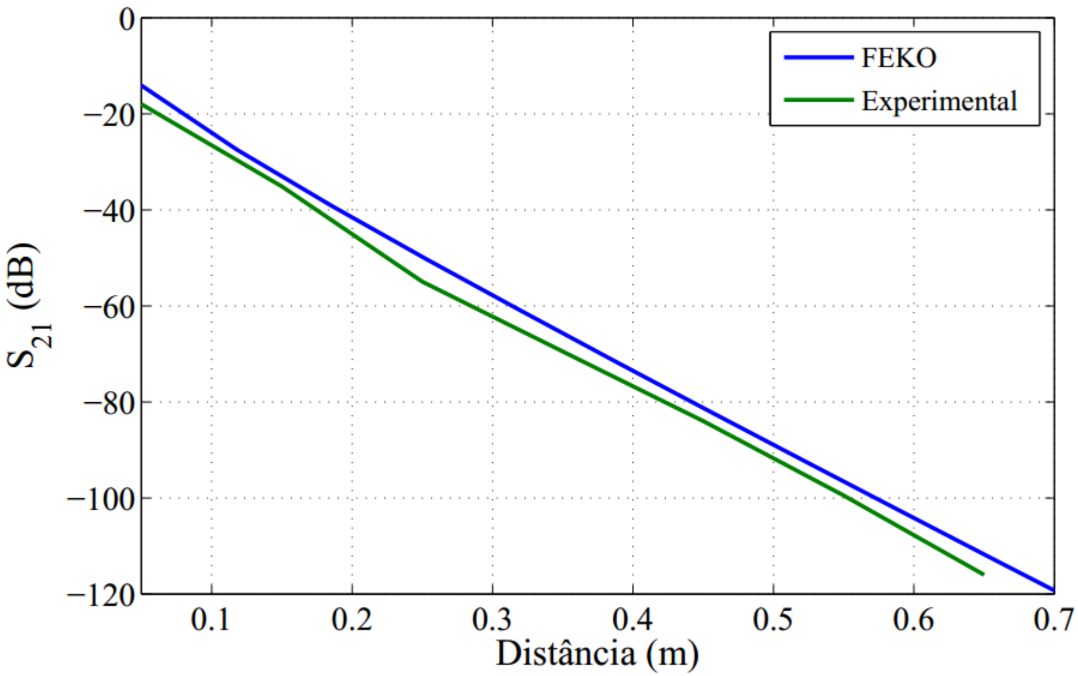


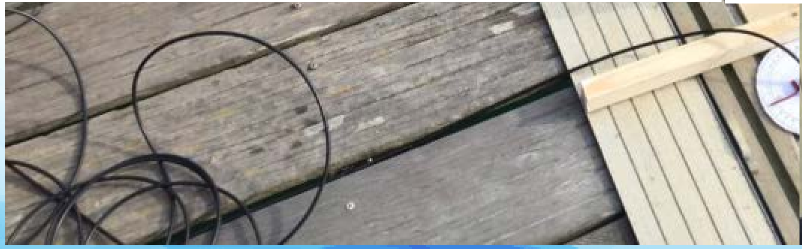
FEKO is a 3D electromagnetic simulator

S21 is a measure of signal attenuation between two antennas

Measurements in sea water (Leixões harbour): Antenna radiation pattern and distance







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Wireless Power Transfer

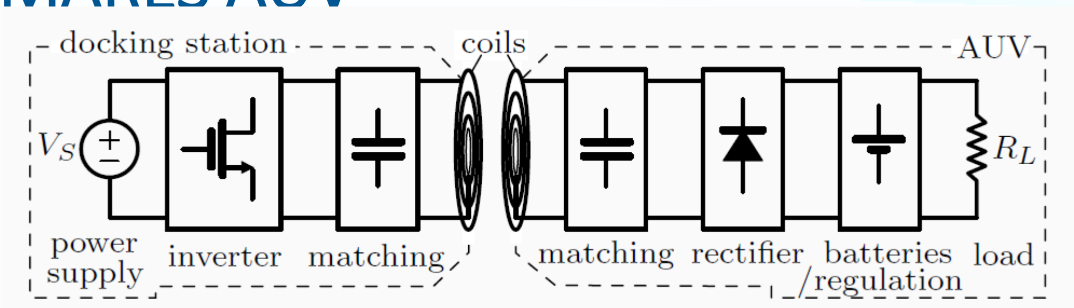
Motivation

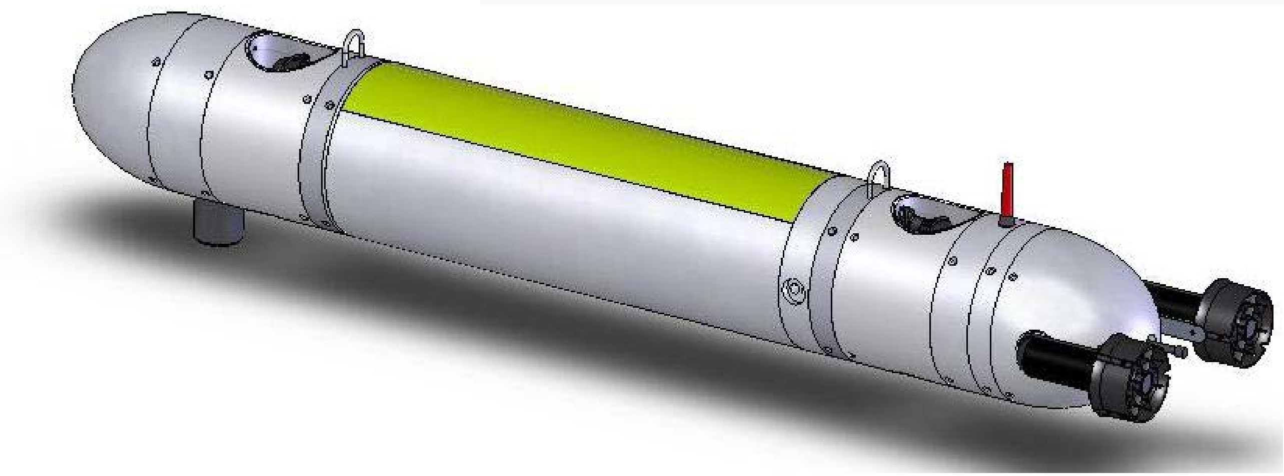
Wet mateable connectors are problematic:

