Project title: Pollution Identification, Mapping, and Ecosystem Observation with AI-powered water quality USV

Acronym: PIMEO-AI

RESULTS

Phase 1:

Since the optimization of the radio communication between the drone and the base station involves the modeling of the specific propagation channel in which it operates, a series of experiments were performed on the basis of which the propagation parameters were determined. For this purpose, an experimental system was developed consisting of a software defined radio equipment with the role of transmitter and a spectrum analyzer acting as receiver.



In order to obtain a reference measurement, the experimental system was placed in an open field, away from potential sources of interference, the so-called Open Area Test Site (OATS).



To model the propagation in the real operating environment of the drone, the system was placed in a configuration that closely mimics the real situation during its operation, using a floating pontoon.



The propagation models necessary for the development of the drone's communication system were obtained.



Scientific articles resulted from phase 1

- Mihaela Hnatiuc, Alin Ghilezan, *Methods of underwater autonomous navigation*, The 10th edition of the International Conference "Advanced Topics in Optoelectronics, Microelectronics and Nanotechnologies", 20 23 August 2020, Constanța, România.
- Alin Dănișor, Răzvan D. Tamaș, Feng Qi, *Description of Underwater Noise in Siutghiol lake, Constanta*, The 10th edition of the International Conference "Advanced Topics in Optoelectronics, Microelectronics and Nanotechnologies", 20 23 August 2020, Constanța, România.
- Mariana Vasilica Gălbiază, Ștefania Bucuci, Liliana Anchidin, Răzvan D. Tamaș, *Characterization of* antenna side and back radiation in a multipath site, The 10th edition of the International Conference "Advanced Topics in Optoelectronics, Microelectronics and Nanotechnologies", 20 -23 August 2020, Constanța, România.
- Mirel Păun, *Software-defined Ground Penetrating Chirp Radar*, The 10th edition of the International Conference "Advanced Topics in Optoelectronics, Microelectronics and Nanotechnologies", 20 23 August 2020, Constanța, România.
- Mirel Păun, *Continuous-wave software-defined radar interferometry*, The 10th edition of the International Conference "Advanced Topics in Optoelectronics, Microelectronics and Nanotechnologies", 20 23 August 2020, Constanța, România.
- Mirel Păun, *Stepped-frequency software-defined ground-based synthetic aperture radar*, The 10th edition of the International Conference "Advanced Topics in Optoelectronics, Microelectronics and Nanotechnologies", 20 23 August 2020, Constanța, România.
- Mirel Păun, *Stepped-frequency software-defined Ground Penetrating Radar*, The 10th edition of the International Conference "Advanced Topics in Optoelectronics, Microelectronics and Nanotechnologies", 20 23 August 2020, Constanța, România.
- Simona Ghiță, Mihaela Hnatiuc, *BIOFOULING MONITORING*, The 10th edition of the International Conference "Advanced Topics in Optoelectronics, Microelectronics and Nanotechnologies", 20 23 August 2020, Constanța, România.
- Ștefania Bucuci, Răzvan D. Tamaș, *Radar cross section analysis for meander line frequency selective surfaces*, The 10th edition of the International Conference "Advanced Topics in Optoelectronics, Microelectronics and Nanotechnologies", 20 23 August 2020, Constanța, România.
- Ana Dumitrașcu, Ana Bordea, *Low Cost Seismometer for Building Integrity Measurement*, The 10th edition of the International Conference "Advanced Topics in Optoelectronics, Microelectronics and Nanotechnologies", 20 23 August 2020, Constanța, România.
- Ana Dumitraşcu, Ana Bordea, Florin Cazan, On the improvement of performance in motorsport by means of acceleration measurements, The 10th edition of the International Conference "Advanced Topics in Optoelectronics, Microelectronics and Nanotechnologies", 20 - 23 August 2020, Constanţa, România.
- Andreea Constantin, Răzvan Tamaş, Impact Reduction of Common Mode Currents for Field Measurements on Directional Symmetrical Antennas, The 10th edition of the International Conference "Advanced Topics in Optoelectronics, Microelectronics and Nanotechnologies", 20 -23 August 2020, Constanța, România.

Phase 2:

Following the analysis from a technical-economic perspective of the existing options for the implementation of the radio communication system between the drone and the base station, the LoRa technology was chosen as the optimal variant. This technology uses spread spectrum modulation, thus providing resistance to multi-path propagation specific to operation on the surface of water bodies. The frequency band chosen for LoRa communication is 868 MHz, because it allows unlicensed operation in most countries of the world.

Constanta Maritime University developed and built the antennas for the drone communication system. For the base station, a directional Yagi-Uda antenna with a gain of 10dB was made, and for the drone, a compact dedicated antenna of the Meander Line type (Meander Line Antenna) was made.



During the measurement campaign for testing the drone and generating the Machine Learning algorithm training data set, the operation of the communication system was verified and it was found operating according to the specifications.



The sonar acoustic transducer was also calibrated.