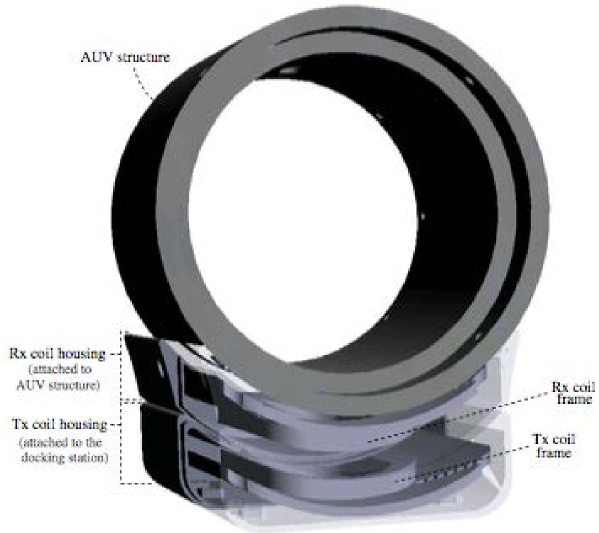
- *Needs to be plugged-in*
- *Pins are exposed to seawater,*
- *Suffers from fouling and corrosion*

Wireless recharging has been proven to be a better choice.

WPT for the MARES AUV



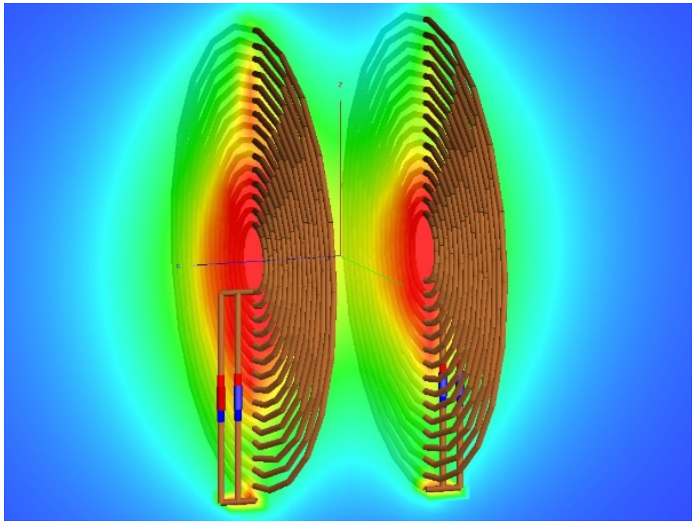




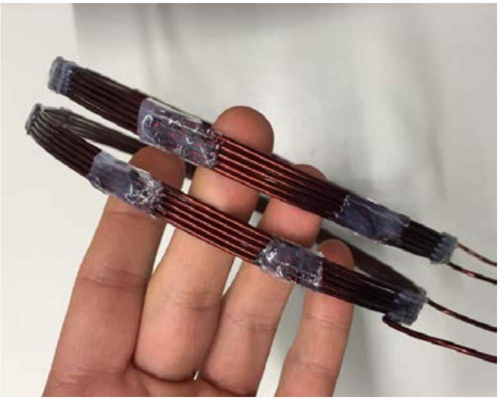
- Limits the size of inductors to approx. 16 cm of diameter
- AUV can dock in near contact (< 5 cm distance)

Inductor Design

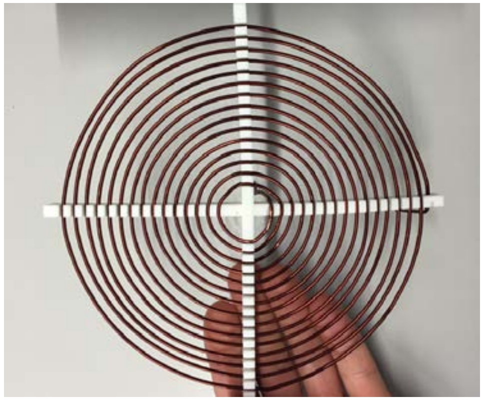
- **Development of resonant magnetic coupling technique for underwater WPT**



Coil based inductor

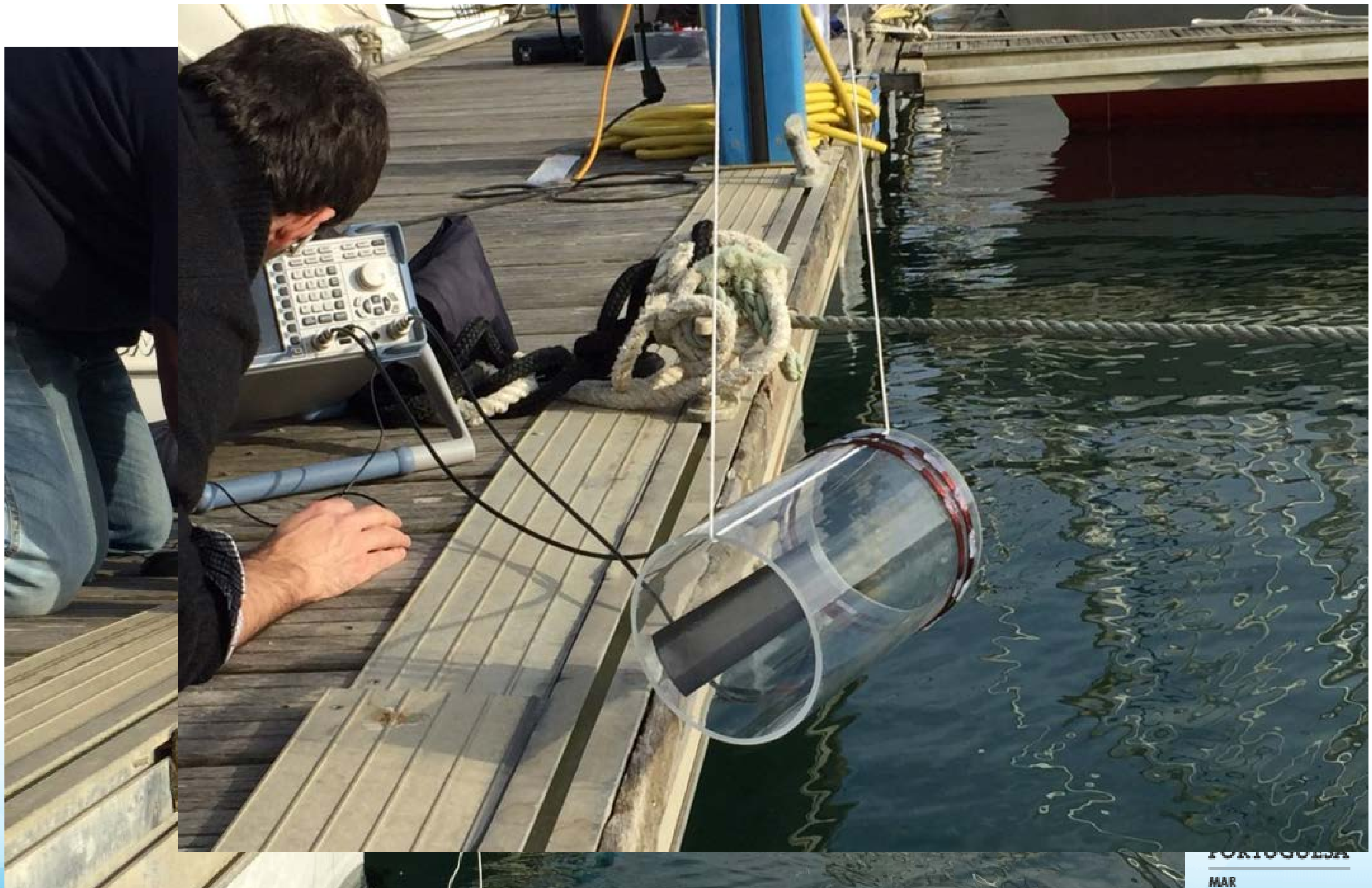


Spiral based inductor

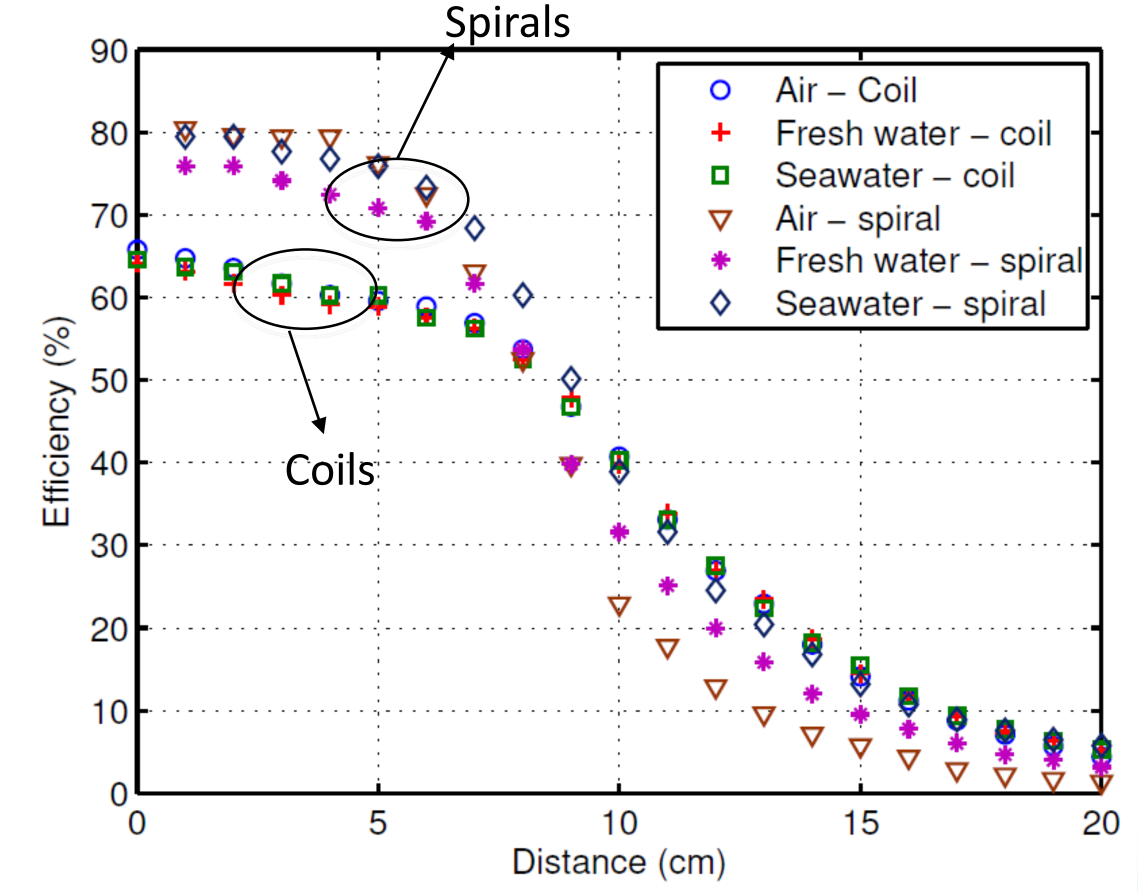


15 cm diameter, anti-ressonant at 100 kHz

Measurements at Leixões Harbour