Scientific articles resulted from phase 2

- Mirel Ciprian Păun, Ștefania Bucuci, Răzvan Tamaş, George Suciu, Mihaela Bălănescu, Wireless channel propagation characterization for USV communication using UWB signals, publicat în Proceedings of 2021 IEEE CONFERENCE ON ANTENNA MEASUREMENTS & APPLICATIONS (CAMA 2021), 15 – 17 Noiembrie 2021, Antibes Juan-les-Pins, Franța.
- Ana-Maria Drăgulinescu, Cristina Bălăceanu, Filip-Emanuel Osiac, Roxana Roșcăneanu, Veronica Sanda Chedea, George Suciu, Mirel Ciprian Păun, Ștefania Bucuci, *IoT-based Smart Water Management Systems*, publicat în Proceedings of 2021 IEEE 27TH INTERNATIONAL SYMPOSIUM FOR DESIGN AND TECHNOLOGY IN ELECTRONIC PACKAGING (SIITME 2021), 27 - 30 Octombrie 2021, Timișoara, România.
- Milis Nilgun Caibula, Constantin Militaru, Răzvan Tamaş, Cosmin Dumitrache, Ramona Dumitrache, *Particularities of the Closing Processes of Project in the Context of Sustainability Requirements*, Postmodern Openings, 12(1), 115-127. <u>https://doi.org/10.18662/po/12.1/249</u>.
- Milis Nilgun Caibula, Constantin Militaru, Stakeholders Influence on the Closing Phase of Projects, Postmodern Openings, 12(1Sup1), 136-148.
 https://doi.org/10.18662/po/12.1Sup1/275.

Phase 3:

The performance of the radio communication system is dependent on the propagation of the radio signal in the frequency band used by the drone (868 MHz). Since the specific conditions of the aquatic environment such as the signal reflections on the water surface and the attenuation (path loss) caused by the propagation through reeds in the conditions of placing the antenna at a low height compared to the water surface significantly change the propagation compared to the terrestrial environment, the sounding of the radio channel was carried out in the real operating environment. Based on the measurements, the excess path loss, necessary to determine the maximum operating distance of the drone, was calculated.



Before performing the measurements in the real environment, the measurement system was calibrated by performing a reference measurement in a controlled environment (anechoic chamber), in order to compensate for the dispersive effect of the two antennas in order to strictly characterize the propagation environment. The calibration of the measurement system in a controlled environment was carried out in the anechoic chamber on the premises of the Constanta Maritime University, intended for the characterization of radiant systems in the 200 MHz - 20 GHz frequency range.





The measurements in the real environment were carried out near the village of Vişina, Jurilovca commune, Tulcea county.





Based on the determined average excess propagation attenuation ($L_{exces} = 22 \text{ dB}$), the sensitivity in the maximum speed operation mode of the LoRa modems ($S_a = -111 \text{ dBm}$), the maximum transmit power ($P_e = 20 \text{ dBm}$), the gain of the control center antenna ($G_{ant1} = 10 \text{ dBi}$) and drone antenna ($G_{ant2} = 1 \text{ dBi}$), the maximum communication distance with the drone was determined:

$$d_{max} = \frac{c}{4\pi f} \cdot 10^{\frac{P_{e,dBm} + G_{ant1,dBi} + G_{ant2,dBi} - S_{a,dBm} - L_{exces,dB}}{20} =$$
$$= \frac{3 \cdot 10^8}{4\pi \cdot 868 \cdot 10^6} \cdot 10^{\frac{20 + 10 + 1 + 111 - 22}{20}} = 27,5 \text{ Km}$$

A sonar with remote operation via WiFi radio connection, intended to be mounted on the drone, has also been developed. The sonar has an integrated battery with 3 hours of autonomy and can operate in active or passive mode. The active mode allows the creation of bathymetric maps, the detection of schools of fish or submerged objects. In passive mode the sonar can be used to monitor underwater noise.







Following the analysis of the results obtained during the 2021 summer test campaign in Romania, improvements were made to the drone's electronic control systems. Operational validation of these improvements was achieved by testing the drone under real working conditions on Lake Créteil, France. The activity also aimed to promote the system created, the tests including a demonstration in the presence of potential beneficiaries of the solution developed within the project.

Scientific articles resulted from phase 3

- Alexandra Dutu, Mirel Paun, Razvan Tamas, Underwater acoustic monitoring sensors network, publicat în Proc. of. Advanced Topics in Optoelectronics, Microelectronics, and Nanotechnologies XI (ATOM-N), ISSN: 0277-786X, Aug. 2022, Constanța, România.
- Adrian Tufan, Stefania Bucuci, Antenna design and optimization for Terahertz applications, publicat în Proc. of. Advanced Topics in Optoelectronics, Microelectronics, and Nanotechnologies XI (ATOM-N), ISSN: 0277-786X, Aug. 2022, Constanța, România.
- Nicusor Ciprian Silvestru, Mirel Paun, Razvan Tamas, Software-defined ground-based synthetic aperture radar interferometry, publicat în Proc. of. Advanced Topics in Optoelectronics, Microelectronics, and Nanotechnologies XI (ATOM-N), ISSN: 0277-786X, Aug. 2022, Constanța, România.
- Andreea Violeta Caragata, Andreea Constantin, Razvan Tamas, Impact Reduction of Common Mode Currents for Field Measurements on a Meandered Monopole Antenna, publicat în Proc. of. Advanced Topics in Optoelectronics, Microelectronics, and Nanotechnologies XI (ATOM-N), ISSN: 0277-786X, Aug. 2022, Constanța, România.
- Andreea Furtuna, Marius Pastorcici, Răzvan D. Tamas, Mihaela Balanescu, Victor Suciu, George Suciu, A novel electronic switch for VHF/UHF low-cost radars, publicat în Proc. of. Advanced Topics in Optoelectronics, Microelectronics, and Nanotechnologies XI (ATOM-N), ISSN: 0277-786X, Aug. 2022, Constanța, România.