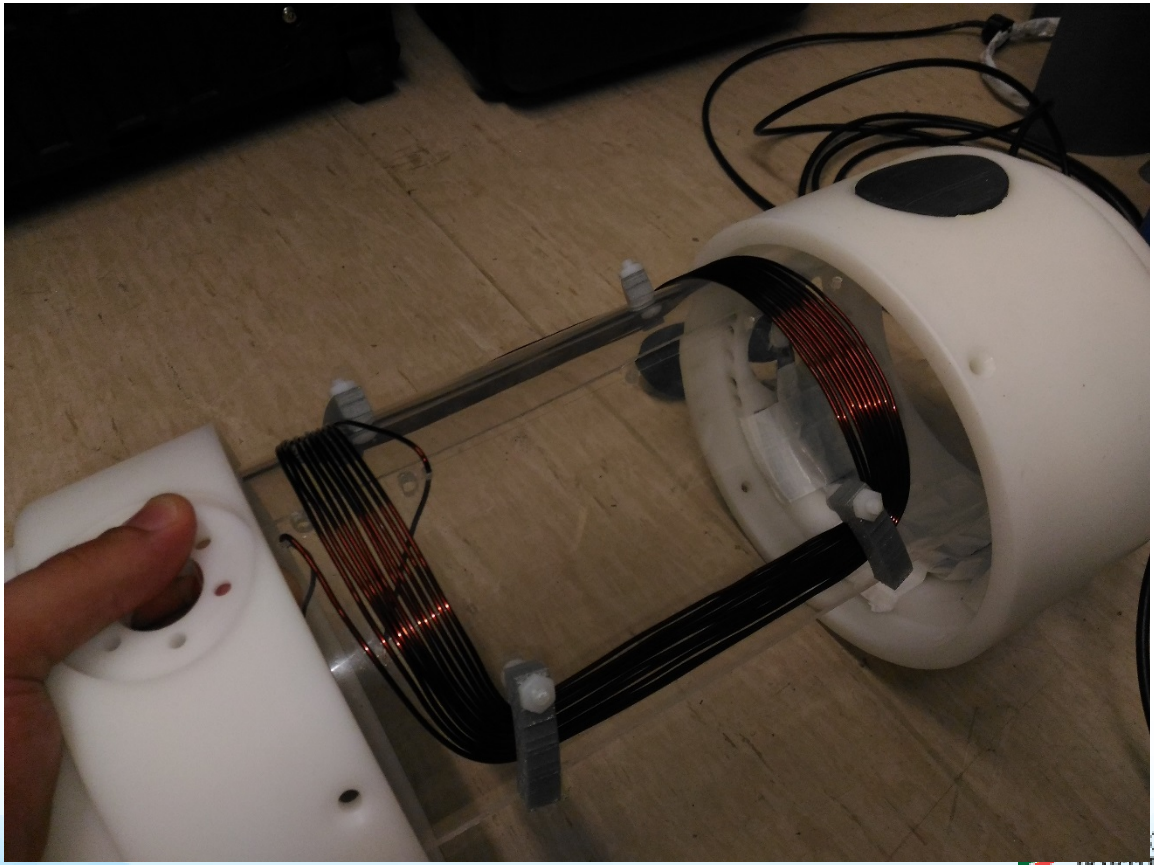
Experimental Results: Inductor-to-inductor efficiency



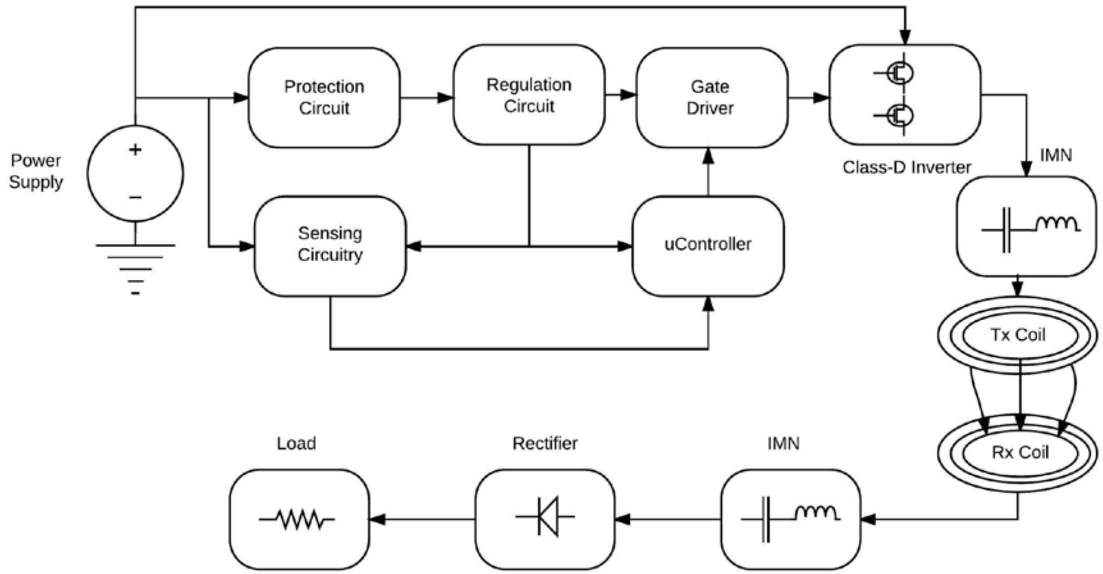
- **Validation of simulation predictions**

Final coil design

- **Conformal rectangular spiral inductors**

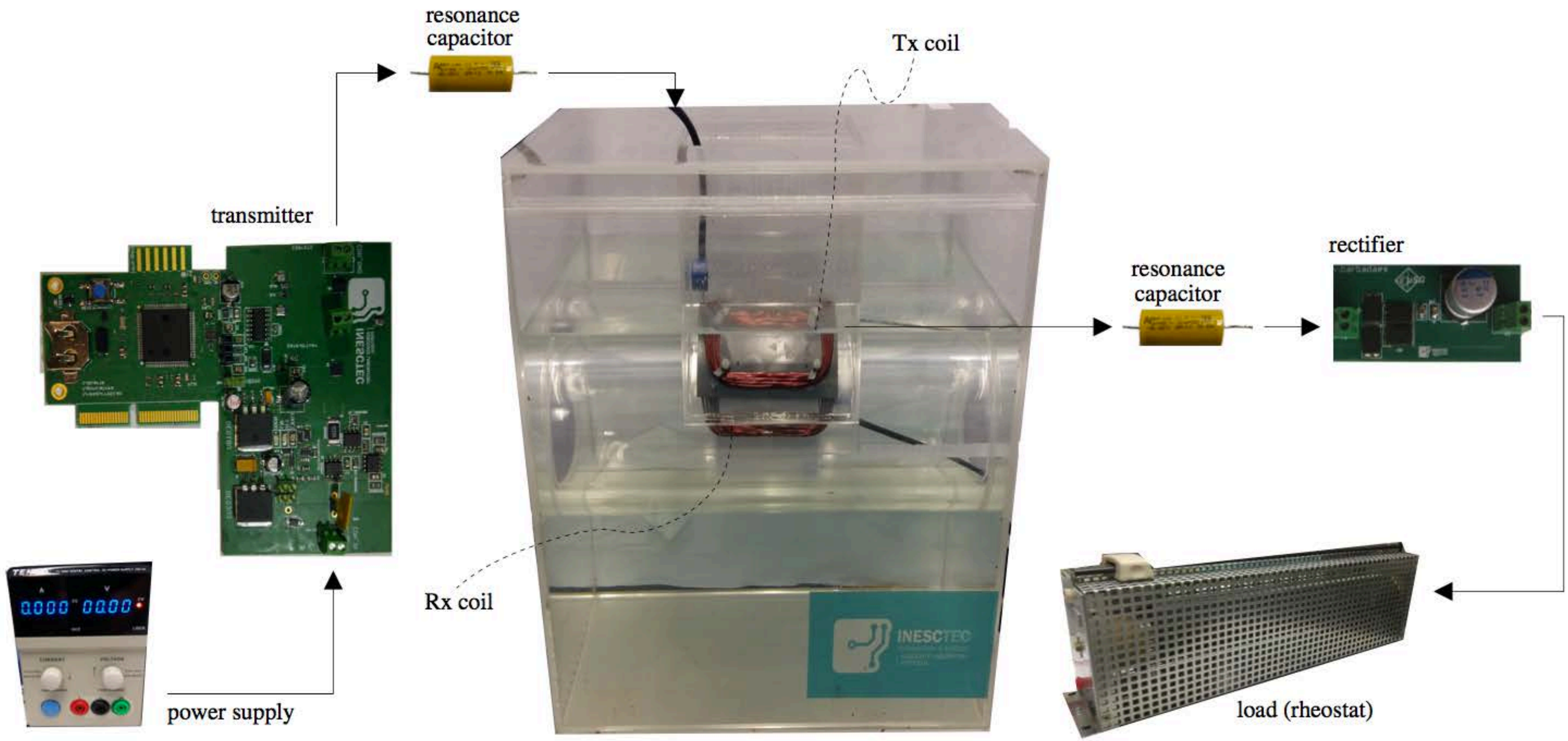


Electronics design: Challenges / Approach

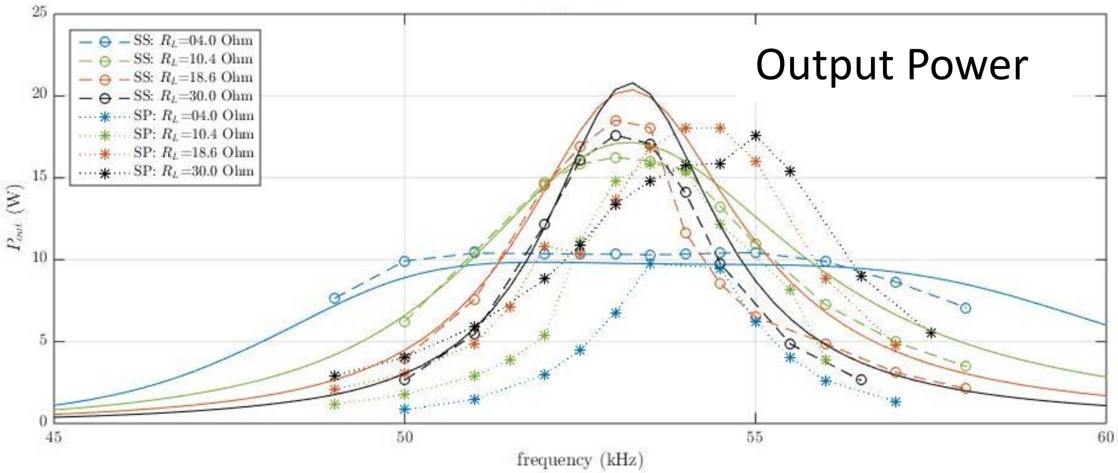


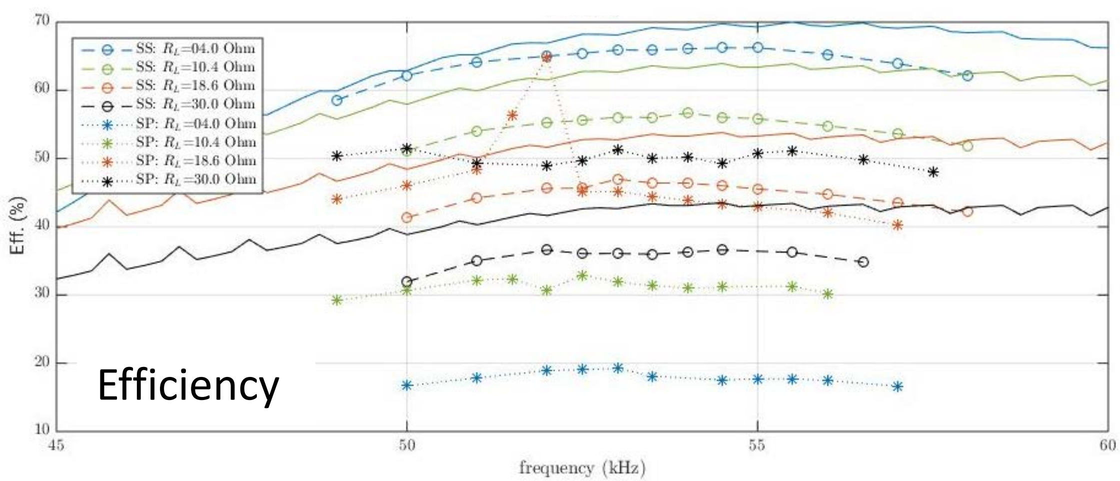
- Salt water conductivity and distance between Tx and Rx
- Load typically varies about one order of magnitude during battery charging
- Load sensing mechanisms required to optimize operation
- Nonlinear driver classes required to improve power efficiency

Experimental Setup



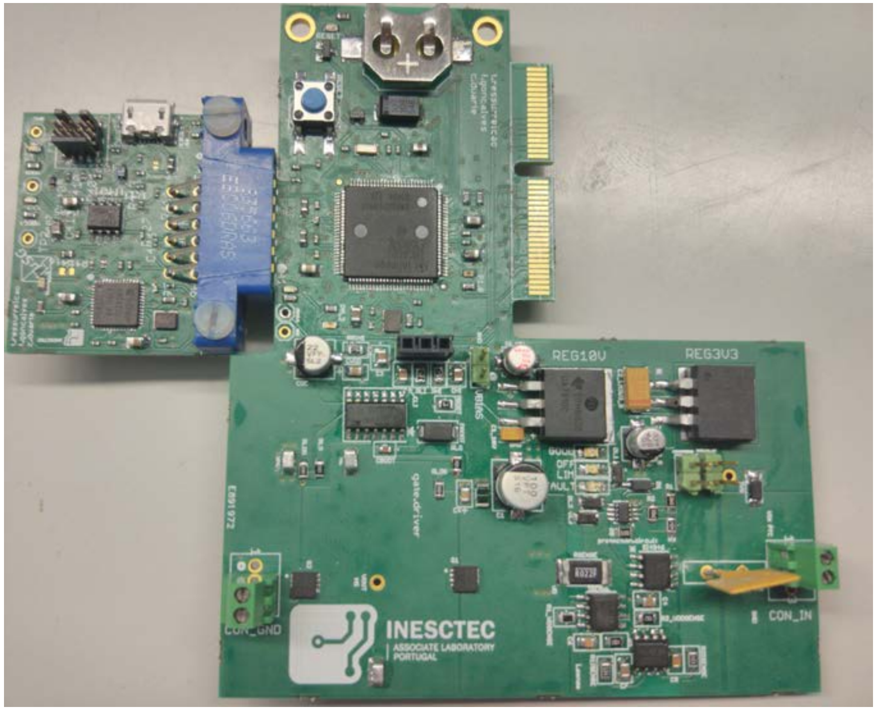
Experimental Results: Output power/efficiency



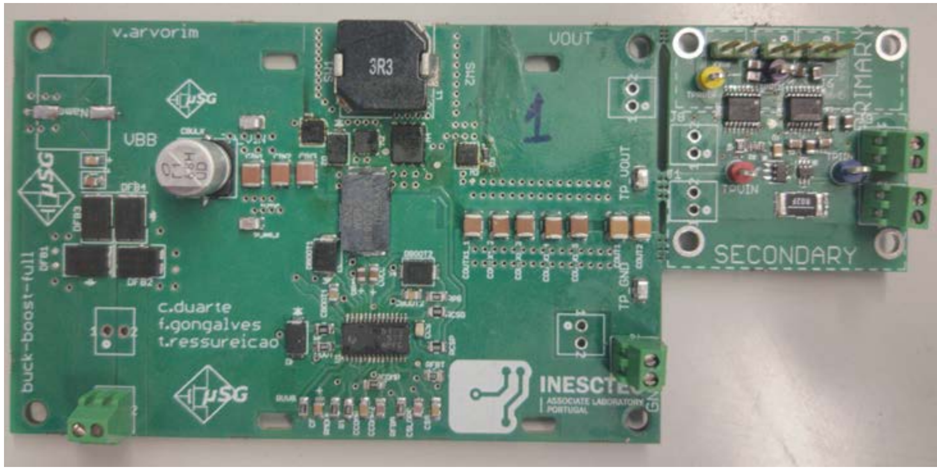


SS: Series-series
SP: Series-parallel
RL=[4, 10.4, 18.6, 30] ohm

Final prototype



Transmitter



Receiver

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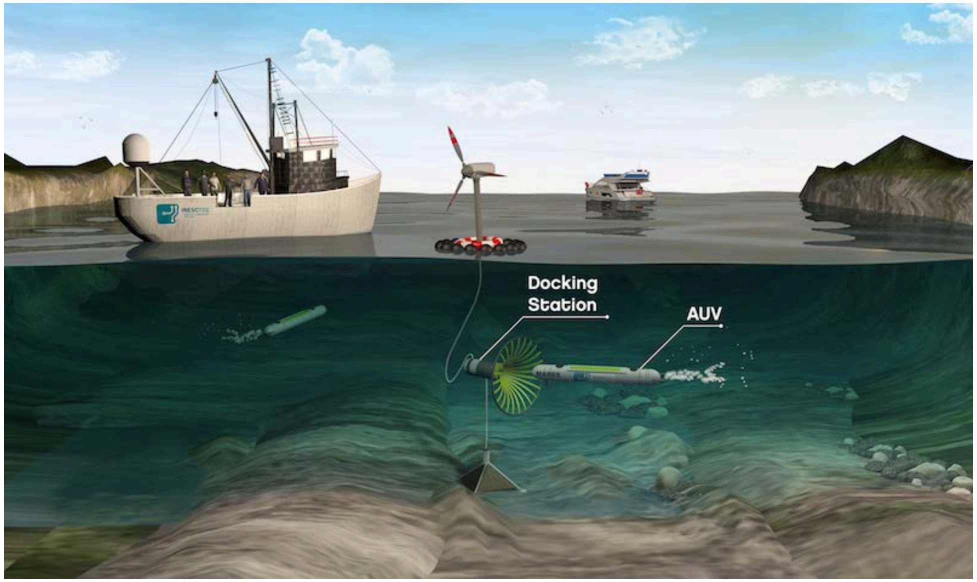
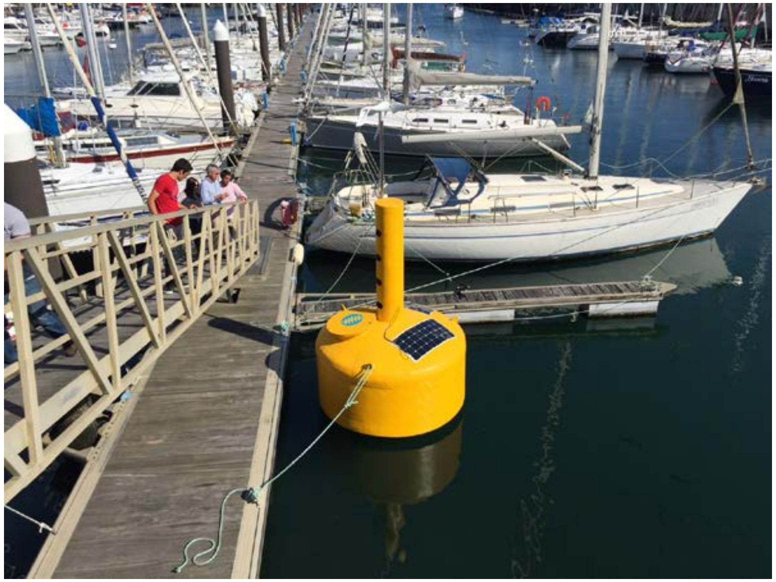
Demonstration

ENDURE demonstration scenario





- Based on a moored surface platform
- Based on the MARES AUV

Marine Buoy
2.4 m diameter, 4 meters height

Demonstration: Marine Buoy (view from inside)

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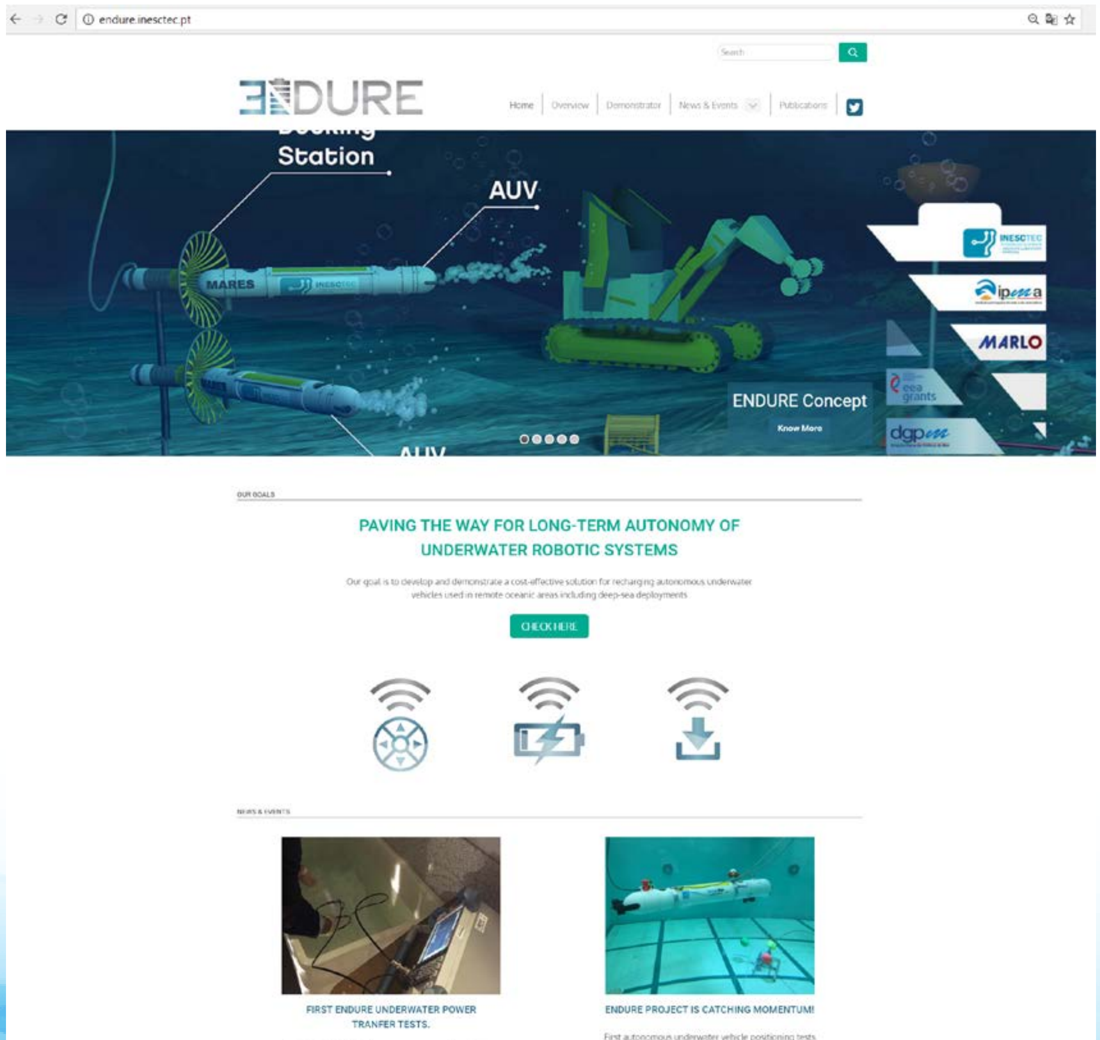
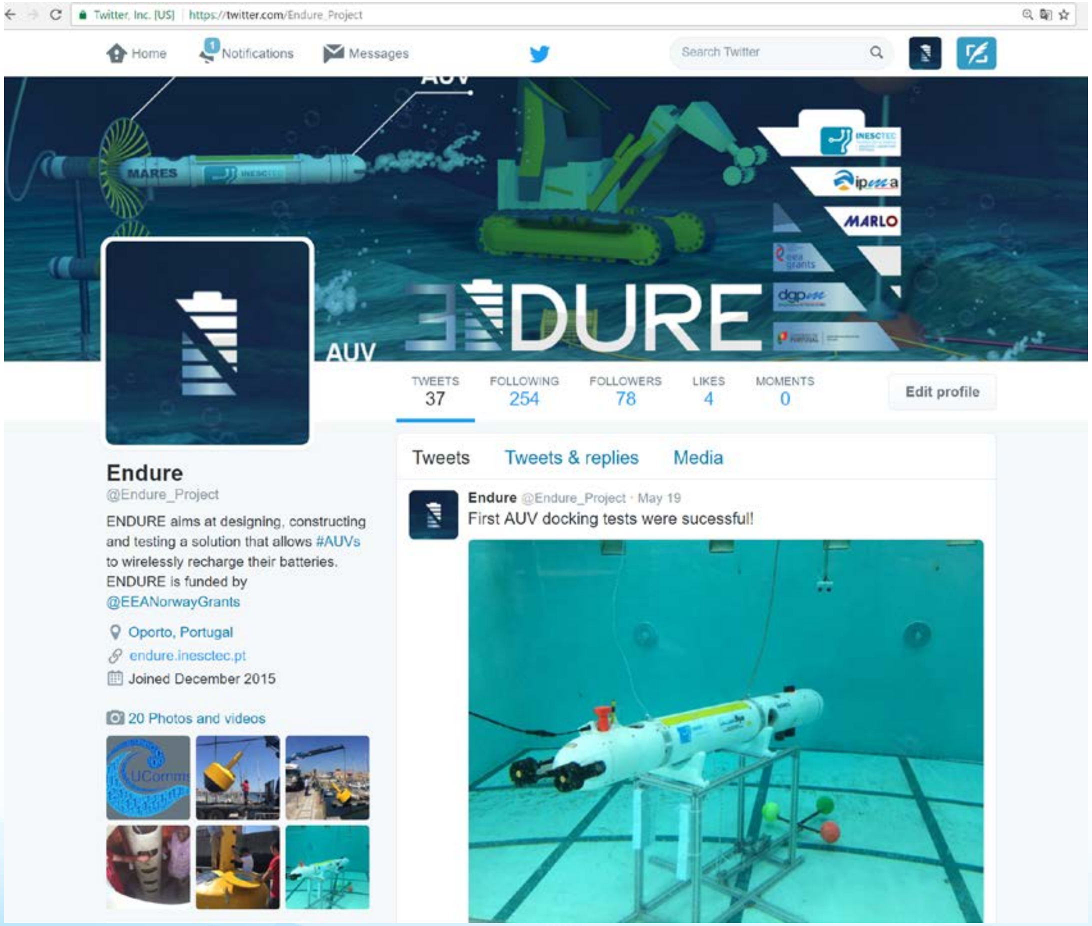
Dissemination

Website



http://endure.inesctec.pt

Twitter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AUV
MARES
MARLO
TWEETS 37
FOLLOWING 254
FOLLOWERS 78
LIKES 4
MOMENTS 0
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Tweets
Tweets & replies
Media
Endure
@Endure_Project
ENDURE aims at designing, constructing and testing a solution that allows #AUVs to wirelessly recharge their batteries. ENDURE is funded by @EEANorwayGrants
Oporto, Portugal
endure.inesctec.pt
Joined December 2015
20 Photos and videos
Endure @Endure_Project · May 19
First AUV docking tests were sucessful!

Publications (14 published)

	Authors	Title	Conference	Date
1	M. R. Pereira, L. M. Pessoa, H. M. Santos, H. M. Salgado	Simulation and Experimental Evaluation of a Resonant Magnetic Wireless Power Transfer System for Seawater Operation	OCEANS'16 Shanghai	April 2016
2	S. Inácio, O. Aboderin, H. M. Santos, L. M. Pessoa, M. R. Pereira, H. M. Salgado	Antenna design for underwater radio communications	OCEANS'16 Shanghai	April 2016
3	Andr B. Figueiredo, Bruno M. Ferreira, Aníbal C. Matos	Vision-based Localization and Positioning of an AUV	OCEANS'16 Shanghai	April 2016
4	H. M. Santos, M. R. Pereira, L. M. Pessoa, H. M. Salgado	Design and optimization of air core spiral resonators for magnetic coupling wireless power transfer on seawater	WPTC 2016	May 2016
5	Francisco Gonçalves, Candido Duarte, L.M. Pessoa	A Novel Circuit Topology for Underwater Wireless Power Transfer	SIMS 2016	June 2016
6	Luís Pessoa, Rui Campos	Wireless Energy and Communications in Remote Ocean Areas: The ENDURE and BLUECOM+ projects	MARETECH'16	July 2016
7	H. M. Santos, M. R. Pereira, L. M. Pessoa, H. M. Salgado	Assessment of design trade-offs for wireless power transfer on seawater	OCEANS'16 Monterey	September 2016
8	O. Aboderin, S. I. Inácio, H. M. Santos, M. R. Pereira, L. M. Pessoa, H. M. Salgado	Analysis of J-Pole Antenna Configurations for Underwater Communications	OCEANS'16 Monterey	September 2016
9	S. Inácio, M. R. Pereira, H. M. Santos, L. M. Pessoa,F. B. Teixeira, M. J. Lopes, O. Aboderin, H. M. Salgado	Dipole Antenna for Underwater Radio Communications	UComms 2016	September 2016
10	Francisco Gonçalves, Adriano Pereira, Andre Morais, Candido Duarte, Rui Gomes, and L. M. Pessoa	An Adaptive System for Underwater Wireless Power Transfer	ICUMT 2016	October 2016

Participation in Events

	Event name	Type of Event	Place	Date
1	Forum do Mar 2015	International Conferences, Seminars and Workshops promoted by the sea cluster partners	Porto	16 to 19 Nov. 2015
2	OCEANS'16	Flagship conference of the Marine Technology Society (MTS) and the IEEE Oceanic Engineering Society (OES)	Shanghai, China	10-13 April 2016
3	Hipeac CSW	Computing system week within the HiPEAC project (High Performance and Embedded Architecture and Compilation), CSA funded under H2020	Porto, Portugal	20-22 April 2016
4	COST WIPE Meeting	COST Action WIPE working group meeting	Aveiro, Portugal	3-4 May 2016
5	WPTC2016	IEEE MTT-S Wireless Power Transfer Conference (WPTC-2016)	Aveiro, Portugal	5-6 May 2016
6	CTM OpenDay 2016	Open Day of the centre of telecommunications and multimedia from INESC TEC	Porto, Portugal	11 May 2016
7	SIMS2016	Second International Conference on Systems Informatics, Modelling and Simulation	Riga, Latvia	1-3 June 2016
8	Oceans Meeting	"Oceans Meeting 2016" focus on three main strategic areas of Ocean Policy: Economy, Ocean Culture, Science and Innovation	Lisbon, Portugal	2-3 June 2016
9	UComms'16	Conference that brings together key people in UW communications networking	Leirici, Italy	30-August to 1-September 2016
10	COST WIPE Meeting	COST Action WIPE working group meeting	Aalborg, Denmark	8-9 September 2016
11	OCEANS'16	Flagship conference of the Marine Technology Society (MTS) and the IEEE Oceanic Engineering Society (OES)	Monterey, CA, USA	19-22 September 2016
12	ICUMT2016	8th International Congress on Ultra Modern Telecommunications and Control Systems	Lisbon, Portugal	18-20 October 2016
13	Business to Sea	International Conferences, Seminars and Workshops promoted by the sea cluster partners	Porto	16 to 18 Nov. 2016

Conclusion

- ENDURE concept successfully demonstrated
- ENDURE provided the first steps required to enable AUVs to remain in operation for longer periods of time, thus increasing the possibility of covering larger areas at lower costs
- Follow-up project (CORAL) will focus on increasing the power levels.
- Together with BLUECOM+, ENDURE is an holistic solution enabling cost-effective, scalable data collection at large remote ocean areas

Iceland Liechtenstein Norway grants

Closing Event of the PT02 Programme
Integrated Marine and Coastal Waters Management "Achieved Outcomes"
December 6th - Lisbon

Thank you for your attention!

Questions?

ENDURE

Enabling Long Term Deployments of Underwater Robotic Platforms in Remote Oceanic Locations

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